

Sailing through History

Reading the Past – Imagining the Future



Proceedings of the 16th International
Symposium on Boat and Ship Archaeology
Zadar 2021

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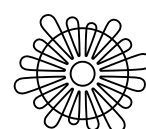
Reading the Past – Imagining the Future

Proceedings of the 16th International
Symposium on Boat & Ship Archaeology
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Edited by

Irena Radić Rossi, Katarina Batur, Tomislav Fabijanić, Dušanka Romanović



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Exegerunt monumenta aere perenniora!

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PREFACE

Nautical archaeology is a multidisciplinary and interdisciplinary field of study which expands our understanding of the past through the historical interpretation of boat and ship remains. In recent decades the discipline has undergone immense changes due to the development of new tools, particularly 3D technologies, which have had a significant impact on procedures such as documentation, interpretation and reconstruction. These more efficient and accurate tools have been adapted for the study of boats and ships and have now been widely adopted by the community of nautical archaeologists. This technology has had major consequences on archaeological analyses, improving speed, precision, reliability, and cost effectiveness.

However, the central issue is to determine whether these new tools help us pose new research questions to obtain greater insight into boats and ships, and ultimately decide whether they lead to more relevant historical interpretations. The main theme of ISBSA 16 was Reading the Past – Imagining the Future, and its core objective was to reflect on the results of traditional methods and tools while considering new possibilities offered by the implementation of modern information technologies. Moreover, as technology is adopted in nautical archaeology, we must consider which methodological standard procedures or analytical practices remain relevant in future excavations.

As in previous symposia, the endeavour was to interrogate the discipline's methods and to investigate the adoption of new technologies in the field of boat and ship archaeology. The question is how we can best adapt them to the requirements of historical inquiry and the interpretation of ship and boat remains.

With the principle theme of “Sailing through History”, the intention of the 16th ISBSA was also to further the experiences gained during previous editions, grouped under the following themes:

- Ship construction;
- Inland navigation;
- Recent discoveries;
- Reconstruction in nautical archaeology;
- Nautical iconography and ethnography and
- Research methods.

Within the scope of the topics listed above, we also reconsidered the foundations underlying the methodological paradigms of nautical archaeology (documentation, analysis and interpretation), particularly with regard to dialogue with historical, iconographic and ethnographic sources.

READING THE PAST – IMAGINING THE FUTURE

The significance of archaeological source data

Pat Tanner

Abstract: All archaeology is contingent on the source data and everything stems from that. Achieving a detailed understanding of both the object and the processes is predicated on the quality of the underlying source data. Past reconstruction projects may have used the source data, but it is not always possible to understand or interrogate how that source data has been used or interpreted, due to the lack of published paradata. This paper examines the development of methods employed in the surveying of an archaeological excavation site, in essence the capture and recording of the raw primary data from the site or artefact.

Keywords: Source-data, Metadata, Paradata, Digital Documentation

Introduction

The main theme of ISBSA 16, 'Reading the Past – Imagining the Future', is to reflect on the results of traditional methods and tools while considering new possibilities provided through the implementation of modern technology. From experience gained on projects such as the Newport Medieval Ship, the Bremen Cog re-analysis, the Poole Log-boat analysis, and the digital reconstruction of the Anglo-Saxon Sutton Hoo ship burial, it is clear that all archaeology is contingent on the source data, and everything produced stems from that source data. Source data by its nature can be difficult to understand, and as noted by Hocker (2004: 2): "the study of ship remains begins with the recording of seemingly trivial details, the thickness of planks, the number and size of nail, the direction of an adze stroke".

The examining of the minutiae of trivial details to understand the workforce involved in building the Vasa (Hocker 2013) is a good example of the great level of detail it is possible to achieve. However, achieving this level of detailed understanding of both the object and the processes involved is predicated on the quality and detail of the underlying source data.

This paper examines the development of methods employed in the surveying of an archaeological excavation site, in essence the capture and recording of the raw primary data from the site or artefact. Reconstruction is not an end of its own, but a logical continuation based on appropriate source data in which we have confidence. Past reconstruction projects may have used the source data, but it is not always possible to understand or interrogate how that source data has been used or interpreted, due to the lack of published paradata (Denard 2009: 13), and the fact that the raw source data is rarely published in a form devoid of interpretation. George Bass points out in his introduction to the Oxford Handbook of Maritime Archaeology (2011: 10–11) that archaeologists publish only a fraction of the sites they investigate and noted that it can take years or decades to produce excavation reports that are more than simple catalogues. This practise inhibits the continuous flow of information and slows down the collective research efforts to reconstruct the past. Primary data is often kept away from peer review even after final publication of an excavation.

As noted by Crumlin-Pedersen (Crumlin-Pedersen 1977: 165), the traditional method of manual scale drawing is considered discontinuous as it is based on measuring a number of points on the object and completing the remaining drawing by interpolating between the measured points. In addition, the selection of what is actually represented, or omitted, on a drawing is a further interpretation by the draftsman. Hocker (2000; 2003) noted that representing complex three-dimensional shapes on two-dimensional paper led to the development of a set of drawing conventions, in which the object is represented as a series of intersecting views, traditional 'top down' or plan, side, and front orthographic views typically perpendicular to each other. These two-dimensional paper drawings are a less than ideal medium for the archival storage of complex three-dimensional data sets. Table 1 illustrates a sample of how the process of documentation, reassembly, reconstruction, and validation of the resulting hypothesis has developed over the past two centuries.

Clearly, the technology used to record site data is not a secondary concern but is central to the activity of site archaeology. We have an obligation to bridge the gap between the exclusive knowledge of the excavator and the published record, utilising a mode of data capture and record that is devoid of interpretation, or where interpretation is inevitable, paradata is used to explain the human processes of interpretation and understanding of the data objects.

Project	Date	Site Survey	Timbers Recorded	As Found	Initial basis for Hull Form	Development of Reconstruction	Validation of Reconstruction
Rother Barge	1822	Detailed site sketch	Some scantlings recorded		Reassembly for Display	Details of artefacts recovered	
Nydam	1859	Traditional 2D offsets survey	Detailed sketches and scale dwgs.		Reassembly for Display	Detailed sketches of artefacts recovered Subsequently re-excavated	full-scale Replica
Gokstad	1880	Traditional 2D offsets survey	2D Offsets		Reassembly for Display	2D scale dwgs. Full-scale Replica	Sinking of the full-scale Replica
Oseberg	1904	Traditional 2D offsets survey	2D Offsets		Reassembly for Display	Full Scale Replica based on measurements from the Museum display	
Woolwich	1912	Traditional 2D offsets survey		Survey Drawing	Name Identification	Name Identification	
Kalmar	1932	Traditional 2D offsets survey	2D Offsets	Survey Drawing	Scale Drawings	Scale Model	Scale Model
Ferriby	1937	Traditional 2D offsets survey	2D Offsets	Interpreted excavation dwg.	Scale Drawings	Scale Drawings and 5 Scale Models	Form Coefficients + displacement and scale replica
Yassi Ada 7th C	1961	Underwater Photography		Corrected and scaled from photographs	Reassembly of scaled model strakes	Scale Models	Tonnage
Skuldelev	1962	Photogrammetry Then scale dwg.	Full-scale Elevated plane tracing	Interpreted Torso dwg.	Reassembly of 2D scaled model strakes	Scale Model	Form Coefficients + displacement and full-scale replica
Kyrenia	1968	Underwater Photography	Drawn full-scale Photographed	Corrected and scaled from photographs	Initial hull form model	18 models – some full-scale	Tonnage and 2 full-scale replicas
Graveney	1970	Traditional 2D offsets survey and full-scale plaster cast	Full-scale Contact tracing	Reduced scale dwgs.	Reduced scale drawings	Scale Drawings and 4 Scale Models	Form Coefficients + displacement and scale replica
Serçe Limani	1977	Underwater Photography	Full-scale Elevated plane tracing	Site Diorama model	Site Diorama model and mould + batten model	Various models	Tonnage
Ma'agan Mikhael	1985	Underwater 2D offsets survey and photographs	2D Offsets	Survey Drawing	Surviving frame shape and reassembly of hull remains	reassembly of hull Remains and 3 scale models	Form Coefficients + displacement causing hull redesign and full-scale replica
Barland's Farm	1993	Traditional 2D offsets survey	2D Offsets	Interpreted 'as-found' dwg.	Reassembly of scaled model strakes	Scale Model	Form Coefficients + displacement
Roskilde	2002	Photogrammetry Then scale dwg.	3D full-scale digitising	Interpreted Torso dwg.	Flatten data to 2D and assemble scaled model strakes	Scale Model	Form Coefficients + displacement and full-scale replica
Newport	2002	Traditional 2D offsets survey and Photogrammetry	3D full-scale digitising	As surveyed and post-deposition model	3D Post deposition model	Full-scale 3D digital model	Full Orca3D hydrostatic and hydrodynamic analysis
Surenga 7	2007	Traditional 2D offsets survey	3D full-scale digitising	Traced from on-site digital scan	Surviving frame shape 3D printed and reassembly of hull remains	Scale Model	Orca3D hydrostatic analysis

Table 1 Summary of documentation and reconstruction approach for archaeological reconstructions

Recording source data

Traditional Surveying

The quality and detail of the source data is directly proportional to the accuracy of the measurements recorded, as well as the level of interpretation employed in that recording and the completeness of the elements recorded. As can be seen from Table 1, the recording of source data has developed from the 19th century two-dimensional site sketches, which were interpretive by their nature, to the 20th century traditional ‘baseline and offset’ survey technique, which involved a degree of interpretation in the reading of measurements, and more significantly, interpretation in the selection of which elements were recorded, often due to either time or economic constraints. The manual surveying of complex sites or objects can be a very time-consuming process and presents challenges in terms of subjectivity and accuracy (Holt 2003), and as noted by Baltsavias (1999: 84), measurement without interpretation is sometimes very difficult or impossible.

Tacheometric surveying

Tacheometric surveying, such as with a theodolite or total station, involves the measurement of individual three-dimensional points relative to one another, using a combination of angular and distance measurements. Both the theodolite and total station have a long history in surveying. One of the first uses of a total station to record large ship structures in Denmark was pioneered by Christian Lemée in 1996 during the excavation of the Renaissance ships at the B&W site in Christianshavn (Lemée 2006).

The concept developed was based on identifying the different structural parts of the ship and carrying out a complete survey of the ship as a whole, through the ‘selective field recording of individual elements’, combined with small sections removed for later detailed documentation. Differences occurred when ‘others’ documented portions of the wreck, not in the shape of the lines created, but in the omissions of features recorded by not knowing exactly what was important to document (Lemée 2006: 87).

This clearly highlights some of the issues with interpretive or subjective recording techniques, as pointed out by Lemée when he acknowledged that the process requires the operator to possess specific knowledge and understanding of ship structures when determining which elements to document. In addition, a decision was taken during recording at Christianshavn not to document the ‘Z’ or height measurement as the equipment used was capable of logging the ‘X’ and ‘Y’ coordinates of a point in two to three seconds, while the addition of logging the ‘Z’ coordinate added another seven to eight seconds. With typical logging of up to 1,200 points per day, and a total of circa 32,000 points logged, the additional ‘Z’ coordinate logging would have added days to the process (Lemée 2006: 82).

However, a major problem arose in that, with few exceptions, the shape of all planks and compass timbers were only known in the horizontal projection or plan view, due to the absence of height measurements from the total station data. Lemée (2006: 87) concluded that the total station is an important tool for recording large coherent structures, however, in most cases it needs to be supplemented with other methods.

The recording of multiple wrecks in Yenikapi, Turkey, also employed a total station with a recorded point density of between 4,000 and 10,000 points per wreck depending on wreck size (Kocabaş 2008: 51). The Yenikapi excavation also insisted on the necessity of including photos, sketches and visual remarks to reach the best possible result (Kocabaş 2008: 53).

3D recording and digital modelling

Photogrammetric surveying

Stereoscopy or photogrammetry to produce a 3D view is not new; it was first developed in the 19th century and more fully developed during both World Wars. For underwater surveying of archaeological sites its potential was recognised as early as the 1960’s when George Bass used paired cameras mounted on a mini submarine to document a late Roman wreck. Over the last two decades stereo paired photogrammetry has been almost completely replaced by structure from motion (SfM) photogrammetry with the advent of multi-image photogrammetric software such as Agisoft Photoscan. Photogrammetric survey as a low-cost and rapid tool for maritime archaeological surveying is well reported on (Canciani *et al.* 2002; Skarlatos *et al.* 2012; Henderson *et al.* 2013; McCarthy, Benjamin 2014; Costa *et al.* 2016; Yamafune *et al.* 2017; McCarthy *et al.* 2019).

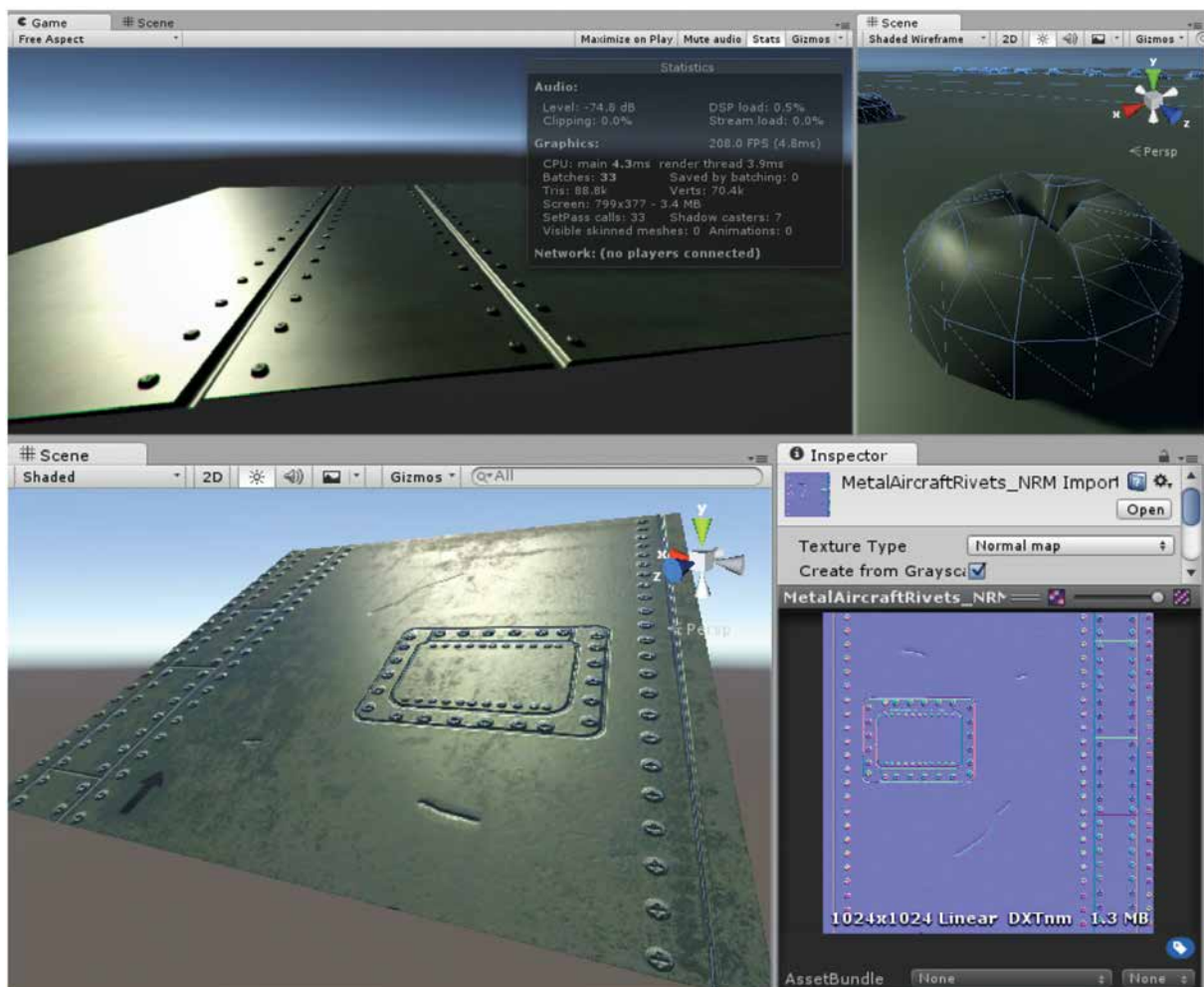


Fig. 1 Computer representation of 3D digital model (images courtesy of Unity Manual 2019.3)

Before discussing photogrammetry in more detail, it is important to understand how computers illustrate or represent 3D digital models. In Figure 1 (top) the digital model of an aircraft panel is a complex three-dimensional mesh model of almost 89,000 polygons (triangles), requiring 33 individual calculations by the computer's graphics sub-system. Model optimization for the video game industry has led to another method of displaying a similarly detailed model Figure 1 (bottom), without the need for complex (time and resource heavy) calculations in the computers graphics sub-system. This approach utilises albedo (colour) map and normal (surface orientation for light reflections) maps to generate the illusion of surface detail on the digital model.

If the model from Figure 1 (top) were 3D printed, it would have all of the detail and geometry as shown in the image. Each of the rivets would be a physical part of the printed model and could be measured etc. However, the digital model shown in Figure 1 (bottom) is a flat square surface consisting of just two polygons. All of the rivets and surface imperfections are an illusion generated using light and shadows, and if 3D printed, the result would be a flat featureless surface.

In the case of photogrammetry, it is not sufficient to simply generate a 3D model with a very high polygon count if there is an insufficient quantity of photographs for the software to calculate the underlying geometry. Figure 2 (top) shows a photogrammetry model of the Bremen Cog created with just 200 photographs using Agisoft Photoscan software. It would appear to have captured the internal structural details of the Bremen Cog, and the model appears to be high resolution, with a total of over 22 million polygons. Figure 2 (bottom) is a close-up view of the same 3D model with the albedo (colour) and normal map removed to illustrate the lack of geometric detail.

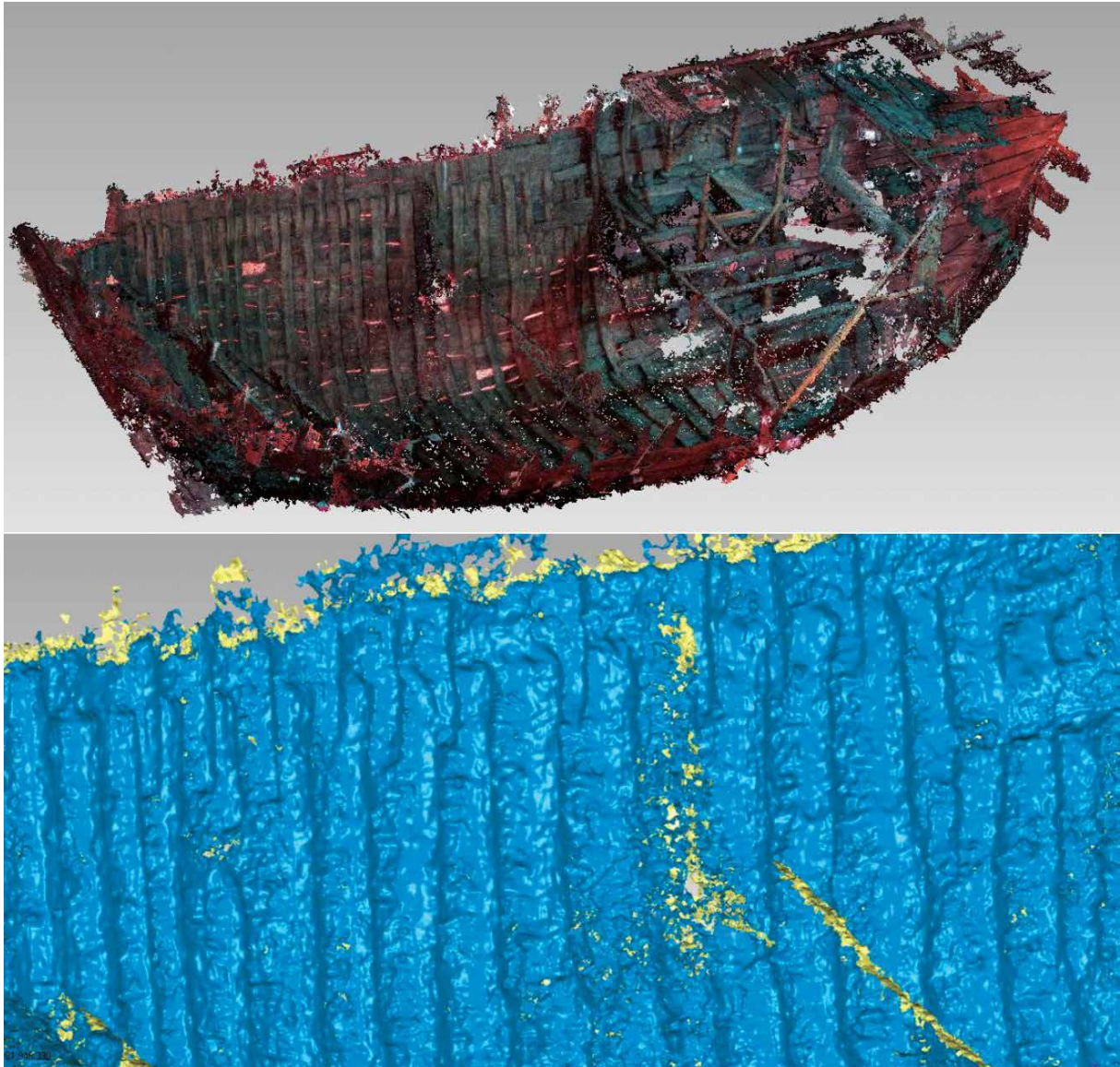


Fig. 2 Photogrammetry model of the Bremen Cog (author: Pat Tanner)

Photogrammetry is not a real time or automated process and most photogrammetric tasks are laborious and tedious. The surveyors can only be sure of the data collection consistency after they have successfully resolved image bundle adjustment during the post-processing phase. It is the software which produces a 3D model by extracting a dense point cloud from the bundle adjusted and stereo matched images. The resultant 3D point clouds created have arbitrary scale, orientation and position in 3D space. All 3D photogrammetric models will require the application of a scale factor correction, as well as a rotation and translation matrix to known correspondence points obtained from other surveying techniques, in order to obtain the correct scaling and georeferencing.

LiDAR or terrestrial laser scanning (TLS)

Photogrammetry and LiDAR are often juxtaposed and presented as being at odds with each other. Photogrammetry uses two-dimensional photographs to interpret measurements between objects and create a three-dimensional geometric representation of the objects themselves. LiDAR uses lasers to detect the position and geometric shape of an object by generating three-dimensional point clouds based on laser shots, and each individual point within the point cloud has its own measured X, Y and Z coordinates. Simply put, with photogrammetry it is each two-dimensional image which is the Raw Source Data, and the 3D pointcloud is a computer based interpretation of that source data, whereas, with laser scanning, the 3D pointcloud is the Raw Source Data.

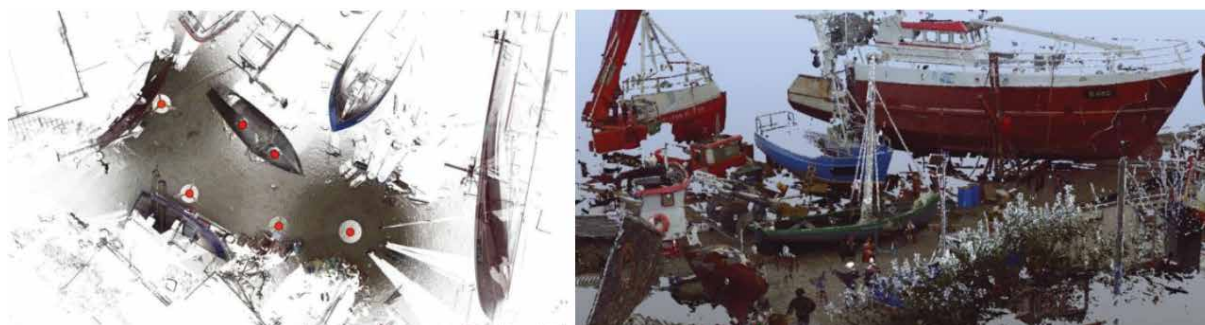


Fig. 3 3D laser scanning a 9 m vessel (author: Pat Tanner)

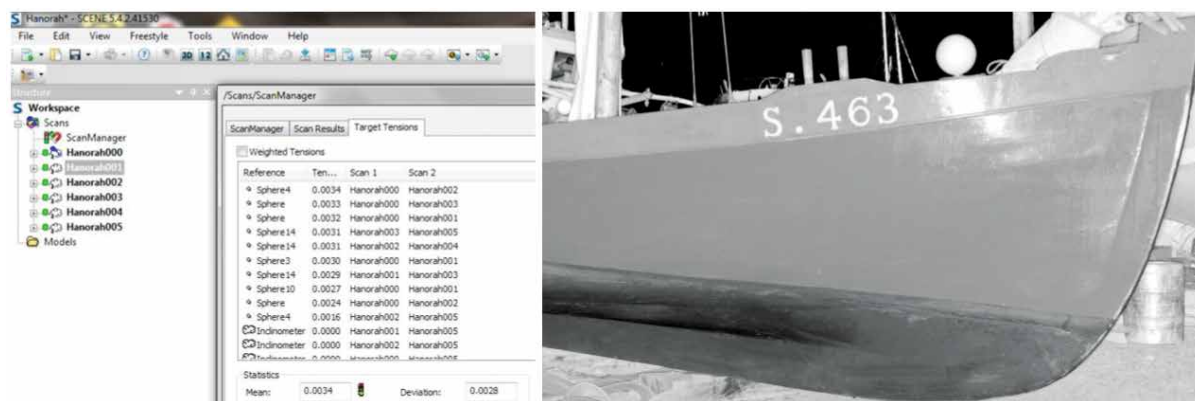


Fig. 4 Post processing scanned point cloud (author: Pat Tanner)

With 3D laser scanning the scanner records the physical characteristics of everything within its line of sight. For this reason, it is necessary to reposition the scanner (red circles in Fig. 3 left) to record the occluded elements not recorded from the initial scan position. Initial on-site registration (Fig. 3 right) between individual scans uses internal GPS sensors, accurate to within a few centimetres. Post processing software allows for further refinement in the registration using a target-based, or cloud to cloud registration (Fig. 4 left), typically resulting in 2–3 mm accuracy. The individual scans are not modified, but rather, a translation and rotational matrix, based on the optimised registration, is stored as metadata with each individual scan file. The result is a geometrically accurate digital three-dimensional pointcloud record of the source data (Fig. 4 right).

Hybrid or Combined techniques

Multi-image photogrammetry software interprets pixel information from digital images to create 3D point clouds, however control points are required to correctly orientate and scale the resultant model. Lidar or terrestrial laser scanning, on the other hand, produces geometrically accurate 3D point clouds, but tends to have a lower surface colour resolution. Recent software developments such as RealityCapture® means the two techniques can now be used together. This software can use the geometrically accurate laser scanning as a control network for scale and relative positioning, while using the high-resolution photogrammetry for colour and surface texture. In addition, any occluded areas which are not recorded from one source can be augmented by the other and vice versa.

In a proof-of-concept case study, 22 individual laser scans were recorded of the Mary Rose, taking a total of two hours scanning time without colour, 11 locations at ground floor level and 11 locations on the third-floor gallery. The limitations on scanner positioning caused occluded areas, resulting in missing data clearly visible on the intermediate decks (Fig. 5 top). In addition to the laser scans, 374 high resolution colour photographs were recorded. With the dimensionally accurate (within 2 mm) 3D laser scan model being used as the control network, RealityCapture® then aligned the photographs, which enabled the creation of the missing geometry in the occluded areas (Fig. 5 middle), and the application of high-resolution photographic quality colour texturing (Fig. 5 bottom). This resulted in a very high

resolution, geometrically accurate, digital research model, as well as lower resolution models for easier dissemination such as on sketchfab (<https://sketchfab.com/3d-models/mary-rose-316db8d7099b42b28f889aedddc86e9d>), which has had over 17,300 views.

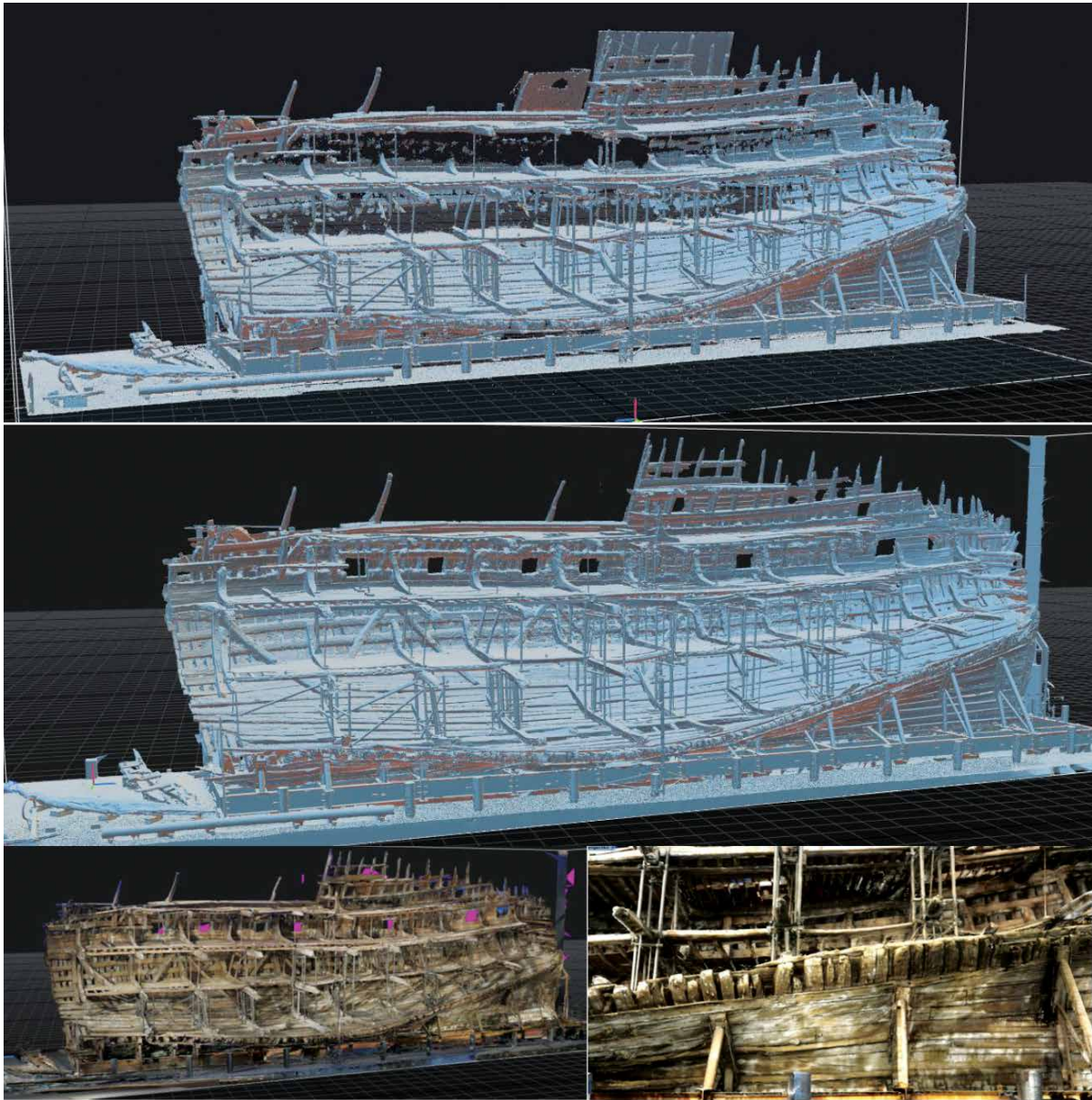


Fig. 5 Hybrid data capture combining 3D laser scanning and photogrammetry (author: Pat Tanner)

4D recording

As each stratigraphic layer is excavated, and the subsequent layer exposed, it is now possible, using photogrammetry, laser scanning or a combination of both, to accurately (and objectively) capture the site information as each subsequent stratigraphic layer is excavated and exposed (Pacheco-Ruiz *et al.* 2018). This would capture an accurate, three-dimensional, point-in-time snapshot, at various significant stages throughout an excavation, and as archaeological excavation is destructive by its very nature, each 3D survey would capture information otherwise impossible to re-examine at later stages.

Metadata / Paradata

Quite simply, metadata is data that describes other data. Metadata describes whatever piece of data it is connected to, whether that data is video, a photograph, spreadsheets, illustrations or reports. Various types of metadata include: Descriptive metadata – in its most simplified version, an identification of specific data; Structural metadata; Preservation metadata; Provenance metadata; Use metadata; and administrative metadata. Even this article has metadata such as the author, number of pages or words, creation date, modification date, file size etc.

Paradata on the other hand, is information about the human processes of understanding and interpretation of data objects. Examples of paradata include descriptions stored within a structured dataset, of how evidence was used to interpret an artefact, or a comment on methodological premises within a research publication. It is closely related, but somewhat different in emphasis, to ‘contextual metadata’, which tends to communicate interpretations of an artefact or collection, rather than the process through which one or more artefacts were processed or interpreted. Once we begin to sort, arrange or interpret the raw source data, paradata becomes critical in order to explain both how and why.

An example of metadata for a single floor timber from the Newport Medieval Ship would be the timber database file which identifies that timber as F44 and relates that to the Cow Tag CT797 attached to that timber on-site, CT797_Timbersheet.pdf – a digitised copy of the hand written timber record sheet describing that timber when excavated, digital photographs (CT797_1.tif, CT797_2.tif, CT797_3.tif etc), F44.3dm – the digital 3D wireframe data from the Faro Arm contact digitising, F44.stl – the digital file for 1:10 scale 3D printing, as well as conservation reports, dendrochronology reports and additional drawings illustrating that timbers find location as well as its location in the hypothetical reconstruction.

The paradata relating to that timber is contained within the specialist report – Reconstructing the Hull Shape (Tanner 2013). That report describes how the object was analysed and interpreted, the process and methodology employed, and the reassembly of individual components into a coherent structure. It also describes how that structure was analysed, how distortions were repaired, how the hypothetical reconstruction was created, and how that hypothesis was tested using hydrostatic analysis to establish seafaring, cargo capacity and performance characteristics.

Conclusion

The capturing of three-dimensional high volume, high quality raw data, using either photogrammetry, 3D laser scanning, or a combination of both, generates a superior archival record, which is stored as a full-sized three-dimensional object, rather than a reduced scale, two-dimensional paper-based interpretation. Advances in viewing technology allow for three-dimensional interactive models to be viewed on a computer monitor, allowing the user to view the object from any angle or viewpoint, or, with the aid of augmented reality or virtual reality headsets, to actually interact with the three-dimensional raw source data.

In the case of cultural heritage sites and historical artefacts, the physical context of the objects contained within a site are just as important as the artefacts themselves. Just as a site has stratigraphy, ships also have a stratigraphy in themselves, which must be carefully recorded. The rapid advances in both hardware and post-processing software means it is now possible to easily capture high volume, high-quality, 3D data. This form of digital data, combined with suitable metadata and, more importantly, paradata, should go a long way towards bridging the gap between the exclusive knowledge of the excavator and the published record, allowing lots of people to use the data in new and novel ways. This raises the question: As archaeologists, should we all be doing this?

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Written Historical Sources on shipbuilding and the archaeological study of a post-medieval Mediterranean shipwreck: the *Gagliana grossa* case study

Mauro Bondioli – Mariangela Nicolardi – Irena Radić Rossi

Abstract: During the excavation campaigns conducted on the Gnalić shipwreck dated to the late 16th century, problems pertaining to the documentation, interpretation and graphic representation of the hull's structural elements were addressed. A project was launched with the aim of finding a solution that combines archaeological data with iconography, archival documents and written sources about shipbuilding. Using 3D graphic technologies, the idea was to sketch the probable shape of the entire hull and update it as the excavations proceed. Archaeologists should always be able to monitor the progress made in the study of the ship in this way.

Keywords: Renaissance shipwrecks, written historical sources, virtual modelling, shipwright, knowledge, archaeological methodology

The different implementation sequence phases usually recommended by nautical archaeology manuals for the study of a shipwreck also include the hypothetical reconstruction of the original hull structure (Steffy 1994: 214–234; Pomey, Rieth 2005: 142–149). A study can be taken into consideration only when there is an opportunity to find an accessible wreck in a good state of preservation, from which sufficient data, both quantitative and qualitative, may be obtained. Should this occur, analysis and interpretation of all structural data documented during the excavation may be initiated. Subsequently, one should proceed to the remodelling of elements that indicate deformations and then to an attempt to integrate the fragmented or entirely absent components.

A procedure that aligns with preliminary indications was formulated as far back as 1976 on the basis of the work done in the first symposium on *Sources and Techniques in Boat Archaeology* held in Greenwich with the aim of obtaining a plan for the hull in compliance with the rules dictated by modern naval architecture (McGrail 1977: 205–232; Crumlin-Pedersen 1977: 163–177; 2004: 44).

It is clear that this extremely complex procedure should be able to encompass as much of the ship's entire surviving structure as possible to ensure maximum reliability of the final results. This is the reason why current archaeological procedures only comply with its execution *a posteriori*, that is, at the conclusion of the excavation campaigns when all data have been collected.

However, even in the presence of a wreck that potentially meets all necessary requirements, it may not be possible to secure sufficient documentation in a reasonable time and with available financial support in order to develop a complete and reliable reconstruction hypothesis. As a rule, all that remains in such cases is to proceed and attempt to document the wreck as much as possible and as accurately as possible using all available means.

This is certainly the case of the Gnalić wreck, located in the waters of the Pašman Channel facing the Dalmatian coastline south of Zadar, near the rocky islet of the same name. It is, as archaeological and historical studies have long shown, a large merchant ship with a burden of 1,200 *botti* (ca. 700 tons) built in Venice between 1567 and 1569 and shipwrecked between the end of October and the beginning of November 1583 during a voyage to Constantinople (Radić Rossi *et al.* 2021).

When excavations were definitively resumed in 2012 after brief and intermittent investigations conducted between 1967 and 1973, the difficulties associated with an archaeological site that covered an extensive area and showed con-

siderable stratigraphic complexity became evident immediately. It was further apparent that it would be long before it could be investigated in its entirety and that, in any case, it would never be possible to recover the entire hull from the depth of roughly 30 meters at which it lies. Nor was it conceivable to dismantle all of the hull's structural elements to conduct a more accurate examination after their recovery.

With these preliminaries, it was difficult to envision the possibility of developing a reliable hypothetical reconstruction of the entire hull's original shape as indicated in the archaeology manuals. At best, it would have only been possible to draw up an archaeological map of the site and accord particular attention to the best-preserved areas and those structural details that attracted the greatest interest. On the other hand, there was an awareness of the rare opportunity to study the only historically documented record of one of the largest ships in the Venetian merchant fleet at the height of its maritime trade in the sixteenth century.

In the continuation of the excavation campaigns, as the slow and methodical work proceeded from the aft sector of the wreck towards its central section, the hull's structural composition became increasingly legible. At the same time, however, any attempts to obtain useful information for reconstructing the hull shape from 3D photogrammetry or measurements taken directly at the wreck and from the few recovered – albeit often fragmented and corroded – timbers were futile. In fact, despite the progressive accumulation of considerable data, these always seemed insufficient to reach any conclusion that was not connected solely to carpentry techniques.

Given the complexity of the situation and the slow nature of conventional techniques, the risk was that we would never be able to achieve the desired results within a reasonable time. Thus, before the commencement of the 2018 excavation campaign, the decision was made to experiment with a different approach.

In fact, if it was obvious from the standpoint of excavation methodology that adherence to the same criteria of systematicity and precision employed up to that point should continue, it was nonetheless equally evident that the traditional system of collecting the necessary data had been proven excessively slow and ineffective. It was, therefore, necessary to rethink the documentation system from a completely different perspective. In other words, the question was whether or not there was a possibility of achieving the same objective of obtaining the most plausible hypothesis on the reconstruction of the original shape of the entire hull but with a significantly lower quantity of data, better if reduced to that most strictly essential.

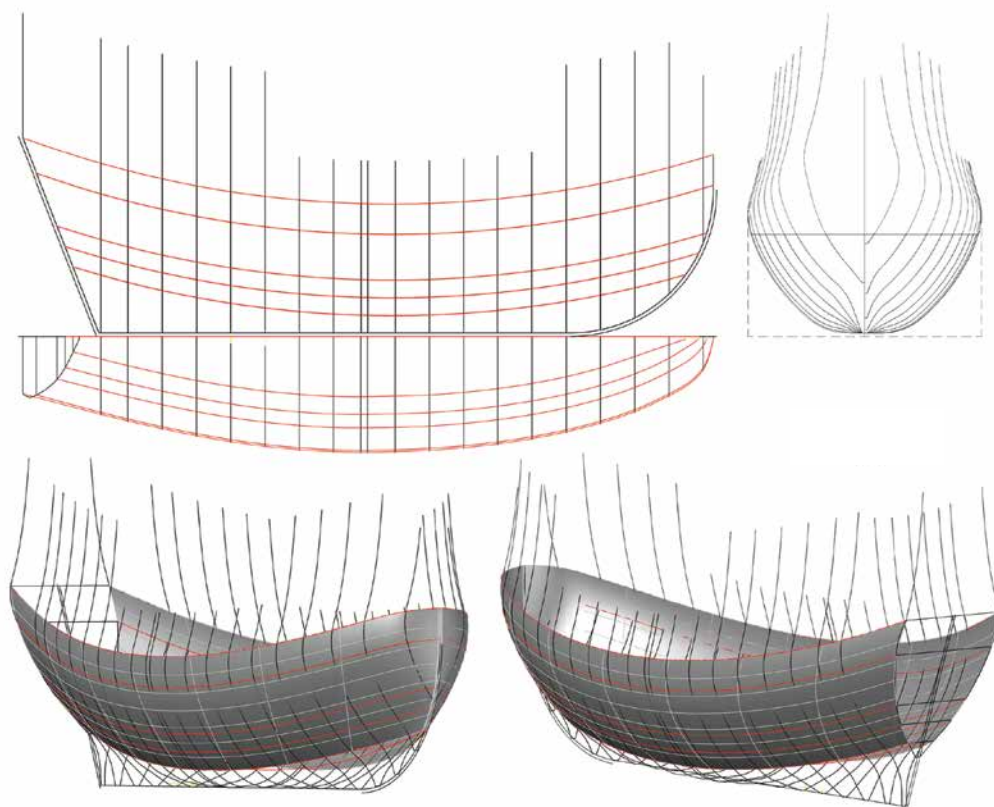


Fig. 1 Hypothetical 3D sketch of the original hull form of the Gagliana grossa

Among the various possible solutions, ultimately the decision was made to make use of historical and iconographic sources in order to create a 3D graphic model that outlined the hypothetical shape that the hull may have had at an imagined point in time close to the date of its construction (Fig. 1). With the indispensable support of photogrammetric data, this model would have to be continuously updated and adapted, in line with new information acquired as the excavations progressed. The aim was to create a tool capable of:

- guiding and organizing the collection of data based on a rational criterion, aimed at identifying in the wreck those conspicuous points that late 16th-century shipbuilders themselves considered fundamental to the design and creation of hull shapes;
- guaranteeing control of the documentation process by monitoring the progress achieved in the study of the hull shape by updating the data and making the subsequent changes to the hypothetical construction plan (Fig. 2).

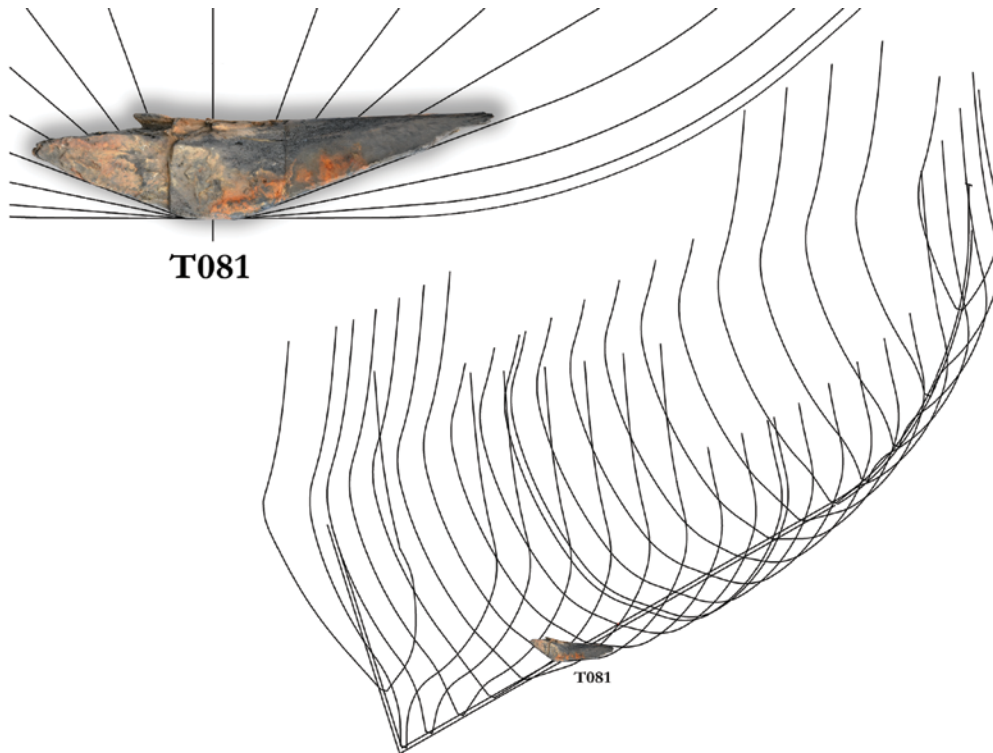


Fig. 2 Update of hull lines based on updated archaeological data

Obviously, the key to the project's success lay in attaining the correct combination between the level of knowledge of late Renaissance Venetian naval architecture contained in archival documents and the actual archaeological data obtained from the wreck. The idea, however, was not to directly combine the archaeological study of the Gnalić wreck with a particular historical document,¹ but rather to compare it to the results of broader systematic research encompassing all available sources, not only Venetian, with the aim of extrapolating two types of information:

- the general design methods used by that era's shipbuilders to formulate a hypothesis about which of these could have been used in the construction of the Gnalić vessel;²
- the dimensional data and construction rules, proportional or geometric, pertaining to Venetian ships of that period, in order to incorporate them into a statistical analysis to obtain reference parameters for the reconstruction.

¹ For example, the manuscript treatise written by the Franciscan father pre' (an abbreviation of priest) Todaro de Nicolò, known by the improper title *Instructione sul modo di fabricare galere* (Lane 1934: 24–49) or the anonymous *Misure di navilii* (Nicolardi 2014: 239–244).

² In Venetian naval architecture, the design process of modifying the frame shape was completely different from that described, for example, in the sources of the Iberian geo-cultural area, especially in the hauling down operations of the futtock mould (Rieth 1996: 47–48, 136–138). On the other hand, since the 14th century, Venetian masters were already familiar with various reduction methods, such as the geometric or mathematical methods involving the incremental triangle (based on the triangular numbers of Nicomachus of Gerasa), half-circle (or half-moon) and circle (or full-moon) (Bondioli 2017; Rieth 1996: 66, 86). At the end of the 16th century, however, the *pavion* (narrowing triangle with planes parallel to the base) and the *scoeto* (narrowing triangle with planes oblique to the base) were already known in Venice (Rieth 1996: 62, 64, 74; Boudriot 1987: 19).

In essence it was a question of developing a research action plan that reversed the conventional paradigm, ensuring that the study was dictated by our knowledge of ancient naval design techniques and not the other way around. It was a theoretical solution which in any case would not have influenced the canonical archaeological procedures in any way, as it would have been an alternative and non-substitutive path from the standpoint of the shipwreck's historical interpretation. In fact, by continuously modifying the hypothetical graphic model following the objective evidence contained in the material evidence of the finds, the principle of the prevalence of archaeological sources over historical sources would never have been broken. Written testimony would therefore always remain confined to a secondary and complementary role:

“... il ne fait aucun doute que cet apport, plus ou moins important selon les cas, des sources écrites représente l'une des dimensions méthodologiques originales de l'archéologie navale médiévale. Pour autant, il ne s'agit pas d'inverser le processus de la recherche en privilégiant a priori cette documentation écrite et en affectant aux sources archéologiques une valeur de complément illustratif. Ce sont les données archéologiques acquises lors de la fouilles qui, fondamentalement, conduisent ici l'interprétation historique de l'épave” (Pomey, Rieth 2005: 182).³

However, before proceeding with the development of the 3D graphic sketch, it was necessary to draw up a detailed documentation protocol based on in-depth documentary research into available written sources, both manuscripts and printed matter, in order to create a database⁴ containing at least:

- the main dimensions of the hull;
- main proportional rules;
- keel length between the surmarks;
- rakes (sternpost, stem);
- heights (sternpost, stem);
- width of the transom;

measurements and geometry of the master frame: breadth (*bocca, reggia, tolda*) and depth (*puntale*) at the decks, the floor (*fondo*) between the surmarks (*poselesi*) and length of the bottom to be narrowed (*piano*); arcs of the futtocks (*valangin de la bocha, valangin de la regia, valangin de sora*) (Fig. 3);

- the main design rules of the whole-moulding system, applied from the midship to the tailframes (*cai di sesto*) of sternpost and stem,⁵ and their related dimensional values⁶;
- narrowing (*partison del fondo*);
- rising line (*stella*);
- widening and sliding down (*partison del ramo* and *scorer del sesto*).

To facilitate its use, the database should have been as simple as possible and therefore contain only the most essential information, such as those listed above. In this way the 3D graphic model would have been continually updated, avoiding unnecessary complications due to the insertion of data, not expressly necessary in the theoretical developmental phase of the sketch.⁷ In fact, it should not be forgotten that any variation introduced in the design would have entailed a series of interconnected modifications which would have involved the hull's entire shape. However, that was a negligible inconvenience if the experimentation employing the new method had actually achieved positive results.

The final processing of the 3D graphic model would necessarily also have to incorporate data pertaining to the hull's structure only if a definitive conclusion of the excavations had been drawn for whatever reason and at whatever

³ “... there is no doubt that this contribution of written sources, more or less important depending on the case, represents one of the original methodological dimensions of medieval nautical archaeology. However, it is not a question of reversing the research process by prioritizing this written documentation and assigning a complementary illustrative value to archaeological sources. It is the archaeological data acquired during the excavations which, fundamentally, here leads to the historical interpretation of the wreck” (Pomey, Rieth 2005: 182).

⁴ The database would have been created by attributing an alphanumeric code to each dimensional indication or design rule contained in the documentary sources, useful for organizing the data into groups and classes. This is the method already adopted previously in the synoptic study of the construction sources of 15th century galleys, which proved to be fundamental to the graphic interpretation of the information (Bondioli 1999: 70–73).

⁵ Through the application of these design rules, shipbuilders were able to design hull shapes between the tailframes of the sternpost and stem. The missing shapes were obtained empirically through the use of long longitudinal ribbands called *maistre*.

⁶ With these data it would perhaps have been possible to attempt the reconstruction of the original moulds and their incremental marks (*partison*), brilliantly defined by E. Rieth as the tools of “conception non-graphique des careens,” i.e. the “*maître-gabarit, la tablette et le trebuchet*” (Rieth 1996).

⁷ To further simplify the graphic model's sketch, it was not even necessary for it to contain information pertaining to the upper parts of the ship, as they were now considered to have disappeared or were so collapsed, eroded and fragmented that they would never have been the subject of a useful archaeological comparison

level of progress it had reached up to that point. In anticipation of the latter, the documentation protocol should have contained a timber database of technical carpentry details observed during the excavations in addition to the actual dimensions of each discovered wooden object. Information would have been added to the data collected during the historical-documentary research phase within the limits of available documentation.⁸

Once the collection of the necessary data has been completed, the most important structural element of the entire hull, the master frame, would be recovered. In fact, the precision of measurement necessary for the correct initiation of study of the ship's forms could be accomplished only through the direct study of the profile of the floor timber (*corba de mezo*) and the first futtock (*forcame de prima man*).⁹

We are perfectly aware of the enormous difficulties of dialogue between historical and archaeological sources, that is, between our assumed knowledge of Venetian shipbuilding and the reality of material evidence which we will confront in this project. However, we are also fully aware of the fact that the hull remains from the Gnalić site will never be fully recovered, and that in the future, if we will have adequate resources, many more excavation campaigns will be needed before we will arrive at the final data. For these reasons, we are convinced of the need to try an alternative method of collecting the information needed to formulate a hypothesis for the reconstruction of the original shape of the hull. Only time will tell whether or not this different methodology will be successful.

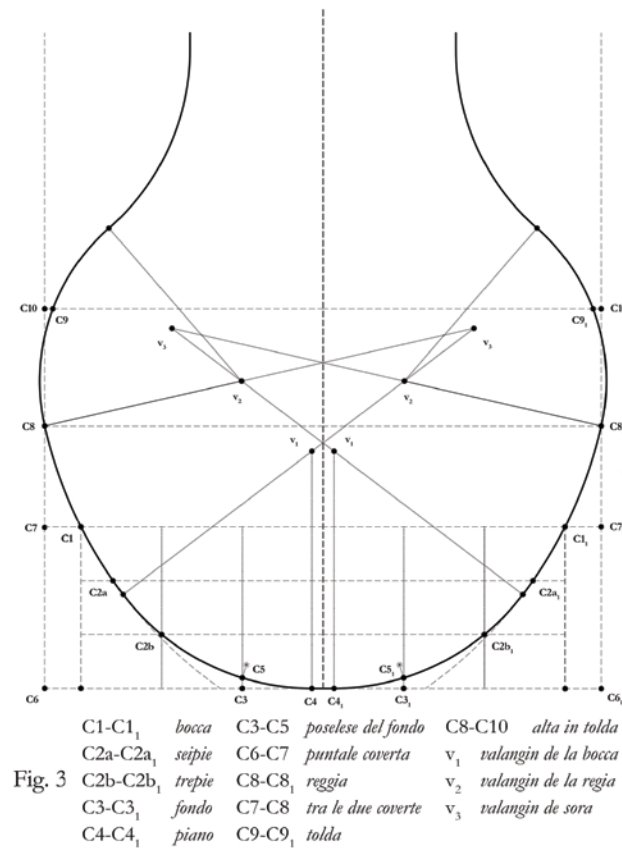


Fig. 3

Fig. 3 Alphanumeric classification of the measurements and geometry of the master frame contained in Venetian written sources and the associated graphic interpretation

Acknowledgement:

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⁸ An example is the discovery of a notarial deed in the State Archives of Venice dealing with the purchase of the oak timbers by the ship owners listing the dimensions of the timbers necessary for the ship's construction.

⁹ The authors hope that this recovery will take place soon after the delays caused by the Covid 19 pandemic and other setbacks which have fortunately been overcome.

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Shipwreck OR49 and the shipping of peat around the Zuiderzee area in the 17th century

Wouter B. Waldus

Abstract: In this article the results of the excavation of a 17th century inland peat ship on lot OR49 in the IJsselmeerpolders are analyzed in a broad maritime historical context. Peat was the main source of energy in premodern times, and the economy of the cities of the Republic was dependent on these transport ships. Based on historical and geographical data the transport volume of peat is reconstructed and compared to other sectors of seafaring. Besides this, wreck OR49 offers a unique perspective on life on board of inland cargo ships during the Dutch Golden Age.

Keywords: Dutch Golden age, inland shipping, peat extraction, energy consumption, Zuiderzee, 17th century

1. Introduction

In the third quarter of the 17th century a storm took a peat skipper heading for Amsterdam by surprise (Fig. 1). Sudden heavy gusts of wind hit the sprit sail making the cargo ship, with peat logs stacked up to above deck level, list dangerously. While capsizing the logs spread into the wild waves of the Zuiderzee leaving a big brown stain behind. During the subsequent wreck formation process the ship transformed into an archaeological source of information. In 2014 and 2015 the well-preserved shipwreck was excavated at lot OR49 in the Flevopolder, a reclaimed land area from the former Zuiderzee or present-day IJsselmeer (Fig. 2). The site offered a fascinating insight into the life on board a peat ship. At the same time, it is an important contribution to the research on the significance of peat shipping for the development of the early modern economy in the Netherlands as will be argued in this article.



Fig. 1 Oil painting of the peat ship OR49 about to capsize during a storm by Arnold de Lange (2020). All details of the scene are based on the excavation data.



Fig. 2 Location of shipwreck at lot OR49 near Dronen, Flevoland (the Netherlands) (author: W. B. Waldus)



Fig. 3 The excavation of shipwreck OR49. The forward part of the hull is located in the forefront (photo: Groningen Institute for Archaeology).

2. Shipwreck OR49

In the context of the International Field-school for Maritime Archaeology Flevoland (IFMAF) it took two campaigns to excavate shipwreck OR49 in its entirety (Fig. 3). The ship was well-preserved and still joined together over a total length of 18 m and a width of 7.8 m. The excavation made it clear that the ship's bow was pointing in a north-westerly direction, with a 20 to 30 degrees list toward its starboard side when it settled in the mud. The port side collapsed at the turn of the bilge and fell inwards over the timbers of the hull. The stempost and parts of the forward hull were missing. However, OR49 could generally be reconstructed. A length from stem to stern of 20 m is probable. The width of the ship's bottom near the mast is 4.30 m, this is the widest part of the original ship. The width from board to board, measured on the outside of the hull, is 5.15 m. The hold of the ship near the mast is determined to be 2 m in depth. From the presence of deck knees, it was possible to infer the length of the cargo hold opening being 10.9 m. It is plausible that the cargo space extended towards the bulkheads separating the after hold and the living space forward. However, the exact position of the bulkheads and consequently the extra dimension of cargo space could not exactly be determined. Taking the position of the finds into account and the extent to which they were observed, the total length of the cargo hold must have been 13.1 m.

The shape of the hull is best described as bulky. The ship's sides, running parallel near the cargo hold, slightly curve towards the stern. The resulting rounded hull shape aft indicates a need to equip the ship with lee boards, unfortunately not found at the site location. The dimensions of OR49 as described signify that the ship-design cargo volume took precedence over maneuverability characteristics. In the cargo hold a high concentration of peat logs was still present.



Fig. 4 The hearth-plate dating 1638 features the picture of a man in a Roman-like outfit (photo: ADC ArcheoProjecten)

The construction of OR49 was dated dendrochronologically after 1630, and the provenance of the oak used for this vessel was Westphalia in Germany (Jansma 2015). Archaeological evidence suggests the launching of the transport vessel in 1638, the year mentioned on a recovered hearth-plate featuring a 17th century interpretation of a Roman soldier (Fig. 4). A lead textile-seal for sheets was marked 1664, indicating that the ship must have been operational for at least 26 years. Thanks to an abundance of ship-finds it is possible to reconstruct life on board in a fairly detailed manner. For example, a total of seven recovered tin spoons indicates what the crew-size might have been. Inland waterway ships like the OR49 could be handled with a skipper and two deckhands as a maximum, so the family of the skipper possibly lived on board also. The remaining finds in the forward living space support this proposition. Many elements of a typical Dutch 17th century household were retrieved, including a hearth, ornamental plates and tiles with and without maritime elements, children's toys, and a knife-handle crafted in the shape of a loving couple. These all indicate that a family lived on board.

Another element inferred from the assembly of finds is the standard of onboard living. Not only the amount but also character of the valuables leads us to believe that it relates to a thriving business. More specifically, the retrievals of two rummers and a so called 'kuttrolf' bottle are definitely clues for wine consumption. Wine drinking was not a common activity in the 17th century; wine glasses were not used by the working class (Waldus 2021: 213). Of all known 17th century wrecks of inland ships in the Zuiderzee area, no similar evidence for wine drinking has been found.

3. From OR49 to the larger context of peat shipping

Contrary to the international shipping trade, there are hardly any written accounts enabling us to reconstruct the Dutch inland shipping trade of the 17th century. Attempts to search for journals of inland trade skippers in the Zuiderzee area were fruitless. Some toll registers are the only administrative sources of information for this branch of trade. Therefore, the archaeological record of shipwrecks is relevant as source of information, currently comprising more than 500 shipwreck sites. The expectation is that a similar number of shipwrecks remain to be discovered in the IJsselmeer and Markermeer, the part of the former Zuiderzee that is not reclaimed. As written sources are largely missing, it is not surprising that the mainstream research on the rise and development of the early modern economy does not include the inland shipping trade.

However, there is much discussion about the role of the peat trade, a subject that is closely related to the inland shipping trade (De Zeeuw 1978; Gerding 1995; Van Zanden 1997; Waldus 2021). Extensive peatbog areas were available in the Netherlands, enabling the workforce to harvest peat logs on a large scale. This was the basis for the development of theories on the growth of this country as an economic focal point in 17th century Europe.

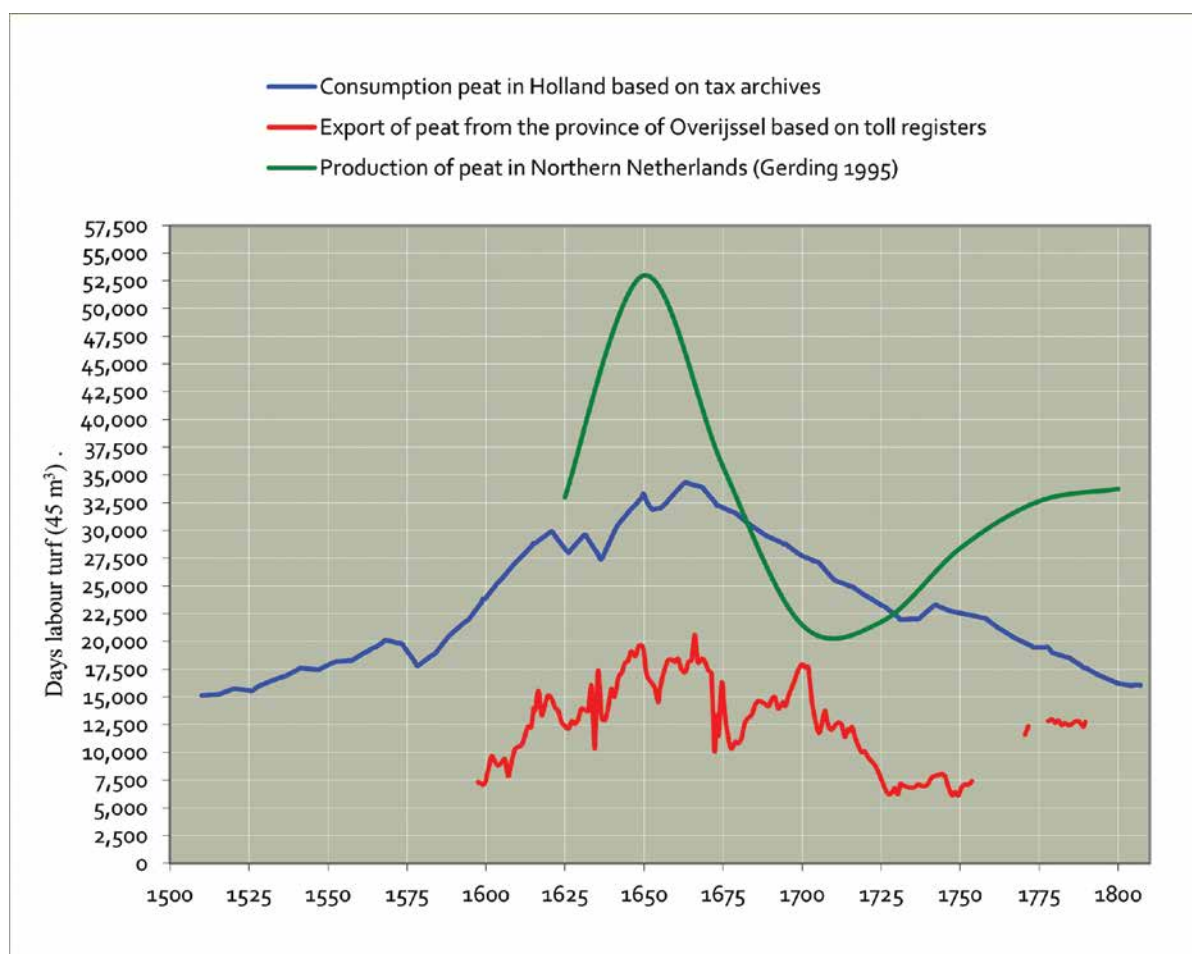


Fig. 5 Graphic of the peat production (green line), peat consumption (blue line) and transportation (red line) over time from Overijssel (author: W. B. Waldus)

The description of the site excavated at lot OR49 reveals an interesting little history about life on board of a peat ship. The question, however, is to what extent the archaeological record has the potential to contribute to the large-scale socio-economic developments of the past. The answer is found when a broad perspective on shipwrecks is studied. On the one hand, a shipwreck is a unique archaeological source, a time capsule or a frozen moment in time of a distant past in which all remains correlate to each other. On the other hand, a shipwreck is a leftover of an economic activity, rooted in a maritime system that evolved over a long period of time. In this case the economic activity is a complex combination of peat exploitation, trade activity and transportation involving a host of organizations and individuals. Cargo ships are an important link in the logistics chain from peat company to end user. The study of shipwreck OR49 has yielded evidence on the provenance of the cargo and the home city of the skipper, which allowed reconstruction of the maritime transport landscape of this sector. The comparison of all known wrecks of cargo vessels in the Zuiderzee area has clarified relevant aspects of the adaptations in 17th century shipbuilding to optimize cargo capacity within the socio-economic system of inland peat trade (Waldus 2021, 220-222).

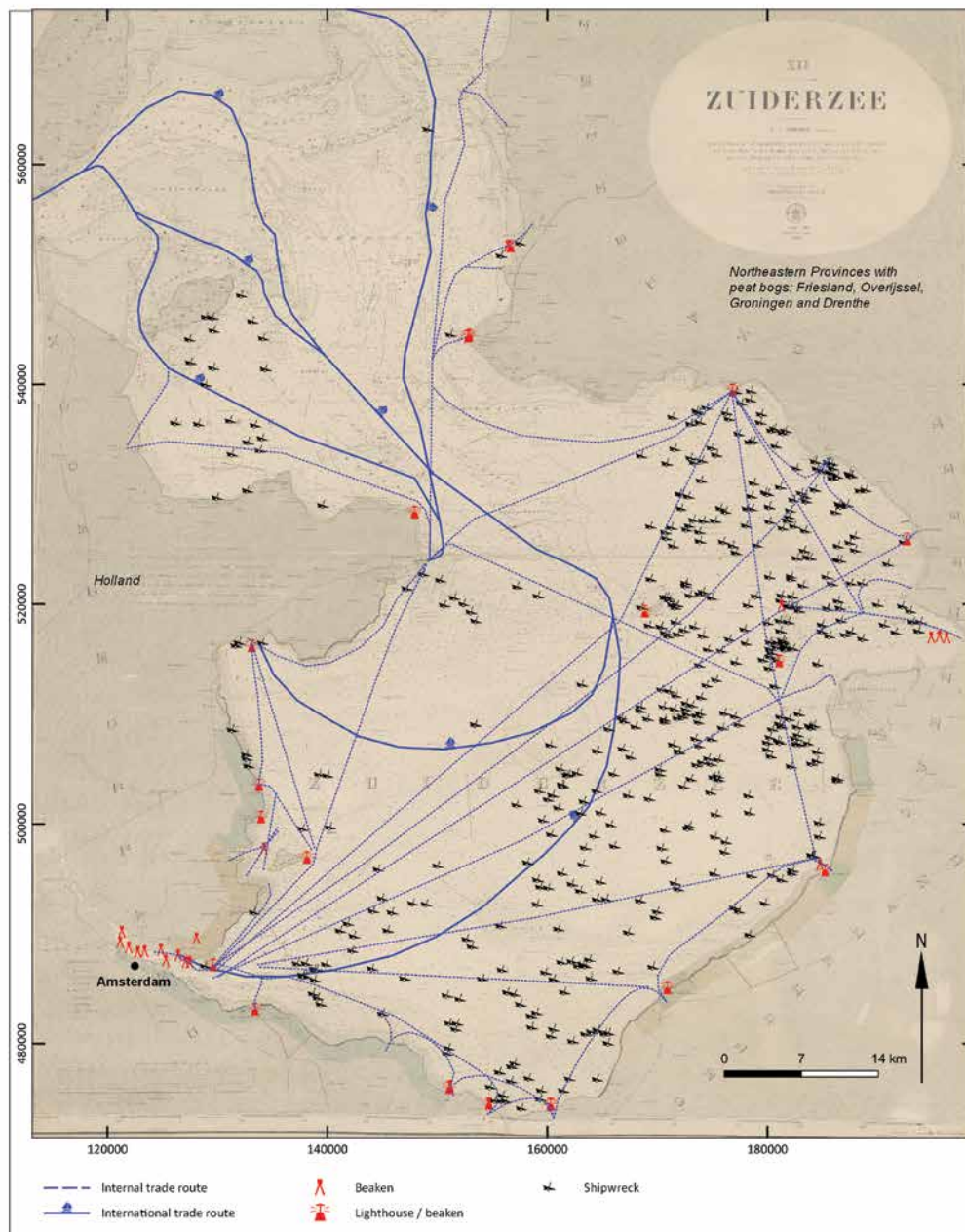


Fig. 6 Shipping routes across the Zuiderzee and all known wreck sites (N=489) in 2020, projected on a 19th century map (author: W. van Baarsel)

4. The volume of peat shipping on the Zuiderzee in the 17th century

A challenging question is to determine the volume of the peat-shipping fleet supplying Holland with this energy source. Holland is a province west of the Zuiderzee. The scarce data in the peat tax-return record provide some answers. It lists transaction costs which is a determining factor in establishing the market price of the peat logs. Based on documented tax and toll data, combined with a set of estimates, the volume of the peat trade and the size of the associated fleet of cargo ships were calculated. The calculations were based on three elements: (1) the total peat production in the northern part of The Netherlands as revealed by Gerding in his book *Vier eeuwen turfwinning*, (2) the peat consumption in Holland calculated on the basis of tax returns from peat logs as an energy source in the project *Nationale Rekeningen* at the University of Utrecht as conducted by Van Zanden, and (3) tax data of Overijssel from which the export volume of peat logs can be inferred: the turfimpost and the Ensser geld. Overijssel is a province east of the Zuiderzee. The data is projected in the next graphic (Fig. 5).

Figure 5 shows that during the 17th century Overijssel accounted for around half of the export demand for peat-energy of Holland. Practically all this peat was mined in Drenthe, a province that lacked a harbor at the Zuiderzee. The remainder was imported by peat ships from Groningen and Friesland, both provinces to the northeast of the Zuiderzee area (Fig. 6). The arithmetic unit of 'a day's labour', the production of a team of peat diggers in one day, corresponds to 10,000 peat logs and has a volume of 45 m³ (Gerding 1995: appendix 1). Based on the reconstructed volume of the hold of a selection of 89 wrecks in the Zuiderzee cargo ships with a length of more than 15 m, it can be deduced that an average load of 2 to 3.5 day's labour of peat logs could be loaded for every transport. The number of peat transport-runs into Holland in a year was derived from accounts of 19th century peat skippers in Overijssel. The number of peat ships from Zuiderzee ports in Overijssel crossing the Zuiderzee amounted to around 20 per year. From Groningen and Friesland 10 to 15 crossings per year were made into Holland. By combining all available data it was possible to put a number on the volume of the peat-ship fleet needed to meet the energy demand of Holland. In the 17th century the size of this fleet must have amounted to 600 in all.

To be able to determine what the ratio is to the total number of cargo ships sailing the inland waterways in this period, an inventory of the Dutch taxation office covering 1808 was scrutinized. It appears that in this year 18,421 professional inland cargo ships sailed the Dutch waters (De Vries, Van der Woude 1995: 230–231). The subgroup with a cargo capacity smaller than 40 ton includes a total number of 16,176 ships, almost 88%. On the basis of the same source it was calculated that 1337 large cargo ships, central to this study, must have sailed the inland waterways of the Netherlands in 1808. By comparing the population size in 1808 to the population size in the middle of the 17th century, and applying this ratio to fleet size, it is concluded that around the year 1650 a total of 1111 cargo ships with a cargo capacity of 40 tons or more sailed the Dutch waters. The number of peat ships, full-time involved in the peat trade, therefore amounted to over half this number.

5. The intensity of maritime traffic on the Zuiderzee in the 17th century

How does this fleet of peat ships compare to other sectors of maritime traffic on the Zuiderzee? This can be estimated from a variety of different written sources. The numbers presented in this paragraph do not add up to a grand total, however they do give some quantification for the intensity of shipping in the Zuiderzee area.

According to Ypma (1962: 66–67), the volume of water-ships in 1505 amounted to 90 vessels. The water-ship was the top-of-the-line fishing vessel at the time in the Zuiderzee area. Around 1600 this number had increased to 130 ships. When it is assumed that the fleet-size increased proportional to population size, the number of these vessels back in the 17th century must have amounted to around 200.

The so called 'beurtschepen' a regular service transporting goods and people on inland waters, is a sector in the maritime trade that is better quantifiable. Numbers from the start of the 18th century provide clues about the intensity of this close-knit transportation network. Each week 800 ships in the regular service departed to 121 different destinations (De Vries, Van der Woude 1995: 222). Looking at the departures with destination Amsterdam around 1700 in the Zuiderzee area alone, it is concluded that each day many ships sailed from Hoorn, Enkhuizen and Workum. Also, seventeen ships sailed the Zuiderzee from other towns with destination Amsterdam, eight departures more often than weekly and seven departures once a week or less (Lesger 2004: 158). This amounts to a fleet of 30 to 50 ships sailing the Zuiderzee in a regular service towards Amsterdam. Additionally, other regular services to multiple destinations in the Zuiderzee area existed (De Vries, Van der Woude 1995: 223; Fuchs 1946: 32–33). If each city or town in Holland

bordering the Zuiderzee area maintained at least one regular service to the most important destinations, then it would mean that another 56 ships sailed the Zuiderzee on a daily basis. So it is likely that a total number of around 100 'beurtschepen' daily sailed the Zuiderzee area.

As detailed before, a minimum of 900 large inland cargo ships with a length of more than 15 m were connected to the Zuiderzee area. Additionally, numerous small vessels were professionally active on a daily basis; however, it is not possible to make an educated guess of total volume. On top of that, coasters and international seafarers used the Zuiderzee routes. The Dutch merchant navy combined with the ships of the East Indies Company and West Indies Company included between 1750 to 1800 ships at the time (Bruin 1977: 200; De Vries, Van der Woude 1995: 470). The fleet of herring boats operating in the North Sea included 500 to 600 ships of which 50% were based in Enkhuizen (Willemsen 1988: 56–57). Concrete administrative information on the number of whalers operating from the Zuiderzee area into the high seas is not available. On the basis of known shipping contracts, the number may have been around 60 ships in the 17th century (De Jong 1979: 314). Finally, the five admiralties operated a navy comprising 64 ships after the assignment for scaling up by the Republic in 1654 (Bruin 1998: 95–97).

In summary, numerous ships arrived regularly in the many Zuiderzee ports. At the apex of shipping intensity in the 17th century the Amsterdam port-registers listed 5000 payments of duty per ton in a year, which is a taxation for the large seagoing vessels (Lesger 2004: 120). All-in-all the trading activities of small boats and large ships from all corners inland and abroad must have been overwhelming. Seventeenth century paintings and etchings depicting the harbor of Amsterdam and the adjacent IJ-river seem somewhat exaggerated while featuring an endless number of masts. However, based on the numbers mentioned in this study it may be concluded that they do reflect reality more than might be expected at first glance. Last but not least, the study of peat shipping in the Zuiderzee area shows that it was dominant in the overall maritime trade business.

6. Concluding remarks

The research of the peat trade in the Zuiderzee included an extensive synthesis of a wide variety of data. It placed the site of a 17th century shipwreck found at lot OR49 in a broader perspective. Peat trade is an important topic in Dutch history as it interfaces with socio-economic processes, inland waterway trade, ship building processes, water management and with the natural changes in the maritime landscape. This article highlights some of these aspects. The answer to the question what the role was of inland shipping in the spectacular developments of the 17th century Netherlands is not an easy one. First, it must be concluded that the conditions for economic growth were already present in the late Medieval period, such as a relatively large population, a dense city landscape, and relatively free citizens focusing on maritime trade. External factors such as the rebellion against the Spanish ruler acted as catalyst for further economic growth. An important contributing factor was the influx of rich merchantmen from Antwerp.

In addition, two more internal catalyzing factors in the context of this study of the peat shipping trade had a significant effect on the economy. The first one is the orientation of the energy market in Holland on the peat bog areas in the northeastern provinces after 1530 and the second one is the changing natural dynamics of the Zuiderzee between 1575 and 1625. As a result, the maritime landscape rapidly developed and the shipbuilding sector with all related activities developed into a booming business. From the maritime archaeological record, it is inferred that a substantial scaling up of cargo ships happened from the second half of the 16th century onwards, commensurate with innovations in ship building techniques and higher levels of specialization. The cultivation of the peat bog areas, the construction of canals and the development of a maritime infrastructure can be attributed largely to the peat shipping trade. It accounts for the development of an efficient internal maritime transport landscape centered on the Zuiderzee area from which the early modern economy in its totality profited.

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Visualizing shipbuilding features through textual evidence: the case of the 19th century Aegean brigs

Andri Evripidou – Stella Demesticha

Abstract: Brig was the predominant ship type constructed on the island of Syros, Greece, the main shipbuilding centre of the Aegean, during the 19th century. To gain insights into the Mediterranean shipbuilding technology of the period, a project was conducted aiming to retrieve and analyse shipbuilding data from contracts concerning brigs built between 1832 and 1857 in Ermoupoli's shipyards. The information was used for the creation of a digital model. This research highlighted the challenges encountered in examining archival sources, as well as their potential as unique resources for understanding the technology and anthropology of shipbuilding.

Keywords: brigs, Aegean, shipbuilding contracts, digital reconstruction

1. Introduction: the brig

During the 19th century, maritime trade and shipping in the Mediterranean were organized through international merchant networks that concerned mainly bulk cargo transportation (Harlaftis 2001: 85–86). The Aegean and Ionian islands, actively involved in these networks, maintained their own shipyards. The most important among them were in Ermoupolis, the capital of the island of Syros, and the commonest type of ship built in its shipyards was the brig (Delis 2010: 344).

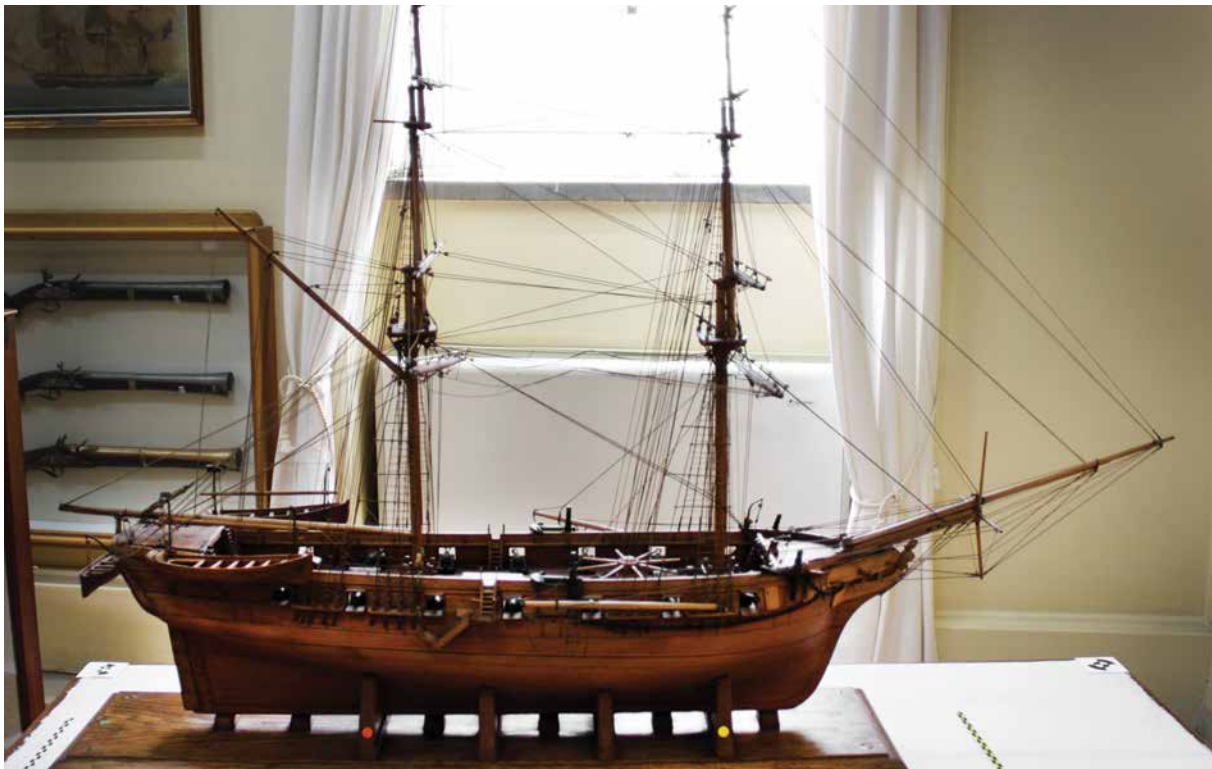


Fig. 1 The model of the brig ARIS (1818), exhibited at the National Historical Museum of Greece, Athens. ARIS is a karavoskaro with inclined transom (photo A. Evripidou, with the permission of the National Historical Museum of Greece)

Brigs were square-rigged vessels with two masts and dominated the Mediterranean waters during the 19th and early 20th centuries (Moore 1925: 45–59) (Fig. 1). This type of rigging, a distinctive feature of brigs, was most probably originally influenced by North European maritime traditions, i.e., full - rigged vessels, with square sails, able to perform fast and low-cost long-distance voyages. Mediterranean shipbuilding traditions, however, were more diverse and developed a large variety of ship types with specific particularities (Konstantinidis 1954; Moore 1970; Kanellopoulos 1983; Damianidis 1998).

Nineteenth century paintings (Tzamtzis 1972: Fig. 65; Harflafts 2002: Fig. 3) illustrate brigs in the Aegean with three to five sails on each mast. Brig rigging could be applied on several hull types. The most common one in the 19th century is known as *karavoskaro* ('καραβόσκαρο' in Greek) (Damianidis 2014: 329–330). From the 1850s onwards, when the mold – loft designing method was introduced, the morphological characteristics of the brigs changed (Damianidis 1998: 153). Following the international trends, they seem to have become smaller, without false gun ports, and with less decorative elements. Also, the original double or S-shaped curvature of the stempost became hollow, and a counter stern replaced the transom (Delis 2014: 54).

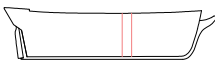
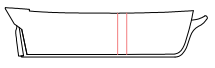
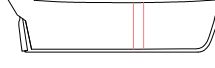
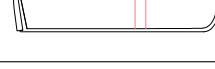
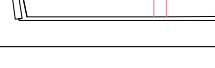
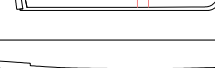
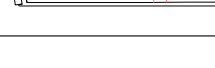
No	NAME	SHEER PLAN OUTLINE	CROSS SECTION AT M.B	CAPACITY (in tons)
1	AYIOS DIONISIOS			162
2	DIMITRIOS			180
3	BIBIKOV			210
4	CANTITO			244
5	NELSON			263
6	EISODIA TIS THEOTOKOU			265
7	PANAYIA TIS AKATHISTOU			271
8	MARIS ATH. VALLIANOS			284
9	MARIGO			293
10	MARIDA			400

Fig. 2 Sections and capacities of the nine ships described in the examined contracts

These general morphological features are known mainly from paintings, as no construction plans have been preserved. This, coupled with the rarity of excavated shipwrecks, created a blurry picture of the construction details of brigs. In this context, archives become a valuable source of information. During the 19th century, ship construction involved several types of documents, such as shipbuilding contracts, contracts of raw material purchase, and title deeds. This paper provides a brief summary of the research conducted on nine such contracts for brigs, built in Ermoupoli's shipyards between the years 1832 and 1857¹. Eight of them were provided by the General State Archives, the Cyclades' Prefecture, Syros,² while one, published by Tzamtzis (1987: 28–30), belongs to the private collection of Spyros Manousakis.

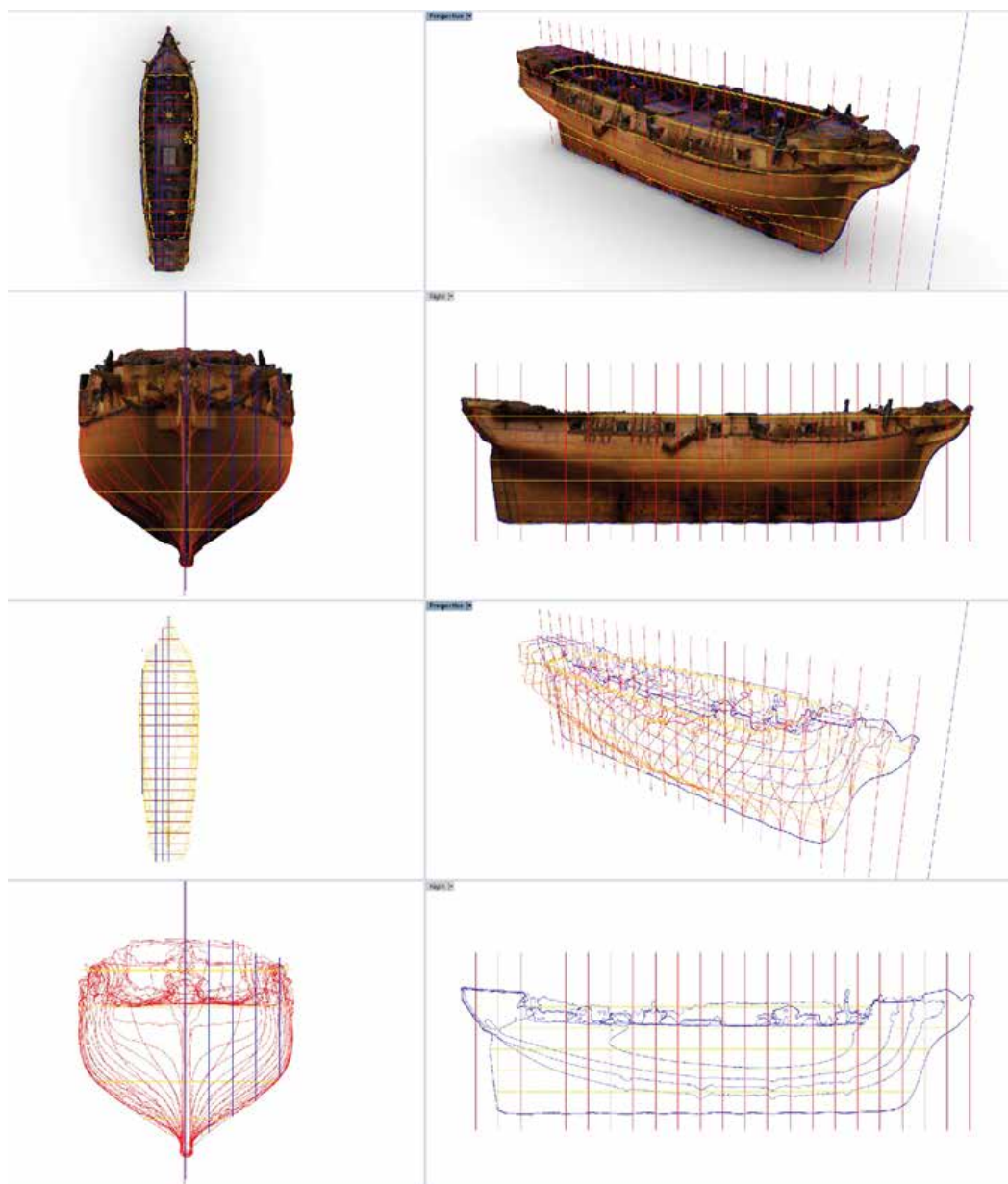


Fig. 3 The top, front, side and 3D view of the digital model of the Brig ARIS, (processed by A. Evripidou, in Rhino 3D software)

¹ This research was part of Andri Evripidou's master's thesis, entitled *Visualizing shipbuilding features through textual evidence: the case of the 19th century brigs*, which was submitted and successfully defended in December 2020 (MA Programme *Field Archaeology on Land and under the Sea*, Department of History and Archaeology, University of Cyprus).

² The eight unpublished documents (contracts and title deeds) provided by the General State Archives were the following: ΓΑΚ/ΑΝΚ Σύρου, Συμβ. Ανδρέας Δαβίδ, Λυτά έγγραφα, αρ. 907, 25/05/1834 (vessel ΑΥΙΟΣ ΔΙΟΝΙΣΙΟΣ); (2) ΓΑΚ/ΑΝΚ Σύρου, Συμβ. Ανδρέας Δαβίδ, Λυτά έγγραφα, αρ. 7090, 13/05/1838 (vessel ΔΙΜΙΤΡΙΟΣ); (3) ΓΑΚ/ΑΝΚ Σύρου, Συμβ. Ανδρέας Δαβίδ, Λυτά έγγραφα, αρ. 7568, 18/08/1838 (vessel CANTITO); (4) ΓΑΚ/ΑΝΚ Σύρου, Συμβ. Ανδρέας Δαβίδ, Λυτά έγγραφα, αρ. 21283, 04/08/1848 (vessel NELSON); (5) ΓΑΚ/ΑΝΚ Σύρου, Συμβ. Ανδρέας Δαβίδ, Λυτά έγγραφα, αρ. 19206, 21/02/1847 (PANAYIA TIS AKATHISTOU); (6) ΓΑΚ/ΑΝΚ Σύρου, Συμβ. Ανδρέας Δαβίδ, Λυτά έγγραφα, αρ. 30178, 14/08/1857 (vessel MARIS. ATH. VALLIANOS); (7) ΓΑΚ/ΑΝΚ Σύρου, Συμβ. Ανδρέας Δαβίδ, Λυτά έγγραφα, αρ. 26722, 29/07/1853 (vessel MARIGO); (8) ΓΑΚ/ΑΝΚ Σύρου, Συμβ. Ανδρέας Δαβίδ, Λυτά έγγραφα, αρ. 19657, 27/06/1847 (vessel MARIDA).

2. Reading the contracts as construction plans

One of the project's objectives was to retrieve metric information of specific structural timbers and their positioning in the hull, in order to create a digital model. The nine contracts that were selected for this project concerned probably *karavoskaro* with inclined transom, since most of them referred directly to the transom or the stern's decoration. They were ships of different capacities and basic dimensions (Fig. 2). Since no construction plans of Aegean brigs have been preserved, the model of the well-known brig ARIS (1818) (Konstantinidis 1954; Adamopoulou 2014; Nikolaou 2014), now at the National Historical Museum of Greece, was photogrammetrically recorded, and was used for the reconstruction of all hull lines (Figs 1, 3).

A challenge faced during the project was the full comprehension of the contracts' original text. The terminology used by the shipwrights was expressed in *katharevousa*, i.e., the official language of the Greek state at the time, but spelling mistakes and the use of some rare terms and expressions of the shipwrights created comprehension problems. For example, some contracts referred to a longitudinal element, called *gyali koutouki* (γιαλί κουτούκι) which is not known from other sources. It was a notch-shaped timber, placed under the shelf clamps. It was running along the sides of the hull, from the stern's bulkhead to the bow's stempost, and was attached on the hanging knees of the beams (Fig. 4).

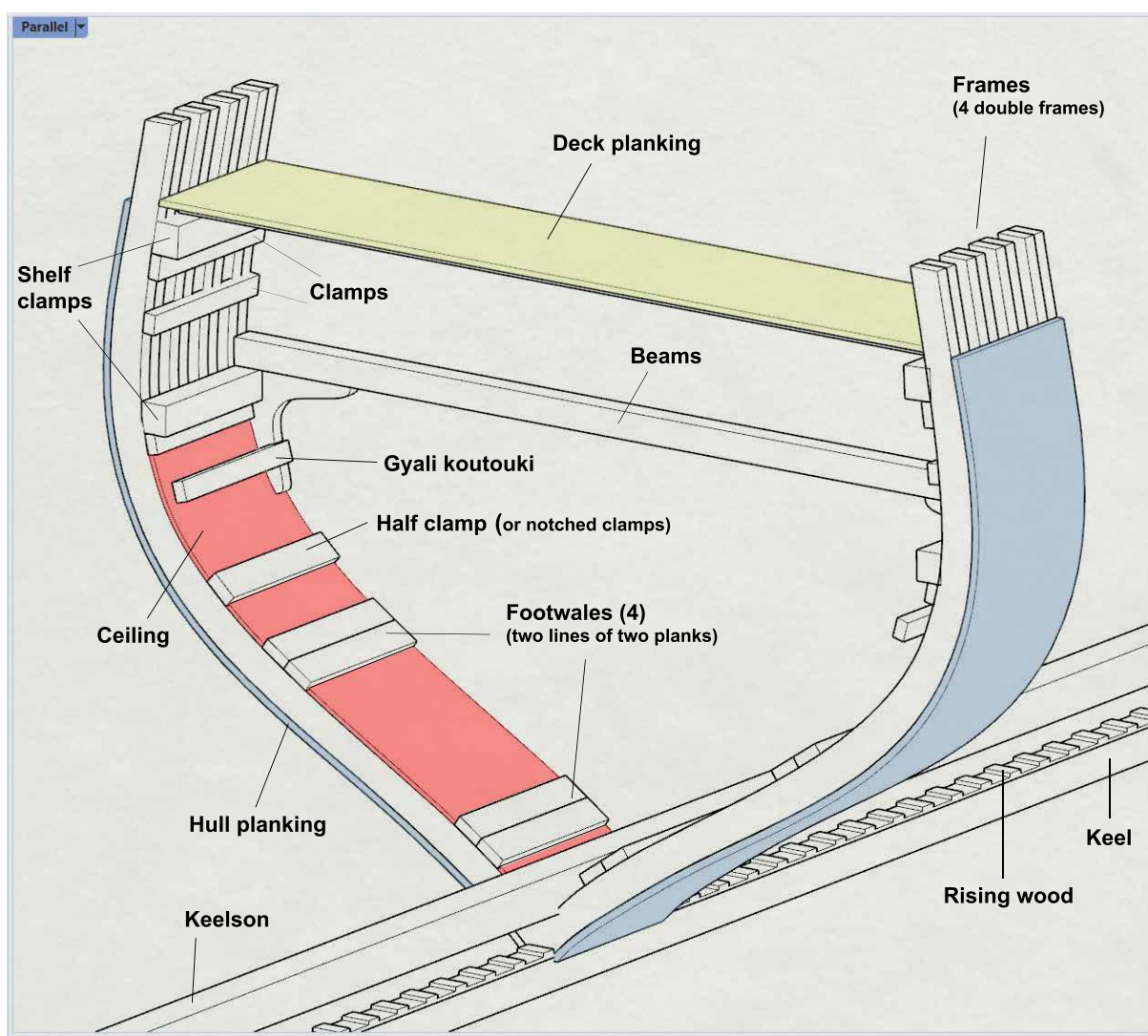


Fig. 4 A 3D mid-section, created by the data selected from the contract of the ship CANTITO, which illustrates the main structural parts of the ship. Colors indicate the different ship's planking: hull in light blue, ceiling in red, and deck in yellow (drawing: A. Evripidou)

The structure of the contracts follows more or less a standard descriptive order, similar to the main steps of ship-building. Specific kind of information is given as follows: (i) the names of contributors, the vessel's type (brig) and its basic dimensions; (ii) the hull's structural elements (i.e., keel, frames, keelson, stringers, shelf clamps, beams and ledges, planking) and superstructures (i.e. the captain's cabin, catheads, canopy, skylight, galley, belfries etc.), which occupied the longest part of each contract; (iii) construction expenses and the shipbuilders' wages; (iv) caulking, nailing and launching equipment; and (v) the dates of the contract's signature and the ship's delivery.

2.1. Measurements and dimensions

The ship's tonnage was not mentioned in the contracts. For some of the brigs, it could be found in their title deeds or historic registers. For the sake of consistency, however, all provided measurements were converted into meters and English feet, and then capacities were recalculated accordingly, using a formula for single decked ships (Delis 2010: 88) (Table 1):

$$\text{L.O.A.} \times \text{M.B.} \times \text{M.D.}$$

/94

L.O.A. (Maximum Length); M.B. (Breadth on the mid-frame); M.D. (Depth from the keelson to the deck)

No.	Ship Name	Dimensions in the Contract			Dimensions in the Title Deed		
		Contract Unit	Meters (m)	Foot (ft)	Title Deed Unit	Meters (m)	Foot (ft)
1	AYIOS DIONISIOS	L.K. = 21 cubits M.B. = 22 barrels M.D. = 11 barrels	L.K. = 19.2 M.B. = 6.7 M.D. = 3.35	L.K. = 63 M.B. = 22 M.D. = 11	L.K. = 21 2/3 cubits M.B. = 22.5 barrels M.D. = 11.5 barrels	L.K. = 19.8 M.B. = 6.9 M.D. = 3.5	L.K. = 65 M.B. = 22.5 M.D. = 11.5
2	DIMITRIOS	L.K. = 20 cubits M.B. = 22.5 barrels M.D. = 12.5 barrels	L.K. = 18.3 M.B. = 6.9 M.D. = 3.7	L.K. = 60 M.B. = 22.5 M.D. = 12.5	L.K. = 21 cubits M.B. = 22 barrels + 6 fingers M.D. = 12 barrels + 6 fingers	L.K. = 19.2 M.B. = 6.85 M.D. = 3.95	L.K. = 63 M.B. = 22.5 M.D. = 13
3	BIBIKOV	L.K. = 22.5 cubits M.B. & M.D. (not indicated)	L.K. = 20.6 M.B. & M.D. (not indicated)	L.K. = 67.6 M.B. & M.D. (not indicated)	L.K. = 24 cubits M.B. = 22.5 ft M.D. = 13 ft	L.K. = 21.9 M.B. = 6.9 M.D. = 4.0	L.K. = 71.9 M.B. = 22.5 M.D. = 13
4	CANTITO	L.K. = 23 cubits M.B. = 25 barrels M.D. = 14 barrels	L.K. = 20 M.B. = 7.6 M.D. = 4.3	L.K. = 65.6 M.B. = 25 M.D. = 14	L.K. = 24 cubits M.B. = 25 barrels M.D. = 14.5 barrels	L.K. = 21.9 M.B. = 7.6 M.D. = 4.4	L.K. = 71.9 M.B. = 25 M.D. = 14.5
5	NELSON	L.K. = 23 cubits M.B. = 25.5 barrels M.D. = 14 barrels	L.K. = 21.0 M.B. = 7.8 M.D. = 4.3	L.K. = 68.9 M.B. = 25.6 M.D. = 14	Not found		
6	PANAYIA TIS AKATHISTOU	L.K. = 23 cubits M.B. & M.D. (not indicated)	L.K. = 21 M.B. & M.D. (not indicated)	L.K. = 68.9 M.B. & M.D. (not indicated)	L.K. = 24 cubits M.B. = 25.5 barrels M.D. = 14 barrels + 4 fingers	L.K. = 21.9 M.B. = 7.8 M.D. = 4.4	L.K. = 71.85 M.B. = 25.5 M.D. = 14.5
7	MARIS. ATH. VALLIANOS	L.K. = 84 ft M.B. = 24 ft M.D. = 13.25 ft	L.K. = 84 ft M.B. = 24 ft M.D. = 13.25 ft	L.K. = 25.6 M.B. = 7.3 M.D. = 4.0	L.K. = 87 ft M.B. = 24 ft M.D. = 13.25 ft	L.K. = 26.5 M.B. = 7.3 M.D. = 4.0	L.K. = 87 M.B. = 24 M.D. = 13.25
8	MARIGO	L.K. = 73 ft M.B. = 26 ft M.D. = 14.5 ft	L.K. = 73 ft M.B. = 26 ft M.D. = 14.5 ft	L.K. = 22.3 M.B. = 7.9 M.D. = 4.4	L.K. = 73 M.B. = 26 M.D. = 14.5	Not found	
9	MARIDA	L.K. = 28 cubits M.B. = 28 barrels M.D. = 16 barrels	L.K. = 25.6 M.B. = 8.5 M.D. = 4.9	L.K. = 84 M.B. = 28 M.D. = 16	L.K. = 28.5 cubits M.B. = 28 barrels M.D. = 16.5 barrels	L.K. = 26.1 M.B. = 8.5 M.D. = 5.0	L.K. = 84 M.B. = 28 M.D. = 16.5

Table 1 The ships' basic dimensions, as indicated in the respective shipbuilding contracts and their title deeds.

The basic dimensions of the ships were indicated in the contracts as follows (Fig. 5):

- Length (L.K.): keel's length, measured between the keel-posts scarf joints (bow to stern). In the shipbuilding contracts, this dimension is defined as 'the distance from one rabbet to the other' (*από ασσόν σε ασσόν*). Although the word *ασσός*, as it is used in current terminology (Damianidis 2014: 391) means rabbet, it does not make sense here: the distance between rabbets can only be the thickness, not the length of the keel. Therefore, we suggest that this word must have had a different meaning in the contracts. Conventionally for this project, we considered the keel's length as the distance between the two keel-post scarf-joints.

- Breadth (M.B.): breadth of the widest frame, measured from the external side of the frames.
- Depth (M.D.): depth of the mid-ship frame, measured from the bottom of the deck beam to the top of the keelson.

The main ship parts described in the contracts, are the following:

- The keel (*χαρίνα*). The word usually refers to one board, not the entire keel structure comprised of scarf jointed

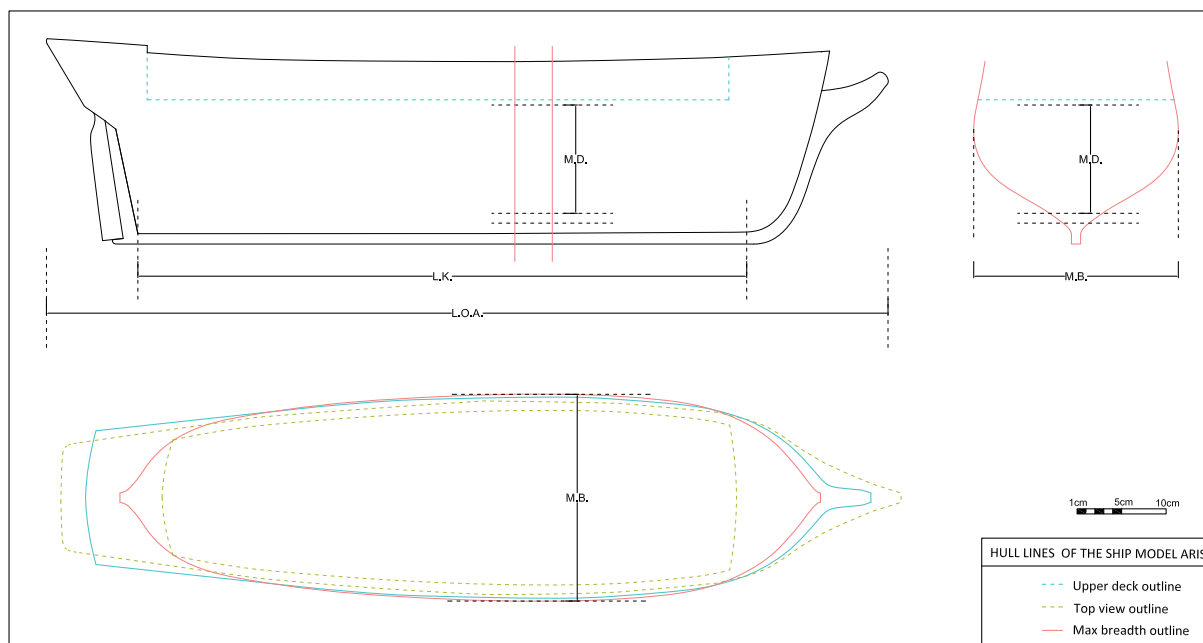


Fig. 5 The basic outlines and dimensions of the ship model ARIS (drawing: A. Evripidou)

pieces. The molded side was always bigger than the sided. In larger ships, a rising wood was fixed on top of the keel, and a false keel is often mentioned.

- The stem and sternposts (*ποδοστάμιο*) have the same size as the keel, in cross-section.
- Double framing (*στραβόξυλη* or *πόστες*) was described in all contracts. The number of the frames was seldom mentioned but could be approximately estimated, using their dimensions (cross-section), the distance between them, and the keel's length; such an estimation was attempted with the contracts of CANTITO, PANAYIA TIS AKATHISTOU, and MARIS. ATH VALLIANOS. In these cases, the number of frames was calculated according to the L.K., so the number was correlated only with it. In some cases, it was mentioned that frames were spread out between the bow's and stern's cant frames named in contracts as *ρεπίδια*. Since we do not know the number, or the room-and-space distance of the cant frames, however, the estimated results represent the maximum number of frames, not necessarily the actual quantity.

The average room-and-space distance was 15.2 cm. However, it the frames' data and the L.K. For example, DIMITRIOS had 50 frames, 22.8 cm sided, and L.K. of 18.3 m. According to the following formulas the distance between frames is 14 cm:

$$50 \text{ (frames)} \times 0.228 \text{ m} = 11.4 \text{ m (total width of frames)}$$

$$18.3 \text{ m (L.K.)} - 11.4 \text{ m} = 6.9 \text{ m (total length of room-and-space)}$$

$$6.9 \text{ m} / 49 \text{ (gaps between the 50 frames)} = 0.14 \text{ m (room-and-space)}$$

- The keelson (*σωτρόπι*) was composed of one board or two scarfed joined timbers. It is always larger than the keel, mainly square in section.
- The number of stringers or footwales (*στραγαλιές*) varied from four to six on each side. The way they were divided per side was not specified, in the contracts.

- Shelf clamps (*κουρζέτο/α*) were positioned below decks. Larger ships had two or three shelf clamps under each deck; those of the lower deck were slightly smaller than those of the upper (main) deck.
- Clamps (*λούροι*) had a complementary role to shelf clamps and were usually positioned below them. Their size was similar to the footwales and they were sometimes named as half-clamps or notched-clamps (*μισοκούρζετα* or *χαρακτά*) (Delis 2010: 185).
- Beams and ledges or half beams (*καθένες, παγκάτσες, σμπάγια, καμάρια*): There were less beams than ledges. Their number and pattern could be only approximately estimated if we knew the sided measurement of both beams and ledges, the beams number, the in-between distance of ledges and the keel's length. For example, in AYIOS DIONISIOS contract, if we assume that beams were extended throughout the keel, then the formulas below estimate that the ship had 45 ledges:

$$10 \text{ beams} \times 0.114 \text{ m (beam's length)} = 1.14 \text{ m (total length of beams)}$$

$$19.2 \text{ m (L.K.)} - 1.14 \text{ m} = 18.06 \text{ m (total length of beams' gaps)}$$

$$18.06 \text{ m} / 9 \text{ (gaps between the 10 beams)} = 2.0 \text{ m (distance between beams)}$$

$$2.0 \text{ m} / [0.0855 \text{ m (ledge)} + 0.266 \text{ m (distance between ledges)}] = 5.7 \approx 6 \text{ (times that ledges and their in-between distance feet in the in-between beams' distance} = 5 \text{ ledges between two beams)}$$

$$\text{Total number of ledges} = 5 \times 9 \text{ (gaps between the 10 beams)} = 45$$

The positioning and dimensions of beams were also related to the frames data. For example, in CANTITO each ledge was responding to each double frame, while in MARIS ATH. VALLIANOS beams were placed every two double frames (Fig. 6).

- Planking: contracts refer to the first planking timbers, as well as the wales or external shelves (*τζ(σ)άπες*), whose number varied from six to ten on each side. The thickness of ceiling planks (*φέδρωμα*) as well as of the deck and hull planking (*στράβαις*) is always indicated.
- The bulwark (*παραπετό*) is composed of the gunwale (*κουπαστή*), the lower gunwale or waterway (*τρυπητή*) and the plank sheer (*ζωνάρια*). It is described as double or single, but it is only the planks' thickness that was agreed in the contracts. The number and position of the breast hook knees, and the knees is also recorded.

The division of the ships' compartments, their superstructures, and equipment are only mentioned briefly. The brigs' interiors were divided by bulkheads in the middle of the hold, the captain's cabin to the aft part, and the sailors' room to the fore of the vessel. Regarding the superstructures and equipment, reference is made to the catheads, canopy, skylight, galley, belfries, hatchways, channels, rudder, wheel or the tiller, bits, hawses, catheads, figureheads, capstan and the windlass.

For the reconstruction of the ship's plans in this study, the following information was recorded about each structural component:

- the dimensions of their cross-section,
- their number and
- their place in the ship's structure.

Not all contracts, however, contained consistent information for all components and sometimes the way they were described was insufficient. Only one contract, for the ship CANTITO, had comprehensive information that allowed for the creation of a 3D mid-section as well as of the longitudinal and transversal parts. However, the dimensions of the clamps, the planking and the gunwale, which were not comprehensive in CANTITO's contract, were taken from PANAYIA TIS AKATHISTOU, which was a ship of similar tonnage.

The 3D mid-section of the 3D photogrammetric model (Fig. 2) was produced based on ARIS hull lines, then processed in Rhinoceros (Rhino 3D) software; twenty-one transversal, five longitudinal and five horizontal sections were taken for the hull, profile, and half-breadth plans respectively. As the model's surface was not very smooth and the section lines were rough, they were exported and reworked in AutoCAD software, where the final plan was designed and used for the final visualization of the brigs.

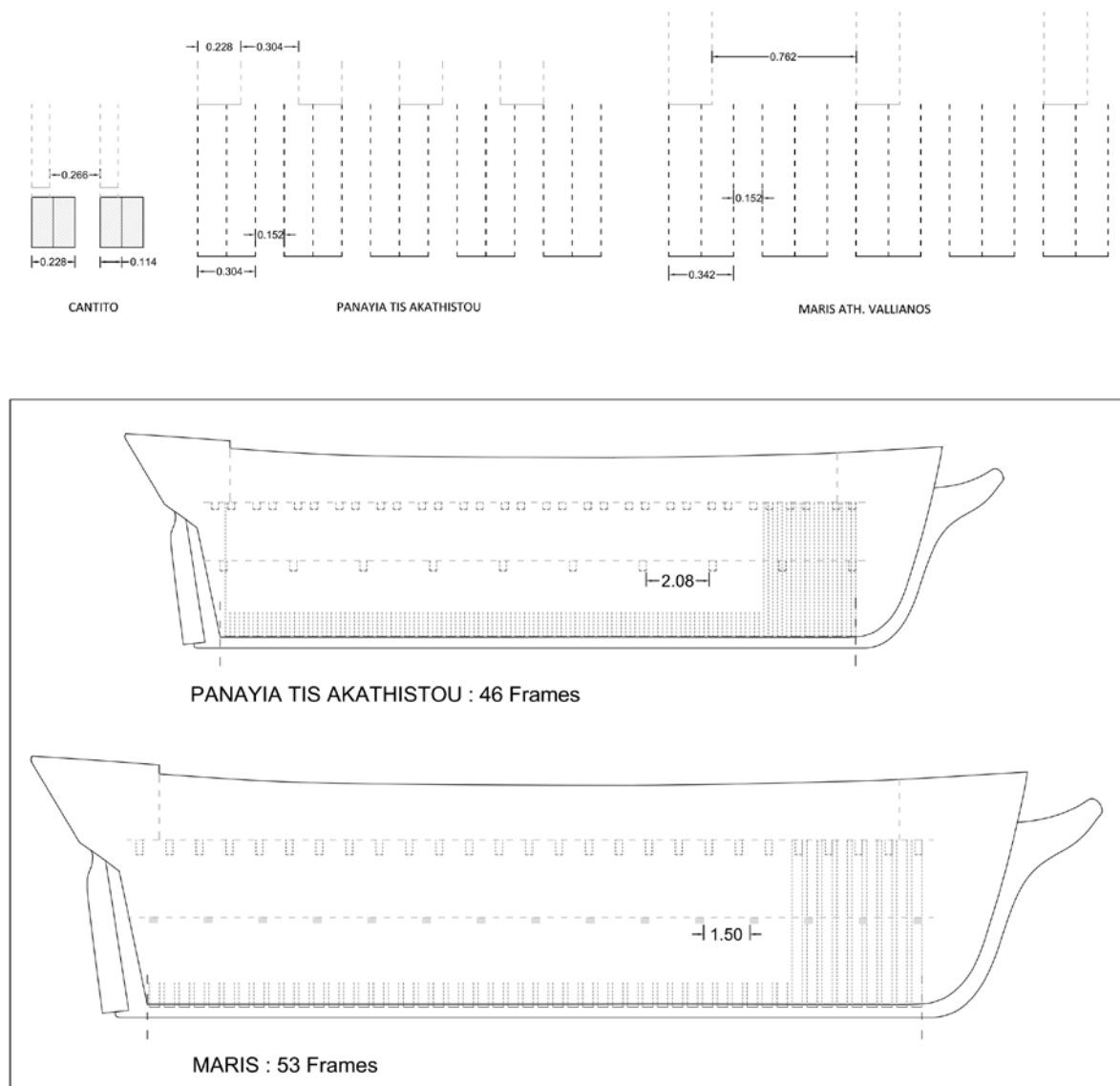


Fig. 6 Top: the relation of beams (green color) and frames positioning of the three ships; CANTITO, PANAYIA TIS AKATHISTOU and MARIS ATH. VALLIANOS, and their in-between distance. Bottom: Sections showing the number of frames and the estimated positioning of the beams, according to frames placement (blue color in PANAYIA, blue and grey in MARIS) (drawings: A. Evripidou)

3. The people behind the contracts

The specific technical information in the contracts provided useful insights into the conception phase of vernacular shipbuilding. It seems that both contracting parties, i.e. the shipowner and the shipwright, were familiar with the technical specifications described in detail, and they agreed that these elements would guarantee the quality of the end product, i.e. the ship. For example, the length of the ship was defined by the keel and its bulk was related to the M.B and M.D. The owners were probably satisfied that agreement on these components could ensure the size of their ordered vessel. Apart from the ship's size, the number and size of timbers required for the ship's construction were also defined in the texts, possibly to secure the economic investment in necessary raw materials, from the part of the shipwrights.

The realization phase depended highly on the empirical knowledge of the shipbuilders. Thus, the number of frames was not specified, perhaps because the shipowner trusted the shipwright to make the final decision on this. Their number remained flexible and was finalized based on the final length of the ship. Their construction details, however, were considered crucial for the ship's integrity and had to be agreed in the contract. Similarly, the exact positioning of the longitudinal reinforcing elements was also not defined, because either it was yet another decision left to the shipbuilder to make, or it was a well-known detail, unnecessary to be described in a legal document. What was important and was

indicated in the contract was their thickness, which determined how much they could add to the ship's ability to resist water or wind strains.

The final structure was most probably perceived in the minds of the shipwrights, during and not necessarily before the construction. Characteristic of this process is the fact that the final dimensions stated in the title deeds of the brigs are often different from the ones in the contracts (Table 1).

With all these uncertainties taken into consideration, it is not a surprise that the data from the contracts could not have led to a comprehensive and precise reconstruction of the brigs in question. Visualization of archival evidence, however, opened a challenging path towards a more concise comprehension of the *chaîne opératoire* and the Aegean nautical traditions in the 19th century.

4. Conclusions

The pre-modern vernacular shipbuilding in the Aegean is a challenging topic that remains poorly studied. The project that was briefly presented above was a first attempt to approach archives as a source of archaeological information, since the physical remains of the wooden vessels have not been preserved. Brigs were used as a case study and their contracts have provided valuable insights into the technological and anthropological context of Aegean shipbuilding during the 19th century.

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Flooding of an ancient ship during the shipwreck

Šimun Sviličić – Smiljko Rudan

Abstract: Shipwrecks are the remnants from the past that contain the story about the ship, sailors, cargo, and some aspects of the world of that time. A shipwreck also acts as evidence of the event, usually tragic, that brought the ship's life to end. Depending on the evidence from the archaeological site, various reasons for the sinking of the ship can be examined. State-of-the-art engineering tools may be used to simulate the events leading to a shipwreck. In this article, numerical modelling and analysis are applied to calculate flooding time until the loss of buoyancy of the idealised ancient vessel, which precedes the inevitable sinking. The paper aims to assess the questions about how much time is needed in various scenarios for the sections of an ancient ship to get flooded, and how the internal design of the ship influences the flooding time.

Keywords: ancient ship, shipwreck Finite Element Modelling, Fluid-Structure interaction, flooding, 2D analysis, ICFD

1. Introduction

Shipwrecks of ancient ships all over the world witness the extensive sailing history of mankind. Transport of people and goods was never without risks. Ancient sailors relied on available resources in shipbuilding and seafaring and were facing dangers such as bad weather, uncharted waters, ship structural damage occurring due to various reasons etc. One of the serious problems was the flooding of the ship. It could have happened for various reasons, such as the action of the storm waves, collision or contact with some rock or object in the water, leaking due to poor sealing of seams between planks and so on. Minor penetration of water in the ship's hull was normal and was manageable by the crew. However, the excessive penetration of water was a serious problem, often leading to the loss of ships and cargo, and sometimes human lives.

Flooding is extensively studied in contemporary naval architecture, and different flooding scenarios are examined to secure ship survival in the case of water ingress. Commonly, watertight bulkheads and compartments, as well as openings and passages, are designed to minimise the effects of flooding, or maximise the time available for evacuation or salvage operations. On the other hand, forensic analysis of historic ship flooding is rarely performed using state-of-the-art engineering tools. Stettler and Thomas (2013) performed flooding and structural forensic analysis of the sinking of the RMS Titanic. They modelled progressive flooding, using GHS software, which seeks the static equilibrium between the weight of the vessel and its buoyancy, and considers the change of internal liquid-free surface. In subsequent analysis, authors performed a structural analysis of the complete FEM model of the Titanic.

The fast simulation approach, based on potential theory, was done by Ancafora *et al.* (2017). Even though it predicted with reasonable accuracy the flooding volume of water, the mathematical model did not predict roll motion and behaviour under waves in a satisfactory way. Rudan and Radić Rossi (2017) presented a two-stage numerical simulation of the floating, flooding and sinking of an ancient ship. Arbitrary-Lagrangian-Eulerian (ALE) method was used to simulate the floating of the 2D ship model with cargo in the waves. Flooding was modelled as a simple loss of buoyancy over time. In the second stage, motions of the surface ship were applied to the structural model with cargo, and the simulation was performed until the ship rested on the seabed.

A more common way to study the flooding process is by the application of the Finite Volume Method. Gao *et al.* (2011) performed computational fluid dynamics (CFD) analysis of a flooded Ro-Ro ship, which showed that rolling frequency decreased over time, but mainly from internal sloshing, and less from flooded water. Further dynamics of ship flooding were done by Khaddaj *et al.* (2012), by conducting physical experiments of a scaled compartment,

with the main goal of investigating water and air behaviour during flooding. Abrupt flooding of ships with multiple compartments was done by Zhang *et al.* (2019) by using the Finite Volume Method, and air compressibility was introduced. While the study captured very advanced physical behaviour, such as air compressibility and formation of bubbles, simulations lasted over 161 hours.

This article aims to examine the flooding process for some idealised internal designs of ancient ships, as well as different dimensions, and different locations of hull ruptures. Ancient ships were capable of long-distance sailing while withstanding rough weather conditions. Structural material used in ancient shipbuilding was usually wood, which did not have large safety margins, and often suffered from structural damages. This led to openings in the hull sections, and consequently to the sinking of the ships. The goal of the study was to investigate how much time was needed for the loss of buoyancy and sinking, and if the internal design of the ship influenced greatly the flooding time. Finite Element Modelling was used, accompanied by the Fluid-Structure Interaction method, so the fluid could be modelled and incorporated into the analysis.

2. Numerical model

2.1. Geometry

The ship's mid-section was extracted using 3D modelling software, and a 2D surface model of the ancient ship was created. Both ships' outer width and height are equal to 3 meters with additional added taffrail that captures a water-on-deck effect equal to 0.1 meters in height. The internal geometry directly influences the ship's stability and flooding time. As an ancient ship's internal geometry is difficult to understand without well-preserved ship remains, the most common arrangements of ship compartments are used. Those are: ship with one compartment (Fig. 1a), ship with three compartments (Fig. 1b) and ship with four compartments (Fig. 1c). To better understand the difference between flooding time for three different ships, structure density was adjusted so all three ships weigh equally 3.5 tonnes.

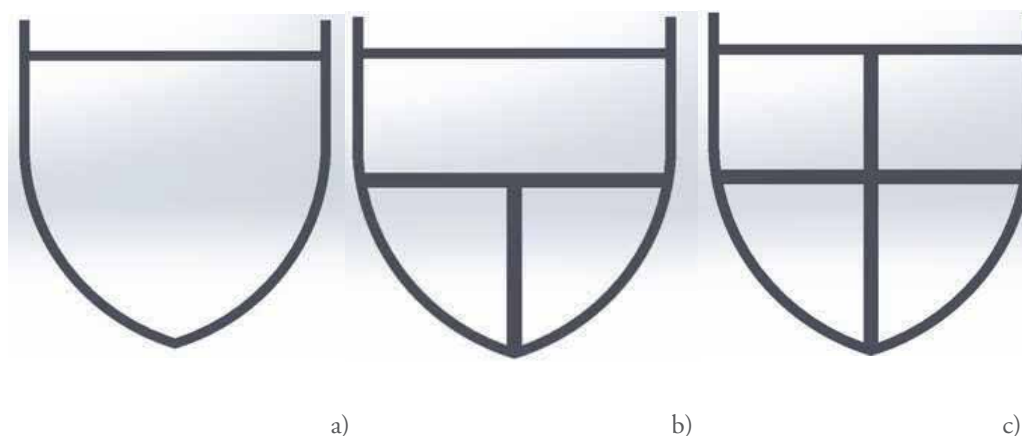


Fig. 1 Internal ship design: a) One compartment; b) Three compartments and c) Four compartments (author: Š. Sviličić)

2.2. Fluid-structure interaction

Analysis of a fluid environment requires dividing the fluid into basic computational elements, or finite elements. The interaction and iterative solving of the elements is a complex process which requires significant computational resources and high simulation time. In order to decrease simulation time, 2D analysis was performed. For solving ship flooding, an incompressible fluid dynamic (ICFD) solver, which is incorporated in the LS-DYNA (software which annualizes failure analysis of ships), is used. To adequately mesh this domain, initial elements were prescribed on the domain boundaries (Fig. 2a), and afterwards, the mesh algorithm extruded initial elements from the boundaries into the inner domain (Fig. 2b). The initial fluid mesh consisted of 1578 surface elements, which were then extruded, and raised to the number of 26630 elements. The free surface was modelled, and divided water and air.

Finite Element Modelling of damage and element deletion was not possible because of the software limitations. The ICFD cannot be combined with damage mechanics, so instead of modelling it, the point load is introduced as water weight. Load from flooding was coded using Fortran, and it incorporated Bernoulli's equation.

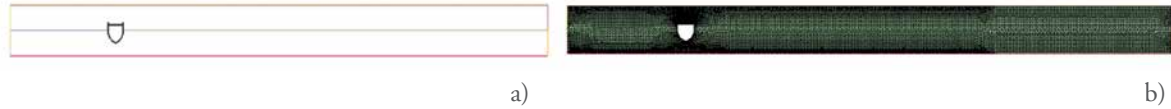


Fig. 2 Numerical domain: a) initial, b) extruded (author: Š. Sviličić)

$$\int_p \frac{1}{\rho g} dp + \frac{u^2}{2g} + z = \text{const} \quad (1)$$

$$u = \sqrt{2gz} \quad (2)$$

$$Q = \int_A u \cdot n \, dA, \quad (3)$$

where p is pressure, g represents gravity, u is the velocity field, z is fluid level height, Q is water flow, n is a unit vector, and A is the surface which in this study case represents the hole in the ship's hull.

For this type of analysis, implicit dynamics was used, with a time step of 0.1 seconds. The total simulation time varied between 25 and 70 seconds. Implicit dynamics use the Newmark method, with time integration constants $\beta=0.4$ and $\gamma=0.6$. To simulate rough weather conditions, the wave is generated at the boundary as a Stokes second-order wave, with a height of 0.8m and a length of 20 meters. Finite Element Modelling of the structure is simple, and consists of 500 finite shell elements.

2.3. Case studies

As every simulation runs for approximately 2 hours, many case studies are done, so the conclusion can be drawn, and a correlation between different parameters can be found. Case studies are varied based on the inner ship geometry, hole diameter, hole position as well as water velocity, e.g., calm water or waves. Table 1 presents all the cases with added descriptions.

Number	Description
1.	Bigger hole, Low position A1 → height=1.6m, d=0.2m
2.	Bigger hole, High position A2 → height=0.8m, d=0.2m
3.	Smaller hole, Low position A3 → height=1.6m, d=0.05m
4.	Smaller hole, High position A4 → height=0.8m, d=0.05m

Number	Description	Number	Description
1.	C1 – Calm water – Bigger hole – Lower position	10.	C3 – Waves – Smaller Hole – Lower position
2.	C1 – Waves – Bigger Hole – Lower position	11.	C3 – Calm Water – Smaller Hole – Higher position
3.	C1 – Calm Water – Bigger hole – Higher position	12.	C4 – Waves – Bigger Hole – Lower position
4.	C1 – Calm Water – Smaller Hole – Lower position	13.	C4 – Calm Water – Bigger Hole – Lower position
5.	C1 – Calm Water – Smaller Hole – Higher position	14.	C4 – Calm Water – Bigger Hole – Higher position
6.	C3 – Calm Water – Bigger Hole – Lower position	15.	C4 – Calm water – Smaller Hole – Lower position
7.	C3 – Waves – Bigger Hole – Lower position	16.	C4 – Waves – Smaller Hole – Higher position
8.	C3 – Calm Water – Bigger Hole – Higher position	17.	C4 – Calm water – Smaller Hole – Higher position
9.	C3 – Calm Water – Smaller Hole – Lower position		

Tab. 1 All case studies

3. Results

3.1. Ship with one compartment

For the ships with one compartment, the flooding scenario is straightforward. Water penetrates the internal chamber and causes slight disbalance of the ship, due to the surrounding fluid pressure, until the end when water reaches the deck. The first scenario, C1 with initial position of the ship (Fig. 3a) and final position of the ship (Fig. 3b) are shown. Flooding of the ship's interior is intense and due to the shape of the hole, the volume rate of leaking water is big. The initial three seconds do not include ship flooding, instead, they are used to let the system naturally stabilize in the neutral position. These three seconds are used for all the analyses.

The ship's centre of gravity is tracked over a period. The initial period (Fig. 3c, marked red) has slight oscillation due to the system balancing, after which the flooding is started. The period from the third until the 23rd second has slight oscillation, due to the surrounding oscillation of pressure. After 23 seconds, water fills in the deck and an abrupt change in the ship's centre of gravity is noticed. This means that the ship lost buoyancy, and its sinking is inevitable.

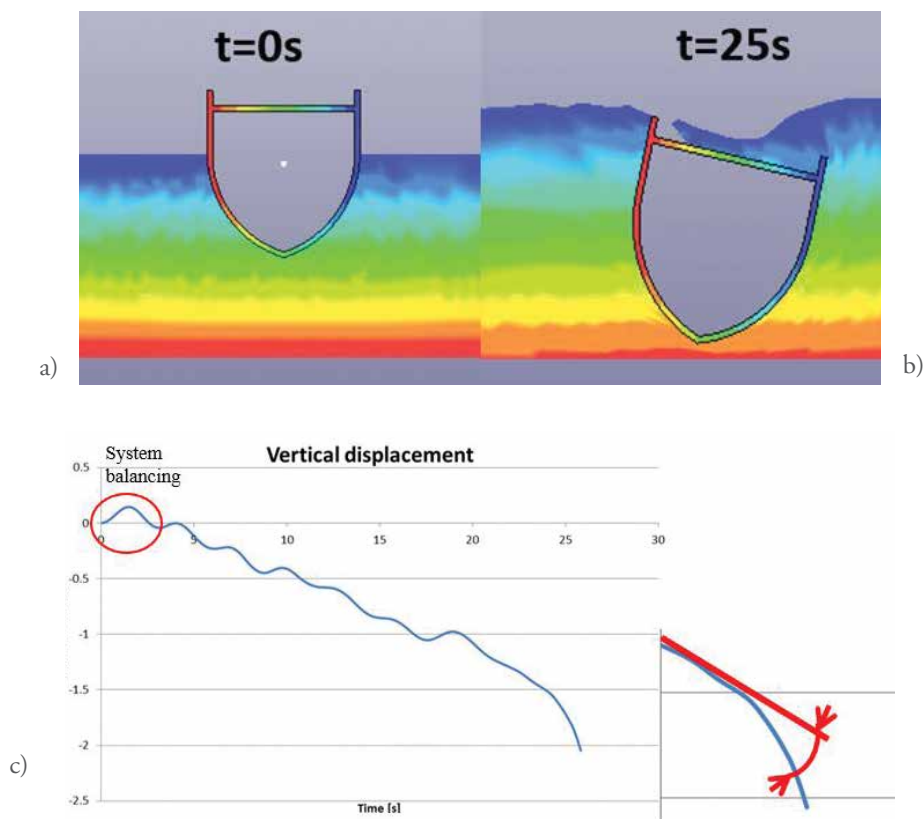


Fig. 3 C1 ship case a) initial position; b) final position and c) vertical displacement of ship centre of gravity (author: Š. Sviličić)

3.2. Ship with three compartments

As damage introduction is not feasible while using ICFD analysis, a predefined flooding scheme should be introduced for ships with more compartments. Two different flooding schemes are presented for ships with three compartments. All internal holes are of the same size, and the scheme is applicable for both, higher-positioned holes (0.8 m from the free surface, Fig. 4a) and lower-positioned holes (1.6 m from the free surface, Fig. 4b).

Next, the position of the centre of gravity of each compartment is compared for both cases, on calm water (Fig. 4c) and on waves (Fig. 4d). Due to the unbalanced mass caused by flooding, the rolling of the ship is much bigger than in the case of a ship with one compartment (Fig. 4c). The centre of gravity of each compartment shows a spike in displacement at five seconds due to rolling from water ingress on one side. Further ship oscillation with lower amplitude continues until water starts to enter the second compartment and pushes it down at approximately 23 seconds. In the case with waves (Fig. 4d), the influence of waves is visible. A high displacement peak occurs around the fifth second, due to the wave impacting the ship. Again, after 20 seconds, linear sinkage is visible after the water reaches the deck.

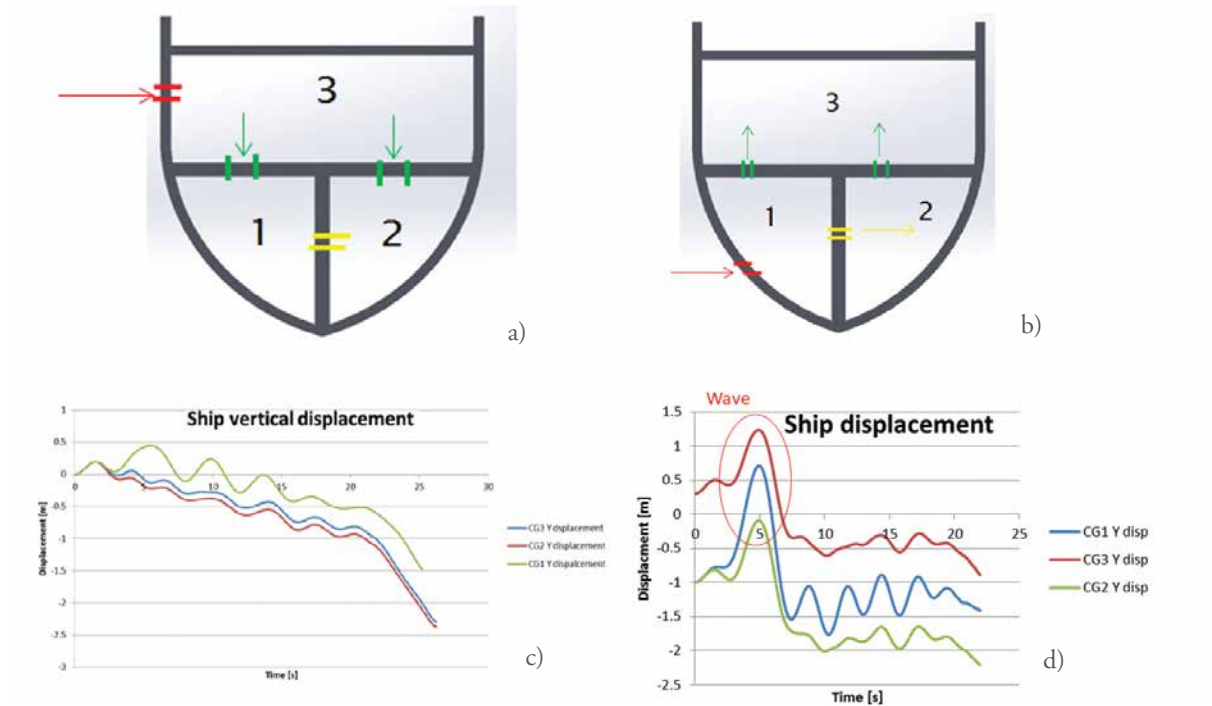


Fig. 4 C3 ship case with flooding scheme a) flooding starts at the top compartment; b) flooding starts at the bottom compartment; c) vertical displacement on calm water and d) vertical displacement on waves (author: Š. Sviličić)

3.3. Ship with four compartments

As position of the hole is defined for ship with three compartments in previous figures (Figs 4a and 4b), the same logic can be applied to the ship with four compartments, but further explanation of interior compartments flooding is needed. When water ingress starts at the upper hole (Fig. 4a), water passes through compartment 3 holes (Fig. 4a, marked green) and fills both compartments 1 and 2 simultaneously. After both compartments 1 and 2 are full, compartment 3 starts to fill up. If water ingress starts at the bottom hole, the flooding scheme is different (Fig. 5). Flooding initially starts at compartment 1 (CG1), which is filled until the interior hole (positioned at the middle of the height) is reached. Then, compartment 2 (CG2) is filled, while the force in compartment 1 is constant until the water level between the two compartments is equal. Finally, the water level in the two compartments continues to rise and fills the final, third and fourth compartments (CG3 and CG4).

As in the case of a ship with three compartments, a ship with four compartments has a defined flooding scheme. The results for Case 12 are shown (Fig. 6). Opposed to the ship with three compartments, ships with four compartments have a bigger roll due to constant mass disbalance during flooding (Fig. 6b). If the hole diameters are compared, less roll of the ship, and a bigger time till buoyancy loss is visible (Figs 6c and 6d), which shows that a small hole diameter prolongs buoyancy loss for more than 40% of the time making it the less severe case.

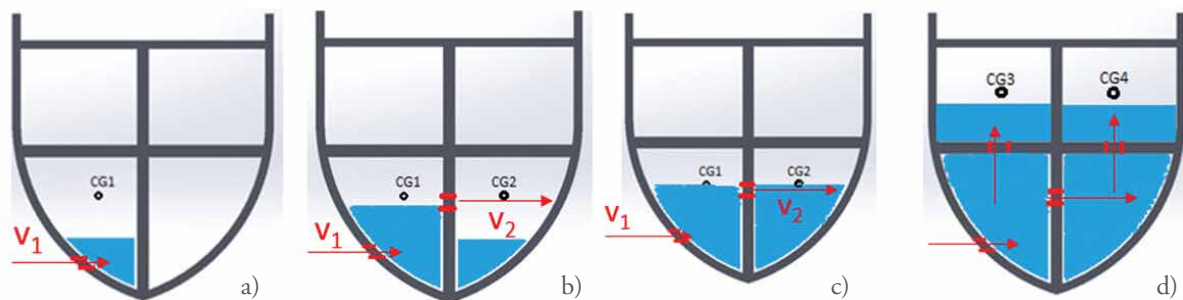


Fig. 5 Flooding algorithm for the lower hole (author: Š. Sviličić)

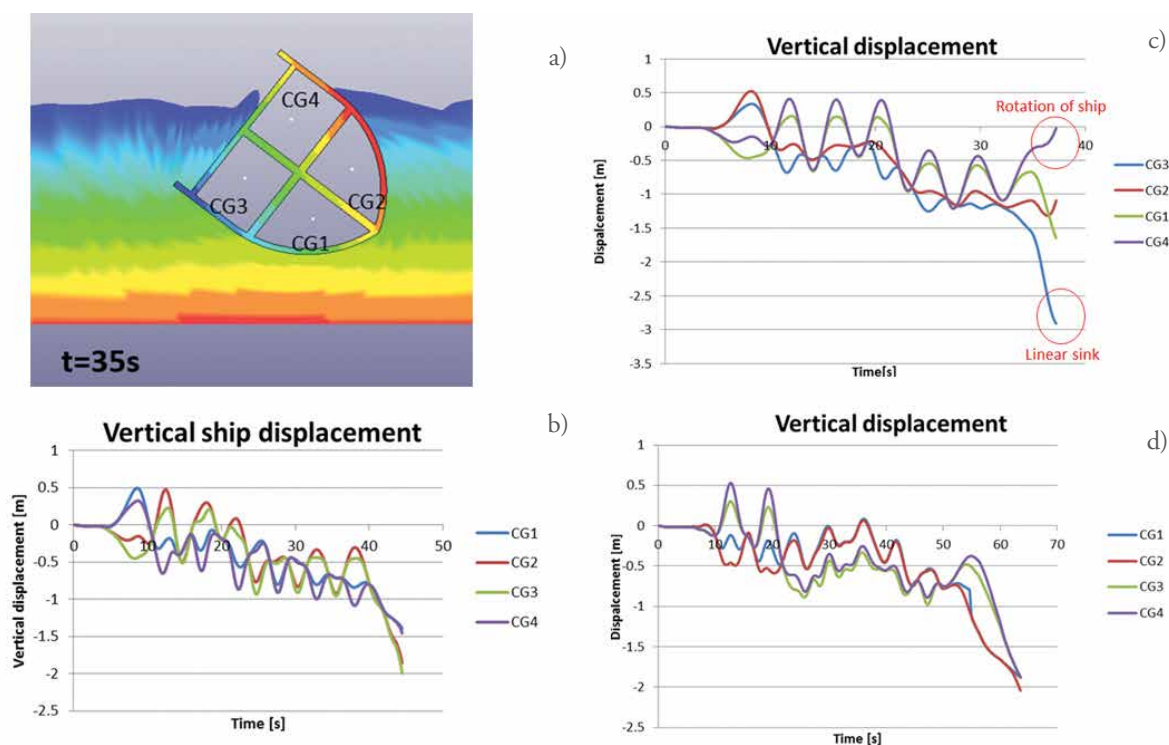


Fig. 6 C4 ship case: a) final position of Case 12; b) vertical displacement for Case 12; c) comparison of displacement for Case 13, and d) comparison of displacement for Case 15 (author: Š. Sviličić)

4. Conclusions

Results from all the case studies are shown in Table 2. It is shown that the size of the ship damage, i.e., hole diameter is a crucial parameter which has the biggest influence on the flooding time, more than the position of the hole. When assessing the different designs, the increased number of compartments caused bigger rolling of the ship, which led to more ship-on-deck effects, but a higher time till stability loss in general. The application of waves showed that for the same set-up (hole diameter, hole position and internal design), the time till loss of stability is slightly shorter, on average 10% less till the loss of stability. Additionally, as expected, waves generated more rolling of the ship, which caused more water on the deck, decreasing the time till buoyancy loss.

While the application of the 2D analysis approach for flooding simulation is a big simplification of such a complex case, it gives a quick solution for parameter study, and can potentially help in the assessment of how the given parameter influences flooding. Additionally, it helps in the assessment of the value of the parameter in real ship forensics, and gives good guidelines for some parameters such as hole position or diameter, which should be used in real 3D simulations.

C1 – one compartment	Time [s]	C3 – three compartments	Time [s]	C4 – four compartments	Time [s]
1.	25	6.	26	12.	35
2.	22	7.	25	13.	44
3.	32	8.	27	14.	43
4.	43	9.	56	15.	63
5.	46	10.	53	16.	57
		11.	59	17.	66

Tab. 2 Results from all the case studies

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Developing a craft perspective on the interpretation and reconstruction of boats

Fredrik Leijonhufvud

Abstract: In this article, analogue and digital methods for the surveying and reconstruction of boats are discussed from a boat builder's perspective. The examples are from an ongoing study of vernacular clinker-built boats from the Stockholm Archipelago. The craft knowledge of the contemporary boat builder can be useful in the interpretation of old boats, and their reconstruction in practice, combined with cooperation between boat builders and marine archaeologists, may lead to synergetic results that improve related research.

Keywords: boat building, craft tradition, survey methods, reconstruction, photogrammetry

1. Introduction

In my PhD project, I explore how a boat builder's interpretation of boats can enhance research that aims to reconstruct boat building skills and knowledge from an older tradition. In this article, I discuss methods for surveying and reconstructing boats and ships with a craft perspective. I am in the process of evaluating the differences in outcomes between digital photogrammetry and conventional analogue survey methods when examined from the perspective of a skilled boat builder. With experience gleaned from surveys of Nordic clinker boats, I can pinpoint specific examples concerning the use of photogrammetry versus the use of analogue tools. The advantages and possible shortcomings of digital methods need to be considered to reach good practice in the surveying of boats.

The current case study focuses on a local type of Nordic clinker boat tradition, boats from the Stockholm Archipelago that were partly built with hewed planking, a tradition discontinued in the late 1800s. During the Viking Age and until the 19th century, clinker-built boats were built with planks that were split and hewn from logs to get the right shape. In some local traditions, these archaic methods survived into the 20th century, even though most boats have long since been built with sawn planks shaped with the help of steam. Hasslöf has described this transition and examines some of the last local boat-building traditions that used hewed planking (1953).

The absence of living tradition bearers is a reflection of the craft tradition being lost, but traces of it can be deciphered from the few remaining boats. Both theoretical insights and practical experience are crucial in such surveys to accurately interpret craft objects from the past (Leijonhufvud 2022). The boat builder's perspective on the surveys and reconstruction of boats can therefore contribute significantly to maritime archaeological research. However, even if the craftsman—researcher is highly skilled, artefacts have limitations as sources of craft knowledge, limitations that must be considered in the interpretation process. To interpret a boat built in an older tradition, one needs to be aware of one's own traditions and prejudices, as well as that one's perspective will always differ from that of boat builders from the past.

2. Case study: the Stockholm Archipelago öka clinker boat

The *öka* is a clinker-built boat from the Stockholm Archipelago, examples of which are shown in Fig. 1. These are clinker-built vernacular sailing boats with a transom. Their length was 5–8 m; the large ones were called *storöka* and the smaller ones *skötöka*. The boats were made with pine keel and planking, stem, stern and transom of oak, and timbers (*vränger*) of oak or pine. The Stockholm Archipelago *öka* is a local traditional boat within the Nordic clinker boat traditions that was included on UNESCO's Representative List of the Intangible Cultural Heritage of Humanity in

December 2021. Similarly to some other traditional clinker boats (Hasslöf 1953), the öka is built with hewed planking from spiral-grown logs. The wood fibers in a spiral-grown pine log are twisted around the center of the log like a screw. The majority of the pines are straight-grown, and of the minority that are twisted, most are twisted to the right, similar to a common screw thread. It could therefore be difficult for the boat builder to find logs that were twisted to the left.



Fig. 1 A collage of old photos of öka boats (Nordic Museum archives and private collections)

A unique feature of the öka was a spiral hewed plank in the stern that has a carved bend in its upper edge (Fig. 2). This plank was called a karmvinda and facilitates the transition from a sharp underwater surface near the stern that is helpful for upwind sailing to an almost horizontal flat surface near the transom that makes the boat surf upon the water. It is almost the same as the karmvinda that can be found in traditional boats from the Åland islands (Törnroos 1968).



Fig. 2 The spiral-grown and hand-hewed plank called karmvinda. The author's photo of the original boat is on the left, and a sketch from the Nordic Museum is on the right (photo: F. Leijonhufvud; Nordic Museum archives).

Today, the tradition of building that produced the Stockholm Archipelago öka is lost. The last of the tradition's craftsmen are gone, and we are left with the original boats as evidence of their master craftsmanship. In my PhD project, I explore to what extent the interpretations of the original boats can be used to reconstruct broken craft traditions. There are just six known boats left, all of which are in different stages of decay, often lacking wood in the area near the keel as a result of storage that placed them standing on the shore where they were exposed to rain. My research focuses on surveying and reconstructing these boats. The reconstructions enable the interpretations to be tested in craft practice.

Currently, two boats are being reconstructed, one as an anastylosis project and the other a new-build sailing replica. The anastylosis project is based on an original boat in which some parts of the hull are missing. These parts have been refabricated as part of reconstructing the full shape of the original boat. If there is time, I will also build a third boat as 'a new original', i.e., a boat built in the revived tradition that does not replicate a specific original. Reconstructing this broken craft tradition is part of an effort to discover the system underlying the design of the boat, i.e., the ideas, shared norms and standards that constitute the craft tradition that I am researching.

3. Survey, interpretation, and reconstruction

My initial goal was to develop a workflow starting with the survey of the original boat and then moving to its reconstruction and the associated boat building skills. I have found that this goal was too optimistic, as well as being deficient in some aspects. For example, it lacked a dialogue between the original boats and their interpretations and reconstructions. The reconstruction has raised questions concerning the original boat and its interpretations, necessitating a reinterpretation. The boat's examination should instead be regarded as an ongoing dialogue or process, reminiscent of a hermeneutical circle or spiral (Fig. 3).

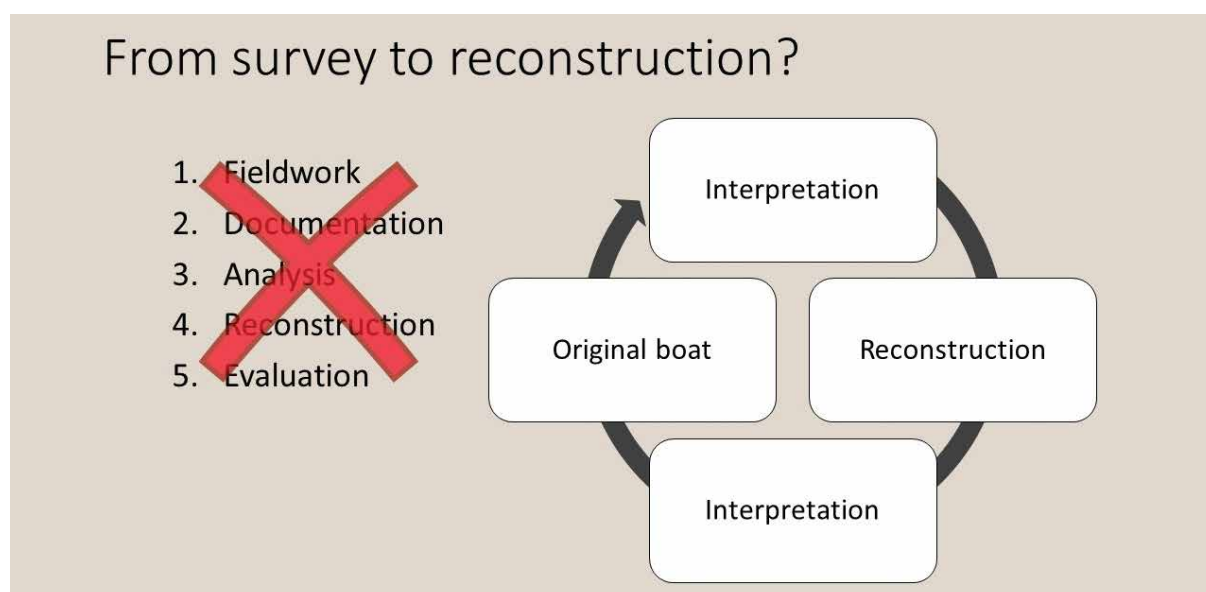


Fig. 3 Abandoning the linear process in favour of a reinterpreted dialogue between the original boat and its reconstruction (author: F. Leijonhufvud).

3.1 Approaching the original boat

My surveys are inspired by forensic methods (Almevik 2017). In my case, this means investigating the boat as it appears to me: material, form, tool traces, evidence of use, repair and alterations, and sensory impressions, as well as measurable values. The forensic method also includes documenting written and oral sources, for example older photographs, tool inventories and interviews. I use multiple sources and combine them with analogue or digital measuring tools. The original boats are of course the main source material, but I supplement them with photos from archives and private collections, as well as with archive material such as ethnological questionnaires from the early 20th century. In some cases, it can be fruitful to interview boat builders that have a closer relationship to the broken tradition, for

example a boat builder whose grandfather was active in the old tradition. When it comes to the measuring, I have used analogue methods for more than twenty years, but the last five years I have also explored the opportunities of photogrammetry as a cost-efficient digital tool.

My approach is guided by hermeneutic theory and an awareness of my own prejudices. The interpretation will be partly a result of my prejudices, which are based on my role as a researcher and craftsman, which in turn is a result of my contemporary craft tradition, that of a 21st century traditional boat builder. One of the fundamental ideas of modern hermeneutics is that methods have a limited value and cannot render the research objective or liberate the researcher from subjectivity. The truth is something that stands independent of the method, which can inadvertently obstruct the truth (Gadamer 2004).

In trying to answer my research question, it is important to switch between detailed and holistic perspectives to capture patterns that will unlock an understanding of the boat's system of design and the boat builder's abstraction of the boat. This process includes the systematic recording of details and returning to the studied boat several times. It entails spending time with the object with focus and awareness to discover new insights that were not apparent on a first or even second visit. In short videos or blog texts, I force myself to focus on the important issues and to put my interpretations into words. Art studies have shown that an observer's awareness can be trained (Bresler 2006), a fact known among boat builders. An experienced boat builder looks at boats in a different way than an untrained one does.

3.2. Some pros and cons of digital surveys

Computers are machines and, as such, can provide an honesty and directness that is hard to find in human interpretations. They have no preconceived ideas about how a boat should look, which can be a significant advantage in the recording of a boat's shape. But though computers are excellent calculating machines, they lack common sense. They can come to conclusions that are obviously wrong, something that probably all users of photogrammetry software have experienced. Working with a traditional craft and meeting craftspeople, I have encountered individuals who tend to feel that the digital output feels estranged from the tangible reality. There is also a risk that the digital model may create additional content to the object, new narratives that must be understood as not belonging to the original artefact (Gartski 2017). After a certain learning curve has been mastered, photogrammetry is time efficient. However, this time efficiency tends to reduce the time spent with the original object, resulting in a reduced sensory experience of the object. The physical distance that is possible with digital recording should also be considered. It is important to compensate for these limitations in the survey process. For a more thorough presentation regarding the pros and cons of digital methods, I refer the reader to a previous article (Leijonhufvud 2021).

From my boat building perspective, 3D models are often adequate for visualising the shape of a boat's hull, designing construction plans or making a replica that has a similar physical appearance. However, when it comes to interpreting and understanding details and how the boat builder produced them, a 3D model often lacks the level of detail that the original boat provides. This is a combination of the detail lost to insufficient resolution in digitalisation and the fact that the original object has tangible and sensible properties.

3.3. Misinterpretations

The problem mentioned above about lack of detail is not only due to digitalisation; the same problem is present in analogue boat surveys as well. I present examples of this in Fig. 4. The boats in the top of the figure are two of the original öka boats from around 1880. The next row shows the excerpts of the drawings/lines plans that were recorded from the originals for use in building replicas. The boats on the bottom line are the replicas. It is interesting to see how the characteristic shape of the stem has already been smoothened out in the lines plans. The boat to the left was recorded with a digital total station, the plans were drawn by a marine architect, and the replica was built by local professional clinker boat builders. The boat to the right was recorded by a boat building school, and the replica was built as a student project. Both replicas are well-built boats but lack some of the significant features of the original boats' hull shape. The typical stern shape of these boats was smoothened through the lens of contemporary professionals. The replicas were designed with influence from the traditional boat builders of today. This example shows that surveying and reconstruction are interpretive processes, guided by prejudice. It also shows that a photo or a digital model can often present a more authentic image of the original boat than a lines plan.

If possible, the boat builder should check the original boat for information that is lacking or is vague in the survey. That is why the ideal way to build a replica is to have the original boat nearby. If that is not possible, the survey should be performed with the craft processes and reconstruction in mind.



Fig. 4 Stem shape of original boats interpreted with the characteristic shape smoothened out by the replica builders (photo: F. Leijonhufvud).

3.4. Adding original methods of measuring to the survey

As an example, my case study of Nordic clinker boat traditions found that the individual planks in the hull are controlled by the boat builder with a tool called in local Swedish dialect a *pass*. The *pass* is a simple plumb bob level, made and used by the boat builder (Christensen 1970; Leijonhufvud 2023). Fig. 5 shows an old *pass* used by an original öka builder and my reconstructed *pass* used on the survey of an original boat. In my studies, I have compared replicas built from plans made with analogue and digital surveys and have found that the replicas have lost their original shape, especially in the parts of the boat where the original boat builder used the *pass*. This could have been avoided if the use of this tool had been included in the survey and the angle of the planks had been measured using the original boat builder's method. Integrating this boat building tool into the survey can improve the understanding of the design conventions of the tradition because it links directly to the craft processes without the detour of lines plans. The measured angles recorded with the *pass* can also be compared to those of other original boats to reveal a common system of design.

The *pass* was used as a guide for the build of the boat, but it must be emphasised that in Nordic clinker boat traditions, the boats are seldom identical, even though they have characteristic local features. The specific design for a new boat was often made in dialogue with the buyer of the boat, taking into consideration the use of the boat, the local natural conditions and what kind of wood could be provided for the build.

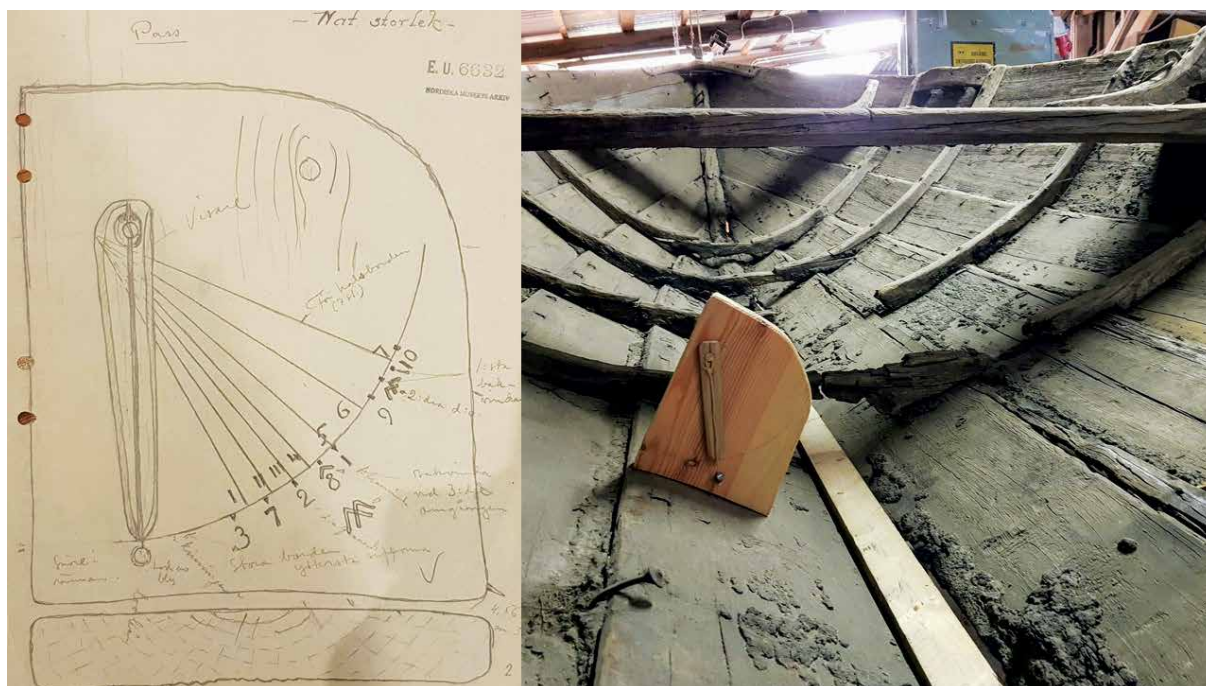


Fig. 5 The boat builder's pass. To the left is a traced sketch from the Nordic Museum and to the right is my reconstructed pass placed in an original boat (photo: F. Leijonhufvud; Nordic Museum archives).

4. Summarizing guidelines

If possible, the survey of boats should be guided by craft practice in reconstruction. The ideal situation is to make a reconstruction of the whole boat, reinterpreting the original boat throughout the process. The reconstructed boat then becomes a detailed documentation of the original. The second-best method is to reconstruct details of the original construction or to make scale models, focusing on specific design features. The reconstruction process will immediately generate new knowledge and raise new questions. If it is not possible to build reconstructions, the survey can still be guided by boat building practice, deliberately focusing on the questions that reconstruction work typically generates. I suggest calling this 'Survey with the Boat Builder's Eye'. This 'eye' of the boat builder will highlight questions about why and how the original boat was constructed, including the choice of dimensions, material, tools and design. The 'boat builder's eye' can also provide supplemental knowledge on what archaeological material to save or record, identifying sources of craft knowledge.

Boat builders and marine archaeologists should cooperate in these projects. Their complementary interpretations can provide answers to questions that their individual perspectives alone cannot solve. The results reached through their different methods and knowledge may create a synergy that creates new insights and understanding.

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SHIP CONSTRUCTION

Visible and invisible water transport components of the East European Plain and Trans-Urals in prehistory

Ekaterina Kashina – Aleksandr Shutikhin

Abstract: In this paper we briefly discuss the direct and indirect evidence of the diverse watercraft in existence in the East European and the Trans-Ural forest zone since the Mesolithic until the Bronze Age. Two Bronze Age logboats have been investigated in Lithuania and Russia. The presence of skin and bark boats is hypothetically based on the unique find of a ceramic canoe sculpture from the Central Russia dated to the 3rd millennium BC. The group of lightweight, short wooden paddles and of the rare two-blade paddles gives us the indirect evidence of frame/bark boat extensive use since the Mesolithic Age.

Keywords: prehistory, watercraft, logboat, skin boat, birch-bark canoe

Introduction

Until recently the East European watercraft archaeological cultural heritage was not represented properly to the English-speaking audience. In the framework of the project funded by the Russian Foundation for Basic Research (No. 19-09-00301) we have built a database consisting of nearly 100 logboats from all over Eastern Europe. For the very first time we have made more than 20 AMS-radiocarbon dates of logboats from Russia and Belarus. The final publication with the full database of vessels, their contexts, and radiocarbon dates will be prepared in the future. The preliminary catalog of East European excavated logboats is already available in Russian (Kashina, Gak, Okorokov 2021).

During the project we have become involved in a separate topic – the light boats, namely the bark/frame boats in Eastern Europe: what do we know about them in prehistory? This investigation would be impossible without the kind help of my co-author, Aleksandr Shutikhin – an independent researcher and artisan, who has studied the Siberian birch-bark boat indigenous heritage for many years and has already built more than twenty birch-bark boats (Shutikhin 2019).

The aim of this paper is to clarify the existence of boat types other than logboats based on the archaeological sources, which are unfortunately extremely poor and questionable when we speak about the forest hunter-gatherer-fishers of the East European and Siberian Stone and Bronze Ages. We will subsequently analyze the available sources starting from logboats, then turn to skin boats and bark boats, and finally will pay attention to paddles. As a result, conclusions will be made about the water transport peculiarities in the East European and Trans-Ural Stone and Bronze Ages.

Logboats

Archaeological finds of Stone Age (Mesolithic and Neolithic) logboats are known in Western Europe (Arnold 1995). The most ancient surviving logboat in Eastern Europe is made of oak, dated to the Early Bronze Age, and belongs to the Corded Ware culture (around 2800–2600 cal BC), its representatives were both hunter-gatherers and herders. It was found at the Sventoji 58 site in Lithuania in 2015, measuring 6 m in length, and probably was supplied with a 2 m long outrigger, found together with the logboat (Piličiauskas *et al.* 2020). The most ancient logboat in Russia was made of oak, 7.5 m long, dated to the 18th–17th centuries BC, the Middle Bronze Age, and belongs to the Srubnaya (Timber Grave) culture. These inhabitants of the Middle Don River (Voronezh region) were semi-sedentary pastoralists of the forest-steppe and steppe zones (Gak *et al.* 2021). The rest of the surviving East European logboats belong to the Early Iron Age and later epochs (Kashina, Gak, Okorokov 2021).

Skin and bark boats

As for the extrapolation of frame boat and birch-bark canoe existence to the Stone and Bronze Ages, there is a known mismatch between our assumptions inspired by the Siberian ethnographical watercraft materials and the set of the available archaeological finds which can be firmly attributed to such vessels. We can suppose the frame boat existence in parallel with logboats. In Arctic and tundra zones the skin of sea animals could have been used. In taiga/forest zones the skin of large mammals, birch bark, or bark of some other wood taxa were likely materials, as the choice depended on the resource availability. The light weight and the ease of manufacture are the most wonderful properties which ancient people could not neglect. Unfortunately, there is still no archaeological evidence of skin boat usage in the Stone and Bronze Ages of North Eurasia. The only supposition could be made by judging Scandinavian and North Russian Stone and Bronze Age petroglyphs. The boat images involved in the sea-mammal hunting scenes cannot represent logboats, and most probably depict frame boats (Kolpakov, Shumkin 2012, 320).

According to the personal boat-building and travel experience of A. Shutikhin, the comparison of the bark canoe and the logboat gives advantage to the first one. Bark is widely available in the forest zone, but for the logboat the straight tree, healthy and of large diameter is required, so the choice was quite narrow. For the bark boat only the bark and branches are sufficient, so the choice was wide for the production of ribs, beams and stringers with the minimal labor input. The only instrument for its making is a good knife. It is light: the individual canoe can be moved by one person, as it weights from 12 to 16 kg. Oppositely the lightest modern logboat cannot weight less than 35 kg.

The written sources from the New Age (*carnet de passages* of the year AD 1655) give us the evidence of wide birch-bark boat usage in Northern Russian Arkhangelsk region as individual river transport (Shutikhin 2019: 116). In the European part of North Russia they seemingly vanished at the end of the 17th century AD. By the beginning of the 20th century the birch-bark canoe had almost vanished as well among the Siberian indigenous peoples and was mostly replaced by Russian plank boats.

Very few birch-bark vessels and their models went to museum collections. The Yenisey, Lena and Amur types (the Eastern Siberian variations, named according to the largest river basins) can be studied through existing vessels and models, but the Ob' type (the Western Siberian one) had completely disappeared even before the start of the ethnographical studies (Fitzhugh, Luukkanen 2019). The Siberian birch-bark boat typology can be traced back only for several centuries, but the general principles of the hull making were similar, with differences found mainly in the forms of the bow and stern.

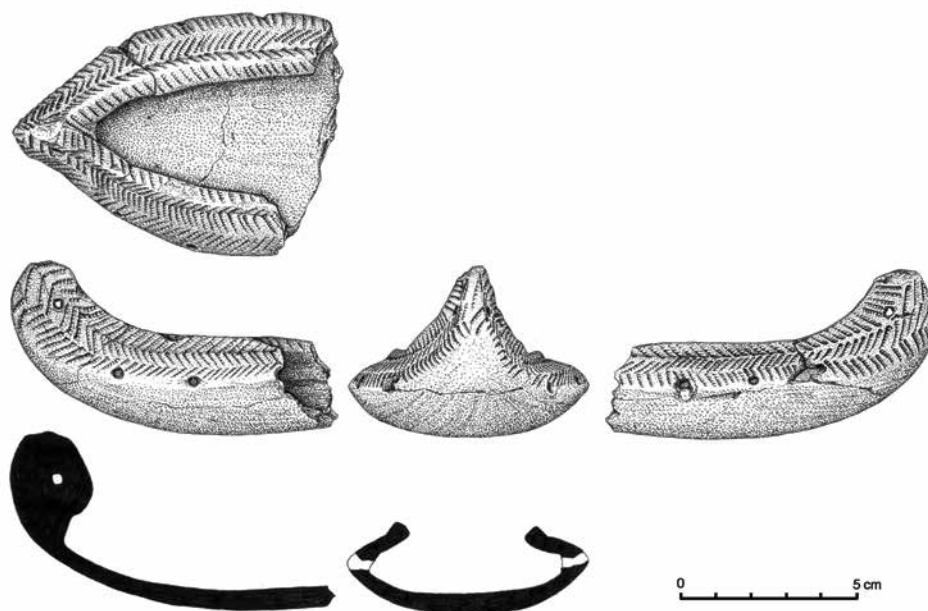


Fig. 1 The ceramic model of a birch-bark (?) canoe. End of the 3rd millennium BC, Shagara burial ground, Ryazan region, Russia (drawing: S. Konnova, State Historical Museum)

The most ancient evidence of the skin/bark boat existence comes from the Central Russia Ryazan' region, and dates to the end of the 3rd millennium BC, the Middle Bronze Age (Fig. 1). At the Shagara burial ground in one grave, four skeletons were found, and near one of them, a child, a ceramic boat model fragment was found, 8.2 cm length (Kaverzneva 2011). The paired holes for wooden beams are visible, made in the raw clay. The stamped decoration is reminiscent of ceramic vessels used by these forest communities, known as the Shagara archaeological culture, who were still hunter-gatherer-fishers at that time period, but the decoration could represent the binding. According to A. Shutikhin's view, the prototype of this model could have had five to six beams, been around 6–8 m long, and probably carried two persons. We are prone to interpret this find as a model of a birch-bark canoe, as in the forest zone the use of birch-bark instead of skin seems simpler and more logical. Its silhouette recalls the canoe of the Eastern Cree Native Americans (Arnold 2021: 94).

The Prehistoric archaeological finds of large mats of spruce and elm bark are known in Dąbki, Poland (dated to the beginning of 4th mill BC, measuring 4 × 3 m) and Byslätt, Sweden (dated to 900 BC, measuring 3.5 × 1 m; also, four wooden ribs have survived) (Kotula *et al.* 2018; von Arbin, Lindberg 2017). Both are interpreted as the remains of boats because of their size, morphological peculiarities, and archaeological context.



Fig. 2 Wooden paddles from the Trans-Urals peat-bog sites, Russia. 1 – simple paddle (Gorbunovo), 2 – details of a composite paddle, paddle and handle (Shuvakish 1), 3 – short paddle (Gorbunovo) (photos: 1-3 – E. Kashina, State Historical Museum, 2 – N. Chairkina, Scientific Production Center, Ekaterinburg)

Paddles

In Middle Trans-Ural (Sverdlovsk Region, Russia) the multi-period peat-bog site Gorbunovo and many other settlements situated in the lake depressions dated to the 4th and the 3rd millenniums BC have yielded a wide series of wooden paddles, both intact and fragmented. Most of them are light, thin, and rather short, measuring from 130 to 150 cm, with weight only up to half a kg (Kashina, Chairkina 2017) (Fig. 2.1). They could have been used to paddle a bark canoe or skin boat, but also a logboat.

The Mesolithic paddle finds from Northern Germany have the same features. For example, the Duvensee paddle dated 6500 cal BC is 1.5 m long and weighs 300 g (Groß *et al.* 2019). There exist some other finds of light paddles from Northern Germany and Denmark Ertebølle sites, as well as from Central Russia (Andersen 1986; Lozovski *et al.* 2013). These finds could point at the existence of Mesolithic bark canoes.

Among the Trans-Ural paddles, curious composite ones exist, designed to be assembled as a double-paddle (having two blades) or used as a simple one (Fig. 2.2). The double-paddle fits exclusively the skin-boat or the bark canoe. The Siberian ethnographical data show the wide use of double-paddles together with birch-bark canoes (Chepelev 2004). The main function of this device was to add some balance to small individual vessels.

Some extra-short paddles of around 35 cm length found in Gorbunovo have parallels in Siberian ethnography (Kashina, Chairkina 2017) (Fig. 2.3). The purpose of such paddles was to approach game quietly while hunting in the water, or to push the canoe more effectively in shallow waters.



Fig. 3 Aleksandr Shutikhin and Aleksandr Martynov during their experimental sailing in a birch-bark canoe, the White Sea (photo: A. Shutikhin)

Discussion

The strand/riparian areas of peat-bog archaeological sites usually contain such artifacts as the remains of paddles and other wooden waste, as well as discarded fishing equipment. The canoe or frame boat debris could have been left there, or the area itself could have been used for canoe repair. Some elongated pieces of worked wood, kept in museum collections, hypothetically could have been the canoe framing details, such as stringers, ribs, and beams. It should be noted that unlike the Inuit vessels *kayak* and *umiak*, birch-bark canoes do not have such well identifiable and recognizable details (Anichtchenko 2016). Birch-bark canoes often utilized materials taken literally ‘right from the forest’, with minimal treatment. Additionally, the Inuit normally did not discard those materials: they were always re-used in the situation where the wood was rare and precious.

According to the Siberian ethnographical data, the birch-bark canoe could serve for a maximum of five to six seasons. Being mainly an individual transport, it was used every day. All details could have been easily replaced (Shutikhin 2019). During one experimental journey, led by A. Shutikhin in 2008, his birch-bark canoe traveled 600 km by river in twelve days and required no repair at all. In the year 2009, a 60 km White Sea travel was performed by him from the mainland to the Solovetsky Islands, where the birch-bark canoe performed perfectly in salt water (Martynov *et al.* 2011) (Fig. 3). These experimental data allow us to suppose that some petroglyphic images found in Northern Russia could represent birch-bark vessels involved in sea-mammal hunting (Kolpakov, Shumkin 2012: 335).

Even more convincing archaeological evidence of birch-bark canoe existence in Prehistoric forest belt settlements could be the finds of birch-bark mats, sewn with spruce or some other kind of roots, and also having some traces of tar sealing. In this case the diameter of holes should be from 2 to 4 mm. Such finds are still not known to us. Nevertheless, continued searches among peat-bog archaeological materials should be continued in order to locate more probable wooden frame details, which could fit the bark or skin vessels. Also, the future peat-bog settlement excavations could provide new finds.

The multiple forms of light vessels and paddles reflect a deep spiritual background in Prehistoric and traditional societies. The vessel was perceived as a living being, which required worshipping, offering and decoration. Not only vessels but also paddles were sometimes decorated or marked to show the kinship, social position, or ethnicity of their owners. They could have been used in rituals or to give signals (Andersen 1986). For example, the fragmented tip from a light paddle found in the Modlona Northern Russian hunter-gatherer-fisher' peat-bog site dated to the second half of the 4th millennium BC, was decorated along the edge with triangles painted by red color (Fig. 4).



Fig. 4 The tip fragment of a painted paddle from the Modlona site, Vologda region, Northern Russia, second half of the 4th millennium BC, Late Neolithic (photo: E. Kashina, State Historical Museum)

Conclusion

The existence of dugouts in Western Europe is well documented since the Mesolithic period, but in Eastern Europe the archaeological finds of dugout remains belong to the end of the Stone and to the beginning of the Bronze Age. The existence of frame boats and bark canoes already in the Mesolithic and Neolithic is proved by the archaeological finds of light and quite small wooden paddles at peat-bog sites across Europe and in Western Siberia. The rare finds of probable bark canoe remains as well as the ceramic model of a canoe are dated the Bronze Age. There is still a chance for new discoveries of even more ancient bark boat remains. The Stone Age petroglyphs of Northern Russia and Scandinavia show diverse watercraft images, but unfortunately, they do not help much to identify the particular vessel types. This state of affairs certainly deserves more investigation and precise observation of old and new archaeological materials, as well as the international exchange of experimental results.¹

Acknowledgments

We are grateful to Dr. Natalia Chairkina (Ekaterinburg) for providing us the photo of a composite paddle from the Shuvakish 1 site.

¹ The presentation of this topic made at the ISBSA 16 congress in Zadar can be downloaded here: <https://www.academia.edu/53655692>

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An unusual shaped Bronze Age logboat from the Starnberger See near the Roseninsel, Bavaria, Germany – an early evidence for push-rowing in Central Europe?

Timm Weski

Abstract : A logboat of 13.34 m length dendrodated to 900 BC was discovered in the Starnberger See. Most of its port side, the bow, and about two-thirds of the upper parts of the starboard side are missing. The prominent feature is a square balk protruding from the stern of unknown purpose. Further there are several auger holes, whose use cannot be explained. To show all these details a 3D documentation was necessary. Perhaps the logboat, which may have served as a ceremonial vessel, was rowed facing forward and not paddled.

Keywords: logboat, Bronze Age, dendroarchaeology, 3D documentation, propulsion

The Starnberger See is situated about 30 km south of Munich (Fesq-Martin *et al.* 2008). It is a long narrow lake of about 20 km length with a small island in its western part, the Roseninsel, which became part of the UNESCO World Heritage 'Prehistoric Pile dwellings around the Alps' in 2011 (DE-BY-03). Though it must remain open whether there is any relationship between the island and the wreck, since the ongoing archaeological and geological research around the island has only been published in preliminary reports (Ahl, Gschwind, Schlitzer 2019; Gschwind 2023).

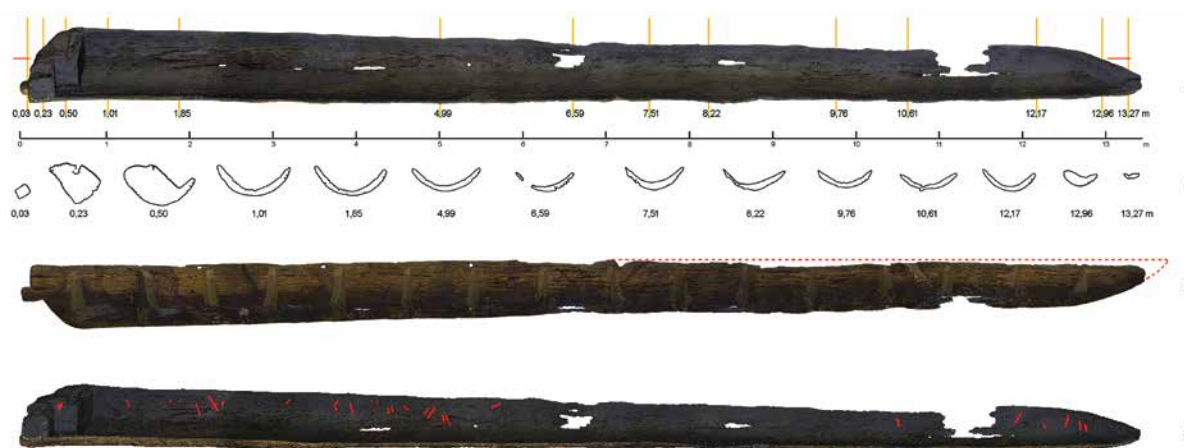


Fig. 1 1) Top view of the logboat in the position as it was found; 2) Sections of the logboat in the position as it was found; 3) Side view of the logboat in reconstructed floating position. Dotted red line: reconstructed outline of the hull; 4) Top view of the logboat in reconstructed floating position. Red lines = tool marks (model: S. Gollub, G. Sorge, Archäologische Staatssammlung)

In 1986 volunteers of the Bayerische Gesellschaft für Unterwasserarchäologie discovered the remains of a logboat in shallow water, close to the shore of this island in the Starnberger See. Until 1989 the vessel was recorded underwater in several campaigns (Beer 2020; Schlitzer 2023). The vessel was raised in 1989 and was handed over to the Archäologische Staatssammlung München, where it was conserved with PEG for several years (Beer 2020: Figs 1–4). After cleaning off the remaining wax from the hull in 2017 a detailed study of the vessel became possible. It was only noticed during this observation that the logboat had not sunk in its floating position, a fact which had led to several misinterpretations before (Weski 2020: 7, footnote 7).

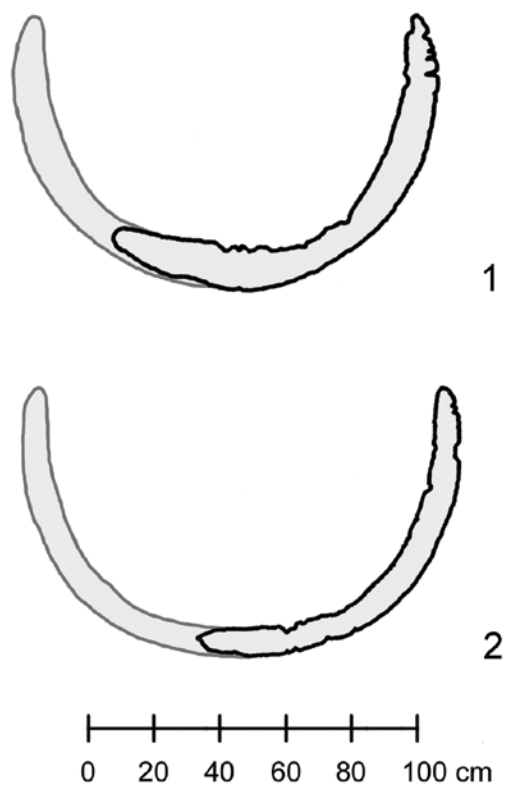


Fig. 2 1) Reconstructed hull section in floating position at 1.01 m from the stern, looking from aft to forward; 2) Reconstructed hull section in floating position at 4.99 m from the stern, looking from aft to forward (drawing: T. Weski, G. Sorge, Archäologische Staatssammlung)

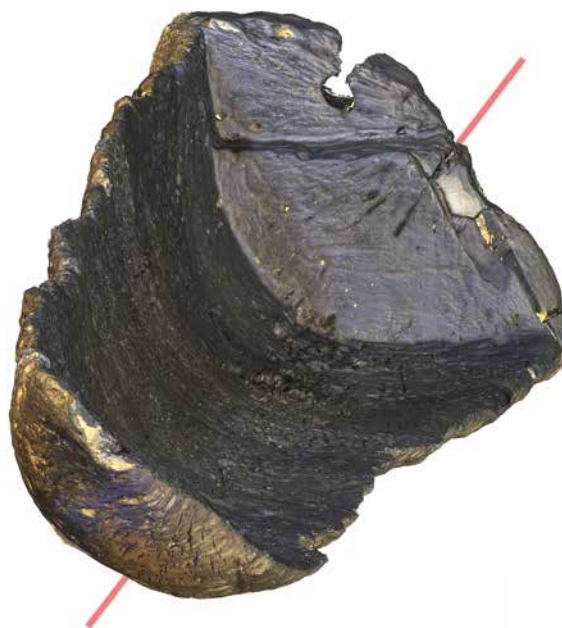


Fig. 3 View from the bow towards the stern in reconstructed floating position; red line indicates the reconstructed center of the trunk (model: S. Gollub, G. Sorge, Archäologische Staatssammlung)

The most spectacular feature of the logboat is a balk measuring about 10 × 10 cm protruding out of the stern (Fig. 4; Weski 2020: Fig. 9). The stern itself is a massive block with a kind of step cut into it on its foreside (Figs 3, 5). Apart from several smaller holes, there are five oval shaped holes along the gunwale of the starboard side (Fig. 1.3; Czaja, Gollub 2020: Tab. 1, Fig. 7.2). Further, there is a notch cut into the starboard gunwale on the outside, which appears to be new, but was already observed during the excavation (Weski 2020: Figs 15.1, 16.2). On the inner side of the hull there are several toolmarks (Fig. 1.4). Most of them are longitudinal cuts pointing in different directions, but in one case the shape shows that a tool with a half round blade was used (Weski 2020: Fig. 17.3). The incisions are all situated on the bottom of the vessel and not on its sides (Fig 1.4). This may indicate that the bottom was originally covered by boards, mats, bundles of twigs etc. Dendroarchaeological studies indicate that the oak tree from which the boat was hewn was felled in 900 BC (wane) (Herzig 2020: Tab. 4).

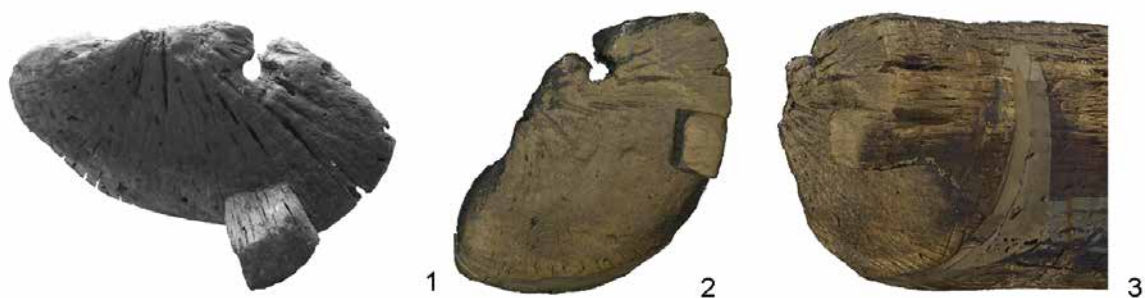


Fig. 4 1) View of the stern in position as found; 2) View of the stern in reconstructed floating position; 3) View of the starboard side of the stern in reconstructed floating position (model: S. Gollub, G. Sorge, Archäologische Staatssammlung)

A detailed drawing of the boat with sections of the hull was made immediately after it had been raised (Beer 1990). This drawing was used in 2000 by the Pfahlbaumuseum Unteruhldingen for making a replica, because the logboat was inaccessible for any kind of research at that time. Therefore, the breadth and the freeboard of the replica were too small. Because of this, it was sunk by the long waves created by a steamer passing by some way off (Schöbel 2000/01). It was in 2017 during the preparation for displaying the logboat in an exhibition, when it was discovered that the boat had not sunk in an upright position, but had listed to starboard. Further, the bow rested higher than the stern. Therefore, only parts of the starboard side near the stern were fully preserved. In addition, the position on the lake floor was not identical with the floating one, instead the hull has to be rotated about 45°, anticlockwise, looking from aft. As can be seen at the place where the sample for the dendroarchaeological analysis was taken close to the stern, the trunk has not been split along the centreline but higher (Figs 5, 6.2).



Fig. 5 View of the stern from the inside in position as found: 1-8 – position of auger holes, B – vertical cut, yellow circles – centre of the trunk (photo: T. Weski, G. Sorge, Archäologische Staatssammlung, H. Voß, Bayerisches Landesamt für Denkmalpflege)



Fig. 6 Detail of the stern: 6, 7 – position of auger holes, A – worked surface, B – vertical cut (photo: T. Weski, G. Sorge, Archäologische Staatssammlung)

In the starboard side there are the already mentioned five large, oval holes of obscure function starting about 2 m from the stern (Fig. 1.3). Another auger hole at the bow possibly indicates that it was crowned by some kind of decoration (Weski 2020: Fig. 16.3). Perhaps chisels were used to cut the larger holes, but the smaller ones must have been drilled. Holes 3–5 in the stern were most likely made by a push drill, as there is not enough room to turn the handle of a spoon bit. Push drills are known from the Mediterranean area and Egypt, but none has ever been identified in Central Europe yet (Weski 2020: 29–31).

The logboat is much longer than other archaeological and historic ones from the Starnberger See, which usually measured 5–7 m. Some were used as late as AD 1900 (Pfelderer 2023). The water table of the lake lays about 584 m above sea level and the surrounding uplands are about 100 m higher. This means that oaks can only grow on the slopes of the lake (Herzig 2020: 18). As the trees on the lakeshore will develop a wide crown and the trunk used for the logboat had only a few small branches, it must have grown in a thick forest on the hillside. Even in 900 BC trees of this quality must have been rare.

The inadequate early documentation made a complete photometric and 3D documentation preferable (Czaja, Gollub 2020: Tab. 21, Figs 5–8), which was conducted by Sven Gollub in 2019 as his BA thesis (Hochschule München, supervisor Jens Czaja). With the help of these data, it was possible to turn the hull to its floating position (Figs 1.1–4). The surface of the step and that of the balk are now horizontal (Fig. 4.2). The balk at the stern is carefully worked out of the starboard side and lays above or just below the waterline (Fig. 4.3). Looking from the bow towards the stern, one can see that the port side, most of the bow, and the very top section of about two-thirds of the upper parts of the starboard side are missing (Fig. 3). Unfortunately, the centre of the trunk at the bow could not be identified precisely, therefore its original shape cannot be reconstructed.

The present length of the boat is 13.34 m, but originally it must have been slightly longer. Due to the missing port side, it was only possible to reconstruct the section in the aft part of the vessel. The reconstructed breadth of the hull about 1 m from the stern was 1.12–1.20 m and the depth was 78 cm. Further forward, about 5 m from the stern, the dimensions were a little more than 1 m and 63 cm (Fig. 2). Both dimensions are considerably larger than those of the replica.

Particularly in the block at the stern there are several auger holes whose purposes remain open. The holes nos 2–7 have a diameter of 1.1–1.6 cm (Weski 2020: Tab. 5). A thick, conical one (No. 1) runs straight through the ‘transom’. Another one (No. 2) sits diagonally in No. 1 obviously to fix something in that hole. Holes 3–5 in front of the stern block are 2–6 cm deep. Holes 6 and 7 run askew and reach a depth of 4 cm and 13 cm. Most likely they were meant to secure a heavy load (Fig. 5). The wood around the two holes had been carefully smoothed, but some remains of wood can be observed on top of it. Thus, it must have been a kind of slot originally (Fig. 6). Together with the square balk outside the hull and the step, the holes may have been part of some superstructure of unknown purpose.

No hints for the means of propulsion were discovered during the excavation, but paddles, like the ones unearthed in the so-called Wasserburg Buchau, Baden-Württemberg, could be a likely answer (Kimmig 1992: 58, Figs 31, 32). Perhaps more paddles were excavated, which were not recognised as means of propulsion, but were published as baker's shovels or spades (Weski 2020: 33, footnote 69). The paddlers were either kneeling or standing in the boat as it is shown in Bronze age depictions or recorded in ethnographic evidence (Weski 2020: 32–35). On the other hand, the mentioned oval shaped holes spaced between 1.40 m to 1.70 m in the starboard gunwale may indicate that another technique could have been employed. Perhaps oars were fixed by grommets in these holes and the rowers were standing facing forward. Such a solution could be depicted on the rock carving in Brandskog, Sweden, dating to Montelius Period V (c. 900–700 BC) (Fig. 7; Weski 2020: Fig. 20). The crew is standing and the position of their arms would suit with this rowing methods. Though it must be pointed out that the history of rowing, in particular push rowing, has not been researched yet. Up till now no rowing technique of any kind has ever been recorded from prehistoric times in Central Europe.

Usually, the landing places for boats at the Starnberger See are only a few piles driven into the foreshore. But in many places, in particular on the east side of the lake, the slope is very steep and there is hardly any shoal water to erect a kind of jetty. Therefore, a long logboat cannot be entered from the bow or the stern, but only from the side. This means that the vessel must lay parallel to the shore. Perhaps the balk at the stern together with a construction held by the mentioned holes was employed to hold some kind of gangway to enable higher rank persons to enter or leave the boat in a dignified way.

This raises the question of the purpose of the logboat. The Starnberger See was not part of a trading route with bulk goods like salt in prehistoric times, because it has no tributary and the outlet, the Würm, is too small for a vessel of this size. In fact, it was not used for water transport in modern times apart from occasional drifting firewood. Therefore, the logboat may have been a warrior or ceremonial vessel, comparable to the chariots discovered in graves of the Urnfield-Culture (Winghart 1999). As the lake is too small for amphibious warfare (Kaul 2003: 176–182), the latter is more likely, though many questions remain to be answered.

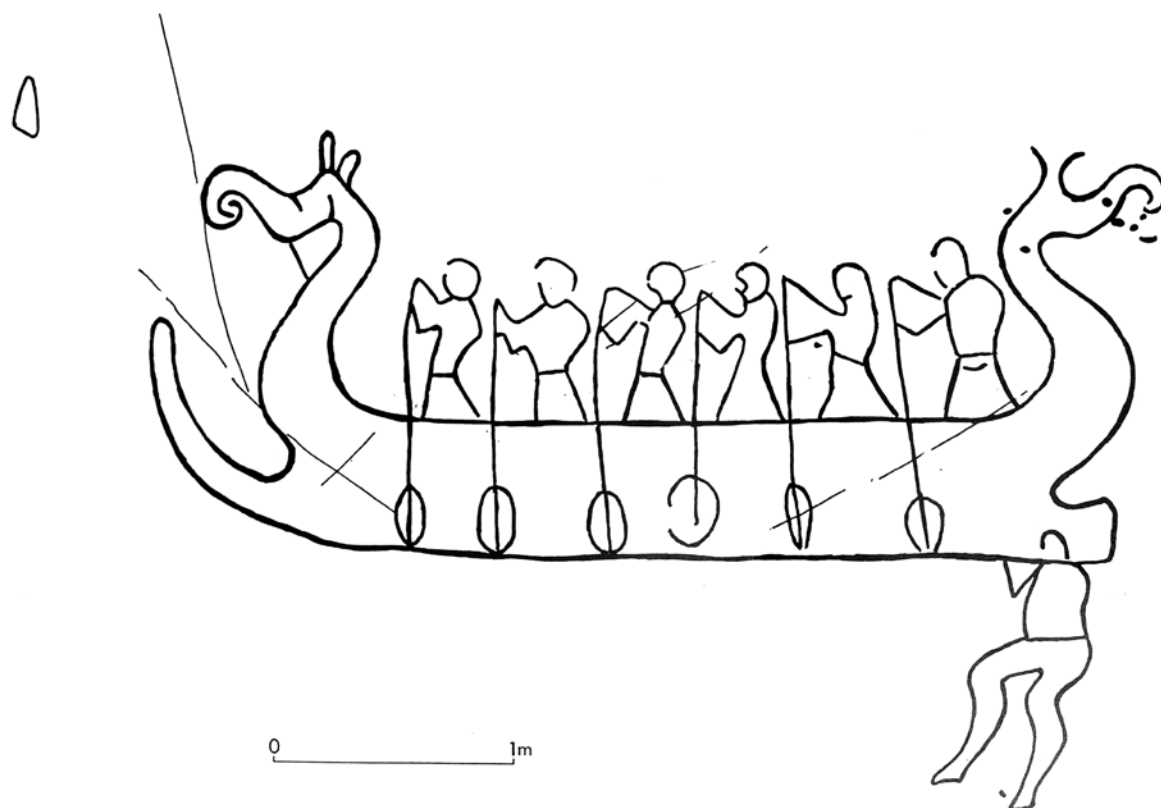


Fig. 7 Brandskog, Boglösa 109:1, Uppland, Sweden. The persons are shown in a position possible for push-rowing (Coles 2000: Fig. 37).

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The Mazotos Shipwreck: preliminary results of the hull analysis

Stella Demesticha – Carlos de Juan

Abstract: The 4th century BC shipwreck of Mazotos lies at -44 m off the south coast of Cyprus. Archaeological work on the site started in 2007 by a team of the University of Cyprus and is still in progress. After eight excavation seasons a good part of the hull has been unburied, mainly at the fore part of the ship. Evidence thus far suggests that it was a round bottom ship, fastened with pegged mortise and tenons. Some distinctive features, such as the round bottom profile of the hull, the framing pattern, and the presence of tetrahedral recesses at the bow extremity, open the question of the ship's broader technological context, and underscore its important contribution to our knowledge on shipbuilding traditions in the eastern Mediterranean during the Classical period.

Keywords: Greek shipbuilding, shipwreck, ship construction, fourth century BCE, Cyprus

1. Introduction

The Mazotos shipwreck lies at a depth of 44 m, off the south coast of Cyprus, near the village of Mazotos (Fig. 1). The site was discovered and reported to the Authorities by recreational divers in 2006. The Archaeological Research Unit of the University of Cyprus commenced archaeological investigation at the site in 2007, first with surface survey, followed by systematic excavation since 2010 (Demesticha 2009; 2011; Demesticha *et al.* 2014; Secci *et al.* 2021). The site was initially defined by a dense oblong concentration of more than 500 visible transport amphorae; these surface finds expanded across an area of approximately 16 × 6 m, with a north-south orientation (Fig. 2).

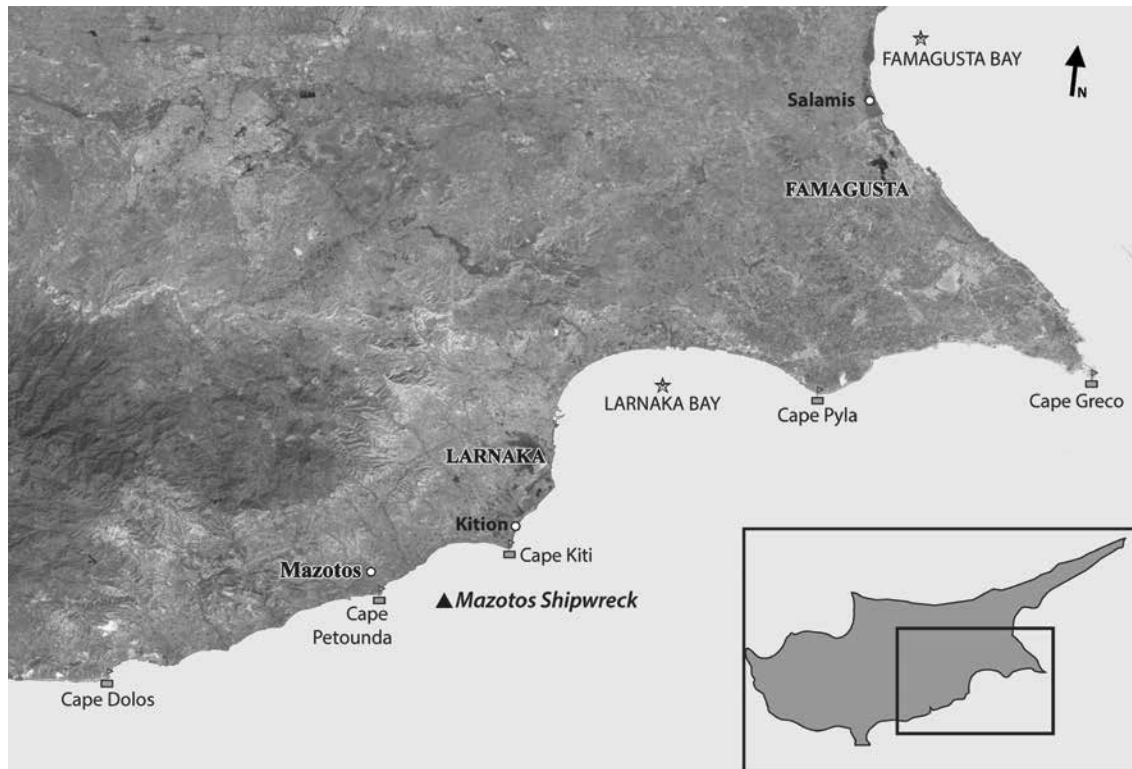


Fig. 1 Map of Cyprus showing the location of the Mazotos shipwreck (map: A. Neophytou, I. Katsouri)

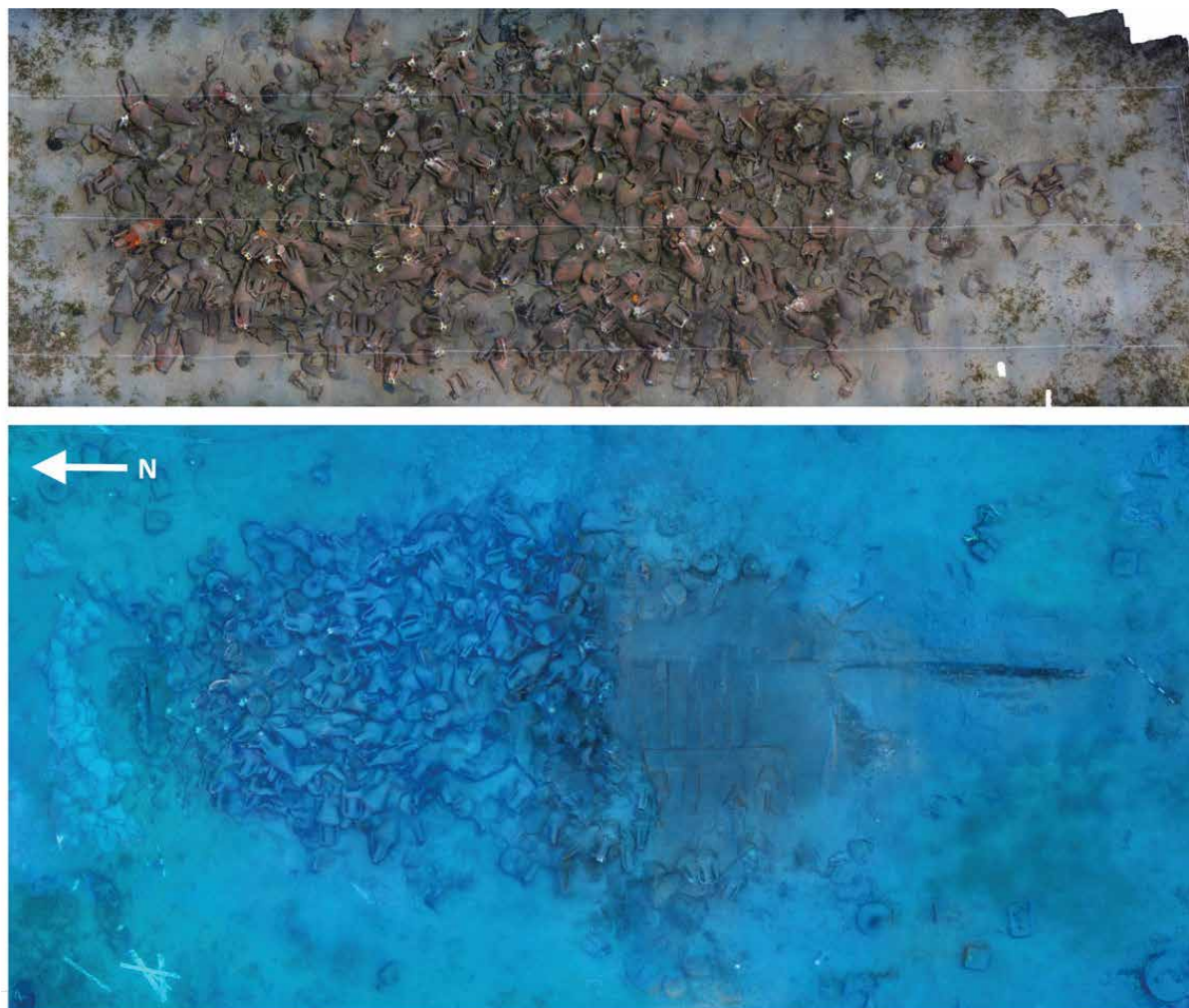


Fig. 2 Orthophotomosaics of the Mazotos shipwreck site; top: in 2007, before any excavation took place (processing: M. Vlachos; photos: B. Harzler); bottom: after 2019 field season (figure: M. Secci; photogrammetry: D. Skarlatos, M. Vlachos)

The cargo was a homogenous assemblage of transport amphorae of a well-known type from the island of Chios, in the Aegean. Their typological analysis had provided a tentative date of the site, to the middle of the fourth century BC (Demesticha 2009: 390; Demesticha 2011: 41–46). Radiocarbon dates and dendrochronology analysis were also applied to organic samples from the ship: a piece cut from a strake made of pine (*Pinus nigra*), dunnage consisting of short-lived (<5 years) complete twigs of *Lamiaceae* family, and pits from olives that were transported in Chian amphorae. A wiggle match on the ship timber suggested a minimum *terminus post quem* for the ship's launch somewhere between ca. 409–387 BCE, whereas radiocarbon dates on dunnage and olive pits yield a closely defined last voyage date range, between 390–377 BCE, thus pushing the originally estimated date back for about a quarter of a century (Manning *et al.* 2022).

Despite the fact that the excavation is still ongoing, the ship-shaped assemblage along with some key finds, i.e. the remains of three anchors at its southern end and the galley wares at its northern end, have allowed for the confident interpretation of the ship extremities as the bow and the stern, respectively. Most importantly, excavation has also exposed part of the wooden hull of the ancient ship. This paper is a preliminary analysis of these remains and a first attempt to place them in their nautical archaeological context.

2. The Hull Remains

Excavation has mostly progressed at the southern part of the site, where the fore part of the ship has been exposed. The hull sections include part of the keel and eight strakes, with six frames and a stringer still *in situ* (Fig. 3). At the northern end of the assemblage, which has been identified as the aft part of the ship, a smaller section of the hull was also exposed: the keel, one frame and at least five strakes extending to the west. The ship tilted to its starboard side after it reached the sea bottom, so under the western part of the assemblage (starboard) is the best part of the hull is preserved.

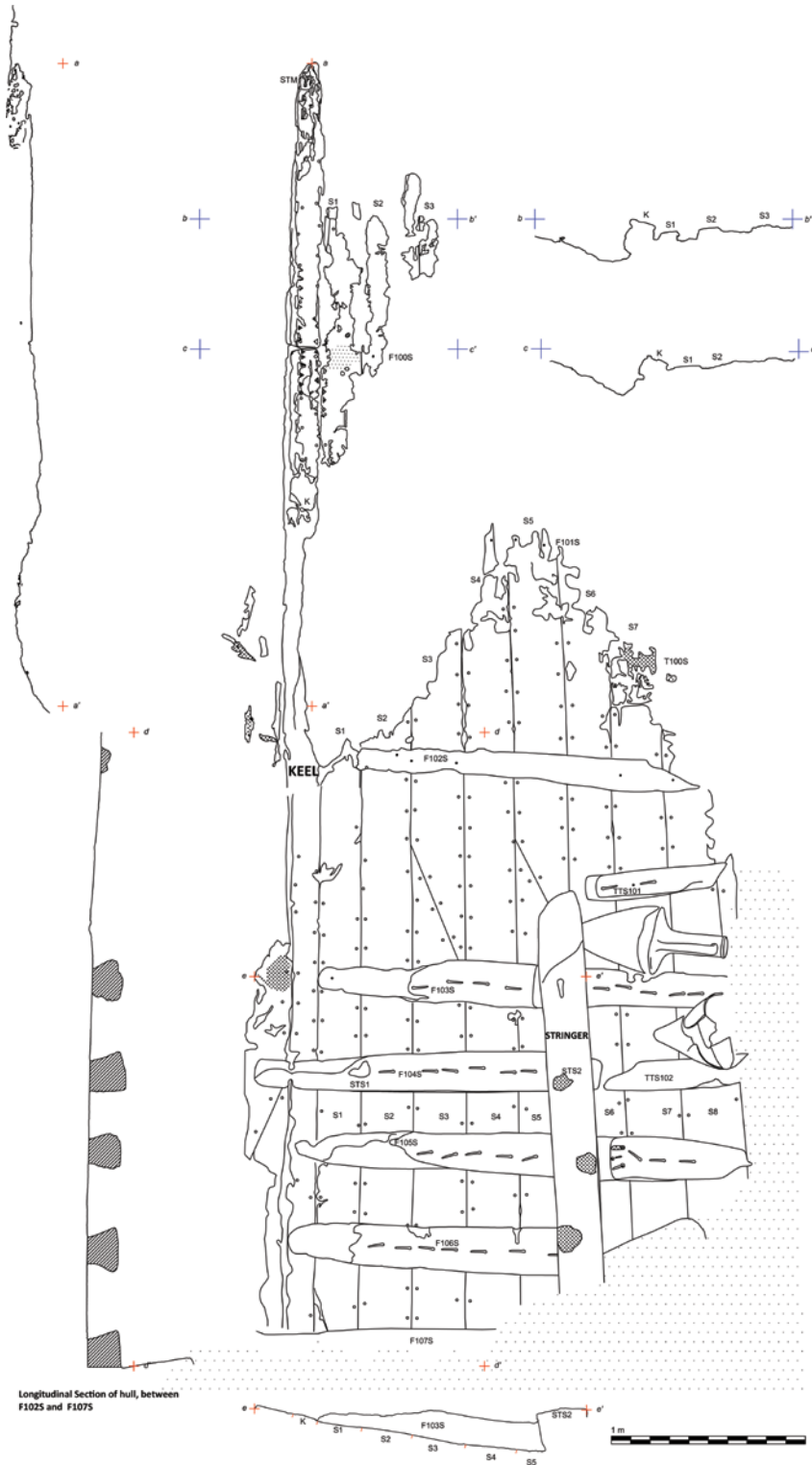


Fig. 3 Plan of the excavated hull remains of Mazotos Ship (drawing: C. De Juan)

2.1. Longitudinal elements

Stem. The first timber that was exposed, at the far southern end of the site, was the stem. It was preserved at a length of 1.47 m and it was joined to the keel with a complex locking hook-scarf, also known as a Jupiter scarf (Fig. 4). It was very eroded and *Teredo*-damaged but its section could still be measured, 13 cm sided 17 cm molded. Five almost vertical mortises were recorded: the best-preserved ones were 4 cm long and 0.9 cm thick, spaced at intervals of 4.2 cm edge to edge. They were noted on both sides, but because of the stem's poor state of preservation, it was impossible to understand if rabbets were associated with them, something that could have given a sharp profile to the vessel's bow. No joining remains of a knee above the stem were observed.

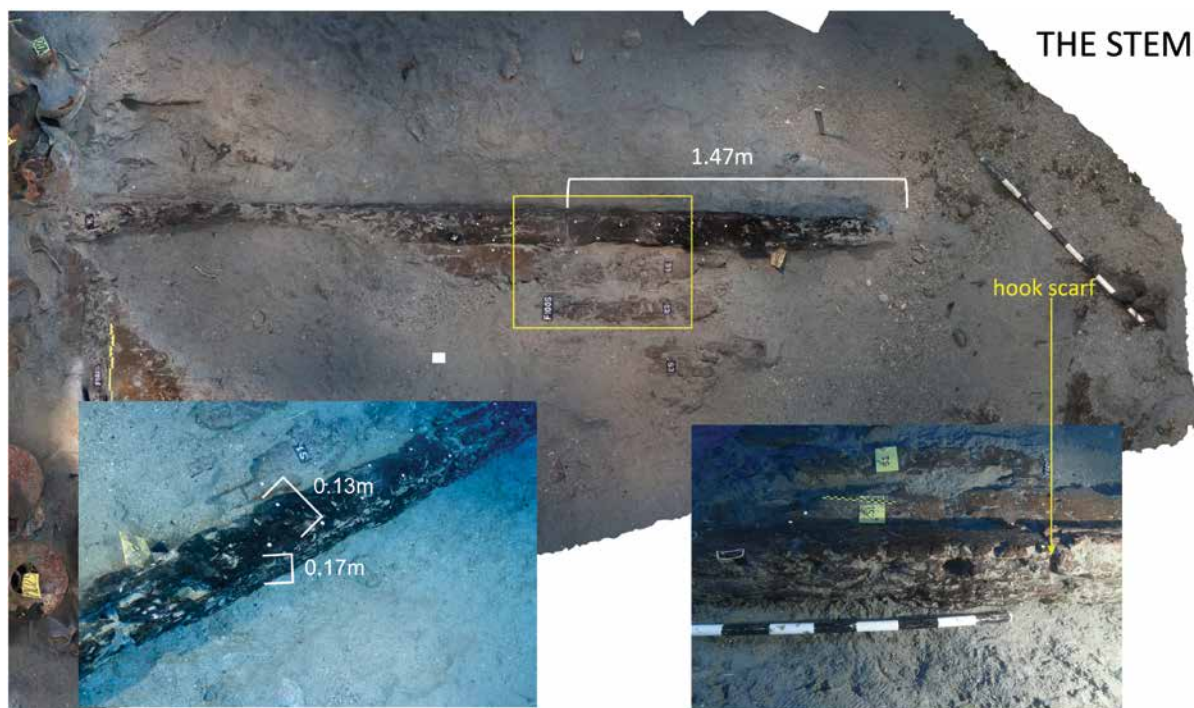


Fig. 4 The keel was joined with the stem by a hook scarf (photo: A. Kazamias)

Keel. The keel runs in a roughly north/south direction, tilted laterally in a way that its upper face slants down west-erly. It is exposed from the hook-scarf to Frame 7 (F107S), where the latest field season ended (in 2019). It is badly eroded for 1m after the scarf, between the first and second frame (F101S–F102S), but it is better preserved closer to midships and continues under the unexcavated cargo all the way to the stern, where its broken end was exposed. The keel is narrower than the planks, and appears to be slightly larger in its molded than in its sided dimension (17 × 15 cm, respectively). Its lower face was too eroded in places that excavation could reach it, so the shape of its cross-section remains uncertain. An important feature, however, is that it has no rabbet or chamfer to hold the garboards.

Pegged mortise-and-tenons, opened in a quincunx pattern, were recorded by the hook-scarf. They were 8.6 cm long and 0.8 cm wide, placed 15.1 cm apart. Pegs, 1.3 cm in diameter, were placed vertically to fix the tenons.

At this same area, i.e. the joint between the stempost and the keel, more interesting features were documented, which deserve special attention. The attested plank joining technique is ‘pegged mortise-and-tenons’, all along the exposed part of the bow, but at the hook-scarf section, where the garboard strake attaches to the keel and stempost, tetrahedral recesses were clearly visible (Fig. 5). The tetrahedral recesses were opened on the keel and stem as well as on the respective, partly preserved, starboard garboard. They co-existed with mortise-and-tenons joints. Some incomplete tetrahedral notches, without perforations, were also marked on the starboard side, towards midships. Diagonal perforations, with a diameter of 8 mm, were opened inside tetrahedral recesses of 18 mm of axis, with a gap edge to edge of approximately 20 mm between them. No pre-assembling and reinforcing components, such as dowels, were found and no remains of the ligature itself were preserved. The co-existence of the two joinery techniques, coupled with the incomplete tetrahedrons and the absence of dowels, suggest a repair or an effort to reinforce some structural weakness or an incomplete juncture at the hook-scarf area.

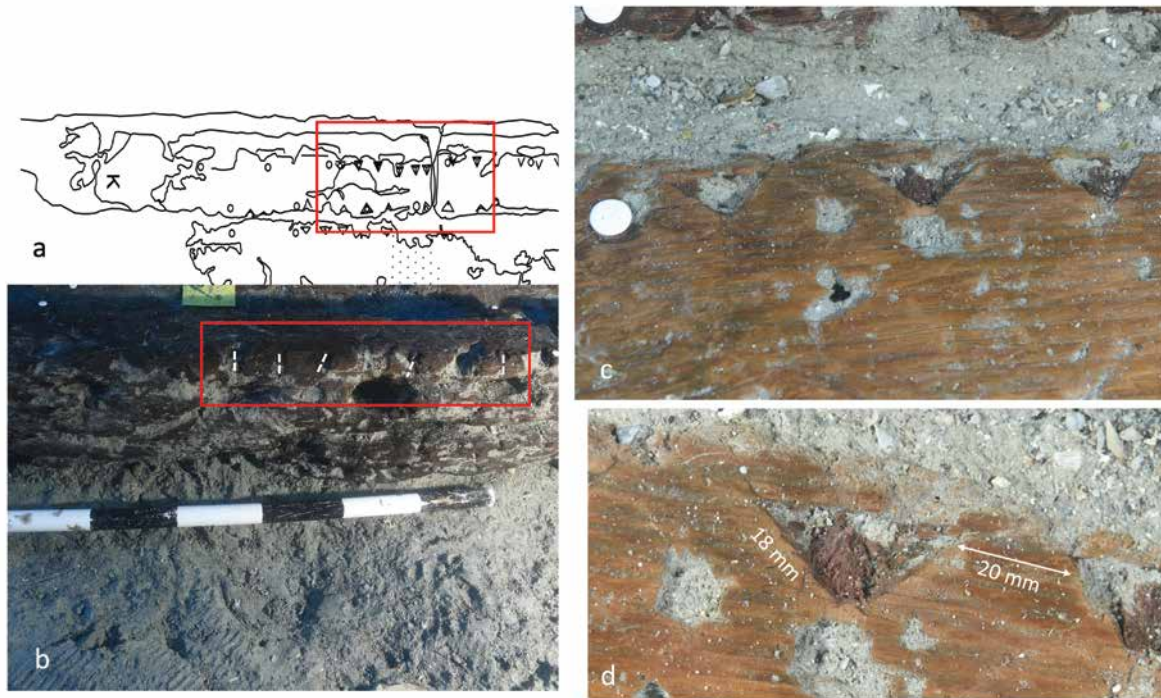


Fig. 5 The sewn parts of the Mazotos ship: a) top view of the keel-stem join (drawing: C. De Juan), b) side view of the keel; the vertical ligature grooves are marked with dash line, c) and d) details of the tetrahedral notches (photo: A. Kazamias)

Only the port side of the hook-scarf could be exposed, because no planking was preserved at this side. Despite its poor state of preservation, it was possible to identify a tenon key, placed horizontally on the hook-scarf. A false keel appeared to have been attached to it, which probably continued for about 1.5 m towards midships, but no further than Frame 2 (F102S). It was not possible to have a clear picture of the different timbers under the keel but this looked also like a repair, rather like a false keel that continued all the way to the stem.

Garboard. The starboard garboard was partially preserved at this area. Its thickness was the same as that of the rest of the recorded strakes, i.e. 4.9–5 cm. Right where the mortises changed from horizontal to vertical, its contact face was preserved for approximately 14 cm, beveled in a wide angle of 125° between its upper and lateral faces. Thanks to this carpentry work at the garboard contact face, a sharp profile was achieved at the bow, different to the almost ‘flat’ one at midships, from Frame 1 to 7 (F100S to F107S). From Frame 3 (F103S) the port side garboard was partially preserved as well. The angle between its contact face and the keel was close to 90° .

Stringers. Stringers were also preserved in the inner hull. Remains of the first starboard one (STR1S), were located along Strake 1, nailed to Frame 4. Also starboard, along Strake 5 (S5), a second, much better-preserved stringer was excavated, 23 cm wide and 4 cm thick. Both of them were joined to the frames with clenched nails, driven from the outside. On Stinger 2 (STR2S), four nails were recorded: one right in the center of the plank, and three closer to the sides, in a zig-zag pattern. The position of STR2S above hook scarves of the frames, as well as the position of the of top timbers right next to it, suggest that the turn of the bilge most possibly started from this position, i.e. from Strake 6 (S6).

Planking. In total, eight strakes were preserved at the starboard side of the bow, most of them well preserved and only minimally teredo-damaged. Strake width values range between 26 and 29 cm and their thicknesses range between 4.9 and 5 cm. They were joined with pegged mortise-and-tenons: on average, mortises, $5 \times 1.2 \times 12.2$ cm, were placed 11.7 cm apart, edge to edge, and 17 cm center to center. The tenons fitted and filled the mortises completely, which must have left no room for sideways movement during the construction process. Pegs are regular, faceted, of conical profile; their largest diameters vary between 1.2 and 1.3 cm and the smallest ones between 0.9 and 1 cm. Most of them were placed from the inner hull.

The side faces of the planks were slightly beveled to give an angle to every single joint and thus create a round bottom midship profile (Fig. 6). That profile was very smooth from the keel to S6 and S7, where the turn of the bilge must have

begun. In S6 that angle is pronounced, as attested by the mortises' orientations. Also, the outer face of this plank could have been worked to achieve its transversal curve.

2.2. Transversal Elements

Frames. Frames have a trapezoidal cross section with beveled angles in their upper faces. Two top timbers were documented, which were smaller than the complete frames. Instead of a trapezoidal profile they both had a rounded upper face and were joined to the hull with square treenails and clenched nails. Although most of the floor timbers were erod-



Fig. 6 Hull profile recorded on the fore part of the hull, where planking is well preserved (3D point cloud: M. Secci)

ed, Frames 4 to 7 (F104S to F107S) provided evidence that they were crossing over the keel towards the port side (Fig. 3). Two limber holes of trapezoidal profile were opened 8 cm apart, under Frame 6 (F106S), right on the keel-garboard joints, similar to those documented in laced Western Greek wrecks, such as *Cala San Vicente* (Mallorca, Spain, 530–500 BCE) (Nieto and Santos 2008), or the round-bottom ones of Pomey's (1998) transition group 1, such as *Jules Verne* 7 (Marseille, France, 525–510 BCE). The starboard one was clearly visible, while the port side one was right at the end of the preserved floor timber. It also became possible to observe a limber hole with a rectangular profile (7 × 4 cm approximately), under Frame 4 (F104S), placed in the joint between Stakes 3 and 4 (S3 and S4).

Although the study of the hull's fastening is still in progress, it was possible to identify three different fastening methods were used to join floor timbers, hook scarfs and top timbers: clenched nails, clenched nails driven through square treenails, and square treenails, all placed from outside of the hull. The nails have a square cross section that ranged between 4–5 mm, measured in the holes they left inside the planking.

As a good part of the hull remains unexcavated, it is too early to make a comprehensive assessment of the framing pattern. Moreover, the first two frames and top timber (F100S, F101S and TT100S) have disappeared completely, so it was only thanks to nail holes and oxidation residue that it became possible to distinguish the few remains of their lower faces above planking. But as excavation progressed from Frame 2 (F102S) to midships, the condition of the hull improved. Full frames from side to side (F103S, F105S and F107S) were alternating with top timbers (TTS101 and TTS102), placed from Strake 6 (S6) probably to the bulwark. The futtocks of the starboard side were connected to the floor timbers with hook scarfs, both documented in Frames 3 and 5 (F103S and F105S). Stringer 2 is positioned right above these scarves, and next to the top timbers. These arrangements indicate that the turn of the bilge most possibly started close to Stringer 2, i.e. from Strake 6. In the space between the three full frames (F103S, F105S and F107S), 45 cm on average, Frames 4 and 6 (F104S and F106S), made of different wood species and with different profile section,

were placed. It is not yet clear if they were part of the original construction or if they were added at a second stage, to reinforce the transversal carpentry towards midships.

3. Discussion

The hull of the Mazotos ship is preserved up to the turn of the bilge at its starboard side. Despite the poor state of preservation of the excavated timbers at the fore extremity of the hull, and the fact that excavation is still in progress, some distinctive shipbuilding features have already been recorded: a) two different fastening techniques, mortise-and-tenons and sewing, co-existed for about 40 cm on either side of the hook-scarf, most probably to repair a damage or to reinforce a weak part of the bow; b) the angle of the garboards as well as the profile section of the planking point towards a round bottom ship; c) the framing system is still uncertain, but it is possible that the main pattern is shaped by sparsely placed full frames, of trapezoid section, alternating with top timbers.

These features, combined in the same ship, find no parallels with shipwrecks that have been associated with the ‘development phase’ of the Greek shipbuilding tradition (Pomey, Rieth 2005, 163; Pomey, Boetto 2019: 27). Ships with round bottom profile, of Ionian influence, have been excavated around Marseilles, such as *Jules Verne 9* and *7* (Pomey 1995), as well as *Gela 1*, in Sicily (Benini 2001). Further into the Classical period, evidence suggests an evolution towards hull profiles with more elaborate lines and a pronounced concavity on both sides that gave them a ‘wine-glass’ section or a *retour du galbord*. Such hulls were fully shaped by the time of the late 4th century BCE ship of *Kyrenia* (Steffy 1985; Womer Katzev, Wylde Swiny 2022). Fifth century shipwrecks, like *Gela 2* in Sicily (450–425 BCE) (Benini 2001) and *Ma’agan Michael* in Israel (*ca.* 400 BCE) (Kahanov, Linder 2004) belong to a transitional period with a hull of ‘wine-glass’ section, a keel placed in a low position, in relation with the turn of the bilge, and garboards worked accordingly. The *Ma’agan Mikhael* ship is of particular importance for this discussion since it is associated with the Aegean or Ionia (Pomey, Rieth 2005: 162). Its hull lines followed the new trends of the period, namely the ‘wine-glass’ section (Kahanov, Linder 2004: 4–6), while the builders of the round-bottom Mazotos ship, dated a quarter of a century *later*, followed an older ‘trend’. Still, similarities, such as the use of ligatures for repairs or reinforcements at the extremities, and the framing system (widely spaced full frames), could place both ships in the wider Greek tradition.

4. Conclusions

The Mazotos shipwreck, dated to the first quarter of the 4th century BCE, carried a homogenously Aegean cargo. Although it was found off the coasts of Cyprus, no finds thus far can associate it with the island or another eastern Mediterranean region, such as Egypt or the Levant. Its date places it between two important excavated ships of the Classical period, the *Ma’agan Mikhael* and the *Kyrenia*. Although the study of its particular shipbuilding features is still in progress, the Mazotos ship has already opened the discussion about the diverse shipbuilding traditions and practices of the 4th century BCE in the eastern Mediterranean.

More specifically, it does not seem to belong to the same tradition with the known 5th and 4th century ships, all with ‘wine-glass’ section hulls, i.e. the *Gela 2*, the *Ma’agan Mikhael* and the *Kyrenia*. Rather, according to our interpretation, all evidence recorded on the hull of the *Mazotos* ship point towards a distinctive shipbuilding ‘evolution branch’, characterised by the round-bottom hull lines, the use of mortise and tenons, the sparse framing system and the partial use of ligatures. Such features have already been recorded on the archaic ship of *Jules Verne 7*, excavated in Marseilles (525–510 BCE) (Pomey 1998). Given the Aegean origin of the cargo and all other artefacts excavated from Mazotos thus far, this shipbuilding tradition could be associated with the Greek world or Ionia, in particular. It is also interesting that along with these archaic elements, others, like the reinforcement of transversal carpentry towards midships, can place the ship in the transitional phase, towards Pomey’s ‘Hellenistic Republican Architectural Family’ (1998). This suggests a parallel technological evolution, along with other attested eastern Mediterranean shipbuilding traditions.

As the excavation progresses, further study of the hull elements of the Mazotos ship is expected to provide a better understanding of its construction and a better contextualisation within the archaeological record of eastern Mediterranean ships, which remains rather poor in excavated examples.

Acknowledgments

The hull remains of the Mazotos ship were exposed during four field seasons (2015–2019) which were conducted thanks to the support of the Honor Frost Foundation, CYTAVISION and the University of Cyprus, to whom the authors are grateful. Special thanks are also owed to Dr Massimiliano Secci for his valuable help with 3D models. Andreas Kazamias, volunteer diver of the project, has taken close-up underwater pictures of excellent resolution, which facilitated exceedingly the study of the hull details; we cannot thank him enough. Last but far from least, we express our gratitude to all the members of the Mazotos team for their enthusiasm and valuable contribution to the project.

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Reinterpretation of the third sewn boat from the ancient port of Zaton in the vicinity of ancient Nin (*Aenona*), Croatia

Dušanka Romanović – Irena Radić Rossi – Katarina Batur

Abstract: The port of Zaton was an ancient port of the municipium *Aenona*, in the province of *Dalmatia*. Intense port activity was recorded from the middle of the 1st until the end of the 3rd century AD. An underwater structure, either a breakwater or a pier, is visible in the maritime environment. On the inner/eastern side of this structure three sewn boats were found sunken. This paper concerns the only remaining boat at the site, Zaton 3, discovered in 2002 and recently reinvestigated. The paper presents the hull construction features.

Keywords: sewn boat, port, *Aenona*, Zaton 3, boat structure

1. Introduction

The Roman-period port in Zaton near Nin is located some 17 km northwest of Zadar and was discovered in the mid-1960s (Brusić 1968). The Roman city of Nin (ancient *Aenona*), although located on the coast, had its port 2.5 km to the southwest, at Cape Kremenjača (Fig. 1). There were a number of reasons for dislocating the port: *Aenona* was located on a small island in the shallow waters of Gulf of Nin, whose shore was unsuitable for a larger port due to the sandbars and shallows in front of it; reaching *Aenona* by circumnavigating the present-day island of Vir (which was connected with the mainland in the Roman times) was an arduous and time-consuming feat because of the strong winds and numerous shallows and hidden rocks along the route (Ilakovac 1997).

Zaton was a sizable port in the Roman times that consisted of a breakwater or a pier with a cargo-handling wharf and landing place on its eastern (inner) side. Today, the remains of that structure – what's left of it after it had collapsed and after the sea level had risen – can be seen 1.5 to 4 m under the surface. The ancient port in Zaton was operational for as long as three centuries. The first use of the port dates back in mid-1st century AD, it was intensively used until late 3rd century, and most probably it ceased to exist in early or mid-4th century AD. The remains of three sewn boats (Zaton 1, 2 and 3) – called *serilia* by the ancient authors (Pacuvius and Verrius Flaccus apud Festus, *Epitoma*, 508, 33)¹ – constitute the most interesting and certainly the most valuable finds in the port (Fig. 2). The technique used for shipbuilding can be positively identified as Liburnian tradition. The fact that they were found in the layer which contained the Roman finds can be seen as evidence that the Liburnian shipbuilding tradition technique persisted during Roman rule.

¹ Sextus Pompeius Festus – *Sexti Pompei Festi De verborum significatu quae supersunt cum Pauli epitome*. Edidit Aemilius Thewrewk De Ponor. Pars I. Budapestini 1889.



Fig. 1 Position of the site (map: D. Romanović)



Fig. 2 Aerial photo from the north-east of Cape Kremenjača with position of the three sewn boats (photo: D. Grosman)

2. Excavation

There have been several excavation campaigns at the port since its discovery. Boats Zaton 1 and 2 were discovered very close to each other, where the seabed is now 1.5 meters deep. Zaton 1 wreck was discovered in 1966 and recorded and recovered in 1979 (Brusić 1968; 1995; Brusić, Domijan 1985; Radić Rossi, Brusić 2014). Zaton 2 wreck was discovered in 1982 and recorded and salvaged in 1987 (Glušćević 1984; 1986; 1987; Brusić, Domijan 1985; Brusić 1995; Radić Rossi, Brusić 2014). All these excavation campaigns were directed by Zdenko Brusić and Miljenko Domijan. The systematic archaeological excavations at the port were resumed in 2002 when a third sewn boat, Zaton 3, was discovered, some 40-50 m further south along the breakwater, where the seabed is now 3 m deep. Between 2002 and 2013, during eight campaigns, the excavations were directed by Smiljan Glušćević (Glušćević 2002; 2004; 2005; Pydyn, Glušćević 2011). Since during the previous campaigns the boat was not fully excavated, in 2019 the boat was reinvestigated, revealing the full dimensions of the boat's structure. The campaign was carried out in cooperation of the Archaeological Museum Zadar represented by Dušanka Romanović and Department of Archaeology of the University of Zadar represented by Irena Radić Rossi and Katarina Batur.

The best researched of the three sewn boats from the Roman-period port in Zaton is the third boat (Fig. 3). Data about Zaton boats 1 and 2 is very scarce. Only a few reports on the underwater excavations were found in the archives, and many questions about Zaton 1 and 2 remain unsolved (Romanović 2021). The remains of this third boat are in better condition than the remains of the other two. The boat's structure was explored by sections in four campaigns from 2002 to 2007, but not entirely and it was not documented in detail. During the 2019 excavations, the entire preserved boat's structure with its periphery was cleaned up and documented, providing new data on its construction.



Fig. 3 Orthoimage of the first phase of Zaton 3 boat excavations in 2019: the inner carpentry (ceiling and keelson are still in place) (author: K. Yamafune)

After the boat's structure had been uncovered, multiphase recording ensued. The first phase focused on thorough cleaning of all the boat structure elements and marking them for the first recording phase. The second phase included the lifting of the ceiling, thorough removal of the sediment from the boat structure, and marking its elements for the second recording phase. The third phase included extraction of dislocated elements for detailed recording and lifting the keelson for the third recording phase.²

Detailed descriptive records and photographs were performed, followed by the elaboration of georeferenced photogrammetric models in all excavation phases. All elements of the boat's structure were measured, and samples were taken in order to establish the type of wood used in the construction, and for dendrochronological and 14C analysis.

3. Hull remains

The total area of the researched part of the boat's structure, with all of its extremities, measured approx. 40 m². Dislocated elements that belonged to the boat's framing and planking were found around the main structure. The seabed on which the boat lies slopes slightly towards the east. The structure lost its original shape by the weight of the sand and silt layers that had deposited on it over centuries. Based on the information from the previous excavation reports, the cultural layer above the boat was almost sterile. The boat is oriented in direction of SW-NE and is preserved in the length of 6.7 m and width of 2.7 m (Fig. 4). The starboard side and bow are in better condition than the stern and port side. The stern is poorly preserved due to devastating shipworms.

3.1. Keel

The boat rests on its keel (K) that is preserved in length of 6.13 m. The total length of the keel and its original shape remain unknown. The eastern extremity is entirely preserved, while the western extremity was damaged heavily by degradation process. The eastern extremity (the bow) ends with a finely processed scarf for attaching the stem or transitional timber (Fig. 5). The cross-section of the keel is visible on the eastern side, where it is almost rectangular and chamfered. The oblique channels for the stitches were drilled perpendicular to the keel edges, along both sides of the upper part of the keel.

² The photogrammetric recording was performed by Kotaro Yamafune from A.P.P.A.R.A.T.U.S. LLC, Japan.

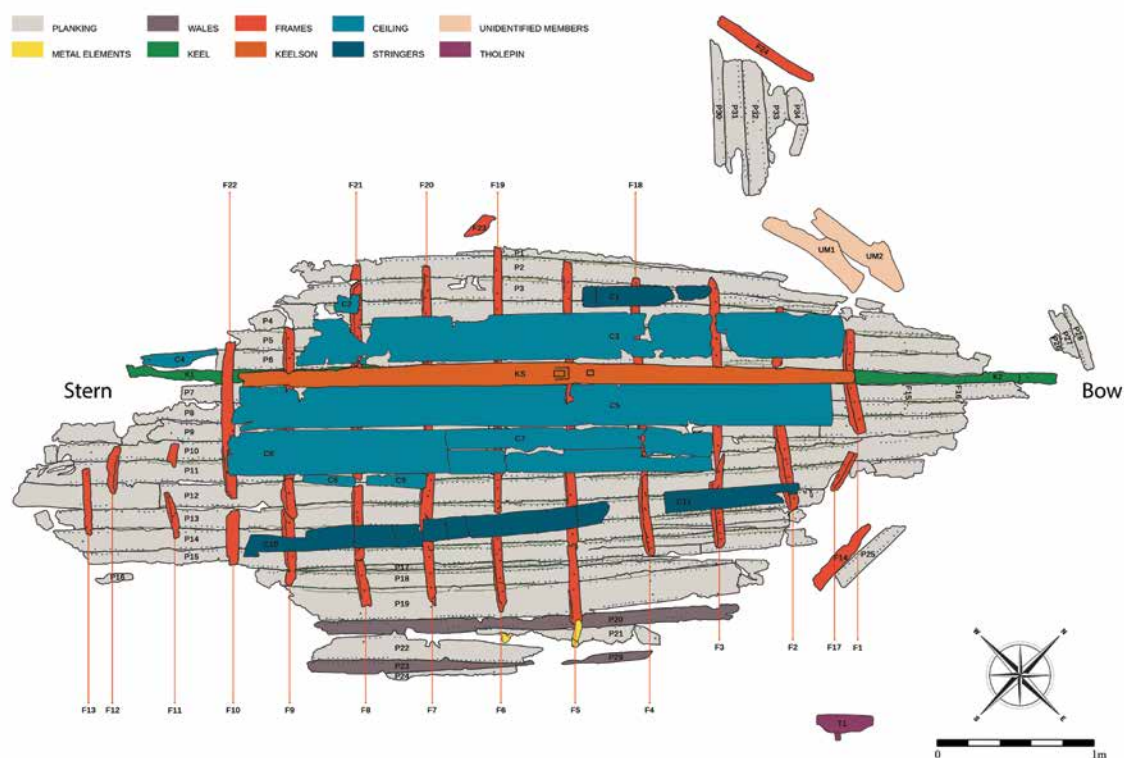


Fig. 4 Zaton 3 boat, plan view (drawing: R. Maršić, D. Romanović)

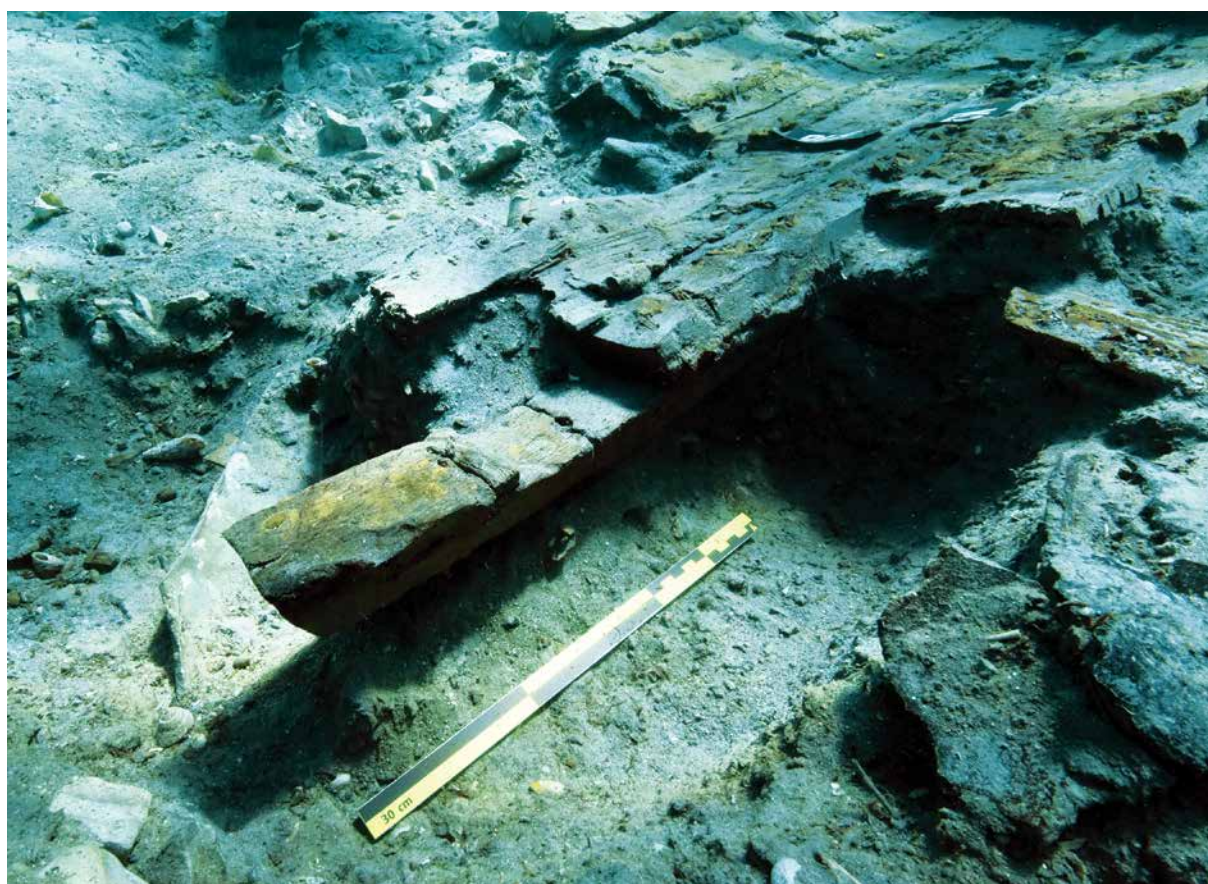


Fig. 5 Keel end with scarf for attaching the stem or transitional timber at the bow (photo: M. Martinčak)

3.2. Strakes and wales

The remains included a total of 23 strakes – six on the on the port side (P1 – P6) and 17 on the starboard side of the boat (P7 – P15 and P17 – P24). There were also several dislocated elements of the planking (P16, P25 – P34). The average strake width was 12-15 cm. The sewing pattern with simple overedge stitches is typical for most of the sewn boats preserved in the Eastern Adriatic (Pomey, Boetto 2019). The same sewing system was used for all three Zaton boats (Zaton 1, 2 and 3). The planks were sewn together longitudinally through the small channels set perpendicular to the edges of the plank. Small notches for inserting the stitch were made on the lower inner edge of the planks so that the stitches would be protected from wear and tear. A wadding pad was placed along the upper side of the seams. This sewing system included simple parallel stitches, created by spanning the sewing thread over the wadding pad diagonally only one time. The stitches run through small angled channels (in the cross-section) and perpendicular towards the edge of every plank (in the plan view). Stitches connecting planks were then immobilized with pegs that were placed in each hole.

No planks connected with oblique scarfs have been noticed. We can single out three strakes that narrow towards the bow as stealers, P3 and P10, the fourth strake on each side of the keel, and strake P18. Plank P17 is only 4 cm wide. After lifting the ceiling, plank repairs were noticed on two spots on strake P14, in the vicinity of frames F3 and F7.

The starboard side is preserved to the second wale (P23, P24 and P29). Dislocated plank P25, given that it is made of oak, may also be part of the wale. In the area of the first lower wale (P20), from the middle towards the stern of the boat, some metallic heavily corroded elements were noticed at the position of the frames F5, F6 and F7. Those could be the remains of metal fastenings that once connected the frames to the lower wale. Due to the wales' thickness, the channels with small pegs were drilled perpendicular to the plank edges.

3.3. Ceiling

The boat Zaton 3 had partially preserved ceiling planks (C1 – C11) above the frames. A total of 11 ceiling planks were recorded, some of them fragmented. Based on their position and shape, we can assume that the elements marked C1, C10 and C11 had the function of stringers. As traces of nails can be seen on a few places on the ceiling planks, it is believed that nails once connected them to the frames.

3.4. Frames

Framing is composed of floor timbers and futtocks (F1 – F13, F18 – F22), that are not joined but simply butted, and attached to the planks by treenails. There are 13 frame stations in various conditions, found *in situ*. Five dislocated frame fragments (F14, F23 and F24) were also discovered, as well as traces of two imprints (F15 and F16) with one row of treenails (F15) where the frames once stood. The frames measure from 5 to 8 cm sided, and from 5 to 8.2 cm moulded. The distance between frames center-to-center is 41 to 49 cm. The recesses on the floor timbers and futtocks, cut above the seams, vary in shape and size.

A dislocated element found in the southern part of the grid was initially marked as F17, but the analogy with the Herculaneum boat (Steffy 1985; 2005) changed the interpretation to a tholepin, and the element was remarked on the plan from F17 to T1.³

3.5. Keelson

A massive keelson (KS) placed above the keel and frames represents one of the longitudinal reinforcements of the boat structure. The 2019 excavation campaign established that the bow was oriented to the east. The preserved length of the keelson is 3.75 m. It extends from frame F1 at the bow to frame F10 at the stern, where it is quite damaged so its full length cannot be established. The dimensions of the keelson are 7.6 to 14.2 cm sided and 7.1 to 7.9 cm moulded, with the widest part in the central section of the boat. On the lower side of the keelson there are recesses for accommodating it on the frames, as well as slight arch-shaped indentations between the recesses which allow circulation of bilge water. On the upper side, on its central (and widest) section, there is the mast mortise (Fig. 6). The mast mortise is rectangular, and the north-east edge is cut obliquely to facilitate lowering of the mast towards the stern. The mast mortise is flanked by rectangular recesses on three sides, for hosting vertical planks to support the mast. To enable the final part of the third recording phase, the keelson was lifted and photogrammetrically recorded. On the upper side

³ We are grateful to Elisa Costa for suggesting the original function of this element.

of the keelson, at the position of frame F20, a trace of a nail that once joined it to the keel and frames is visible. After removing the keelson, on its lower side, at the position of frames F3, F20, and F21, traces of nails were observed, which were probably hammered in from the bottom of the keel, passing through the keel and entering the frames and keelson.



Fig. 6 Orthoimage of the four sides of the keelson: a) top view; b) view from the south-east; c) bottom view; d) view from the north-west (author: K. Yamafune)

3.6. Wood analyses

A total of 74 wood samples were taken in 2019. The samples were sent to the Faculty of Forestry and Wood Technology of the University of Zagreb for xylological and dendrochronological determination, and to the Ruđer Bošković Institute for the ¹⁴C analysis, with analyses carried out in 2020. The xylological analysis established that the samples belong to five different tree species: *Quercus sp.* (oak), *Fraxinus sp.* (ash), *Fagus sp.* (beech), *Ulmus sp.* (elm) and possibly *Cedrus sp.* (cedar). As cedar is not a common tree species in the Adriatic area, the result of the analysis should be taken with caution and the analysis should be repeated.⁴

Xylological analysis showed that the keel was made of oak; the planking was made of two types of wood, mostly beech, and a few made of elm; the wales were made of oak; the ceiling was made of two types of wood, beech and possibly cedar (?); the frames were made of two types of wood, mostly oak, one made of ash, and few remained undetermined; the keelson was made of possibly cedar (?); the tholepin was made of beech; and two unidentified members were made of oak (Table 1).

The samples were also submitted to dendrochronological analysis, but unfortunately, the number of tree rings did not allow any accurate dating. The Laboratory for Low-level Radioactivities at the Ruđer Bošković Institute in Zagreb, carried out a ¹⁴C analysis in 2020, using the Accelerator Mass Spectrometry technique. The result for the Z-7391 sample of the Zaton 3 boat provided the date of 74–127 cal AD (68.3%). The sample was taken from one part of the planking (P5).

⁴ The samples were sent for analysis to the Faculty of Forestry and Wood Technology in Zagreb at the end of 2019, before the corona pandemic. At the beginning of 2020, beside corona pandemic, Zagreb was hit by a big earthquake that damaged the laboratory, so the analyses were not carried out according to all standards. Some samples remained undetermined, and some samples gave unusual results. Given these circumstances, the samples were resent for analysis in 2023. The results will be presented at the next ISBSA congress.

SAMPLES	NO. OF SAMPLES	TYPE OF WOOD
FRAMES		
Frames F1 – F4, F6, F8, F11 – F12, F14, F18 – F24	16	Oak (<i>Quercus sp.</i>)
Frames F5, F7, F9	3	not determined
Frame F10	1	Ash (<i>Fraxinus sp.</i>)
Frame F13	1	not determined
KEEL		
Keel K	2	Oak (<i>Quercus sp.</i>)
KEELSON		
Keelson KS1	1	Cedar (<i>Cedrus sp.</i>) (?)
PLANKING		
Planks P1 – P15, P17 – P18, P26 – P28, P30 – P34	25	Beech (<i>Fagus sp.</i>)
Planks P16, P19, P21 – P22	4	Elm (<i>Ulmus sp.</i>)
Planks P20, P23 – P25, P29	5	Oak (<i>Quercus sp.</i>)
CEILING		
Ceilings C1, C8 – C11	5	Beech (<i>Fagus sp.</i>)
Ceilings C3 – C7	5	Cedar (<i>Cedrus sp.</i>) (?)
OTHER		
Unidentified members UM1 – UM2	2	Oak (<i>Quercus sp.</i>)
Tholepin T1	1	Beech (<i>Fagus sp.</i>)
Peg	1	not determined

Table 1 Results of xylological analysis of Zaton 3 boat done in 2019 at the Faculty of Forestry and Wood Technology of the University of Zagreb

4. Conclusion

As the documentation of the first two sewn boats recovered from the Port of Zaton is lost, and the boats are disassembled and stored in the deposit of the Archaeological Museum Zadar, the remains of Zaton 3 give us a more detailed glimpse into construction characteristics of the sewn boats used in the 1st century AD. Their original purpose remains unclear. They probably sailed in the neighbouring area, and maybe to the islands of Zadar Archipelago. They could have been used in loading and unloading of the cargo in the port, fishing, and short-distance transport of passengers or cargo. Based on the keelson with mast mortise, it can be concluded that the Zaton 3 boat had a mixed propulsion and harnessed the power of wind, using probably a square sail, and also used oars. Considering the other finds of sewn boats in the north-eastern Adriatic, like Caska, Pula, Poreč and Zambratija (Radić Rossi, Boetto 2020; Koncani Uhač *et al.* 2017; 2019, 162–166; Boetto *et al.* 2017; 2023), the boats of Zaton could be attributed to the north-eastern Adriatic tradition, preserved by Liburni and Histri in the Late Roman Republican and Early Imperial period (Pomey, Boetto 2019; Boetto *et al.* 2023, 16–18).

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The columns shipwreck of Kamarina (2nd c. AD) – New data from the Kaukana project, Sicily

Massimo Capulli

Abstract : The shipwreck of the Columns, dated at the end of the 2nd c. AD, lies on a sandy bottom at a depth of 2.5 to 4 m in the bay that opens south of the promontory on which the Syracusans, at the beginning of the 6th century BC, founded the colony of Kamarina. The main cargo consisted of a pair of half-finished columns 80 cm in diameter and approximately 6 m long. The new research on this site, known since the 1970s, is part of an organic program of study of the historical-archaeological evidence preserved along the Ragusa coastline by the University of Udine, in collaboration with the Superintendence of the Sea of Sicily and with the support of the Institute of Nautical Archaeology.

Keywords: shipwreck, landscape, Kaukana, Kamarina, anchors, columns

1. A brief history of research

The shipwreck of the Columns of Kamarina is located in the bay that opens south of the promontory on which the Syracusans, at the beginning of the 6th century BC, founded the colony of the same name (Fig. 1). The underwater site, which owes its name to the main cargo consisting of a pair of columns, has been known to the authorities since the first half of the 1970s, when it was reported to the Kamarina Excavations Office of the Archaeological Superintendence of Syracuse (Di Stefano 2016: 143–148).

After a preliminary investigation by Parker in the same years (Parker 1976: 25–29), the shipwreck was subjected to a more thorough investigation in two campaigns conducted by the company Aquarius in 1989 and 1996, which benefited from a period where the site was naturally exposed, since the morphology of the sandy bottom varies here according to the shifting currents and wave action. In particular, the space between the columns was investigated, then following the portion of the hull which had remained in a southerly direction; during the excavations, in addition to the monumental cargo, numerous lithic slabs and other accompanying goods were also identified such as 21 examples of Africana IA amphorae, form XXIII of Ostia, and to a lesser extent of the Mid Roman 18 type, form Reley 288 (Di Stefano 2016: 143–148), in some cases still with the cork. To these finds, which are certainly part of the cargo, we must add artefacts that are also representative of refined artistic craftsmanship, such as a pyriform copper vase decorated with plant and geometric motifs and blue glass paste inlays or a thermos decorated with theatrical masks and lion's paws (Di Stefano 1998: 36–43; Di Stefano 2003: 10–31; Di Stefano, Ventura 2012: 633–638).

2. The investigations of Kaukana Project

The shipwreck has been located and investigated again in recent times. The new research in Kamarina Bay is part of a larger scientific project, called the Kaukana Project, which was born from Sebastiano Tusa's¹ desire to realize an organic program of study of the historical-archaeological evidence preserved along the Ragusa coastline between the ancient cities of Ispica, Kaukana, and Kamarina. In the period 2017–2020, the Department of Humanities and Cultural Heritage Studies of the University of Udine, in collaboration with the Superintendence of the Sea of the Sicilian Region

¹ The former Superintendent of the Sea and then Councilor for Cultural Heritage of the Sicilian Region, Sebastiano Tusa co-directed the research until his tragic disappearance on March 10, 2019, in the Ethiopian Airlines flight crash while on his way to Malindi, where he was supposed to attend an international conference organized by UNESCO. The research continued on behalf of our missing colleague.

and with the support of the Institute of Nautical Archaeology, thus conducted four research campaigns aimed at the diachronic reconstruction of the underwater landscape of the Ragusa region: the first year the activities focused on the Punta Secca wreck (Capulli 2021: 33–45), the second year a survey was carried out in the waters of Porto Ulisse and those of Kamarina (Capulli, Innocenti 2019: 10–16), and the third and fourth years they returned to Kamarina for an in-depth investigation of the Columns shipwreck.



Fig. 1 The bay of Kamarina with the Columns shipwreck at the bottom right (photo: D. Innocenti)

Reconnaissance carried out in 2018 in Kamarina Bay, with the aim of expanding the study of known shipwrecks, resulted in the rediscovery and geo-referencing of the wreck of the Columns, as well as a previously unknown anchorage. That site could also be interpreted as a shipwreck area given the chronological-typological consistency and position of the anchors. Specifically, there are four iron anchors that lie at the foot of a vast rocky outcrop and rest at a bathymetry of about -3.7 m along an alignment oriented roughly 70 degrees north. Typologically, the anchors can be traced to the inverted ‘T’ type and generically referred to as Byzantine. Of the four anchors, only three are identifiable: two belong to the D typology of the seriation proposed by Gerhard Kapitän (Kapitän 1984: 33–44), while the third, which orthogonally overlaps one of the D typology anchors, seems to represent a transitional moment between typology C and typology D (Capulli, Innocenti 2020: 6–7).

About 120 m from the anchorage in a direction 10 degrees north, as anticipated, the shipwreck of the Columns was also identified. In fact, in spite of increased silting of the bay, possibly caused by the Scoglitti harbor extension work that had taken place since the previous archaeological investigations, the two column shafts were still partially visible. Thus, the following year a new excavation campaign was conducted² aimed at completing the 1996 work, investigating north of the columns as well, and to initiate the study of the hull. Indeed, except for the stone cargo and non-diagnostic and crushed ceramic materials, the cargo had been recovered in previous campaigns.

² All activities at sea were coordinated with Fabrizio Sgroi of the Superintendence of the Sea of the Sicilian Region and with the collaboration of the Scoglitti Local Maritime Office of the Pozzallo Port Authority.

2.1. The columns shipwreck site

The shipwreck lies on a sandy bottom at a depth of 2.5 to 4 m and a distance from the beach of about 80 to 90 m. The main cargo consisted of a pair of half-finished columns 80 cm in diameter and approximately 6.25 m long (the one on the sea side) and 6.04 m long (the one on the beach side) (Fig. 2). For both, the shafts are smooth and have only a 1/2 cm raised band at both ends, with a height of between 24 and 27 cm. In order to observe and document the hull,



Fig. 2 Part of the hull preserve (keel and the two gardboards) and the columns seen from the south-east (M. Capulli)

it was necessary to make a large trench longitudinal to the axis of the ship. In particular, the underwater archaeological investigation, also carried out for the purpose of a teaching exercise, involved the use of a water dredge to remove a thick layer of sand by proceeding in inclined planes. That is, the sediment was removed by constantly looking for the correct angle of friction, which made it possible to contain the sliding of material along the walls of the excavation. Having uncovered the hull both south and north of the columns (previous investigations had never uncovered the preserved portion of the hull north of the columns), it was possible both to proceed with the execution of a series of direct surveys and to obtain additional documentation to that produced during the 1989 and 1996 excavations. Thanks to the technologies available today and taking advantage of a prolonged period of weather-marine stability³, it was possible, for example, to carry out a series of aerial shots, both zenithal and oblique, using a DJI drone, model Mavic 2 Pro. These operations, also aided by the limited bathymetry and generally good water visibility, allowed production of a rich photographic documentation of the shipwreck and the coastal landscape in which it is embedded. In addition, the thousands of high-definition digital images acquired during underwater operations have enabled the construction of a three-dimensional model of the shipwreck (Fig. 3) from the pixel cloud (Balletti *et al.* 2016: 1–8; Yamafune *et al.* 2016: 703–725).



Fig. 3 The 3D model of the Columns shipwreck (author: M. Capulli)

³ The 2019 campaign lasted 26 days, including nine days of weather stand-by; however the latter were not intermittent, but concentrated from the middle of the third week of excavation to the end of the campaign.

The same methodology was used in the following year, however 2020 saw a short campaign, necessarily with reduced participation and with constraints imposed by actions to contain Covid. Thus, a focused search was opted for, aimed at verifying whether other parts of the hull had been preserved beneath a pile of lithic slabs lying along the outer side of the north end of the land-side column.

2.2. New data from the Kaukana project

Originally stowed probably in parallel, the columns (for which a total weight of about 16 to 18 t is estimated) today appear divergent by a few centimeters at the north-northwest end and by about 3 m at the south-southeast end; both shafts, moreover, are broken into two trunks slightly offset from each other. Based on the analyses performed⁴, it can be stated that the columns are of ancient yellow marble, the so-called *marmor numidicum*, although from a strictly petrographic point of view it is a fine-grained limestone composed almost entirely of microsparite grains. In particular, it is noted that the southwest column lies partly above the keel, crushing the keelson against the other column. It is therefore likely that during the sinking the columns moved and one dismantled the bulwark, possibly contributing to unbalancing the ship. From a post-depositional point of view, this explains the observed asymmetrical conservation, in which the ship's center and northeast side are better preserved since they were covered and to some extent protected by the columns⁵.

The hull extends for a length of 15 m, running from one end (northwest) to a Jupiter dart on the keel (southeast). The latter is formed by a beam 28 cm wide and about 26 cm high, suitably shaped at the upper edges to form a rabbet of variable angle into which the garboards were inserted. The width of the planking boards is between 32 and 27 cm, while the measured thickness is 7.5 cm. At the fracture points we were able to document the mortise and tenon joint system peculiar to the ancient age, here atypically secured by a double order of joints (Fig. 4), arranged in a staggered manner in two parallel rows only 1.5 cm apart (Capulli, Innocenti 2020: 12). In contrast, the distance between mortises within the same row is 8.5 cm, which corresponds to the width of the mortises themselves. These, 0.73 cm high, are 7 cm deep and juxtaposed between planks, housing tenons 12.5 cm long, 6.5 wide and 0.72 thick, clamped inside the mortises by pegs, about 1 cm in diameter. Above the planking, sixteen floor timbers have been preserved, attached to the planking by 1.5/1.8 cm diameter treenails, in which there is a single central limber hole. The average width of the floor timbers is 11/12 cm and is slightly less than the distance between them, which is 13 cm; the height measured between those preserved between the columns is 20/22 cm and rises as one proceeds toward the northwest end. It is worth pointing out, however, that almost all of the frames found to be preserved between the columns during the Aquarius excavations are missing today⁶. As anticipated, although offset from the axis of the ship, part of the keelson consisting of a beam 24 cm wide and 22 cm high, suitably shaped in the lower face to intrude on the sideboards, has also been preserved.

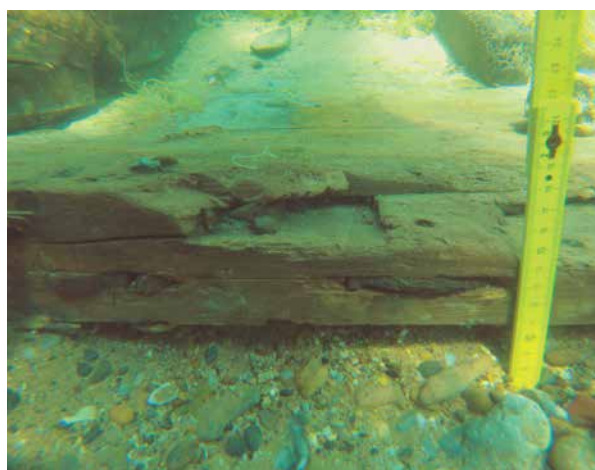


Fig. 4 Detail of the joining system of the planking with mortise-tenons arranged staggered on two parallel rows (photo: M. Capulli)



Fig. 5 Obverse side of the sesterius of LVCILLAE AVG-ANTONINI AVG F, with the representation of draped bust (photo: M. Capulli)

⁴ The petrographic analysis was conducted by Cristina Stefani of the Department of Geosciences, University of Padua, Italy.

⁵ This is not only a contact protection, but also resulted in this part of the wreck becoming more silted up.

⁶ It is safe to assume that the removal of the cargo left the timbers free and that during one of the many swells that 'hollow out' the wreck these must have been ripped away.

The research conducted in 2020, while quantitatively extending the previous survey area, allowed the acquisition of important new information. In fact, the excavation was conducted at the pile of lithic slabs that lie along the outer side of the north end of the beach-side column. These, consisting of regular blocks⁷ of quartzose sandstone⁸, covered and protected the hull parts; thus some ‘tall’ elements of the ship’s framework, such as the half-frames, 8 cm wide and 9 cm high, and a wale consisting of a beam 10 cm wide and 11 cm thick, that is, protruding from the side by about 4 cm, have been identified and documented.

Sample	Essence
Keel	<i>Pinus nigra / Pinus sylvestris</i>
Keelson	<i>Quercus robur</i>
Planking	<i>Pinus cembra</i>
Tenon	<i>Quercus suber</i>
Peg	<i>Quercus suber</i>
Floor timber	<i>Quercus robur</i>
Treenail from floor-timber	<i>Olea europea</i>
Half frame	<i>Quercus robur</i>
Wale	<i>Quercus robur</i>
Floorboards	<i>Pinus cembra</i>
Strand of rope	<i>Poaceae spontanee gruppo</i>
Amphora stopper	<i>Quercus suber</i>

Table 1 Species identification of materials used, performed by the Centro Agricoltura E Ambiente lab of Crevalcore (BO, Italy)

The chronology of the shipwreck, placed at the end of the 2nd century AD, has also been confirmed by a new monetary find⁹. Specifically, this is a sestertius depicting Lucilla, daughter of Marcus Aurelius and sister of Commodus (Fig. 5), datable to AD 164–169¹⁰.

2.3. Open questions

The shipwreck of the Kamarina Columns is preserved about 15 m long and 4.5 m wide, but as with any *relictus* this is only what remains of the original ship. Establishing from the archaeological record what the original dimensions were is not always easy, nor is it sometimes possible. In this case the maximum width can be estimated with an acceptable approximation, thanks in part to the upper part of the side excavated in the 2020 campaign, at no less than 6 m at the center of the ship. Much more doubt remains regarding the length, however, since we have for certain only one of the two ends and precisely the northwest end. This has the characteristic, unusual for the ancient period, of presenting a straight element in place of a curved one, which runs almost orthogonally into the keel (Fig. 6) and which on the basis of comparison with the 1st c. AD wreck of Saint-Gervais 3 (Liou *et al.* 1990: 157–264) could perhaps be interpreted as the bow. Conversely, the southeast end, which, as seen, terminates in a Jupiter’s dart, could see the curved post directly engaged, probably aft, as much as continuing with another keel element. Unfortunately, the angle of the keel rabbet observed near the keel fitting is still very open and therefore not entirely resolved.

⁷ The five slabs sampled showed identical widths of 25 cm, while lengths ranged from 55 to 73 cm and heights from 8 to 11 cm.

⁸ This petrographic analysis was also conducted by Cristina Stefani of the Department of Geosciences, University of Padua.

⁹ During the 2020 campaign, a small metal concretion had been recovered that had disintegrated during its long stay in fresh water at the University of Udine’s Water Archaeology Laboratory, from which a coin emerged.

¹⁰ RIC III (Marcus Aurelius) 1756.

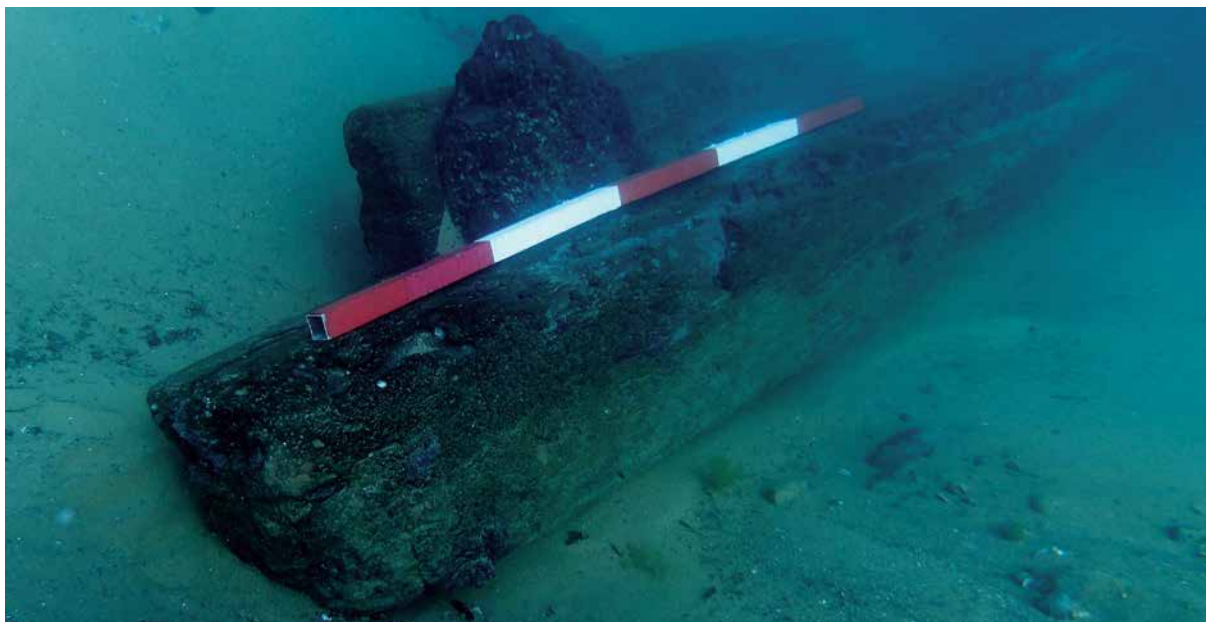


Fig. 6 North-west extremity of the shipwreck with the straight stuck orthogonally in the keel (M. Capulli)

From a constructional point of view, the hull falls into the type known as 'shell-first', that is, one in which the planking courses are firmly connected to each other with a structural function, while the frames serve only as reinforcement. As seen, the assembly of the planking in this case is ensured by a double order of joints (mortises and tenons) arranged in a staggered manner in two parallel rows, as if it formed a sort of uninterrupted line of tenons connecting the planks. This peculiarity has also been observed on other important hulls of the Roman period. They present mortises and tenons in two rows, for example, the wreck of Antirrhodos (see Sandrin *et al.* 2013: 51, Fig. 9) and Caesarea (see Derenne *et al.* 2019: 81, Fig. 6), but the spacing is such that they do not constitute a true uninterrupted line. Comparisons with the joinery observed in the Antikythera wreck (see Bouyia 2012: 40) and in southern Italy in that of Punta Scifo A (see Medaglia 2015: 5, Fig. 7) seem decidedly more similar. However, it is still not entirely clear whether this technological choice can be uniquely linked to the vessels that Pliny said were built for the transport of marble: *navesque marmorum causa fiunt*¹¹.

3. Conclusions

On the basis of these data the shipwreck has been interpreted as what remains of a medium-sized ship, engaged in the transport of a mixed cargo from North Africa, namely from Tunisia, where the quarries of the 'Ancient Yellow' of Simitthusu (Lazzarini 2002: 243–244), present-day Chemtou village, are located. That the city Kamarina was the final destination cannot be established¹², indeed, nothing excludes that its port constituted only a coveted shelter during a storm. What would seem certain, however, is that the ship was wrecked on a semi-submerged sand dune in the late 2nd century AD. With a known mechanics in shallow water (Muckelroy 1975: 173–190), the hull must have run aground in the sand, where it lost buoyancy and especially steering by remaining at the mercy of the waves, which over time then broke it up.

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¹¹ Pliny N.H. 36,1,14.

¹² On the transportation and trade of marble in Sicily, see Pensabene 2003: 533–543; Purpura 2008: 23–44, while for a broader look see Gianfrotta 2016: 341–359; Pensabene 1972: 317–362; Pensabene 2002: 3–67; Russell 2013: 95–140 and especially Pensabene 2013.

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New insights into the Ma'agan Mikhael B shipwreck, Israel

Maayan Cohen – Deborah Cvikel

Abstract: The Ma'agan Mikhael B ship was a lateen-rigged merchantman, about 23 m long, with an estimated displacement of 120 tons, dated to the mid-7th–mid-8th centuries AD. In six excavation seasons so far, from 2016 to 2019, the hull and the artefacts have been recorded underwater, and some of the latter were retrieved and studied on land. Based on its construction details – no planking edge-fasteners, and planks butt-jointed at frame stations – it appears that the ship was built to a 'frame-based' concept. It is thus among the earliest frame-based shipwrecks found to date in the eastern Mediterranean.

Keywords: frame-based, Late Antiquity, lateen-rigged, Mediterranean, transition in construction

1. Introduction

The shallow sandy seafloor off kibbutz Ma'agan Mikhael is characterized by a dynamic sediment regime, which created optimal anaerobic conditions for the preservation of archaeological remains. This is testified by the discovery of two ancient wooden shipwrecks in the area: the 400 BC Ma'agan Mikhael shipwreck, found in 1985 (Linder 2003; Kahanov 2011), followed 20 years later by the 7th–8th centuries AD Ma'agan Mikhael B shipwreck (Cvikel *et al.* 2017).



Fig. 1 Divers on the Ma'agan Mikhael B shipwreck site (photo: A. Yurman)

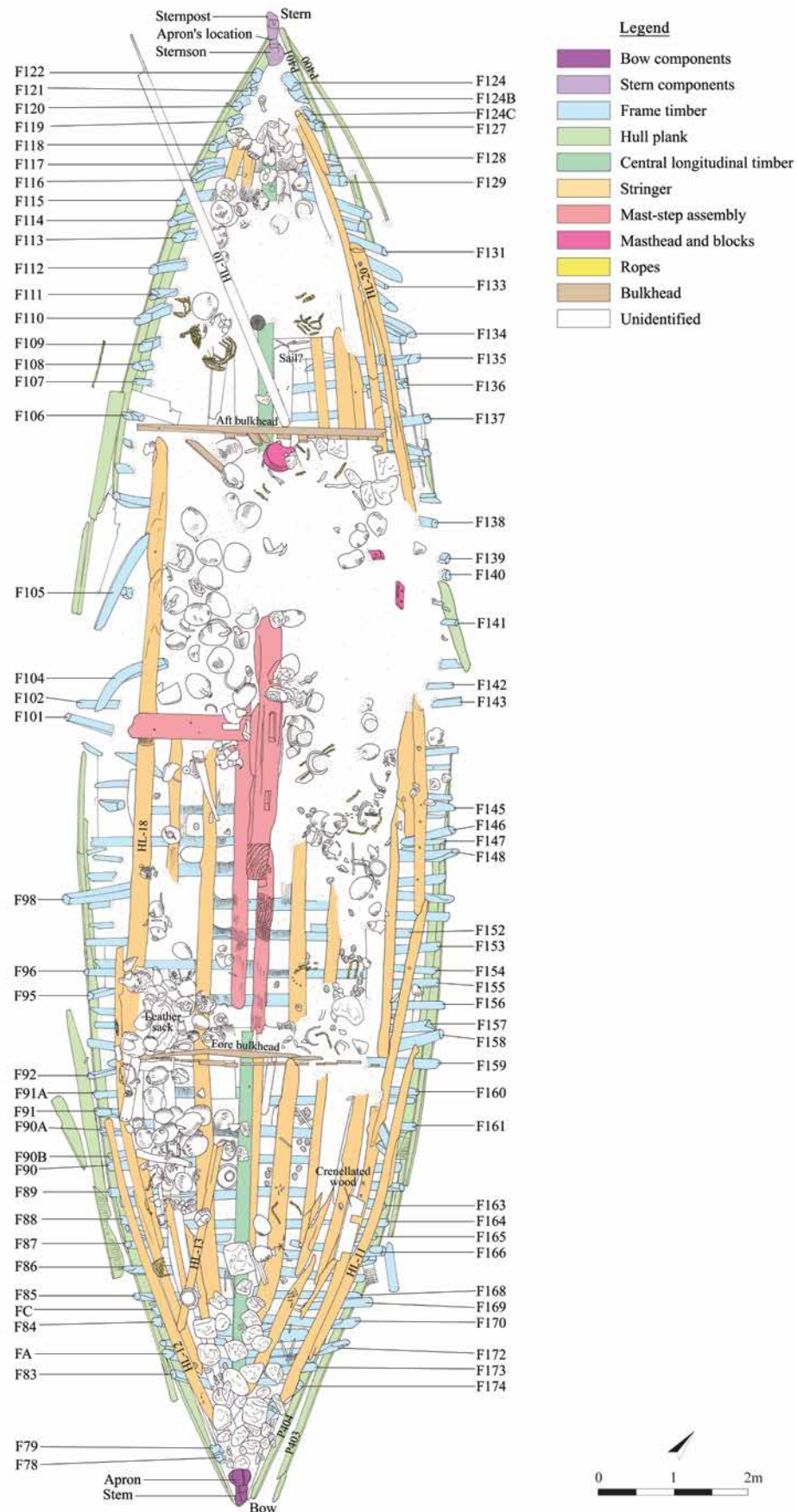


Fig. 2 Plan of the Ma'agan Mikhael B shipwreck (drawing: P. Sibella, adapted by K. Asuli and S. Haad)

In the second half of the 1st millennium AD, there was a transition in ship construction technique from ‘shell-first’ to ‘frame-based’ in Mediterranean shipbuilding. The dating of the Ma‘agan Mikhael B ship was a major reason for the long-term programme of underwater excavation and research by the Leon Recanati Institute for Maritime Studies of the University of Haifa (Fig. 1) (Cohen, Cvikel 2019). It had previously been claimed that shipwrecks at Dor/Tantura lagoon, dating from the Byzantine and Islamic periods, could undermine the notion that Serçe Limanı, dated to 1025, was the earliest found using a purely ‘frame-based’ design (Kahanov 2011: 169–172, 176–177; Pomey *et al.* 2012). The dating of the Ma‘agan Mikhael B ship supports an earlier dating of the transition.

In the course of the underwater excavations, which were sometimes hampered by harsh weather conditions, the shipwreck remains were revealed at a depth of 3 m and found to be oriented roughly east–west. The hull was 19.6 m long between endposts and 4.9 m wide. The main components of the shipwreck found in a good state of preservation include the keel, endposts, framing timbers, central longitudinal timbers, hull planks, stringers, bulkheads and a mast-step assembly (Fig. 2). A wide array of finds was found, including ceramic sherds and intact amphorae, bricks and ballast stones, matting and baskets, faunal remains, food remains, and rigging elements (Cohen, Cvikel 2019; Creisher *et al.* 2019; Cohen, Cvikel 2020). All wood species were identified by S. Wicha, at Archéobois, Marseilles, and fibre analysis was conducted by A. Rast-Eicher, at Büro für archäologische Textilien, Bern.

2. Hull remains – main components

2.1. Keel

The keel was made of three wood species: fir (*Abies* sp.), sampled in the bow area, sycamore (*Acer pseudoplatanus*) and cypress (*Cupressus sempervirens*), both sampled in the stern area. The use of three different tree species may imply that it was either difficult to obtain suitable timbers for the keel, or perhaps these may indicate repair. However, this requires further investigation. Where measurable, its average dimensions were 18 cm sided and 27 cm moulded. So far, no rabbet or chamfered corners for fitting the garboards have been detected.

2.2. Stem and sternpost

The stem was 1.88 m long, 9–12.5 cm sided and 13–23.5 cm moulded. It was made of two timbers that were joined by a complex keyed hook scarf similar to the ‘Jupiter’ scarf. The upper timber was of Aleppo pine (*Pinus halepensis*), and the bottom timber was of walnut (*Juglans regia*).

The upper timber of the sternpost was not found. The bottom timber, of walnut, was 34 cm long, averaged 13 cm sided and was 10–29 cm moulded, narrowing towards its top. A projection on its upper face, 3 cm long and 3 cm wide, probably secured the upper missing element.

2.3. Framing timbers

The remains of 60 framing timbers were revealed on the starboard side and 63 framing timbers on the port side. There was evidence of at least 30 frame-stations. They were of walnut, except for two which were of holly oak (*Quercus ilex*) – perhaps a repair. On average the framing timbers were 12 cm sided and 14 cm moulded, with room and space of 43 cm. Some of the framing timbers were simply partially worked branches, while others were more carefully worked, with rectangular cross sections and a smooth face fitting an adjacent frame or hull plank. Carpenter’s tool marks, such as a saw and an adze, were visible. A layer of yellowish paint (of unknown composition) and a pine pitch layer were preserved on most of the framing timbers.

2.4. Hull planks

Thirty-one hull planks of fir were exposed: 20 on the starboard side and 11 on the port side. They were on average 19 cm wide and 3 cm thick. They were butt-jointed to strakes at frame-stations, and fastened to frames by two square iron nails, driven from the outside. No edge-fasteners of any type were found.

2.5. Central longitudinal timbers

Two central longitudinal timbers were installed, one at the bow and the other at the stern. These beams were separate, not forming a traditional keelson. The bow timber was of fir. Its entire length was 4.9 m, and it was on average

16 cm wide and 25 cm thick. The stern timber was of Aleppo or Turkish pine. It was about 5 m long, averaging 18 cm sided and 30 cm moulded.

2.6. Stringers

At least three stringers made of fir half-logs were found on each side of the keel. They were on average 18 cm wide and 13 cm thick, and the longest one was 4.9 m long (Cohen *et al.* 2021: 168).

2.7. Bulkheads

Two bulkheads made of vertical planks were found. The top extremities of all the planks were broken. The fore bulkhead was located 13.8 m from the sternpost and was made of 19 planks, all of fir, except for one which was of Aleppo or Turkish pine. The longest measured plank was 1.31 m. The average width of the planks was 13 cm and the average thickness was 3.6 cm. Charred clay bricks found near the fore bulkhead indicate the possible location of the galley.

The aft bulkhead was 5.5 m from the sternpost. It was made of 15 planks; eight of cypress, four of fir or cypress and two of fig. The longest measured plank was 1.54 m. The average width of the planks was 14.4 cm and the average thickness was 3.7 cm.

2.8. Mast-step assembly

The mast-step assembly comprised the mast-step itself, two longitudinal support timbers, and a lateral buttress. The mast-step and support timbers were of walnut and the buttress of fir. The forward end of the mast-step was located about 8.1 m from the stem. The mast-step was 3.5 m long, 25 cm wide and 19 cm thick. Two mortises were cut into its upper surface: the smaller forward one was 27 × 8 cm, and 12 cm deep, probably securing a stanchion supporting a mast partner. The aft mortise, 37 × 10 cm and 6 cm deep, sloped downwards towards the stern, and most likely held the mast heel (Cohen, Cvikel 2020: 298).

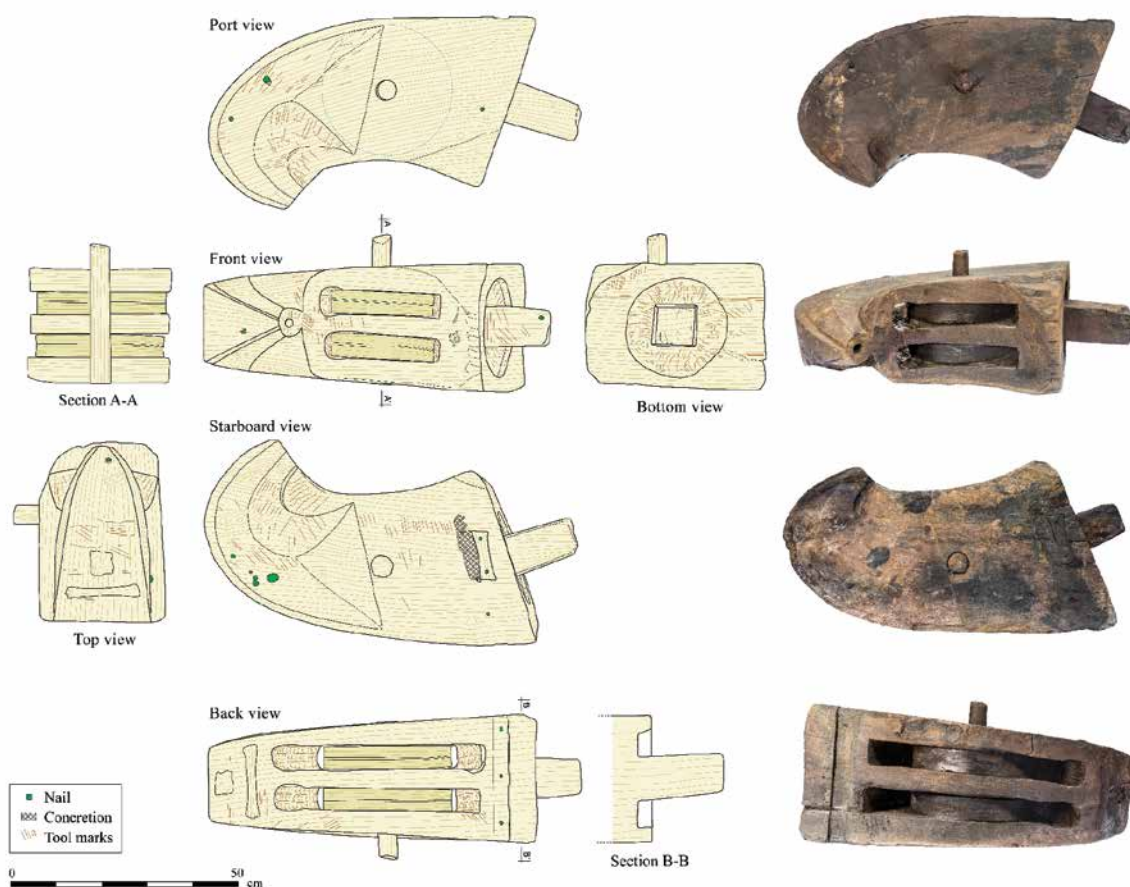


Fig. 3 The hook-shaped masthead (photos: A. Efremov, drawings: S. Haad)

3. Finds

The Ma'agan Mikhael B shipwreck excavations revealed a wide variety of finds, providing information about the date of the ship and its route.

3.1. Hook-shaped masthead

An unattached hook-shaped masthead was discovered in the hold of the shipwreck, in a superb state of preservation (Fig. 3). As far as archaeological records go, this is the only hook-shaped masthead found in context (Beltrame, Medas 2021). It was made of walnut and was 73.5 cm long, 40.3 cm wide at its base and 24.9 cm thick. The lower face of the masthead bore a 20 cm-long tenon bearing a square cross-section of 9.5 × 9.8 cm protruding from a round indentation 23 cm in diameter with apparent adze marks. The masthead contained two sheaves of walnut, both 30 cm diameter and 4.6 cm thick (Cohen, Cvikel 2020: 291, 293). Its location inside the hull suggests that it was a spare part or meant for sale.

3.2. Rigging elements – blocks, ropes and sail

Four wooden rigging elements were found: two turning blocks similar in shape and size, 35 cm long and 10 cm wide; a smaller turning block, 14 cm long and 5.5 cm wide; and a three-sheave block, 42 cm long and 12 cm wide (Cohen, Cvikel 2019: 194–195; Cohen, Cvikel 2020: 295). The outer shell of the two large turning blocks was of walnut and that of the small turning block was of holly or cork oak (*Quercus suber*). Their sheaves were all of holly oak. The parts of the three-sheave block were all holly or cork oak, except for one sheave which was of walnut.

Ropes of various lengths and diameters were discovered, from short fragments up to coils, parts of the standing and running rigging of the ship. The rope fibres were identified as hemp (*Cannabis sativa*), halfa grass (*Desmostachya bipinnata*), sedge (*Cyperaceae*), coir (coconut fibre), and bast (unidentifiable species) (Cohen, Cvikel 2020: 295).

Pieces of fabric, maybe remains of the sail, were found near the aft bulkhead. The fabric was a high-quality sheep wool weft-faced tabby. It was most probably made in the Levant or southern Europe (Cohen, Cvikel 2020: 296–298).

3.3. Amphorae

The ceramic assemblage of this shipwreck is the largest maritime cargo collection to be discovered along the Israeli coast from this period. Typological studies of the amphorae have identified several types, including Late Roman Types 1, 2, 4, and 5 (Fig. 4). Table ware, cooking ware and one lamp were also found. Based on petrography, the origin of the clay is Cyprus, Egypt and the Levant coast. Many of the amphorae still contained some of their final contents, mainly food products such as raisins/grapes, olives, dates, pistachio, walnuts and pine nuts (Creisher *et al.* 2019).

3.4. Bricks and ballast stones

Ten reddish-brown clay bricks (Munsell 5YR 4/4 to Munsell 2.5YR 5/6) were found near the fore bulkhead. They were on average 18.5 cm long, 9.4 cm wide and 5.5 cm thick. Petrographic analysis indicated that the clay originated from Cyprus or Egypt.

Some of the ship's ballast: 108 hewn stones, about 30 cm long, 23 cm wide and 15.6 cm thick, weighing about 1.5 tons, were discovered in the fore part of the hull. Petrographic analysis suggests some of the stones to have been local, while others were from the northern Levant.

3.5. Baskets and matting

Seven baskets were discovered in the shipwreck; two were in an excellent state of preservation. Their original contents were not preserved. The basket fibres were identified as halfa and other grasses. Matting lay on the stringers and mast-step. The matting fibres were identified as halfa and other grasses, reeds (*Gramineae/Cyperaceae*), spiny rush (*Juncus acutus*) and papyrus (*Cyperus papyrus/rotundus*). The fibres used in making the baskets and matting grow mostly in northern Africa, specifically Egypt, implying that these artefacts were made in Egypt, or that their raw material was from Egypt.



Fig. 4 Late Roman 5 amphora as found in the shipwreck (photo: A. Yurman)

3.6. Faunal remains

Faunal remains were identified by S. Harding as belonging to a goat, donkey, pigeon, chicken, turtle and tortoise – and probably indicate the crew's diet. The remains of five rats were discovered in the hold.

3.7. Food remains

The food remains – typical of daily life aboard a ship of this period, and possibly part of the crew's diet, consisted of well-preserved olive pits, walnuts, grape seeds, peach stones, carob pods and pine cones. Some were found inside amphorae, while others were discovered as clusters, indicating that they were stored in baskets and sacks. The remnants of fresh fruit suggest that the ship sailed between September and December.

4. Proposed reconstruction

Based on the archaeological data, the hull of the Ma'agan Mikhael B ship is estimated to be 23 m long, with a beam of 7 m and a displacement of 120 tons (Fig. 5). The directions of the bow and the stern were determined by the slope of the larger aft mortise found in the mast-step. The mast-step assembly found in the Ma'agan Mikhael B ship resembles that of the Tantura F ship. The large mortise in the Tantura F ship slopes down towards the south-east, and researchers suggested that this was the direction of the stern (Barkai, Kahanov 2016: 7, 14–15). The large mortise of the Ma'agan Mikhael B ship sloped down to the west, also suggesting that the bow faced east.

As illustrated in different depictions, mosaics and graffiti – hook-shaped mastheads are characteristic of lateen-rigged ships of the Mediterranean during Late Antiquity up to the 12th century (for example: Basch 1991a; Basch 1991b;

Pomey 2006; Whitewright 2017: 229; Beltrame, Medas 2021). The rig of the Ma'agan Mikhael B ship was reconstructed as lateen-rigged, like other shipwrecks from this period, e.g.: Dor 2001/1 (Kahanov, Mor 2014: 63), Yassiada 1 (Steffy 1982: 85) and Tantura F (Barkai 2012: 166). The height of the mast must have been 17 m long, with a yard about the same length or slightly longer than the hull – 23 m. The two sheaves in the masthead were most probably used for a double halyard.

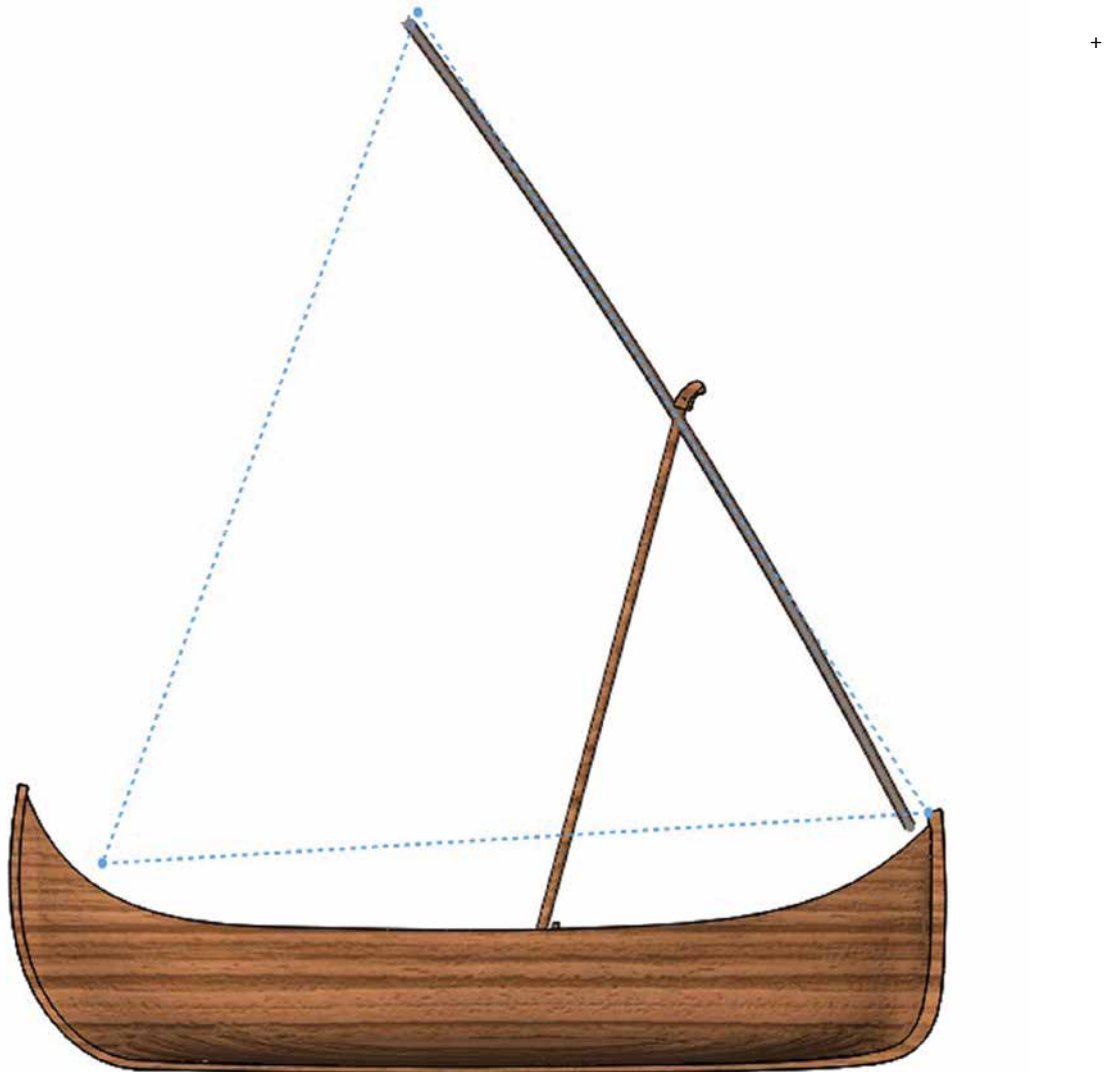


Fig. 5 Proposed reconstruction of the Ma'agan Mikhael B shipwreck (drawing: N. Helfman)

5. Conclusions

Based on the archaeological remains, it is suggested that the ship was 23 m long, with a beam of 7 m. It was built to a 'frame-based' concept, thus making it among the earliest frame-based shipwrecks discovered in the Levant, suggesting that the transition in construction occurred earlier than thought previously. The mast-step assembly and hook-shaped masthead indicate that the ship was a well-built lateen-rigged merchantman, with a 17 m mast and a 23 m yard.

Its cargo of amphorae originated in various places, including Cyprus and Egypt. Further excavation and research of the Ma'agan Mikhael B shipwreck is expected to provide a rich resource for gaining insights into aspects of shipbuilding, seamanship, navigation and trade in Late Antiquity.

Acknowledgments

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A 13th century shipwreck with cog features, investigated off Skeppstad, western Sweden

Staffan von Arbin

Abstract: This paper accounts for the preliminary investigations of a well-preserved shipwreck with several distinct cog features, discovered in Jorefjorden on the Swedish west coast and dated to the early 1260s. Investigations revealed a vessel with straight posts, clinker-built sides, and through-beams supported by large standing knees. Since the bottom section of the hull is missing it is uncertain whether it too was clinker-built, or if it was constructed with flush-laid planking in the so-called bottom based tradition, characteristic for vessels of the cog type. Furthermore, the paper discusses the shipwreck in relation to both contemporary European maritime transport geography and the local context of the site.

Keywords: Norway, 13th century, lapstrake vessels, cogs, *ummeland* voyaging

1. Introduction

During an aerial survey of filamentous algae distribution on the Swedish west coast in the summer of 2008, marine biologists spotted a distinct ship shaped feature in shallow water. The observation was made close to a place called Skeppstad on the northern side of Jorefjorden – a wide and shallow fjord situated approximately 100 km north of Gothenburg in the province of Bohuslän (Figs 1–2). A later diving inspection, conducted by maritime archaeologists from Bohusläns museum, revealed the archaeological nature of the feature. Archaeologists concluded that it constituted the remains of a wooden vessel, largely buried in silt, at a water depth of less than 1 m.



Fig. 1 Map showing the location of the Skeppstad wreck, together with some of the more important locations referred to in the paper (from von Arbin 2021b, 187; map: A. Gutehall, Visuellt Arkeologi Norden)



Fig. 2 Aerial photo of the Skeppstad wreck, taken shortly after its discovery in the summer of 2008 (photo: L. H. Jenneborg, HydroGIS)

Observations of so-called through-beams signalled that the wreck was possibly of medieval date. In 2009, the wreck site was therefore revisited in order to retrieve wood samples for dendrochronological dating. Sampling was carried out as part of the project *Medeltida trader och transportstrukturer i Bohusläns skärgård* (Medieval routes and transport structures in the Bohuslän archipelago), led by the present author. The initial dendrochronological analysis suggested a building of the vessel in the early 1210s or 1220s, pointing towards a likely wood provenance within the regions of Westphalia or the Ardennes (Linderson 2010; von Arbin, Linderson 2011). Unfortunately, of the four analysed samples only one was possible to date at the time.

For this reason, additional timber sampling was carried out in 2012, in conjunction with a limited test excavation of the wreck. Thus, a further seven samples were provided for dendrochronological analysis, of which four eventually could be dated. An additional two samples, including one also of the previously analysed, were dated but with a slightly less degree of certainty. Taken together, the results show that the Skeppstad vessel was most probably built in the early 1260s, that is, approximately 40–50 years younger than initially assumed. Analysis also managed to further narrow down the geographical origin of the timber, showing that trees most likely grew in the Ardennes, that is, the wooded upland areas of south-eastern Belgium and adjacent parts of Luxembourg and France (Linderson 2013).

2. Field investigations: preliminary results

To determine the archaeological content and preservation status of the site, and to get a general idea of the vessel's construction, limited test excavations were conducted in 2012 and 2013 on behalf of the County Administrative Board. The following account is based on the excavation report (von Arbin 2021a; see also von Arbin 2022: 20–21).

During two five-day campaigns, a total of five square metres were excavated within the coherent hull structure. Trenches revealed that the hull is partially preserved to a height of approximately 1.7 m. During excavation, however, it became apparent that the bottom section of the vessel, including keel and keelson, was missing in the excavated midship area. This probably explains why no traces of a cargo were detected. Except for a fully preserved proto-stoneware jug, which is likely to originate in the Lower Rhine region – most probably the area of Siegburg (Fig. 3) – very few artefacts were encountered as well.

The shipwreck is oriented in a northwest–southeast direction, slightly listing towards the southwest. Both sides of the vessel are more or less degraded down to seabed level but are still mostly discernible all the way from stem to stern. Both the stem and the sternpost appear to be straight. Unfortunately, it has not been possible to establish which of the posts constitutes the stem, and which is the sternpost. Even though exposed timbers are heavily degraded due to woodborer infestation, excavation has shown that buried parts of the hull are generally very well preserved. The preserved overall length of the hull has been measured to 17.4 m, while the beam reaches to 5.5 m (Fig. 4), thus suggesting a vessel of perhaps 19–20 m in length.

Examined parts of the hull all appear to be built of oak in the lapstrake fashion. However, since the bottom section of the vessel is missing, it is currently not possible to determine whether it was clinker-built as well, or if it was constructed with flush-laid planks. Lapstrake planking is fastened with square-shafted iron nails that have been riveted with rectangular and rhombic roves. Planks are tangentially extracted from the logs, typically 20–44 cm wide and 3–5.5 cm thick. Luting between strakes consists of moss, of which the species Pointed Spear-moss (*Calliergonella cuspidata*), Kneiff's Hook-moss (*Drepanocladus aduncus*), and Heart-leaved Spear-moss (*Calliergon cordifolium*) have been identified. Instead of ending in rabbets on each side of stem and sternpost, planks seem to 'embrace' both posts, thereby suggesting that they were scabbed directly onto the timbers.

The dimensions of the frames are typically 18–20 cm sided and 10–12 cm moulded. Frames are fastened to the planking with treenails. Ceiling planks, placed some distance apart, are resting on top of the frames (Fig. 5). Like the



Fig. 3 Proto-stoneware jug, recovered during the 2012 field campaign (photo: E. Phillips, Western Sweden Conservator's Trust)

frames, they are fixed with treenails. Massive beams, with large standing knees on top, have served as transverse reinforcements of the hull. As previously mentioned, heads of beams have originally protruded through the hull sides. Six such beams and one loose knee are still visible on the wreck site. In a few cases knees are still attached to the beams; these knees however are almost entirely degraded. Even though beams are no longer interconnected with the planking, they appear to be situated in or close to their assumed original positions (Fig. 4).

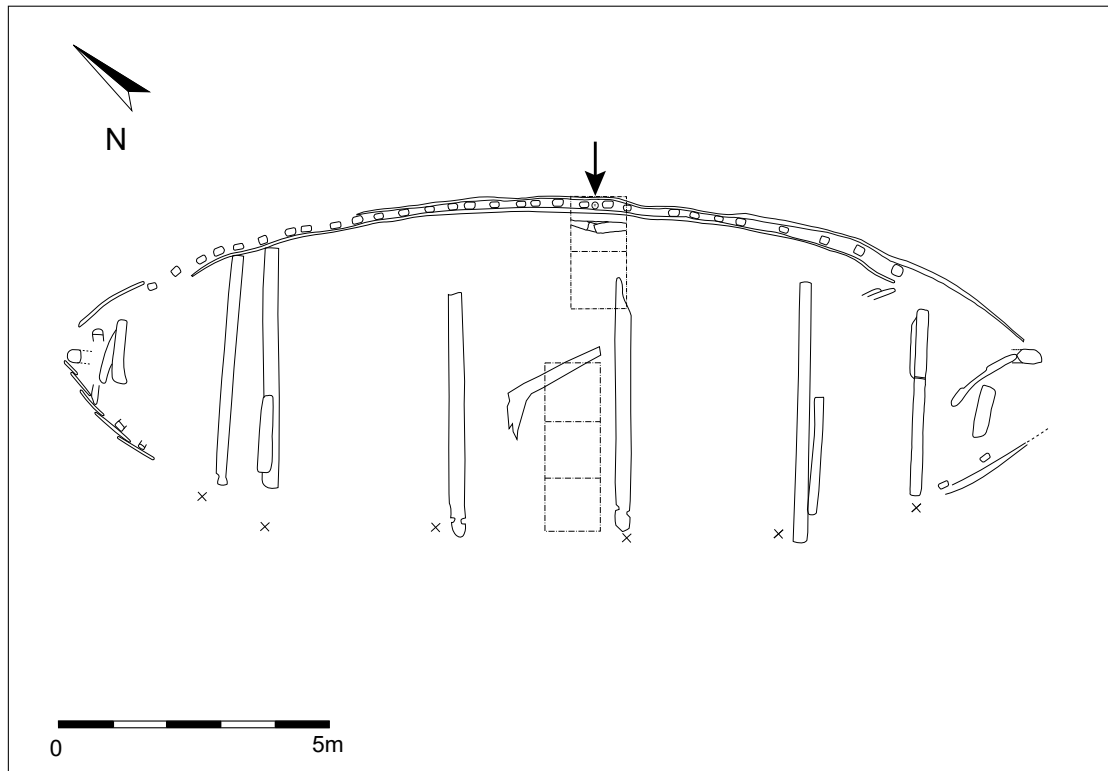


Fig. 4 Site plan of the Skeppstad wreck with trenches excavated in 2012 and 2013 and the find-location for the proto-stoneware jug marked with an arrow (drawing: D. Ní Chíobháin Enqvist, Bohusläns museum)



Fig. 5 Photo (detail) of trench 2, excavated in 2013, showing frames, lapstrake planking with rove imprints, and a ceiling plank (photo: S. von Arbin, Bohusläns museum)

3. Fish or fowl?

The Skeppstad wreck displays features that are often considered diagnostic for medieval cogs (see e.g., Crumlin-Pedersen 2000; Dokkedal 1996; Hocker 2004; Reinders 1985; Vlierman 2021; Weski 1999). One of the most prominent features – the straight stem and sternpost – would most certainly have given the vessel a cog-like outer appearance in its time. Planking scabbled directly onto the posts may also be considered a typical cog feature, although in most cogs, additional ‘false’ stems and sternposts have been mounted onto the proper posts. This double-post solution seems to be lacking however in some of the very earliest cog finds, such as the mid-12th century Kollerup cog (Andersen 1983). Whether the Skeppstad vessel was originally equipped with a false stem and sternpost is currently not known. Massive through-beams with large standing knees and moss luting between planks are also common features in cogs, even though they occur in medieval vessels of other types as well.

Some diagnostic features, such as double-clenched nails, used for holding together the lapstrake planking, and wooden laths and *sintels* (iron cramps, or staples) for keeping the moss luting in place, appear to be missing in the Skeppstad wreck. Others again, such as carvel bottom planking, plank keel, and so-called stem- and sternhooks, are yet to be confirmed or refuted. A most crucial question is of course the construction of the bottom section of the vessel, which is highly uncertain due to missing parts. Thus, it is currently not possible to determine whether it was entirely built in the lapstrake fashion, or if it was built with flush-laid bottom planking in the so-called bottom based tradition (Hocker 2004), characteristic for vessels of the cog type.

It is indeed possible that the loss of the vessel’s keel and bottom planking may be related to constructional weaknesses in the bilge area, which, in that case, could indicate a different construction of the bottom section compared to the rest of the hull. This, however, is merely speculation. An entirely clinker-built hull is also fully plausible. There are in fact several wrecks of regionally built lapstrake vessels from the medieval period in present-day Belgium and the Netherlands, which suggest that there may have existed a domestic clinker tradition, similar to the Nordic, alongside with the other, more well-documented shipbuilding traditions of this coastal region (e.g., Reinders, Aalders 2007; van Holk 2003; cf. van de Moortel 2011: 95–97).

An interesting object of comparison is Kalmar II from the medieval harbour of Kalmar on the Swedish east coast. This wreck – found and excavated in the early 1930s, and tentatively dated to the 14th century – was fully clinker built, with planks fastened with iron nails and roves. It had a straight stem and sternpost with a stern rudder and was equipped with through-beams like the Skeppstad vessel. Hull size and timber dimensions are also very similar to the Skeppstad find (see Åkerlund 1951: 51–55). In some of the previous research it has alternatively been referred to as a cog and a Nordic vessel with strong cog influences (Hocker 2004: 73). However, since its timber provenance has yet to be established, the notion of it being of Nordic origin could very well prove to be wrong.

4. The Skeppstad wreck, *ummeland* voyaging and cogs

As has been stated already, timber used for the building of the Skeppstad vessel seem to originate in the Ardennes. This would in all likelihood exclude the possibility for a Nordic or Scandinavian-built vessel. Timber provenance instead implies that building may have taken place somewhere along the river Meuse or further downstream in the Rhine–Meuse–Scheldt delta, in the southern part of present-day Netherlands, close to the Belgian border. The vessel’s homeport was likely one of the contemporaneous trading ports of Flanders, Zeeland, Holland, or the Zuiderzee region (von Arbin 2021a: 19–20).

Investigations thus show that the Skeppstad wreck is likely to be an exponent of the so-called *Ummelandfahrt*, that is, the hazardous circumnavigation of the Skaw that allegedly commenced after the silting-up of the Limfjord passage in the first decades of the 12th century (see von Arbin 2021b with references). *Ummeland* voyaging is first mentioned in the year 1251 in two charters issued by King Abel of Denmark, in which he grants merchants, presumably from the town of Kampen, certain privileges in relation to the so-called Scanian fairs (Höhlbaum 1876: Nos 411, 413). However, early Danish cog finds, such as the so-called Kollerup and Skagen cogs, dated to c. 1155 and c. 1195 respectively, suggest that vessels of the cog type were circumnavigating the Skaw on a regular basis already in the second part of the 12th century (Crumlin-Pedersen 2000: 238–239, 244; Hocker, Daly 2006).

Interestingly, there seems to be a connection between early cogs and *ummeland* voyaging, illustrated not only by archaeological ship finds, such as the Danish shipwrecks mentioned here, but also by various written sources. For instance, in one of his 1251 charters, King Abel specifically mentions cogs (*coggone*) in the context of *ummeland* voyaging (Höhlbaum 1876: No. 411). Possibly, this indicates that the development of this ship type was triggered by *ummeland* voyaging and the increase in seaborne long-distance trade of bulk commodities at that time (cf. Westerdahl 1995: 222; Crumlin-Pedersen 2000: 238–239; Zwick 2016: 33–35).

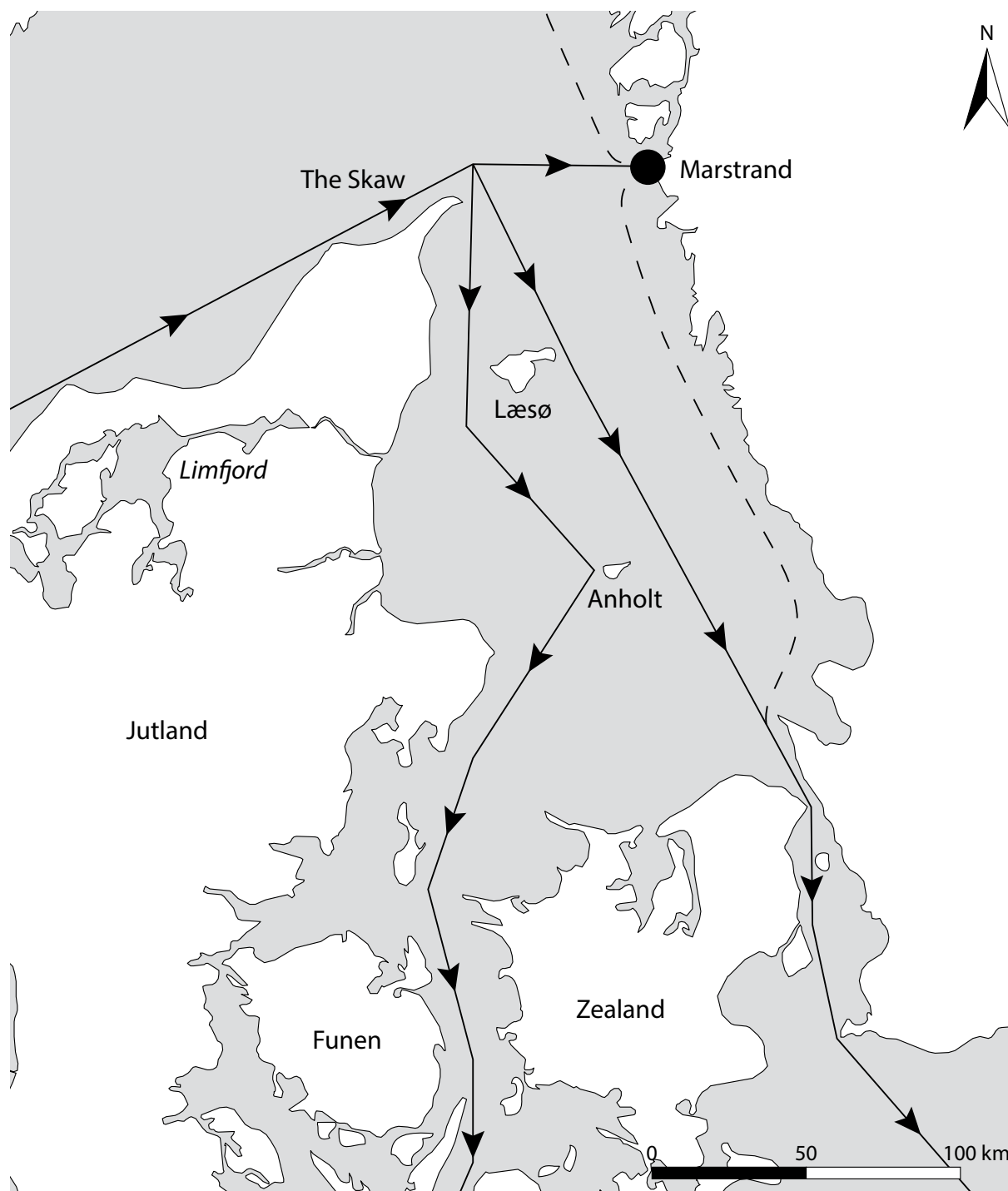


Fig. 6 Alternative sea routes around the Skaw, according to the *Seebuch* of c. 1470 (from von Arbin 2021b, 193; map: A. Gutehall, Visuell Arkeologi Norden)

5. Medieval maritime transport geography

In order to understand why a 13th century cargo vessel, presumably from the area of present-day Netherlands, ended up being shipwrecked in one of the fjords of northern Bohuslän, it is necessary to take a deeper look into the maritime transport geography of medieval Europe. Before doing so, however, it should be pointed out that Bohuslän in this period was not Swedish, but Norwegian. One of the most important written sources regarding seafaring and maritime transport geography in Europe in this period is the German so-called *Seebuch* (Koppmann 1876). Although written around 1470, this sailing instruction is believed to go back, at least in part, to 14th century Dutch sources (Sauer 1997: 219–221). Of particular interest in this context is its description of *ummeland* voyaging. According to the instruction, the helmsman of a ship, sailing northwards from the Rhine–Meuse–Scheldt delta, bound for the Baltic Sea, would have had three main options after having circumnavigated the Skaw (Koppmann 1876: XII; Fig. 6):

- (1) He could follow the eastern coast of Jutland southwards to the Danish straits;
- (2) Alternatively, he could take a more direct southerly route to the Sound, keeping east of both Læsø and Anholt;
- (3) Finally, he could choose to go along with the Jutland Coastal Current, aided by the prevailing westerly winds, aiming for Marstrand on the southern Bohuslän coast.

The latter, direct route between Jutland and Marstrand, across the Kattegat, was most likely the preferred option also for vessels heading for Kungälv, Oslo, Tønsberg, Skien, or any of the other contemporary ports in the so-called Viken region (von Arbin 2021b). Western ships bound for ports further north along the Norwegian coast however probably chose a more direct course to either Lindesnes, on the Agder side of Viken, or Skudenes, on the southern tip of the island of Karmøy in Rogaland, as indicated by the *Seebuch* (Koppmann 1876: XII). When travelling in the opposite direction, coming from the Baltic Sea, it appears as if most vessels followed the Norwegian coast all the way up to Lindesnes before setting the course for either the West European mainland or the British Isles (*cf.* Stylegar 2004). Jorefjorden was situated along this heavily trafficked northern coastal route.

In this period, sea voyages were mainly undertaken during daylight hours. Often, they were hindered by bad weather and foul winds. Therefore, medieval seafarers were largely dependent on good anchorages and natural harbours, situated at regular intervals along the sailing routes, where they could seek shelter for the night, weather storms, and await fair winds. In the vicinity of Jorefjorden are at least three such harbours, which, according to both written sources and archaeological evidence, appear to have been in use during the 13th century: Dyngö, 4.5 km to the west (von Arbin 2023), Hamnholmarna, 7 km to the southwest (Bergstrand 2015), and Hamburgsund, approximately 4 km to the south (Linder, Haggson 1872: 211). Hamburgsund, however, was more than just a sheltered natural harbour. In this period, Hornborg, a high rock situated in the southern part of the Hamburgsund strait, is likely to have been the location of the thingstead of Ranrike (corresponding to northern Bohuslän). Allegedly, this was also where the mythical Hornborg castle was situated (Arvidsson 1985: 42).

6. Concluding remarks

That no cargo has been observed during test excavations makes a reconstruction of the Skeppstad vessel's intended route difficult at the present stage. Possibly, future investigations of the wreck may shed some light on this issue. In addition, further investigations of the wreck could help determine the building method of the lower hull. Such investigations may strengthen the assumed relationship between cogs and *ummeland* voyaging, as described above, but may also reveal a much more complex picture. In any case, investigations would most certainly lead to new insights regarding the technical development of the vessels used in early *ummeland* trade.

Acknowledgements

The author would like to thank Jeroen Veermersch for help with literature regarding archaeological finds of lapstrake vessels from the Middle Ages in Belgium and the Netherlands; Anders Gutehall, Visuellt Arkeologi Norden, for help with illustrations; and Fred Hocker for valuable comments on an early draft of the manuscript.

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A 14th century boat from Vordingborg Castle, Denmark, and the use of boats in medieval military operations

Morten Ravn

Abstract: In 2012, the remains of a well-preserved 14th century boat were found in the moat at Vordingborg Castle, Denmark. This paper briefly presents the boat-find. Subsequently, the written evidence for the use of small boats comparable to the Vordingborg Boat, in special military operations in Northern Europe – from the Viking-Age to the High Middle Ages – will be discussed. The paper concludes by comparing the Viking-Age and Medieval maritime special military operations with operations conducted in the Second World War (1939–1945).

Keywords: medieval boat-find, Vordingborg Castle, maritime warfare, special military operations, *Gesta Danorum*

In the second half of the 14th century, Vordingborg Castle was completely rebuilt and modernised. The outdated fortress underwent a makeover, building a state-of-the-art stronghold with an inner and outer castle, heavy walls and a water-filled moat. Besides being a military stronghold, the new castle housed the royal treasury and archives along with Valdemar IV's chancellery and personal chapel. Clearly, the king had chosen the castle as a place for long-term residence, and for demonstrating his ambition of restoring the Danish Kingdom to its former glory as a Northern European and Baltic superpower (Wille-Jørgensen 2014: 226–240).

A very big ambition to strive for, since the kingdom that Valdemar IV (ca. 1320–1375) had inherited was in a very bad condition. Under the reign of Valdemar IV's father, Christopher II (1276–1332), the Kingdom of Denmark became bankrupt, and Christopher II had pawned both land and castles to magnates from Germany and Holstein in order to survive. Valdemar IV saw it as his calling to restore Denmark's position as one of the most important powers in Northern Europe and especially in the Baltic Sea Region. Impressive diplomatic skills, determination, increased taxation, and use of military force led to a gradual restoration of the Danish Kingdom (Daly *et al.* 2021: 111–113).

Due to its geographic position, Vordingborg Castle was a key site in securing Valdemar IV's Baltic ambitions. It was a well-suited location for assembling war fleets before embarking on military operations in the Baltic Sea Region, and well-placed for summoning the king's advisors, the realm's magnates, and high-ranking men of the clergy. Furthermore, it functioned as a place for diplomatic meetings with foreign powers.

After Valdemar IV's reign, Vordingborg Castle served many different purposes, but soon lost its status as an important military and political site. In the second half of the 17th century, a royal mansion was built at the site, but the royal family never took up residence, and bit by bit, the buildings were demolished and the building materials used for other purposes. In the early 19th century, the remains of the castle tower – the so-called Goose Tower – were declared as a protected historic monument, one of the first buildings in Denmark to be given this designation. This was followed by extensive and continued archaeological excavation campaigns at the castle site and a protection of the remains at the castle site as a whole (Wille-Jørgensen 2014: 20–189).

Between 2005 and 2014, Vordingborg Castle underwent major restorations, turning it into a modern historical experience centre, The Danish Castle Centre. Besides building new exhibition facilities and a new museum shop and café, a large-scale restoration of the historical buildings and fortifications was conducted. The construction works led to renewed archaeological excavations and among the many interesting finds was a small clinker-built boat found in the castle's moat (Fig. 1).



Fig. 1 The excavation of the Vordingborg Boat was conducted in October–November 2012. Lars Meldgaard Sass Jensen headed the overall survey and excavation campaigns at Vordingborg Castle, and Christian Lemée and Thor Giversen conducted the excavation of the boat-find (photo: C. Lemée)

The well-preserved boat was excavated and documented in a campaign stretching from October to November 2012 (Lemée 2013). After completing the *in-situ* recording, all the components were salvaged and kept waterlogged, awaiting post-excavation recording. The outline and details of boat components were recorded using a FaroArm and the NURBS-based drawing programme Rhinoceros-3D (Daly *et al.* 2021: 97–98).

A detailed presentation of the boat-find and the dendrochronological and metallurgical investigations conducted has already been published in the International Journal of Nautical Archaeology (Daly *et al.* 2021). In this paper, I will therefore only briefly present the boat-find, focusing mainly on its reconstruction, and then discuss the use of boats, comparable to the Vordingborg Boat, in medieval military operations.

Analysing and reconstructing the boat-find

In 2018, the recording of the boat components was completed, and the process of analysing and reconstructing the boat began. The oak (*Quercus sp.*) keel is much worn and the scarf joining the keel and aft stem has been repaired with numerous repair patches – both from the inside and outside. The profound wear on the underside of the keel probably stems from frequent grounding and dragging the boat ashore, and since the wear is also found on the repair patch, placed on the outside, the use of the boat continued for quite some time after the boat were repaired. The aft stem is also made of oak, and has joining surfaces for four runs of strakes on each side. The fore stem was not preserved, but it is estimated that it was crafted in a similar fashion to the aft stem (Daly *et al.* 2021: 97–101).

All preserved planks are made from oak. Only one – the uppermost strake port side – is tangentially converted, the rest of the planks are converted by radial cleaving. No decorative mouldings have been found on the planks and the

length of the planks differs significantly, from 78 to 283 cm. The longitudinal scarfs between the planks are between 12 and 15 cm long, and terminate in diverse ways: some with a lip and others smoothly. The planks are riveted together using iron rivets and roves. The planking also shows numerous repairs and the Vordingborg Boat was clearly a much-worn and heavily repaired boat when it was finally deemed beyond repair, and abandoned. The boat had seven floor timbers made of naturally-curved oak. The floor timbers were attached to the planking with treenails and wedges (Daly *et al.* 2021: 101–104).

A 1:10 reconstruction model was built (Fig. 2). Piece by piece, the hull form and the dimensions of the original boat re-emerged, revealing a small boat: 5.45 m in length, 1.33 m wide, and with a distance of 45 cm from the upper keel surface to the top of the inwale. The boat was powered by oars only, and due to two preserved sets of thole-pins, the rowing stations and number of rowers could be established. Hence, seated at two rowing stations, two persons with an oar in each hand would have powered and steered the boat (Daly *et al.* 2021: 104–105).

The documentation of the boat-find also included dendrochronological analysis, leading to AD 1355–1366 as the estimated felling date for the trees used for building the boat. The building and use of the boat are therefore suggested to have taken place during the second half of the 14th century, which corresponds with the major construction works and fortifications at Vordingborg Castle initiated by Valdemar IV (Daly *et al.* 2021: 105–107).

Valdemar IV's building activities, turning the Castle into one of the most important military and political sites in his realm, must have resulted in years where the site was buzzing at times with activities conducted by craftsmen, military personnel, and servants in the royal household. It is in relation to these activities that the building and use of the Vordingborg Boat should be interpreted.

Small boats, like the Vordingborg boat, were used for many purposes, and it is impossible to determine the exact usage of the specific boat found at Vordingborg. In fact, it is probably most likely that the boat was used for many different purposes, such as fishing, small-scale transport of people, goods and building materials, or as a tender transporting people, goods or messages between land and ship or between two ships. And lastly, due to the military context in which the boat was found, it could have been used in different military situations, a usage that I will investigate in greater detail in the following.

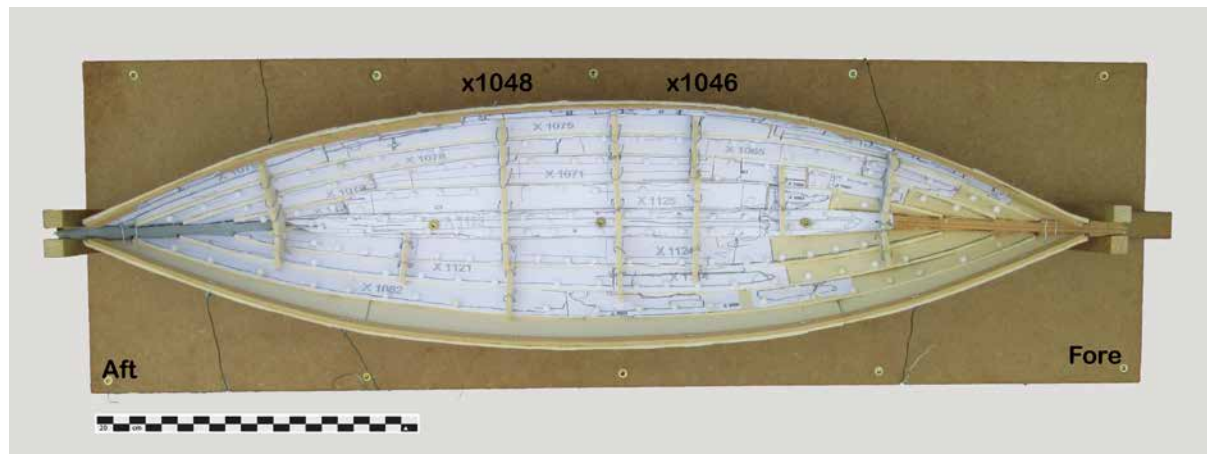


Fig. 2 The 1:10 reconstruction model crafted by Vibeke Bischoff. The boat's two rowing stations were placed at frame x1046 and x1048 (photo: M. Ravn, Viking Ship Museum in Roskilde).

Boats in Medieval Military Operations

Small boats are rarely mentioned in the written sources of the late Viking Age and High Middle Ages. However, the archaeological record clearly shows that small boats – log boats, expanded boats and plank-built boats – were crafted and used in great numbers. Also, by scrutinising the early 13th century book *Gesta Danorum* (the history of the Danes), written by the clerk Saxo Grammaticus (ca. 1160–after 1208), I have been able to find several examples of small boats being used in military activities.

Boats were used as tenders supporting the communication between the commanders of large warships of the fleet, or for transferring supplies and personnel between warships or between land and ship. Small boats were also used in military operations conducted in waters where large ships could not be used, including places like the rivers of continental Europe and especially the Ukrainian and Russian river systems (Hjardar, Vike 2014: 350; Sorokin 2015). Finally, boats were used in special military operations conducted by small military units.

In *Gesta Danorum* book five, there is an account of a magnate and fleet commander, Erik, conducting a sabotage operation in a small boat. The text reads:

“He therefore climbed into a small boat and, rowing silently, carried himself close to the enemy’s keels, where he gradually drilled with a gimlet through the timbers near the waterline and shortly made his return, scarcely lifting his oars above the surface. He conducted the operation so cautiously that none of the sentinels detected his arrival or departure.” (Saxo Grammaticus [1998], 125).

It does seem strange that a fleet commander conducts a sabotage operation all by himself, and the story may have been slightly exaggerated, designed to show the courage and willpower of Erik. Perhaps Erik did in fact have a few warriors with him in the boat or maybe Erik simply gave the order for the operation?

In book fourteen, a mid-12th century medieval magnate and pirate, Vedeman, uses small boats for reconnaissance before initiating landing operations. This in regard to navigational obstacles, and to prevent an ambush by the enemy when landing his warriors:

“As often as they sailed close in to land, it was their habit to entrust an initial survey of the territory to their scouts, in case they should happen to encounter anything unknown or unforeseen there.” (Saxo Grammaticus [2015], Book xiv.6.2., 1025).

Vedeman’s warriors participated in defending the Danish coasts from Wendish pirate attacks and conducted small-scale raids in the homeland of the Wends. Vedeman also participated in large-scale amphibious military operations against the Wends in the second half of the 12th century, and in one of these operations, led by bishop and magnate Absalon (ca. 1128–1201), reconnaissance was conducted in small boats in order to find a suitable place for landing cavalry:

”On that same day, when the king had mooted a plan to invade the province of Julin once more, Absalon during the first watch of the night sought out suitable landing places; noticing a firmer-looking piece of ground, he fixed stakes there and, as markers, knotted together reeds by the bank, so that at dawn the next day by locating these identifying signs he was able to indicate the access point on the shore where they could easily set down men and their horses.” (Saxo Grammaticus [2015], Book xiv.42.7., 1335)

A similar reconnaissance operation conducted in order to find a suitable place for landing ships and warriors is mentioned in *Flateyjarbók* in the *Saga of Kong Olav Haraldsson* (written ca. 1300). In this case, however, the special forces encounter four men guarding the landing site. The small unit, consisting of nine warriors, decide to engage the four guards and kill them before setting up markings at the spot best suited for landing the main forces of the fleet (Flatøybok [2015], Book 1, 75).

The military operations against the Wends in the second half of the 12th century, led by Absalon and the Danish king Valdemar I (1131–1182), were not the first conflicts between Danes and Wends. From the mid-10th century and onwards there was a constant struggle for supremacy over the south-west part of the Baltic Sea Region between Danish and Wendish magnates and kings. Some families were allies, others were in an everlasting state of conflict.

In *Gesta Danorum* book ten, there is an account of Wendish warriors conducting a special operation in a small boat resulting in the kidnapping of the Danish king Svend Tveskæg (ca. 963–1014):

“[...] rowing in a small skiff across the harbor, which was bristling with longships, they ventured right alongside the king’s vessel, where the steersman announced that he had some confidential information which Sven really ought to know about. Believing that he was bringing a report of some matter discovered in the night, the king drew back the awning which covered the ship and, poking his head out, leaned forward towards the caller, expecting a friendly conversation. When the other saw that Sven was ripe for his treachery, he suddenly gripped his neck in a brutally savage clasp, dragged him from the ship and with the help of his assistants tossed him into their pirate boat. Then they sped away in flight with rapid strokes of their oars.” (Saxo Grammaticus [2015], Book x.9.3, 709).



Fig. 3 Rowing tests conducted in 2015 on Roskilde Fjord with Gisle, one of the Viking Ship Museum's Gislinge Boat reconstructions. The Gislinge Boat is a boat-find from Zealand, Denmark dated to ca. 1130 (photo: W. Karrasch, Viking Ship Museum in Roskilde).

Svend Tveskæg's large war fleet campaigned in the Wendish's homeland, and the account shows that bold, brave and well-executed special operations could in fact delay or even stop a superior military force.

The examples above provide a glimpse of the Early Medieval special military operations, but the accounts provide little insight in terms of the design of the small boats used in the operations. Here, we must turn to the archaeological finds for guidance, boat-finds like the one from Vordingborg Castle (dated to 1355–1366), the three Gokstad boats from Norway (dated to ca. 895) and the boat found near Gislinge on Zealand, Denmark (dated to ca. 1130). Together, these finds show how small boats looked during the 9th–14th centuries. It was probably in vessels similar to these that the special military operations mentioned in *Gesta Danorum* were conducted (Fig. 3).

Since the Vordingborg boat has not been reconstructed in full-scale, no rowing tests have been conducted, and the boat's seaworthiness and speed are unknown. However, the smallest of the Gokstad boats (6.5 m long) has been reconstructed by the Viking Ship Museum in Roskilde nine times, and the Gislinge boat (7.7 m long) three times, while the largest Gokstad boat (9.7 m long) has been reconstructed twice by the Viking Ship Museum's boatbuilders. Norwegian and British researchers and boatbuilders have also reconstructed some of the Gokstad boats, and recently an article about the middle-sized Gokstad boat (ca. 8 m long) has been published (Planke *et al* 2022). Reconstructing the Gislinge boat has turned into a global phenomenon, due to an open source boatbuilding project conducted at the Viking Ship Museum in Roskilde, making the working drawings for the boat available for free download. Hundreds of people from many different countries have downloaded the drawings and many have crafted their own full-scale reconstruction or model of the boat (Sørensen *et al.* 2016).

In the following, I will summarize the data gained and insights learned from rowing and sailing with the Viking Ship Museum's reconstructions of the smallest and largest of the Gokstad Boats and the Gislinge Boat, exploring the boats' usability in regard to the special military operations specified in *Gesta Danorum*. However, it must be stressed that the data and insights are only estimates, since very few proper rowing tests and test-sailings with the reconstructions have been conducted.

Both of the Gokstad boats are lightly-built. They have a hull-form which makes them fast but also likely to capsize if not handled correctly. The largest Gokstad Boat has considerable rowing power – ten oars operated by five rowers – compared to the light hull, and the estimated top speeds for both oars and sail are significantly higher than for the smallest Gokstad Boat. The shallow draft of the boat – making it possible to navigate in shallow waters – and the potential for high speed suggests that this boat type was suitable for the reconnaissance operations mentioned in *Gesta Danorum*. The smallest Gokstad Boat is easy to row silently through the water, making this boat type suitable for the nightly sabotage operations mentioned in *Gesta Danorum*. The boat from Gislinge is a somewhat heavier built boat than the Gokstad Boats. It has greater stability and is less likely to capsize. The boat is especially suitable for transporting a small amount of cargo, but a vessel like the Gislinge Boat could also have been employed in the special military operations described in *Gesta Danorum* (Tab. 1).

Boat-find	Reconstruction	Top speed (est.)	Average speed (est.)	Comments
Largest Gokstad Boat, dated to ca. AD 895	<i>Eik Sande</i>	Oars: 5–6 knots Sail: 6–7 knots	Oars: 2–3 knots Sail: 3–5 knots	Lightly built and fast boat, with a considerable rowing power.
Smallest Gokstad Boat, dated to ca. AD 895	<i>Joanna</i>	Oars: 4–5 knots Sail: 5–6 knots	Oars: 2–3 knots Sail: 3–4 knots	Lightly built and fast boat. Easy to row silently through the water.
Gislinge boat, dated to ca. AD 1130	<i>Estrid</i>	Oars: 4–5 knots Sail: 5–6 knots	Oars: 2–3 knots Sail: 3–4 knots	A heavier built boat, with greater stability, than the Gokstad Boats. Primarily suited for small-scale transport of cargo.

Table 1 Data and insights gained from rowing and sailing with the Viking Ship Museum’s reconstructions of the smallest and largest of the Gokstad Boats and the Gislinge Boat. The data was estimated in collaboration with the Viking Ship Museum’s sailing manager and boatbuilder Tom Nicolajsen.

Comparing operations – past and present



Fig. 4 One of Denmark’s memorials for Anders Lassen (1920-1945), a Danish soldier and commando, who participated in several of the operations conducted by SSRF and SBS during the Second World War. Lassen was awarded the Victory Cross and Military Cross (two bars) along with other awards and honors. Today, Lassen serves as a role model and inspiration for Denmark’s special forces, the Frogmen Corps and the Huntsmen Corps (photo: M. Ravn, Viking Ship Museum in Roskilde).

The history of warfare and armed conflicts shows several examples of special military operations: operations by small, specially-trained military units conducting reconnaissance, sabotage, raids, and deceptions. The seaborne sabotage, kidnapping, and reconnaissance operations mentioned in *Gesta Danorum* are part of the earliest evidence we have of such special military operations in Scandinavia and Northern Europe. To conclude, I will compare the late Viking Age and early Medieval operations with seaborne operations conducted by the British special forces during the Second World War (1939–1945).

First coined Special Operations Executive, later Special Air Service, the British special forces were commissioned by Churchill to “set Europe ablaze” by conducting sabotage, reconnaissance, and guerrilla warfare against the Axis Powers. Within these organisations, more or less independent and self-governing maritime units operated, including units like the Small Scale Raiding Force (SSRF) and Special Boat Section/Special Boat Service/Special Boat Squadron (SBS) (Parker 2004).

While the SBS mainly operated in the Mediterranean Sea Region, the SSRF conducted raids in the English Channel region from the beginning of 1942 until the SSRF’s operations ended in November 1942. Founded by Major Gus March-Phillips and Major Geoffrey Appleyard, the SSRF conducted amphibious raids at night on military installations and coast defenses on the Channel Islands and in Normandy. Raiding parties of

only 10–15 persons in small boats executed successful sabotage missions, captured several German soldiers, and confiscated code and signal books (Fig. 4) (Harder 2010: 211–273).

Even though the direct impact of the raids was minimal in regard to the Germans' ability to defend the Northern coasts of occupied France, the attacks had a demoralizing effect on the German soldiers manning the remote radar stations and other military installations on the Channel Islands, and it seems reasonable to assume that the sabotage and kidnapping raids mentioned in *Gesta Danorum* had a similar demoralising effect on enemy forces (Harder 2010: 243–245).

It is interesting to note the similarities in regard to assignments throughout the history of special military operations. We find detailed written examples of reconnaissance, sabotage and raids conducted by special forces using small boats from the late part of the Viking Age and onwards. And even today, the special forces are mainly engaged in these tasks. The means – methods, skills and equipment – utilised today are different from those in the Viking Age and High Middle Ages, but there is still a link between the special forces of the past and the special forces of today when it comes to the objectives of the operations.

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A mid-16th century carvel-built ship from Mukran, Jasmund-Peninsula, island of Rügen, Germany

Mike Belasus – Jens Auer – Konstantinos Alexiou

Abstract: The 16th century ‘Mukran wreck’ is one of the earliest carvel-built ships found in Germany. Naval armament found in the vicinity of the site and traces of fire within the remains may relate the wreck to a hostile encounter between a joined squadron of Danish vessels and ships from the Hanseatic town of Lübeck with Swedish ships in 1565 during the Nordic Seven Years’ War (1563–1570). In 2016 and 2017 a detailed investigation and recording of the wreck was carried out. The wreck represents an important source for the understanding of the development of carvel shipbuilding in northern Europe.

Keywords: 16th century, shipbuilding, Baltic Sea, carvel construction, warship

Introduction

In 1985 divers of the East German Navy found a wooden shipwreck during a diving exercise in the Baltic Sea near the commercial port of Mukran on the island of Rügen (Fig. 1) and lifted the remains of a gun from the site. Although the inscription on the gun pointed to a date of 1551, the discovery caused little interest at first, and a more thorough investigation of the newly found wreck was only attempted after the gun was handed over to the Maritime Museum in the Hanseatic city of Rostock in 1987.

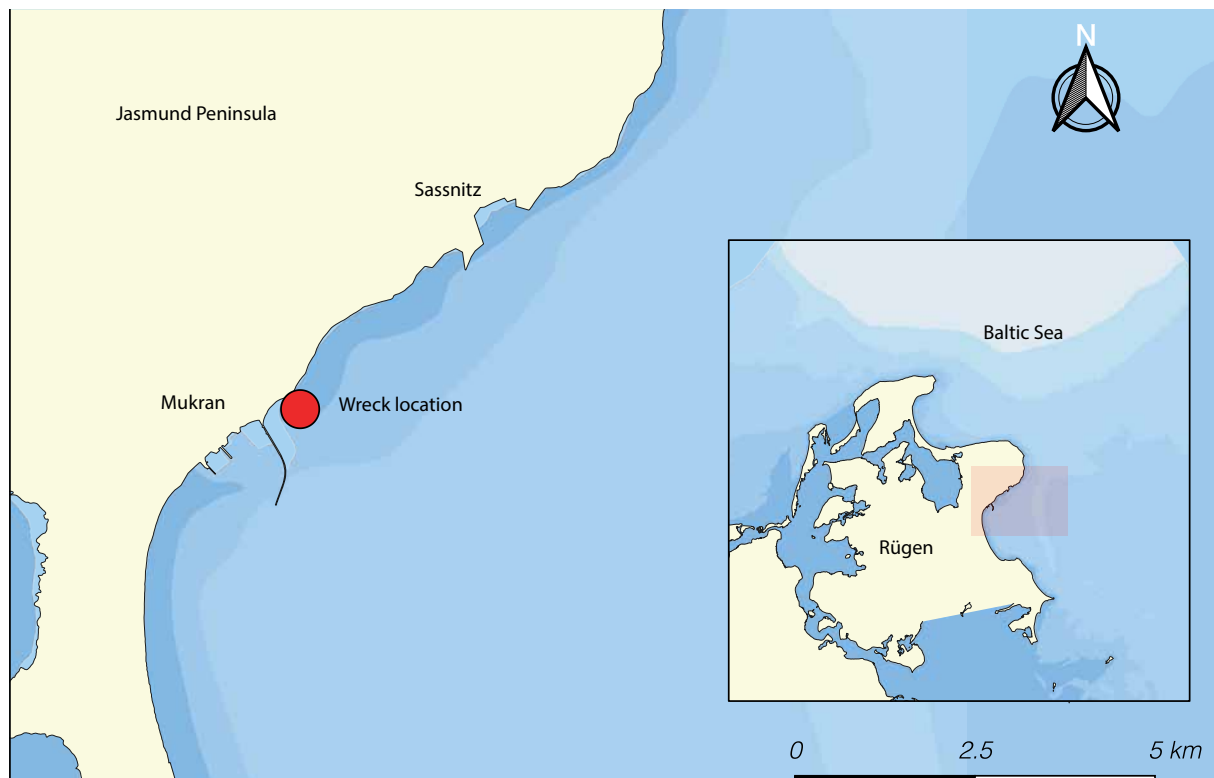


Fig. 1 Location of the so called ‘Mukran’ wreck 250 m off the coast of the island of Rügen in 3 m of water (graphic: J. Auer, LaKD M-V, Mecklenburg Western Pomerania, 2022)

A series of smaller surveys and investigations followed from 1990 onwards, but these mostly focussed on a basic assessment of the site and protection *in situ*, rather than the archaeological documentation of the wreck (Förster 1994; 1999; Springmann 1997; 1998; 2014; Auer 2000).

Based on the dating of the guns from the site and the analysis of first dendrochronological samples, the wreck was quickly associated with a naval encounter during the Nordic Seven Years War (1563–1570) in May 1565 between a Danish–Lübeck fleet, under the command of the Dane Peter Hvitfeldt, and a Swedish fleet, commanded by Claes Kristersson Horn (Förster 1994; Springmann 1998). In order to prevent the capture of his ships by the superior Swedish enemy, the Danish–Lübeckian commander ordered his ships to be burned at anchor off the coast of Rügen near the small village of Mukran. A layer of burnt material on the wreck and guns showing traces of extreme heat or explosion support this theory.

Two maritime field schools

So why return to the ‘Mukran Wreck’ or as it is officially designated, site Jasmund, Ostseebereich VII, Fundplatz 7?

In 2015 the Maritime Archaeology Programme at the University of Southern Denmark planned a course on Early Modern ship construction, which was intended to update a paper on Archaeology and early modern merchant ships by the late Thijs Maarleveld (Maarleveld 1998). The wreck near Mukran was identified as one of the study sites with high potential to reveal more details about 16th century ship construction techniques and the introduction of flush outer planking in Northern Europe. As earlier publications often focussed on the historical events around the wreck site or lacked extensive recording and dendro-sampling, a joint project was planned in close collaboration with the State authority for the protection of culture and monuments in Mecklenburg-Western Pomerania and the German Maritime Museum.

The first campaign took place in 2016 and focussed on recording the archaeological remains to archaeological standards. This was achieved through a combination of photogrammetry and traditional offset recording. Additionally, all artefacts and guns lifted in earlier campaigns were recorded and catalogued and an extensive archive of published and unpublished information on the site was compiled.

In 2017 a second campaign, addressing more targeted questions, followed. Besides excavating a trench through the wreck to document hull construction and waterproofing techniques, an extensive programme of dendrochronological sampling was undertaken in order to establish timber provenance and felling dates.



Fig. 2 Diver on the exposed wreck in about 3 m of water (photo: SDU MAP)

The shipwreck

In the shallow water of the exposed East coast of the island, the lower part of the hull survived with almost no sedimentation cover (Fig. 2). The bottom of the ship is preserved over a length of 17.6 m and a width of 6.4 m in 3 m of water. It lies in approximate East-West orientation with the bow pointing to the West. While the keel still exists over its full length, only the lower remains of the stem and stern post assemblies are preserved *in situ*. The floor timbers still cover the lower part of the turn of the bilge, with remains of ceiling planking on both sides of the heavily eroded keelson, which is covered by a mix of ballast and local stones. Eight strakes of the outer planking are preserved on both sides of the keel. Framing timbers survive at 21 frame-stations, but are mostly eroded or missing in the more exposed aft part of the vessel (Fig. 3). Most of the surviving components are made from oak. Exceptions are some of the filler planks between the stringer-like ceiling planks, which are made from pine (*pinus spec.*) and fir (*abies spec.*). Selected samples of trenails also confirm the use of pine, fir and willow (*salix spec.*).

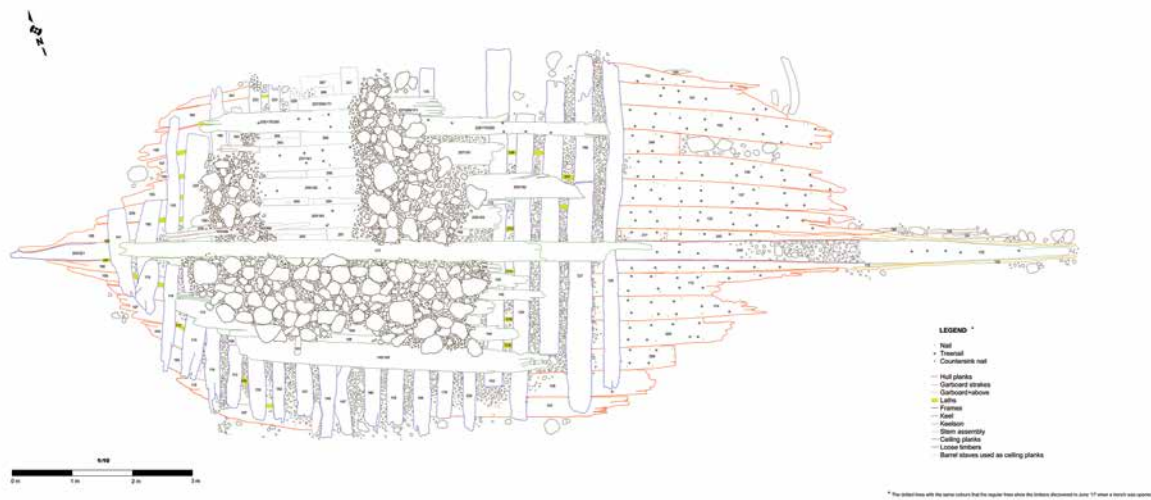


Fig. 3 Overview plan of the site (I. Muñoz, 2019); based on the results of the two field schools and the work of Robert de Hoop, Nicole Schoute and Irene Muñoz (SDU MAP)

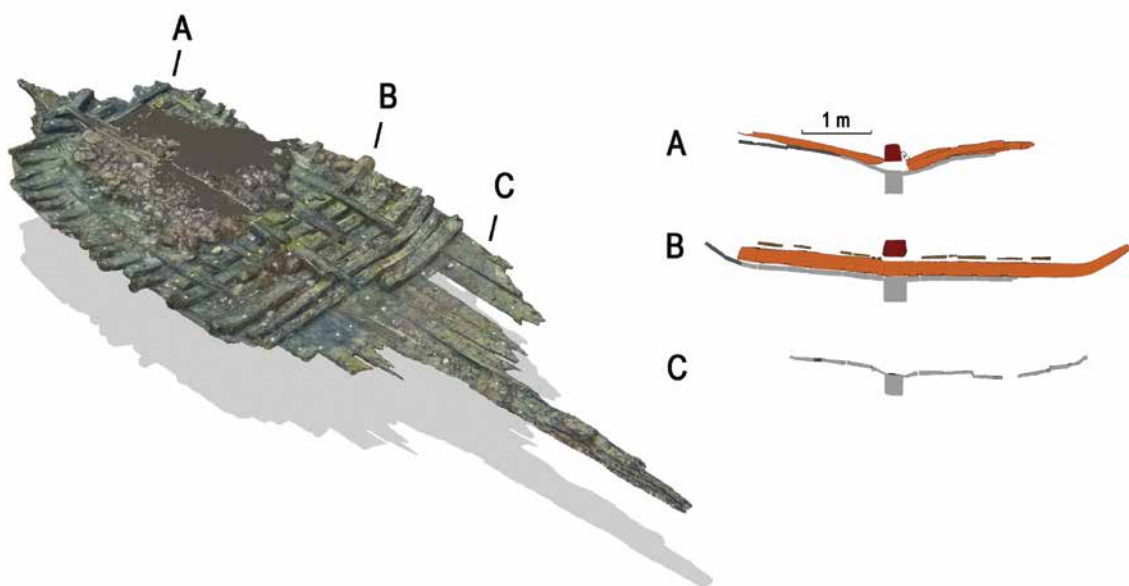


Fig. 4 Perspective view of the photogrammetric model of the wreck with cross-sections on three positions (graphic: M. Belasus, NIhK; model: R. de Hoop, RCE; cross sections by SDU MAP)

The dendrochronological analysis of the oak-timbers indicates a felling of the trees in the winter of 1557/58 possibly in the wider lower Elbe region (Daly 2017). However, fir has no natural distribution in the North. It originally only grew South of the central mountain ranges of Europe. Therefore, fir timbers are likely connected to timber-rafting on the Elbe River, which rises in the Giant Mountains in Czech Republic. This result supports the theory put forward by Maik-Jens Springmann (1997) that the vessel may have been built in the vicinity of Hamburg.

The hull has a flat bottom with no bilge or detectable deadrise in its central section (Fig. 4). The considerable width just before the stem post remains suggests a wide and bluff bow construction. The surviving part of the lower stem post assembly suggests a curved shape in its lower section.

The lack of framing timbers and the eroded state of all outer planks except the garboard strakes make it difficult to describe the hull shape in the aft part of the vessel. The remains of the surviving lower sternpost assembly are c. 3.7 m long. It is constructed from several components, which could not be identified individually due to the timbers' deterioration. Fragments of the horizontal arm of a knee and an unknown number of filling pieces are on top of the keel. The actual sternpost itself is missing, leaving a gap between the garboards above the keel (Fig. 5a). The garboards are an integral part of the sternpost construction, covering the keel, the lower parts of the knee, the filling timbers, and the missing sternpost and serving as a connection between these timbers. The ship's stern is the only spot where the cross-section of the keel of 0.11×0.11 m could be documented. It gets wider towards the middle and reduces again slightly towards the bow. It measures 0.32 m at the last surviving floor-timber towards the ship's aft and 0.26 m at the remains of the sternpost. The lower part of the keel is still buried in the sediment under the wreck's remains. Its length can only be estimated to be between 14 m and 16 m. However, it is currently not clear if it is beam- or plank-like in shape.

The garboards have no direct connection to the keel apart from the area covered by the sternpost construction, and probing the seam towards the keel with a thin blade gave no indication of any kind of rebate. The garboards are fastened to the frames at a 90° angle towards the keel in the ship's central section, resulting in no visible deadrise. They are twisted by 90° towards the stern. Here, the garboards are bent from horizontal to vertical within a distance of 3.0-3.5 m to cover the keel and stern post components. Each garboard strake is made up of at least two planks. The distribution of impressions of round nail heads at the scarf indicates a flat diagonal stop-scarf, which was connected by double-clenched or riveted iron nails (Fig. 5b).

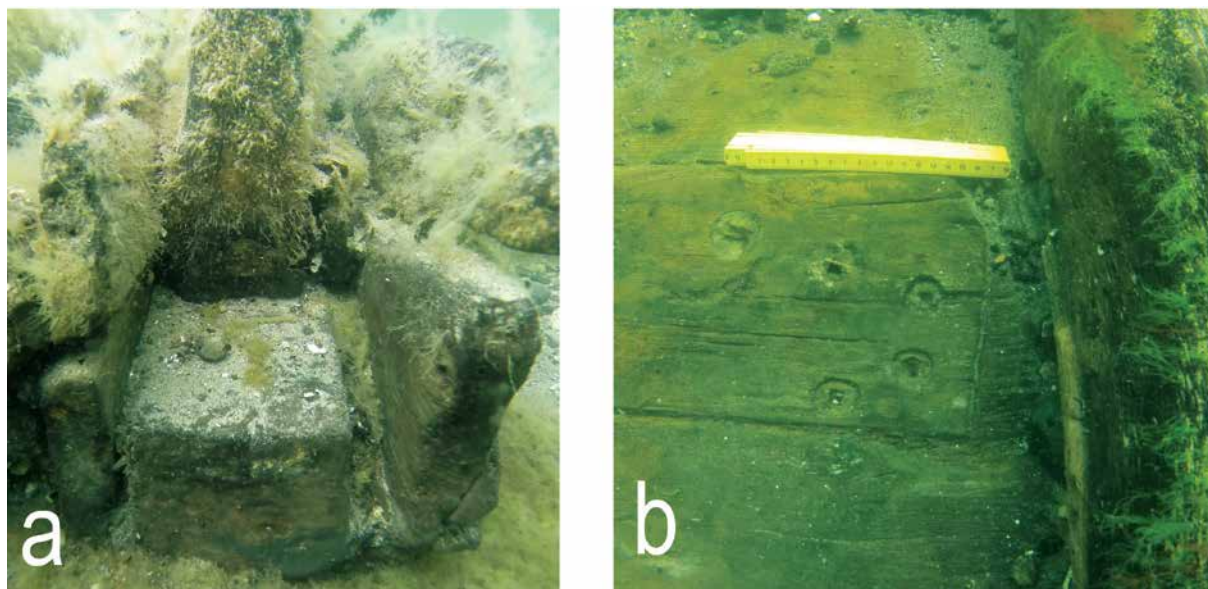


Fig. 5 a) Stern post assembly showing the gap of the missing post; b) Impressions of iron nail heads at the garboard scarf (photos: SDU MAP)

The surviving framing components are mainly rather straight floor timbers in the centre and towards the bow. They are between 0.17 and 0.38 m wide and 0.15 m high. They increase in curvature only in the bow section following its shape. Most of the floor timbers extend to the lower part of the turn-of-the-bilge on one end, which is alternating between portside and starboard. Only in a few cases do fragments of the first futtocks survive. These were only connected to floor-timbers where they were positioned close to the turn-of-the bilge. In these spots, they were either nailed to the

top of the upper surface of the floor timber, or a recess was cut out of the futtock to create an overlapping lip, which served as a simple preliminary connection between the timbers. In cases where the floor-timber ends already in the horizontal part of the bottom and at a distance to the turn-of-the-bilge, they simply abut the futtocks.

About 9.7 m of the keelson is preserved, while possibly another one-third towards the stern is missing; no evidence for a mast-step was found. The keelson is 0.22 m wide, which increases to 0.3 m in the mid-ship section. It runs parallel to the keel on top of the floor timbers. Ceiling planking is preserved under a stone cover to both sides of the keelson. The ceiling consists of at least four oak planks or floor-stringers on the starboard and portside. They are between 0.33–0.41 m wide and about 0.05 m in thickness and are fastened with treenails and iron nails to the floor timbers. The gaps between them are filled with planks, 0.11–0.27 m wide and about 0.035 m high, and barrel staves in multiple layers. These gap-filling elements were made from oak, pine, and fir.

The remains of the outer planking have a width range between 0.37 and 0.435 m and are 0.054 m in average thickness. The planks within the strakes are butt-end joined with their ends secured to the frames by two or three 0.01 m square shanked iron nails, while two treenails of 0.035 m diameter per frame-station were used to connect outer planks, framing timbers, and ceiling planks everywhere else. Observations on a few treenails indicate that the treenails were expanded with an inserted wooden wedge on the inboard side and had dome-shaped nail heads slightly thicker than their shaft diameter. Along the long sides of the planks, additional iron nails were documented, suggesting a focus on securing the seams between the strakes.

The caulking process seems to be supported or accompanied by the installation of short laths, which are placed on the inside of the hull between the frames over the seams. They are fitted into shallow recesses on the lower edge of the frames (Fig. 6). The recesses were either square or consisted of a roughly axe-bevelled edge. The function of these laths might have been to prevent the caulking material from being pressed out of the seams on the inside during the caulking process. However, considering their rather loose fit, their function as a possible precaution to enable quick repairs of leaking seams while at sea may also be considered. The lath-feature is among others also present in the wrecks of the *Mars* and *Elefanten*, which also sank in the Nordic Seven Years War (Adams 2013: 87 ff.) and seems to be a common technique in Northern shipbuilding of the time. Two samples of caulking material have been recovered from the wreck and are currently being analysed. They appear to be highly fragmented plant fibres.



Fig. 6 Lath over seams between the frames (photo: SDU MAP)

During his investigation of the wreck site, Thomas Förster assumed the ship was built in the shell-first Dutch-flush building method (Förster 1999). However, the recovery of timbers during the second field school in 2017 produced no evidence for this hypothesis. No traces of plugged iron nail holes as confirmation for a preliminary assembled outer plank shell were found. Instead, a building process can be considered where the shape of the hull was created in a frame or floor-timber-guided fashion. In this process, only a few floor timbers or frames would have been firmly attached to the keel to be used as guidance for the bottom planks. Such a firm connection might be indicated by the only iron-bolt connection between a floor timber and the keel that could be documented about 2 m from the sternpost construction. The planks would have defined the shape of the hull between the floor timbers. The fact that no proper joint between framing components is present at any frame station can be seen as argument against a fully frame-based construction. Altogether, one could probably describe the process employed in the construction of the Mukran Wreck as a bottom-first approach which differs from the Dutch-flush shell-first construction in that a number of floor timbers are used to define the shape of the lower hull.

Concluding remarks

The so called 'Mukran Wreck' might well be one of the armed merchant vessels in the Danish-Lübeck fleet which Peter Hvitfeld ordered to be burnt at anchor in 1565 (Springmann 1998). The dendrochronological analysis points to a construction after 1558 with timbers from the Lower Elbe region, while dimensions and shape are indicative for a merchant vessel. As such, the wreck fits into Maarleveld's category of German and Scandinavian shipbuilding, exemplified by sites such as the Swedish warship *Elefanten* or the 'Wittenbergen Wreck' (Maarleveld 1998: 90 ff.). Based on a small sample of known wrecks from this area, Maarleveld stated that the "...archaeological evidence seems to indicate that..., the scheme of 'commonplace carvel building practice' in which built-up frames are used and the planking is added later has not been applied rigidly around the Baltic and that possibly the same applies for the North German shores" (Maarleveld 1998: 92). This statement certainly holds true for the 'Mukran Wreck' as well. The hull shows evidence of remnants of medieval shipbuilding methods and was probably built in what might be called a frame-guided construction. As has been pointed out by Adams (2013: 90), the use of caulking laths seems to be "...a local variant in building procedure associated with the retention of caulking" and supports the impression that the wreck exemplifies the long period of adaptation of the flush planked outer hull in Northern Europe. Altogether, the construction of the 'Mukran Wreck' shows that during the 16th century the process of the construction of carvel ships in Northern Europe was far from a simple transfer of knowledge. Instead, it involved adapting old techniques as well as creatively finding new solutions to problems encountered along the way.

Acknowledgements

The authors would like to dedicate this paper to the late Prof. Thijs Maarleveld who sadly passed away in 2021. Not only did his work inspire the fieldwork on the 'Mukran' wreck, Prof. Maarleveld also participated in both field schools, pitching his characteristic canvas tent next to those of his students. He was an enormous inspiration for his colleagues and for generations of students at the University of Southern Denmark and will be dearly missed. The authors would also like to thank both field school teams and all project contributors for their dedication, hard work and input.

Abbreviations

LaKD M-V = Landesamt für Kultur und Denkmalpflege Mecklenburg-Vorpommern (State authority for culture and monuments, Mecklenburg Western Pomerania)

NiHK = Niedersächsisches Institut für historische Küstenforschung (Lower Saxony Institute for Historical Coastal Research)

RCE = Rijksdienst voor het Cultureel Erfgoed (Cultural Heritage Agency of the Netherlands)

SDU MAP = University of southern Denmark Maritime Archaeology Program

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Clinker & carvel. A mid-16th century wreck find from Terschelling, the Netherlands

Alice Overmeer – Thijs Coenen – Heidi E. Vink

Abstract: During a stormy night on February 12, 2020, a large ship fragment appeared on the North Sea shore of the Dutch island of Terschelling. The timbers turned out to have belonged to a wooden ship, of which the lower strakes were lapstrake built, and the upper strakes were flush-laid. The clinker strakes were interconnected with rivets as well as small wooden plugs, and both clinker and carvel parts were built shell-first. The aim of this paper is to present the latest results of the research, and to place the wreck find in a wider context of European shipbuilding traditions.

Keywords: clinker, carvel, 16th century, 3D-photogrammetry, shipbuilding developments

1. Introduction

Beachcombing has been a tradition in the Dutch coastal communities for centuries, especially on the Dutch Wadden islands. After every northwesterly storm, locals roam the beaches for washed up goods and driftwood, to use as building materials or for decorating their houses and gardens. Often single ship timbers are discovered, but sometimes more substantial wreck parts emerge on the shore. After a storm in February 2022, a large hull fragment from a wooden ship was discovered on the North Sea shore of Terschelling, between two kilometre markers on the beach, *Paal* (Post) 9 and 10 (Fig. 1, Fig. 2).

Although the find was reported to the Dutch Cultural Heritage Agency (RCE) on the day of discovery, unauthorised excavation by locals could not be prevented. While attempting to salvage the wreck with a crane, they broke the hull fragment into several fragments. The informed police decided to gather all the fragments and fence the site off. Unfortunately, the rising tide scattered the remains a second time. After consultation with the RCE the remains were transported to the municipal yard. The main reason for this was the remarkable construction method of this fragment: the lowest part of the hull was clinker-built, while the upper part was carvel-laid. This indicated a date of origin in the 16th century, a period of change from clinker- to carvel-built ships, during which shipbuilders experimented with several variations (Overmeer 2017: 199).

Because of the fascinating construction method, the RCE decided to document the wreck parts, and assess their archaeological value. A team of three maritime archaeologists travelled to Terschelling to document the remains, with help of local volunteer Nico Brinck.

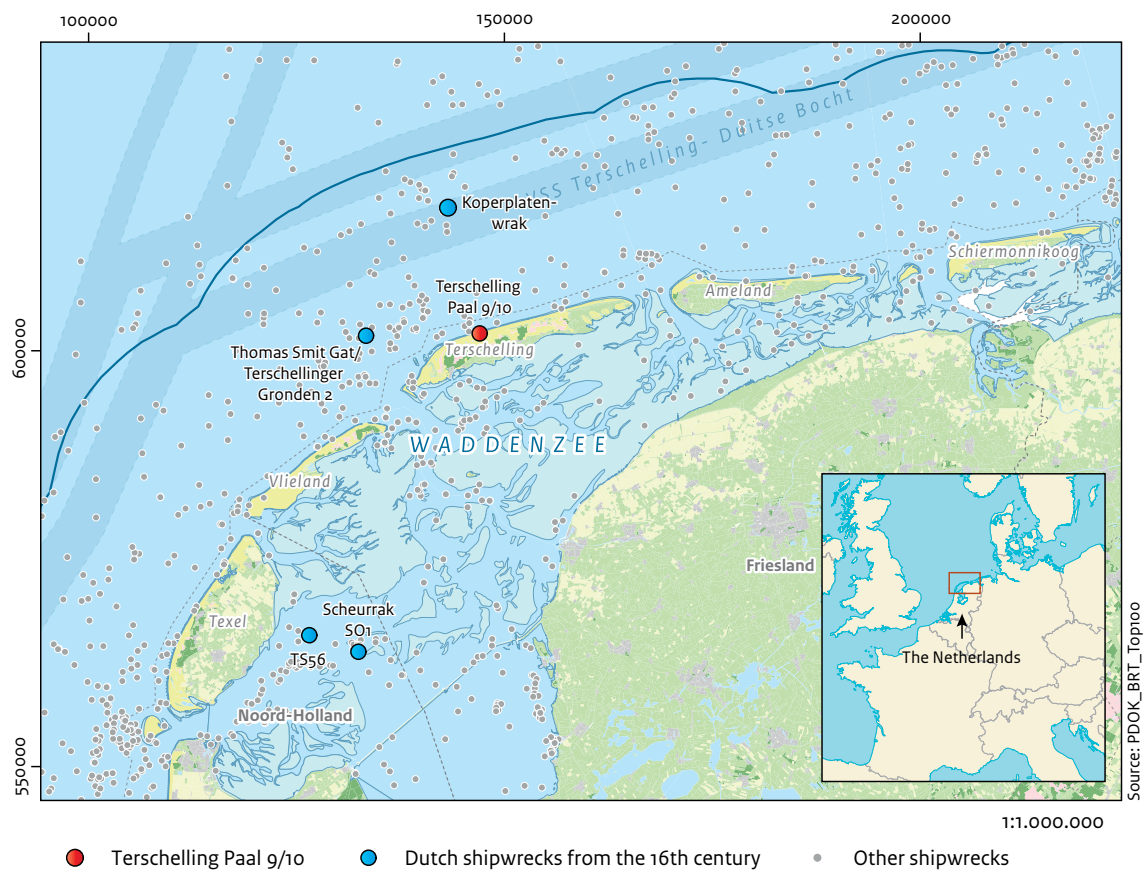


Fig. 1 Location of the wreck find 'Terschelling Paal 9/10' on the island of Terschelling, the Netherlands, with an overview of other shipwrecks in the area (map: Cultural Heritage Agency - RCE)



Fig. 2 The shipwreck on the day of the discovery, on the North Sea beach of Terschelling (photo: S. Kok, ROSE photography, Terschelling/Omrop Fryslân)

2. Documentation

2.1. Manual Documentation

A single day was available for recording all the wreck parts. Therefore, the focus was on obtaining information on the size, building details, and preservation of the timbers. The primary method of documentation was 3D-photogrammetry. In addition, the wreck parts were manually documented through measuring, sketching, and describing the parts (Fig. 3).

During documentation it became clear that almost half of the observed wreck was missing. Only the elements described in this paper survived the looting and the flood, a total of eighteen different parts.



Fig. 3 Manual documentation of the remaining wreck parts (photo: L. Conijn, Laura Conijn Fotografie, Terschelling)

2.2. 3D-Photogrammetry

In addition to the manual documentation, thirteen of the eighteen constructional elements were completely or partially photographed or filmed, in order to generate 3D-models. These thirteen elements were selected according to their size, preservation, special features, or composite nature, i.e. consisting of several planks, or planks connected to frames.

Photographs were taken using primarily a Nikon D850 photo camera, and additionally an iPhone XR. The RAW photographs and video frames were optimized using the photo-editing software Lightroom. The basic values that were adjusted include chromatic aberration, dehaze, white balance, clarity, exposure, highlights, and shadows. Among these, reducing overexposure was a large adjustment in a few photo assemblages. While taking photos at the open spaced yard, we were not equipped to move the larger constructional elements or to create shadows. This problem could be easily solved in Lightroom.

After adjustments, the images were uploaded to the 3D-photogrammetry software Agisoft Metashape. The process of generating a 3D-model followed the general procedure of alignment up to creating textures, and orthomosaic images. In between steps the emerging models were cleaned, i.e. the surroundings of the constructional elements were removed. For this case study, attention was particularly paid to the larger wreck parts consisting of several strakes of hull planks. These were placed on their sides, in order to create sufficient overlap for smooth alignment of the photographs. Due to their disarticulation from the shipwreck and flexible nature, the planks tended to bend slightly. They were nevertheless accurately generated as high quality 3D-models in Agisoft.

Smaller constructional details, which are discussed below (the so-called *spijkerpenen*), are also visible on the 3D-models, and beautifully demonstrate the strength of combined digital and manual documentation methods. These tiny features and their patterns might not have been evident had we relied solely on digital documentation.

3. Results

3.1. General

The ship fragment on the beach was about 13.40 m long and 5 m wide (Overmeer, Coenen, Vink 2024). A sketch of the fragment was made, based on the photos taken right after discovery (Fig. 4). The fragment consisted of ten hull strakes, 20 frames and one inner strake. During documentation we observed that only half of the fragment was left (Fig. 4, dark coloured part). It was broken into 18 different parts: loose futtocks and planks, but also larger fragments of still connected strakes. Two loose planks, positively belonging to the wreck, washed ashore a few days later, and were included in this study. All elements were made of oak.

The most striking feature noted from the wreck fragment is the construction of the hull. The seven lower strakes were clinker-built, while the three upmost strakes were flush and carvel-laid.¹

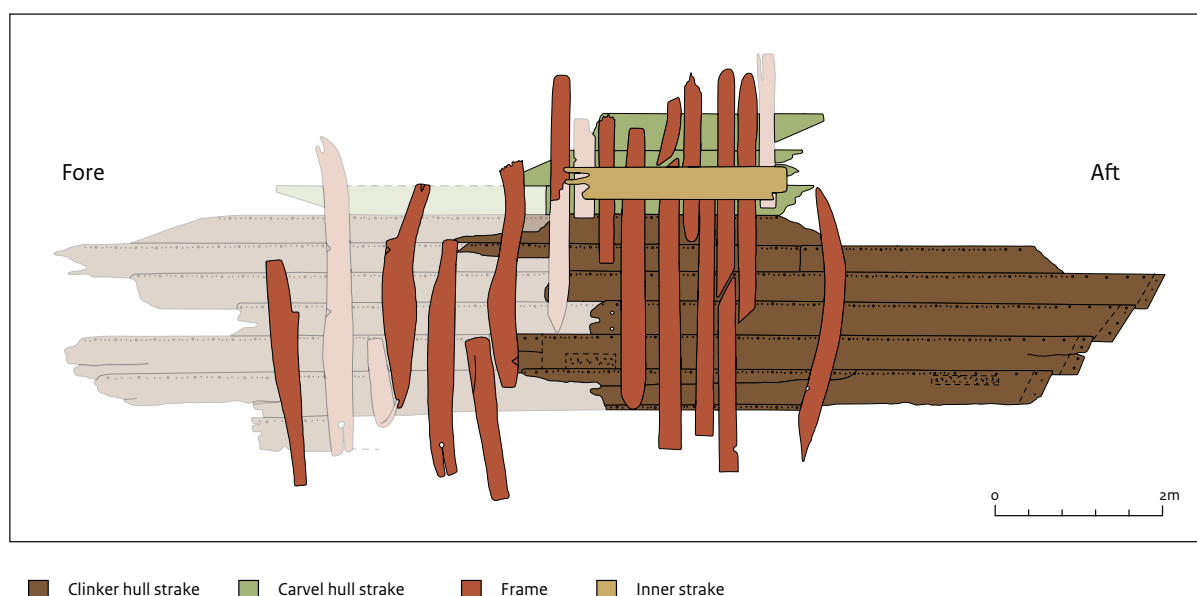


Fig. 4 Reconstruction sketch of the ship fragment on the beach, based on photos of the discovery. The dark coloured parts indicate the elements that remained after the looting and flooding (after A. Overmeer & T. Coenen, Cultural Heritage Agency - RCE).

¹ It is subject to debate whether the eighth strake of the fragment belonged to the clinker part of the hull or to the carvel part, since the lower seam of this strake was lapstrake-laid and the upper one was flush-laid. According to our interpretation, this strake is considered part of the carvel part of the ship.

3.2. The clinker-built part of the hull

The lower, clinker-built strakes consisted of several planks, connected by simple flat scarfs. The planks had widths varying between 31 and 45 cm and thicknesses of 5 to 6 cm. In between the scarf tables, moss had been applied to make the structure waterproof.

The strakes overlapped 7 to 9 cm, and on the land, they were interconnected with both rivets and small wooden pegs. Between each two rivets, which were spaced 24 to 30 cm, two to three wooden pegs were placed (Fig. 5). The pegs had a diameter of 1.5 cm and were wedged on the inboard side. Simple lines were carved at the spots where the pegs were meant to be placed.

The overlapping strakes were luted with moss, covered by a mossloth, and secured with so-called *sintels*, small iron cramps. The sintels were not preserved, only the holes of the lugs were visible in the hull planks.

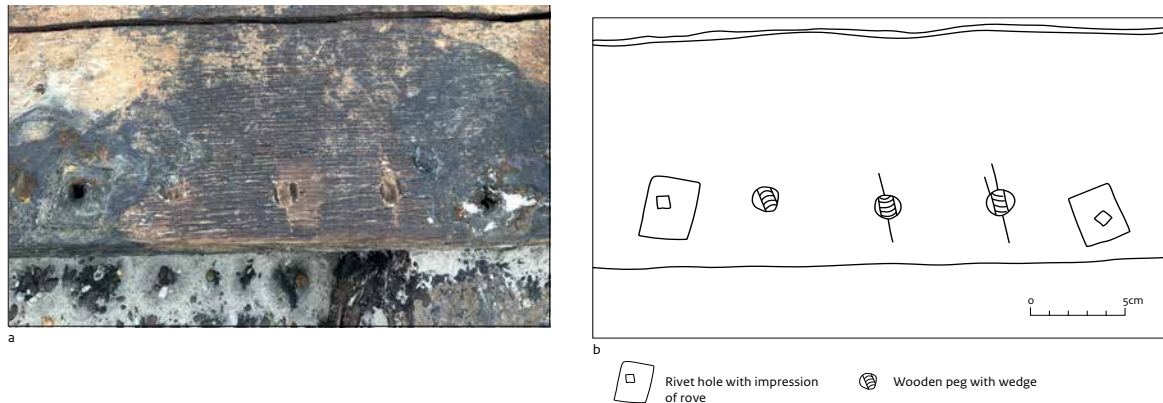


Fig. 5 Combination of rivets (square impressions) and small wooden pegs in the clinker strakes of the ship fragment of Terschelling Paal 9/10. The shipbuilder has scratched in guide lines to indicate the position of the wooden pegs (after Overmeer, Coenen, Vink 2024, Fig. 21).

On four hull strakes the original end had been preserved. The planks were bevelled at an angle ranging from 123° to 127°. Originally, these hood ends fell into individual rabbets in the sternpost or stem. Given the position of the scarfs in the hull planks, they most likely fitted to the sternpost, and therefore the ship fragment concerns the aft part of the starboard side.

The hull had also been repaired on the inside. The actual repair planks (63 × 13 cm and 20 × 10 cm) have not survived, but the nail holes and caulking material were still present.

3.3. The carvel-built part of the hull

The upmost three strakes of the ship fragment consisted of carvel-laid planks, placed side-to-side. The strakes originally consisted of multiple planks, connected by diagonal nibbed scarfs of 64 cm long, completely different from the scarfs in the lapstrake part. There is no evidence these scarfs were waterproofed with any kind of luting or caulking material. The planks were 37 to 46 cm wide and 6 cm thick.

The three carvel strakes were not interconnected, they were only fastened by treenails to the framing. The lowest carvel strake was connected to the upmost clinker strake by means of rivets and small wooden pegs.

The clinker part of the hull was built shell-first, and the carvel planks also show indications of shell-first construction. In all three carvel strakes, square wooden plugs of about 6 by 8 mm were found (Fig. 6). These wooden plugs are a well-known phenomenon in Dutch shipbuilding and are related to the bottom-based construction method.² During the assembly, the planks were laid side to side, and were held together by temporary clamps. These clamps were removed when the frames were inserted, and the remaining nail holes were filled with square wooden plugs, in Dutch *spijkerpennen*.³ The *spijkerpennen* in the Terschelling wreck find were found on the inboard side as well as on the outboard side, implying that the clamps had been placed on both sides of the hull.

² This way of bottom-based building, which seems to have been often used in the Netherlands, is called 'Dutch flush' by Thijs Maarleveld (Maarleveld 1994: 155).

³ The term *spijkerpennen* was first mentioned by Van Yk in his book about Dutch shipbuilding of 1697 (Van Yk 1697: 41). However, the earliest *spijkerpennen* have already been observed in the thirteenth-century cog-like ship NA57 (see Oosting 1987: 59). They have even been found in nineteenth-century wrecks (see: Oosting, Vlierman 1990: 16). See also Lemée 2006: fig. 4.1.16 for the sequence of the building concept.

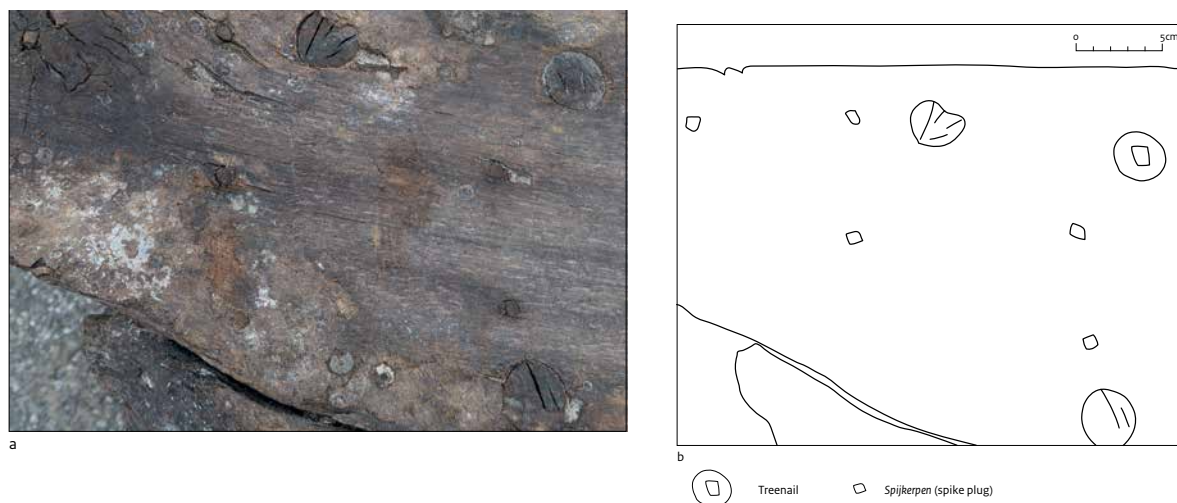


Fig. 6 Small wooden plugs, so-called spijkerpennen, on the outboard side of the carvel hull part of Terschelling Paal 9/10 (after Overmeer, Coenen, Vink 2024, Fig. 33)

3.4. The framing

Of the 20 frames visible on the discovery photographs, only 17 survived. These were all futtocks, placed directly next to each other, or with small interspaces. They were fastened to the hull with treenails with a diameter of 3 to 3.5 cm and wedged on the inboard side. The aftmost futtocks have a significant S-shape, implying the stern was very sharp below the waterline, and became fuller above the waterline (Fig. 7).

Most futtocks were notched on the lower part to fit the clinker strakes, and were smooth in shape on the upper part (see Fig. 7). There are no indications that the upper parts of the futtocks were notched in an earlier phase, and later planed to fit a carvel hull. Therefore, it is likely that the ship was originally designed with this combined clinker and carvel construction.

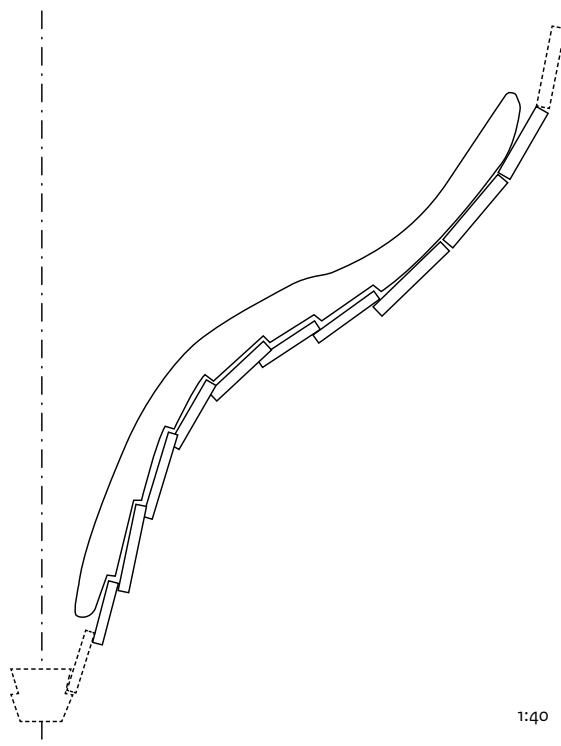


Fig. 7 Reconstruction of the stern, approximately 5 m from the stern post. The dotted parts have not been found (after Overmeer, Coenen, Vink 2024, Fig. 47).

3.5. The inner strake

On the inside of the ship, an inner strake had been applied to the futtocks. This one plank had a remaining length of 237 cm, a width of 33 to 36 cm, and a thickness of 8.5 cm. It might have been a ceiling plank, but it is quite heavy for this purpose. It possibly served as a beam shelf (although notches for deck beams are lacking) or as a lower beam clamp. It was attached to the underlying frames by treenails.

4. Dating & provenance

A total of 13 wood samples for dendrochronological analysis were taken from the timbers. Eight of them provided enough rings for dating. One sample had a felling date of spring AD 1546. The other samples had felling dates supporting this dating (Doeve 2020: 4). The geographical origin of the trees from two clinker planks lies in Westphalia or Lower Saxony in Germany. For the other samples a direct region of origin could not be determined, only a larger area of origin that includes eastern Belgium, eastern Netherlands, and central Germany (Doeve 2020: 4).

5. Preservation and post-depositional processes

The ship's timbers were in remarkably good condition. No shipworm infestation was observed. All iron elements on the other hand, such as rivets and sintels, had become heavily concretized or had even completely disappeared. Dark discolorations of the oxidized iron could be seen everywhere on the wood. This indicates sulfide corrosion, which occurs in marine contexts without oxygen. It can be concluded that this wreck part has been buried deep in the seabed all this time.

6. Interpretation & Comparison

The ship fragment found on the North Sea shore of Terschelling concerns the aft part of the starboard side of a mid-sixteenth century seaworthy ship. Based on the size of the fragment, it is thought that the ship was originally at least 22.5 to 30 m long, approximately 7.5 m wide and over 5.5 m high. The ship was originally built in a combined clinker and carvel construction. The combination of a lapstrake hull in the underwater ship and flush strakes above the waterline had not yet been found in the Netherlands before. A few examples are known from Germany and Scandinavia (Tab. 1).

Wrecksite	Date (dendro)	Provenance	Dimensions	Specs	Literature
Terschelling Paal 9/10 (Netherlands)	spring AD 1546	Germany	13.4 x 5 m (max. 22.5-30 m ²)	Lower planking: clinker-built, rivets & wooden pegs; upper planking: carvel-built, spijkerpennen; all elements of oak	Overmeer, Coenen, Vink 2024
Åkroken-wreck (Sundsvall, Sweden)	summer AD 1577	Sweden/Finland	14.3 m (max. 16-17 m)	Lower planking: clinker-built; upper planking: carvel-built	Eriksson 2010
Japsand wreck (Hallig Hooge, Germany)	after AD 1617	Sweden	12 x 2.5 m	Lower planking: clinker-built, rivets; upper planking: carvel-built, no spijkerpennen; all elements of oak	Zwick 2024
Gröna Duvan (Sweden)	AD 1730's	?	16 m	?; all elements of oak	Erikson 2010
Bockholmen wreck (Åland, Sweden)	AD 1788-1790	?	25 x 8.5 m	Lower planking: clinker-built, nails; upper planking: carvel-built; all elements of pine	Lindholm 2002
Engman wreck (Axmar, Sweden)	about AD 1810	Sweden	28-29 x 8 m	Lower planking: clinker-built, double bent nails; upper planking: carvel-built; all elements of coniferous wood	Alopaeus <i>et al.</i> 2011
Märsman (Rödlöga, Sweden)	no dendro (1800-1850)	?	23 m	Lower planking: clinker-built, nails; upper planking: carvel-built; all elements of pine	Eriksson 2010
Ågabets wreck/Pettu (Denmark)	AD 1865	Swedish eastcoast, Finnish mainland	24 m	1 st layer: lower planking: clinker-built, wooden pegs; upper planking: carvel-built; 2 ^d layer: carvel-built; all elements of pine	Auer <i>et al.</i> 2013

Table 1 Ship finds in Europe with a combination of clinker and carvel hull

The hitherto oldest example is the Åkroken wreck, dating to 1577 (Eriksson 2010). The Japsand wreck, discovered off the shoals of Hallig Hooe in the North Frisian Wadden Sea, is also built in a similar manner, and dates after AD 1617 (Zwick 2024, in this volume). There are more wrecks found, mainly in Scandinavia, but most are dated to the 18th and 19th centuries. With its date of AD 1546, the Terschelling Paal 9/10-wreck is currently the oldest known ship built in this manner. Olof Hasslöff (1972) refers to this particular construction as ‘half-carvels’. Eriksson and Zwick have put forward that both clinker construction and half-carvel construction were primarily associated with small-scale shipping in rural communities, and regarded as indigenous, old-fashioned, and obsolete. Carvel-built ships on the other hand were considered as modern, and were fiscally privileged (Eriksson 2010; Zwick 2024). Following Hasslöff, the term ‘half-carvel’ is now often used for ships with mixed planking. However, it is uncertain if this was a commonly used term at the time, and it should therefore be used with caution.⁴

Besides the clinker-carvel combination, there have been other variants of clinker construction, including vessels built with alternating strakes of clinker planking (e.g. the Björns wreck, the Melböda wreck), or ships which originally had a clinker hull, but in a later phase were converted to carvel ships by applying an extra carvel layer (e.g. B&W6, the Maasilinn wreck, FPL77 and the recent ship find Bispevika 19 in Oslo; Belasus 2014: 251–254; Lemée 2006; Belasus 2014: 258–263; Steen 2019).

The mixture of clinker and carvel hull is not the only striking aspect of the wreck. The presence of combined rivets and small wooden pegs is also interesting. Thus far this method of joining strakes is only known from four other early 16th-century wrecks. One of them was found in Køge harbour in Denmark (AD 1520–1530; Færch-Jensen, Daly 2023); three other wrecks were found in the Netherlands, and had wrecked in the former Zuiderzee. The Dutch ships, named NE159 (AD 1500–1512), OM11 (AD 1531–1533), and the 30m-long OU34 (AD 1522–1537), were all completely clinker built (Overmeer 2017).

Conclusions

The preliminary results indicate that the ship fragment found on the beach of Terschelling was a large, seaworthy ship, built with a combination of clinker strakes below the waterline, and carvel strakes in the upper part of the vessel. Both parts were built shell-first. Due to the presence of wooden pegs combined with rivets in the clinker part, and *spijkerpennen* in the carvel part, this ship might well have been built in the Netherlands. Together with the other ship finds with mixed planking in the several above mentioned variants, the Terschelling wreck exemplifies and contributes to a growing body of evidence demonstrating that shipbuilding in the 15th and 16th centuries was far from standardized.

Economic, political, and social developments in this era, mainly driven by the need and desire of different European sea powers to obtain resources, and later on also to conquer territories and establish colonies, created an increasing demand for larger cargo vessels, and the need to carry guns aboard. To meet these requirements, much changed in the way ships were conceptually and physically built. The Terschelling Paal 9/10 wreck is one example that this change was not linear or unambiguous, but rather inventive and adaptive.

⁴ Personal comment Thijs Maarleveld †.

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Homemade? An early 16th century carvel ship found in Oslo harbour, Norway

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Abstract: Bispevika 8 is the only wreck out of the 50 wrecks found in Oslo's late medieval/early modern harbour that was carvel-built. Through documentation and analysis, it became clear that it is a 16th century Dutch-Flush built vessel. While the natural assumption would be that the ship was built in the Netherlands, elements of the construction, the provenance of the timber, results of the analysis of the waterproofing material, and written sources strongly indicate a local, Norwegian, place of origin.

Keywords: Dutch-Flush, Norway, 16th century, shipbuilding, Bispevika 8

1. Introduction

Excavated in 2015, Bispevika 8 is one of over 50 wrecks from late medieval/early modern times found in Oslo's harbour. The 50 vessels sank, or were sunk, close to timber wharves dated to the same period. None of the vessels are fully preserved with their cargo, decks, or rigs, but a majority have the main parts of their hulls intact. Bispevika 8 differs from the other vessels by having a flush-laid hull, while the rest have overlapping strakes.

This paper presents the preliminary results from the excavation and documentation of Bispevika 8. With a focus on the ship's, construction, shape, dating, and provenance, we will attempt to answer questions concerning where this early carvel ship was built, and by who.

2. Carvel construction

Bispevika 8 was constructed in a transitional period of shipbuilding in Northern Europe. Lapstrake vessels were gradually replaced by carvel-constructed ships. This transition has been a popular field of study (e.g.: Adams 2003; 2013; Bill, Gøtche 2006; van Duivenvoorde 2008; Lemée 2006; Maarleveld 1998; Uldum 1999), but with few surviving Northern European carvel-constructed vessels from the late 15th to the early 16th century, more data is essential to elucidate this period of change.

By now, it is well established that there were different ways to construct a carvel vessel. One of these methods is the Dutch-Flush manner presented by Thijs Maarleveld (1991; 1998), or 'bottom-built' as defined by Fred Hocker (1991). Dutch-Flush is a style of building that has been described in 17th century Dutch writing (Hoving 2012), and the majority of finds of the earlier Dutch-Flush ships have been ascribed to the Netherlands or specifically the Wadden Sea area (Hocker 1991; Kühn 1997; Lemée 2006; Logan 2013). The Dutch-Flush method could include two to three master frames but the majority of the shaping of the hull took place during the planking process, before the framing was added. The hull planks were initially held together with clamps and cleats; small lengths of wood nailed to the planking, that were removed as the framing was added to the hull.



Fig. 1 What remained of Bispevika 8 had been damaged by fire, dredging, and the insertion of a cofferdam (photo: Norwegian Maritime Museum).



Fig. 2 The boat parts that did survive included a keel, a stern post with stern knee, a keelson, frames, strakes, graving pieces, ceiling planks as well as the foot of a bilge pump (photo: Norwegian Maritime Museum).

3. The construction of Bispevika 8

Only 6.4×5 m of Bispevika 8 was preserved, and those remains had been badly damaged by a fire. More than half of the hull's length was dredged away sometime in the 19th century (Fig. 1). Among the boat parts preserved were a rabbeted keel, a three-part stern post with stern knee, a keelson, 73 frames, parts of nine strakes, seven graving pieces, and small pieces of ceiling planks, as well as the foot of a bilge pump (Fig. 2). What remained of the Bispevika 8 keel was rabbeted, 34.9 cm sided and 26 cm moulded. This is a deeper keel than many of the Dutch-Flush ships, but it is not unique, with the later B&W 2 and B&W 5 Christianshavn vessels having a similar ratio of sided to moulded dimensions (Lemée 2006). The aft stem was made of three parts, securely fastened to the ship with treenails and iron bolts.

3.1. Hull planking

Few of the hull planks were preserved to their full length, but those that were had lengths of 3.23–5 m, widths of 22.6–32.3 cm, and thicknesses of 3–6.7 cm. The planks were scarfed with diagonal nibbed scarfs, except for the garboard strakes which were butt-ended. The length and shape of the scarfs varied somewhat, but the placement of the scarfs in the planking were roughly mirrored on either side of the keel, suggesting some pre-design of the hull. In at least one place, the second strake on the port side, and possibly on the eight strake starboard, the planks encroach into the overlying strake. This might be an indication of a more symbiotic way of making the hull, where planks to a certain degree were individually shaped, or at the very least adjusted, as they were being installed. This ongoing adjustment of the planks is indicated by the seven graving pieces in the hull, which were probably inserted where cracked or knotted wood was removed. This apparently occurred during the construction phase, as the caulking material is identical to the caulking in the rest of the hull (Kubrik-Maartens 2020).

During the insertion and fastening of the frames in a Dutch-Flush ship construction, temporary cleats were used to hold the strakes together. When the cleats were removed, their nail holes were filled with small wooden plugs called spike-plugs. During the 1:1 documentation of the Bispevika 8's planks, spike-plugs were documented on the inside and outside of the hull planking, with evidence for cleats from the keel to the seventh strake, approaching the turn of the bilge.



Fig. 3 One of the many spike-plugs found in the hull planking of Bispevika 8. Also visible in the picture is an arrow shaped stop-mark, used to stop the progression of a crack (photo: Norwegian Maritime Museum).

3.2. Framing

The placement and organization of the frames in Bispevika 8 is best described as unsystematic. The shape of the frames varies considerably, with sided dimensions of 10–23.5 cm. While some of the frames are almost straight as seen from above, others are more S-shaped. The way the frames were joined to one another also varied considerably. Some have no joints at all, others were somewhat randomly shaped to make them fit into the hull. There were a few examples of butt-ended joints, otherwise the majority of joints were found on the fore and aft faces of the frames, mostly L-shaped, but others S-shaped to accommodate the natural curve of the timbers.

There were no surviving frames connected to each other with any sort of fasteners, except for one small iron nail between a floor timber and a futtock. From what remains of the aft end of the vessel, there is no evidence of pre-assembled frames, or a pre-designed system of framing of Bispevika 8. It seems as if the focus of the framing was to strengthen the hull as much as possible with frames, whilst utilizing what curved timbers were available. Apart from the lack of joggles, the floor timbers are quite similar in shape to the frames of 16th century lapstrake floor timbers, even sporting identical triangular limber holes, which sit above either side of the keel. However, treenails were hammered through some of the limber holes, making them obsolete (Fig. 4). Both the degree of different solutions in the shaping and joints between the framing, and the treenails in the limber holes, might be a result of a rebuilding of the vessel, or quite possibly the result of two forms of ship-building techniques colliding.

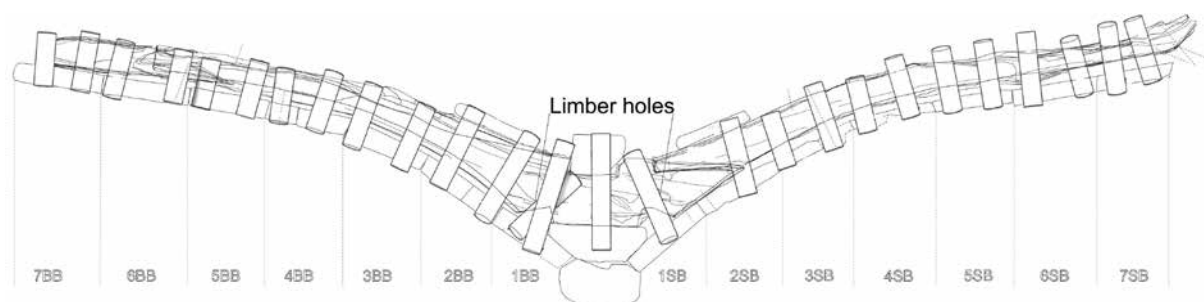


Fig. 4 Treenails were hammered through some of the limber holes, making them obsolete (drawing: Norwegian Maritime Museum).

4. Original shape of the vessel

Bispevika 8 was narrow at the stern, had a deep rabbeted keel, and plenty of deadrise at the surviving aft end. In this, its shape was not dissimilar to the beamy lapstrake vessels found in Oslo's harbour from the 16th century, all of which sported deep keels and V-shaped bottoms. Bispevika 8, however, had a 'chine', where the bottom of the hull changes sharply and obviously to the side of the hull. In this, Bispevika 8 differs from the rounded bilges of the lapstrake vessels (Fig. 5). Bispevika 8 does not mirror the flat-bottomed style of other 'Dutch-Flush' type vessels either. Its underside still retains some deadrise at the furthest surviving point forward in the vessel. Nor is its chine as sharp as those of many of the other Dutch-Flush type vessels. One vessel that did transition from having more deadrise in the aft third of the ship to a flat-bottomed, barge-like lower hull, mid and forward was the Dutch B&W5 ship dating to 1625, found in Christianshavn, Copenhagen. However, the B&W5 is not a perfect match either, as it had rounded bilges at its aft end, with the chine only appearing further forward as the bottom of the hull flattened out (Lemée 2006: 182, Fig. 4.2.54). So, although the Bispevika 8 ship differs from the others by being built in Dutch-Flush carvel technique, the reconstruction of the hull shows similarities to the shape of clinker-built hulls found in Oslo from the same period.

5. Dendrochronology

Eleven dendrochronology samples were sent to Aoife Daly at Dendro.dk for analyses: seven from the planking between the second and seventh strakes, two floor timbers, and two futtocks. One of the samples, from plank x150, had six sapwood rings remaining, so the felling date of the tree could be narrowed down to between 1534 and 1539 (Daly 2019: 34). Six of the planking samples matched with three data sets from Southern Norway, while the remaining planking sample, x126, best matched to a dataset from Denmark. The frames date to the winter of 1557–1558, suggesting a second phase of building (Daly 2022: 38). Three of the frame samples match with datasets from southern Norway and one to a dataset from Western Sweden. More dendrochronology samples need to be analysed to fully understand the different construction phases of the vessels.

Bispevika 8 predates many of the other excavated Dutch-Flush wrecks. The Dutch-Flush wreck with the closest felling date is the Dutch OE34 found in Flevoland, the Netherlands (Logan 2013), with a felling date of 1553 (van Holk 2014: 39). Many other excavated vessels built in the same style are dated to between the late 16th century and the middle of the 17th century. Such as Oost Flevoland B71 (OB71) (Hocker 1991: 184), the aforementioned B&W wrecks (Lemée 2006: 255, 217, 164), Scheurrak T24 (Maarleveld 2013: 7), and Paléhaven 1 dating between 1636 and 1643 (Borvik *et al.* 2015: 21).

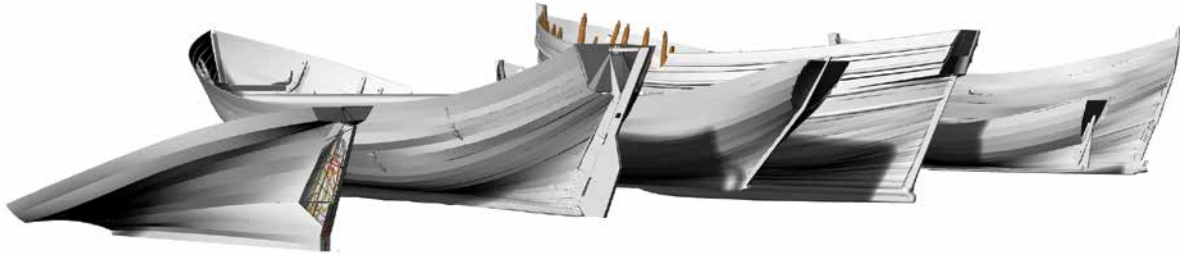


Fig. 5 Bispevika 8 shown in the foreground of the picture is similar in shape to other 16th century vessels that were excavated in Oslo harbour. Although its chine differentiates it from these lapstrake vessels. From the left, Bispevika 8, Barcode 14, Barcode 8, Barcode 2, Barcode 6, Barcode 5 (drawings: Norwegian Maritime Museum)

6. Caulking analysis

Sixteen caulking samples were taken from Bispevika 8. The samples were taken from a variety of locations in the hull: from the first to the fourth strake, between strakes and the keel, between strakes and stem, and under graving pieces. A simple visual inspection of the samples revealed that the caulking material consisted mainly of moss. Six samples were sent to Lucy Kubiak-Martens at Biax-consult for further analysis. Almost all the caulking samples from the Bispevika 8 were composed exclusively of two moss species, *Warnstorfia fluitans* and *Calliergon cordifolium*. Similar inclusions in all the samples, of needles and scales from Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*), and birch trees, suggest all of the waterproofing material was collected at the same location, on wet, nutrient-poor ground, possibly in fens or bogs, or by shallow pools in coniferous forests. All of the trees and mosses are native to Norway but are also found widely in Europe. Norway spruce, however, is not found on the west coast of Norway or the south-east coast of Sweden, or in northern Germany, Denmark, or the Netherlands (Fig. 6) (Kubrik-Maartens 2020: 10). Assuming the caulking material was gathered close to where the ship was built, this narrows down the most likely construction location for Bispevika 8 to the south coast of Norway.

7. The black swan – contextualizing Bispevika 8

Bispevika 8 is believed to have been destroyed in the historically documented town fire of February 21, 1567, when Oslo's citizens were forced to burn down their houses, warehouses, and ships to dissuade the attacking Swedish army from taking shelter in the town. The ice laid thick on the fjord, and although the shipowners pleaded with the king's men that they needed to cut a passage through the ice and take the ships somewhere safe, they were denied the option, and the ships were burnt down with the rest of the harbour area. This also meant that the wealthy citizens had few means to rescue their goods in the 24 hours warning they were given. From these dramatic circumstances we get unusually rich information when the burnt wrecks were rediscovered 450 years after the fire. We know for sure that Bispevika 8 must have been anchored for the winter in Oslo's harbour, and since foreign merchants were not allowed to stay in town over winter, we can be quite certain that the ship was owned by Norwegians, most likely Oslo citizens. But where was the ship built, and by whom?

Despite the dearth of archaeological finds for this time period, historical records of carvel shipbuilding for the Danish/Norwegian crown in Norway certainly exist. In a letter dated November 1538 the Danish/Norwegian king Christian III ordered a large carvel-constructed ship to be built by the citizens of Oslo (NRR 1, 55). In another letter from the king, dated the same month and year, the king asks the Bohus lord Claus Bilde and Bernt Sasser to finish the bottom of a carvel ship and make sure to order enough ship timber before the timbermen and shipbuilders arrived (NRR 1, 56).

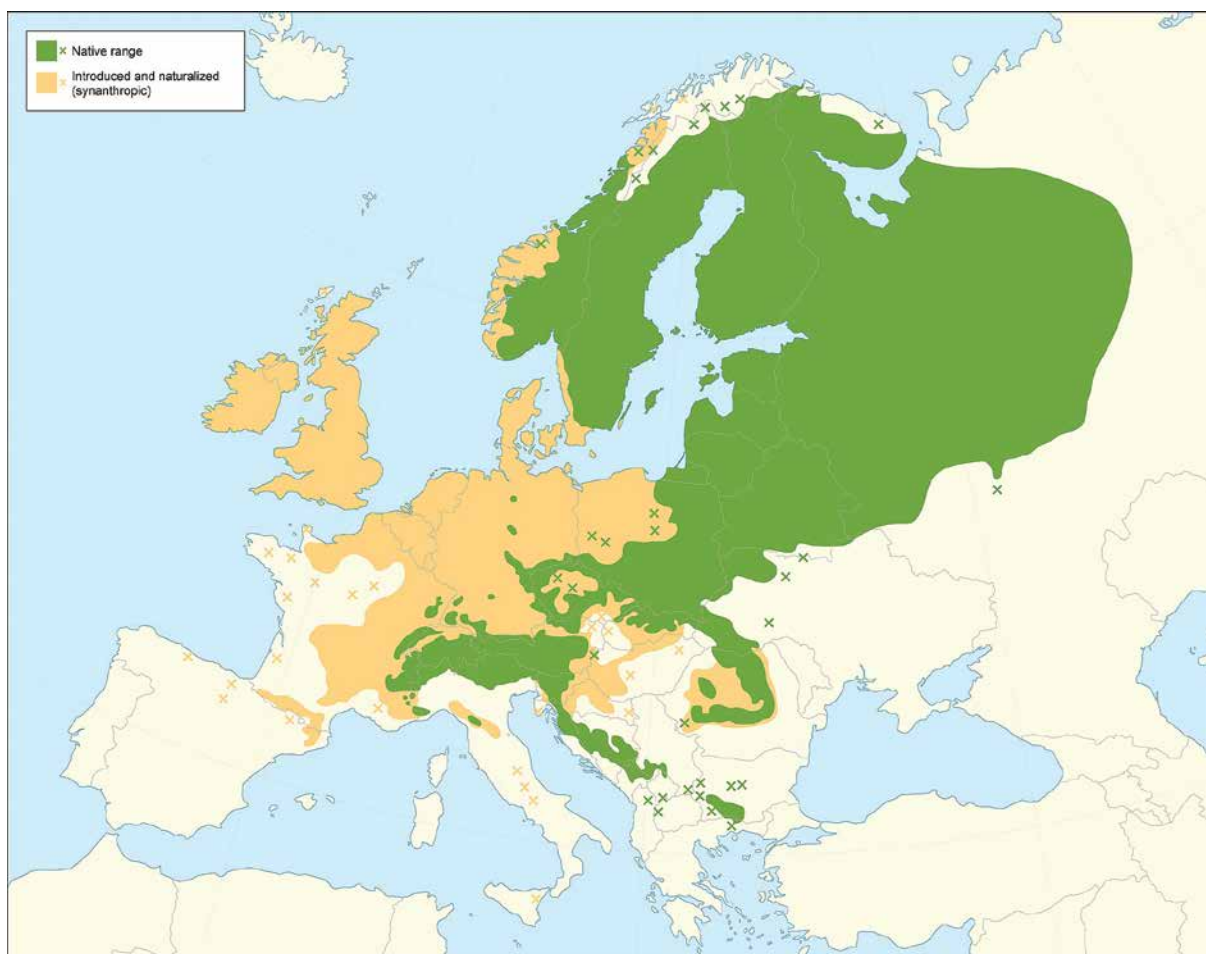


Fig. 6 Distribution of native Norway spruce shown in green (*Picea abies*) in Northern Europe (after Caudullo *et al.* 2017)

Shipbuilders of English, French and Dutch origin were working in Denmark and Norway, in the 16th century (Rasmussen 2008: 22; Lemée 2006: 47, 61, 62). It is reasonable to imagine that they brought their own craftsmen, but also that they employed local shipbuilders and craftsmen. We know from the 1570's the English master shipbuilder Hugo Beda built several large vessels for the king in a shipyard in Moss by the Oslofjord (NRR 2, 76, 125, 176, 180-181). Beda was responsible for building at least one ship, Gideon, in a Dutch-Flush style (Grue 2010: 54).

A century after the construction of Bispevika 8 a naval shipyard was established, on a small island named Hovedøya, close to Oslo. Some of the era's largest warships like Sophia Amalie (1650) were built here, and ship builders came from the king's shipyard Bremerholm in Copenhagen. The shipyard, believed to have been in use for around 50 years, may have been the site of an older shipyard but as of now no information about one has been found, so this is pure speculation. It is reasonable to assume that many of the boats and smaller clinker-built ships from the 16th century found in Oslo harbour were built in smaller, traditional shipyards in the Oslofjord region. Royal, and larger scale, shipbuilding may have been shorter lived popping up in timber-rich coastal areas and disappearing again some years later, along with the timber supply. Bispevika 8, with its different technological construction, must have been built at a shipyard exposed to new technological thought and by a group with the will and or need to use it. It is plausible that Bispevika 8 was constructed in a Royal or larger shipyard where the motivation for change was perhaps greater, and the connection to tradition somewhat less.

8. Conclusion

Bispevika 8 is one of the oldest excavated Dutch-Flush vessels and the people building Bispevika 8 were clearly well versed in how to build in the Dutch-Flush manner. The shape of the wreck, the provenance of the timbers, and the likely provenance of the caulking in addition to the context and written sources, must call a Dutch origin into question. While each parameter by itself might be circumstantial, together they form a picture of a ship that could have been built in the south-eastern part of Norway, owned, and commissioned, by tradesmen living in Oslo, or perhaps the Danish king. From written sources we know that the Danish king ordered a carvel to be built by the citizens of Oslo at the exact same time as the construction of Bispevika 8, and even if this ship is not actually Bispevika 8, it shows at least that carvel ships were being built in the area at this point in time. To understand more about shipbuilders and the society in which the ship was built, we need to gain more information about the short-lived Norwegian royal naval shipyards, as well as identify smaller, traditional boatbuilder's workshops. With an increasing number of wrecks from Oslo harbour, perhaps at some point in the future we will be able to identify characteristics that separate one shipyard from the other in the Oslofjord area in the 16th century.

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Recording, analysis, and interpretation of the hull remains of *Santo Hieronimo* (1576), a vessel from the merchant fleet of the Maritime Republic of Ragusa

Jose L. Casabán – Irena Radić Rossi

Abstract: Following the discovery of the remains of *Santo Hieronimo* in the early 1970s near the Island of Šipan (Croatia), the Maritime Museum of Dubrovnik carried out the rescue excavation of the wreck. The pioneering work led to the preliminary interpretation of hull remains and recovered artifacts. Ten years later, the research conducted at the National Archive of Dubrovnik resulted in the identification of the sunken ship. The archaeological study of the remains of *Santo Hieronimo* continued in 2014. This paper presents the latest research results on the hull features of *Santo Hieronimo*, aimed at understanding the shipbuilding techniques of the post-medieval vessels that sailed the Adriatic.

Keywords: shipwreck, *Santo Hieronimo*, Maritime Republic of Ragusa, wooden hull, lead sheathing

1. Introduction

The *Santo Hieronimo*'s hull remains were discovered at the Bay of Suđurađ, on the Island of Šipan (Croatia), in the early 1970s. Following its discovery, the Maritime Museum of Dubrovnik carried out the rescue excavation of the wreck between 1972 and 1974, under the direction of Anica Kisić and Zdenko Brusić (Kisić 2006: 131, 143). This pioneering work led to the preliminary interpretation of hull remains. The artifacts recovered from the site dated to the second half of the 16th century and connected the wreck with the wealthy Ragusan merchant family Primi. Ten years later, the research conducted at the State Archive of Dubrovnik (DAD) resulted in the identification of the sunken ship. According to the archival documentation, the wreck of the Island of Šipan was the 'nava' *Santo Hieronimo* which sunk in 1576 and was the property of the famous merchant Hieronimo Benedicto de Primi (Jerolim Benedikt Primojević), of Ragusan origin (Vekarić 1987: 65–71; Kisić 2006: 132).¹ The archaeological study of the remains of *Santo Hieronimo* continued in a systematic form from 2014 to date, carried out as part of the Archaeology of Adriatic Shipbuilding and Seafaring Project (AdriaS).² This paper presents the latest results of the ongoing archaeological survey, excavation, recording, and interpretation of the hull features, dimensions, and assembly of *Santo Hieronimo*.³

2. Location of the site

The Island of Šipan is located off the Dalmatian coast of Croatia, in the Adriatic Sea, 18 km to the northwest of Dubrovnik (Ragusa), the capital of the former Maritime Republic of Ragusa. Šipan is the largest of the Elaphiti Islands and is separated from the mainland by the Koločep Channel. The island extends parallel to the coast, following a north-west-southeast orientation, with a maximum length of 9 km and a width of 2.6 km. Šipan has two ports, Šipanska Luka (Port of Šipan) located in the northwest and the port of Suđurađ (Saint George) in the southeast.

¹ Researchers of the Santo Hieronimo Project conducted archival research at the State Archive of Dubrovnik in 2016 and 2017, confirming the previous identification. However, no new archival data regarding *Santo Hieronimo* has been located yet.

² The aim of the project is the interdisciplinary study and interpretation of the archaeological and historical record of shipbuilding and seafaring in the Eastern Adriatic.

³ The remains of *Santo Hieronimo* have been systematically surveyed and excavated thanks the support of the Croatian Science Foundation, Ministry of Culture and Media of the Republic of Croatia, University of Zadar, Institute of Nautical Archaeology (INA), Center for Maritime Archaeology and Conservation (CMAC) of the Texas A&M University and German Association for the Promotion of Underwater Archaeology (FUWA) from Koblenz.

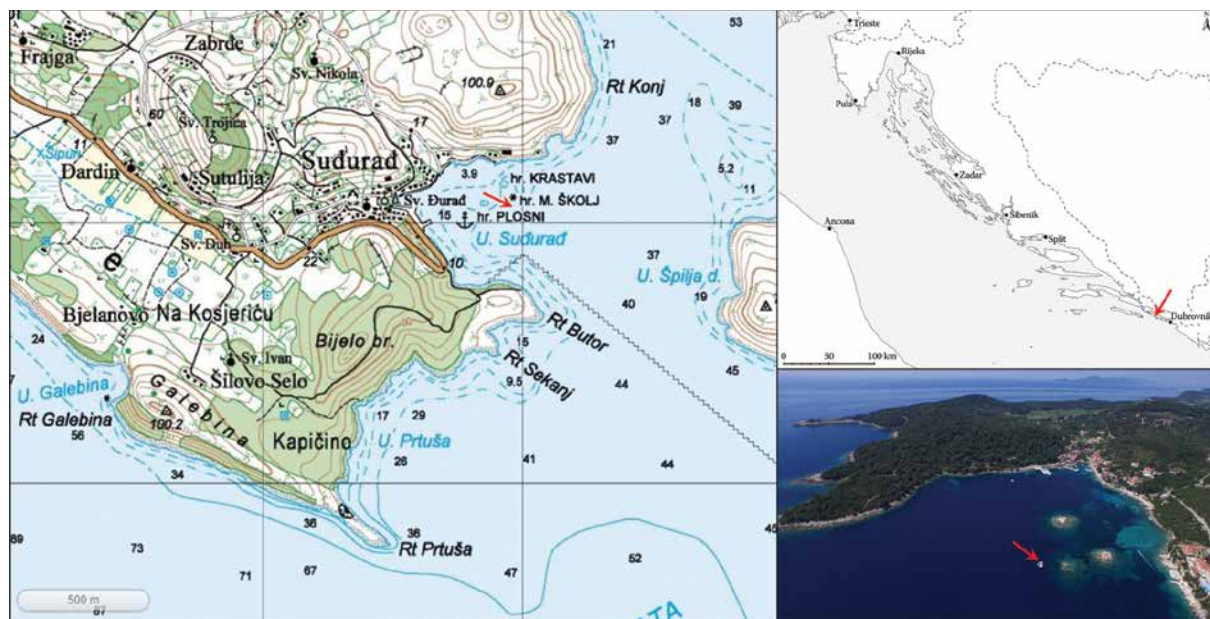


Fig. 1 Location of the site

The village of Sudurad is situated at the bottom of the homonymous Bay. At the Bay's entrance, a group of three rocks rises from the bottom to slightly above the surface (Fig. 1). *Santo Hieronimo's* hull remains and artifacts are located on a sandy seabed, south of the outer rock named Mali Školj, between 27 and 33 m deep, scattered over an area of approximately 543 m² (Fig. 2).

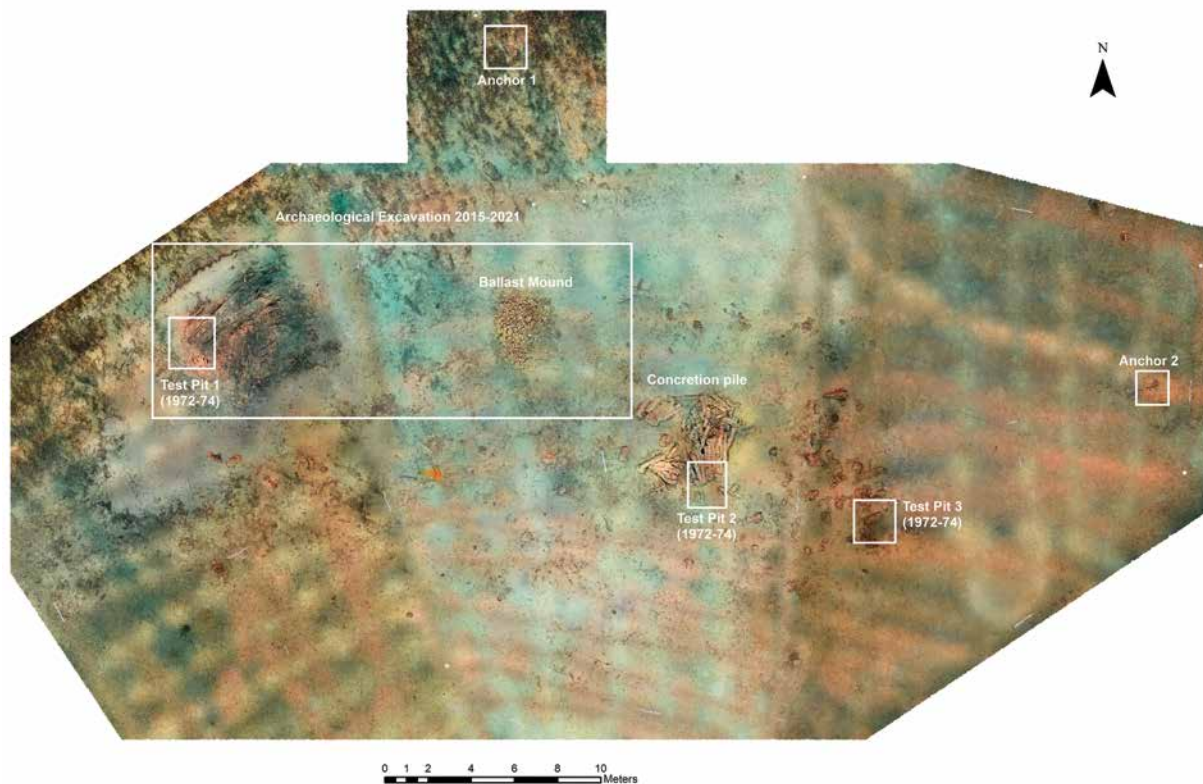


Fig. 2 Situation in 2017 (orthomosaic: K. Yamafune; interpretation: J. L. Casabán)

3. Fieldwork

Between 1972 and 1974, after the wreck's discovery, the Maritime Museum of Dubrovnik organized and conducted a series of archaeological rescue campaigns due to the constant looting that the site was being subjected (Kisić 1979; 2006). In 2000, the Department for the Protection of Archaeological Heritage of the Croatian Ministry of Culture (Mihajlović, Jurišić 2010: 104–105) carried out a short-term research test campaign on the wreck, determining that continuing its research was not a priority in Croatian underwater archaeology.⁴ In 2008, a joint team of the University of Zadar and the University Ca' Foscari from Venice (Italy) briefly revisited the site, concluding that it was worthy of systematic excavation based on its condition.⁵ In 2014, a preliminary photogrammetric recording of the site was conducted, and in 2015 the systematic research of the site began in cooperation with the University of Zadar and the Institute of Nautical Archaeology of Texas A&M University (USA).⁶

3.1. Archaeological rescue excavations 1972–1974

Zdenko Brusić directed the archaeological rescue excavation, and Anica Kisić interpreted the archaeological data (Kisić 2006: 131, 143). The archaeological research included the mapping of the site and the excavation of the three test pits. The excavated area covered approximately 20–30% of the wreck (Kisić 2006: 130).

The first test pit was excavated east of the wreck's ballast mound, the second on a pile of concreted metal bars, and the third south of the pile (Fig. 2). Brusić and Kisić interpreted the wooden hull remains uncovered in test pit 1, mainly frames and fragments of lead sheathing that protected the wooden hull from marine organisms, as part of the ship's bow. Test pit 2 revealed a mix of timbers which, according to Kisić, could be part of the upper works of the ship's stern (Kisić 2006: 130). Finally, the thickness of the sediment layer in test pit 3 prevented the archaeologists from uncovering the remains of the hull timbers. This test pit was located southeast of the area, interpreted as the ship's stern (Kisić 2006: 130). The underwater survey of the site also revealed the location of two anchors, one about 19 m east of the ballast mound and the other deeply buried in the sand 13 m to the north (Kisić 2006: 131) (Fig. 2).

Two hundred artifacts were recovered during the archaeological rescue excavations, including part of the ship's defensive armament, such as a small iron gun, stone shots, lead shots, a bullet mold, a copper powder scoop, and firepots. Among the ceramic artifacts found were cups, bowls, plates, different types of food containers, and cooking pots. Finally, a series of well-preserved metal objects, including a bronze stamp, a steelyard with a copper bowl, two lead weights, and 11 bronze coaks from the ship's blocks were also recovered (Kisić 2006: 132, 136–137, 140–142). The ship had no recognizable cargo materials, with the exception of the pile of concreted metal bars whose composition and function are still unknown. This situation led Kisić to propose that the ship was carrying some organic cargo, such as cereals, salt, or wool, which would not have been preserved (Kisić 2006: 131).

3.2. The systematic archaeological research 2015–2021

The current systematic research of *Santo Hieronimo* began in 2015 in the test pit 1 area excavated during the 1972–1974 archaeological rescue campaigns. The project's objective was the excavation, recording, and interpretation of the vessel's hull features, dimensions, and assembly. The 2015 excavation confirmed that this wreck area corresponded to the port side of the ship's bow. Since then, except in 2020, the initial excavation area has been progressively extended towards the north, south, and east using an expandable metal grid composed of 2 × 2 m squares as a reference system. The total excavated area between 2015 and 2021 covers approximately 165 m² (Figs 2, 3). In addition, the site's surface was surveyed again to record and map the different types of metal concretions scattered on the seabed. *Santo Hieronimo's* hull remains and concretions have been documented using underwater photogrammetry and direct measurements to produce a 3D model of the wreck, orthomosaics, and 2D site plans.

⁴ The research was directed by Mario Jurišić.

⁵ The operation was directed by Mate Parica, Irena Radić Rossi and Carlo Beltrame, in the framework of the Educational programme in the field of nautical archaeology and maritime history; 16th and 17th century, funded by UNESCO Participation Programme 2008–2009. Parica 2009.

⁶ The systematic research is directed by Irena Radić Rossi and Jose L. Casabán.

4. The hull of Santo Hieronimo

The excavation revealed that the best-preserved section of the vessel corresponds to its port side, with eleven strakes still assembled under the frame timbers of the bow area. In contrast, due to its collapse, most of the starboard side is composed of disassembled planking, lead sheathing fragments, and only four intact strakes extending from the bow to the stern area. The hull features identified and recorded during the 2015–2021 archaeological excavation include the keel and stem, hull planking, lead sheathing, frame timbers, keelson, mast step, ceiling, stringers, the probable remains of the pump well, and rigging components such as metal straps and chains (Fig. 3).

4.1. The keel and stem

The keel's upper surface of *Santo Hieronimo* is partially visible among the floor timbers, from the midships to the bow area, forming a flush seam with the upper edge of the garboards. The keel's width between the garboards is 28 cm, although this measurement does not include the width of the rabbets. The seams between the keel and the garboards, and even the keel's upper surface, are partially covered with pitch for most of their length, especially towards the hull's forward end. A fragment of the ship's stem, probably its lower timber, was also identified in the bow area of the wreck. Its upper end is broken while the lower part, including the stem-keel scarf, is hidden beneath the remains of the V-shaped frames and a layer of pitch and gravel that fills the spaces between them. The stem timber's lower surface is badly eroded, while the upper one appears preserved, including the rabbets where the diagonal hooding ends of the hull planking are still inserted. The rabbets have a depth of 6 cm and a width of 5 cm.

4.2. The frames

The remains of 50 frame timbers, including the master frame amidships and the V-shaped frames at the bow, were partially documented during the excavation. Thirty-three frame timbers were documented before the master frame, including the remains of V-shaped frames, or crotches, at the bow. However, the foremost V-shaped frames are badly damaged, having lost more than half of their original thickness. Sixteen frame timbers are located aft of the master frame until the eastern limit of the excavation area. On the starboard side, the floor timbers are broken just before the turn of the bilge, and only two have a fragment of the first futtock lower end still attached. On the bow port side, however, six first futtocks and five second futtocks of the V-shaped frames are partially visible. The rest of the port side floor timbers are hidden by the limber boards, and only four first futtocks lower ends are visible still attached to floor timbers aft of the mast step (Fig. 3).

The sided dimensions of the floor timbers range between 14.3 cm and 24.7 cm. However, the average width from the aftermost excavated floor timber to the 20th before the master frame is 16.7 cm, and 21.3 cm for the remaining V-shaped frames towards the bow. The increase of sided dimension of the floor timbers could be related to the location of the bow tailframe, which, together with the master frame and stern tailframe, determined the hull's shape. However, this hypothesis must be correlated with the examination of the design methods described in 16th and early 17th century Mediterranean shipbuilding treatises and archaeological parallels⁷.

The floor timbers before and aft of the master frame have an almost identical average room and space, 36.1 cm and 35.7 cm, respectively. The room and space average becomes 38.8 cm from the 20th floor timber before the master frame to the bow, with a room and space ranging between 51.1 cm and 31.4 cm.

The floor timbers amidships are 21.4 cm molded on average, including the master frame. The molded dimension increases progressively up to 45 cm from the 10th to the 20th floor timber before the master frame. The molded dimension of the rest of the V-shaped frames towards the bow is not visible because the space between them is filled with a thick layer of pitch up to the keelson. In addition, the spaces between the 29th and 33rd floor frames are also filled with a type of mortar composed of gravel and pitch, although only the lower surface of the frames is preserved.

The first futtocks in the bow area are 18.4 and 15.2 cm sided, and 19.3–16.1 cm molded. The second futtocks are 15–19.2 cm sided. The stringers hide the types of scarfs between the floor timbers and first futtocks, and the first and second futtocks, so they cannot be identified yet. However, it is expected that these scarfs will be documented as the excavation progresses.

⁷ Historical sources, e.g. Lane 1934; Nicolardi 2014; Bondioli *et al.* 2020. Archaeological sources, e.g.: Guérout *et al.* 1989; Villié 1994; Beltrame *et al.* 2014; Cazenave de la Roche 2020.

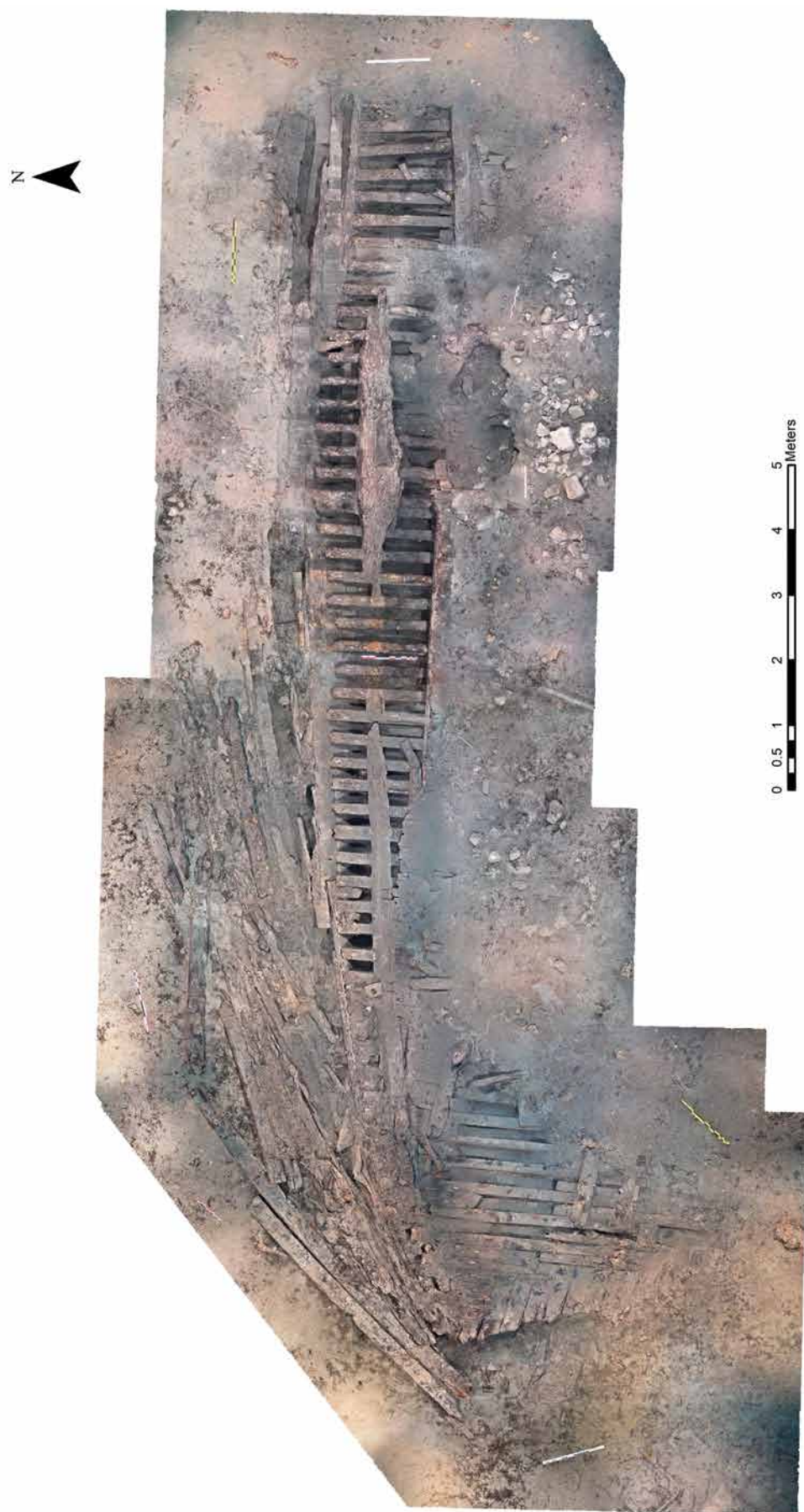


Fig. 3 Hull remains uncovered until 2021 (orthomosaic: J. L. Casabán)

The double-floor timber situated amidships beneath the forward end of the mast step was identified in 2021 as the ship's master frame. As with the rest of the floor timbers, its starboard side is broken just before the turn of the bilge, while its port side appears to continue underneath the limber boards of the ship's ceiling (Fig. 4). The floor timbers of the master frame are 17.4 cm and 16.7 cm sided, and 21 cm molded, with a combined width of 34.1 cm and a room and space between the first floor timbers before and aft of the master frame of 51.9 cm and 52.2 cm respectively.



Fig. 4 Mast step, master frame, and presumed pump well (orthomosaic: J. L. Casabán)

4.3. The planks

The average planking thickness is 6.5 cm, and the width is 20–31 cm. The maximum preserved plank length is 6.37 m, although this length might increase since several planks have not been fully exposed yet. The hull planks were fastened to the frames with iron nails that have not survived, apart from small dark ferrous deposits left in the planks. The iron-nail holes on the planks have a circular section with a diameter of 1.5 cm. Two iron nails were nailed at each plank-to-frame joint following a diagonal orientation, while at the butt joints of the planks, the orientation was vertical. There is no evidence of treenails being used to fasten the planks to the frames.

4.4. Lead sheathing

Exceptionally large sheets of lead sheathing appear underneath *Santo Hieronimo's* lower hull, especially on the port side of the bow area, where the strakes' forward ends have disappeared. The overlapping lead sheets have a width of 50 cm and a maximum length of 229 cm. Comparing the dimensions of these sheets with other published finds, the lead sheets from *Santo Hieronimo* are by far the largest. The only ones that are somewhat comparable are those from Lomellina, which measure 40 × 120 cm (Veyrat 2016: 390).

The lead sheathing is 0.1–0.2 cm thick, and some fragments present layers of pitch that may increase its thickness up to 1.3 cm. The holes and impressions on the lead sheets' surface indicate that they were fastened to the outer hull planking with tacks whose round heads had a diameter of 0.7–2.8 cm.⁸

⁸ Given the limitations of the length of the text, more will be said about the lead sheathing in a comprehensive publication of the research results.

4.5. The keelson and the mast step

The *Santo Hieronimo's* keelson appears to be composed of a single timber, with an expanded central area that forms the mast step. However, only the forward section of the keelson and the mast step are still preserved (Fig. 3). A fragment of the keelson, 6.48 m long, extends from the 10th to 28th frame before the master frame. It has a section that is 28 cm sided and 22–19.5 cm molded, and its lower surface is notched with mortises to fit the upper surface of the floor timbers. The forward end of the keelson appears to be joined to the aft end of the stemson with a horizontal flat scarf with an approximate visible length of 88 cm. The stemson fragment is 1.16 m long, with the upper surface badly eroded, and was fastened to the keelson with two iron bolts of 3.5 cm in diameter. The keelson upper surface presents three quadrangular notches, which probably served to insert the heel of the stanchions that supported the lower deck. The average dimensions of the notches are 15 × 15 cm, 4 cm deep, and have an average center-to-center spacing of 1.6 m.

The mast step extends over nine floor timbers, from the first floor timber before the master frame to the seventh aft (Fig. 4). It measures 3.21 m in length, 63 cm in width, and has a preserved height of 21 cm, with its center just after the master frame. On its upper surface, it has a rectangular mortise for the heel of the mainmast located between the first and fourth floor timbers aft of the master frame. The mortise is 73.2 cm long, 23 cm wide, and 15 cm deep. The upper surface of the mast step surface is damaged, especially from the mortise to the aft end, and a portion of its port side is also missing. The damage was probably caused by the weight of the ballast mound that was visible on the site's surface and located directly above the mast step.

The starboard side of the mast step presents four notches cut on its upper edge to insert the buttresses that laterally reinforce the mast step, although only three are completely visible (Fig. 4). The preserved edges of the notches are 17.5 cm long, 4 cm wide, and have an approximate depth of 5 cm, with a 44–50 cm center-to-center spacing. The traces of two more notches, and two preserved buttresses, 15 cm sided and a visible length of 81 cm, have been identified aft of the master frame, directly opposite the notches documented on the starboard side of the mast step.

Finally, the remains of a wooden structure, currently under excavation, situated amidships south of the mast step, have been tentatively interpreted as the western side of the ship's pump well (Figs 3, 4). A horizontal wooden plank 2 cm thick and 30 cm wide would form the partially visible side of the western wall of the pump well. The inner side of the plank is attached to a vertical, although slightly tilted outwards, post with a 20 × 13 cm section situated aft of the master frame floor timber. The pump well is not preserved north of the vertical post, and, at this stage of the excavation, it is unclear if the southern and eastern walls survived since the weight of the ballast mound severely damaged this hull area.

4.6. The ceiling, stringers, and shelf clamp

A large section of the partially excavated limber boards appears on the keelson's port side, from the bow to the presumed wall of the pump well and towards the stern of the ship, near the eastern limit of the excavation area.

The twenty-five limber boards, 47–30 cm wide and 2.5 cm thick, that form the ceiling before the master frame lie almost perpendicular to the keelson, from the scarf between the stemson and the keelson to the western wall of the structure tentatively interpreted as the pump well. However, only the edges of five limber boards are preserved up to the keelson. These edges rest on a narrow plank 10 cm wide and 2.5 cm thick situated along the port edge of the keelson, and the other edge is butted against the stringer forming an almost horizontal platform (Fig. 5). A series of transversal and longitudinal timbers situated on top of the floor timbers supports the limber boards between the keelson and the stringer. The transversal timbers, 13 cm sided and 12 cm molded, are butted against the keelson and nailed to the top of the floor timbers with two iron nails. The longitudinal timbers, 14.5 cm sided and 10.5 cm molded, are placed between the keelson and the stringer and appear to be nailed to the transversal ones. There is only one longitudinal timber near the bow whose outer side end overlaps with the forward inner side of a second timber that continues up to the floor timbers of the master frame. However, a row of slightly concave notches on the transversal timbers would indicate the presence of another longitudinal timber between this longitudinal timber and the keelson, although only the outer one survived.

The port side first stringer is visible near the ship's bow and has a preserved 8–9 cm thickness and 28 cm width. It is situated on top of the scarf joints, between the floor timbers of the V-shaped frames and their first futtocks. It also presents a notch to insert a sill that protects the space between two first futtocks. Another stringer also appears on top of the scarf joints between the floor timber and first futtocks of the frames aft of the master frame. Although this area of

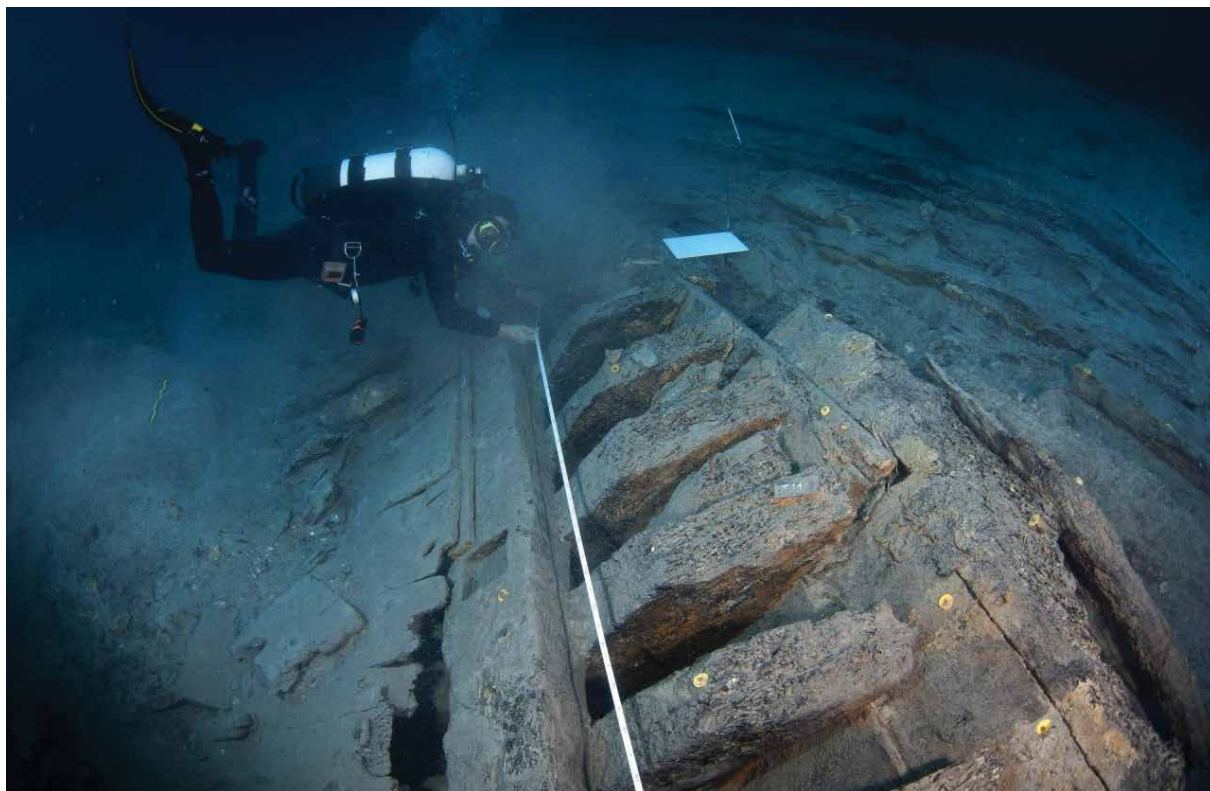


Fig. 5 Keelson and limber boards, detail (photo: B. Vukičević)



Fig. 6 Shelf clamp and second stringer on the port side of the bow (orthomosaic: J. L. Casabán)

the hull is still under excavation, the stringer presents a thickness of 10.8 cm and a width of 28 cm. A series of poorly preserved planks are situated immediately to the south of this stringer, although it has not been possible to determine yet if they correspond to the limber boards of the ship's ceiling. A second stringer is also visible on the port area of the bow, located on top of the joint scarf of the first and second futtocks (Fig. 6). This stringer is 27.2 cm sided and 10 cm molded, and its forward end is not preserved.

Finally, a timber situated above the second stringer at the bow was interpreted as a shelf clamp supporting the lower deck's beams (Fig. 6). The clamp is 27 cm sided and has a minimum molded dimension of 9.5 cm. Its upper edge presents a series of dovetail mortises where the 13 cm molded head of the beams are still inserted, with a center-to-center spacing of 39 cm.

5. Conclusion

Santo Hieronimo's hull features, location of the wreck off the Dalmatian coast in the Adriatic Sea, and the fact that the ship belonged to a merchantman of Ragusan origin could suggest that it was built in a Mediterranean shipyard. However, *Santo Hieronimo's* expanded mast step would indicate the influence of Ibero-Atlantic constructional characteristics in 16th-century Mediterranean-built vessels to be confirmed through the comparative analysis of contemporary hull remains.

It is expected that dendrochronological analysis of several wooden samples from the ship's hull taken in 2021 and the current research at the National Archive of Dubrovnik will also help to confirm the geographical location for the construction of *San Hieronimo*. In addition, and following an experimental methodology proposed by Mauro Bondioli and presented at the ISBSA 16 conference in Zadar (Croatia), a theoretical model of *Santo Hironimo* is currently being developed based on 16th-century historical sources on Mediterranean shipbuilding.⁹ This model will be adapted based on the archaeological data recorded during the ongoing excavation of the wreck to provide an accurate representation of the original design and construction of *Santo Hieronimo*.

⁹ See the text by M. Bondioli, M. Nicolardi and I. Radić Rossi, published in this book.

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Ottoman wrecks of the Black Sea

Kroum Batchvarov

Abstract: The Black Sea Maritime Archaeology Project documented at least 36 shipwrecks dating to the period of Ottoman dominance. About half the vessels were of one- and two-masted sailing merchant ships. Though broadly similar, there are significant variations between them within the common shipbuilding tradition. The sites provide us with unique view of rigs and rigging in the Ottoman Black Sea.

Keywords: Black Sea, Ottoman, rigging, shipwrecks, seafaring

Introduction

The publicity of the Black Sea Maritime Archaeology Project makes introduction unnecessary. It is enough to say that in the process of gathering data, 65 wrecks were encountered and documented to different levels of detail. A group of 36 wrecks were of local origin, from the Ottoman period (15th–19th centuries). Of these, 17 ships were identified as sailing vessels, 16 were open rowing and sailing boats. Three wrecks remain uncertain (Adams *et al.* 2018).

Though in different states of exposure and preservation, most wrecks are able to provide some information on Ottoman naval architecture in the Black Sea. The size of the sample of shipping permits to see patterns and variation within the patterns. This paper will look at a few examples from this group.

Ottoman Period Wrecks

Shipping was a secondary aim of the project and therefore limited resources were available for the study of individual shipwrecks and sampling for dating, particularly for those of the Ottoman period (Ruiz *et al.* 2019). Despite the restrictions, the information obtained is unique and extends our hitherto limited knowledge on the technical aspects of Ottoman shipbuilding in the Black Sea region. The current paper offers preliminary descriptions of a sample of the sailing ships found by the expedition.

Many of the vessels were found in less complete condition than the ancient or medieval ships. Furthermore, vessels in depths of up to about 100 m, were generally less well preserved than wrecks in deeper waters. Two explanations can be hypothesized: first, the anaerobic conditions in waters deeper than 150 m decrease the presence of the wood-eating critters. Second, in deeper waters no bottom trawling is practiced. In shallower waters a number of wrecks were found dispersed to the point of losing coherence. Also, on the later period vessels, the iron fastenings corroded and failed in a way that did not happen with the mortice-and-tenon joinery of ancient ships.

Some wrecks, though apparently well preserved, are so deeply buried in the bottom sediment that little data could be extracted from them. Examples of such wrecks would be BSMAP_2017_002 and BSMAP_2017_003. In both cases little more can be established than that the ships were double-enders.

BSMAP_2016_WRK_004

It was initially misidentified as a rowing vessel. Upon further study, it proved to be a sailing ship, though differing significantly in proportions from the rest of the vessels of the Ottoman group (Fig. 1). It is much narrower in beam, similar in proportion to the rowing boats, with a beam to length ratio of 4.6 to 1. The bow of the ship is tentatively



Fig. 1 Ottoman Wrecks off the Bulgarian Coast (author: K. Batchvarov)

identified by the presence of a single grapnel-type anchor in the ENE end of the ship. The bow is fuller than the stern and the vessel achieves its maximum beam in the first third of the overall surviving length aft of the visible stem. Initially the beams were assumed to be rowing benches. A more detailed observation of the model, video footage and still photography of the site, however, demonstrated the presence of lodging knees. Additionally, some of the beam ends seem to have mortices cut into them that may have held standard knees. The bow is obscured by a jumble of substantial timbers that may contain catheads, bitts and deck structure.

At about one-quarter of the overall length aft of the stem begins a large area devoid of beams, likely the main cargo hatch. Through the opening is visible a large quantity of squared timber, oriented fore and aft, lying under the beams. It appears that the ship carried a cargo of lumber. The hatch ends at about mid-length of the hull with a beam that is *in situ* and has a lodging knee in place on the starboard end. This knee's long arm points towards the bow, while the long arm of the knee at the forward end of the hatch points aft. Therefore, it can be concluded that the midship frame is in the area of the hatch. Eight or nine lodging knees are visible, with the majority in the aft section of the ship still *in situ*, even if the beams themselves have been dislodged. No direct evidence of the deck survives beyond the beams and knees. The stern post is present, protruding from the bottom. It appears to have been higher than the stem. On top of the site, parallel to the centerline, lies a long round spar. It likely is a sprit, as no tapering is observable and because it is shorter than the length of the vessel on deck, but a lateen yard cannot be excluded. Considering the overall shape and how much it differs from the other vessels discovered, as well as the still-present cargo, it is possible that the vessel was a specialized timber carrier.

BSMAP_2015_WRK_007 and BSMAP_2017_WRECK_005

These vessels are of approximately the same size and proportions, 18 m length by about 5 to 6 m beam, and share the same main hatch cover arrangement. It consists of a curving, vault-like frame. A central piece, like a keel, is supported by series of frames, the whole resembling the skeleton of a boat. The framework is well preserved on both ships and is not planked, which suggests that a tarp covered it when the ships were at sea. Both vessels carry their beam far aft,

creating a curved, but full stern without a transom. Despite other similarities, the vessels differ in rig. BSMAP_2015_WRK_007 is a single-masted ship. About 6 m of the lower mast survives, lying across the wreck to port, including the heel. Little of the upper spars is in evidence, but most of the bowsprit is present. The ship has remnants of a deck visible through the overburden, but unfortunately is too deeply buried to yield much more information. There seem to be some evidence that the deck in the stern stepped up to a quarterdeck. BSMAP_2017_WRECK_005 is the more exposed of the two ships (Fig. 2). It has the same main hatch cover as WRK_007, but is distinguished from it in having two masts, both of them broken. The foremast is of smaller diameter than the mainmast and is located very close to the stem, in the extreme bow. The mainmast is about mid-length of the ship, it is broken at deck level and the upper part is lying diagonally aft and to starboard. There is no evidence for a bowsprit. It appears that the vessel had a beakhead bulkhead similar to a *xebeque* (a Mediterranean fast-sailing three-masted vessel with long bow and stern overhangs). A similar structure is clearly visible on an Antoine Roux depiction (Meissonnier 1991: 43). The upper works of the vessel seem to have survived to their original height amidships and indicate low freeboard there. In the bow and stern, frame timbers survive to a greater height, which indicates higher topsides there. Amidships, off the port side lies a single grapnel anchor. Based on the location of the masts and visible spars, a lateen rig seems most likely, though the research is ongoing and this conclusion may change. Two beams seem to demarcate the end of the foredeck and the quarterdeck, but no evidence is visible of raised platforms in these areas.

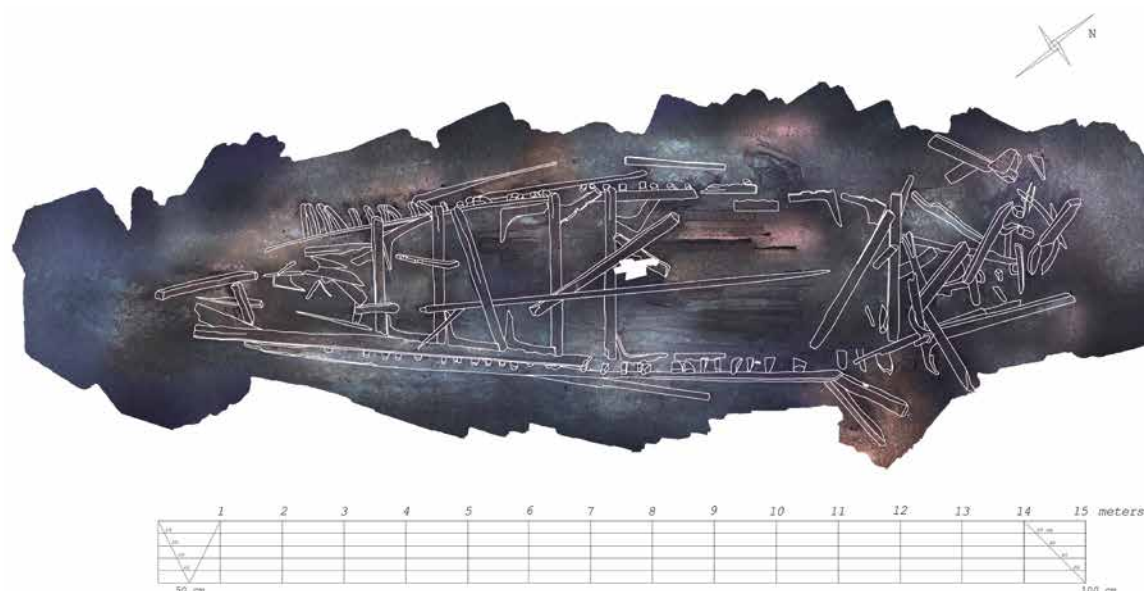


Fig. 2 BSMAP_2016_WRK_004. Ill. (author: D. Garbov)

BSMAP_2015_WRK_006

Arguably this is the most spectacular of the Ottoman wrecks (Fig. 3). The archaeological crew nicknamed it the 'Flower Wreck' as it is heavily decorated in carved floral elements on the bitts, the crutch and the tiller. The vessel is among the larger ships in the group at about 21 m overall length. Beam on deck is about 5 m, giving it a 4 to 1 ratio. The vessel's deck is divided into three parts by massive beams which lie on top of the deck. The bow area is covered with overburden and debris, but it does not appear to have had a raised platform. In contrast, the stern did have a quarterdeck with a low balustrade of turned pillars separating it from the waist of the ship. The waist itself extends over half the length of the wreck and is distinguished by having a very long central hatch, extending practically the entire length of the area. At present no covers are identifiable in the wreckage, but five of the beams of the ship are visible, spanning the hatch clearly visible in Figure 3. At the forward end are visible the mast-partners consisting of two wide planks with half-round cutouts, which once fit around the mast at the deck level. As in the previous example, the frames in the bow and the stern are higher than the frames amidships. In the waist, surviving on the port side only are the remnants of an open two-tier rail that extended between the higher sides of the bow and the stern. Further aft, on the port side of the quarterdeck lies the heavily curved tiller, the rear end of which is richly carved with the known floral decorative elements. Most of the sternpost survives and the rudder is still hanging off of it, protruding above the sternpost. Coils

of rope are hanging off the tops of the frames. Aft of the forecastle terminus, on the larboard side, lies an Admiralty pattern anchor. The stock is on the deck, the arms are mixed in the timbers of the open double rail and are lying on the mud surface. It is visible that the arms are almost straight with sharp angle of the crown, suggesting an earlier rather than later postmedieval date.

The mast itself is broken at the level of the hatch coamings with a chunk of it fallen forward over the starboard forecastle. Forward of the mastpartners, at the front end of the hatch, are located the bitts. They are carved with floral elements, shaped from hemispherical dots. They would have formed the step for the bowsprit, too, though the spar is no longer in place. At the aft end of the hatch opening, a crutch with two hooks is standing. It too is decorated with carved flowers similar to the ones on the bitts. A long thin spar is now supported by the crutch that likely was once a

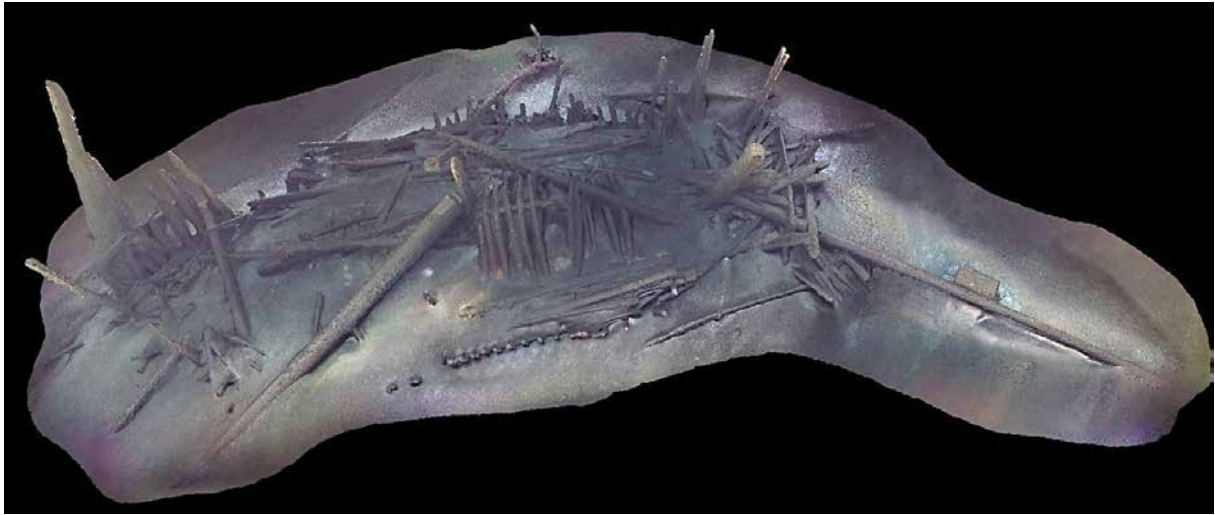


Fig. 3 BSMAP_2017_WRECK_005. Ill. (author: K. Batchvarov after R. Pacheco-Ruiz)



Fig. 4 BSMAP_2015_WRK_006. Ill. (author: R. Pacheco-Ruiz)

topgallant mast, as crosstrees and trestletrees are still attached to it. It is now upside down stuck into the mud. On the forecandle lie a few spars that likely are fragments of the topmast and the bowsprit. Off the starboard side of the ship is a long thin spar, which seems to be a sprit, based on a shoulder cut into its forward end, where a strop for a halyard would have stood. On the port side and also leaning from the crutch forward are light round timbers that likely are yards.

BSMAP_2014_BS_763

BSMAP_2014_BS_763 is a small vessel of about 14-15 m, with two masts (Fig. 4). The hull is double-ended, well exposed above the mud line, though as usual for the later wrecks, the planking has mostly fallen off the frames, as the iron corroded. The frames are very nearly straight, flaring, with no tumblehome which is a common characteristic of the Ottoman sailing ships observed so far (Chapelle 1957). As in some of the above cases, the stern and bow platforms are delineated by massive beams running athwartships on top of the planking. The aft mast is split at about deck level, with the upper part lying to starboard. In context with each mast, lie two, overlapping spars. For the foremast the pair of spars lies to starboard and for the mainmast – to port. No other spars are visible. The well-preserved stem has a notch in its upper end that could be faying face for a knee for a beakhead, as seen on lateen-rigged vessels (Delacroix 1997: 9–17; Gueroult de Pas 2004 (1710): pl. 2, 5, 6). Based on the location and description of the spars, it is logical to conclude that this vessel was lateen-rigged and the yards were built up from two scarfed timbers.

BSMAP_2014_BS_1287

BSMAP_2014_BS_1287 is a small ship of about 15 m length. It is notable for having a well-preserved mast with topmast still attached, lying to starboard. It has raised forecandle and quarterdeck with distinguished planking pattern. On the forecandle, the planks are at a diagonal, meeting on the centerline with the narrowing forward, towards the stem. On the stern castle, the pattern reverses. The waist of the ship is planked parallel to the centerline. At least one more wreck has the same pattern of deck planking, BSMAP_2014_BS_1428. A wreck lying about 20 m away from the excavated Kitten shipwreck, had the same pattern of planking on its forecandle when last observed in 2010. BSMAP_2014_BS_1287 has its rudder still attached to the sternpost, though the tiller has fallen. In the bow, powerful bitts, as seen on most Ottoman wrecks that have bowsprits, are fayed to the aft face of the beam separating the forecandle. The bowsprit still butts into them, raises above the foredeck to the point where it crosses the stem through a crutch acting as bollard timbers. Arguably the most interesting feature of this wreck is the topmast doubling. While on most western ships, the topmasts are forward of the lower masts, on this Ottoman ship it is aft of the lower mast. Furthermore, the doubling is strengthened with three brackets that substitute for the western mastcaps. The spars strewn around the wreck demonstrate that the ship was rigged with a spritsail and square sails. Similar rigs are depicted both in contemporary western iconography – particularly by Melling – and by the French naval officer Admiral Edmond Paris (Paris 1999).

BSMAP_2014_BS_1392 and BSMAP_2014_BS_1428

Vessels BSMAP_2014_BS_1392 and BSMAP_2014_BS_1428 are very similar. Unfortunately, the first one is in very bad state of preservation, practically entirely broken up. Nevertheless, enough coherence survives to be worth a description. As with most of the Ottoman wrecks, this vessel, too, has a distinct division between the stern, bow and waist. The stern and forecandle are delineated with the ubiquitous beam on top of the planking. It was a single-masted vessel with the mast lying nearly perpendicular to port. It is clear that the vessel was fully decked, that the bow and stern had the same decking pattern as BSMAP_2014_BS_1287. The difference lies in the decking of the waist, where a wide and thick kingsplank is observable. Just forward of the mast, there is an offset square cutout into the surviving kingsplank. It likely was intended for a hatch, the port side of which is no longer observable. Aft of the mast is seen a small round opening, with the kingsplank around it notched in a square shape. Off to port, and close to this location, lies a very crudely made crab-capstan. It is carved from a single tree, with no whelps, but the lower part of the capstan is shaped into an 8-sided trunk, while the upper part is a hexagonal pyramid. There are three levels of mortices for the capstan bars. The stern has a very narrow – single plank width – transom that tapers to nothing towards the waterline. It also is a feature known from iconography.

BSMAP_2014_BS_1428 is by far the better preserved of the two similar vessels (Fig. 5). The vessel is practically

intact. A notable feature is that the vessel's forecastle does not end aft in a straight line, but in an arc, centred, presumably, on the stem. This may be unique to this specific vessel. Similar to the previously described ship, BSMAP_2014_BS_1428 has a massive kingsplank along the centerline of the deck in the waist. At the forecastle and sterncastle breaks, square scuttles are cut into it. Beginning at the mast and offset to starboard is the main cargo hatch. Between it and the scuttle in the stern, is located a crab-capstan. This example is built up with separate whelps and its square head has its corners so heavily chamfered as to make it practically octagonal in shape.

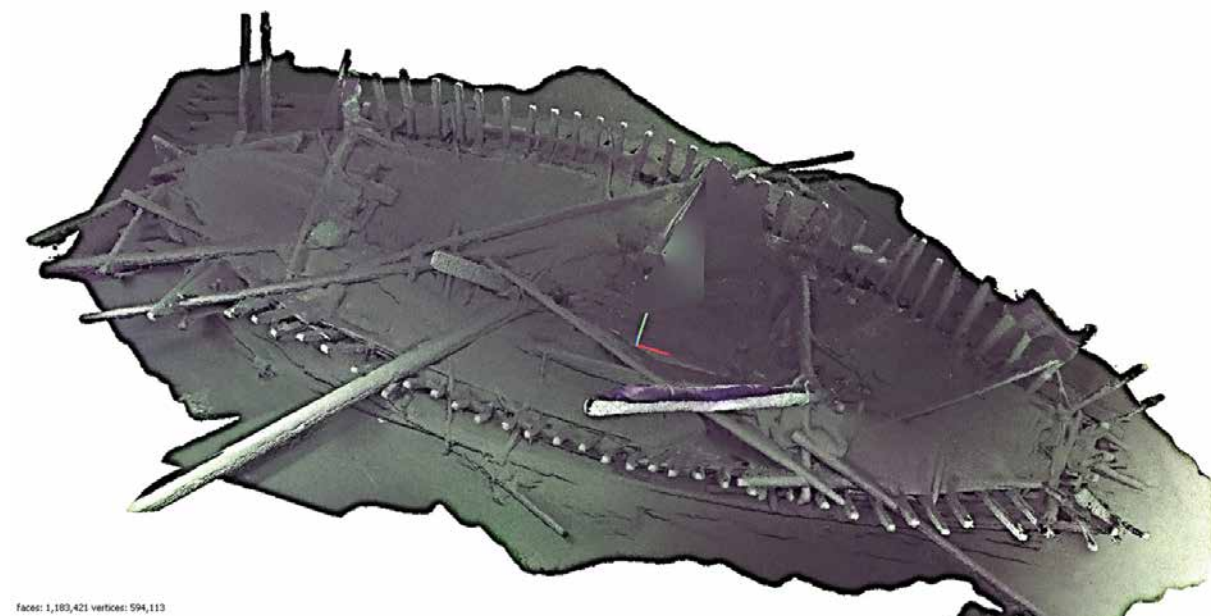


Fig. 5 BSMAP_2014_BS_763. Ill. (author: K. Batchvarov after R. Pacheco-Ruiz)

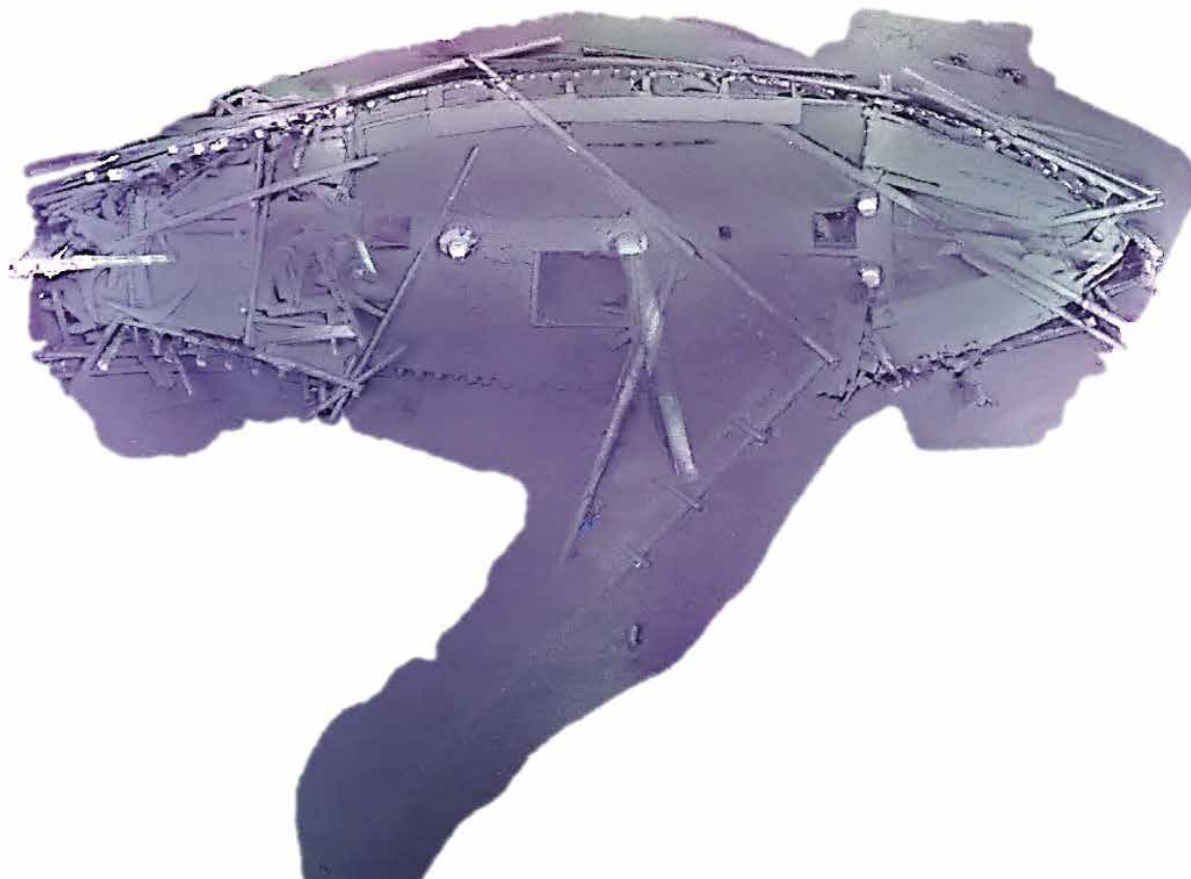


Fig. 6 BSMAP_2014_BS_763. Ill. (author: K. Batchvarov after R. Pacheco-Ruiz)

Off the starboard side of the vessel lies most of its tophamper: mast, sprit, topmast. It, too, has the triple brackets at the doubling. Yards are lying on the deck, parallel to each other and in positions appropriate for close reaching. Finally, in the stern, the rudder is still present together with the tiller.

BSMAP_2017_WRECK_004

The only vessel that may have carried guns in this group is BSMAP_2017_WRECK_004 (Fig. 6). The wreck is substantially complete, but much of the starboard side is entirely covered by the overburden. The port bulwarks have peeled off at the level of the deck, though the toptimbers are still held by planks and wales. At least three gunports are clearly visible, though there may have been more. No cannons have been observed so far. The ship has a very short raised quarterdeck, separated by a 4-stanchion rail. There is no raised forecastle and no separation of the bow from the waist; however, there may be a beakhead step-down from the deck. The ship possessed two, widely separated masts. Aft of the mainmast are located two reciprocal pumps with the plungers still in place. Just ahead of the foremast are the bitts into which the bowsprit butts. The vessel possesses a total of four anchors: three Admiralty type and one grapnel. On each side of the bow, hanging off the bulwarks are admiralty anchors. The third admiralty anchor is lying on the starboard side of the bowsprit, while the grapnel is to port. Both are adjacent to the bitts.

Concluding remarks

Though the ships differ in details such as length, proportions, rigs and deck details, all of them share at least some characteristics. These include the shape of the vessels – all of them are double-enders as far as can be established – all are of frame-based construction, with fairly straight toptimbers, with no tumblehome, but flaring out sides. Based on the visible regularity of the frames, it seems reasonable to suggest that the vessels were built with some variant of whole-moulding, as was the case with the Kitten shipwreck (Batchvarov 2011). Probably the most significant contribution to our understanding of Ottoman shipbuilding in these waters is the information derived on the rigs of Black Sea merchantmen. This author is not aware of any Ottoman treatises on masting and rigging; thus, this is the first time that we can glean knowledge of this subject outside of iconography and memoirs because of the survival of the actual spars (Verwey 1932).

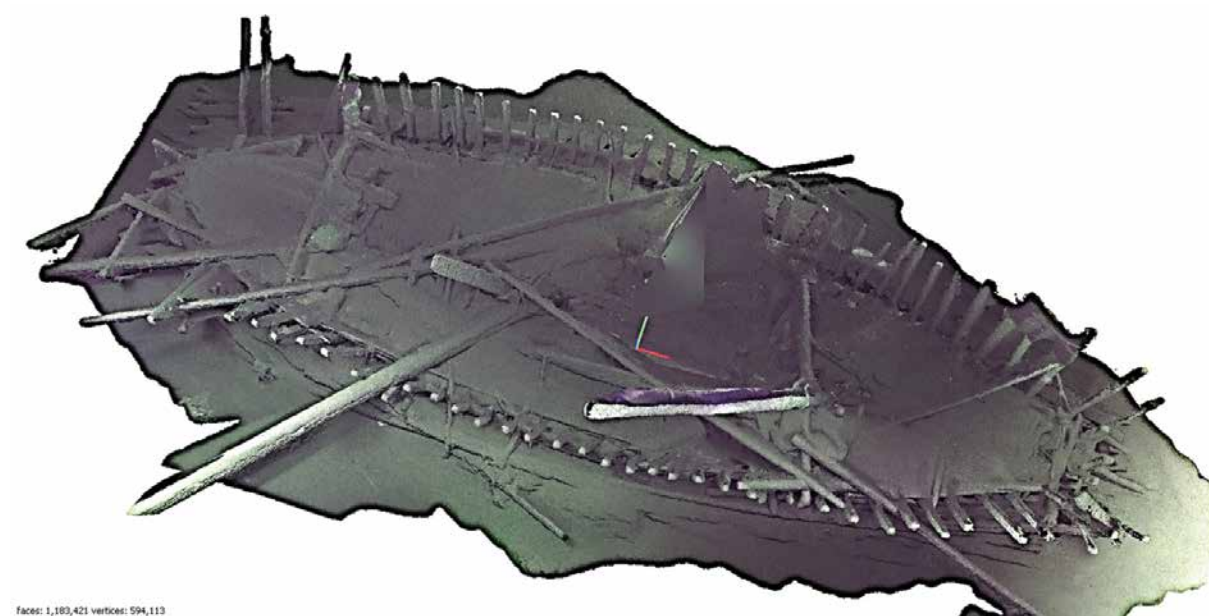


Fig. 7 BSMAP_2017_WRECK_004. Ill. (author: K. Batchvarov from model by R. Pacheco-Ruiz)

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Yesterday's watercraft, tomorrow's watercraft.

Documenting the 20th century wooden watercraft abandoned on the banks of Basque intertidal estuaries

José Manuel Matés Luque

Abstract: In the Basque Country there are many wooden watercraft abandoned on the banks of estuaries. They are a rich source of information for insight into not only ships and boats built in the 20th century, of which the last examples have been disappearing since the 1980s, but also they may provide information on older watercraft as they represent the last stage in ship- and boat-building rooted in the Middle Ages. Study of these watercraft has revealed interesting details that engender an understanding of the possible evolution of medieval and/or 16th century features. Hence the need to document such contemporary and abandoned watercraft is vital.

Keywords: intertidal archaeology, nautical archaeology, ethnoarchaeology, Basque Country, Bizkaia

1. Introduction

This paper will discuss abandoned watercraft in the estuaries of Bizkaia (one of the provinces in the Basque Country), as they are the last stage of wooden watercraft built there in the 20th century. They are important not only because they are part of the maritime heritage but also because they might provide a glimpse into past shipbuilding techniques, perhaps even as early as the Middle Ages.

2. Background

Basque shipbuilding is widely known due to its importance in the development of naval architecture during the Middle Ages and 16th century and shipwrecks of Basque origin have provided information that sheds light on boat- and shipbuilding in that period. Among those shipwrecks are the Newport ship (Nayling, Susperregui 2014), the Urbietta wreck (Izaguirre, Valdés 1998; Izaguirre, Valdés, Matés 1999; Izaguirre *et al.* 2001; Rieth, Izaguirre 2004; Rieth 2006), the Barceloneta wreck (Pujol i Hamelink, Soberón Rodríguez 2011; Soberón *et al.* 2012), the Orio wrecks (Izaguirre 2004a; 2004b) and the Red Bay (Grenier, Bernier 2004; Grenier, Bernier, Stevens 2007).

Regarding their location, only the Urbietta (at Gernika) and Orio (at Orio) wrecks were found in the Basque Country. Certain isolated and single timbers dated in the Middle Ages and found in the Basque estuaries should be added (Gómez Bravo, Zallo Uskola 2014; 2021; Matés Luque 2016a; 2016b) to these wrecks.

A question therefore arises: where are the remaining wrecks in the Basque Country? Their discovery awaits, either based on a proper research plan or simply by chance discovery. Meanwhile, attention should focus on the wrecks still visible in the intertidal zone in the Basque Country. Unfortunately, many people do not consider these wrecks an archaeological resource due to their 20th century provenance. Leaving their dating aside, however, their importance rests on the fact that they are still accessible and they may exhibit features which can be dated back to earlier times, as per the discussion below.

3. Wooden ships and boats

In 2017 we began surveying the estuaries, noting any type of man-made artefacts or structures (Matés Luque 2015; 2016a; 2017; 2018; 2019; 2020b; 2020c); after the first survey, further focus was accorded to documenting abandoned watercraft (Matés Luque 2019; 2020a; 2022) (Table 1). Some of such watercraft have shown interesting features.



Fig. 1 View of Mendexa I at the time of her recording in 2019. Previous photographs showed part of her sides still upright. It is clear that considerable data have been lost (photo: J. M. Matés Luque).



Fig. 2 Details of the floor frame head and futtock heel on the Mendexa I double frames. The futtock for the middle and left frames is not present but the floor frame head can be seen cut and ready to join the futtock. This joint can be seen on the right floor frame and futtock (photo: J. M. Matés Luque).

3.1. Mendexa I

This is a fishing vessel abandoned perpendicular to the riverbank, possibly in 1965 or earlier. Since its abandonment, the remains have endured considerable damage. Photographs from earlier periods show the sides still standing, but by the time of our investigation they had already disappeared (Fig. 1). This proves how important it is to immediately document these vessels so that the entirety of their features are recorded.

While documenting the timbers, an interesting feature was observed: the way in which the floor frames' head and futtock heel are connected (Fig. 2); the floor frame creates a longer frame by joining the head to the futtock heel. This feature has been observed in other wrecks.

3.2. Mendexa II

This vessel is the largest wreck recorded. Abandoned in 1978 or earlier, this fishing vessel still has some framing and outer planks in situ (Fig. 3). Although it needs to be fully cleaned to document and identify its various parts and timbers, some cleaning has been done. Some of the upper timbers have apparently collapsed on the bottom deck. Thus, the complete removal of mud to identify the upper and bottom timbers is needed so that its proper structure can be identified.

The same feature of a joined floor frame head and futtock heel, as already documented in the Mendexa I, has been observed.



Fig. 3 General view of Mendexa II (photo: J. M. Matés Luque)

3.3. Mendexa III

Lying flat next to Mendexa II, it was chosen to ascertain whether the timbers from Mendexa II had collapsed outwards or they belonged to a different vessel. The removal of mud revealed that it was indeed a different vessel. The stempost was identified several days later, several meters forward from the main structure. Unfortunately, the wreck was covered midships by an overturned small (and contemporary) boat which needs to be documented and removed before Mendexa II's midship can be cleaned. Because it is small and positioned further inside the creek than Mendexa II, Mendexa III seems to be older than Mendexa II.

Again, double frames were found, although their size is not long enough to confirm the joining of frame head and futtock heel.

3.4. Mendexa IV

Found while cleaning Mendexa III, this is a clinker-built boat lying on its side; several oval copper sheets (similar to a military dog-tag) and copper nails were recovered. It was also covered by the same overturned modern boat that covered Mendexa III, thus interfering with the full documentation of the other and more interesting vessels.

It is worth mentioning that this is the first clinker-built boat excavated, albeit partially, during our research and it dates to the 20th century¹. The interesting feature about this vessel is that it proves that the clinker-built tradition had not disappeared by the 19th century, as was always assumed, based on the introduction of the carvel tradition to the Basque Country in the late Middle Ages.

3.5. Lekeitio I

This is a large flat-bottomed river barge (Fig. 4). Its importance rests on the fact that it may be the only wooden barge left since the latter were supposedly made redundant by iron barges, mainly in Bilbao at the end of the 19th century (Odriozola Oyarbide, 2002: 133). Tool marks were observed on some timbers, which suggested that it was mainly built with hand tools. This may suggest that it is old, perhaps dated to the end of the 19th century. The high number of limber holes at the bottom of the floor timbers indicate that it may have had a water pump.

A question arises as to how such an immense barge ended up on this riverbank if the river course is narrow. Does it mean that it was used when high tides were active so more water allowed a wider course to navigate up the estuary? And are there any other wooden river barges waiting to be found? If they existed, they would be a very important archaeological resource to understand river navigation and ancient boat-building.



Fig. 4 Lekeitio I at nearly low tide. The prow is still buried (photo: J. M. Matés Luque).

3.7. Ondarroa I

Documenting this vessel was difficult; its position in the lower part of the estuary did not allow sufficient time for cleaning between high and low tide (Fig. 5). Moreover, the deposits were full of debris (bricks, concrete, plastic...) which formed a rather hard surface that required the use of a pick. Water from the sediments on the upper part of the riverbank found its way down to the wreck; once such debris was removed, very liquid mud appeared. This made excavation difficult since mud and water could not be entirely removed, which prevented us from recognizing and documenting the timbers. A different approach to excavation is needed, since its bottom part is still covered by debris;

¹ Clinker boat- and shipbuilding in the Basque Country was supposed to have disappeared during the 19th century or earlier. However, another clinker-built boat was excavated in 2022 in a beach in Getxo, about 42 km away across the province from Mendexa IV (Matés Luque 2023). This vessel is also discussed herein.

proper cleaning will help to identify its timbers and features. Having said that, its frames are also double and the floor frame head and futtock heel are joined to create a frame as in Mendexa I.

Additionally, it is the only vessel for which a name has been determined. It might be a Mediterranean vessel called *Santa Fe*; however, there is a mismatch between the date when the archive shows its final and working year and aerial photographs which show it abandoned on the riverbank. Thus, is the floor frame head and futtock heel feature a component of the Mediterranean style or was it only used in northern Spain? More archival research and fieldwork are needed to find out whether it is indeed the Mediterranean *Santa Fe* or the Atlantic *Santa Fe*.



Fig. 5 View of Ondarroa I as the tide comes in. This makes excavating it difficult due to the short time between high and low tide (photo: J. M. Matés Luque).

3.8. Gorrondatxe boat

Although this vessel was not abandoned on any estuary but on a beach, it is worth presenting here (Fig. 6). This is a recently excavated small clinker-built boat (Matés Luque 2023). Found on the Gorrondatxe beach (Getxo) by the late provincial archaeologist, Mikel Unzueta, he asked us to confirm whether the small visible timber protruding from the sand was a wreck or just a post for different use (for instance, a beach hut). The many visits performed at different times showed no difference regarding the timber exposure, since the hard sand which covered it had not been removed nor exposed any other part of the original timber or further timbers. Therefore, an excavation was done; on the first day, it was clear that it was a clinker-built boat, possibly abandoned in the 1960s or 1970s. A full excavation was completed in the following days, in two stages, nearly six months apart.

Several internal patches appeared. They consisted of 12 copper nails divided into four columns. The first three patches were thought to be repair patches, but after the appearance of the fourth it was clear that they were too many repair patches for such a boat. Besides, they were placed in a regular pattern so that intent when placing them at the time of its construction was clear. Such patches might represent a boat-building style. More small clinker-built boats are needed to confirm this style.

The interesting fact about this boat is that it is the second clinker-built boat found (see Mendexa IV above) which supports the idea that this boat-building style did not disappear despite the introduction of the carvel style in the Basque Country back in the 15th century.



Fig. 6 View of the Gorrondatxe boat fully excavated, with the sea washing over the beach. This is the second modern clinker-built boat found, dated to the late 19th or early 20th century and abandoned or wrecked in the 1960s or 1970s (photo: J. M. Matés Luque).

4. Conclusion

Besides these wrecks, some others or the remains thereof were also recorded². The wrecks presented here are those which exhibit certain noteworthy features. This demonstrates the importance of documenting wrecks even if they date to the 20th century.

² There is a bottom section of a vessel in the middle of the protected zone in the River Lea, large enough to provide interesting details. Unfortunately, the Environment Agency forbade us from approaching it on foot, since apparently, the *Zostera noltii*, an endangered seagrass which covers the wreck (and is present in the area), could be affected. A solution to access the wreck without damaging the seagrass should be found. The recording of this wreck will provide new features to document which will be extremely useful in our research.

For example, the joining of floor timber heads and futtock heels might be a 20th century evolution of the dovetail joint, a common feature of the so-called Ibero-Atlantic shipbuilding tradition ((Loewen 1998; 2007; Alves 2001; Oterling 2004; Grenier, Bernier and Stevens 2007). Such evolution since the 16th century may be due to an easier way of shaping frames and joining them head to heel, since carving the dovetail joint using an adze requires more expertise, and time, than using a saw to prepare frames of similar shapes and dimensions.

It is clear that new data is needed to support this statement; older wrecks, dated between the 16th and 20th centuries, are needed to support this hypothesis, i.e., the dovetail joint evolved, albeit slowly, into the head and heel double frames observed in the 20th century wrecks.

As archaeologists, we tend to focus on old watercraft to understand past societies. By documenting such watercraft, our intention is to understand the people who built, used and, sometimes, died in them. As a general rule, the older they are, the more interesting they become, since it is supposed that less data is available for older times and, therefore, they provide us with a glimpse into an unknown period to complete our knowledge on ancient shipbuilding.

Unfortunately, some people tend to think that recent watercraft are widely known so there is no need to document 20th century watercraft. This statement is misleading. In the Basque Country, the fishing fleet began to disappear when European fishing policies from the 1980s supported the dismantling of “old wooden fishing ships and boats” and/or the sinking of many of them beyond the continental shelf, in the Capbreton submerged canyon. Many Basque wooden vessels were, therefore, intentionally destroyed or sunk³. A few fishing boats are held in museums or are maintained and restored by associations; this provides an opportunity to admire the watercraft which once were the nation’s pride. Unfortunately, in this process, some vessels which were ‘saved’ were, later, destroyed due to poor maintenance on dry land⁴.

Fortunately, there are several books and articles containing photographs and drawings which are good sources of information on traditional Basque vessels (Astui Zarraga 1984; 2012; 2023; Apraiz Zallo 1997; 1998a; 1998b; 2000; Erkiaga Laka 2001; Cayuela Camarero *et al.* 2007; Pueyo 2008). However, it is insufficient to simply have a collection of old photographs which show many of these vessels in their heyday; we should not consider this enough just because photographs are available. Archaeology relies not only on external photographs but also on the documentation of all available details. Therefore, unless a full set of photographs, drawings, plans or sketches had been done before a wreck disappeared, there is truly a loss of data from an extraordinary machine which will no longer be available to us. This is, therefore, why it is so vital that those remains in the intertidal zone do not suffer a similar ‘second’ oblivion.

Currently a great deal of enthusiasm can be found in the small associations⁵ which restore, maintain and even build small traditional wooden boats. Additionally, some important fishing vessels held in museums, such as the *Nuevo Antxustegui*,⁶ *Ortube*, and *Mariñel*, are fortunately being restored.

Such efforts are welcome and noteworthy, as it shows a clear desire to keep a legacy alive. In recent years, the Basque Government has been supporting such efforts with an annual subsidy for those who apply and fulfil the requirements.⁷

While these different initiatives are welcome and supported, many wooden watercraft are still abandoned on the banks of estuaries in the Basque Country. They are a rich source of information for insight into not only ships and boats built in the 20th century, of which the last examples have disappeared after being replaced by fibreglass and metal vessels, but also to understand older watercraft, as they represent the last step in ship- and boat-building with roots in the Middle Ages. Changes on joining the timbers and many other features (yet to be identified) may be there, still buried under the mud of the abandoned wrecks. Their documentation will help archaeology when old wrecks are found, recorded and researched.

For example, the two small clinker-built boats suggest that such a style never disappeared. This may be related to the fact that small vessels were still built in that style, a tradition maintained by small boat builders, while bigger vessels were built in the carvel style. Furthermore, the first nautical sporting events in the Basque Country in the last quarter of the 19th century somehow helped keep the clinker style alive for a time until the full carvel style was adopted for nautical racing (Aguirre 2009: 12–15).

Hence, the final statement is that it is important to document the abandoned wrecks now that they are still available

³ Other than a few random photographs, they were not documented properly before such sinking or destruction.

⁴ For instance, the fishing ships *Lucía* and *Playa de Ondarzabal*.

⁵ Among them are Itsas Egurra Haizean, Beduola Elkartea, and Euskal Bateleroak Elkartea.

⁶ This vessel suffered considerable problems until its reconstruction began. Prior to that, a 3D recording was done in case of its destruction (Matés Luque, Moral Goirigolzarri 2017). Luckily, it is enjoying a second lease on life in the Bilbao Maritime Museum mainly thanks to the input of its owners and friends of such supporting team and the leadership of the Maritime Museum to restore her.

⁷ So far, this subsidy has been ongoing for the last 5 years, so this is a remarkable effort which has to be acknowledged. The subsidy rules for 2024 can be seen in BOPV 14 June 2024. <https://www.euskadi.eus/web01-bopv/es/bopv2/datos/2024/06/2402891a.shtml> (last accessed on 6 October 2024).

and form a structure. If we allow time and the environment to devastate them before they are properly documented, they will collapse, fall apart and disappear. Then it will be too late to document anything. If this happens, what will future archaeologists think of us? We had the opportunity but did nothing. We hope that our current efforts to document such a variety of vessels in the intertidal zone will add new information to our current knowledge.

Vessel name	Type	Town	Date of abandonment (by)	Length	Width	Height
Mendexa I	Fishing vessel	Mendexa	1965	8.1	2.64	
Mendexa II	Fishing vessel	Mendexa	1978	16.74	4.45	1.56
Mendexa III	Fishing vessel	Mendexa	Before Mendexa II	11.61	1.68	
Mendexa IV	Boat	Mendexa	After Mendexa III	1.34	1.02	
Lekeitio I	River barge	Lekeitio	1956	13.35	5.1	
Lekeitio III	Fishing vessel	Lekeitio	1965			
Lekeitio X	Fishing vessel	Lekeitio	2011	4.9	3.55	
Lekeitio XI	Fishing vessel	Lekeitio	2011		3.8	2.08
Ondarroa I (Santa Fe)	Fishing vessel	Ondarroa	1965	14.85	4.6	
Ondarroa II	Small boat	Ondarroa	1985	6.86	1.75	
Ondarroa III	Unknown	Ondarroa	Unknown			
Gorrondatxe	Auxiliary boat	Getxo	1970's	4.8	1.89	

Table 1 Main details of the vessels excavated and/or documented (adapted from Matés Luque 2020: 318; those in bold are presented herein).

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A nearly intact bombarde in the western Black Sea: initial observations

Dragomir Garbov

Abstract: This paper discusses a shipwreck recorded by the Black Sea Maritime Archaeology Project. The site lies in 137 m of water on Bulgaria's continental shelf. It represents the remains of a 20-metre-long two-masted wooden sailing ship. Physical evidence was examined against documentary sources in an attempt to contextualise the archaeological site. The vessel is discussed as an early 19th century bombarde, a light cruiser or armed merchantman typical for the region of Provence, but also built in other parts of the Mediterranean. The shipwreck symbolises the re-integration of the Black Sea in the globalised maritime world of the 'long nineteenth century.'

Keywords: Black Sea MAP, shipwreck, polacre, ketch, bombarde

1. Introduction

The Black Sea Maritime Archaeology Project (Black Sea MAP) was undertaken in waters under Bulgarian jurisdiction (Territorial Sea, Contiguous Zone and Exclusive Economic Zone) between 2015 and 2017 (Vagalinski *et al.* 2016; 2017; 2018; Fig. 1/A). The research program was aimed at assessing impacts of Late Pleistocene and Holocene environmental change on human populations. Geophysical investigations contributed to the recording of 65 wooden shipwrecks in various depths of water between -30 and -2,200 m. The palimpsest of archaeological sites reflects over 2,400 years of navigation on the Black Sea.

This paper presents the author's preliminary remarks on a shipwreck recorded by Black Sea MAP. The archaeological site retains the largely coherent remains of a ketch-rigged wooden vessel. It is part of a category of three similar sites containing the wrecks of 19th century bombardes, scattered along the present-day Bulgarian coast. This is the earliest and the best preserved of the three shipwrecks.

The site was recorded via non-intrusive methods in 2016. As no destructive sampling was undertaken, this study is built upon examination of records as accumulated by Black Sea MAP and comparative analysis with known parallels. The archaeology of the shipwreck is discussed against contemporary sites, documentary sources and published research, and a working hypothesis on the chronological and cultural parameters of the vessel is proposed. Future research on the specifics of hull and rigging will allow for more detailed conclusions.

2. Investigation and recording

The 2016 season marked the second deep-water expedition of Black Sea MAP. Works were focused on core-sampling and geophysical survey in Bulgarian waters. The archaeological permit did not contain allowances for destructive investigations and sampling of shipwrecks. Non-intrusive inspections and archaeological recording were undertaken opportunistically when shipwrecks were detected during geophysical surveys (Vagalinski *et al.* 2017).

In 2016, the Black Sea MAP team worked aboard the ROV support ship MV *Stril Explorer* (Fig. 1B). The archaeological site was located via the ROV *Surveyor* (Fig. 1C) and recorded in a *c.* two-hour long archaeological inspection using a *Supporter* work-class ROV on September 21, 2016 (Fig. 1D). Low-altitude high-resolution surveys via side-scan sonar and multibeam echosounder were undertaken, followed by video and photographic recording, contributing to a high-resolution scaled georeferenced photogrammetric model (for method refer to Ruiz *et al.* 2019). The information acquired during these surveys forms the basis of the current study.

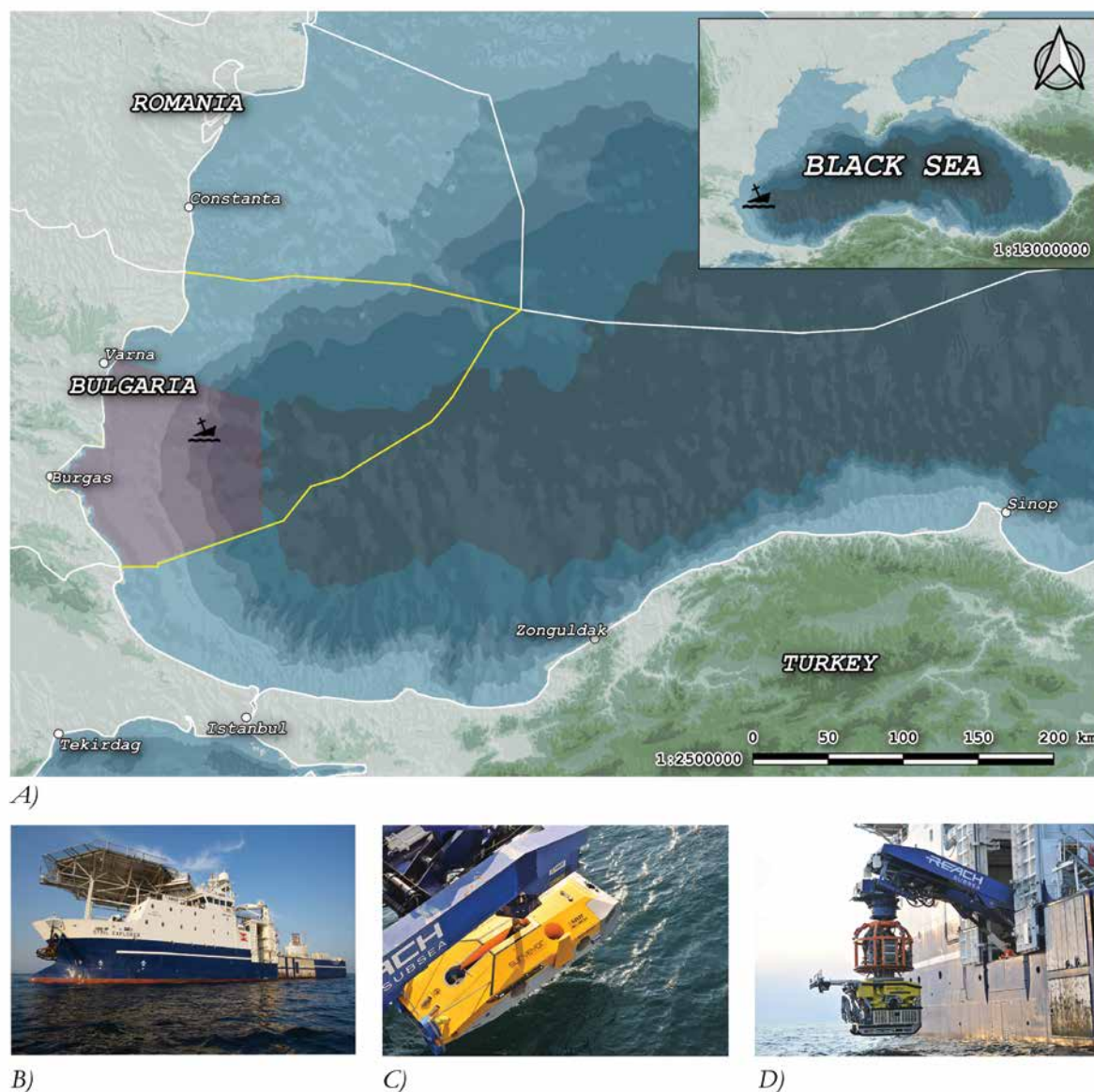


Fig. 1 A) Location of the subject site within the Bulgarian EEZ (outlined in yellow) and the Black Sea MAP study area (shaded in red); B) MV Stril Explorer; C) ROV Surveyor; D) ROV Supporter (images: Black Sea MAP)

3. Previous investigations

The post-processing of data revealed that this archaeological site is known from previous studies (Peev 2004; 2018; Pletnyov *et al.* 2013). According to Pletnyov *et al.* (2013), the shipwreck was initially discovered during sonar surveys in 2001 and inspected via ROV in 2008 and submersible and 2012. Limitations of the previous investigations, combined with the lack of published (or accessible) coordinates, made it difficult to align this investigation with earlier publications. This became possible after comparison of processed Black Sea MAP records against the two photographs published by Pletnyov *et al.* (2013, Fig. 2, 3). The data acquired by Black Sea MAP represents a major contribution to this site's recording, significantly enhancing our understanding, and allowing for a more detailed assessment.

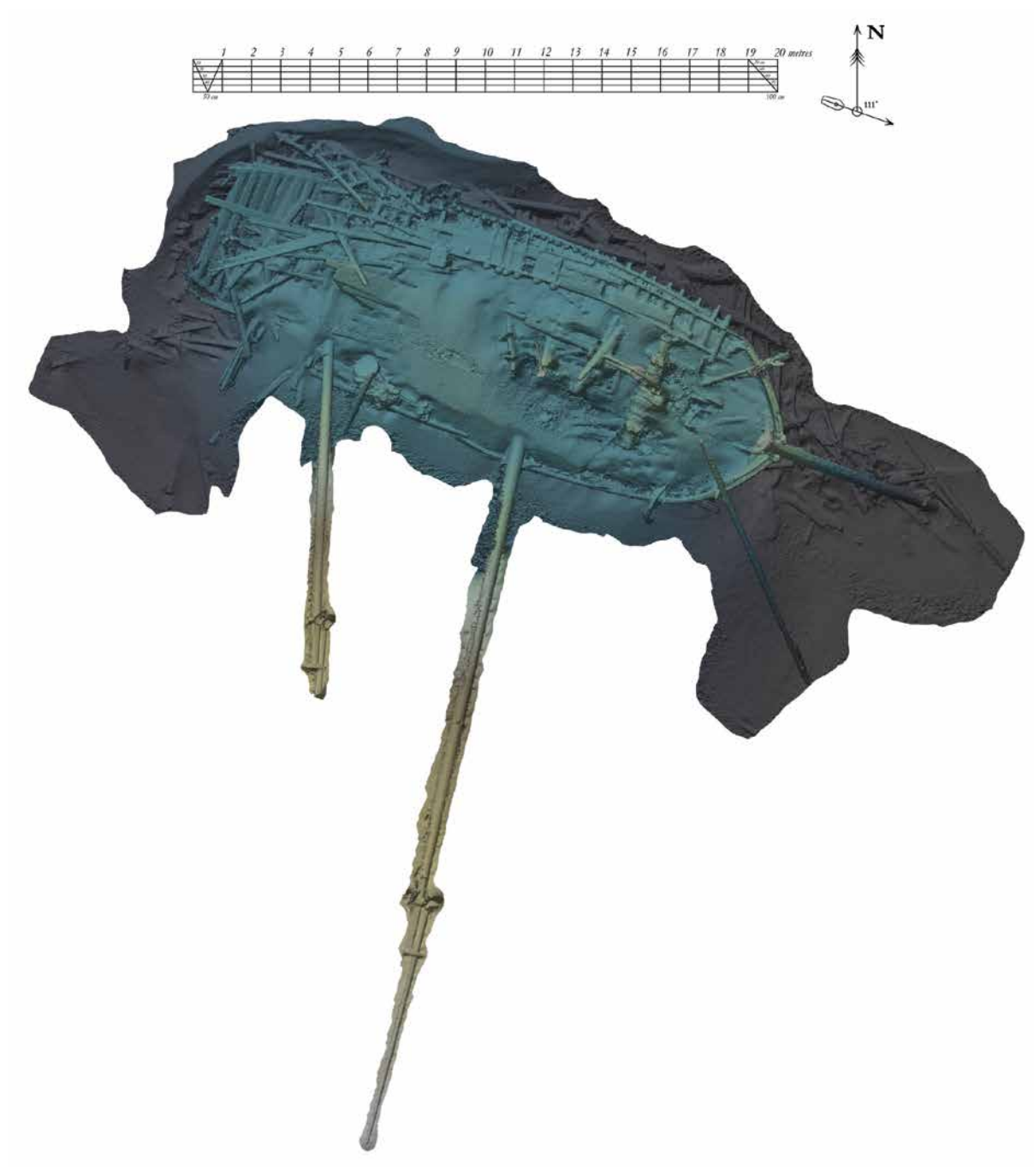


Fig. 2 Digital elevation model (author: D. Garbov, Black Sea MAP)

4. Description of the archaeological site

The archaeological site lies in 137 m of water *c.* 36 nm east of Obzor, Bulgaria. It consists of a largely coherent wooden shipwreck and associated debris scatter with overall dimensions of *c.* 35 m (E-W) x 35 m (N-S) and *c.* 1225 m² area (Figs 2 and 3). The shipwreck is oriented NW-SE, bow pointing to SE, with a bearing along the centre line of 291–111°. The hull and rigging are well preserved and any damages identified could be attributed to natural degradation.

The vessel is lying on an even keel. The bow is preserved better than the stern and rises *c.* 4 m above the seabed. While the stern area may have been the point of seabed impact, its damaged state is better explained through scouring via the N-S current typical for the Western Black Sea. Scour damage is evident along the northern (port) side of the hull, where

it has led to the dislodgement of planking (along the entire port side), and dislocation of frames (in the port side stern quarter). The southern (starboard) side is mostly buried in a scour pile and is better preserved. Both masts have fallen over to the south. The deck is largely covered with sediment, which appears to have filled most of the ship's cavities, with the thickest deposits towards the starboard side along the starboard bulwark. A debris scatter, consisting of planks and other construction elements, is concentrated densely around the hull, with a sparse plume developing southwards, where most objects appear to be associated with the vessel's rigging.



Fig. 3 Photogrammetric model of the shipwreck, view from NW (image: Black Sea MAP)

5. Hull and rigging

The length of the hull between the posts (along the deck) is 20 m; the beam is 6.6 m. The ship's bottom is buried in the seabed sediments, consequently none of its features could be observed. The bow is nearly intact, complete with planking on its starboard side, therefore the stempost could not be sufficiently recorded (Fig. 4A). The sternpost is also buried in the sediments and only its top $\frac{1}{4}$ could be observed showing the uppermost rudder gudgeon. The rudder is missing (Fig. 4B).

Scouring has exposed portions of the vessel's frame along the port side. The hull was double framed with closed paired futtocks. The second futtocks, third futtocks, and toptimbers are currently visible. The midship frame is identifiable (Fig. 4C), with 25 frames counted ahead of it and *c.* 30 frames abaft (the overall number of frames abaft the midship frame could not be established due to obscuring and dislocation). Measurements, based on the scaled photogrammetric model and field observations (using the Supporter ROV's laser scale), indicate an average frame thickness (at the second and third futtocks) of *c.* 25 cm and room-and-space of *c.* 35 cm. The port side bulwark has partially collapsed on deck (forward and amidships), and partially over the side (towards the stern). It shows evidence of seven *c.* 50 × 50 cm gun ports (Fig. 4D). No other evidence of armament was identified. Six deadeyes with iron chain plates associated with the main mast were recorded on the main rail near the midship section.

While the deck is largely obscured, some notes can be made on the vessel's deck plan. Not much is visible in the fore and midship areas. A forecabin skylight and companion way can be seen before and abaft the windlass. The outline of a main hatch (*c.* 2.5 × 3 m) is discernible as a depression in the sediment in the midship area. The stern is more exposed. As the laid deck in this area is largely missing, it could be established that the ship had a *c.* 4.3 m long low quarter deck, which has collapsed over the partially dislodged frame. A companion way to the stern cabin and a skylight are visible on the quarter deck. No evidence for the steering mechanism is present.

The fittings are represented by a windlass, capstan and one pump. The windlass is *c.* 3.8 m wide, handspike-operated, and has an octagonal barrel combining hemp cable on the port side with chain cable on the starboard side. It has a central ratchet wheel with pawls on the king post. The starboard barrel is fitted with whelps to accommodate the chain – still wrapped *in situ* (Fig. 4E). The capstan is dislodged from its original position. Its broken-off upper portion is visible next to a heap of chain near the starboard rail, before the mizzen mast. A single wooden pump stands proud of the deck abaft the forecabin companionway and before the main mast's original position.

Four admiralty pattern anchors were identified: two bowers in their original locations on the port and starboard bow, and kedge and stream anchors hooked over the windlass. These were likely stored abaft the latter and have ended up in their current location during the sinking. The catheads are missing from their positions; one of them was identified *c.* 7.3 m S of the starboard stern quarter in the debris plume.

The vessel was ketch-rigged. A bowsprit and two masts were recorded. The bowsprit (8 m) has collapsed from its original position, crushing the beak-head, and is leaning over the bow with its head in the sediment. No evidence of the jib boom was identified. A main topsail yard is leaning over the starboard bow. The end of a stunsail boom protrudes from the sediment immediately SE of it. The 25.4 m tall main mast is rigged polacre fashion and consists of a single stick (combining main and main topmast), and a fidded topgallant mast. The rigging of mainsail, main topsail and main topgallant sail is clearly traceable along the mast (Fig. 4F). The mizzen mast (13.2 m preserved height) is rigged traditionally with a fidded topmast, which is broken-off above the mast cap. A fragment of a trysail mast, or 'horse,' with a gaff jaw still attached indicates that the vessel was rigged with a spanker.

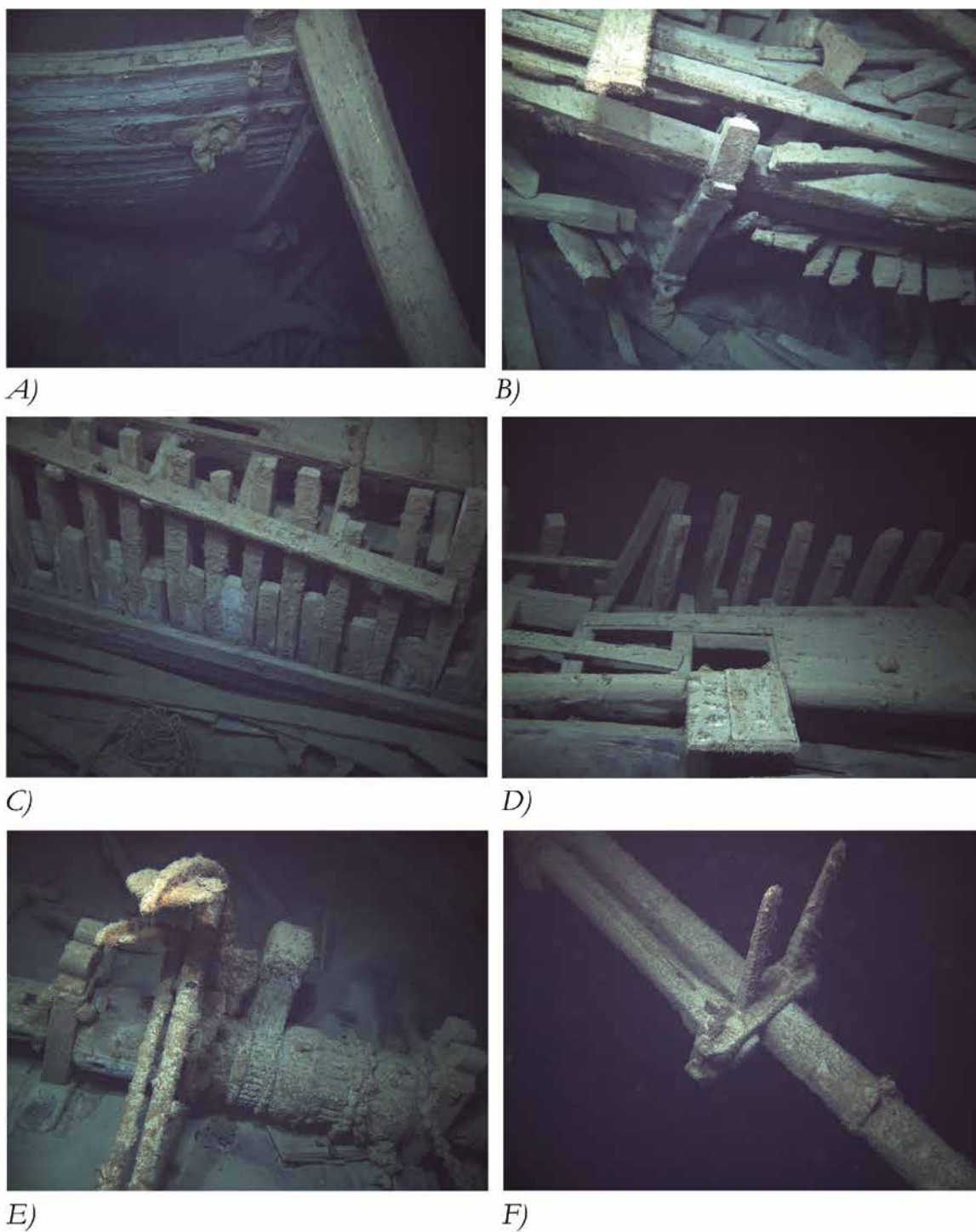


Fig. 4 A) Bow and bowsprit, view from SW; B) Stern and stern post, view from NW; C) Waist with midship frame visible in the centre of the image, view from N; D) No. 5 gun port on the port bulwark, view from S; E) Stream and kedge anchors leaned over the windlass, view from W; F) Main mast top and fidded topgallant mast (strops for rigging the main topsail visible in the bottom right corner), view from NE (images: Black Sea MAP)

6. Discussion

The evidence for hull and rigging suggests that the shipwreck should be interpreted as that of a Mediterranean bombarde. The hull appears to be framed in a typical late 18th and 19th century fashion, recorded on numerous sites in Europe and North America: a notable case being the US brig *Eagle* (e.g. Crisman 2014: 322–327), and the most recently published example being the Akko Tower wreck (Cvikel 2016; 2022). While the presence of a trysail mast/horse could indicate construction in the late 18th century, research on the introduction of chain cables suggests that the vessel was likely in operation during and after the second decade of the 19th century (Harland 2013). The absence of typical mid-19th century features, such as a pump-action windlass, iron (and chain) rigging, copper- or yellow metal sheathing, etc., suggests that she may have been built and lost prior to the 1840s and 50s. As this seems to be the first bombarde identified in the archaeological record, and to discuss her specifics further, the archaeology of this site is interrogated against relevant documentary sources.

The origins of Mediterranean bombardes can be traced to the Atlantic coast of France in the late 1600s (Prins 1995: 95). This type of vessel was initially conceived as a bomb ketch and referred to as *galiote a bombe*. A lithograph in Saint Remy's *Memoire d'Artillerie*, leaves no doubt as to the kinship with *fluyits*, and *galjoots* (Surirey de Saint Remy 1697: Plate 83; Fig. 5A).

During the 18th century bomb vessels spread to the Mediterranean and were employed by most local navies (including La Serenissima and the Ottoman Empire: e.g. Maffioletti 1785; Yener 2018). Over the course of the century, they were adopted in the merchant marine due to their cargo carrying capacity and modest crewing requirements. Atlantic influence is evident in the hulls of these Mediterranean vessels (e.g. Gueroult du Pas 1710: 25). The characteristic *mate à pible* rig that some of them received is believed to have been a contemporary technological development (Dennis 1957). Towards the end of the century, bomb vessels had become obsolete and bombardes were henceforth built and employed as small merchantmen (up to 100–125-ton). Their name endured in homage to their naval origins.

Merchant bombardes were a common sight in the early 19th century Mediterranean, and typical for the Provence (Pâris 1885: 24). Their transition from navy to merchant marine is explained in the caption to Plate XVI of Jean Jerome Baugean's *Collection de toutes les espèces de bâtiments* (Fig. 5B):

On ne sert plus dans la marine de guerre de ces sortes de bâtiments destine à porter sur leur avant des mortiers de fort calibre a la place on emploie des frégates qui sont plus propres à évoluer que ces sortes de bâtiments.

(Baugean 1826: 11)

Apart from Baugean's lithographs, such vessels appear in the works of Nicolas Cammillieri, Domenico Gavarone and the Roux family of artists, whose ship portraits present opportunities for comparison with the Black Sea example.

According to the abovementioned plate by Baugean, and as noted by Harland, around the turn of the 19th century French merchant bombardes were still able to carry guns and could be armed as small cruisers or privateers (Harland 2000: 70; Fig. 5B). The vessel on the right-hand side carries at least ten guns and two swivels; the one on the left presents four open gun ports on her starboard side. A watercolour by Antoine Roux, dated to the naval blockade of Marseille (Meissonnier 1968: 49), provides another contemporary example (Fig. 5C). It depicts a bombarde at anchor sending down her spars: an open gun port is visible on the starboard bulwark. The rigging of this vessel, as well as of those on Baugean's lithograph, is closely similar to the Black Sea bombarde, a notable difference being that the mizzen mast is represented as a single stick. The right-hand side vessel on Baugean's lithograph raises a square mizzen topsail. With seven gun ports per side, the Black Sea bombarde was able to carry more guns than the above examples.

The 114-ton *La Volonté de Dieu* of La Ciotat (1816), is possibly the best documented Provencal bombarde. It was painted by Antoine Roux (Meissonnier 1968: 19; Fig. 5D) and his son François (Pâris 1885: 24, Plate 61); its builder's plan was redrawn and published with a commentary by Admiral François-Edmond Pâris (1882, No. 46), who also issued further comments on the second portrait by Roux the Younger (Pâris 1885: 24); a model of this bombarde is kept in the *Musée National de la Marine* in Paris.

The plan of *La Volonté de Dieu* is of particular pertinence to the Black Sea bombarde. It shows an unarmed vessel of nearly identical proportions (Prins 1995: 95). The length and beam are a match and Admiral Pâris's description of the frame indicates that both vessels were framed in the same fashion (Pâris 1885: 24). A difference is the denser and more robust frame of the Black Sea bombarde, which, unlike *La Volonté de Dieu*, was designed and built to carry armament.

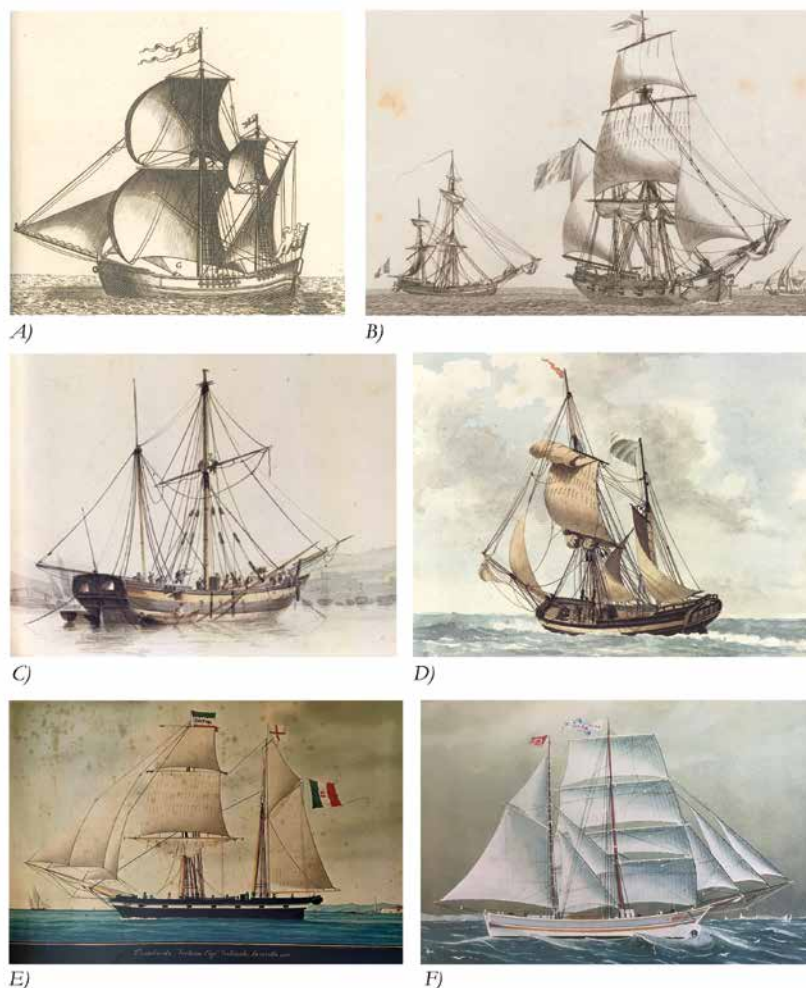


Fig. 5 A) 'Galiote de Dunkerque' (after Surirey de Saint Remy 1697, Planche 83, image courtesy of Eisenbibliothek, Schlatt, Switzerland); B) 'Bombardes françaises de la Méditerranée' (after Baugean, 1846, Planche XLV, image courtesy of Bibliothèque Nationale de France); C) Bombarda at anchor in the Old Port of Marseille (painting: Antoine Roux, after Meissonnier 1968, 49; image: public domain); D) *La Volonté de Dieu* (painting: Antoine Roux, after Meissonnier 1968, 19; image: public domain); E) 'Bombarda Fortuna Cap. Fortunato Lavarello 1862' (painting: Domenico Gavarone, after Schiaffino 1987, Plate 27); *Αγία Ζώνη* (painting: unknown artist, after Vassiliou 1961, 112)

Noting the fully pole-masted rig of *La Volonté de Dieu*, the rigging proportions of the two vessels, as far as they could be compared (main mast height, location of sails along the main mast and length of topsail yard), are also a match. Apart from the fully pole-masted rig and the lack of armament, *La Volonté de Dieu* is the closest parallel to the Black Sea bombarde that this author is currently aware of.

In the 1820s and 30s, merchant bombardes were built in Provence (Marseilles, Saint Tropez, Martigues etc., e.g. Pavlidis 2012), Liguria (Varazze, Voltri, Sestri Potente etc.; e.g. Delis 2012) and the Greek isles (Syros, e.g. Delis 2012).¹ Gavarone's 1862 portrait of the 125-ton *Fortuna* of Camogli, built in 1834 (Schiaffino 1987: Plate 27; Fig. 5E), shows a vessel of slightly larger proportions and a later date. The style of beak-head, the use of chain in the bowsprit's standing rigging and the iron-stocked anchors reflect some mid-19th century trends, absent from the Black Sea bombarde. While *Fortuna* appears to be fully pole-masted on the main, unlike the previous examples – but similar to the Black Sea bombarde – her mizzen is rigged with a fidded topmast.

In his commentary on Roux the Younger's portrait of *La Volonté de Dieu*, Admiral Pâris states that by the 1860s bombardes had largely disappeared from the Western Mediterranean (Pâris 1885: 24). While over the later course of the century vessels referred to as 'bombardes' continued to be built in the Eastern Mediterranean (Tr. *bumbarta*, Gr.

¹ No contemporary portraits (1820s–1860s) are known to this author from the Greek Isles. I kindly invite any esteemed colleagues, who may be aware of such portraits, and have an interest in sharing their knowledge, to contact me.

βομβάρδα), contemporary sources suggest that by this time the term was used in a broader fashion. The 1890s–1900s Ottoman-Greek vessel *Άγία Ζώνη*, referred to as a ‘schooner’ in the original publication by Vasiliou (1961: 112), and identified as a βομβάρδα by Lyman (1970: 166–167) is a good example of a pole-masted ketch, whose traditional Eastern Mediterranean hull does not appear to be marked by the same Atlantic influence as earlier Provencal bombardés and the Black Sea example (Fig. 5F). It must be noted however, that more research is required on the chronology and typology of Eastern Mediterranean bombardés to discuss their evolution further.

7. Conclusions

Mediterranean bombardés would have appeared on the Black Sea soon after the reopening of the basin for international shipping, after the 1774 Treaty of Küçük Kaynarca (King 2004: 146–147). The features of the archaeological site discussed in this paper indicate that the vessel in question was likely built around or after the turn of the 19th century and could have been lost prior to the 1850s. While the closest parallels identified to date associate the Black Sea bombarde with the French region of Provence in the first two decades of the century, more research is required on Eastern Mediterranean bombardés to discuss the chronology and origins of this vessel further.

The evidence for armament, together with the presence of both windlass and a capstan, indicate that this was a versatile ship. She could sail under arms, as a small cruiser or privateer, relying on the larger complement required to man up to 14 3–4 pounder guns and turn her capstan. However, she would also have been able to sail unarmed with a crew of around six, as typical for merchant bombardés (see Pâris 1885) and enough to work with just her windlass (Harland 1991). While the Black Sea bombarde appears to have sailed unarmed when she sank, the ability to carry guns can be seen as another hint for dating her construction prior to the French conquest of Algeria in 1830 and elimination of piracy on the Mediterranean.

Archaeological sites such as the Black Sea bombarde signify the early phase of reintegration of the Black Sea, within the globalised maritime world of the long 19th century.

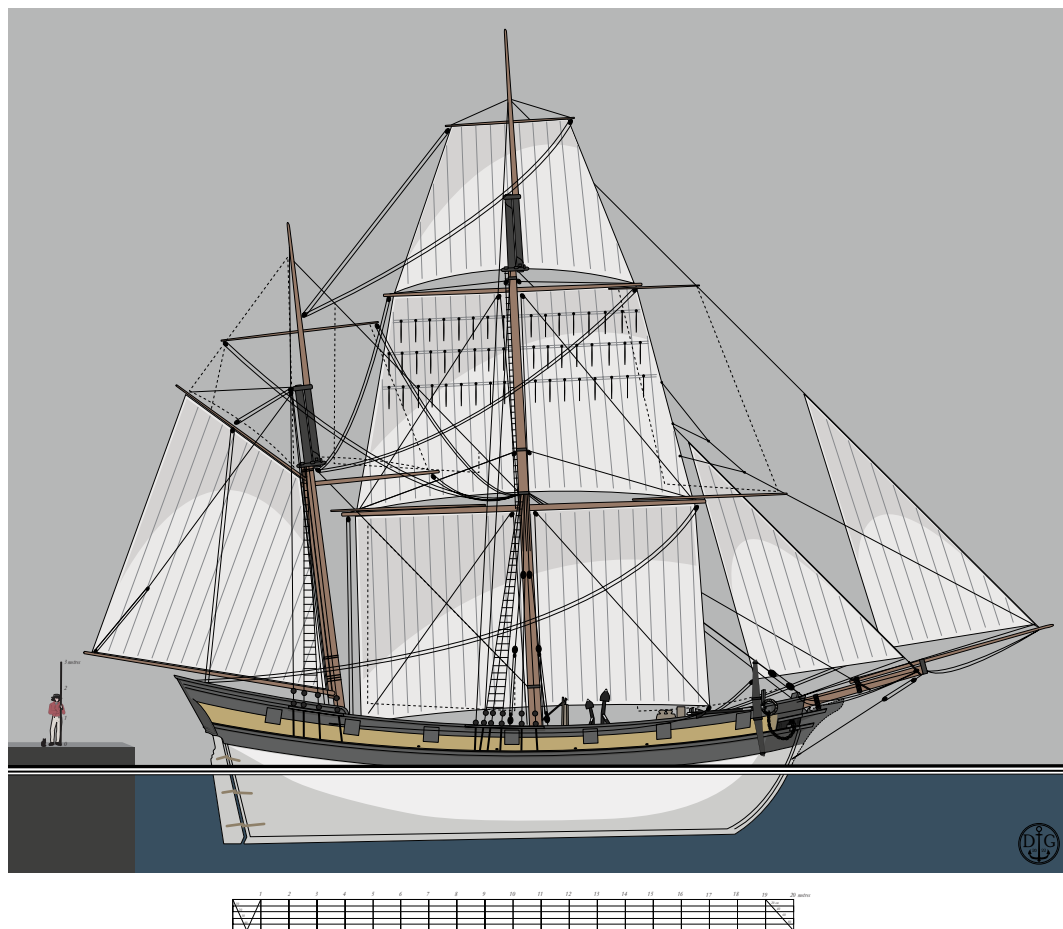


Fig. 6 Tentative reconstruction of the sheer and sail plan of the Black Sea bombarde (author: D. Garbov)

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INLAND NAVIGATION

A cargo ship from Lake Onega and the shipbuilding tradition in Northern Russia

Petr Sorokin

Abstract: In 2018, the wreckage of a sewn ship was discovered in Lake Onega near the city of Vytegra, Russia. The wreck was dated by the dendrochronological method to the mid-17th century. The wreck included a bottom (20.6 × 1.64 m) made up of five timbers, with the bases of the stems and the frames up to 5.8 m in length, as well as two fragments of the sides of the ship. The construction style of the ship is similar to the Late Medieval North Russian ship, based on three archaeological vessels. In many respects the Vytegra ship corresponds to the design of the lodia, described in documents from the 17th and 18th centuries.

Keywords: Vytegra, Russia, Onega Lake, Late Middle Ages, sewn vessels, lodia

1. The Vytegra vessel

In late autumn 2018, the shipwreck was beached ashore by a storm and discovered by local residents on the southern coast of Lake Onega near the mouth of the Vytegra River. The vessel was studied by us in the spring of 2019 in the city of Vytegra, where its remains were moved. It is currently being preserved under conservation in a Vytegra museum.

The shipwreck included the flat bottom with remains of floor timbers and two fragments of the sides. The bottom was preserved to its full length of 20.6 m, and the midsection of the ship was 1.64 m wide. The bottom consists of five laterally connected beams up to 35 cm wide and 26 cm thick, converging at the ends at an angle of about 22° (Fig. 1).

The central beam, in section 35 × 23–26 cm, consisted of two parts, joined together in a half lap splice in the center of hull, 9.72 m from the stem and 10.17 m from the sternpost, by two 5 cm thick treenails. Both central beam halves appear to be made from a single log of fir, ending in the bow and stern with the natural root parts of tree (kokora), which became the bases of the stem and sternpost. The ship's bow was determined based on the preserved inclination at the stem (Fig. 1). At the bow, the four lower planks, up to 30 cm wide, were fastened together and to the stem with a sewing technique (Fig. 2). The base of the stem consisted of two parts. The first, 10–12 cm thick, preserved to a height of 48 cm, is the upturned root part of a tree, which passed below into the central bottom beam. The second, on the port side, is a separate beam of stem 8–10 cm thick, installed in a rectangular groove at the central bottom beam (20.5 × 7 cm and 5.5 cm deep). It was fastened by treenails and seam with bottom. The seam also connected both parts of the stem and the adjacent ends of board planks together (Figs 1, 3). The stern of the ship, in a worse state of preservation, utilized a similar construction design.

The four side beams of the bottom converged in pairs to the central beam from 0.9 to 3.1 m distance from the pointed end of the central beam at the bow and the stern. Their outer edges were made like those of a T-shaped keel, with a protrusion in the upper part for fastening the lower planks of the sides. At the ends of the bottom beams behind the stem and stern, L-shaped profiles were hollowed out for this purpose (Figs 1, 4).

The bottom beams were joined together with the help of 16 long wooden nails hammered through holes drilled from the sides. The holes were drilled starting 1.9 m from the bow, with hole spacing varying between 0.39 m and 1.75 m. They were connected by eight iron studs as well, four on each side, with an interval of 1.3–1.5 m, at a distance of 1.3–2.9 m from the bow and stern ends.

There are three round depressions 1–2 cm deep in the central beam with diameters of 16–21 cm, two located at 2.10 m and 3.05 m from the ships bow, with the third 3.96 m from the stern. These depressions could relate to the bases of masts and anchor devices (Figs 1, 4).

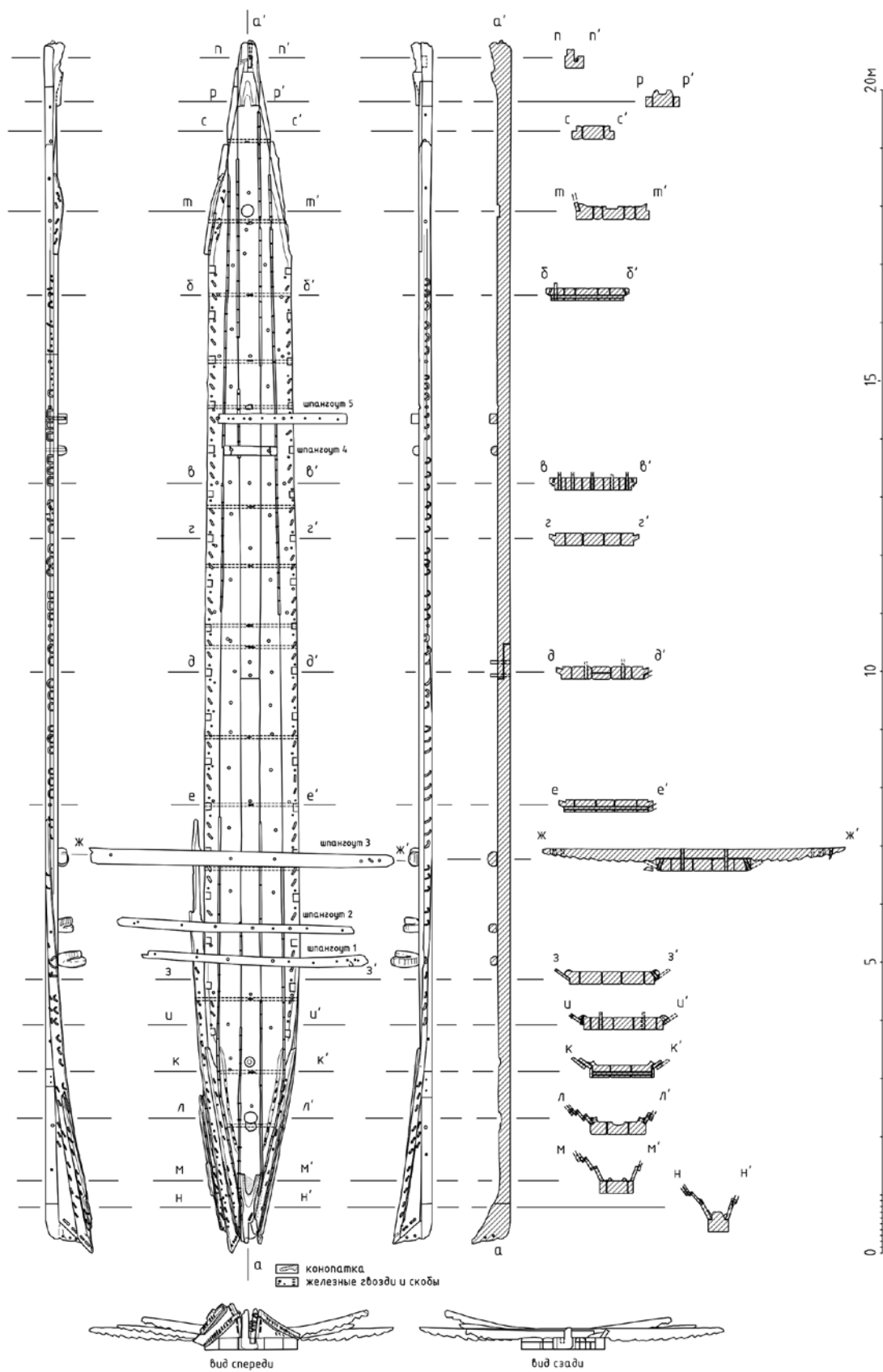


Fig. 1 Drawing of the vessel from Vytegra; plan and sections (drawing: P. Sorokin)



Fig. 2 The bow of the vessel: starboard side (photo: P. Sorokin)



Fig. 3 The bow of the vessel: stem base (photo: P. Sorokin)



Fig. 4 The bow tip of the vessel: the connection of the starboard side to the stem (photo: P. Sorokin)

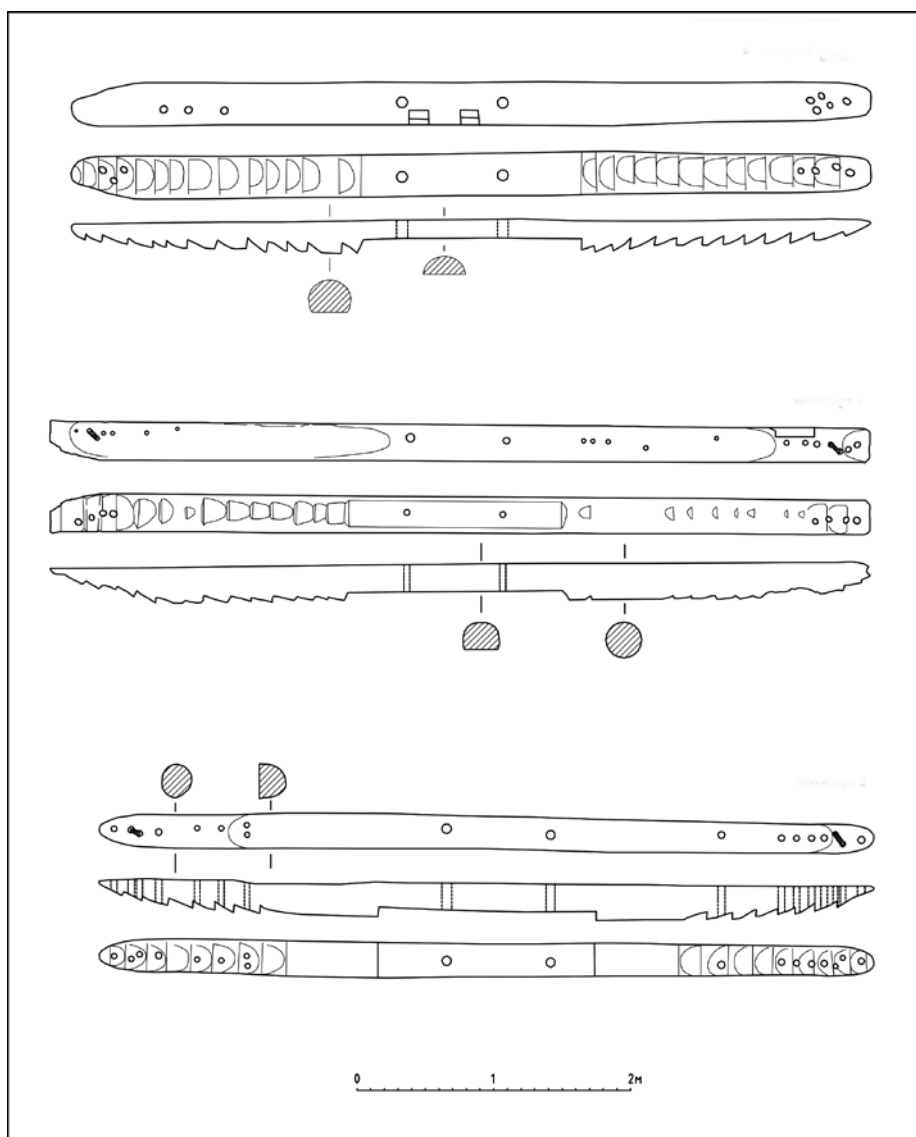
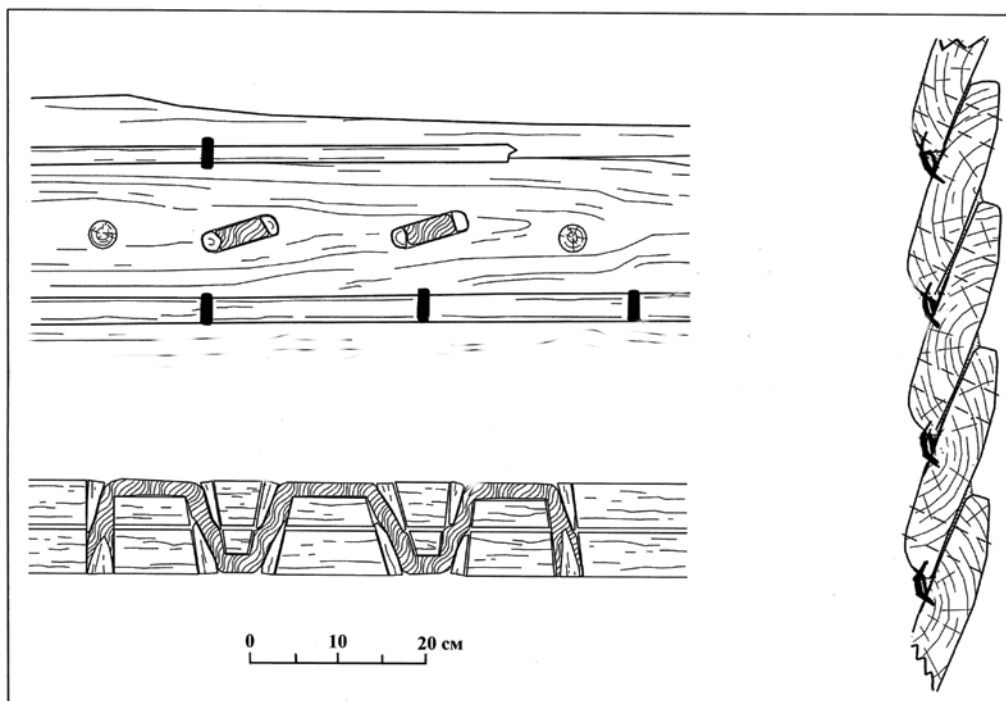


Fig. 5 The floor timbers of the vessel (drawing: P. Sorokin)



1



2

Fig. 6 The sewing and caulking technique of the boards planking of the vessel: 1) the system of connecting and sealing the seams of the board planking; 2) photo of a fragment of the ship's side (drawing and photo: P. Sorokin)

Judging by the preserved exemplars (4–5.8 m long) and nail holes in the bottom planks, there were about 29–30 frames, with frame spacing of 0.4 to 0.6 m. The frames were fastened to the bottom with two wooden nails 4 cm thick in the center and with a sewing technique at the ends. The shape and dimensions of the five partially preserved frames indicate the width and contours of the vessel's base. The five partially preserved frames had central cross-sections that varied between 12–18 × 14–25 cm (Figs 1, 5). Based on the cuts along the bottoms of the preserved frames, it is clear that the frames were shaped to adjust to the already-sewn bottom part of the ship's hull, assembled in shell-first technique.

Two fragments of the vessel's sides, measuring 11.4 × 1.05 m and 3.4 × 0.5 m respectively, included seven and four board planks 6–8 cm thick (Fig. 6). The planking was fastened in clinker overlapping construction with a sewing technique. The planks, cut from the outer parts of young pine trunks, had a rounded external profile. The joints between the planks of the bottom and sides inside the vessel, and in some places outside the vessel, were caulked by moss, then

covered by laths secured with sintels, then tarred. The moss was laid in grooves about one cm deep and pressed by a flat or triangular in cross-section lath 2–3 cm wide. The laths were fixed every 20–25 cm with iron sintels (Fig. 6.1). The planks were sewn together by fir tree branches or roots (*vica*) about 2 cm thick with short seams – three stitches – each 7–10 cm long, with intervals of 10–15 cm. The gaps between the seams were 20–25 cm. The stitches, placed at an angle of 25–45° to the plank's edge, have sunk into the cutout grooves 2 cm deep (Fig. 6.2). Each stitch was fixed both inside and outside the ship's sides with wooden pegs 2 cm thick.

The vessel was built mostly of pine, with some details made of fir. Moss, for caulking seams, was impregnated with a mixture of birch and pine tar and possibly with inclusions of animal fat. Based on dendrochronological analysis of the ship's wood, the dates 1632–33 and 1649 were obtained. It has been suggested that the latter date is a sign of repair of the vessel (Zhavoronkov, Zhavoronkova 2019: 15–17). However, the difference in dates can also be explained by the secondary use of old parts and details. Ships built from coniferous wood, mainly pine, were short-lived. According to the documents of the 17th century, large vessels were used on the White Sea basin for up to 10 years (Frantsuzova 1994: 241). However, after a decade of use they were often disassembled and disposed of. Thus, the construction of the Vytegra vessel may date from a later time than the date of its earliest components.

2. Archaeological finds of similar vessels

The sewn vessels from Paraniha (Arkhangelsk area) and Stockholm (Skeppargatan) had technological similarities to the Vytegra ship (Cederlund 1978: 69–80; Bryzgalov *et al.* 1995). The Paraniha shipwreck, more than 15 m in length, 1.1 m in width and 0.4 m in height, was found at the mouth of the Northern Dvina River in 1991. “Four powerful beams located in the same plane were rigidly connected to each other and to the stems” (Bryzgalov *et al.* 1995: 47). The bottom beams are about 29 cm thick and 15–35 cm wide, taper to the ends, forming sharp corners. They were joined by wooden nail hammered from the sides into pre-drilled holes. The side beams had protrusions with grooves at the ends, for attaching them to the base of the stem and to the lower side's planks. The parts of four arc-shaped frames, 3.75–4.63 m long, with cutouts to fit against the bottom beams, were found separately from the bottom. They were trimmed and had two nails holes in the center, in the places corresponding to holes in the bottom. One of the fragments, preserved up to 3.75 m, had an initial length of about 6 m. Judging by the shape of the surviving frames, the contours of the bottom were rounded, like the Vytegra vessel. The wreck, interpreted as part of the *doschanik* (a ship built of planks), was dated to the end of the 18th / beginning of the 19th century, on the basis of the lack of metal fasteners in the hull (Bryzgalov *et al.* 1995: 47, Figs 1–3; Yasinsky, Ovsyannikov 1998, vol. 1: 358–363).

The remains of the Skeppargatan 4 sewn ship were discovered in Stockholm in 1896. Based on 14C and historical signs, the wreck was dated to the end of the 17th / beginning of the 18th century. The main part of the wreck, 2.4 m long, was interpreted as a fragment of the keel with the base of the stem (Cederlund 1978: 23–54, 69–80, Figs 18, 20, 25–28, Pls 1–27). According to a number of similarities, it can be attributed to the same type of vessel as the Vytegra wreck. The preserved part of the central beam of composite bottom had a width up to 35 cm, and two turn-up profiled boards (33 × 12 cm) were attached to grooves in the sides out to 1.7 m from the vessel's end. Their upper edges were deployed at an angle of about 60° to connect with the lower plank of the side. The wreck can be visualized as a fragment of the end of a composite bottom with side planking, including the base of the stem. The ship details and planks were sewn together in the clinker technique. The root part protruding at the end of the central beam, projecting upwards at an angle of 90–110°, served as the base to which the stem was fastened from the side with wooden and iron nails. The planks of the side covering, in cross-section 16–30 × 4–5 cm, have a rounded external profile. They were connected by a *vica* (a rod made of a spruce branch), 2 cm in diameter, with short seams in three stitches of 6.5–10 cm. The boards were fastened to the frames, the distances between which were 55–70 cm, with two stitches to planks.

C. O. Cederlund noted the unusual design of the vessel and suggested its Russian or Eastern Baltic origin, or possibly based on Eastern designs in use in the Swedish Navy in the 17th and beginning of the 18th century (Cederlund 1978: 28–36, 76–79).

3. Written sources and the types of North-Russian late medieval vessels

The ship design featured in the Vytegra vessel, the Paraniha shipwreck, and the Skeppargatan 4 ship has been known from the documents on the construction of ships in the White Sea basin in the 17th and 18th centuries. They described the connection of the bottom beams – kolod (usually three) into the expanded keel base of the ship – matica. Detailed information about the construction of the matica and its connection with the stems, corresponding to the design of the Vytegra wreck, is contained in 18th century documents on the construction of the lodia of the Solovetsky monastery, situated on an island in the White Sea. The documents indicate that the composite bottom – matica, made of several beams – kolod, is a traditional characteristic of a lodia. The descriptions of other seagoing vessels: Koch and karbas, smaller than lodia, have mentioned only one koloda – a keel and bottom apparently made from one tree (Filin 2013: 22–23; Sorokin 2021: 81–83).

The remains of North Russian Late Medieval vessels are known mainly in secondary use from excavations in Mangazeya (Vizgalov, Parkhimovich 2008: 73–75). Most of the remains, including keel fragments 15–17 m long, with a cross section of 45 × 20 cm, made from a single tree, were associated with a koch (Naimark *et al.* 2013; Filin 2013). Representations of other types of North Russian vessels, including lodia, karbas, nasad, doschanik are based on written sources. The classification of the Paraniha wreck as a cargo ship – doschanik (Bryzgalov *et al.* 1995: 47; Yasinsky, Ovsyannikov 1998, vol. 1: 358–363), is not supported by definitions in these documents.

The doschanik – the main type of cargo ship in the White Sea basin in the 16th–18th centuries, was distributed on the rivers of Western Siberia in the 17th century. A doschanik, built in 1677 in Verkhoturys (West Siberia), had length of matica 21.6 m, a thickness about 18 cm, width of the bottom in the mid vessel – 4.5 m, space – 22.5 cm (Vershinin 2001: 95). The construction of this ship and its use of kokora as floor timbers indicates that it was a typical flat-bottomed vessel – Barca type, with straight sides.

4. Conclusion

The structural and technological type of late medieval North Russian sewn vessels can be distinguished on the basis of three shipwrecks: Vytegra, Paraniha, and Skeppargatan 4. These ships are characterized by a number of features that find correspondences in historical documents: a composite bottom (matica) with a side through connection of the beams with wooden and iron nails; a composite central beam made of two trees trunks ending in root parts and one-piece side beams; a method of attaching the stems to the root parts and the boards; and connecting the boards and the ship's shell and components with a sewing technique.

The main structural elements of these vessels and their manufacturing technologies are characteristic of the Medieval (12th–15th century) shipbuilding tradition of north-western Russia (Sorokin 1997; Dubrovin 2000); however, the time and area of appearance of the described type of vessel need to be clarified.

The reconstructed dimensions of the Vytegra vessel are about 22 m in length and up to 6.5–7 m in width; the height of its sides could reach about 1.5–2 m. According to the size and design features that are consistent with historical documents, the find can be recognized as the remains of a lodia. In contrast to the Medieval period when the term was generic, in the 16th–18th centuries in the North, lodia belonged to a particular type of vessel, ranging from 18 to 22 m in length, about 6–7 m in width, with the height of the sides – 1.5–2.7 m. The lodia was a large seagoing vessel, used mainly for long fishing voyages and transportation of goods on the water routes, including internal operations in the basins of the Barents and White Seas. They have been divided into several variants, which, in addition to the construction site, could reflect the design features, sizes and areas of their use (Frantsuzova 1994; Yasinsky, Ovsyannikov 1998: 338, 352–354; Filin 2004). According to the ship inventory of 1702 from Vologda, 235 vessels were designated for transportation of large volumes of cargo, including grain, salt, and weapons; 52 lodias were mentioned (Guslistova 2004: 92–94). Dozens of trade ships from North-West Russia including the Onega Lake area sailed to Stockholm via the Baltic Sea in the 17th century (Sorokin 2021: 83). The Vytegra vessel, a large cargo shipwreck corresponding to a lodia, found on the southern coast of Onega Lake, may well be associated with 17th century trade and communications in the Baltic Sea.

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Shipwrecks of flat-bottom vessels used in local transport in the Gulf of Gdańsk from the 16th to the 19th century

Tomasz Bednarz

Abstract: Out of nearly 30 wooden shipwrecks identified and examined at the bottom of the Gulf of Gdańsk, dated back to the 15th–19th centuries, five are flat-bottom vessels presented in this article. They were used to reload goods, transport cargo between the ports within this area, or operated as an inland means of transport for timber floated down the Vistula River. The most interesting vessel is the F53.26 shipwreck, identified as the remains of the 17th-century reloading ship, discovered with its cargo of quern stones and lead ingots. The article also discusses four other flat-bottom wrecks, F53.9, F53.12, F32.9 and F53.20.

Keywords: wreck, flat-bottom, local transport, Vistula River, Gulf of Gdansk

In the waters of the Gulf of Gdańsk, we have identified and examined five wrecks constituting the remains of flat-bottomed vessels of similar shape, size, and construction details. The wrecks date back to the period between the 16th and 19th century. They all survived only in part in the form of structural bottom elements, including one with its cargo.

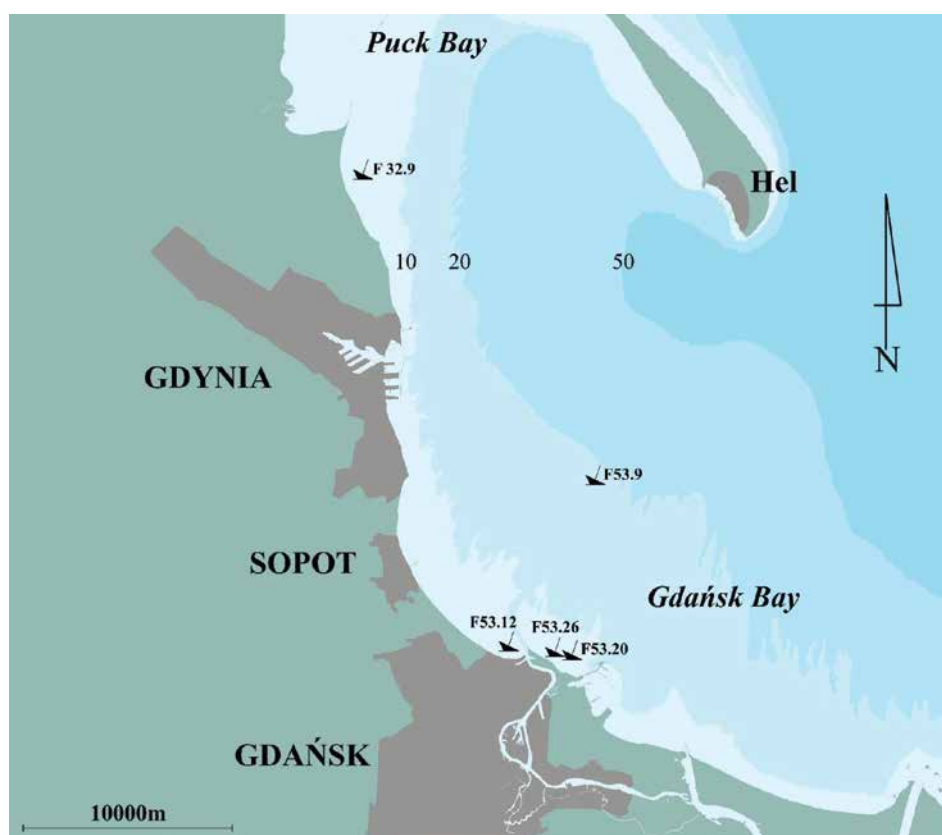


Fig. 1 Location of the wrecks F53.26, F53.20, F53.12, F53.9 and F32.9 in the Bay of Gdańsk (map: K. Treder, T. Bednarz)

Two of the discussed group of wrecks, marked as F53.26 and F53.20, were discovered in the immediate vicinity of the shore of the Gulf of Gdańsk, west of the North Port, near Westerplatte, between 2009 and 2010, at a depth of 4.5 and 5 m. This is the area of the former entrance to the port of Gdańsk, the so-called North Deep, used as one of the entrance channels until the 18th century, when it ultimately became silted and shallow (Podgórski 1998: 49). Two other wrecks are located at a similar distance from the shore and at a similar depth; the first of them, near Brzeźno, marked as F53.12 and the other, F32.9 near Mechelinki, north of Gdynia. The last, fifth wreck from this group, marked as F53.9, is the only one lying at a deeper depth of 16 meters, further away from the shore (Fig. 1).

Wreck F53.26

The most characteristic and the most interesting in terms of research potential is the wreck F53.26 „West B” discovered in September 2010 by the employees of the Maritime Office in Gdynia. The wreck lies at a depth of 4.5 m near Westerplatte at a distance of 100 m from the current coastline.

The preliminary identification of the object was conducted by archaeologists from the National Maritime Museum (NMM) in Gdańsk between 2010 and 2011. The field survey continued between 2017 and 2020, when the site inventory was performed with the use of 3D photogrammetric documentation, as part of the project Virtual Open-Air Museum of the Gdańsk Bay Shipwrecks (www.wsw.nmm.pl). In 2017, when the survey began, the wreck was completely buried in the sandy bottom. With the use of an air-operated ejector it was possible to expose the middle part of the wreck structure, 9.7 m in length and 2.9 m in width, with processed round stones discovered lying inside and in the immediate vicinity of the structure. Moreover, directly on the wooden structure, seven lead ingots were found. In 2018, the structure identification was continued, moving in a south-westerly direction to find one of the ends of the wreck. When the end of the structure was exposed, on the south-west side, a 3D model of this part of the wreck was performed. In 2019, a similar operation as the year before was conducted on the north-east side of the wreck. The 3D photogrammetric documentation developed for all the three stages of work from between 2017 and 2019 was finally combined to form one 3D model presenting the whole structure and the field of stones (Bednarz 2020: 294; Fig. 2).



Fig. 2 Photogrammetric 3D model of the F53.26 wreck in top view with the uncovering phases of the structure in 2017, 2018 and 2019 (model: T. Bednarz, K. Treder)

As for the F53.26 wreck, we identified the bottom part of a spindle-shaped flat-bottomed vessel, 14 meters in length and up to 2.35 m in width, in the bottom part. The bottom of the wreck is made of five, flat-laid massive pine staves, 10 cm thick and from 46 to 51 cm wide. In the course of the survey no thicker middle stave was detected constituting the vessel's longitudinal axis. The 50-cm-wide stave from the south-west side is rectangular at the end to match the sloping planking and the stem. The other end of the stave is destroyed. The outer sides of the bottom staves are mounted at an angle of ca. 135 to 145 degrees to match the sloping planking. The elements of the bottom part transverse reinforcement are formed with oak floor timbers, 13 to 19 cm wide and 9 to 11 cm thick, spaced every 18 to 20 cm. Some floor timbers are cut flat at an angle of ca. 140 degrees, similar to the outer bottom staves, which forms the shape of sloping sides. From the ship's sides, the floor timbers feature drain culverts. On the floor timbers there are partially preserved inner formwork staves, 30 to 45 cm wide and 3 to 4 cm thick. A 32-44 cm wide and 6-7 cm thick keelson runs through the longitudinal axis of the wreck, along the southwest – northeast direction, preserved at a length of 12.5 m, with a grooved mast step, 25 cm long, 14 cm wide and 3 cm deep. The mast step is situated 5.1 m from the end of the wreck structure on the south-west side. This is the area of the largest width of the ship's bottom, which is situated at ca. 1/3 of its total length. On both sides of the wreck's flat bottom, we can see the preserved fragments of ship's sides in the form of single oak staves. The structural elements are mounted with wooden pegs of 3.5 cm in diameter (Bednarz 2020: 296).

On the wreck structure and in its immediate vicinity there are at least 45 sandstones in the form of low cylinders, with a diameter of 40 to 140 cm in diameter and 8 to 14 cm thick. They constitute the ship's cargo which can be interpreted as semi-finished quern stones. The stone cargo protrudes to 90 cm above the keelson and takes the area of ca. 10 cubic meters, which indicates the stones total weight at ca. 25 t. Taking into account the uncovered stones lying outside the wreck, the weight of the total freight, preserved until now, can be estimated at ca. 30 to 35 t. Four samples collected from the sandstone were subject to detailed petrographic analyses. The survey conducted by Dr Wojciech Bartz of Wrocław University ruled out the possibility that the sandstone came from the Republic of Poland or Scandinavia. Regions of Germany or France were identified as the sandstone's potential origin. This information shows that the ship's cargo was imported to the port of Gdańsk from Germany or France, probably to be distributed further in Pomerania or the whole country (Bednarz 2020: 297).

The above-mentioned lead ingots in the form of oblong loaves also constitute the ship's cargo. On these treasures we can see heart-shaped maker's marks which indicate the merchant's or manufacturer's ownership, and there are from three to eight of them on each ingot. The ingots have a length of 795 to 820 mm and a weight of 57.450 kg to 62.750 kg. They most likely come from England. Lead ingots were discovered on the wreck lying in the Bay of Bengal off the eastern coast of India, some of which were similar in shape to the ingots from the F53.26 wreck. The ingots had markings, one of which was a heart motif. Some of the ingots bear the name of the manufacturer, the English company Blackett. Chemical analyzes have shown that the lead comes from the North Pennine region in Great Britain (Tripathi 2015: s. 805).

A total of 14 wood samples were collected from the wreck for dendrochronological analyses. The absolute dates were identified for three oak samples and one of them contained alburnum. The tree was felled in 1632 and the ship was built shortly after that year. It was also identified that the oak wood used to build the ship came from the region of Gdańsk Pomerania (Bednarz 2020: 301).

The analysis of the boat structure and the nature of its cargo indicates that the F53.26 wreck constitutes the remains of a *bordyna*-type vessel i.e., flat-bottomed watercraft used to load or unload seagoing ships, which due to deep draught could not operate within the port of Gdańsk. These operations were performed at the roadstead by the members of *bordyna* guild, operating in Gdańsk since the mid-fifteenth century, using *bordyna* and keel boats. The written sources mention the term *burdynek*, *bordyna* (in German – *bording*), *byrding* already in the 13th century and refer inter alia to inland vessels from the Upper Vistula basin and port vessels used for reloading of goods (lighterage) and in coastal shipping (Ossowski 2012: 19).

The first wreck unambiguously identified as the remains of *bordyna*-type vessel was discovered in 2008 at Dead Vistula (Martwa Wisła). The boat was ca. 18-20 meters in length, 6.3 m in width, with 4.7-m-high sternpost. The trees to build the boat were felled in the 1720s. It was a spindle-shaped flat-bottomed boat made of seven carvel-built planks. The boat was built by the shell method or flat bottom method (Ossowski 2012: 16). This interpretation can also be applied for the construction of vessel known as the remains of F53.26 wreck, as it belongs to the same type.

Bordyna-type vessels had one mast and were additionally propelled and steered with quant poles, the so-called setting poles (Fig. 3). The boats had a flat bottom, block coefficient of the hull, large cargo hold with high coamings and narrow communication decks.

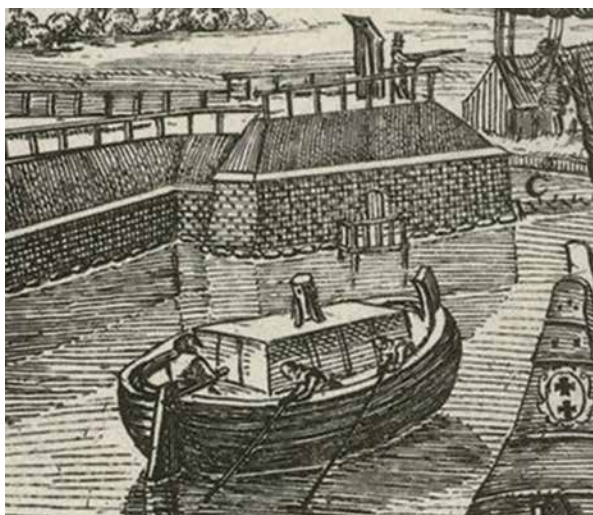


Fig. 3 Bordyna type vessel in the area of the Wisłoujście fortress on the drawing of Aedigius Dickmann from 1617. Bordina's crew moves the vessel using quant poles, the so-called setting poles (Herzog Anton Ulrich Museum).

In the 15th century in Gdańsk the reloading of goods could only be performed by the residents of Gdańsk; however, from the end of the 16th century, after obtaining the consent from the mayor of Gdańsk, non-residents of the city by the Motława River could also do it for a living. The members of bordyna guild also included the owners of seagoing vessels and granaries, who decreased the costs of service of their own vessels by investing in the transport of goods. Since 1724, in the St. John's Church in Gdańsk below the southern gallery there was the bordyna guild lodge (brotherhood). The lodge survived until modern times as the only one out of several lodges placed in this church (Bednarz 2020: 304).

Already in the 16th century, bordyna-type vessels used in the port of Gdańsk were divided into three classes by their size and capacity. The largest of them fell into class I of the capacity from 60 to 100 lasts, smaller ones fell into class II of the capacity from 30 to 60 lasts and the smallest class III of less than 30 lasts in capacity. In 1733, the mayor of Gdansk instructed the guild to build new bordyna-type vessels of the capacity up to 70 lasts. In 1765, there were 85 bordyna-type vessels and ballast boats used in Gdańsk (Matysik 1958: 107, 117).

Although in the case of the F53.26 wreck we only have a partially preserved structure, we can try to approximate the tonnage of the vessel. For this purpose, the dimensions of the unit must be determined in order to subject them to appropriate calculation methods. Length of the bottom part (keel) – 14 m, width of the bottom part 2.35 m, of which, by analogy to the Bordyna wreck from Dead Vistula (Martwa Wisła), we can indicate that the width of the unit was about 5.3– 5.5 m, and the maximum draft can be approximately point at approximately 2 m¹. The above dimensions in feet² divided by 100 with 1/3 of the value added to the result indicate the approximate tonnage of the unit (Ossowski 2012: 21). The conversion rate is as follows $(48 \text{ length} \times 19 \text{ width} \times 7 \text{ maximum draft} / 100) + 1/3$, which gives a result of approximately 80 lasts. Comparatively using another conversion factor used to calculate the load capacity of units, where the length and width of the hull and the height of the hold in feet are divided by 2003, we get a result of about 60 lasts. As for the F53.26 wreck, its capacity can be estimated at ca. 60–80 lasts (120–160 t). This indicates that the boat belonged to class I i.e., the largest bordyna-type vessels used for reloading in the port of Gdańsk and its roadstead. On the wreck, a load with the total weight of ca. 35 t was identified, including lead ingots and stones undiscovered during the site exploration. This potentially shows that the boat was not loaded to the maximum. However, we need to remember that some part of the cargo could have been recovered after the shipwreck, which occurred near the shore at a shallow depth, or could have been scattered near the site.

The identification of the F53.26 wreck as the remains of a bordyna-type vessel allows us to assume that the cargo in the form of semi-finished quern stones and lead ingots was being transported to the port of Gdańsk after transfer from a seagoing vessel. The microscopic analysis of the stones proved that they were imported from Germany or France. The lead ingots most probably also come from outside the Republic of Poland (most likely from England), since the lightered cargo most likely came from one ship.

¹ Analogous dimensions for the *bordyna* from Dead Vistula are as follows: keel length – 16 m, width 6.3 m, maximum draft 2.2 m.

² For the calculations, the dimension of 1 Gdańsk foot (ft) was assumed, which is 28.69 cm.

³ Estimated dimensions used for calculations: length between staves 58 ft, width 19 ft, height of the hold 11 ft.

Wreck F53.9

Another wreck examined by the archaeologists from the National Maritime Museum is the F53.9 wreck, a flat-bottomed vessel with inland vessel structural elements which could have been used as a lighter to transport goods within the port of Gdańsk. The wreck was discovered by a group of divers from Gdynia in September 2002 and lies at a depth of 16 m, at a distance of ca. 7 nmi north of the entrance to the port of Gdańsk. Underwater investigation of the wreck was performed in 2003, 2006 and 2015.



Fig. 4 Photogrammetric 3D model of the F53.9 wreck in the top view (model: T. Bednarz, K. Treder)

In the plan we can see the wreck as a spindle-shaped flat wooden structure, made of oak planks, 9–11 cm thick and 25 cm wide, carvel-built, with massive pine floor timbers spaced ca. every 50 cm (Fig. 4). We also identified the elbow frames mounted to the floor timbers with metal pegs and fragments of the lower strake of one of the ship's sides. The frame shape indicates that the sloping sides (ca. 120 degrees) were carvel-built, with planks from 6 to 7 cm thick. The strakes of the sides were caulked with laths, mounted in specially carved grooves in planks. The length of the wreck totals 25.6 meters, whereas its width amounts to 6.2 meters. The results of dendrochronological analysis indicated that the earliest date of the ship's construction was 1854. The wood used to build the ship came from the centre or upper Vistula River basin (Ossowski 2010: 147; Bednarz 2016: 9, Fig. 4).

Wreck F53.12

Another investigated vessel is the F53.12 wreck, the remains of a flat-bottomed vessel made of pine wood (bottom planking) and oak wood (floor timbers, ship's sides), operating most probably as a reloading ship or used in local freight shipping between the ports of the Gulf of Gdańsk. The materials used to build the ship were similar to the F53.26 wreck. The wreck was discovered in 2008 by the employees of the Maritime Office. The exploratory works of the wreck were conducted by the archaeologists of the NMM in 2009. In 2018, the museum research team performed a thorough inventory of the site.

The ship's flat bottom was made of pine planks, whereas the floor timbers and ship's sides were of oak wood. The object lies at a depth of 4 meters near Brzeźno, ca. 300 m from the shore. The longitudinal axis of the wreck is oriented along the north – south direction. The end of the wreck on the north side is buried in the sandy seabed. The ship's total length totalled ca. 24–25 m and its width ca. 7 m. The ship's structure comprises carvel-built bottom planking, 32–41 cm wide and 6–7 cm thick; 17 oak floor timbers, 11–20 cm wide and 11–15 cm high, mounted to the planking with 3 cm diameter pegs; and partially preserved fragments of oak staves, up to 18 cm wide, mounted with iron nails. The bottom planks along the length were joint on nibbed scarf. The ship was built after 1869, of wood from the north-eastern part of Poland (Bednarz 2018: 9, 22, Fig. 5).



Fig. 5 Photogrammetric 3D model of the F53.12 wreck in top view (model: T. Bednarz, K. Treder)

Wreck F32.9

Another ship within the analysed group is the F32.9 wreck, which constitutes the remains of a flat-bottomed vessel, 20–22 m long and 5 m wide, most probably used in local transport within the ports of the Gulf of Gdańsk. The wreck was discovered in 2015 by the employees of the Maritime Office. The investigation of the wreck was conducted by the archaeologists of the NMM in 2015. The underwater inventory of the wreck was performed in 2018.

The site lies at a depth of 3 m near Mechelinki, ca. 200 m from the shore. The ship was most probably built and used in the second half of the 18th century. In the absence of dendrochronological dating, the chronology was defined based on radiocarbon survey. The ship's structure comprises carvel-built oak planking, 22–8 cm wide and 7 cm thick; oak floor timbers, 26–30 cm wide and 16–20 cm high were spaced 24–32 cm apart and mounted to the bottom with 3 cm diameter pegs; and fragments of ship's sides, 25 cm high, in the form of oak staves, 3–5 cm thick. The preserved end of the bottom part on the south-east side is shaped as a wide, massive floor timber reinforcing the ship's structure and shaping the ship's sides at the stem or sternpost. The preserved fragments allowed us to identify the length of ship's bottom at 19.5 m. Several bricks which could constitute a part of the ship's cargo were discovered in the wreck and in its immediate vicinity (Bednarz 2018: 9, 22, Fig. 6).



Fig. 6 Photogrammetric 3D model of the F32.9 wreck in the top view (model: T. Bednarz, K. Treder)

Wreck F53.20

The last flat-bottomed object identified at the bottom of the Gulf of Gdańsk is the F53.20 wreck, whose structural features prove that it constitutes the remains of a no-keel inland watercraft, at least 19 m in length and ca. 5 m in width (Fig. 7). The wreck was discovered in 2010 by the employees of the Maritime Office. Underwater research of the wreck was conducted by the archaeologists of the NMM in 2010 and 2011. The underwater inventory of the wreck was performed in 2018.

The wreck is turned upside-down and lies at a depth of 5 m near Westerplatte, at a distance of 440 m from the shore and 420 m north-east of the F53.26 wreck. The wood sample dating indicates that the ship was built after 1547, and it was used most probably in the second half of the 16th century. During the survey we documented seven carvel-built oak planks, from 20 to 50 cm wide, forming the ship's flat bottom. The planks are V-shaped, chamfered for moss caulking. The caulking was clenched with wooden strips, and these were mounted to the planking with iron clamps. Oak floor timbers were made of naturally curved pieces of timber spaced every 60 cm and connected to pine staves with 3 cm diameter pine pegs.



Fig. 7 Photogrammetric 3D model of the F53.20 wreck in the top view (model: T. Bednarz, K. Treder)

Some floor timbers have drain culverts, and in one there is a rectangular opening used to mount the base of the superstructure. The place where the bottom meets the ship's side is formed by the L-shaped chine girders – grooved beams of 20 cm in height. This is proven by the cuts in curved pieces of floor timbers. The L-shaped chine girders, fitted at the same angle as floor timbers, formed the first strake of the ship's sides (Ossowski 2011: 21; Bednarz 2018: 7, 22). Figure 8 is showing 3D model of a flat-bottomed Vistula vessel. The same type like wreck F53.20.

From among 30 wooden wrecks identified and examined at the bottom of the Gulf of Gdańsk, dated to the 15th–19th centuries, the five discussed in this article are flat-bottomed vessels from the 16th–19th centuries, used to reload and transport goods between the ports of the Gulf of Gdańsk or, as in the case of the F53.20 wreck, to operate as inland means of transport to float goods down the Vistula River.

Detailed knowledge about the units discussed in the article was obtained thanks to systematic archaeological and archival research conducted in recent years by the author of this publication. This is the first synthesis of all wrecks of flat-bottomed vessels that were discovered and researched at the bottom of the Bay of Gdańsk.



Fig. 8 3D model of a flat-bottomed Vistula vessel (model: T. Bednarz, K. Treder)

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Boats from a Silesian coal mine

Robert Domżał

Abstract: In January and April 2013 two unique boats were discovered in the layer of silt in a 200-year-old Adit in the area of Zabrze (Silesia, southern Poland). They lay in a disused gallery about 22 m underground. The boats are similar in size: 5 m in length and less than a metre in width. Probably they were not used to transport the coal, but to carry the miners, tools and materials, possibly also for inspections of the mine site. It is presumably one of the oldest galleries carved out in coal in the world. Author discusses the circumstances of the discovery of the boats, their construction and their utility details.

Keywords: boats, coal mining, x-ray, conservation, digitalization

For 62 years the National Maritime Museum (NMM) has been gathering and preserving objects pertaining to the maritime history of Poland. The cultural heritage of inland waters – rivers and lakes – is one of the more important aspects of our work. Our collections include a few dozen of traditional types of boats from all over Poland (Domżał 2017). Among the archaeological and restoration project we have been pursuing, there are two peculiar boats, discovered in a 200-years old mine adit in Zabrze (Silesia, Southern Poland).

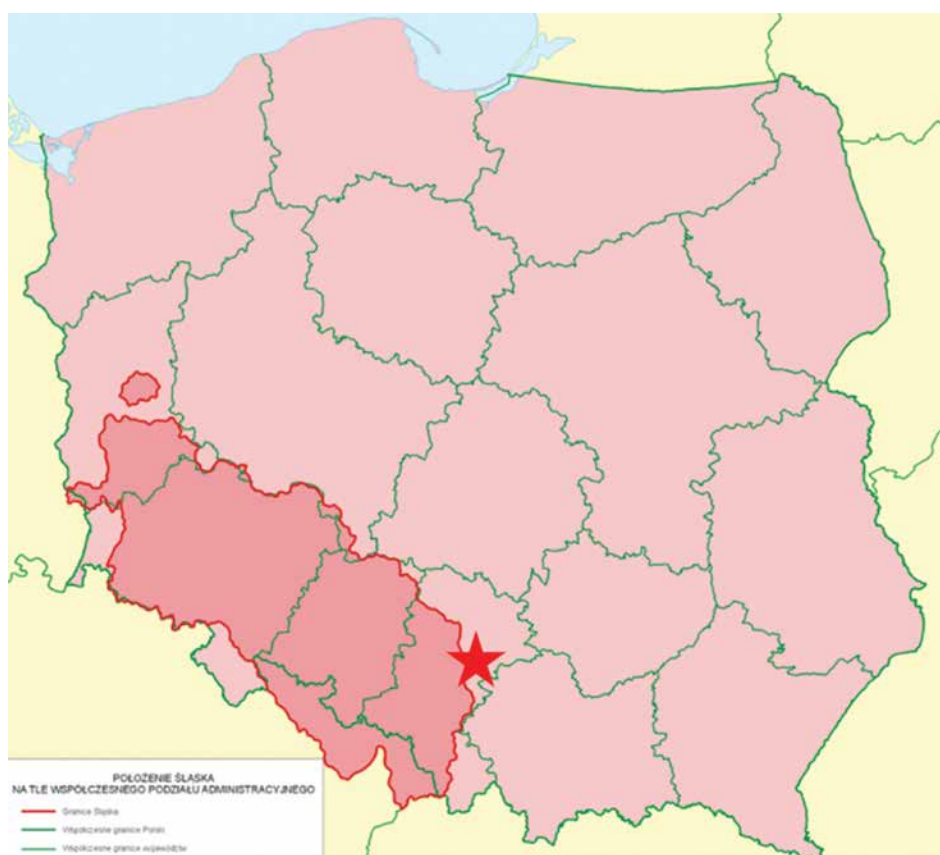


Fig. 1 Map with localisation of Silesian region and Zabrze city, where boats were found (author: R. Domżał, based on Wikipedia maps, https://en.wikipedia.org/wiki/Lower_Silesia)

In January and April 2013 two unique boats were discovered in the layer of silt in a 200-year-old adit in the area of Zabrze (Fig. 1). They lay in a disused gallery of the adit about 22 m underground. How did these vessels end up at such depth under the ground? At the end of the 18th century the construction of the Main Key Hereditary Adit began. It served as both a drainage adit and as an underground water canal between Zabrze and Królewska Huta in Upper Silesia. It is one of the longest hereditary adits in Europe and is the longest hydrotechnical construction in European coal mining. It is presumably one of the oldest galleries carved out of coal in the world (Kossuth 1965).

Drainage adits were used to transfer boats already in 1766 in Worsley, England, and from 1794 in the Fox Adit in Waldenburg, Germany (currently Wałbrzych, Poland). Based on these examples a plan was conceived to build the Main Key Hereditary Adit (*Hauptschluselerbstollen*) in order to drain the coalfields between Królewska Huta (Königshütte) and Zabrze, and, by means of the Gliwice Canal, to connect the Queen Luise Mine with the iron works in Gliwice and the river port on the Odra river in Koźle (Jurkiewicz 2002). The Main Key Hereditary Adit underground canal was dug in 1799–1863, which runs a few dozen metres below ground for 14 km, connecting Chorzów and Zabrze (Fig. 2). The canal was used to drain the local coal mines and as a route for coal-laden boats to the entrance of the adit, located in the current centre of Zabrze. From there the boats passed into an over ground canal leading to Gliwice (Jaros 1991). In 1951 the entrance to the adit was walled up.



Fig. 2 One of the boats covered with mud found in the adit (photo: courtesy of Coal Mining Museum in Zabrze)

The construction of the Main Key Hereditary Adit began on June 23, 1799. The exit of the adit was located in Zabrze, in the valley of the Bytomka, at the point located 231.4 m above sea level, or in one of the lowest points in the whole Upper Silesian Coal Region. The work on the Kłodnicki Canal joining the coalfields with the rest of the country began in 1792. A new stretch of the Gliwice Canal up to the exit of the Main Key Hereditary Adit was built in 1801–1806 (Jaros 1965).

The Main Key Hereditary Adit became an important waterway for transporting coal to the Royal Iron Works in Gliwice and further on to the Odra River. The first transports of coal went through the adit most probably in 1806. After making coal seams accessible, ports were built, from which mining roads were carved. The coal was loaded into wooden crates reinforced with flat bars and girdles, capable of holding about 370 kg of coal. These crates were in turn loaded onto rail carts and pulled by horses or men up to the bank of the adit (Frużyński 2007).

The crates used to transport freshly dug coal were detachable from the rail chassis. Then cranes lifted the crates into special compartments in the boats. The boats conveyed the coal through the 8.5 km long canal to the iron works in Gliwice. There the crates were hoisted onto rail carts, which transported the fuel where needed. A small port was built on the grounds of the iron works to load the coal from the crates onto river barges. An interesting aspect of this system is that the adit canal had no locks, but two inclined planes – one in Sośnica (10.6 m high), and the other within the iron works (5.1 m high). In another port a small crane was used to service a pier, to which the coal carts were lowered by means of a windlass.

The first of the ports described above was most probably the main underground loading port in the adit. It was connected to the rest of the mine not with a drift, but a gallery, which allowed the use of horse transport. The horses pulled carts loaded with three coal crates placed transversely. The man-operated windlasses at drifts could lower only one box at a time. The length and the width of the wharf sufficed for building the necessary track sidings, allowing to manoeuvre the horse-pulled carts as needed. The rotating crane between the tracks could, with one rotation, hoist an empty crate from the boat and lower a laden crate onto it. To accommodate the workhorses, a small stable was built right next to the port. Regardless of the economical aspect, the Main Key Hereditary Adit was undoubtedly one of the most profound achievements of mining and hydro-technical engineering in late 18th early 19th century Upper Silesia (Jurkiewicz 2002).

The coal transport boats used in the Adit were made of wood reinforced with iron bars. Each of the boats had two iron rings mounted on the bow and two plug-ended chains on the stern, which were used to attach the boats to each other. Each boat was divided into 10 or 11 compartments, each for one coal crate, which amounted to four tons of cargo.

Each coal transport was usually composed of three or four linked boats. One worker stood on the bow of the first boat, grabbed on handles protruding from the ceiling of the adit and pushed the boats forward using his legs. When he found himself on the last boat, he walked to the fore boat and repeated the procedure. Pushing a train of boats from the underground pier to the exit of the Adit (1.6–2.5 km) took six to seven hours. Joining the boats was more economical, as it shortened the operation. However, due to the difficulties with long trains of boats passing each other in the Adit, only occasionally would more than four boats be linked. The introduction of a wooden pole, with which the driver would push the boats against the roof and sides of the Adit, shortened the transport time to three to four hours. The boats leaving the Adit moored in the transfer port, where a crane hoisted the crates onto larger barges, capable of taking 18 crates. During a single workday a few workers operating the crane could offload about 100 crates, which means that daily two or three 3–4 boat trains would leave the adit. The barges, pulled by men walking along the canal, would then be taken to Gliwice and on to Koźle (Frużyński 2000).

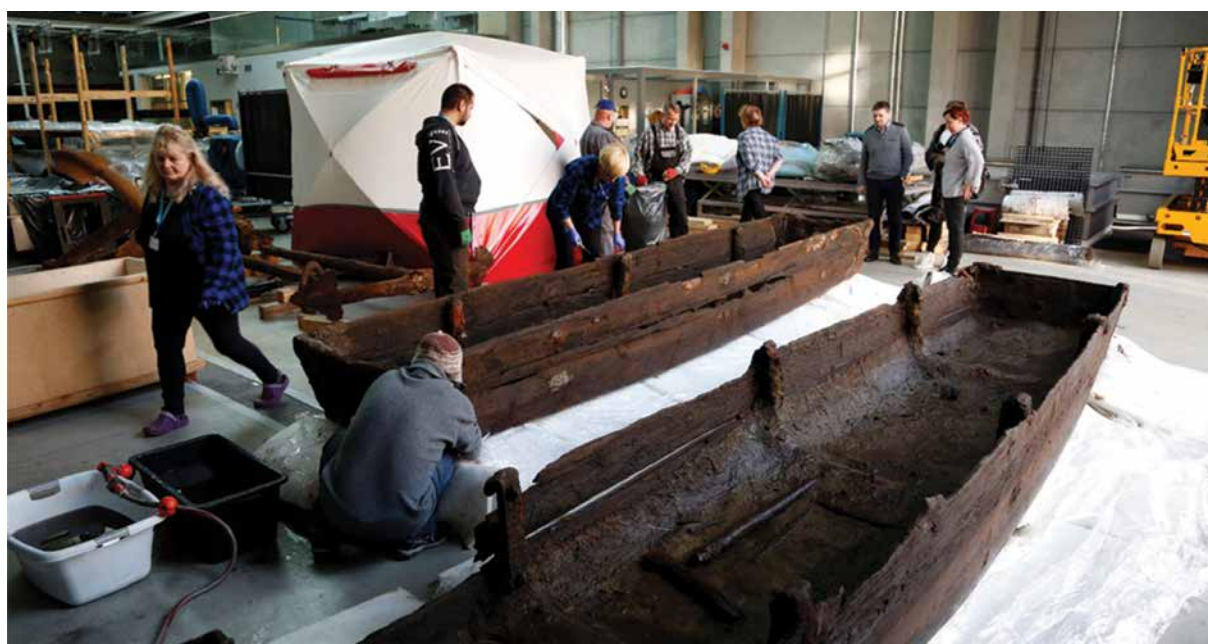


Fig. 3 Both objects examined in the Shipwreck Conservation Centre in Tczew, branch of the National Maritime Museum in Gdansk (photo: P. Jozwiak)

The two boats found in the Main Key Hereditary Adit in Jan and April 2013 were called Z1 and Z2 (Fig. 3), and soon after discovery were stored in special tanks with water. Both artefacts are the property of the Coal Mining Museum in Zabrze. Due to the lack of specialised conservation laboratory in Silesian region, NMM in Gdansk was asked to take care of the conservation process. In result, both boats were transported to the Shipwreck Conservation Center in Tczew, 50 km from Gdansk. This branch of the NMM was opened in 2016. The boats are similar in size: 5 m in length and less than 1 m in width. Z1 was made from the Douglas fir wood and Z2 from pine wood. None of the boats was used to transport coal, as one might assume, but rather to carry the miners, tools and materials, and possibly also for inspections of the mine site. Vessels of this kind might have been used in mining from the middle of the 19th century until the second half of the 20th century. Despite numerous distortions, the condition of the boats can be considered to be good (Fig. 4).



Fig. 4 Boat no. 1 after cleaning, prepared for scanning (photo: P. Jozwiak)

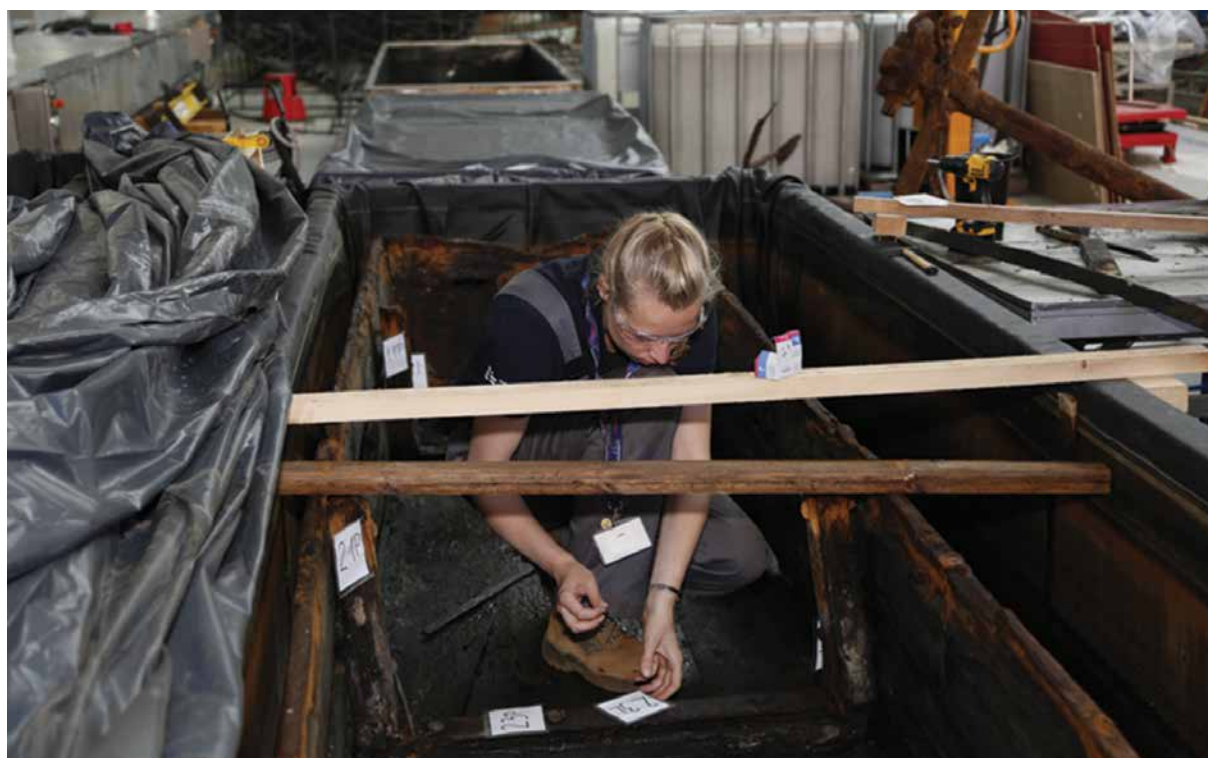


Fig. 5 Taking samples for the analytical research from both objects (photo: P. Jozwiak)

The Coal Mining Museum in Zabrze has tasked the National Maritime Museum in Gdańsk to conserve both objects. Prior to the beginning of the conservation proper tests were conducted to determine the deterioration of the wood and choose the appropriate conservation method (Fig. 5). The objects were x-rayed in order to check the condition of metal elements fastened to the wooden construction (Figs 7a and 7b). The chemical composition, both qualitative and quantitative, was determined by using a scanning electron microscope and X-ray spectroscopy.

Examination and conservation of the two boats found in the disused coal mine in Zabrze began in 2019. The microscopic testing was conducted to determine the type of wood used in the construction of boats Z1 and Z2. The physicochemical testing was conducted to determine the condition of the wood in both boats, which had remained in water for dozens of years. A number of standard tests were conducted: measuring the maximum humidity, the holocellulose, cellulose, cellucotton, and mineral content. The moisture content varied between 153–250% in Boat Z1 and from 71 to 250% in Boat Z2, which shows the large difference in the level of deterioration of the wooden construction. The side planks were found to be in much worse condition than the vertical elements of the frame and of the bottom. After the disassembly of the metal elements the process of removal of deleterious iron compounds began. A few dozens of the wooden and metal elements were submerged in coordinating complex solution, which has been replaced every few months. Former wreck conservation projects enabled assessment on the proper treatment methods (Jagielska 2015).

At the same time test conservations were performed on wood, first on samples, later on smaller elements of the boats. The samples were conducted by impregnation with various solutions of PEG and by freeze-drying. The best effects – largest increase in durability and decrease in shrinkage – were achieved by PEG 4000 impregnation and by lyophilisation.



Fig. 6 Boat no. 1 after cleaning, prepared for scanning (photo: P. Jozwiak)

In 2020 Boat Z2 was disassembled, while in 2021 it was decided to proceed with the disassembly of Boat Z1. Samples of the conserving agent are taken regularly to monitor the chloride ions content. After the removal of chlorides from the metal is completed, the elements will be cleaned mechanically. The final stage will be sealing the elements to protect them from harmful external factors. The investigation into the metal elements of Boat Z2 is still in progress. Published results of tests on Boat Z2 and the research into the professional literature will help in determining the best conservation method, including one option which is not very common, but has already been implemented in some research (Almkvist, Hocker, Sahlstedt 2013).

Based on the analysis of test results and conferring with conservators from a number of Polish museums, a decision was made to separate the metal and wooden elements and to conserve them separately. All the elements will be reassembled after completing the conservation procedures. Before the boats were dismantled, they were photographed and 3D-scanned to provide documentation necessary for restoration process.

Scanning of two boats from Zabrze in the Shipwreck Conservation Centre in Tczew took one workday. Each of the boats was scanned along all the planes. Fifty scans were made, 20 for the first, and 30 for the second boat. The scanning was conducted using a handheld Artec Eva optic scanner, which uses structured light, i.e., projects narrow strips of light which fall on the surface of the scanned object; the cameras then analyse the distortion of the light. The scanner is able to detect the geometry and the texture of the scanned object. Artec Studio software was used to create the 3D models. The whole process took three workdays, used for processing the images, removal of artifacts and errors, merging the scans in order to create a 3D image, and finally, geometrical corrections and application of textures (Fig. 6).

In November 2021 the Digitalisation Department of the National Maritime Museum began the process of scanning the parts of the disassembled boats, which was done in the Conservation Workshop of the Maritime Culture Centre. Again, the Artec Eva optical scanner was used. Scanning over 100 parts took two weeks, during which about 500 scans were conducted. Overall, the creation of 3D models of the boats, including processing the scans, required three months of work. Similar 3D documentation projects of the objects from coal mines are known from Germany (Schmidt-Reimann, Reuter 2015).

This documentation has proved very helpful in the conservation and the disassembly of both boats. We believe that the conservation of both boats will require about four years. After that, we would be happy to share the results of this project.



Figs 7a and 7b Radiography as a tool to assess state of preservation of metal parts before the dismantling (photo: B. Galus)

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RECENT DISCOVERIES

The Phoenician shipwreck off Xlendi Bay, Gozo – initial observations, size and shipbuilding technologies used

Alberto Bravo-Morata Rodríguez – Timmy Gambin

Abstract: In 2007, during an offshore remote sensing survey aimed at mapping Malta's Underwater Cultural Heritage, a small anomaly was noted in the sonar data. Since then, a team led by the University of Malta has been studying what turned out to be an extremely important discovery.

Found at a depth of 110 m off Xlendi Bay in Gozo (Malta), the Phoenician shipwreck consists of an intact and well-preserved mixed cargo of amphoras, saddle querns and grinding stones datable to the 7th century BC. The paper focuses on a particular aspect of the site – the ship itself. Using the limited evidence available so far, the authors present aspects related to the site's size, the wood used for its construction as well as construction techniques.

Keywords: Phoenicians, Shipwreck, Trade, Amphora, Malta

1. The discovery

In 2007, the University of Malta was conducting a systematic survey off Xlendi Bay in Gozo. The main aim of this survey was to delineate archaeological deposits situated close to a reef under Xlendi tower. During this survey, a small anomaly was noted at a depth of -110m (Fig. 1). The anomaly measure twelve by five meters with an outline proportions that resembled the remains of an ancient ship. Moreover, some of the 'objects' seemed to be of anthropogenic origin.

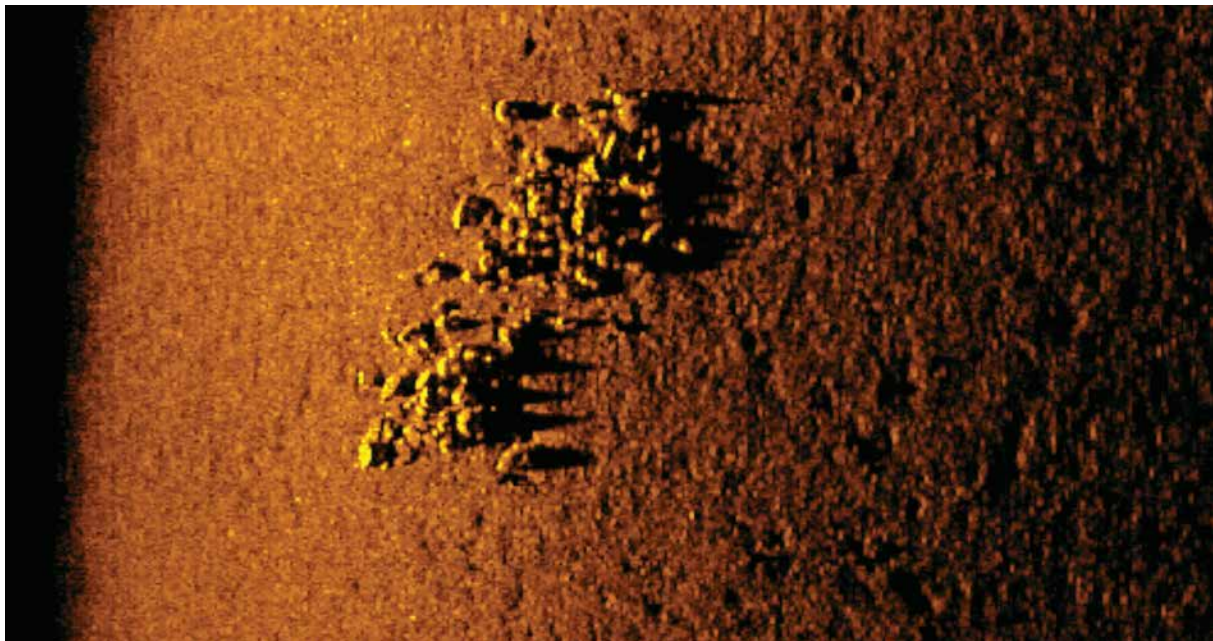


Fig. 1 First SSS image of the site (author: University of Malta)

2. The first visual inspections

In 2009, the site was explored using a remotely operated vehicle (ROV). This ROV survey confirmed that the anomaly was indeed an ancient shipwreck with a mixed cargo of stone blocks and ceramic containers. Using an ROV, the team was able to produce a photomosaic of the entire site which in turn facilitated a better understanding of the site, its age and state of preservation. The site was identified as a 7th century BC shipwreck, with a well-preserved cargo of various types of amphoras and urns as well as numerous saddle querns, found in a concentration of 12 × 8 m.

In 2014, an international team consisting of personnel from the University of Malta, the CNRS (*Centre National de recherche Scientifique*), and Comex returned to the site to acquire high resolution imagery, create a detailed 3D photogrammetric model and to recover some objects. To achieve these objectives, dives were made with a small, manned submersible. This approach permitted the team to inspect the site at proximity as well as to make the first close observations (Fig. 2). The photogrammetric documentation produced on these inspections permitted the planning for object recovery.



Fig. 2 Inspecting the site with the Comex manned submersible (photo: University of Malta / Comex)

Although the site was well-documented in 2014, it was clear that a substantial part of this important archaeological site was still buried in the sediments – a fact evidenced by the presence of objects barely proud of the seabed. Despite the fact that no wooden remains are visible on the seabed, the deposit is quite concentrated, pointing to a wrecking process that must have seen the ship sink in a relatively intact state. It is evident that the cargo is purposely laid out in three sections with the stone blocks at either extremity and the centre of the ship reserved for ceramic objects.

3. Diving the site

Following exploratory dives in 2016 and 2017, a decision was made to conduct diver-led excavations of the site. In order to plan the difficult logistics and conduct this challenging project, an international team of highly qualified technical divers was brought together. This case has the added complexity of being located at a depth of -110m. The fact that no scientific excavations had ever been conducted at this depth meant that certain established techniques for underwater archaeology had to be adapted.

Dives were conducted using rebreathers. It takes approximately 6 minutes to descend to the site leaving divers with a maximum of 14 minutes on the shipwreck, with a final ascent which takes over two hours. Normally, dives last a total of around 3 hours. Safety is paramount, and a series of redundancy measures were put in place to reduce risks. These measures included the carrying of bail-out cylinders by individual divers, the placing of extra bail-out cylinders, the presence of a fast emergency boat and the presence of a fully qualified doctor.

4. Excavating the site

The area chosen for excavation coincides with a part of the wreck that seemed to have been disturbed in the past. Due to earlier disturbance, there was less surface material to clear. An area of two 2 m² grids were installed, which allowed the divers to easily position themselves in a short time after arriving on the site. The grid also facilitated stabilisation; an important matter due to the amount of equipment carried by technical divers (Fig. 3).



Fig. 3 The excavation area (photo: University of Malta / D. Gration)

4.1. The Cargo

After seven seasons of diving at least seven amphora typologies have been identified. Petrographic studies of some of the ceramic containers indicate that some of the cargo originated in Tunisia, Malta and Sicily (Anastasi *et al.* 2021). The saddle querns were confirmed to have been quarried on the island of Pantelleria, situated to the northwest of Gozo (Renzulli *et al.* 2019). As with most ancient wrecks, the amphoras found on the Xlendi site were unsealed. Most of the necks of the containers were found broken or the seals were lost at some point after the ship came to rest on the seabed.



Fig. 4 Wooden stopper of one of the extracted amphoras (photo: University of Malta / A. Bravo-Morata Rodríguez)

Nevertheless, in 2021 a significant discovery was made. Amphoras are brought to the surface are raised with the sediments still inside. The thick and compacted sediment also contains other ceramic fragments, small pieces of wood and numerous molluscs. Contents are sieved in order to separate the sediments from the remains. Sub-samples are retained for further studies. Whilst sieving one of the amphoras, fragments of what turned out to be a large wooden amphora stopper was found. The object is broken in four pieces but is 96% complete, which will allow us to reconstruct its shape (Fig. 4).

4.2. The Vessel

Wooden fragments started to be uncovered during the first excavation season in 2018. These fragments were in secondary contexts and could not be matched to a part of the ship. However, one sample was sent for C-14 dating and a sub-sample was sent for the identification of wood species. The C-14 test was conducted by the Poznan Radiocarbon Laboratory and yielded a date of circa 770BC (2555 ± 35 BP - OxCal v4.4.2 Bronk Ramsey (2020); r:5 Atmospheric data from Reimer *et al* (2020)). The wood was identified by F. Guibal as Aleppo pine or Italian stone pine (*Pinus halepensis* Mill./*P. pinea* L.). This is a common tree found throughout the Mediterranean region in antiquity (Mauri *et al.* 2016: 122–123).

In 2020, the first diagnostic wooden piece was excavated. Among fragments of wood in secondary contexts, a mortise section with a fragment of tenon and a peg still *in situ* was recovered (Fig. 5). This important find was subsequently raised to the surface so further studies could be conducted. Although broken into three pieces, when placed together it is relatively straightforward to understand. It consists of a section with a mortise measuring approximately 4 cm wide but of unknown length made out of Aleppo pine. The tenon (which has been identified as Olive tree, *Olea europaea*) is partially preserved and has a thickness of 0.8 cm. Its exact width and length cannot be measured. The peg, also made from Olive tree, has a diameter of 1 cm with an unknown length. Further in-depth studies are being carried out on all the wooden fragments recovered from the wreck. Based on the current evidences of structural elements, we propose that the hull could have been made from Aleppo pine using a mortise and tenon construction method. This should be confirmed once more elements from the structure appear.



Fig. 5 Fragments of mortise and tenon found within the excavation area (photo: University of Malta)

5. Conclusion

Although the post-excavation phase of the project has only just started, early results are promising. The cargo is shedding light on the economic history and trade networks of the Central Mediterranean during the Archaic period. Previously unknown ceramic typologies, alongside more commonly known objects, are providing new information on how the Phoenicians moved consumables such as wine as well as other functional objects such as the saddle querns. A series of scientific analysis to determine the exact contents of the ceramic containers are currently underway. On the other hand, the wooden fragments are starting to shed light on ship construction methods from a period from which we know very little.

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Shipwreck 5 from Thonis–Heracleion, Egypt

Franck Goddio – Alexander Belov

Abstract: The site of Thonis–Heracleion located in the Nile’s Delta contains more than a hundred ancient shipwrecks, most of which date to the Egyptian Late (664–332 BC) and Ptolemaic (332–31 BC) periods. Shipwreck 5 was excavated by the Institut Européen d’Archéologie Sous–Marine (IEASM) in 2019 and dates from the first half to the middle of the 4th century BC. The ship caught fire and sank during a putative naval battle. The preserved portion of the hull measures seven by three meters while the original length of the ship may be estimated at 14 to 15 m. The hull’s remains were in a good state of preservation and contained a considerable amount of thick ropes.

Keywords: maritime archaeology, Egyptian Late Period, Thonis–Heracleion, ancient shipwrecks, Greco–Roman type of construction

1. Introduction

The Institut Européen d’Archéologie Sous–Marine (IEASM) has identified 125 ancient ships in the waters of the Egyptian port–city of Thonis–Heracleion on the Mediterranean coast of Egypt (among the latest publications on the subject see Robinson *et al.* 2017; Goddio *et al.* 2020; Robinson, Goddio 2021). Some of these shipwrecks form accumulations with their hulls held in place by wooden stakes and may correspond to boat bridges, some could also have been used for the purpose of land reclamation (Fig. 1).

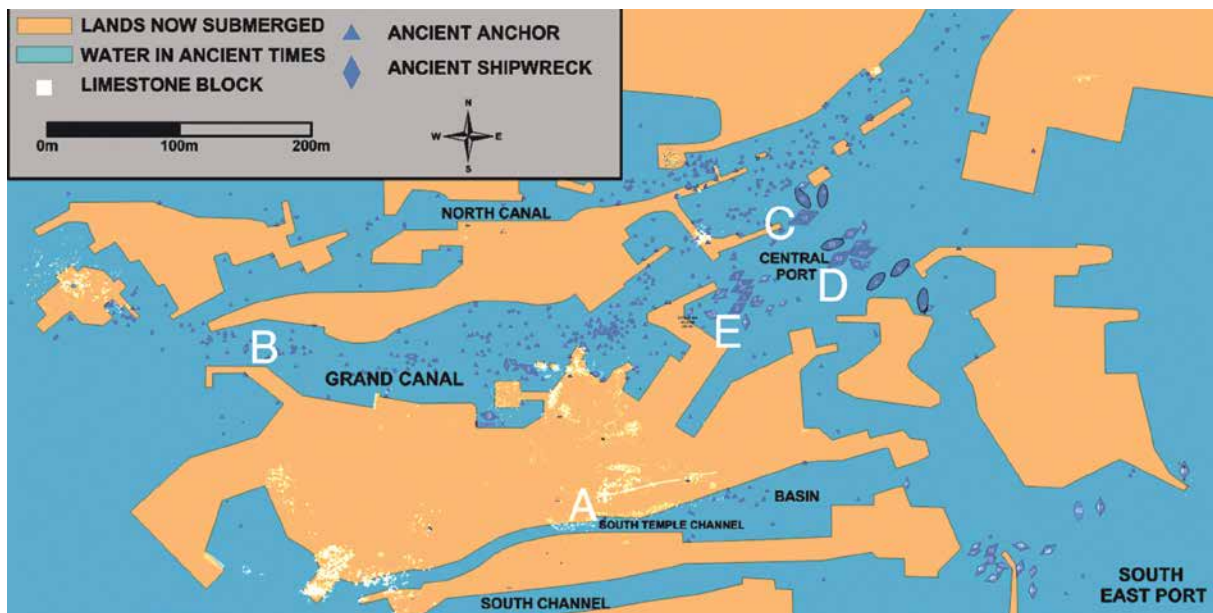


Fig. 1 Map showing the accumulations of ships in Thonis–Heracleion, after Robinson 2018, 326, Fig. 1 (map: F. Goddio, © F. Goddio/IEASM)

Two ships (Ships 17 and 43), belonging to the Eastern accumulation in the Central Port of the city (marked 'C' and 'D' on Fig. 1), have been fully or partially excavated and published (Belov 2014; 2019; Robinson 2015). These ships were identified as *barides* – local river-faring multipurpose freighters that were described by Herodotus in the middle of the 5th century BC (Belov 2015). Quite numerous on the site of Heracleion, they were built with local wood and demonstrate a very specific type of construction. However, the excavations in the spring of 2019 brought to light the remains of a small ship built in a classical shipbuilding tradition, relying on a dense network of mortise-and-tenon joinery for its planking.

2. Context and date of the ship

Ship 5 belongs to the accumulation of ships in the eastern part of the Central Port (marked 'E' on Fig.1). The depth at the excavation site was about seven meters. The upper planking of the ship was discovered under approximately 70 cm of sand. The interior of the hull below the sand was filled with dense fluvial clay. Ship 5 was surrounded by other shipwrecks, namely Ships 4, 6 and 41 (Fig. 2). Moreover, Ship 5 was deposited inside the hull of Ship 6 whose dimensions were considerably larger. All of the surrounding ships belonged to the *baris* type. A layer of sediment between Ships 5 and 6 confirms that some time had elapsed between the separate events of their deposition on the seafloor.

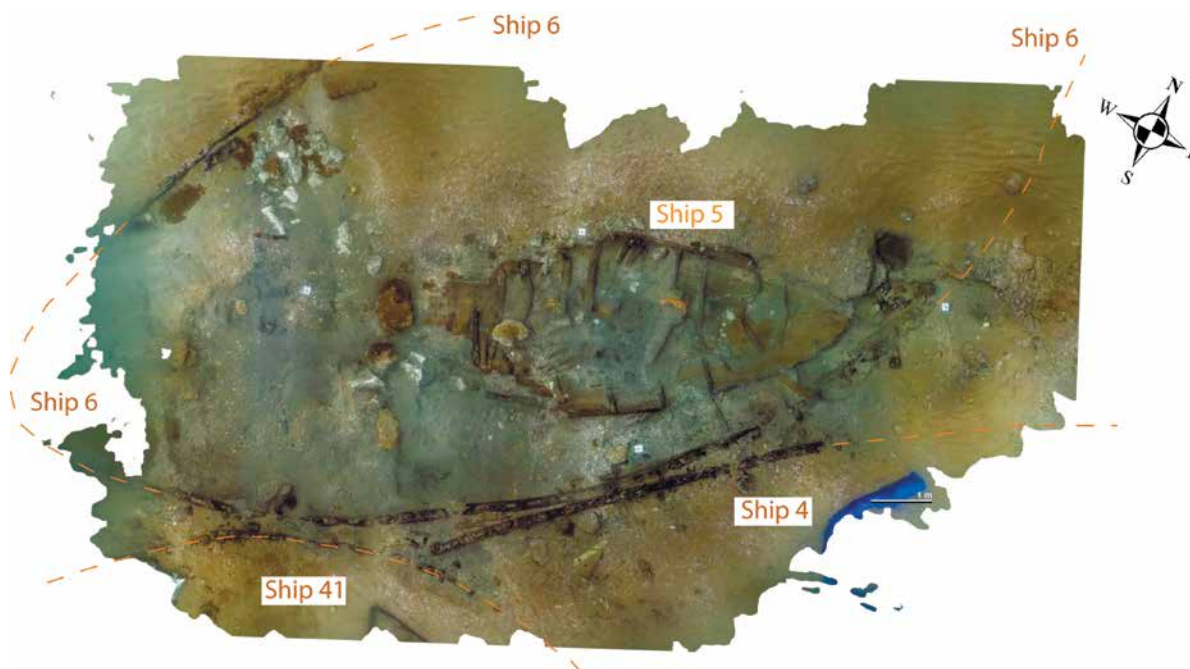


Fig. 2 Orthographic photograph showing the position of Ship 5 in relation to the surrounding Ships 4, 6 and 41 (photo: Ch. Gerigk, © F. Goddio/IEASM)

After the end of the excavation of Ship 5, it was recovered with the sediment and left *in situ*, as Egypt currently does not have facilities for the treatment and conservation of water-logged wood. The calibrated radiocarbon date for the sample of the planking is available from the Archéolabs laboratory in France (report ARC2118, 2001). It was dated 745 cal BC–380 cal BC at 95.4% and 595 cal BC–400 cal BC at 59.6% (calibration curve: IntCal98, Stuiver *et al.* 1998). The calibrated radiocarbon date for Ship 5 is very close to that of Ship 6 (Archéolabs, report ARC2119, 730–370 cal BC at 95.4% and 595–405 cal BC at 56.0%, calibration curve: IntCal98, Stuiver *et al.* 1998). Our experience shows that radiocarbon dating generally provides estimates that are less precise than those derived from the artefacts discovered on the site of Thonis–Heracleion and that pottery often affords a much narrower date range for associated objects. Several amphorae and pieces of tableware found directly resting on the interior of the hull of Ship 5 indicate that its sinking occurred sometime between the first half and the middle of the 4th century BC. It is possible that the recovered artifacts belonged to the cargo, although more research is needed to confirm this hypothesis.

Evidence further suggests that the ship was lost under tragic circumstances. The preserved section of the outer hull, many internal constructional members, and pieces of rigging bear witness to a strong fire (Fig. 3). Consequently, a considerable amount of charcoal was deposited inside the hull. The excavation brought to light several lead sling bullets and a Greek helmet of Chalcidian type (5th–4th c. BC). These artefacts allow for the suggestion that Ship 5 was lost during a military conflict, a hypothesis that will be elaborated on in the Conclusions.

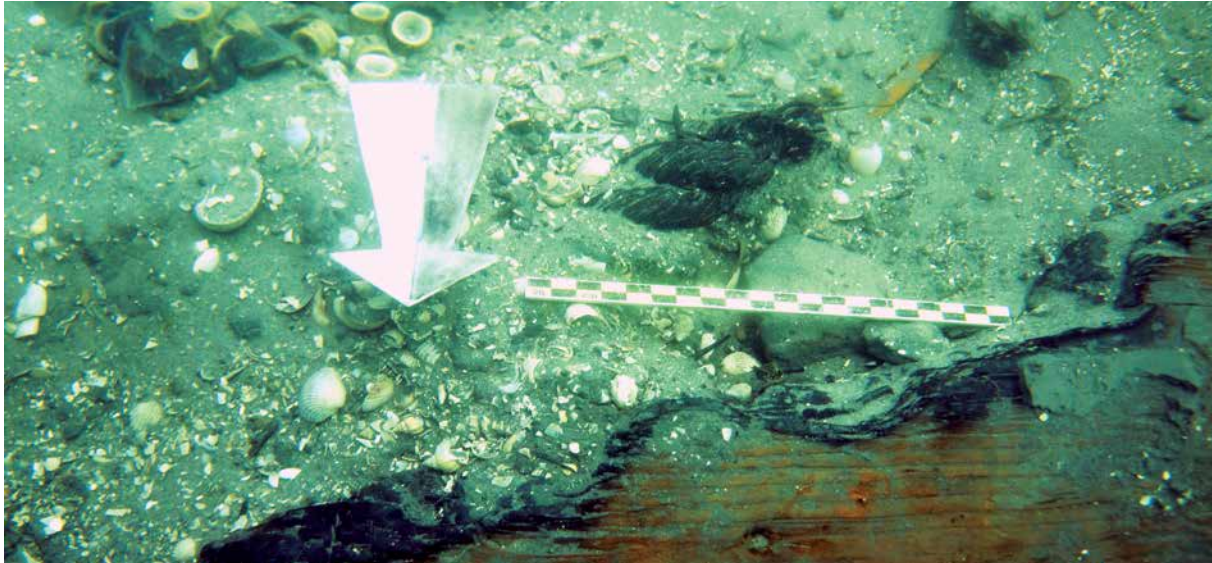


Fig. 3 The charred preserved section of the outer planking of the southern board of Ship 5 and the charred end of a rope (photo: D. Honoré © F. Goddio/IEASM)

3. Wood species and Construction

The wood species used in the construction of Ship 5 were determined by A. Belov in November 2021 using thin section microscopy (see Hather 2000: 12–20 and Akkemik 2015: 15–29 for descriptions of the standard methodology used). The use of species such as fir, pine, maple, and walnut in the construction of Ship 5 favours a foreign origin.

The wreck remains measure 7 by 3 m which corresponds to approximately one half of the initial length of the hull (Fig. 4). The remains of the ship do not allow for establishing which end was the bow and which was the stern. However, the mortise in the keel, probably destined to accommodate a mast, favours the position of the bow at the south–west. The southern board was found in a much better state of preservation than the northern one due to the considerable lurch of the ship to the south, reaching an angle of 36° at the eastern preserved extremity. The hull was also deposited with a considerable pitch towards the north–east.

3.1. Keel

The preserved length of the keel was about 7 m. The keel was formed from two pieces of wood cut from species of pine (*Pinus sylvestris* / *mugo* / *nigra*). It had no rabbet, and the inner garboard edges were simply set flush with its sides. It was essentially rectangular in section and was 11 cm high and 12 cm wide on mean average.

3.2. Fore or aft transition timber

Towards its north–eastern preserved extremity, the keel was continued with a transitional piece that had a pronounced angle of elevation. This piece represents either a gripe or forefoot timber at the bow transitioning to the stem or a similar timber at the aft end of the keel transitioning to the sternpost. The Jupiter scarf between the keel and the transitional timber had no key, probably owing to the modest size of the ship. The outboard preserved extremity of the transitional timber was broken and charred. However, a transversal rectangular opening was preserved that was probably part of a joint with a stem or a sternpost.

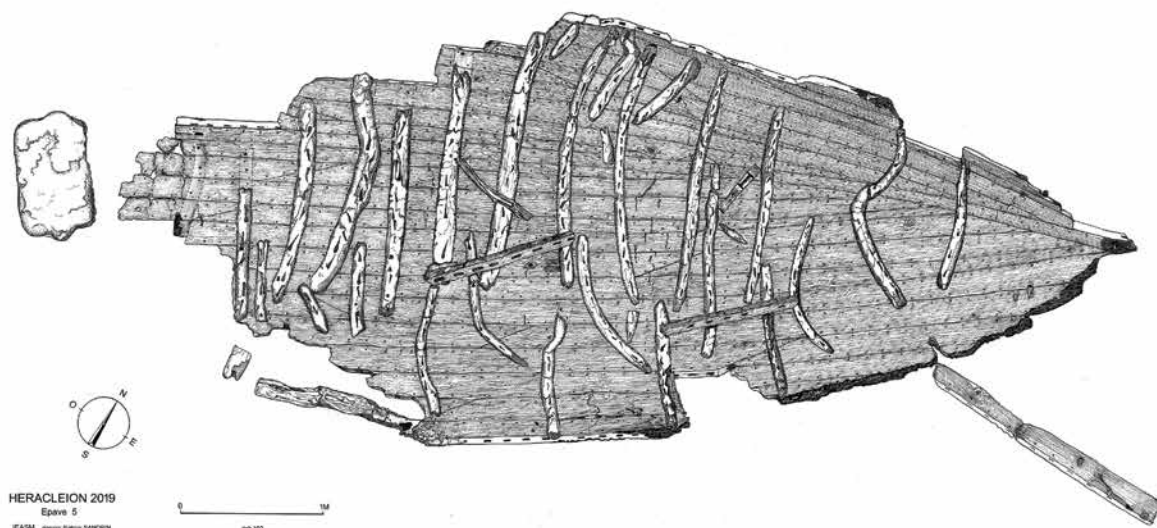


Fig. 4 Plan of the wreck (drawing: A. Roy, P. Sandrin, © F. Goddio/IEASM)



Fig. 5 Mortise-and-tenon joinery between strakes S13 (top) and S12 (bottom) with the mortises opened to reveal the interior of the joints (photo: D. Honoré, © F. Goddio/IEASM)

3.3. Planking

The planking of the ship was made of pine and silver fir (*Abies alba*). It was well preserved but rather worn, suggesting that Ship 5 was not new when it sank. The planks were plainly sawn, with their longitudinal edges cut square with no bevelling. Ten lines of strakes were preserved on the northern side and thirteen on the southern side. The plan of the planking was asymmetrical. The planks were tapering towards the extremities of the vessel and included several stealer strakes. The length of the six completely preserved planks varied from 2.7 to 5.5 m, with a mean average of 3.9 m. However, several incomplete strakes were longer, exceeding 6 m in length. Plank widths varied between 9 and 19 cm. The average thickness of the planks as observed in the preserved part of the hull was 2.5 cm. The upper wale was probably located at starboard strake S13, by far the thickest in the preserved part of the hull (3.8 cm). This strake had mortise-and-tenon joints in its upper edge, probably to secure a bulwark. This latter detail is now missing, but a plank found near the north-eastern extremity of the hull may be identified as a fragment of a bulwark. The diagonal scarf was exclusively used to join the planks of the same strake. The carvel planking of Ship 5 was assembled with pegged mortise-and-tenon joints cut in the middle of the edges of the planks. Traces of ligatures, sometimes reported from shipwrecks of this age, were nowhere to be seen on Ship 5. There were no traces of caulking or tar

either. Mortises were cut into both edges of each plank (Fig. 5). The majority were rectangular, but a few were hexagonal in shape. The mortises were, on average, 4.7 cm wide in the middle and 1.3 cm high (thick). The depth (height) of the pair of mortises was about 16 cm on average. However, the mortises composing a pair were not of equal depth (see Fig. 5). In several cases, the mortises were overlapping. The tenons were made of walnut (*Juglans cf regia*). Their corners were angled to fit the mortise bottoms. The tenons were secured inside the mortises by tapering pegs, which had an average diameter of 0.9 cm. The pegs went through the thickness of the planking and had been inserted from the outside of the hull. The distribution of mortise-and-tenon joints across the planking was regular and rather dense. The average centre-to-centre horizontal distance between the joints was 12 cm. Several planks bear witness to a repair.

3.4. Frames

27 elements belonging to the transversal structure were preserved in the construction of Ship 5, including 13 floor timbers cut from walnut and maple (*Acer sp.*). Their distribution was not very regular, nor were they positioned exactly at a right angle to the keel. The form and size of the frames varied considerably, and the distances between them was equally uneven. The floor timbers were fixed to the planking with double-clenched bronze nails driven through wooden pegs from the outside of the hull. Each of them had a single limber hole of triangular shape positioned over the keel. The futtocks were installed rather chaotically, and they were never connected to the floor timbers. The primary strength of the hull was provided by the pegged mortise-and-tenon joinery of the planking, and these frames were of secondary importance.

Although the reconstruction of the hull is still in progress, it is possible to suggest a ship with a round bilge having a reconstructed length of about 14–15 m. No vestiges of a deck were preserved, so at the current stage of research, it is difficult to say whether the ship was decked or not.

4. Ropes and rigging

A dozen rope segments were discovered inside the hull of Ship 5 (Fig. 6). They were in a good state of preservation and undoubtedly belonged to the ship, as they were found lying directly at the bottom of its hull. The samples of rope were collected for the subsequent determination of plant species.

The longest of the preserved segments measured 3.3 m; the others were slightly shorter. As per the orientation of the twist, all ropes were Z-twisted¹ cordage and had a diameter measured in situ approaching 5 cm. However, the ropes were considerably flattened due to post-depositional processes, and their initial diameter may be estimated at 3–3.5 cm. The ropes were composed of two strands, each probably consisting of three yarns of S-twist orientation.

Several hypotheses may be suggested for the accumulation of ropes inside the hull of Ship 5. All segments of rope were of the same diameter and of the same type. They were found lying on the internal hull in parallel lines along the longitudinal axis of the ship. The position of the ropes means that they were not part of the rigging of Ship 5. The diameter of the ropes rather indicates the mooring lines that possibly belonged to Ship 5. The other possibility is that she was transporting them. It remains unclear whether the cable, or cables, were part of Ship 5's cargo when it caught fire or whether she was preparing for the mooring in the harbour. No fragments of deck were found under the ropes. If being transported, the ropes would more likely have been coiled, rather than stowed in the manner in which they were found. The 'mooring' hypothesis remains plausible if the ship was not decked and had her cables stretched out in lines in preparation for the mooring. Inside the hull of Ship 5, a toggle, a dead-eye, and several sailors' tools were found.

¹ To determine the twist, an imaginary letter 'S' or 'Z' is superimposed on a length of cordage. The central stroke of the letter defines the orientation of the twist. A rope of Z-twist can be alternatively described as twisted to the left. Issues of terminology are considered in Sanders 2010.

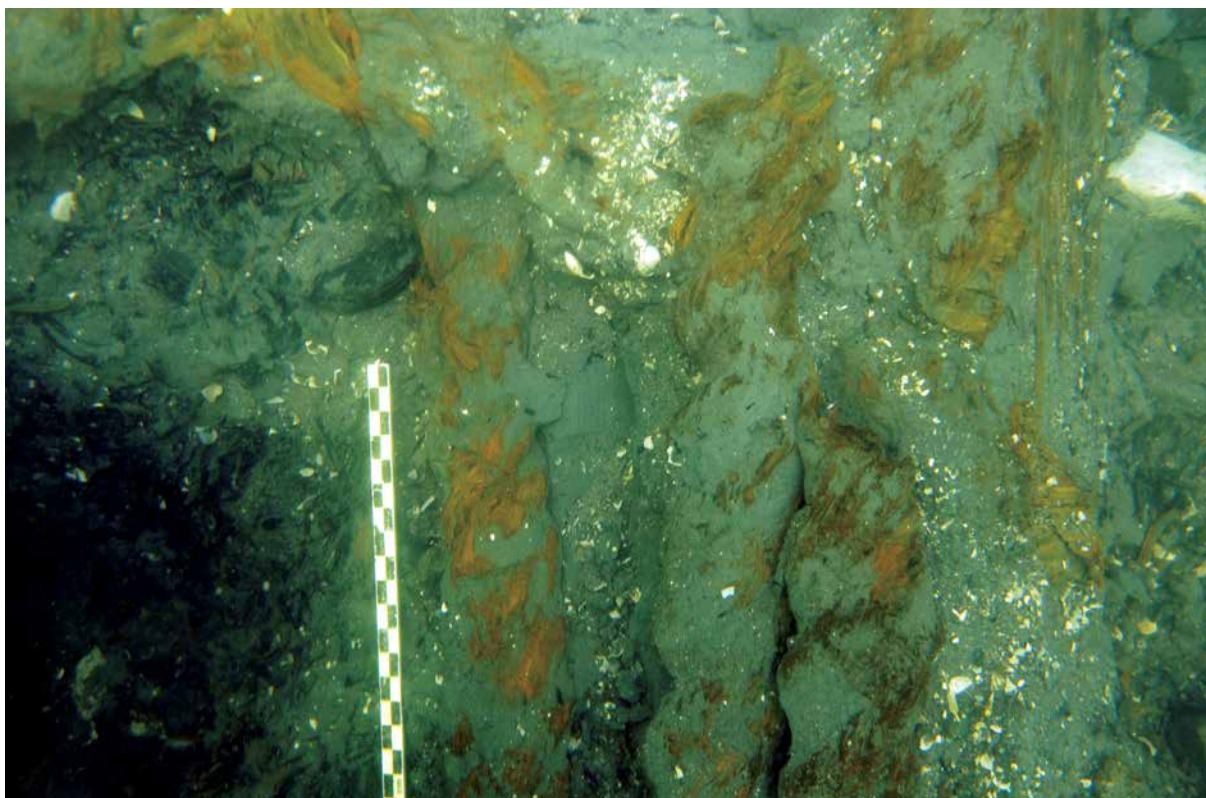


Fig. 2 Orthographic photograph showing the position of Ship 5 in relation to the surrounding Ships 4, 6 and 41 (photo: Ch. Gerigk, © F. Goddio/IEASM)

5. Conclusions

The transition in archaic Greek shipbuilding from the laced type of construction to one mainly relying on pegged mortise-and-tenon joinery took place from the late 6th century BC to the 4th century BC (Pomey 1997; Polzer 2012). Several archaic Greek shipwrecks demonstrate the concomitant use of both methods and testify to a gradual shift towards Greco-Roman shipbuilding traditions (e.g. Jules-Vernes 7 and 9, 6th c. BC). The final stage of this long development is best illustrated by the Kyrenia shipwreck from Cyprus (295–285 BC; see Steffy 1994: 42–59). Although older than the Kyrenia ship, Ship 5 contains no traces of laced joinery in its construction.

Thonis–Heracleion was situated at the entrance of the Canopic branch of the Nile, a point of strategic importance that gave the easiest access route to the Delta and to the Nile valley beyond. The city could not avoid the numerous waves of violence that shook the Delta through the 5th and 4th centuries BC. It seems that the revolt of Inaros and the Athenian intervention in 466 BC preceded the sinking of Ship 5. However, the time of the reconquest of Egypt by the Persians (343–342 BC) and the subsequent reign of Khabbabash (343 and 336–335 BC) was quite turbulent and included many martial episodes, one of which could have witnessed the sinking of Ship 5 (Fabre, Belov 2012: 115).

To conclude, there are not many known Mediterranean wrecks that date to the 4th c. BC and demonstrate a well-preserved hull. In this respect, the data collected from Ship 5 is of prime importance for the study of the naval architecture of the period. Moreover, the ship belongs to a different type of construction than the majority of the ships from Thonis–Heracleion and was in all likelihood built abroad. The ship further confirms that Thonis–Heracleion played an important role in Egyptian history in peacetime and wartime alike. The monograph devoted to the construction and function of Ship 5 is currently in preparation.

Acknowledgements

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The Roman Republican wreck Ilovik–Paržine 1, island of Ilovik (Croatia), Preliminary report

Giulia Boetto – Igor Miholjek – Pavle Dugonjić – Anton Divić – Vincent Dumas – Pierre Poveda – Ivan Vidulić

Abstract: Discovered in 2016 in the bay of Paržine, Ilovik Island (Croatia), the wreck Ilovik–Paržine 1 has been systematically excavated by a joint Croatian and French team from 2018 to 2021. It was a mortise-and-tenon built sailing ship of about 20–22 m in length, transporting a cargo of Adriatic Greco-Italic amphoras containing wine and timbers. Its last voyage took place between the 2nd or 3rd quarter of the 2nd century BC. Thanks to the ballast, the rear third of the ship was better preserved than the bow, part of which was found about 20 m to the east. The ship has a typical Hellenistic hull design (a cross-section with a wine-glass profile), and the large mortise on the easternmost end of the keel could be related to a specific ship shape characterized by nearly vertical stem.

Keywords: Croatia, Ilovik, wreck, mortise-and-tenon, Roman Republican

1. Introduction

The bay of Paržine lies to the south-east of the island of Ilovik in the Kvarner archipelago in Croatia. This bay is particularly well sheltered from the strong wind blowing from the northwest quadrant, the bura, but it is particularly exposed to the winds and storms from the southern quadrant (Fig. 1). It was here that Miran Erič, a conservator from the Slovenian Ministry of Culture, discovered in 2016 the remains of a mortise-and-tenon built ship emerging from the sandy bottom at a depth of 4 m, about 30 m from the beach. Erič reported the discovery to the director of the Lošinj Museum, Zrinka Ettinger Starčić and, the following year, Igor Miholjek from the Department for Underwater Archaeology at the Croatian Conservation Institute, organized a short survey which confirmed the interest for the site and the good preservation of the wooden structures.

During the survey, the upper part of the north side of the wreck was partially uncovered. Twenty frames and three strakes joined by pegged tenons were documented (Miholjek 2018). A wood sample was sent to the Beta Analytic laboratory for AMS radiocarbon dating. The results of the intercepted age with calibration curve indicated a date of 170 BC (cal BP 2120).¹

In 2018, Igor Miholjek contacted Giulia Boetto of the Centre Camille Jullian to start an international collaboration focused on the excavation and study of the ship's remains. The 5th and final campaign took place in September 2022 with the main objective of probing the area around the wreck in search for any detached parts of the ship and its cargo.

Thanks to an agreement signed between the Croatian Conservation Institute and the Croatian Ministry of the Interior, the project had the opportunity to accommodate all participants in a building belonging to the Special Forces of the Police in the bay of Kovčanje on the island of Lošinj. The collaboration with the Special Forces of the Police ensured the logistical support necessary for an underwater archaeological mission (filling of tanks, storage of diving equipment and archaeological material, running water, basins for desalination, work spaces, internet) including the motorboat to reach the bay of Paržine, located 13 nautical miles south of Kovčanje.

Each year in September, the work program was divided into several activities starting with the excavation, cleaning and labelling of the finds and the structure of the ship, continuing with the systematic application of the photogrammetry as the main method of documentation but also employing direct measurements and observations, carrying out selective dismantling of structures to reach and document hidden parts of the hull, sampling for analyses, and ending

¹ Laboratory code: Beta-454977 Ilovik 1.

with the final protection of the site with sand and sandbags. In parallel, a large number of others documentation activities were carried out in Kovčanje base. The elaboration of the digital 2D and 3D documentation, the restoration of finds, the study of amphoras and ceramics, and several archaeometric analyses are in progress.

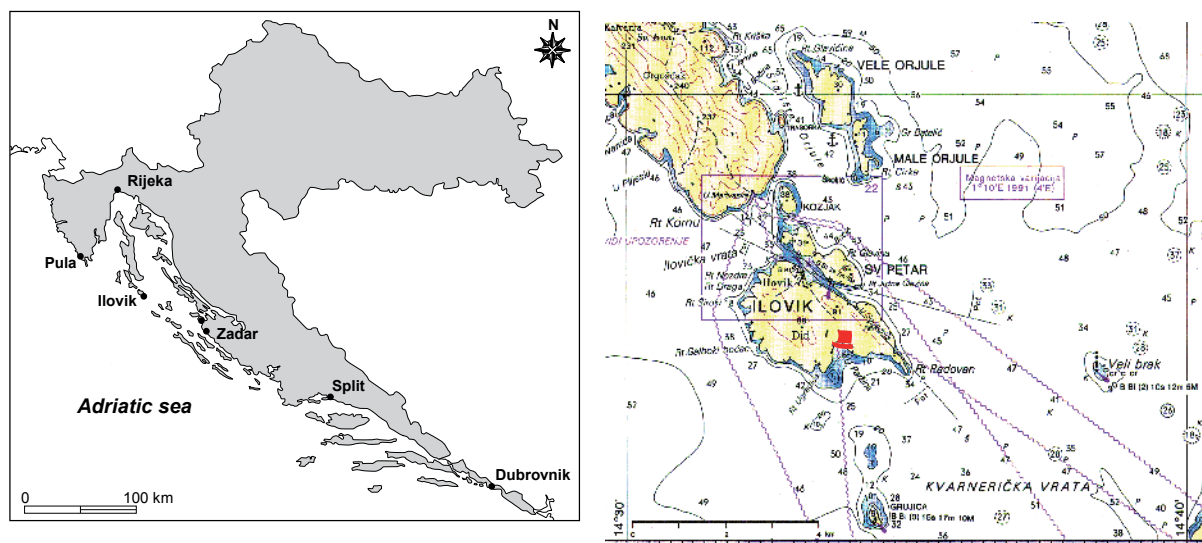


Fig. 1 Location of the wreck in the bay of Paržine, Island of Ilovik (drawing: V. Dumas, CNRS, CCJ)

In 2018, the part of the hull located in 2017 could not be found. Instead, a small survey revealed the front end of the bow structure, oriented north/east-south-west, and, to the north, a large amount of intertwined wood, detached pieces of the ship structure, the remains of amphoras and some other objects belonging to the life on board. In 2019, the trench was extended to a total area of 58 m². The entire bow structure, inclined towards its starboard side, was cleared over a length of 10 m. The main objective of the 2020 mission was to relocate the part of the hull seen in 2017 that was not found in 2018. The initial program included systematic trenching in the north/south, east/west, and northeast/southwest directions, starting from the 2018-2019 trench. The after third of the ship was found about 20 m away from the bow structure, in a westerly direction. The ship rested on its port side which, protected by the ballast, was better preserved than the starboard side. The after third, oriented like the bow towards the north/east-south-west, was excavated from 2020 to 2021 thus reaching a total trench area of about 70 m² (Fig. 2) (Miholjek, Boetto 2021).

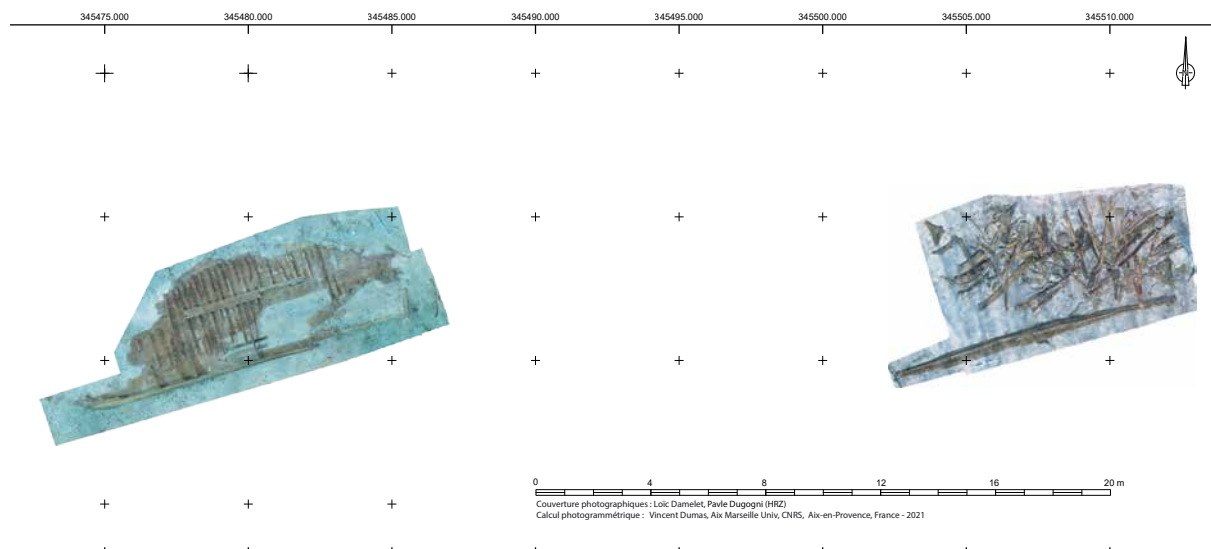


Fig. 2 Ilovik-Paržine 1. Ortho-images of the two trenches: on the left, the rear third of the ship excavated in 2020-2021; on the right, the bow section with the cargo of timbers on the north excavated in 2018-2019 (photos: P. Dugonjić, HRZ; photogrammetry: V. Dumas, CNRS, CCJ)

On average, 19 people participated in the four underwater campaigns on the Ilovik–Paržine 1 wreck, totalling 780 hours of underwater work and 450 dives, and investigating a total area of around 300 m².

2. The cargo and other artefacts

The ship was transporting a cargo of timbers and wine contained in amphoras (Fig. 3). Most of them were found fragmented and scattered around the wreck, and analysis of their diagnostic parts showed that they belonged to the Adriatic Greco-Italic type, which was produced between the middle of the 3rd century BC and the first decades of the 1st century BC when the form evolved into the Lamboglia 2 (Fig. 4)². A precise date for the Ilovik–Paržine 1 amphoras is difficult to determine on the basis of comparisons as complete specimens are rarely found in well-dated contexts. Marie Brigitte Carre (CNRS, CCJ), who is in charge of their study, tends to date the amphoras of the Ilovik–Paržine 1 wreck to the 2nd or 3rd quarter of the 2nd century BC.

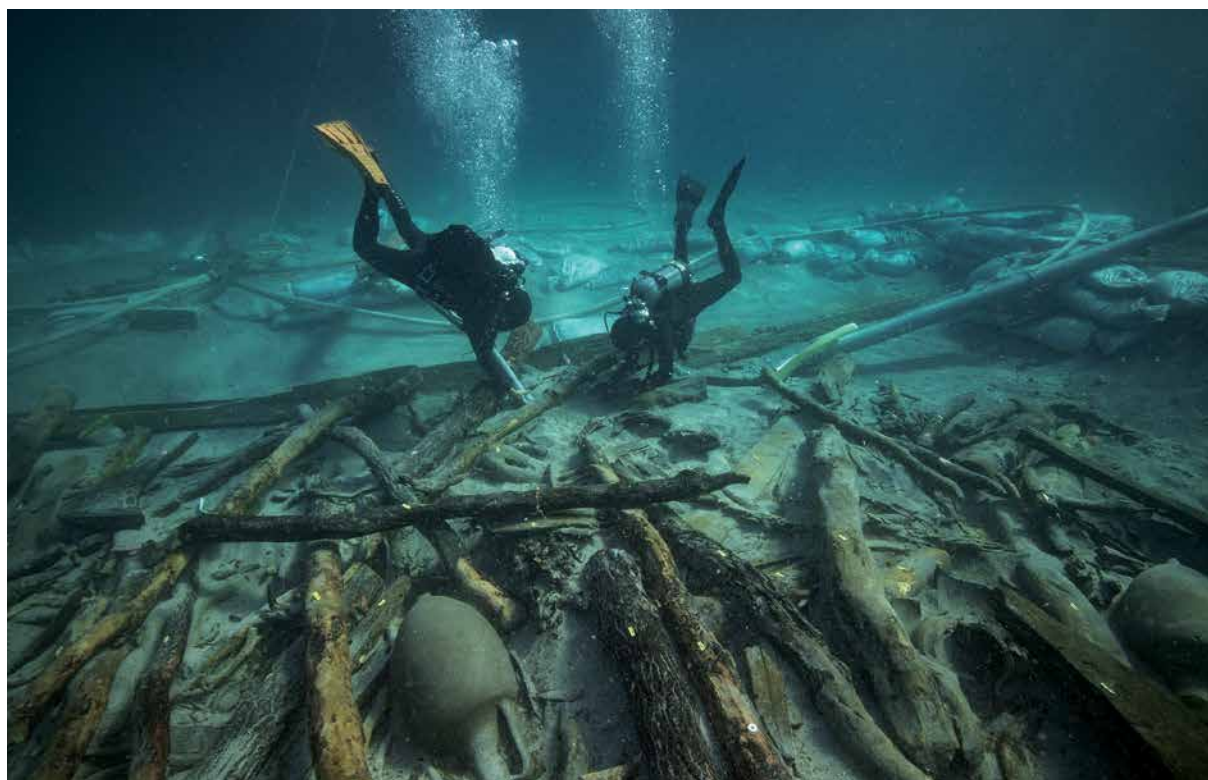


Fig. 3 Ilovik–Paržine 1. Excavation of the cargo of timbers north of the bow section. Two of the best-preserved Adriatic Greco-Italic amphoras are visible in the foreground (photo: L. Damelet, CNRS, CCJ)

The ship was also carrying a cargo of logs and boughs, the majority of which were found on the bow area. Two samples were submitted to Centro di Datazione e Diagnostica (CEDAD) of the University of Salento, Lecce (Italy) for AMS radiocarbon dating.³ The results, although indicating a very large interval for the felling of the trees, are not in opposition to the AMS radiocarbon dating of the wreck and the preliminary date of the amphoras. The xylotomic analyses, realized by Carine Cençon-Salvayre and Alba Ferreira Domínguez, indicate that the trunks and boughs (average diam. 80 mm and 0.23 m respectively, up to 2.5 m long) were mostly cut from evergreen oaks (*Quercus ilex* sp.), stone pines (*Pinus pinea* L.) and small trees and shrubs belonging to the genera *Phillyrea* or *Rhamnus*. Most of timbers preserve their bark and evidence of cutting at one end. A huge number of twigs (diam. 25 mm on average) were also found. As most of them belong to the same species of the larger timbers, they probably are the result of the delimbing process. Wood analyses attested also the presence of twigs from grape (*Vitis vinifera*). All these twigs probably served as dunnage protecting the cargo in the hold (Tchernia *et al.* 1978; 2021).

² The manufacture of amphorae in the Picenum region (Italy) is based on macro-and-microscopic analysis of the clay. The analyses were carried out by Claudio Capelli (DISTAV, University of Genoa, Italy).

³ Radiocarbon ages: 2178 ± 45 BP sample LTL19759A from pole PA19/W65; 2089 ± 45 BP sample LTL19760A from pole PA19/W106.

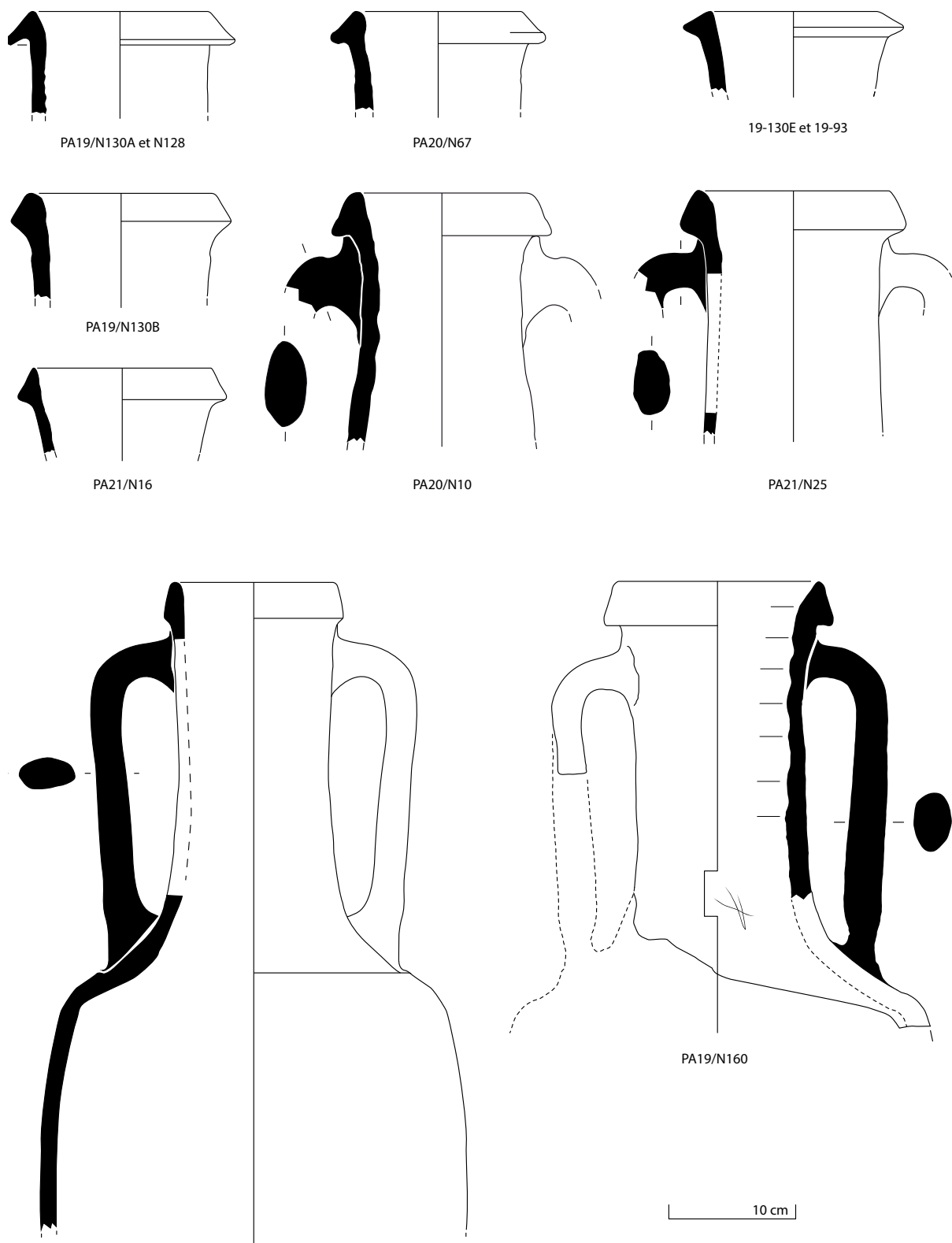


Fig. 4 Ilovik–Paržine 1. Greco-Italic amphoras from Picenum (drawings: L. Cavassa, V. Dumas CNRS, CCJ)

A few fragments of black glazed and cooking ware, a small lamp with traces of soot, part of a *catillus* of a grinding stone and some carpenter's tools (a marlin spike and part of a bow drill) testify to life on board, although the most sensational find is a small female bronze statuette (Fig. 5). Its base was nailed to the structure of the ship and it is likely that it represented the tutelary goddess worshipped by the sailors.



Fig. 5 Ilovik–Paržine 1. 1. Bronze statuette (photo: P. Dugonjić, HRZ)

3. The ballast

The stern area of the hull bottom was covered by a compact layer of rocks and pebbles corresponding to the ballast (Fig. 6a). During the 2021 campaign the rocks were retrieved in order to study the architecture of the ship. 864 rocks (from 10 to 40 cm) were examined by two geologists from the European Centre for Research and Teaching in Environmental Geoscience (CEREGE, Aix-en-Provence, France). All are predominantly carbonate sedimentary rocks and a selection of 72 samples was made for further laboratory studies allowing a finer microfaciological and micropaleontological characterization.



Fig. 6 Ilovik–Paržine 1. a) View from the south-east of the stern with the ballast (photo: L. Damelet, CNRS, CCJ); b) View from the north-east of the frames at the stern. Note the wine-glass profile of the ship. The stringer C4N is nailed to the frames (photo: L. Damelet, CNRS, CCJ); c) Detail of the large mortise carved on the upper face of the keel, at bow. It was intended to lodge a stem not preserved. On the right, two detached floor-timbers can be seen and, on the left, a large trunk belonging to the cargo (photo: L. Damelet, CNRS, CCJ); d) The winch found in the bow area (photo: L. Damelet, CNRS, CCJ)

4. The wreckage and post-deposition processes

With regard to the dynamics of the wreck, a likely hypothesis is that the ship may have hit a shoal (e.g. the one to the west of Paržine Bay) and that the impact damaged its keel. The ship tried to find refuge in the bay before sinking. In fact, the deposit corresponds to the remains of a ship which broke up, as the two main preserved parts of the hull of Ilovik–Paržine 1 are located at a distance of about 20 m and a large part of the axial and other structures of the ship have been destroyed over time, and especially in the last decades by natural and anthropogenic factors, as the site is shallow and subject to coastal erosion and cyclical movement of sandbanks that cover and uncover the hull structures.⁴ In addition, in summer, a large number of pleasure boats anchor in the bay. Finally, due to the shallow depth and proximity to the coast, the cargo was probably salvaged in ancient times or looted later.

⁴ This is the reason why the part of the ship discovered by Erič in 2016, was seen in 2017 but not in 2018 as it was covered by a huge amount of sand. In contrast, in January 2021, after a very violent storm, the protection put in place at the end of the 2020 mission broke down and few fragments of the hull were found on the beach.

5. The ship remains

The ship has a typical Hellenistic hull design (a cross-section with a wine-glass profile) and structure (Pomey 2020). The keel, 10.5 cm sided on the top and 19.5 cm at its maximum, and 20 cm moulded, forms with the garboards a typical wine-shape section (Fig. 6b). The garboards (max thickness 7.4 cm) are trapezoidal in section and joined to the rabbets cut in the upper angles of the keel by large pegged tenons inserted in mortises whose average width is equal to their room-and-space (8 cm).

In the direction of the stern, the keel (K7W) is assembled to a transitional timber (K6W) by a hook scarf secured by a key, rectangular in section and driven perpendicular to the scarf. The assembly between the transitional timber and the sternpost K4W is similar and, here, the scarf is reinforced internally by a timber K5W (1.45 m long, 15 cm wide). The assembly of the garboards and the other strakes into the rabbets is made by pegged tenons and secured by nails (Fig. 6c).

In the bow area, the axial carpentry is composed by two timbers (K1E and K3E) joined by a scarf and reinforced internally by a timber K2E (2.7 m long, 15 cm wide) (Fig. 6c). The foremost timber rises gradually and ends abruptly. Here the upper face is carved with a large mortise (15 cm long, 10 cm deep, 5 cm wide) to settle a stem that was fixed by a pair of dowels. A metallic sheet was inserted in the joining for watertightness. This structure of the keel gives the ship a very peculiar shape, rarely documented in the archaeological record.

The planking, with an average thickness of 4.4 cm, is flush-laid, carvel built, and assembled by pegged tenons. The pegs (average internal diam. 1.4 cm) are spaced on average 14 cm apart (center-to-center). In the after third of the ship, 18 strakes are preserved on the port side and only 3 on the port side. Most of the strakes consist of two planks joined by oblique scarfs.

The frames have only been found in their original position in the after third of the ship (Fig. 6b). They are connected to the planking by treenails driven from outboard (average internal diam. 17 mm) and have the classic alternation of floor-timbers extended by futtocks and half-frames with a side-to-side space of 16 cm on average. The half-frames begin at the level of the 3rd-4th strakes and the futtocks around the turn of the bilge. It should be noted that the identification of this part of the hull excavated in 2020 and 2021 with the after third of the ship is based on the observation of a single anomaly in the alternation of the frames, not far from the extremity of the keel. The shipwrights did not position a floor-timber (F160) and left a free space in the hold where the bilge pump (not preserved) was probably located.

The floor-timbers are up to 45 cm moulded on the keel and have a triangular limber hole at their foot. The other dimensions are similar to those of the other frames (on average 8 cm sided and 11 cm moulded).

The bottom was covered by a ceiling found under the ballast still in its original position at stern, and completely destroyed and mixed into the cargo of wood in the bow area. In the after third of the ship, the ceiling, 1.8 to 2.4 cm thick and 20 cm to 28 cm wide, is mostly nailed to the frames.

Unfortunately, keelson or mast-step remains were not preserved on the wreck. However, one displaced floor-timber (W16) found near the bow structure has a rectangular recess on the top 29 cm long. This measure corresponds to the minimum width of keelson/mast-step. The presence of a sail is confirmed by the discovery of two pulley sheaves. Also in the bow area, an oblong wooden object (56 cm long and 10 cm in diameter maximum) was found that we interpret as a winch, possibly linked to the ship's rigging (Fig. 6d). The hull was entirely covered on the outside and inside by a thick layer of pitch.

6. Conclusion

Following the notion of architectural types and the concept of principles and methods of construction (Pomey 2004; Pomey, Rieth 2005: 29–33; Pomey *et al.* 2012; 2013), the construction principle of the ship Ilovik-Paržine 1 is based on a shell first concept for the hull structure, and on a longitudinal strake-oriented concept for its shape, while the building process is shell first.

Although the study of the ship is at its early stages, it is possible to reconstruct that its original length was about 20–22 m. Of note is the longitudinal section towards the bow with a stem post forming almost a right angle with the keel (Fig. 7). With the completion of the archaeological study, one of the future challenges will be to arrive to a satisfactory reconstruction of the hull profile and ship structure.

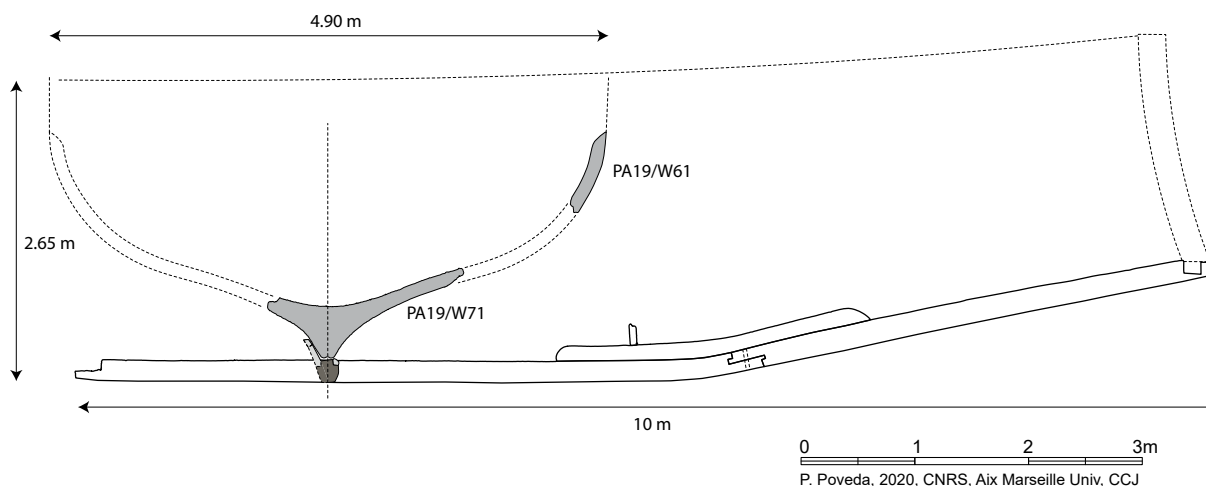


Fig. 7 Reconstruction hypothesis of the bow of the ship Ilovik–Paržine 1 (drawing: P. Poveda, CNRS, CCJ)

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Second scuttled ship of Trstenik, Kaštel Sućurac, Croatia; Preliminary report

Irena Radić Rossi – David G. Ruff

Abstract: In 2020, during the research of a scuttled Roman ship at Trstenik in Kaštel Sućurac, two more scuttled ships were discovered on its western and eastern sides. All the ships were filled with large rocks, and scuttled in order to reinforce the operational waterfront of the economic complex (*villa rustica*), which existed from the end of the Late Roman Republican to the Late Imperial period. In 2021, the westernmost ship, called Trstenik 2, whose total length slightly exceeded 5 m, was fully explored. It is a specific type of vessel, characterized probably by a bow transom, in ancient sources called *horeia*.

Keywords: Gulf of Kaštela, Roman villa, operational waterfront, scuttled ship, *horeia*

1. Introduction

At the location of Trstenik, at the eastern end of Kaštel Sućurac, since 2002 with short interruptions, research has been carried out on the submerged remains of the coastal part of the Roman economic complex, which existed from the 1st century BC to the 4th century AD (Radić Rossi, Ruff 2021). In 2002 a complete perforated ceramic dolium was found in the shallow sea. It was recovered the same year and stored in the Croatian Maritime Museum in Split (Radić Rossi 2003; 2006). Although the underwater site was only entered into official records then, it was already known to the local population (Delić 1994).

The operational waterfront, bounded by horizontally laid planks and a number of poles driven vertically into the seabed, stretched in front of the coastal buildings for a length of over 80 m. At the western end, the wooden structure turns to the north and extends towards the shore for a length of over 30 m. The underwater excavation stopped at a distance of about ten meters from the coast due to the insufficient depth of the sea. The eastern end of the operational waterfront has not yet been confirmed with certainty, but it is much closer to the coast than its western end.

During research in 2006, along the westernmost part of the southern border of the operational waterfront, the remains of a Roman ship were discovered, laid in the east-west direction. Later research determined that it was scuttled to protect the waterfront from the effects of southern winds. During research in 2020, the remains of two more scuttled ships were found, so the ships were named Trstenik 1, Trstenik 2 and Trstenik 3 (Fig. 1). The ship Trstenik 1 was fully explored until 2020 (Ruff 2020; Ruff, Radić Rossi 2015; Radić Rossi, Ruff 2021), and in 2021 the ship Trstenik 2 was researched.

2. Research

The research of the ship Trstenik 2 took place according to the usual work methodology. First, a metal grid was placed over the hull remains (Fig. 2). The cleaning of the ship's structure consisted of the removal of large stones that had been thrown into it before sinking. This was followed by the removal of sediment, then fine cleaning and marking of all the components of the ship and the nearby wooden structure of the operational waterfront (Fig. 3).

After marking the elements of the ship's structure, photogrammetric recording was performed. Based on the virtual 3D model, an orthogonal representation of the ship was created (Figs 4a, 4b). In addition, a series of working photos

was taken, followed by photos of interesting details. All elements of the ship's structure were measured and described, and the details of the hull were drawn. At the end of the documentation process, the ship was covered with sediment and geotextile, waiting for the appropriate funding for its recovery and conservation treatment. In 2023 the sampling and wood sampe analysis were performed by Alice Lucchini, in the Laboratory for dendrochronology of the CNR IBE (Centro Nazionale delle Ricerche – Istituto pe la BioEconomia) in San Michele all'Adige (TN), Italy (Fig. 5).

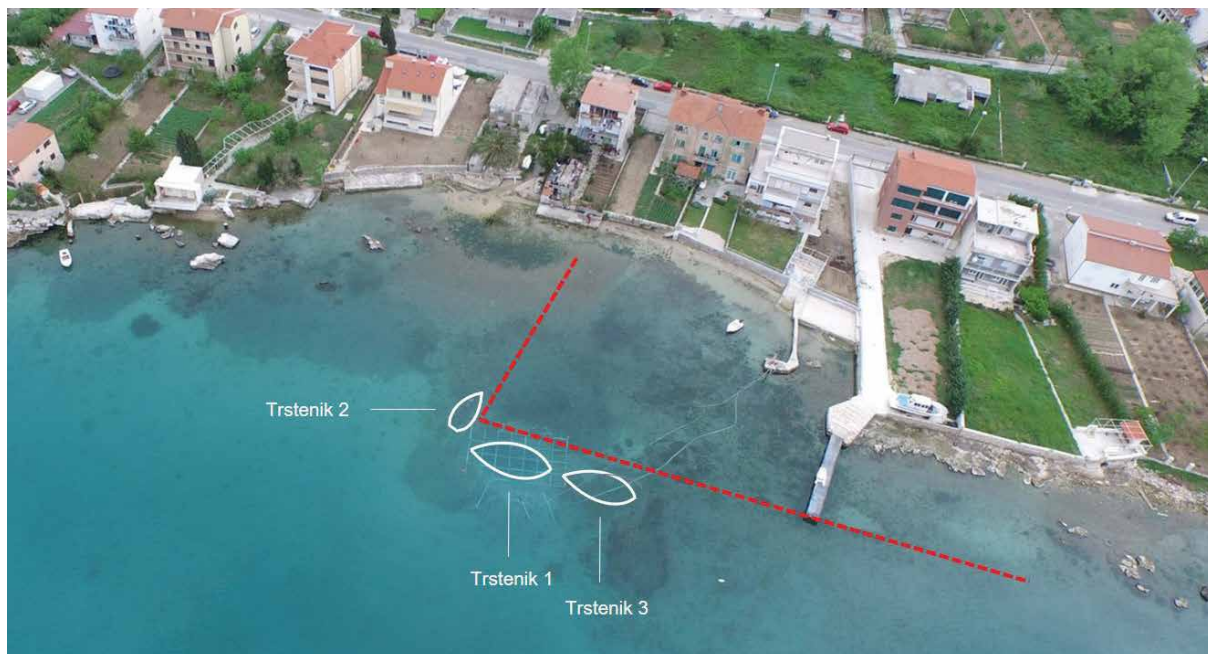


Fig. 1 Aerial view of the site, with marked positions of the three scuttled ships (photo: Project archive, drawing: I. Radić Rossi)



Fig. 2 Aerial view of the ship Trstenik 2 and the metal grid over the excavated area (photo: Project archive)



Fig. 3 Position of the ship in relation to the operational waterfront (photo: B. Vukičević)

3. Preliminary analysis and interpretation

The ship has been preserved with a length of 4.8 m and a width of 1.98 m. It was made using the mortise and tenon building technique. The east side was much better preserved because it was leaning on the wooden structure of the operational waterfront, so it did not crumble under the weight of the stone filling. On that side, the turn of the bilge is preserved (Fig. 3), and in the central and northern part of the ship there is evidence of the sheer strake (TR2.SS). In the extreme northern part, at the height of the frame TR2.F12p, traces of an element added above the sheer strake (TR2.SS1) were noticed. It probably extended to the northern extremity of the hull, but, unfortunately, is rather poorly preserved.

The ship's keel (TR2.K) has been preserved in its full length of 3.42 m, and it is continued by the stern post (TR2.SP) with a length of 1.5 m, which is missing the end part. The average width of the keel is 5.4 cm, and its height is about twice as much. The ship ended in the southern part with a transom composed of two elements, interconnected by three tenons. The transom was found displaced from its original position. Its lower side is slightly rounded, and the edges on the inside are thinned. The transom (TR2.BT1 and TR2.BT2) was found in a horizontal position, lying on its outer side. The maximum width on the upper side is 60 cm, the width on the lower side is 43.5 cm, the maximum thickness is 5.7 cm, and the overall height is 34.5 cm. It was attached to the ship's planking by means of four long metal nails, driven from the outside (Fig. 6). In addition, an element marked TR2.F0, placed in the position of the initial floor timber, tied it to the ship's planking. This element was attached to the keel from the bottom with a metal nail. The function of the small rectangular element measuring 17.8 x 7.2 x 3.4 cm (TR2.UM1), found on the eastern side of the transom, has not yet been satisfactorily explained. As the transom was examined, resin was discovered on its external side. Apparently, resin covered the exterior of the transom.

The east side of the ship consisted of nine strakes. The second strake was probably repaired, which can be concluded from the shape of element TR2.P28 inserted between frames TR2.F3 and TR2.F5p. After that element, the plank marked TR2.P22 continues. The third strake was composed of at least two planks, TR2.P5 and TR2.P17, the second of which is visible at the stern, between frames TR2.F13p and TR2.F14p. For the other strakes, it is not possible to say with certainty whether they consist of only one plank or more, as the joints between them could be hidden under the existing frames, which were not removed from the planking during the excavation.

On the top of the sheer strake, in the immediate vicinity of the front side of frame TR2.F9p, which was preserved to its full height, a square opening was observed. Three metal nails are positioned on its southern side, and two more on the northern one. Another opening of smaller dimensions and without any trace of metal nails is located on the top of the sheer strake, north of frame TR2.F11p.

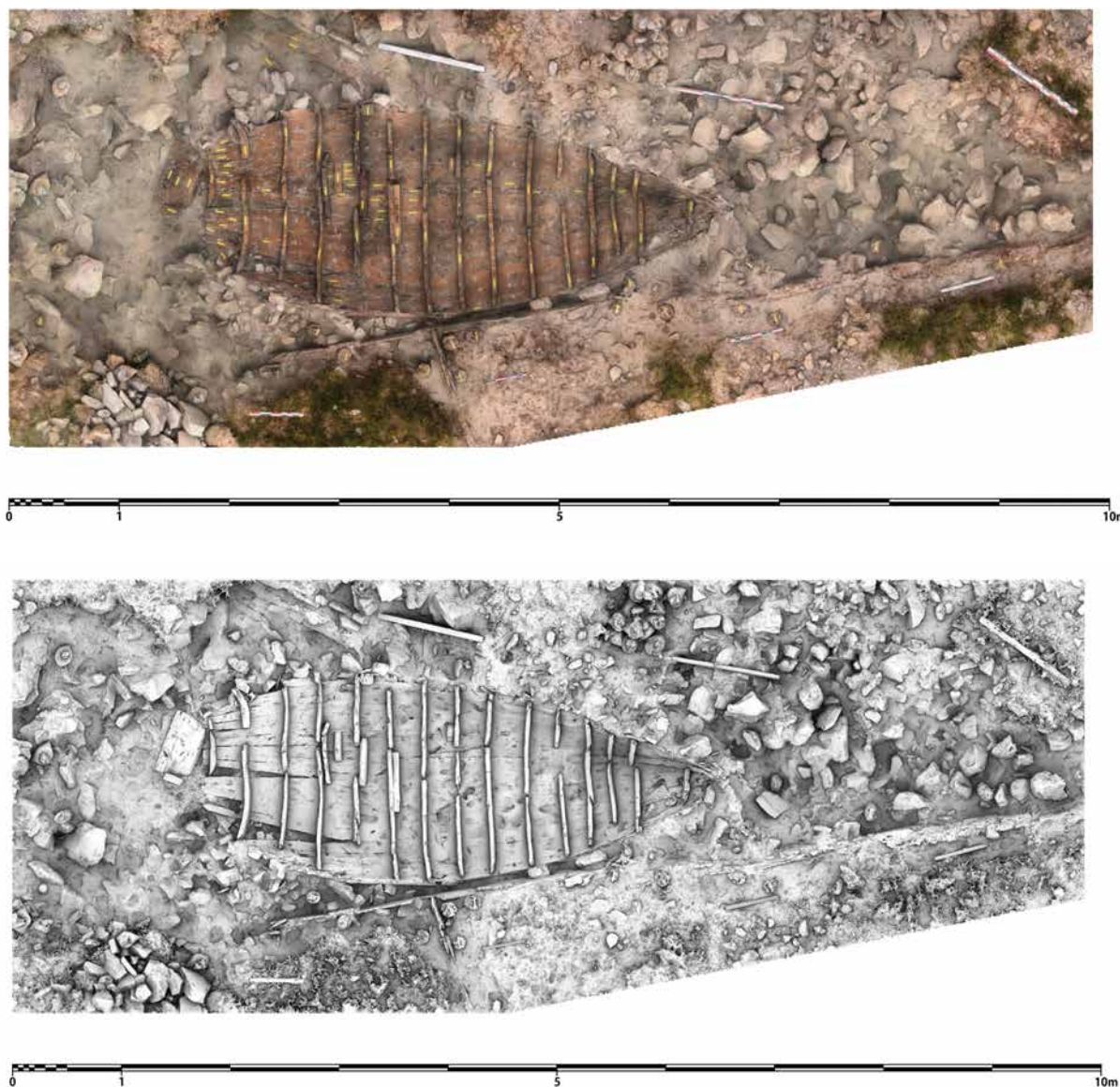


Fig. 4 Orthogonal view from the virtual 3D model of the site, a) color; b) black and white (model: K. Yamafune, D. Taras)

On the west side of the ship, six strakes and traces of the seventh have been preserved. The first strake consists of planks TR2.P8 and TR2.P30, among which there is probably a later inserted plank TR2.P21. The second strake begins with plank TR2.P9, which is followed by plank TR2.P26 and a thinner insertion marked as TR2.P17. The remaining four strakes are in the same situation as the eastern side of the ship, i.e. it is not possible to say with certainty whether they are composed of only one plank or multiple planks. In addition, the planks of the second and third strake do not end on the stern post, but terminate between frames TR2.F12s and TR2.F13s. On the northern side of frame TR2.F4s, at the level of the sixth and seventh strakes, a square element, TR2.UM2, measuring 12 x 12 x 6.8 cm, is attached, for currently unknown purposes.

The average thickness of the planks is about 1 cm. The mortises and tenons are relatively regularly spaced, and the centre-to-centre distance between the pegs is about 16–20 cm. The diameter of pegs is 0.7–0.8 cm. On the dislocated element TR2.SS2, identified as the ship's sheer strake, the mortises and tenons are present only on one side.

The ship's framing consists of two floor timbers, marked TR2.F3 and TR2.F4. Floor timber TR2.F3 continues with futtock TR2.F3s, added on the southern side and protruding towards the east. The TR2.F3p half floor continues to the west. Floor timber TR2.F3 was probably added to the ship later, because it lacks a limber hole. Two futtocks, TR2.F4s and TR2.F4p, were added to floor timber TR2.F4. The appearance of the remaining framing points to the fact that this element could also have been added later to strengthen the ship's structure.

The elements TR2.F1p, TR2.F3, TR2.F5p, TR2.F7p, TR2.F8p and TR2.F11p are asymmetrical floor timbers that only slightly cross the keel towards the western side of the ship. They continue with futtocks to the west. The elements TR2.F2s, TR2.F6s, TR2.F9s and TR2.F13s are also asymmetrical floor timbers that only slightly cross the keel towards the eastern side of the ship, and the corresponding futtocks continue to the east. Only floor timber TR2.F9s protrudes more towards the east. The futtocks TR2.F10s and TR2.F10p are not connected to each other by floor timbers; TR2.F12s and TR2.F12p were made as half floors, and in the case of the futtock TR2.F14p, it is not known what was positioned on the west side of the ship.

The half floor TR2.F5p is fixed at the northern side by frame element TR2.F5, which was also probably added later, because similar to TR2.F3 it lacks a limber hole. In contrast to the centrally located semicircular limber holes on all other frames positioned above the keel up to frame TR2.F9s, the TR2.F11p frame is equipped with two triangular openings, located at both sides of the keel.

All the frames were fixed to the planking by means of treenails with a diameter of 1.1–1.2 cm, driven into each individual row. Traces of metal nails were observed on frames TR2.F3, TR2.F4, TR2.F5 and TR2.F14p, and on the preserved end of the stern post. The lower sides of the four southern and four northern frames were bevelled due to the elevation of the ship's structure. The average sided dimension of the frames is about 5–6 cm, the average moulded dimension is about 5–6 cm, and the average sided dimension of the two symmetrical floor timbers is about 10 cm. The distance between the frames measures 25–30 cm.

On the southwest side of the ship, fragments of three more planks, marked TR2.P31–TR2.P33, and one fragment of a sheer strake, marked TR2.SS3, were observed, which certainly belonged to the west side of the ship, but were separated when the structure collapsed under the load of the stone filling. Along with them, an interesting trapezoidal element (TR2.BT4) was found, which is slightly narrower in the lower part than the transom (46.5 cm), slightly wider in the upper part (62 cm) and less rounded on the lower side. The upper and lower edges are bevelled in profile, with a lower part at the back, and slightly projecting outwards. On the upper part, there are two grooves, the bottoms of which are bevelled upwards, and on the lower part there is an opening in the form of a limber hole. In the left profile, the trace of one metal nail is visible, while in the right profile, there is evidence of two others. In the lower left part, there are two round openings that appear as if they were intended for the reception of treenails, but this is not certain.

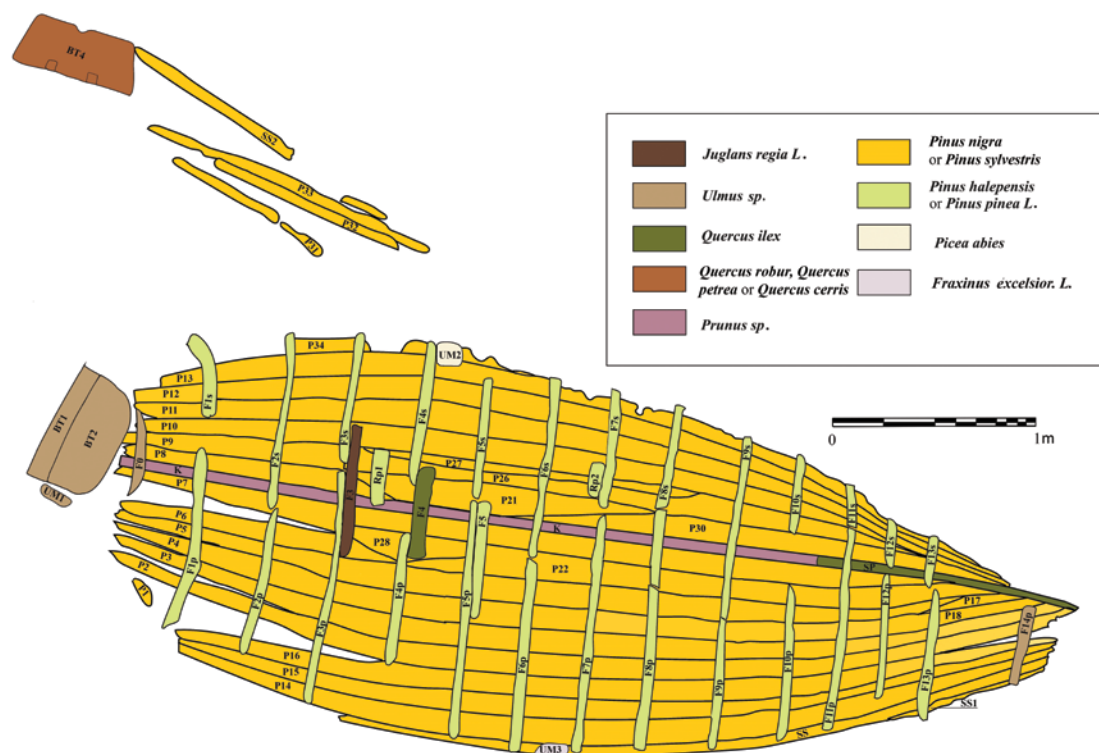


Fig. 5 Drawing of the ship Trstenik 2, with the results of xylological analysis (drawing: N. Lete, E. Šilić, A. Lucchini; analysis: A. Lucchini)

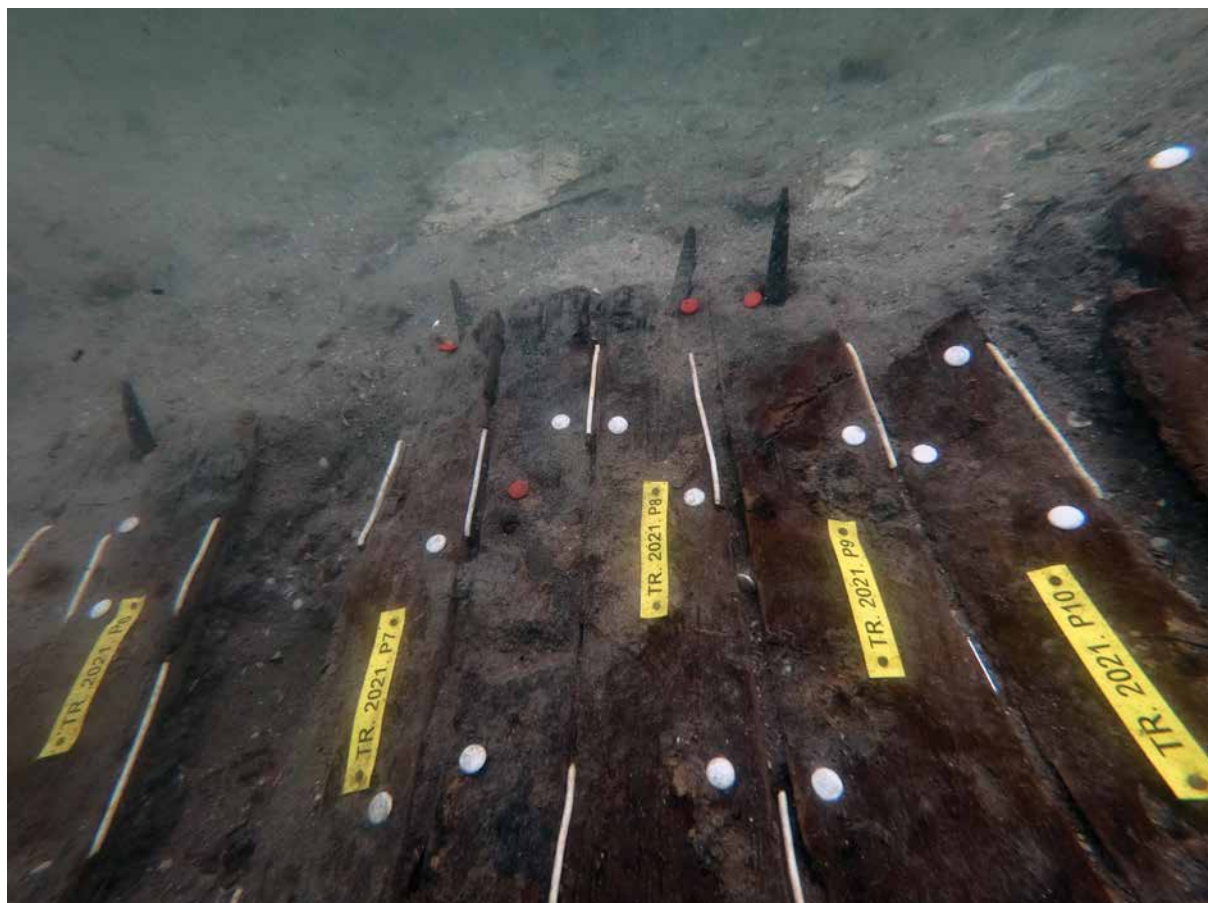


Fig. 6 Four metal nails which were fixing the transom to planking (foto: I. Radić Rossi)

Although at first it seemed that, considering the shape and position of the described element, TR2.BT4 was attached to the outboard side of the transom, this cannot be confirmed. As mentioned, a layer of resin was observed under the transom, i.e. on its outside, which could have been used to connect an outer element. Although the shape of TR2.BT4 roughly corresponds to the shape of the transom, it has on its sides the evidence of metal nails that once connected it to something, but there are no elements of the hull where it could have been attached.

The overall preserved length of the ship, 4.8 m, points to the fact that its original length slightly exceeded 5 m. Judging by the width of the eastern half of the ship, where the turn of the bilge and sheer strake are preserved, its original beam was around 2.3 m. It is, therefore, a vessel of small dimensions that could have been used for fishing and other daily activities in the coastal area of the Gulf of Kaštela.

4. Dating

Unlike the ship Trstenik 1, in which an entire ceramic oil lamp of the Loeschcke X / Iványi XVII type was found under the stone filling (Radić Rossi, Ruff 2021: 28, 37), no ceramic find was found in the ship Trstenik 2 that could suggest a possible dating of the ship's sailing or sinking. The only find that can be attributed to the 1st or 2nd century AD is a fragment of the handle of an amphora of the Rhodian type, found above the ship structure in square D3.

Taking into account the described situation, one sample of the wood of the ship's structure was sent for radiocarbon analysis. The TR2.F1p Trstenik 2 frame sample was analysed at the Beta Analytic Testing Laboratory (Miami, FL, USA), under the number Beta – 601117. Radiocarbon measurement resulted in a dating of 1970±30 BP. This result, calibrated using the IntCal20 calibration curve, corresponds to the period from 41 BC to 124 AD (95.4% probability), which generally corresponds to the results of the radiocarbon analysis of the wooden structure of the ship Trstenik 1.

Given the absence of sapwood in the processed sample, it is not possible to determine with certainty when the wood was cut, and it is necessary to take into account the fact that after cutting the wood could have been subjected to an

aging process, which preceded the construction of the ship. Judging by the results of the radiocarbon analysis and the mentioned facts, the ship was probably built during the 1st century AD, and it is difficult to say how long it was in service before its intentional sinking. As it is a small ship of extremely fragile construction, its lifespan can probably be estimated at a few tens of years, so it is likely that it was deliberately sunk at the end of the 1st or during the early 2nd century AD.

5. Discussion

The ship Trstenik 2 belongs to the type of ships called *horeia* in Roman sources. Such a ship is characterized by a transom at one end, as shown on the mosaic from the 3rd/4th century AD from Althiburus in today's Tunisia. Whether it is the bow or the stern is still being discussed in the professional literature.

The discovery of mosaics depicting various types of ships at Althiburus led to the publication of a catalogue in which Paul Gauckler interpreted the *horeia*-type ship as a ship with a flat stern (Gauckler 1905). Four decades later, Paul-Marie Duval argued that it was a transom bow, and not a transom stern (Duval 1949). Peter Marsden and Marco Bonino tried to deny Duval's theory (Marsden 1963; Bonino 1963), but they were opposed the very next year by Lionel Casson, who further argued for a transom bow (Casson 1964; 1995). Lucien Basch then favoured the transom stern theory (Basch 1987).

In 2002, the problem of fishing boats with a transom end was addressed by Deborah Carlson who, following Casson's conclusion, interpreted the transom of the boat as a transom bow (Carlson 2002). In addition, she concluded that there is a possibility that such ships moved in both directions, which, in fact, softened the previous debate to some extent. Giulia Boetto also agreed with Casson's conclusion, interpreting the archaeological finds from Naples (Boetto 2009), Portus (Boetto, Ghelli, Germoni 2017), and Toulon (Brun 1999; Boetto 2009; Brun *et al.* 2022) as ships equipped with a transom bow (Boetto 2009).

In 2017, Vittorio Bovolin again opposed such an interpretation, and he based his theory on the reinterpretation of iconographic sources and hydrostatic calculations made on the Napoli C ship model (Bovolin 2017). In any case, his arguments proved insufficiently convincing, so five years later the Toulon finds were republished as ships with a transom bow (Brun *et al.* 2022). The find of the small ship J3, found in the eastern port of Alexandria known as Portus Magnus, was initially interpreted in the same way (Belov *et al.* 2022). The researchers, however, changed their minds over time, and based on the position of the mast step, they concluded that the transom was probably at the stern, although the position of the oar locks suggests that the ship could have moved in both directions.¹

The ship from Naples, called Napoli C, is about 13 m long, and its framing consists of 50 frames. The ship from Portus near Ostia, known as Isola Sacra 1, is about 12 m long. Its framing consists of 37 preserved frames, and seven more certainly existed judging by the marks on the planking. The two ships from Toulon are somewhat smaller in size. Toulon 1 was preserved to a length of 8.5 m, and Toulon 2 at a length of 6.3 m. Thirty-five frames were found on the first ship, and 27 on the second. The well-preserved J3 ship from Alexandria is 6 m long and equipped with 21 frames. All boats are characterized by a flat bottom and a slightly rounded hull, with minor differences, while in one extremity they assume the V shape.

Although the Trstenik 2 ship is even smaller than the smallest transom-ended ships found so far, J3 from Alexandria and Toulon 2, and only 15 frames were recorded on Trstenik 2, they are all quite similar in terms of basic characteristics. Taking into account the fact that all mentioned ships were probably used for fishing and port communication in shallow coastal areas, the assumption of the existence of a transom bow, or the extremity for double use, is quite convincing.² Such ships were intended exclusively for local navigation, thus their size and seaworthiness would not have been suitable for the open sea.

Another argument that could be taken into consideration while interpreting the transom end as the bow is the fact that the ships Trstenik 1 and Trstenik 3 lie in the position bow to stern. If the situation is similar for the Trstenik 1 and Trstenik 2 ships, then the transom end should be interpreted as the bow.

¹ A. Belov, personal communication.

² The fact that ships with transom bows existed also in the 16th century is confirmed by a graphic by an unknown author, which shows a Turkish acrobat in front of the bell tower of the church of St. Mark in Venice, whose movements are closely followed by the audience in boats of various shapes and sizes (Carboni 2008: cat. 38, pp. 331, 132, 134).

6. Conclusion

Unlike the ship Trstenik 1, which was much larger in size and intended for the transport of heavy cargo, the ship Trstenik 2 was a small ship with a completely different function, which probably moved exclusively in the area of the Gulf of Kaštela. Although fishing is most often mentioned in the sources, other tasks that could have been performed with it should not be neglected, such as, for example, transshipment of goods from large ships to the coast or in the opposite direction.

The relatively large ship Trstenik 1 was scuttled in an east-west direction near the western end of the southern part of the operational coast, which was probably well protected from the devastating southern wind. The western side of the operational coast was in less danger, which is probably why a much smaller ship was chosen for its reinforcement. For now, it is not possible to say with certainty that both ships were scuttled at the same time, as the oil lamp found in Trstenik 1 suggests a slightly earlier time for its abandonment. Given the radiocarbon dating uncertainty for both ships, coupled with the possibility that the ships were in operation for decades after their construction, it is certainly conceivable that both ships were scuttled and ended up at the bottom of the sea at the same time.

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A preliminary report on newly discovered fluvial vessels from Kostolac, Serbia

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Abstract: The paper presents the results of a preliminary study of a group of four fluvial vessels recently discovered in the vicinity of Kostolac (NE Serbia), dated between the Late Iron Age and the Late Medieval Period. The remains of four vessels were discovered in March 2020 during regular mining activity at the “Drmno” strip coal mine, at four kilometers’ distance from the contemporary course of the Danube. Four different vessels were identified among the wooden remains, well preserved under six meters of clay-like sediment: two dugouts, a single plank belonging to a flat-bottomed vessel, and a well-preserved flat-bottomed planked barge. While focusing on the architectural characteristics and nautical capabilities of the discovered vessels, this paper will also present preliminary conclusions on the context of their discovery concerning the archaeological topography of the region.

Keywords: Kostolac, Danube, Mlava River, fluvial vessels, Serbia

1. Geographical and historical context

The municipality of Kostolac is located in northeast Serbia, approximately 90 km east of the capital city of Belgrade (Fig. 1). It is situated in the northern Stig micro-region, which represents a vast and fertile plain, bordered by the Danube River on the north. Besides the Danube, the Mlava River is the main watercourse in the area (Filipović, Mladenović 2019: 12).

First traces of human presence in the region date back to the late Neolithic period, ca. 5000 BCE. The continuity of inhabitation is attested in the later Copper, Bronze, and Iron ages (Đokić, Jacanović 1992: 68). During the 1st millennium BCE, the area was settled by the Thracian tribe of Triballi, replaced by the Celtic population, which was dominant in the area prior to the Roman invasion (Spasić-Đurić 2015: 17–22; Jovanović 2018, 11–12). Romans built a legionary camp and a civil settlement of Viminacium at the confluence of Mlava and Danube, which gradually gained on importance and became an administrative center of the province of Upper Moesia (Spasić-Đurić 2015; Korać 2019).

From the 4th century CE, the border of the Empire on the Danube is under constant threat from ‘barbarian’ peoples, culminating with the Hunnic invasion and the destruction of Viminacium. The aftermath of this event saw the activities of various Germanic tribes in the area. The Byzantines claimed this area towards the end of the 5th century, and, due to the war efforts in the other parts of the Empire, Germanic populations were hired to defend the border. At the beginning of the 7th century, the Byzantine rule was crushed by Avar and Slavic attacks. The latter sought to settle in the areas south of the Danube (Stojić 2022: 430–437). During the times of the Middle Ages, the northern Stig area was under the dominion of Bulgarian, Byzantine, and Hungarian states, ultimately becoming part of Serbia at the end of the 13th century, which established its northern border on the Danube River (Stojić 2022: 437–442). Serbian medieval state was crushed under Ottoman attacks during the middle of the 15th century and remained part of their Empire until liberation in the 19th century.

2. Discovery

The recent discovery of fluvial vessels near Kostolac took place during salvage excavations of the site called Rit, endangered by the expansion of the “Drmno” strip coal mine.¹ The site itself is located around 5 km northeast of Kostolac.

¹ The archaeological excavations were conducted by the Institute of Archaeology in Belgrade under the supervision of M. Korać, Ph.D. Members of the crew that undertook the works were Bećina Milovanović, Ilija Danković, Goran Stojić, Mladen Jovičić, Ljubomir Jevtović, Snežana Nikolić, Nemanja Mrdić, Ivan Bogdanović and Igor Milošević.

It encompasses a broad area between the old riverbed of the Mlava River and the drained bed of Dunavac, the latter being one of the Danube's branches (Fig. 1). Rit, meaning *swamp* in Serbian, owes its name to the circumstance that until the middle of the 20th century this area was covered by marshes (Đokić, Jacanović 1992: 73). Earlier excavations led to a conclusion that, after various phases of inhabitation of this territory in earlier periods, swamps were formed during the 4th century CE (Danković, Petaković 2014: 60–63).



Fig. 1 Location of discovered vessels (map: Documentation Center Viminacium)

The first archaeological digs in Rit were carried out in 2004 (Mikić *et al.* 2006: 21–26), and from 2012 onwards large-scale salvage excavations are being conducted, which helped in reconstructing human activities ranging from metal ages (Bulatović *et al.* 2019b: 26, 30; Bulatović *et al.* 2019a: 58) until medieval times (Milovanović *et al.* 2018: 50–51). Needless to say, remains dated back to the Roman period are the most numerous, and they include four villas, a textile workshop, several cemeteries, clay and sand pits, water wells, and drainage ditches (Redžić, Jovičić, Danković 2014: 66–69; Danković, Petaković 2014: 60–63; Redžić *et al.* 2017: 77–86; Milovanović *et al.* 2017: 71–76; Milovanović *et al.* 2018: 43–53; Milovanović *et al.* 2019: 97–108; Milovanović *et al.* 2021: 101–114).

In early 2020, the giant bucket-wheel excavator came across remains of wooden vessels on several occasions, at depths greater than 6 m. A total of four vessels were discovered, denominated as Viminacium 1 to 4, each of them dated to a different period spanning from the 2nd century BCE to the 17th century CE. These include two dugouts, well-preserved remains of a flat-bottomed planked boat, and three planks associated with another boat. Each of the vessels will be discussed in chronological order, from the most ancient to the most recent.

2.1. Viminacium 3

The oldest of the four vessels was discovered during the inspection of the profile of the coal mine during excavations of the Viminacium 2 ship. It was positioned 10 m beneath the ground level, on a layer of sand and fine gravel. The vessel was damaged by the bucket-wheel excavator that broke off one extremity and moved it several meters from the rest of the boat.



Fig. 2 Remains of Viminacium 3 vessel (photo: Documentation Center Viminacium)

Viminacium 3 is a dugout boat dated between the 2nd century BCE and 1st century CE.² It is an elongated and straight dugout with parallel sides (Fig. 2), just under 8 m long, 70 cm wide, and 40 cm deep. It has no bulkheads, while its extremity has been pierced with a horizontal rectangular orifice (Fig. 3). The dating of this vessel is most puzzling, and further research is needed to understand whether it belongs to pre-Roman communities or the earliest phase of Roman presence in the area. In the vicinity of the vessel, several shards of Roman pottery vessels, as well as one intact pot, were discovered.



Fig. 3 Piercing on the extremity of Viminacium 3 vessel (photo: Documentation Center Viminacium)

² The AMS analysis was conducted by the Isotoptech Laboratory in Debrecen, and the lab-code of the sample is DeA- 27284 (BP 2047±23; cal. BCE 150–cal. CE 24).

2.2. Viminacium 1

The first of the vessels to be discovered is another dugout, damaged and dislocated by the excavator, which resulted in the preservation of two pieces (Fig. 4). According to the employee that was operating the excavator at the moment of the discovery, these remains were located at a depth of approximately 9 m, in the layer of light gray clay mixed with fine yellow sand and thick stratum of gravel under the vessel. Such circumstances point to the conclusion that the boat was resting on the bottom of a riverbed.



Fig. 4 Remains of Viminacium 1 vessel (photo: Documentation Center Viminacium)

Viminacium 1 is dated between the 7th and the 9th centuries CE.³ Two preserved pieces measure to a total of 7.20 m in length. The width of the vessel is 50 cm and the height is 70 cm. The internal depth is 35 cm.

Two conserved bulkheads were documented within the hull, as well as some interesting elements towards the preserved extremity of the boat. One of these is a semi-circular carved recess that might have served as a bench, while some 40 cm from the extremity, a rectangular recess has been carved into the upper face along the full width, decorated with three carved radial notches. This recess might have held an outrigger for additional stability, or a steering oar.

2.3. Viminacium 4

Viminacium 4 refers to a group of five planks that most likely made up a part of a planked boat (Fig. 5), dated between the 8th and the 10th centuries CE.⁴ Once again, remains were discovered resting on a layer of sand and fine gravel.

Several rectangular metal clamps are associated with one of the planks, driven into its edge. Morphologically, these clamps can be brought into connection with those used for attaching the planks of four Roman-era boats discovered within the Danube hydrographical basin,⁵ although being chronologically apart from them by several centuries. Whether this speaks in favor of the continuation of this attachment technique into the Middle Ages is not yet possible to determine, based on such a small sample.

³ The AMS analysis was conducted by the Isotoptech Laboratory in Debrecen, and the lab-code of the sample is DeA- 28923 (BP 1249±18; cal. CE 678–871).

⁴ The AMS analysis was conducted by the Isotoptech Laboratory in Debrecen, and the lab-code of the sample is DeA- 28924 (BP 1143±17; cal. CE 775–977).

⁵ Sinja Gorica from the Ljubljanic River, Slovenia (Erič *et al.* 2014); Kamensko from Kupa River, Croatia (Boetto *et al.* 2021); Sisak from Kupa River, Croatia (Gaspari *et al.* 2006); Kušjak from the Danube, Serbia (Bockius 2003).



Fig. 5 Remains of Viminacium 4 vessel (photo: Documentation Center Viminacium)

2.4. Viminacium 2

The last of the four discoveries is represented by well-preserved remains of a flat-bottomed fluvial vessel (Fig. 6), dated between the 14th and the 17th centuries CE.⁶ The bucket-wheel excavator obliterated a large portion of what seems to have been an entirely preserved ship, located 6 m beneath the surface level. The bottom of the ship was situated in a layer of sand and fine gravel, in which shells of river shells and snails were present. Apparently, it is the bottom of the same body of water in which the other Viminacium vessels had sunk. The ship itself was surrounded by a layer of clay, intersected with thin layers of organic matter (peat?), which indicates that at some point the river ceased to flow, i.e., the ground became swampy.

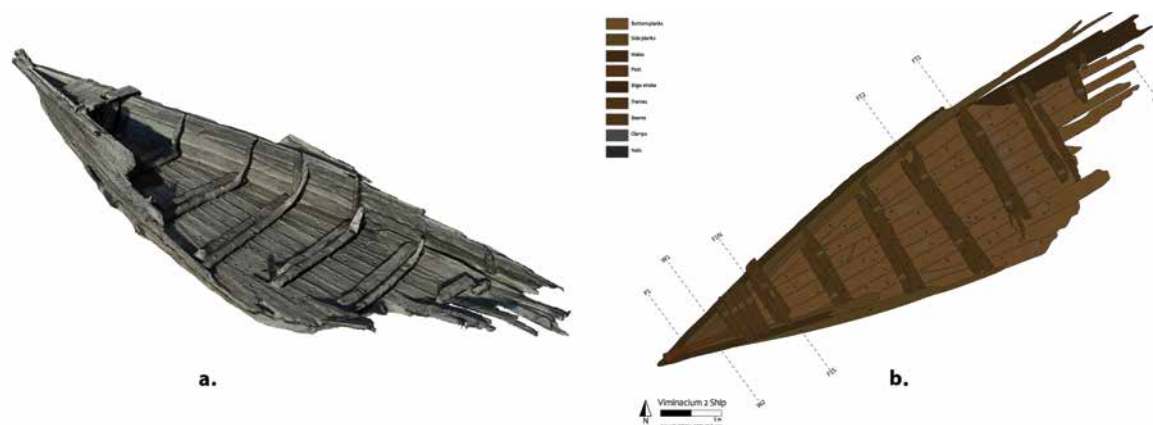


Fig. 6 a) Photogrammetric model of Viminacium 2 vessel (model: Documentation Center Viminacium),
b) Plan of the Viminacium 2 vessel (drawing: A. Divić)

⁶The AMS analysis was conducted by the Isotoptech Laboratory in Debrecen, and the lab-codes of the samples are: 1. DeA- 27281 (BP 349±23; cal. CE 1471–1635); 2. DeA- 27282 (BP 603±22; cal. CE 1303–1403); 3. DeA- 27283 (BP 565±23; cal. CE 1321–1422).

Viminacium 2 is broken approximately amidships, with one longitudinal half of the entire vessel remaining preserved, although it is difficult to determine whether it is the aft or forward one. The discovered remains are 10 m long and 2.80 m wide, while the preserved depth of 0.82 m corresponds to the ship's original maximum draft, as it remained conserved up to the sheer strake.

Wooden architectural elements of the vessel can be divided into longitudinal and transversal ones, held together by the assembly elements. Longitudinal elements include bottom planks, side planks, wales, bilge strake, and a post. Transversal elements are frames, deck planks, and a beam, while the attachment has been achieved with iron nails.

A total of 15 planks that make up the flat bottom of the barge remain conserved. They are up to 20 cm wide and up to 5 cm thick. In three instances two planks have been joined into a single strake by an oblique scarf, while several stealers running towards the extremity can be observed as well. These planks were edge-fastened together by iron nails horizontally driven from the inside of the hull every 37 to 52 cm through triangular notches carved in the upper surface of the planks.

The steep, vertical sides were made up of side planks. The northern flank of the shipwreck, which remained far better preserved than its southern counterpart (the first one being 10 m long, and the latter 5.1 m long), is made up of eight side planks that constitute four strakes. They are of similar dimensions as the bottom planks, up to 23 cm wide and 5 cm thick. They were also attached by iron nails, although driven downwards from the outside of the hull.

The transition between the flat bottom and vertical sides was achieved in two ways. Towards the preserved extremity, side planks were posed directly on the bottom planks, to which they were attached by iron nails driven downwards from the outside of the hull. Amidships, however, adjacent to the northern flank, an element identified as a carved-out bilge strake was observed. This carved-out, monoxyle element served to achieve the transition between the bottom and the sides. It was connected to its associated strake by an oblique scarf and edge-fastened to its adjacent bottom planks by iron nails driven through the upper surface of the bottom plank into the edge of the bilge strake.

Another longitudinal component of the barge were the two wales, attached to the exterior of the sheer strakes. These two elements, 10 cm sided and moulded, provided the barge with additional longitudinal sturdiness, at the same time possibly protecting the hull from any outside damage.

The extremity of the vessel was made out of a post to which the bottom and the side planks were attached by iron nails. It is a monoxyle element, carved from a single piece of timber, flat at its base with a rectangular post rising from it at a 45° angle. Its flat base was attached to the adjacent bottom planks, while the rectangular post presents a carved rabbet in which the side planks were inserted.

Transversal stiffness of the barge was achieved by the insertion of frames, seven of which remained partially or fully conserved, their room-and-space amounting from 60 to 85 cm. They were made out of paired knees settled side by side that had been carved out of tree trunks with integrated branches. The horizontal part of each knee transverses the bottom in full width, while the integrated vertical elements are attached to the flanks in an alternating fashion. In some instances, the insertion of futtocks nailed to the flanks was documented as well. Attachment of frames to the planking was achieved by iron nails, three to six nails per knee, driven from the inside and clenched on the outside of the hull.

About 2 meters from the ship's extremity, a horizontal transversal beam was installed to the sheer strakes and the wales. This roughly rectangular element presents an unusual shape, with one of its short sides cut in an oblique angle and the opposite side irregularly carved. The oblique side of the beam was attached to the wale by three iron nails, while the opposite, carved, side does not seem to present any attachments at all. Approximately in its center, a recess, 15 cm long and 11 cm wide, has been carved through the beam.

The proximity of the beam to the extremity and the lack of mast step do not speak in favor of it serving as a support for a mast. It seems more likely it might be an element connected to the use of the ship's rudder, which might have been handled from the deck platform. Between the beam and the extremity, a small deck made out of four deck planks, 1 m wide and 60 cm long, has been installed and nailed to the wales. This interpretation would identify the preserved extremity of the ship as the stern.

Water-tightness of the ship was achieved by the insertion of organic material in the seams between the planks. It seems most likely that this was done by moss, but the ongoing analyses will give the decisive determination. A lath, made out of small branches, or possibly canes, was placed over the seams and the water-tightness material, and both were secured in place by numerous semicircular, crescent-shaped iron sintels driven across the seams every 2 to 6 cm. The function of these sintels, driven only on the inside of the hull, was to keep the water-tightness material in place.

We can conclude that Viminacium 2 was a fluvial flat-bottomed ship that was between 18 and 28 m long. It is a good example of the bottom-based shipbuilding construction concept, where the flat bottom of the ship was the first element to be conceived and constructed, subsequently determining the size and shape of the vessel (Pomey, Rieth 2005: 33). Due to the combination of planked and monoxyle elements, its structure can be considered as monoxyle – assembled (Rieth 1998: 74–76).

Underneath deck planks, a fragment of a brick was discovered, which represents the only surviving piece of cargo/inventory. Off course, there is a possibility that this fragment was deposited by currents and erosive processes. In the layers of clay, directly above the extremity of the ship, a shard of a Roman amphora was unearthed, while there were several more pieces of pottery and glass vessels on the riverbed itself.

3. Concluding remarks

Remains of the vessels discovered near Kostolac have been relocated to the Viminacium Archaeological Park (Fig. 7), where they are currently undergoing the process of conservation. Simultaneously, an outline for further research is being developed.

One of the important goals is to determine the waterway network in this part of the Danube basin and how it changed in different periods. There is no obvious logic to the spatial distribution of the finds which would confirm one of the initial theories that the riverbed gradually moved towards current position, as the wreckage found furthest to the north is not the youngest.

Another important question to answer is whether these boats were found inside of the riverbed of some of the Danube's branches or if we are dealing with older beds of the Danube River itself before it moved to the north. Several canals can be observed in this area on satellite imagery, and it is possible that the river changed its course multiple times over such a large timespan.



Fig. 7 Extraction of the Viminacium 2 vessel from the coal mine (photo: Documentation Center Viminacium)

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Villeneuve-d'Ornon (Gironde, France): A wreck from the early Middle Ages

Laurent Grimbert – Marc Guyon – Eric Rieth

Abstract: The Villeneuve-d'Ornon wreck was discovered in 2013 south of Bordeaux, near the Garonne River. Its scientific interest led the DRAC Nouvelle Aquitaine to prescribe a preventive excavation, which was begun by Inrap in 2019. Initial observations indicate a robust boat, keel-built, adapted to transporting goods in coastal areas and riverine environments. Several radiocarbon dates provide a chronology between the second half of the 6th and the end of the 7th century. As the dismantling of the wreck could not be completed in 2019, a second operation is under way until September 2022.

Keywords: wreck, early mediaeval, Atlantic, France, Bordeaux

1. History of the discovery

The Villeneuve-d'Ornon wreck (Gironde, France, Fig. 1) was discovered in 2013 during an Inrap archaeological survey, in connection with a major real estate project on the banks of the Garonne River, a little upstream from Bordeaux. An initial radiocarbon dating quickly revealed the age of this boat (7th–8th century), while observations showed its strong scientific potential (Fig. 2): good conservation of the wood, presence of fittings, general quality of the construction.... All of these clues led the Ministry of Culture to prescribe a preventive archaeological excavation to clear the wreck and remove it. The initial intervention, carried out by Inrap, took place from August to November 2019.



Fig. 1 General location of the site
(author: L. Grimbert, Inrap)



Fig. 2 Discovery of the wreck in 2013
(photo: Ch. Dunikowski, Inrap)

2. General and stratigraphic context

The intervention area corresponds to an ancient marshy area (*palu* in local dialect), crossed by tributaries (*estey*s) perpendicular to the Garonne. These marshy areas, very fertile and rich in resources, correspond to very ancient biotopes, regularly drowned by the floods of the Garonne. Their development is attested since Gallo-Roman antiquity and throughout the Middle Ages and the modern era. Historically present throughout the Bordeaux region on both sides of the river, these areas of marshland, partly protected by European regulations (Natura 2000), are shrinking due to the very high level of urbanisation in the sector, which is gradually causing the last remnants to disappear.

The wreck is buried in the old, clogged bed of the Lugan *estey*, a lateral tributary of the Garonne on the left bank, whose current bed, very reduced compared to its ancient width¹, is located some 10 m south of the position of the wreck (Fig. 3). The old northern bank of this tributary, observed during the 2013 diagnostic phase, has a gentle slope on which the bow of the boat partially rests. The boat is sunken in a grey-blue clay sediment, which corresponds to its progressive silting up (flooding of the Garonne and daily input of sediment by the tides whose influence is felt up to here). The level at which the wreck appeared is very close to the current surface of the land, only 1.30 m deep. The proximity of the water table, outcropping in this particular sector, explains the very good preservation of the boat.

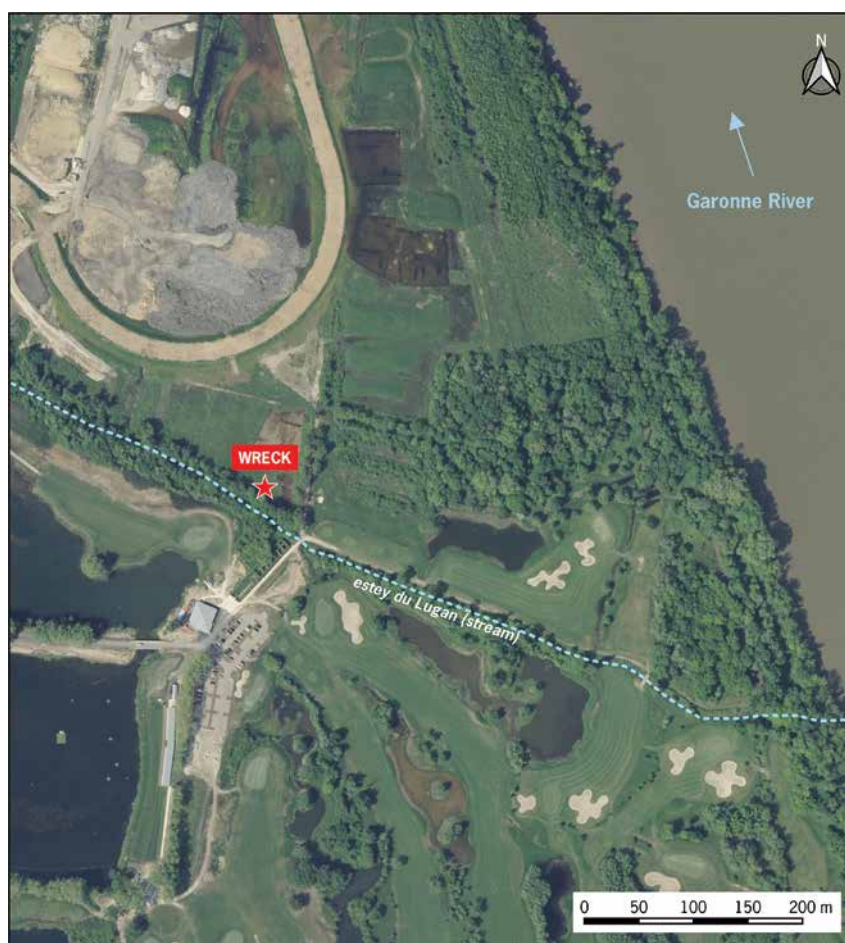


Fig. 3 Aerial view of the wreck area (author: L. Grimbert, Inrap, Google)

3. Architectural elements of the wreck

The 2019 excavation confirmed a remarkable state of preservation of the boat, preserved over a length of 11.20 m, a width of 5.90 m and a height of 1.60 m (Figs 4 and 5). Part of the stern is destroyed over a presumed length of 3 or 4 m, which would restore a boat of an initial length of about 15 m. The reasons for the absence of this part of the wreck have not been identified, but the presence of traces of cutting on the visible part of the keel proves that this is an old phenomenon (a choice to recover some of the elements before the wreck was completely buried?).

¹ The current Lugan stream is less than 1 m wide and looks more like a ditch than a perennial stream bed.



Fig. 4 General view of the wreck (photo: P. Ernaux, Inrap)

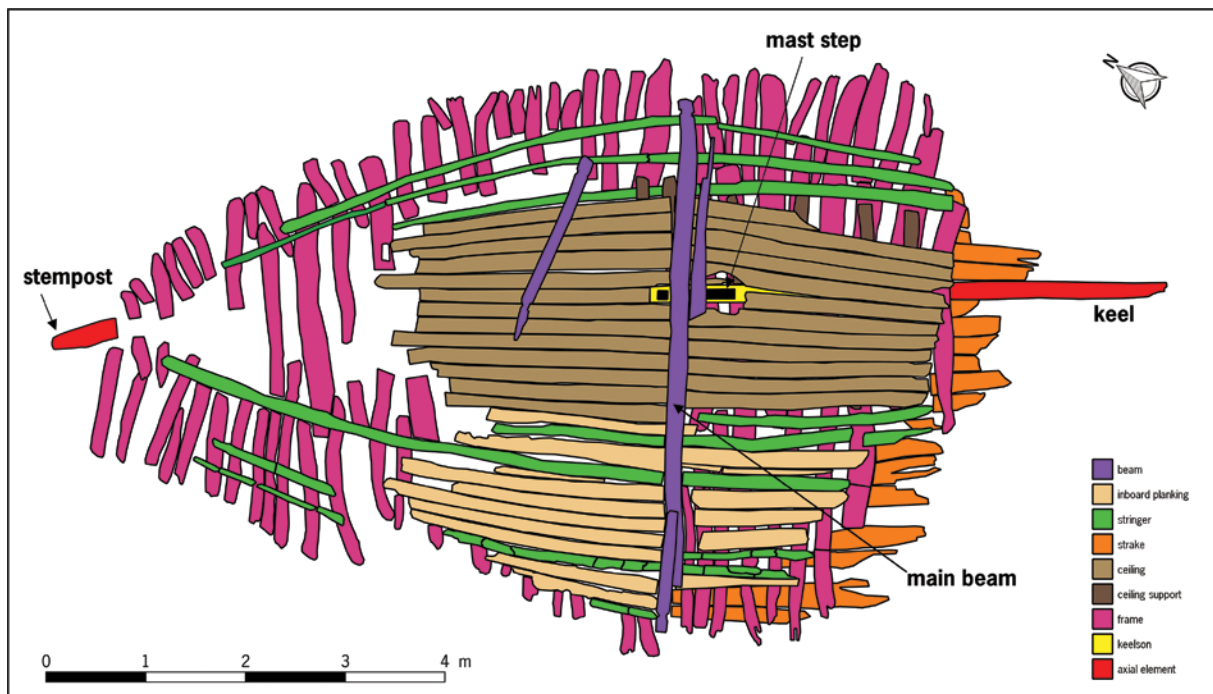


Fig. 5 Plan of the wreck's elements (drawing: L. Grimbert, Inrap)

All the structural elements were observed in a precise manner (keel, planking, ceiling, mast step, beams, etc.) as well as the connections between the elements, mainly by treenails (Fig. 6), but numerous iron nails are also present, particularly at the connections of the important structural parts (stempost, keel, keelson, stringers). Nails were also used for the ceiling.



Fig. 6 Detail of the treenails in the starboard frame (photo: P. Ernaux, Inrap)

Initial macroscopic examinations² carried out *in situ* on some twenty elements of the frame identify ash and oak as the main woods used; only the ceiling planks are made of softwood.

Observation of the strakes on the aft part of the wreck shows that they were carvel planks. The garboard strake is joined to the keel by ‘coaks’ spaced about 0.60 m apart, while the second strake is joined to the garboard by small unpegged tenons, placed in mortises in the edge of each of the strakes.

The frames are made of alternating curved floor timbers and futtocks. At least 74 frame elements, with an average thickness of around 10 cm, were counted but it was not possible during the intervention to observe the presumed join between the floor timbers and the keel. Two characteristics of the frames should be highlighted: on the one hand, their irregular morphology and rough shaping; on the other, their variable rooms.

The scarf between the stem and the keel could not be visually observed but appears to be at the location of a large nail driven vertically through a frame. The preserved ends of the keel and stempost are marked by the presence of hook scarf slots showing the connection of other elements.

The restored lengths of these elements of the longitudinal framework, also made of oak, would be 2.60 m for the stempost and 8.60 m for the keel. The mast step would be 2.90 m long, with a notched underside to secure it strongly to the frames. The mortise of the mast step is 44 cm long and 9 cm wide. The bottom is partially sloped to allow the mast to be set in place.

The main beam, 4.85 m long, was still in place in the centre of the wreck, crossing the port planking but disassembled from the starboard planking, which explains the collapse of the port side. Despite the good preservation of the wreck, the upper parts are missing, which makes it impossible to be certain of the presence of a deck. However, there is archaeological evidence, to be confirmed in the forward part (possible presence of stanchions), which suggests that this type of arrangement (deck or half deck) could be present. Very few elements linked to life on board have been found for the moment. The main ones are fragments of ropes made of plant material, discovered on the ceiling of the bow section of the wreck.

4. Analysis

The architectural study leads to the restitution of a robust boat (wide, numerous and close frames) adapted to the transport of cargo that can be loaded in bulk (grain, salt, stones, etc.) as attested by the presence of a bottom ceiling. This vessel could navigate in both river and maritime environment due to its keel construction, relatively wide and flat bottom. But does it represent a boat exclusively for coastal navigation or long-distance shipping? The new radiocarbon dates carried out in 2019 and the ceramic material taken from the wreck confirm that the wreck dates to the early Middle Ages (second half of the 6th–end of the 7th century).

This discovery therefore constitutes a significant link in the fluvio-maritime shipbuilding techniques of this period and highlights several characteristics. The join of the first carvel planks by ‘coaks’ (garboard/keel) and unpegged tenons/mortise (garboard/second strake) allows us to glimpse a technological evolution, or rather a possible change with the progressive abandonment of ancient Mediterranean ‘shell first’ maritime shipbuilding traditions. But the Atlantic environment of the discovery also raises the question of the relationship with the so called ‘Romano-Celtic’ tradition of shipbuilding and its ‘frame first’ or ‘proto skeleton first’ method.

The lack of archaeological discoveries of wrecks from this period and this type of shipbuilding techniques on the Atlantic coast gives the Villenave-d’Ornon wreck a real importance that contribute to improving our knowledge of this type of shipbuilding. One of the very few regional wrecks from the early Middle Ages identified on the Atlantic coast is the Port Berteau wreck, located in the Charente River (Charente-Maritime) and dated to the early 7th century AD. Ongoing studies will highlight similarities and/or differences in the construction methods of these two boats.

The start of the paleo-environmental studies confirms the existence of the clues necessary for a better understanding of the Villenave-d’Ornon wreck’s environment. The carpological analysis of the plant remains located in the sediment filling the rooms of the aft frames has revealed the presence of endemic Mediterranean species. How to interpret these plant remains? Could they correspond to a hypothetical navigation area, or more probably to the nature of one type of cargo?

² Observations by Didier Pousset, archaeodendrologist.

In 2019, in parallel with the excavation of the wreck, an important ancient occupation (*villa*? 1st century AD) was identified in this sector on the banks of the Garonne. However, no contemporary occupation near the wreck's location is known, which limits the analysis of its presence in this area (small *estey* port? stranding? abandonment?).

5. Research perspectives

In 2019, major technical safety constraints, in conjunction with very unfavourable weather conditions, prevented the complete dismantling of the wreck that was initially planned. Continuing the work in winter would only have led to the deterioration of the wreck, which is why the decision was made to interrupt the work. Only 10% of the wooden parts (scattered parts, main beam, bottom ceiling of the aft part) could finally be removed and transported by truck to the laboratory in charge of their conservation (Arc Nucléart, Grenoble, France).

To avoid degradation of the wreck, it was protected by geotextile and sand before being re-buried in December 2019. After a two-year interruption, the operation is to be resumed in 2022, with the aim of removing the entire wreck while addressing, as the dismantling progresses, the many questions left unanswered in 2019: method of caulking or luting the strakes, process of construction and assembly method (shell first? skeleton first? proto skeleton first? mixed?), presence of upperworks, internal fittings and divisions, repairs, etc.

The continuation of environmental studies (carpology, palynology, geomorphology) is also planned in order to better understand the close environment of the wreck, its possible navigation area, and the possible nature of its cargo. Finally, a conservation and museographic presentation project is currently being studied so that, in the long term, the early medieval ship from Villenave-d'Ornon can be reassembled and presented to the public.

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An extraordinary find? Boa Vista 5, a new early modern ship discovered in Lisbon waterfront (Portugal)

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Abstract: Discovered in August 2020 and excavated until February 2021, Boa Vista 5 is the best-preserved ship ever found in the riverside area of Lisbon. The wreck was discovered in the limits of an anchorage used since Roman times, abandoned on the beach in the intertidal area sometime in the last quarter of the 17th century. The presence of coconuts suggests an operation area on the Atlantic, probably on the Brazilian routes, a rare example of a merchant ship of this period. In this paper we present the excavation and a first analysis of the ship construction features.

Keywords: early modern shipbuilding, Lisbon, waterfront, Portugal, Atlantic

Introduction

The central district of Lisbon has changed considerably over the years through riverside urban design, modified by successive landfills that allowed conquering land for the city. In the last decades, modern construction projects in that area have exposed several structures related to the port use of the Tagus River. Several ships stand out. The older are the 16th century ships, such as Corpo Santo and Cais do Sodré, but for more recent times, from the late 17th or early 18th century, are the Boa Vista ships, discovered since 2012 (Bettencourt *et al.* 2021a).

In this paper we present the first results on the research on Boa Vista 5, discovered during the construction of a new building, intended for a hotel and apartments, between Avenida 24 de Julho and Rua Dom Luís I, in the occidental area of the city. The ship was found during the monitoring of the digging works inside the pre-built molded walls, at an advanced stage of the construction operations. It was excavated from August 2020 to March 2021, during rescue archaeological works, by the company ERA ARQUEOLOGIA, which requested the contribution of Centre for the Humanities (CHAM) of NOVA University Lisbon to ensure the necessary expertise in nautical archaeology.

Site location

Boa Vista 5 was found buried in the early Boavista beach, like Boa Vista 2 and Boa Vista 1, that were just fifteen meters east (Fig. 1). That had been a submerged zone until the beginning of the 19th century, according to ancient cartography, located on the area occupied by the logistics facilities of the *Junta de Comércio do Brasil* (a State Merchant Company), from the 17th century onwards (Bettencourt *et al.* 2021a; Sarrazola *et al.* 2014).

The archaeological excavation revealed a long stratigraphic sequence, similar to the one recorded during Boa Vista 1 and 2 excavations, on the contiguous city block (Bettencourt *et al.* 2021a). The ship was on a port area, located at depths between 2 and 7 m (mean sea level), featuring ceramics ranging from the Roman period to the 18th century as well as several items of nautical equipment, like iron anchors from the Early Modern period or a small river boat, Boa Vista 4. Above these levels, formed by silty sediments, several landfills were made, which became the foundations for the construction of commercial and industrial buildings in the 19th century.

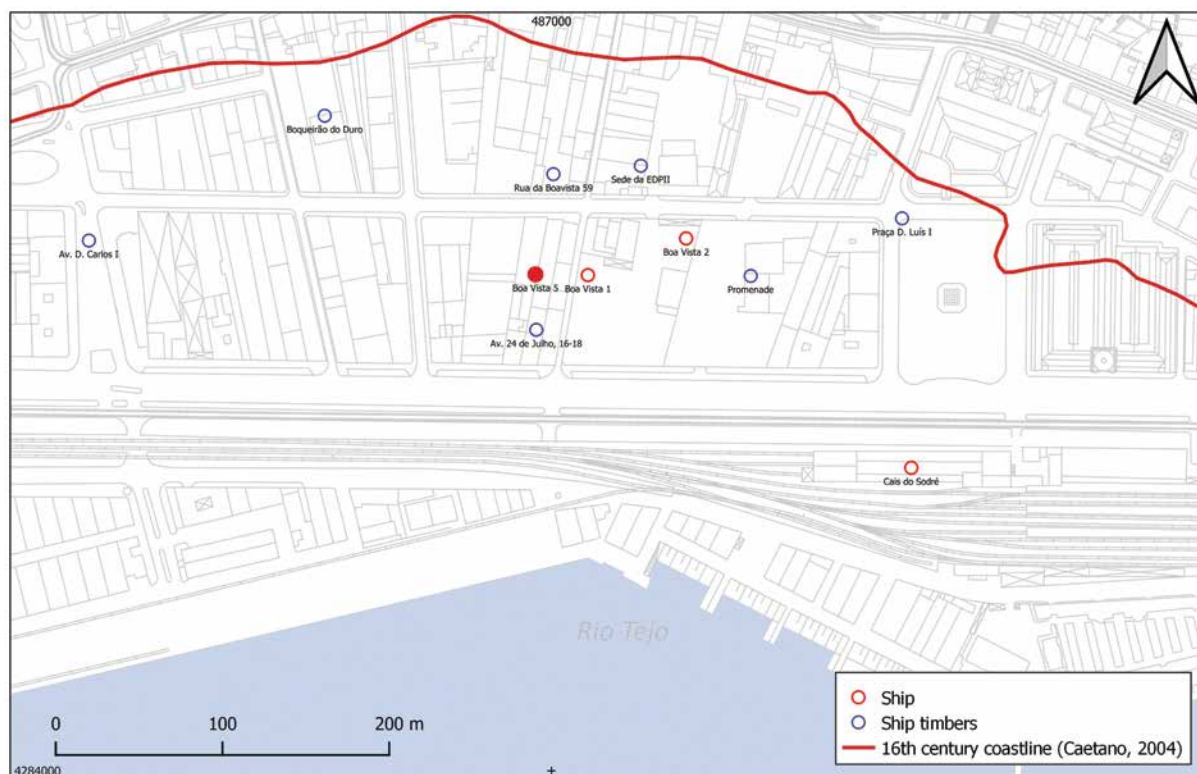


Fig. 1 Site location, in relation to other ship finds on the area (map: J. Bettencourt)

The ship excavation and timbers documentation

Time constraints, related to the engineering works, forced the team to adopt a simplified documentation methodology. All archaeological layers with materials or structures considered relevant to interpret the site and ship hull were recorded by structure via photogrammetry. The digital models were georeferenced based on control points, fixed on the hull, positioned with a total station, seeking to use the same points throughout the entire work.

The different outputs of photogrammetry – models, Digital Elevation Models (DEM's) and orthomosaics were used to produce the site plan and control the descriptive data about the hull and other finds. They were complemented with field observations, noted directly in the orthomosaics or in the draft versions of the site plan.

That strategy was particularly useful during the ship's dismantling phases when the constructive details were revealed. The dismantling was accompanied by an inventory and detailed photography and video records. All the timbers were removed to tanks built from shipping containers, a task that involved the use of engineering resources available on the construction, namely pneumatic hammers, to dismantle structures such as pillars and other support structures that had cut the ship before the excavation, and cranes, to lift most of the pieces, which weighed between a few dozen and hundreds of kilos.

The post-excavation work, in progress, includes the analysis and systematization of the field data and the individual recording of the timbers. Again, due to time constraints, the documentation of the ship timbers follows a very simplified protocol. The structural timbers, like the frames, are being digitized with a hand scanner, following the procedures proposed by Van Damme *et al.* (2020). As on previous projects, we recognize that the texture quality obtained by the scan is not good enough; therefore, all the timbers are also recorded by photogrammetry, which allow a systematic photo coverage and the application of photo textures on the 3D models, if necessary. The photogrammetry is also the basic method on the documentation of planks and other longitudinal timbers that bend during the work.

The descriptive catalogue is supported on this graphic record. 3D models were used to produce prints where construction details or/and timbers interpretation were annotated. These are also used on the preparation of the final drawings.

Finally, the field data and the information from the individual timbers are being organized into a GIS project, which includes raster data (site orthomosaics and DEM's) and vector data (e.g., polygons with the limits of the ship timbers; or points with the position of the artifacts).



Fig. 2 Boa Vista 5 ship general site map (map: CHAM/ERA)

The ship

Boa Vista 5 remains are 24 m long and 17 m in width, maximum dimensions, from the bow to the stern and from the keel to the level of a deck (Fig. 2). The hull was oriented northwest/southeast, with the stern to the southeast, with both ends partially cut by the walls of the engineering work. Scattered timbers could be found under the hull and the structure was open, with the starboard side connected and the port side fallen to southwest.

When discovered, the ship remains were sealed by silted fluvial deposits, but a ballast mound dominated on the central section of the hull. The excavation has shown that the ballast was well arranged in timber compartments that divided and organized the hold of the ship. It is composed of pebbles, cobbles and boulders, with a large variation in shape and size. It includes several petrological types, for example basalt and limestone, most of them available on the coast between Lisbon and Cascais, according to a first observation of a geology team from the Faculty of Sciences of the University of Lisbon.

The artifacts found during the excavation clearly related to the ship were scarce, but include, for example, round iron shots, concentrated in the centre of the hull next to the mast step, and wooden blocks and coconuts, entrapped below and between the ballast. The ceramics are more difficult to relate to some context because some could also be linked to the use of this area as a port. They give, however, a global idea of the site chronology, including materials from the second half of the 17th century to the first half of the 18th century. Also, a level with several artifacts was sealed under the ceiling, between a primary ballast of sand, pebbles and some cobbles. This level includes, for example, a kaolin Dutch pipe, with the EB mark, similar to the ones found in Burgzand Noord wreck 2 (BZ2), lost c. 1670–1675 (Vos 2012: 132–133), the most likely chronology for the ship use.

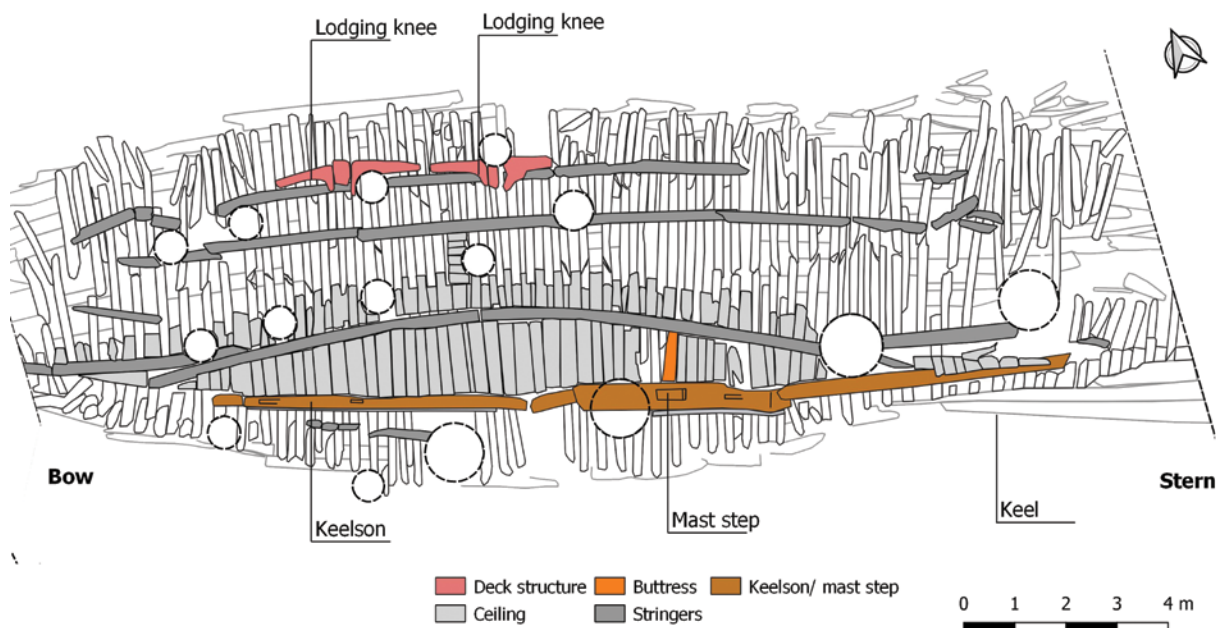


Fig. 3 Boa Vista 5 main section site map (map: CHAM/ERA)



Fig. 4 The stern assembly with the keel, the deadwood, the Y shaped-frames and the filling pieces (photo: J. Bettencourt)

The main section hull corresponds to starboard side, from the keel to the level of the first deck, including frames up to the third futtock, the keelson, the maststep, stringers, ceiling, lodging knees and the planking (Fig. 3). Their analysis, in an initial phase, is an opportunity to understand the anatomy and ship design of their period.

The keel sections are joined with a hooked vertical scarf joint, displaying all along their width several semi-circular notches, filled with stop-waters. A similar scarf was used to connect the stem, which received a stemson and a long deadwood on the top. The deadwood had carved recesses to receive the floor-timbers. The sternpost was not preserved but the aft extremity of the keel received the deadwood, where the Y-shaped frames were also embedded. On the stern the space between the floor-timbers was occupied with filling pieces, shaped similarly to the Y-shaped timbers (Fig. 4).

The frames were preserved from bow to stern, in some parts, until the third futtock, on the beginning of the first deck or false deck, where lodging knees were found. The frames could clearly be divided in two different groups – central frames and filling floor-timbers (Fig. 5).

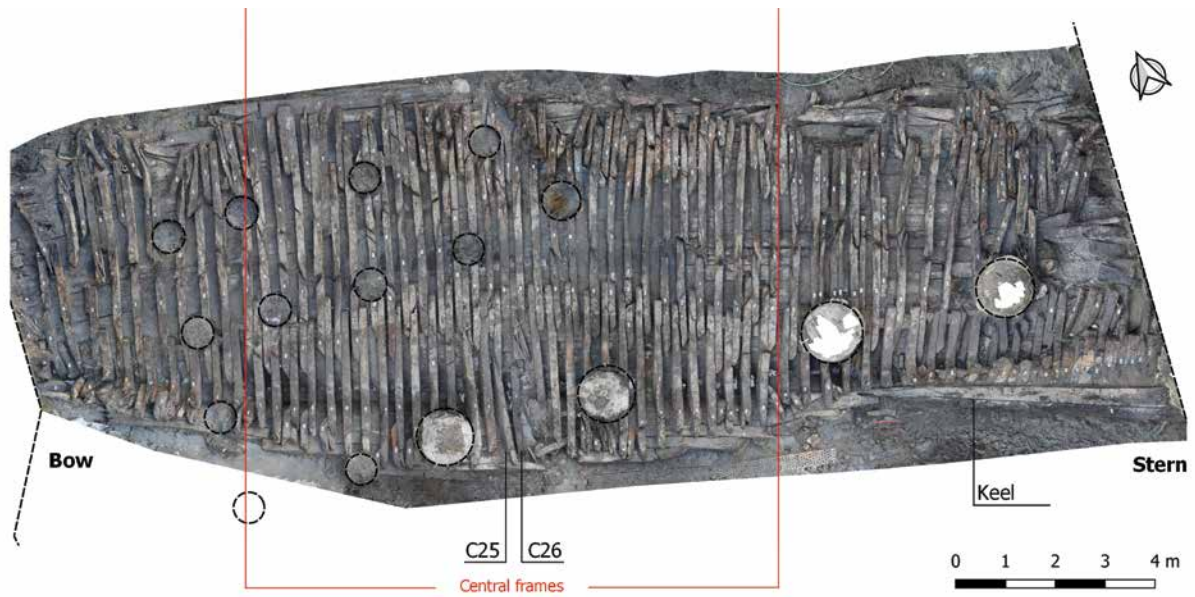


Fig. 5 Boa Vista 5 main section ortomosaic of the frames (ortomosaic: CHAM/ERA)

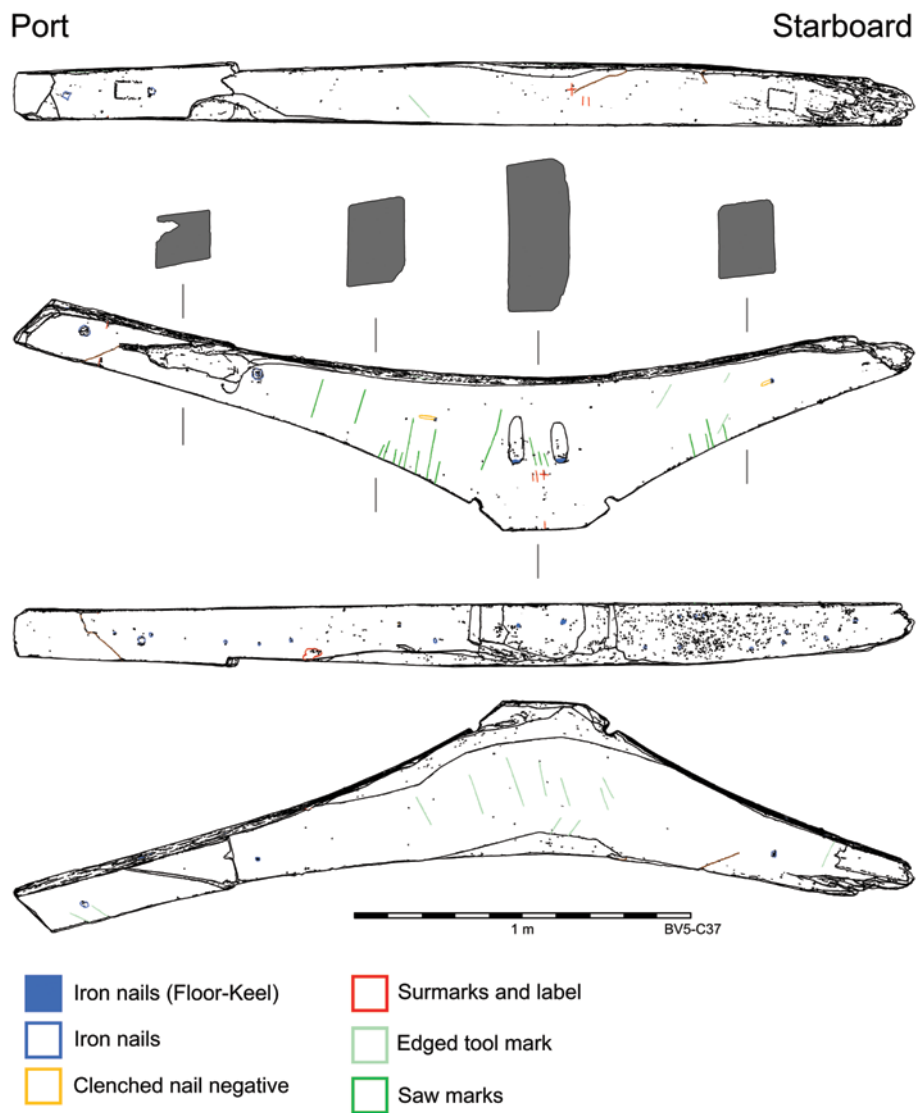


Fig. 6 In red, the design and label marks on C37 floor-timber (drawing: CHAM/ERA)

The 30 central frames show evidence of assembling before they were set up on the keel. Those frames are composed of one floor-timber and two futtocks joined with a kind of hooked scarfs, with the top of the floor-timbers embedded on the futtocks in a recess, like a non-trapezoidal dovetail joint. This characteristic seems to correspond to a hybrid model, between the shape of the scarves documented on ships built in the Ibero-Atlantic area and in the Mediterranean, between the Middle Ages and at least the 17th century (Oertling 2001; Rieth 1998). They were fastened with three iron nails, some of them clenched back into the timber, a feature that has no parallel in other Atlantic ship.

Those central frames were carefully positioned during the ship construction. The floor-timbers were fastened to the keel with two iron nails, inserted through recesses cut on the forward or aft faces, depending on their position on the keel. The space between some floor-timbers was controlled by filling pieces that maintained the distance between them.

The general pattern of the central frames suggests that the middle frames, or master frames, are the C25 and C26. In fact, between the C25 and C26 the futtocks position pattern changes. From C25, towards the bow, the futtocks were attached to the forward side of the floor-timbers; from C26, towards the stern, the futtocks were attached on the aft side of the floor-timbers. Another construction detail pointing to this hypothesis is that the futtock between C25 and C26 is a floating timber, not connected to any of the contiguous floor-timbers.

Unfortunately, C25 and C26 are the floor-timbers in the worst state of preservation, but the crucial role of the central frames was confirmed in the first days of post-excavation work, when several design marks were identified. They correspond to straight lines carved into the floor-timbers, pointing to the centerline on the keel, and surmarks in the zone of the turn of the bilge, similar to the ones recorded in the Cais do Sodré shipwreck (Nicolardi, Castro 2015). Some floor-timbers also preserve location labels, corresponding to their position of the midship frames. For example, the C37 is numbered XII (Roman numeral) and corresponds to the twelfth floor-timber towards the stern from the master frame C26 (Fig. 6).

The internal structures include part of the keelson, the stringers, and the ceiling. Both keelson and first stringer are notched over the top of the floor-timbers. In the ship axis the maststep was partially preserved. The maststep was an independent timber, joined to the keelson through a dovetail mortise, apparently reinforced with only one buttress in each board. The space between the keelson and the first stringer was protected by a transversal ceiling, with most planks not fastened to the frames. The tops of the floor-timbers were also protected by filling timbers.

Finally, the carvel hull planking was nailed to the frames with square iron nails, which had round countersinks in the outer face, some of them clenched over the top of the frames. There are no treenails in the hull planking. No caulking was found during the excavation.

Concluding remarks

Until the 2010s, Portuguese naval archaeology focused mainly on ships from the 16th–early 17th century, of Ibero-Atlantic tradition (Alves 2001). The investigation showed that these ships, with a frame-first construction, shared construction techniques with ships used in transoceanic navigation, built in several shipyards in the Iberian Peninsula. Cross-referencing the archaeological data with historical sources, especially with technical texts written in Portugal and Spain between the end of the 16th century and the first decades of the 17th century, place the design of hulls in this period in a clear area of Mediterranean influence (Castro 2008; Domingues 2004).

Knowledge about ships from the second half of the 17th century is scarce. The absence of archaeological studies is not overcome by historical studies. Naval construction treatises are not known in Portugal for this period and the study of the documentation that might exist in national archives remains to be done. The discovery of the Boa Vista ships (Boa Vista 1 and Boa Vista 2) brought to light the weaknesses in our knowledge regarding shipbuilding from the second half of the 17th century onwards. These ships did not present clear parallels in any known case on an international scale to date, although Boa Vista 1 presented characteristics that appear in Mediterranean and others that could be found in Atlantic space, which could suggest hybrid models, still to be determined (Bettencourt *et al.* 2021b).

The discovery of Boa Vista 5 reinforces the hypotheses of filling the gap in the study of this period of European shipbuilding history. The finds suggests that she was deposited on the beach between the last quarter of the 17th century and beginning of the 18th century. The location in the *Junta de Comércio do Brasil* logistic area and the presence of coconuts between and under the ballast suggests an operation area for Boa Vista 5 on the Atlantic, being a rare example of a probable merchant ship of this period in that region.

To our knowledge, the assemblage of construction features has no close parallel in any other medium to large sized hull published to date in Portuguese and Atlantic contexts. There are, however, construction features possibly from Mediterranean influence, among which we highlight the shape of the scarfs joining the floor-timbers and the futtocks, or the presence of design marks, known in the Mediterranean since the Middle Ages, related to a non-graphic design of the hull (Rieth 1996). The presence of design marks, rare, but known on other vessels from the same period, like the Cais do Sodré (Nicolardi, Castro 2015) and *La Belle*, which seems to demonstrate evidences of a transition to graphic design (Pevny 2017), provides direct evidence of the hull design. The general good preservation of the floor-timbers and futtocks will also allow us to analyze the curvature of frames. The number and characteristics of the arcs used to determine the shape of the hull have not yet been determined, but a very preliminary analysis shows that the floor-timbers use an inverted arc on the base of the floor-timber (there are no floor-timbers with a flat bottom).

To conclude, together with Boa Vista 1 and Boa Vista 2 from the same period, Boa Vista 5 is an extraordinary find, with a very high scientific potential. Assuming the hypothesis that she was built on the Iberian Peninsula, it is an important starting point to review the available sources on later 17th century ship construction for the Atlantic.

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An early 17th-century ‘half-carvel’ construction in the North Frisian Wadden Sea: The Japsand wreckage near Hallig Hooe, Germany

Daniel Zwick

Abstract: This paper outlines the research results of a recent discovery of two early 17th century wreck fragments of a mixed clinker and carvel construction – a so-called ‘half carvel’ – at the Japsand, an outer shoal of the island of Hooe in the North Frisian Wadden Sea, Germany. The description is followed by a discussion on how this find could be contextualised in terms of a northern European shipbuilding tradition and ship-type. This paper advocates that ‘half-carvels’ ought to be seen as part of a broader phenomenon of carvel-analogous shell-first lapstrake constructions prevalent in the Baltic Sea and beyond.

Key words: half-carvel, clinker, carvel, shipbuilding, North Sea, 17th century

1. Introduction

In February 2017, an articulated slab of mixed clinker and carvel planking was discovered by a group of mudflat hikers at low tide to the east of the Japsand, an outer shoal ca. 2 km to the west of the island of Hooe in the federal state of Schleswig-Holstein, Germany (Fig. 1). A few days after this find was reported to the State Archaeology Department of Schleswig-Holstein (ALSH), the ALSH sent a team to the island, as it was feared that this wreck fragment might be relocated by tidal currents. With the assistance of local volunteers, the hike across the mudflats was carefully planned, which involved wading through several tidal creeks. A very short time window of about an hour was planned for the documentation of the wreck, involving GPS localisation, a photographic documentation suitable for a Structure-from-Motion (SfM) photogrammetry, individual sketches, and sampling for a dendrochronological analysis (Fig. 2). The remaining time was required to transport the equipment and samples off site. The team left well before the incoming tide. Although the mudflats could still be traversed for some hours after the lowest ebb, the rising water level in the tidal creeks could have cut off the line of retreat. In May of the same year, another slab of planking was discovered at a distance of ca. 400 m to the northwest of the former. This fragment was discovered on the Japsand itself and needed to be partially excavated (Fig. 3). It had the very same features as the first slab and both wreck fragments would fit together like pieces of a puzzle. There can be little doubt that both fragments originated from the same vessel, which is also corroborated by their identical dating (*cf.* Zwick *et al.* 2018).

Due to the short time window in which the survey had to take place, the wreck fragments could not be studied in greater detail and the exposed location of wreck fragment 1 (WF1) led to its loss shortly after the investigation. WF2 remained *in situ* and was gradually covered by sands again. It was detected through a multi-coil FD-EMI survey three years later, in which WF2 was used as test case to optimise this technology (*cf.* Wilken *et al.* 2022).

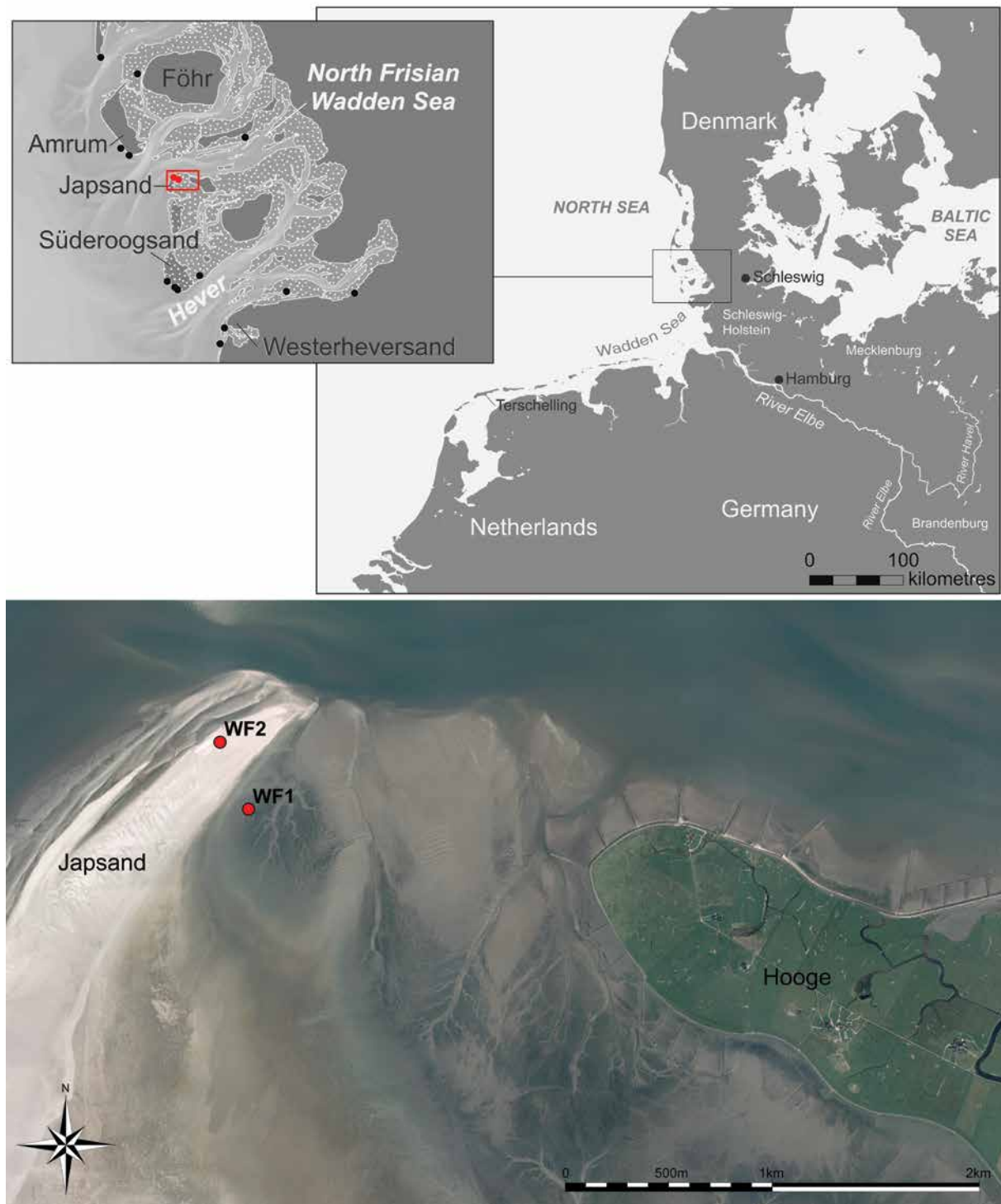


Fig. 1 The location of both wreck fragments WF 1 and WF 2 in a satellite image of the Japsand and the island of Hooe. The map excerpts indicate the location of the Japsand wreckage (red) in the general geographical context, the tidal mudflats (white dotted areas) of the North Frisian Wadden Sea, and other archaeologically investigated wrecks (black dots) (graph: D. Zwick; satellite image: GeoBasis-DE/LVermGeo SH/CC BY 4.0).



Fig. 2 The documentation of the first wreck fragment (WF1) in February 2017 (photo: ALSH)

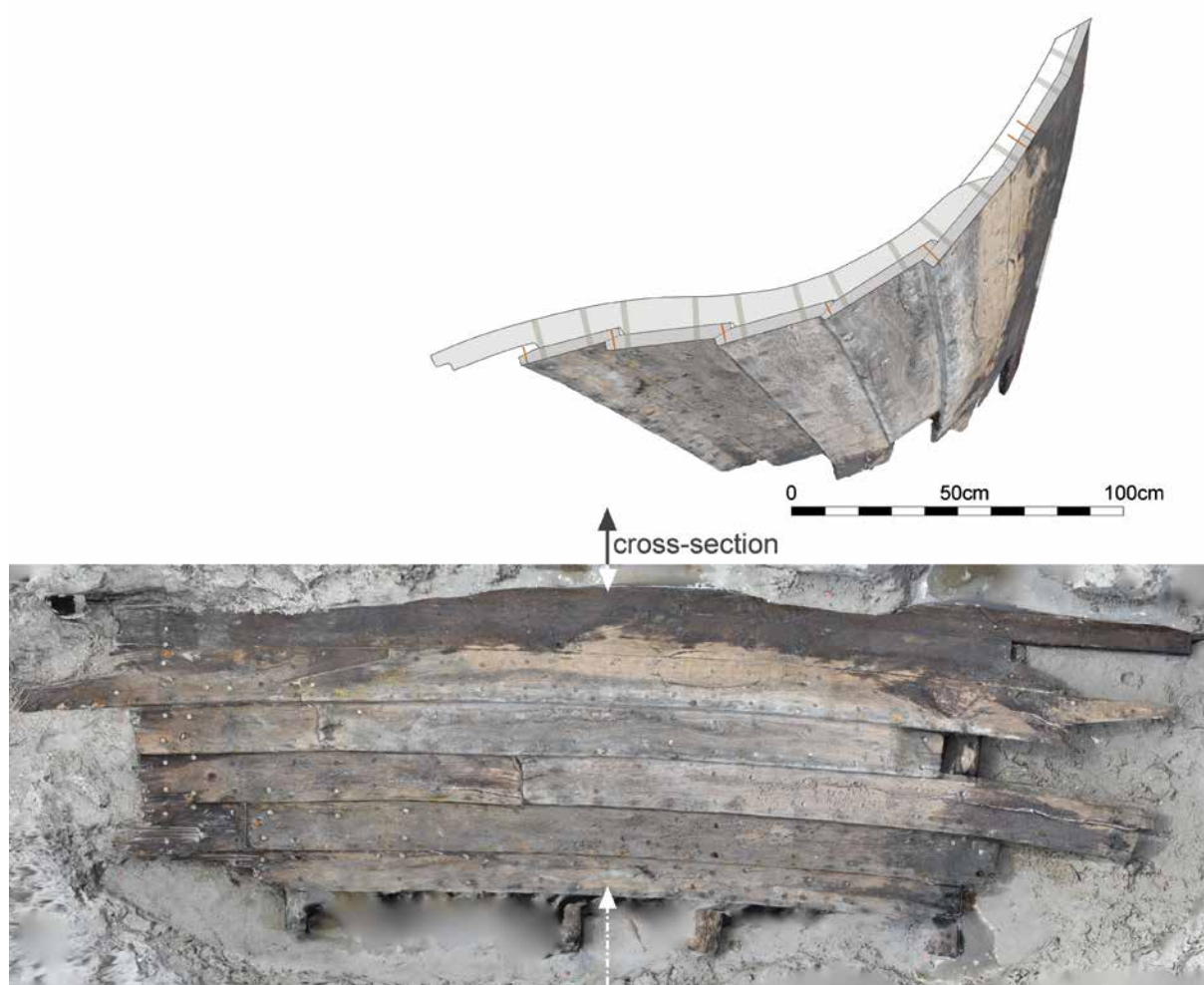


Fig. 3 The second wreck fragment (WF2) as recorded in May 2017. The orthogonal projection and cross-section view was generated as SfM-model with Agisoft Metashape on the basis of over 200 photos. The framing and fasteners were schematically added (graph: D. Zwick).

2. Description of the construction

In terms of general dimensions, the first wreck fragment is ca. 4.5 m in length and the second ca. 9 m. If fitted together (Fig. 4), the combined slab would measure roughly 12 m in length.

Of the first fragment, five strakes (two clinker, three flush-laid) and of the second fragment seven strakes (four clinker, three flush-laid) are remaining. A strake sheer is discernible and in WF1 a slight increase of plank widths could be observed towards the ship's midship area, i.e. strake 1 from 35 to 38 cm, strake 2 from 33 to 34 cm, strake 3 from 34 to 35 cm, strake 4 from 32 to 35.5 cm, strake 5 from 34.5 to 36 cm.

The plank widths vary between 32–38 cm and the plank thicknesses seem to be fairly consistent at ca. 4.5 cm. The tree-ring structure observed in the sampled planks' cross-sections indicate that they were tangentially extracted from the trunk and most probably sawn, as indicated by the regular thickness and the absence of adze marks on the even surface. While the flush-laid planks¹ are fastened to each frame normally with three treenails, sometimes less, most clinker planks² were fastened with two treenails as well as iron fasteners on the upper and lower landing at a fairly regular distance of 22 cm +/- 2 cm in the centre of the landing, measuring ca. 6.5 cm. The iron fasteners were subject to an advanced state of corrosion, leaving only some rectangular rivet plate impressions measuring ca. 2.5 × 2 cm. The nail shafts are ca. 0.9–1.0 cm in thickness.

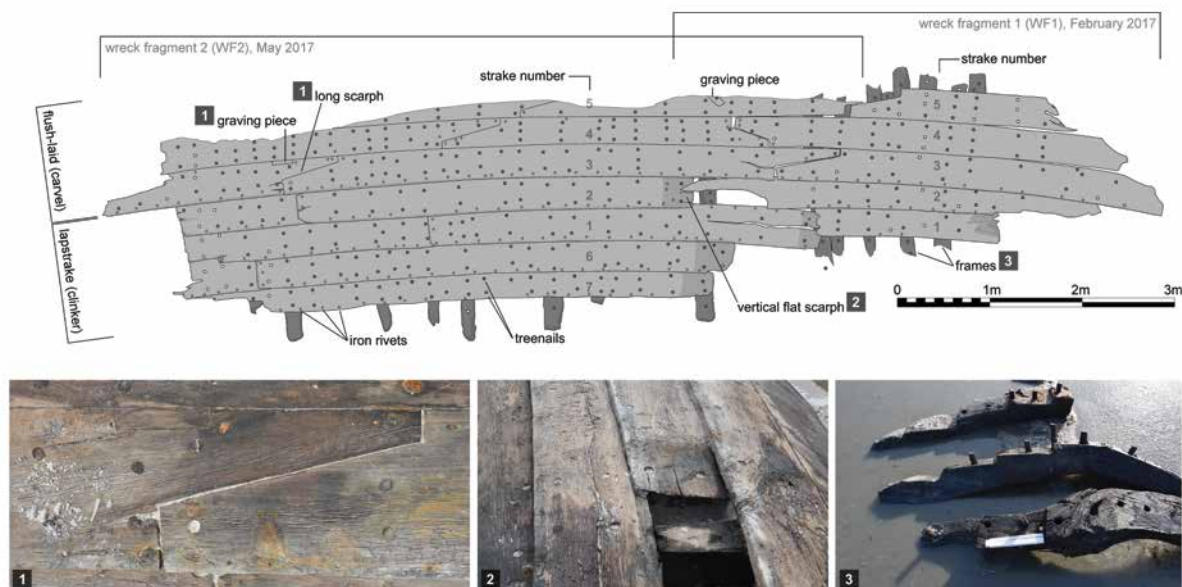


Fig. 4 Plan of both wreck fragments hypothetically fitted together (graph: D. Zwick, photos: ALSH)

Nails were also used to reinforce the long scarphs (ca. 60 cm, Fig. 4.1) of the flush-laid planks, as well as the flat scarphs (ca. 30–40 cm, Fig. 4.2) of the clinker planks. In the case of the flush-laid planks' scarphs, the tapered ends were secured with 1-2 iron fasteners onto a frame. Thus, the frame has to be in alignment with both tapered ends. Based on the observation of the frames protruding from beneath the slab of planking, this indeed seems to be the case. Naturally warped timber – i.e. compass timber – was used to ensure that two closely spaced frames were inserted at the beginning and the end of the flat scarph. The framing seems highly irregular both in terms of dimensions and bend (Fig. 4.3). A general pattern, however, is the greater curvature of framing timber at the joggled outer side – that is the side to receive the clinker planks – and thus it could be inferred that this must be the turn of the bilge (Fig. 3). Just above the turn of the bilge, the planks were laid flush, thus the clinker-built portion of the hull must have been below the waterline. As a consequence, the vessel must have appeared as a carvel-construction to the outside observer. Some top-timbers

¹ The term 'flush-laid' essentially describes the appearance of carvel-planks, forming a smooth outer surface. As the skeleton-first principle is often implied when speaking of carvel constructions, it makes sense to use the term 'flush-laid' in a context in which a shell-first or alternating building sequence was applied. Nonetheless, the term 'carvel' has become commonplace even for those constructions and in most languages the distinction between 'carvel' and 'flush-laid' is not expressed through terminology, so the term 'carvel' in the original and restrictive sense cannot be upheld in this article throughout, as terms like 'half-carvels' have become proper nouns despite their inadequacy.

² The term 'lapstrake' is used as umbrella term for vertically overlapping planks, which prominently includes clinker (implying the use of rivets). Since the distinction of 'lapstrake' and 'clinker' is not made in other languages (e.g. in German or Swedish), 'clinker' is often synonymously used for lapstrake.

ended just slightly above the turn of the bilge, arranged in between the floor-timbers and not interconnected. Some of the framing timber at the turn of the bilge turned backward at the lower end, forming a slight S-shape, indicating its proximity to the keel.

Two oblong graving pieces in the carvel planking of the second fragment were observed, which are not necessarily later repairs, but could have been inserted over a knot for watertightness.

3. Date and provenance

WF1 was extensively sampled, whereas only few samples were taken from WF2. All samples are of oak. The sample code 'P' indicates plank and 'S' indicates frame. Based on the dendrochronological analysis, the timber was cut between 1603 and 1609, or possibly later. The latest date with sapwood inclusion is provided by sample 'S8' with a felling date of 1609, providing a *terminus post quem* and thus indicating that the vessel could have not been built before that year. Sample 'S12' did not contain sapwood or wane and if a standard margin of 20 years is added, the hypothetical felling date would be 1617.

Sample	Start	End	felling year
Wreck fragment 1 (WF1)			
P 1	1473	1575	Around/after 1595
P 2	?		No result
P 3	1459	1515	Around/after 1536
P 4	1467	1553	Around/after 1573
S 7	1473	1603	1603
S 8	1498	1609	1609
S 9	1515	1607	1607
S 11	1418	1586	Around/after 1606
S 12	1517	1597	Around/after 1617
Wreck fragment 2 (WF2)			
S1			1608
P2			Around/after 1584

Table 1 Dendrochronological results provided by Dr. Karl Uwe Heußner March 24, 2017 and July 20, 2017

Therefore, the building of the vessel will probably have occurred during the second or third decade of the 17th century. The highest correlation of the first fragment is with regional curves of the Swedish island of Öland with a t-value of 7.1. There is also a relatively high correlation with northern Germany, i.e. Schleswig-Holstein, western Mecklenburg, and Hamburg. The second fragment also has high correlations to northern Germany, particularly western Mecklenburg and the Havel region (Ostprignitz-Ruppin) in Brandenburg. In summary, there is no clear provenance but it is safe to assume that the vessel's timber originated from the south-western Baltic Sea region. Since there are no strikingly different locations, the differences could be attributed to the blurred nature of the inconclusive dendrological analysis, and therefore it seems fair to suggest that there is an absence of regional variation in the sourced timber. This is also highlighted by the fact that oak was used for all elements of the preserved hull. This is an indicator for:

- an abundant availability of oak timber near the shipbuilding site. The cost-benefit assessment on the use of oak in sections of the hull that could be built with a less expensive wood species was likely offset by transport costs (in that it was less costly to use more expensive timber than to import other wood species to the shipbuilding site).
- a rural setting, in which the building timber for the vessel was sourced locally – probably from a singular forest – rather than from different groups of imported timber, as was common in an urban setting at that time.

This impression is also corroborated by the graving pieces at the plank edges. If they were inserted during the vessel's construction (e.g. necessary to patch over knots to insure water-tightness), this would be an indicator for the absence of a specialised access to import timber suitable for planks, and an indicator that the craftsmen were obliged to make best use of the locally available timber.

4. Inferences on wreck site formation

The Japsand is the northernmost of the three North Frisian barrier islands, i.e. an outer shoal with an elevation of ca. 1 m above the mean high water, which can be entirely flooded at astronomical peak tides or storms. These shoals are subject to a long-term coastal erosion process affecting the entire western shoreline, which also led to the discovery of the Hörnum Odde wreck (ca. 1690) the year before at the southern tip of Sylt (Zwick 2021). Sedimentation takes place to the east, thus the shoals are effectively 'relocating' up to 20 m eastwards per annum³. The find location of WF1 is peculiar, as it was discovered in a mudflat area normally not affected by erosion. It can be presumed that it was also formerly situated at the Japsand and broke off from WF2 recently. This is corroborated by the fact that WF1 lay totally exposed and with no scour, which is an indicator that the relocation must have occurred shortly before its discovery.



Fig. 5 The destruction caused by the Burchadi Flood of 1634 in a contemporary engraving entitled “Die erschreckliche Wasser-Fluth” (after Henssberg aus Happel, Historische Kernchronik 1682)

WF2 was almost entirely covered by sand, but must have migrated as well, as the Japsand formed in the late 19th century. On a map of 1864 its emergence is indicated by the sandbank ‘Junge Jap’ (young Jap) further south, whereas the find location of the Japsand wreckage corresponds to a mudflat area with the name Knudshörn (cf Handtke 1864). Therefore, it can be ruled out that the wreckage was deposited in the Japsand for more than a century, which must have eroded from a deeper channel or migrated with the sand mass to its current position. The absence of marine borers indicates that it must have been covered by sediments for most of the time. This is contrasted by another wreck fragment

³ Wattenmeerstrategie 2100 (government paper), pages 21–22: <https://www.schleswig-holstein.de/DE/Fachinhalte/K/kuestenschutz/strategieWattenmeer2100.html> (accessed on January 18, 2021).

from the Japsand, an 18th-century sternpost with plank fragments (hood-ends and stealers), rudder-pintles and copper sheathing, which was heavily degraded by *teredo navalis* (Kühn 1999: 35f.).

Due to the absence of associated finds or dateable evidence for later repairs, a lifespan for the vessel could not be inferred from the find itself. In view of the construction date in the 1610's or thereafter, the Burchadi Flood of 1634 seems a relevant date, which devastated the entire coastline of the Wadden Sea (Fig. 5). The storm flood had such a force that even large seagoing ships were swept across dykes into the streets (*cf.* Riecken 1991: 12). The fact that sizeable slabs of articulated planking have disintegrated reflects the forceful impact on a hull's structural integrity, suggesting a major meteorological event as cause for the loss of the vessel.

5. Conceptual similarities and contextualisation

The most striking feature is the mixed planking, with clinker planks on the lower portion of the hull and flush-laid planks on the upper part. This type of construction has been commonly viewed within a Scandinavian context, dubbed 'half-carvel'. A notable case was documented in Bohuslän in 1938, western Sweden (Hasslöff 1970: 58f.) (Fig. 6). The vessel under construction was not referred to as 'half-carvel', but as a *galeas*, and when asked why this mixed construction was preferred, the shipbuilder Anders Mattson attached not much meaning to the carvel-planking, but emphasized instead his preference for building the difficult part of the hull – i.e. the bottom part up to the turn of the bilge – in clinker, for the hull to “take shape under his hands”. Once completed, the futtocks and top-timbers would be raised, to which carvel planks would be attached (Hasslöff 1970: 59).

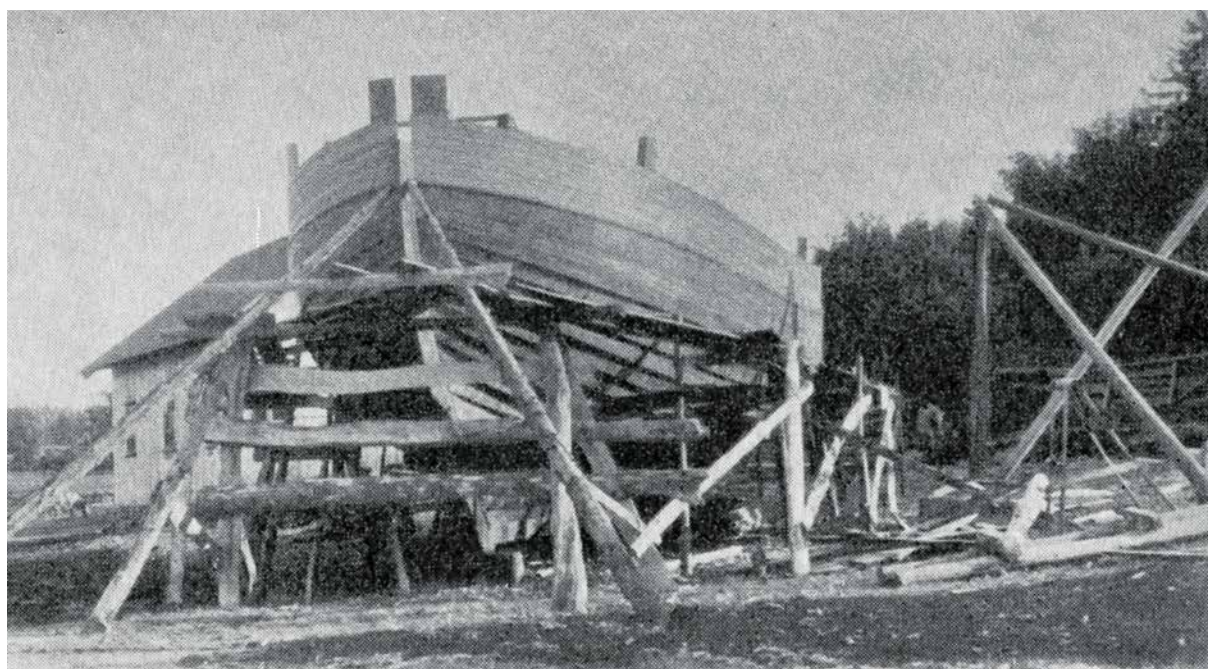


Fig. 6 Anders Mattson's galley under construction in 1938 in Bohuslän, Sweden. The lower portion of the hull is clinker-built and the upper strakes are finished with carvel planks (after Hasslöff 1970: Fig. 19).

Based on this description, the term 'half-carvel' has to be regarded as misleading, as this is first and foremost a shell-first clinker construction, which appears as a carvel only by analogy above the waterline (the carvel part being a secondary feature). Nonetheless, for the lack of a better term, the original term is kept in this article. These half-carvel constructions can be traced from the mid-16th century to the early 20th century and are most common in Sweden (*cf.* Eriksson 2010). Variants occur also in other parts of the Baltic Sea, in the North Sea, along the Norwegian coast, and in the White Sea.

It is notable that the Japsand wreckage is one of the oldest specimens for a half-carvel, predated only by the Åkroken wreck from Sundsvall (Sweden), which timber was sourced from the Swedish province of Jämtland or Finland in 1577 (Eriksson 2008: 5; 2010: 80), and the Terschelling Paal 9/10 wreck of 1546 from the Netherlands (Overmeer 2023: 171). Half-carvels are typically linked to the Baltic Sea, but the recent discovery of the wrecks from Japsand and

Terschelling, as well as Westerheversand at a distance of only some 25 km to the Japsand, raises the question whether half-carvel constructions were a more widespread phenomenon in the North Sea. Although the Westerheversand wreck of 1687 is not a half-carvel, but a construction with alternating lapstrake planks in the upper part (*cf.* Cattryssee 2013: 30ff.), comparable to *sandskuders* in Denmark (*cf.* Gøthche 1991: 85), such constructions were conceptually comparable to half-carvels, as pointed out by Niklas Eriksson (2010, 81f.). Interestingly, all of these North Sea variants were built entirely of oak that was sourced in the general region where the wrecks were discovered, thus forming a contrast to the Swedish half-carvel counterparts, which were mostly built of pine. Another distinguishing feature in the case of the Terschelling wreck is the presence of *spijkerpennen* (Overmeer 2023: 171), a feature linked to the Dutch flush-technology (*cf.* Maarleveld 2013), thus indicating that there were regionally independent developments and not a singular evolutionary branch that lead to the establishment of a specific ‘half-carvel’ type *per se*.

Arguably, half-carvel constructions like the one encountered at the Japsand have to be regarded as a broader phenomenon in shipbuilding, where minor aspects of carvel shipbuilding influenced traditional clinker or lapstrake constructions either during the construction phase or in a later rebuild. This influence could also be asserted for converted clinker/lapstrake constructions generally, of which several were rebuilt as ‘carvels’ by the addition of a secondary layer of flush-laid planks (*cf.* Auer, Ditta 2016; Belasus 2017; Grundvad 2010; Mäss 1994; Ossowski 2006).

It must be stressed that the aforementioned half-carvels and variants were not classified by contemporaries on the basis of their peculiar hull construction, but as ship-types based on region, size or rigging, such as (1) ‘galeas’ (Bohuslän, Sweden), (2) ‘skuta’ (Roslagen, Sweden), (3) ‘sandskuder’ (Denmark), (4) ‘Nordlandsjekte’ (Norway), and (5) ‘schooner’ (Finland and Sweden).⁴ The main connecting factors of all these vessels are their rural character and the coastal shipping routes they were operating on, as well as their reliance on clinker/lapstrake technology or shell-first building methods as guiding principle.

6. Conclusion

Despite superficial similarities to Swedish half-carvels, the decisive question remains whether the Japsand wreckage has to be seen as part of a more widespread phenomenon in carvel-analogous constructions, possibly stemming from an independent development in the North Sea area, or whether it could be specifically linked to a Swedish influence? It dates from the time of the Thirty Years’ War, in which Sweden gained territorial possessions in Mecklenburg and Pomerania, but not in the area of the North Frisian Wadden Sea, which was part of the Duchy of Schleswig-Holstein-Gottorp and the Kingdom of Denmark, Sweden’s main rival for maritime hegemony. If the provenance for the timber is an indicator, the location where the timber was sourced could have been under Swedish control.

Despite the overwhelming evidence for a similar type of construction from Sweden and other Swedish influenced areas, there is also a case to be made for a local North Sea origin. Both the Westerhever and Terschelling find from the North Sea indicate that these carvel-analogous variants were most likely local, which cannot be ruled out for the Japsand wreckage either.

The ‘Dutch flush’ technology (*cf.* Maarleveld 2013) can also be regarded as carvel-analogous construction variant in the sense that it is essentially a shell-first construction too, and thus not a proper carvel-construction in the skeleton-first sense. In contrast to the ‘Dutch flush’ technology, which was used in large merchant ships of the Dutch East Company for instance, the carvel-analogous lapstrake constructions are all small to mid-sized vessels of a vernacular character used in small-scale coastal seafaring. Such vessels are less prominent in historical sources and therefore their archaeological and ethnographic study is of preeminent importance. The Japsand wreckage is – literally – two pieces in this puzzle to address the topic of analogous or partial adaptation of carvel technology in rural coastal communities and its wider cultural-historical implications.

⁴ (1) Hasslöf 1970, 58, (2) Berg 1984, pp.131, 188ff., (3) Gøthche 1991, 85, (4) Thorsvik 1965, 27, (5) Eriksson 2010, 79f.; Auer, Ditta 2016.

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Waste disposal in the Netherlands as reflected in shipwrecks of the former Zuiderzee

Alice Overmeer – André van Holk

Abstract: In 2019 a shipwreck in the Netherlands was re-excavated as part of a training project for archaeology students and volunteers. It was the wreck of a 19th-century pram-like vessel, loaded with a cargo of what seemed to be household waste. However, analysis of the cargo composition showed a different picture. Based on the specialists' investigations it can be stated that the ship's cargo consisted of various components. These can be traced back to different batches of waste, each of which has its own origin. A part of the cargo consisted of household waste, originating from one or a few reasonably affluent households. A second part comprised construction and demolition waste from an urban context. A third component consisted of industrial waste derived from coal gas production. This find may shift the prevailing picture of waste disposal and transport in the Netherlands.

Keywords: 19th-century, pram, composition of cargo, waste disposal, the Netherlands, coal gas production

1. Introduction

The province of Flevoland in the Netherlands is known as the largest graveyard of shipwrecks on land in the world. This province once was the *Zuiderzee*, an inland sea in the centre of the Netherlands. From the Late Middle Ages up to the 20th century, the Zuiderzee served as a highway for ships and brought the Low Countries great prosperity (De Vries, Van der Woude 1995: 221–225; Van Holk 2010: 10–14). This all came to an end when in the 1930s the Zuiderzee project was initiated: the Zuiderzee was closed off by a 32 km-long dam, the *Afsluitdijk* (1932), and parts of the Zuiderzee were drained between 1942 and 1968. During the drainage and cultivation of the land over 450 shipwrecks have been found, dating from the 13th to 19th centuries (Van Popta, Van Holk 2018). A total of nine could be identified as vessels carrying a cargo of waste. Eight of them dated from the 19th century.

One of these wrecks, named ZP 5/6, was discovered in 1973 and partially excavated in 1982. The wreck was back in the spotlight in 2019 as part of a training project for students and volunteers in archaeology. In this paper we will explain the different cargo composition of the waste transporters found in the Netherlands, and look into the historical context of waste disposal and transport. Wreck ZP 5/6 and its cargo plays an explicit role in this.

2. Discovery and former research

In September 1973, a shipwreck was discovered when a drainage ditch was further expanded in the agricultural area of the town of Zeewolde. The ditch was situated between the two agricultural lots ZP5 and ZP6, and the wreck found there was named after the location. Some years later, in 1982, the wreck site was partially excavated by members of a youth history association: a team of ten adolescents from the Netherlands and France. Three trial trenches were dug and the ship structure was recorded by hand. Unfortunately, no photos or reports remained; only the field drawing and about 80 finds were preserved. The remaining length of the ship was 17 m and the ship seemed to be loaded with a cargo of waste: a mixture of broken pottery, bone, glass, brick rubble, coal, and pipe bowls. According to the dating of the waste, the ship had foundered somewhere in the end of the 19th century (Van Holk, Overmeer 2024).

3. The field school of 2019

The wreck site was visited again in 2019, because it was the perfect research object for a practical field school. The project was initiated by the Dutch Cultural Heritage Agency (RCE). The main goal was a practical education of young professionals and volunteers interested in maritime archaeology. In addition to teaching the standard excavation methods, the excavation site was visited by experts, giving workshops in photogrammetry, dendrochronology, recognition of ships timbers, micromorphology, geochemical composition of materials and knowledge of post-medieval pottery and bone material. In a period of five weeks' time, a total of 11 students and 11 volunteers were educated (Overmeer, Van der Heiden, Van Doesburg 2024).

In the meantime, the agricultural land on which the wreck was found, had come into the hands of the State Forestry Management (*Staatsbosbeheer*). Nowadays, the wreck is located in the middle of a young forest, the Horsterwold, which produces beautiful, but rather surreal drone images of a wreck in the woods (Fig. 1).

Three trial trenches were planned, which in fact were extensions of the 1982 trenches, or placed adjacent to them. One was positioned at the stern, one amidships, and one at the forward end of the wreck (Fig. 2).

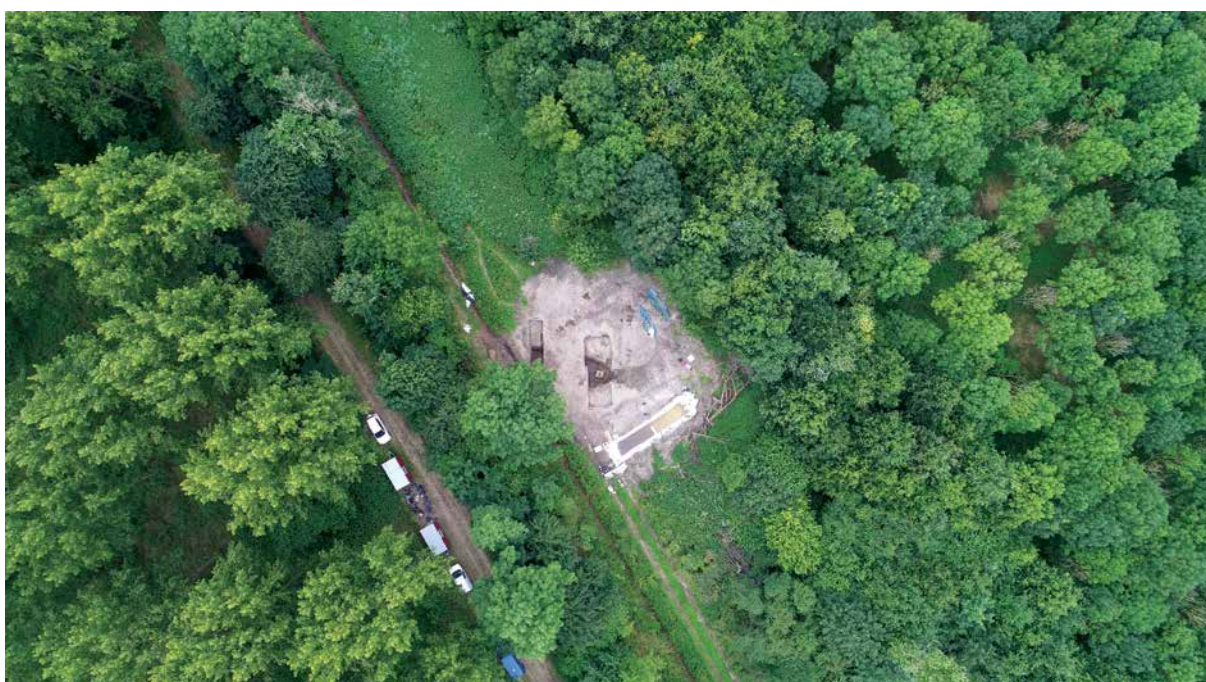


Fig. 1 Drone view of the excavation of the shipwreck in the woods (photo: Cultural Heritage Agency – RCE)



Fig. 2 Overview of the ZP 5/6 wreck, photogrammetry results (authors: T. van Damme, J. Opdebeeck, Cultural Heritage Agency – RCE)

4. Results

4.1. Ship Structure

The 2019 expedition showed that only 16.3 m of the wreck remained (Overmeer 2024a). Due to the construction, regular maintenance and deepening of the drainage ditch between the ZP5 and ZP6 lots, the stempost and parts of the foreship have disappeared. The sternpost was still *in situ*, but only the iron fittings were preserved. Overall, the wood was in very bad condition, totally soft and rotten. Due to natural processes, mainly the fluctuating ground water level and biological processes such as fungi and bacteria, the higher parts of the wreck had decayed.

The ship had a lance-shaped bottom, which was flat and carvel-laid. It had no keel, but a central bottom strake instead (w: 31.7 cm, th: 4.2 cm). On either side of this central bottom strake, five ‘normal’ carvel-laid strakes were placed. The planks were between 3.5 and 5 cm thick and varied in width from 12.5 to 39 cm. The vessel had a hard chine, meaning that the first side strake was attached to the outer bottom strake at a sharp angle of about 113° to 125°, by means of iron nails.

Only the lower side strake was preserved: it had a maximum width of 38 cm and was 3.5 cm thick. The other side strakes were not preserved. It was not possible to determine whether the sides were carvel-laid or clinker-built.

The sternpost aft in the ship seemed to have been reasonably preserved in 1982, but in 2019 there was hardly anything left of the wood. The post only consists of some remnants of rotten wood and two iron U-profiles. These are the iron fittings that connected the sternpost, central bottom strake and skeg. The dimensions of the fittings show that the sternpost once had a lower width of 39.5 cm and a thickness of 11.5 cm.

A 2.5 m long skeg was still present. At the stern it was 10 cm thick and 10.5 cm wide, but at the fore end it ended in a lip with a remaining thickness of 0.5 cm and a width of 14.5 cm. It was fastened to the bottom and the sternpost with small iron nails.

The framing system was composed of floor timbers, extended by knee-like first futtocks in the bilges. They were fastened to the bottom strakes with wooden treenails of 2.5 to 3 cm in diameter. In the sides, the frames were connected to the side strakes by means of iron bolts or nails.

On top of the floor timbers a 32 cm wide and 1.4 cm thick central plank was laid. Most likely this was the keelson, although the adjacent ceiling planks had the same thickness. A mast hole has not been found. The ship had a closed ceiling on the bottom, and only one ceiling strake in the bilges. On top of the bilge ceiling strake, small horizontal planks were placed to close off the spaces in between the frames. Furthermore, there are indications that the ship had a gangway, supported by hanging knees. These were seen in 1982, but in 2019 these higher parts had decayed.

4.2. Layout of the ship

Based on the various layers and the find material in the ship, we can say that the internal space of the ship was divided into at least two, presumably three, different compartments. Aft in the ship was the cabin, which was used as kitchen and living quarters. It must have been a cramped room, not much larger than 3 × 3 m. In the centre of the cabin was a hearth place, consisting of a horizontal iron base plate of 75 × 63 × 1 cm and a vertical iron plate of 75 × 77 × 1 cm (Fig. 3). To either side of the hearth, vertical wooden boards were attached, covered with copper plates. A stove or furnace may have been placed on it, but it may also have been a fireplace, of which the wooden frame and chimney are missing. Many peat bricks were found next to it, in very bad condition.

The find material in the stern area consisted of household goods and personal items; even the glasses of the skipper or his mate were found. Forward of the cabin was the cargo hold. No physical partition was found separating the cabin and cargo hold, but there was a clear difference between the soil layers in the stern area and a characteristic dark waste layer in the hold. It is plausible that the two compartments were separated by a wooden partition or a cupboard wall, but nothing as such has been found. The hold was at least 11 m long but was probably longer. The width of the hold was 3 m on the bottom, increasing to about 4 m at the waterline (Overmeer 2024b).

It is likely that the fore part of the ship was used as fore cuddy, a compartment used for storing tools, sails, and extra rigging, which could also serve as the living quarters of the skipper's mate. However, this is an assumption, as the fore part was severely disturbed by the drainage ditch.



Fig. 3 Trench in the stern of the ship, with the hearth place in the centre (photo: Cultural Heritage Agency – RCE)

4.3. Ship type and dating of the wreck and finds

The main characteristics – a lance-shaped bottom, a hard chine, a straight raking stern, its dimensions and the find material – all lead to the conclusion that wreck ZP 5/6 was a pram-like vessel from the last decades of the 19th century (Fig. 4). It probably had a length of over 18.5 m, a width of 4.15 m and a depth of about 1.5 m.

Twelve samples of the ship construction were taken for dendro-analysis. Unfortunately, none of them could be dated. The find material dates roughly between 1850 and 1880, with the youngest dated pottery being made between 1876 and 1886 (Van Doesburg, Van Egmond 2024).

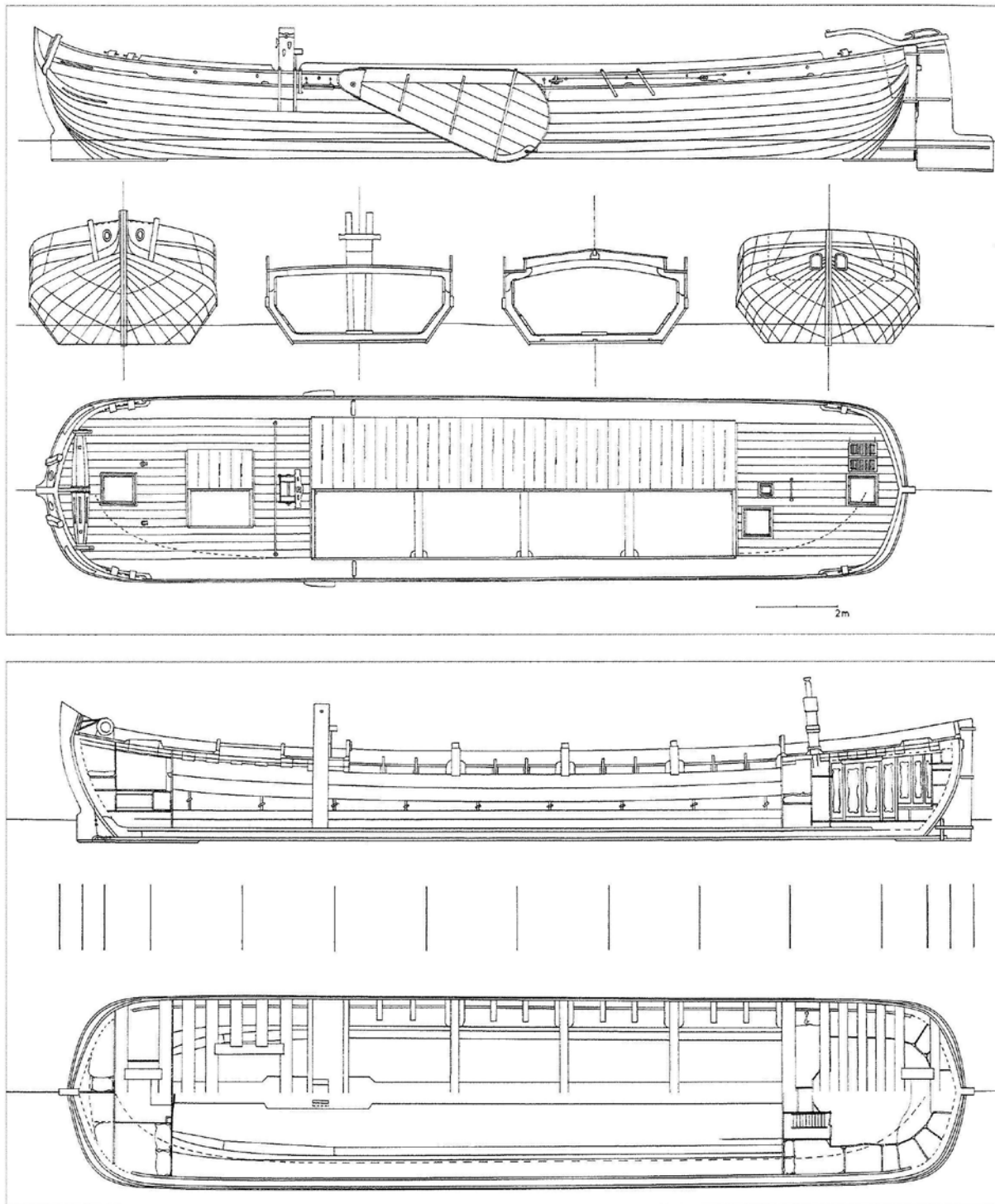


Fig. 4 Reconstruction plan of a large pram (drawing: Schutten 2004: Fig. 2.16)

4.4. Composition of the cargo

The composition of the cargo of wreck ZP 5/6 is remarkable and raises some questions. In 1982 part of the cargo was salvaged. It was composed of a great variety of materials, which initially could visually be identified as the contents of a cesspit (Fig. 5). So, it was thought that the vessel transported city waste, consisting of street sweepings, the contents of cesspits, hearth-ashes, and household waste.



Fig. 5 Waste consisting of different kinds of broken ceramics from the cargo of ZP 5/6 (photo: A. van Holk)

In the 2019 excavation, the cargo was sampled and sieved and additionally investigated by two scientific techniques: micromorphology and XRF (X-ray Fluorescence). The results of the sieving work, the micromorphology and XRF seem to point in different directions. A part of the cargo consisted of household waste, like ceramics, glass, clay pipes and bone material, originating from one or a few reasonably affluent households. A second part comprised construction and demolition waste from an urban context. A third component consisted of slag, cokes and coal; presumably industrial waste derived from coal gas production. Also, the many detected leaves indicate that street sweepings formed an important component of the cargo. The XRF analysis showed that the cargo contained high concentrations of heavy metals, especially lead, and almost no phosphate (which would be expected in the case of dung). The first question is: why this waste was transported by ship to somewhere else?

4.4.1. City waste

First of all, city waste was used as dung on poor soils. In the northern Netherlands peat was dug on a large scale. The sandy soil that remained was barren and needed a lot of dung to make it suitable for agriculture (Van der Veen 1992: 21). Per hectare, around 100 t of city waste was needed to make the soil fertile. The price of dung per shipload of 17.700 kg rose between 1767 and 1878 from fl. 23.90 to fl. 77.84 (Keuning 1989: 111–112; Van der Woud 2007: 229). The only way these enormous amounts of city waste could be transported was across water (Van der Woud 2007: 230).

Most of the peat was used as fuel and was transported by ship to the western part of the Netherlands, as discussed by Wouter Waldus elsewhere in this volume (Waldus 2024). As a return cargo, city waste was taken to the north. The hunger for dung was so great that on Sundays during the church service the pastor would announce the dung auctions of the next week. As a consequence, ships lined up in enormous traffic jams in the *Veenkolonieën* (a peat district in the province of Groningen, in the northern part of the Netherlands) (Keuning 1989: 112–113; Van der Veen 1992: 22). So, city waste was transported on a large scale. Eight other shipwrecks found in the province of Flevoland (the former Zuiderzee) have a cargo consisting of city waste (Tab. 1).

Garbage barges in the province of Flevoland		
Lot	Size	date built/wrecked
NK 7	19.5 x 4.3 m	../19b–20a (around 1900)
NS 101	unknown	../20a
OB 13	9.3 x 2.5 x 0.5 m	../17b (on the basis of the artefactual inventory)
OC 52	18–20 x 3.9 m	../19c (coin William II of 1846)
OH 60	22 x 5.5 m	../18d (coins: after 1788)
OH 71	18–20 x 3.9 m	../19d
OLnn	no data	../1890–1900
OO 2	18–20 x 4 m	../19B (coin, Netherlands 1/2 cent from 1822)
ZP 5/6	18.5 x 4.5 m	19d/20a

Table 1 Findspot, size, and date of nine garbage barges excavated or still present in the province of Flevoland (b = second quarter of a century; B = second half of a century).

The ships, except for one, are comparable in size (around 20 m) and in date (second half of/end of the 19th century). In the second half and especially at the end of the 19th century, on the demand side, the intensified long-distance transport of city waste was caused and made possible by the increase of arable areas in the peat districts in the Northern Netherlands, reflected in the increased price of city waste.

Next to that, on the ‘production’ side, infectious diseases such as cholera and typhus became pandemic in the 19th century. There was a bad vicious cycle of drinking ground or canal water coupled with the discharge of infected stomach and intestinal contents into the same water. Canal water in the 19th century could become lethal for thousands of city dwellers (Van der Woud 1987: 398, 401). Slowly the idea gained ground that waste and drinking water had to be separated.

One of the wrecks with a cargo of waste dates from the 17th century and is half the size of the other vessels. It has a low freeboard of 0.5 m and no mast, so this working-vessel was not suited to sail the Zuiderzee (Reinders *et al.* 1984: 35). In the 16th century, houses in Amsterdam had lavatories that drained into pits, which were emptied at night. Early in the morning, barges sailed with this waste to the river IJ, where they were emptied (Faber *et al.* 1973: 267). Probably this barge broke loose and drifted away to founder in what today is the province of Flevoland (the former Zuiderzee). So already in the 16th and 17th century there was some awareness that waste had to be disposed of outside of the city.

4.4.2. Waste from the production of coal gas

If we consider the results of the XRF analysis and the sieving work, we could launch another hypothesis about the cargo. A significant part of the cargo consisted of slag material (from the combustion of coal and charcoal), heated natural stone, cokes, coal and charcoal (Fig. 6). All of these products are generated during the production of gas for light from coal in a gas factory (Van Os 2024).

In the second half of the 19th century, a revolution took place in the Netherlands with regard to the illumination of streets: the introduction of gas lanterns. Before that time, only some streets or dangerous or important points were illuminated (for example in the provincial town of Assen only the City Hall was, symbolically, lit by a candle in a lantern) (Van der Woud 1987: 417). When it was misty, ropes were put along the canals in Amsterdam to prevent people from falling into the water (Van der Woud 1987: 413–414). It was darkness all around!



Fig. 6 Coal ashes and slag from the cargo of ZP 5/6, waste associated with gasworks and some pieces of slate (photo: A. van Holk)

Gas for street lanterns was produced from coal. Waste associated with former gasworks include amongst others coal, ashes, and slag. At first, this waste was used to fill ditches near the gas factories (Urbanus 2008: 9–10; Pol 1982; De Vries *et al.* 2003). Later on, the waste was used to raise peat bogs in Holland and Utrecht (Van Zon 1987: 160). In Dutch, these raised grounds are called *toemaakdekken*. Many of these terrains are still polluted today by heavy metals and are of serious environmental concern (Rietra, Römkes 2007: 10–11; Marmos Bodemmanagement 2014: 15–16).

4.4.3. Mixed waste composition

The first interpretation of the cargo as remains from a cesspit was based on the fact that only the visible archaeological objects of the cargo were collected. Through the XRF examination it became clear that the chemical composition contained almost no phosphate, but high concentrations of heavy metals. The intensive sieving work revealed that the cargo consisted of a combination of household waste, construction rubble and industrial waste. Micromorphology provided a picture of the cargo consisting of different batches of waste from different sources, which were loaded into the ship in small units, for example with buckets, wheelbarrows or cart loads. They all show the important role of scientific study in archaeology.

The presence of the household waste can possibly be explained by the fact that the manager of a gas factory was obliged to live next to the factory, so he could immediately intervene in case of a dangerous situation (Fig. 7) (Waszink 1996: 77). In this case, it is possible that the waste of the manager's household got mixed up with the waste of the gas factory.



Fig. 7 Company house (to the right) next to a gas holder (to the left) at the Haarlemmerweg in Amsterdam (photo: Cultural Heritage Agency – RCE, Amersfoort/ 232.669)

However, perhaps a more obvious explanation for the composition of the ship's cargo is that it consisted of different batches of waste, the main ones being construction and demolition rubble from a city, industrial waste from a gas factory, and household waste from the factory manager or from other reasonably affluent households in the city. The different kinds of waste simply got mixed in a waste dump (in the vicinity of a city?).

4.5. Conclusion

From the main characteristics – a lance-shaped bottom, a hard chine, a straight raking stern, its dimensions, and the find material – it could be inferred that the wreck of ZP 5/6 was a pram-like vessel from the last decades of the 19th century. It probably had a length of over 18.5 m, a width of 4.15 m, and a depth of about 1.5 m. Based on the find material, the ship's sinking can be dated between 1876 and approximately 1880.

The cargo of the wreck was a mixture of different batches of waste from different sources. A part consisted of household waste from one or a few reasonably wealthy households. Another part comprised construction and demolition waste from an urban context. A third component consisted of industrial waste derived from coal gas production.

Towns had to dispose of their waste from households as well as from industries. The shipwrecks in the former Zuiderzee seem to show that at first waste was mainly reused or dumped nearby, but in the long run it was transported further away to be dumped or reused. The transport of waste across the Zuiderzee shows a clustering in the dates of the ships wrecked towards the end of the 19th century. From the demand point of view – as the demand for dung rose – it became economically profitable to transport city waste over long distances.

The cargo of ZP 5/6 shows it was also profitable to transport industrial waste from the production of coal gas. The chemical composition of the waste makes it probable that, instead of being used as dung on arable fields, it was intended for foundations, raising or paving yards and roads or filling ditches or other depressions.

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RECONSTRUCTIONS



The Late Hellenistic military ship of Phanagoria; New data for the reconstruction of the ship

Pierre Poveda – Giulia Boetto – Sergey V. Olkhovskiy

Abstract: The ship of Phanagoria was discovered in 2012 during the exploration of the port structures of the ancient city. The remains are nearly 16 m long and 2.7 m wide and preserved up to the caprail on port side. In 2014, a bronze casing decorated with a crescent and a five-rayed star was found 1.5 m to the west of the bow end. This bronze casing and the slender shape of the vessel have provided arguments to identify it with a military unit associated to Mithridates VI Eupator. This article presents the process carried out recently to reconstruct the original shape of the ship of Phanagoria, and discuss the results.

Keywords: Black Sea, Phanagoria, 3D model, Ship reconstruction.

Over forty years the Phanagorian expedition of the Institute of Archaeology of the Russian Academy of Sciences has been focusing its researches on the land and coastal area of the Greek city of Phanagoria. Located on the Kerch Strait separating the Black Sea and the Azov Sea (Fig. 1), the city was founded ca. 543 BCE by settlers from Teos (Asia Minor). Occupied until the Middle Ages, Phanagoria underwent a remarkable development in the first centuries BCE, and maintained, until the 4th c. CE its dominant position following the Mithridatic wars, during which Phanagoria allied with the Romans (Kuznetov, 2016: 10–19).

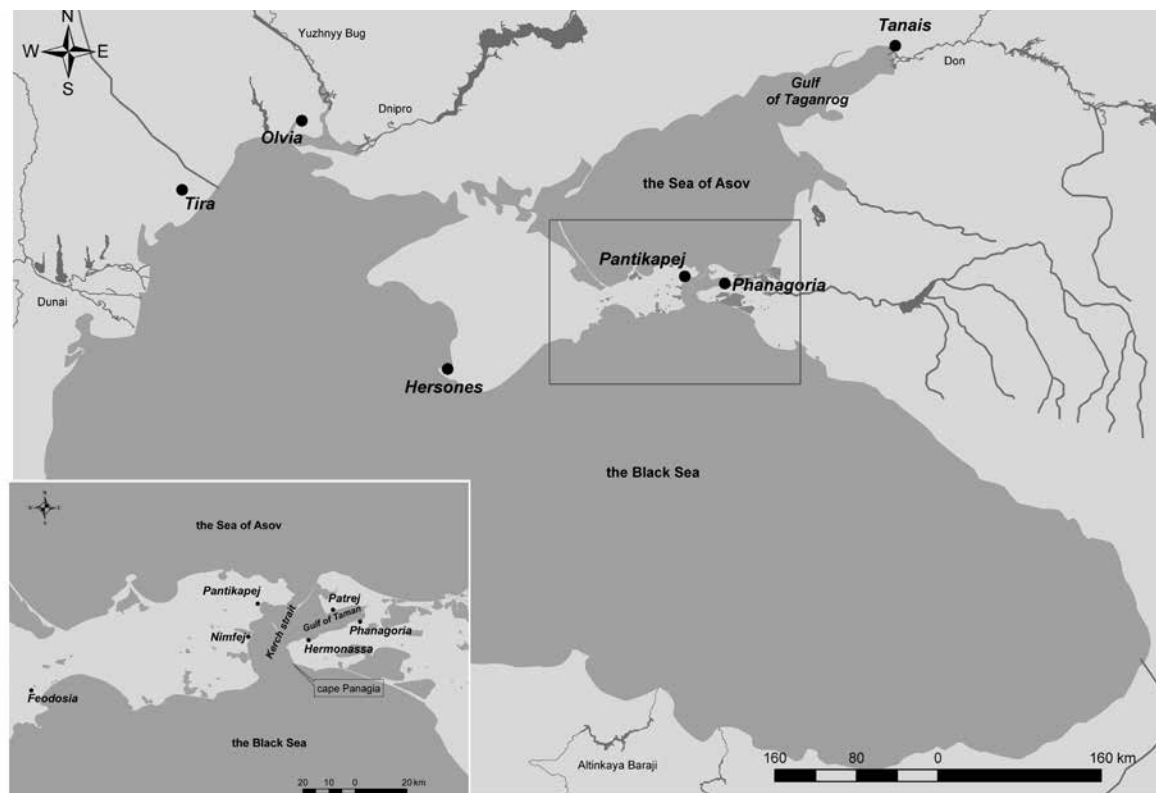


Fig. 1 The Black Sea and the Sea of Azov with localisation of Phanagoria (map: IA RAS)

From 2011 onwards, the underwater team led by Sergey Olkhovskiy has used different methods of survey on the maritime area next to the ancient city. The most informative method, considering the shallowness of the body of water in front of Phanagoria, proved to be geomagnetic survey. It allowed the localisation of part of the city's port infrastructures composed of two large berthing facilities: the eastern pier built in the 5th–4th centuries BCE (Fig. 2A) and the western pier of a latter unknown date (Fig. 2B), both built with large stone blocks. Between these two piers, a third smaller harbour structure, composed by poles, horizontal timbers, stones and reused elements from the destruction of the city in the 1st century BCE, has been discovered (Fig. 2C) (Olkhovskiy 2016: 51–54; Khotylev, Olkhovskiy 2020). In 2012, during the excavation of the massive stone embankment composing the eastern pier, the remains of a mor-tise-and-tenon built vessel were discovered (Fig. 2S). The bottom of the hull appeared to be covered with small stones and tile fragments, interpreted as ballast intended to improve the nautical capabilities of the ship. On top of the ballast, a Megarian bowl, a jug, some cooking pots, and two Colchian amphoras were also found and were probably used on board (Zhukovsky *et al.* 2013; Boetto *et al.* 2022).

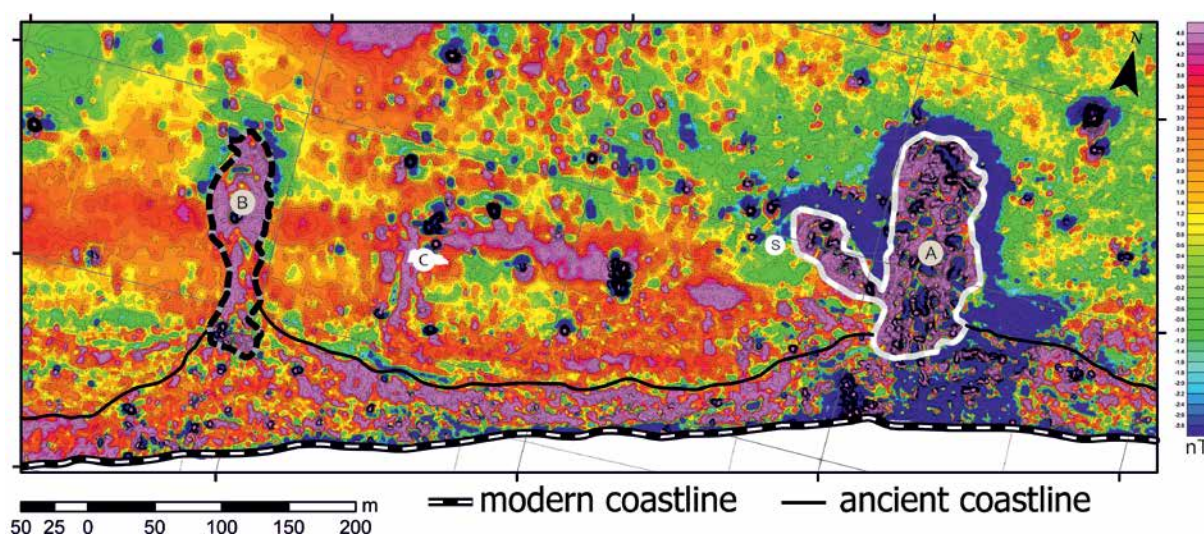


Fig. 2 Geophysical survey of the submerged zone in front of the ancient city of Phanagoria: A) eastern pier and the adjacent stone embankment (5th–4th c. BCE); B) western pier (unknown dating); C) Roman structure; S) the shipwreck (author: A. Luchnikov)

Two years later, the ballast was removed and the excavation trench was enlarged in NE direction. At a distance of 1.5 m from the end of the wreck, a bronze casing decorated with a five-rayed star and a crescent was found (Boetto *et al.* 2022). This symbol, well attested in coins minted during the Kingdom of Pontus, especially during the reign of Mithridates VI Eupator (120–63 BCE), offered important chronological information which, together with the other data collected, places the wrecking event within the first half of the 1st century BCE. The position of the bronze casing allows the location of the bow and the deduction of the sailing direction of the ship too.

In 2019, a team of the Centre Camille Jullian joined the Phanagorian expedition. The wreck was reopened, cleaned and documented, samples for xylological analyses were collected, and the ceiling and some other components were removed from the seabed.

The wreck consists of a remarkably well-preserved hull 15.82 m long and 2.40 m wide (Fig. 3A). The ship is keel-based and built shell-first in the typical Mediterranean fashion with planks assembled by a network of pegged tenons. The frame system, alternating floor-timbers and half-frames, is reinforced by paired floor-timbers, fastened to the planking by the means of clenched nails passing through treenails. The structure is strengthened by an axial internal carpentry composed of two keelsons as well as the mast-step. Two timbers, discovered not far from the bronze-casing, were interpreted as the remains of a fore-ram/*proembolion*. The wood species used for the construction are homogeneous and well adapted to the function of each ship's component. Noteworthy is a red pigment residue found on several spots on the outer hull in addition to the typical protection provided by pitch (Boetto *et al.* 2022).

Finally, the slender shape of the ship, the bronze casing decorated with a crescent and star, a symbol associated with the Kingdom of Pontus, and the remains of the fore-ram are strong arguments to identify the ship as a small Phanagorian military vessel, possibly used during the siege of the city by Mithridates VI Eupator.

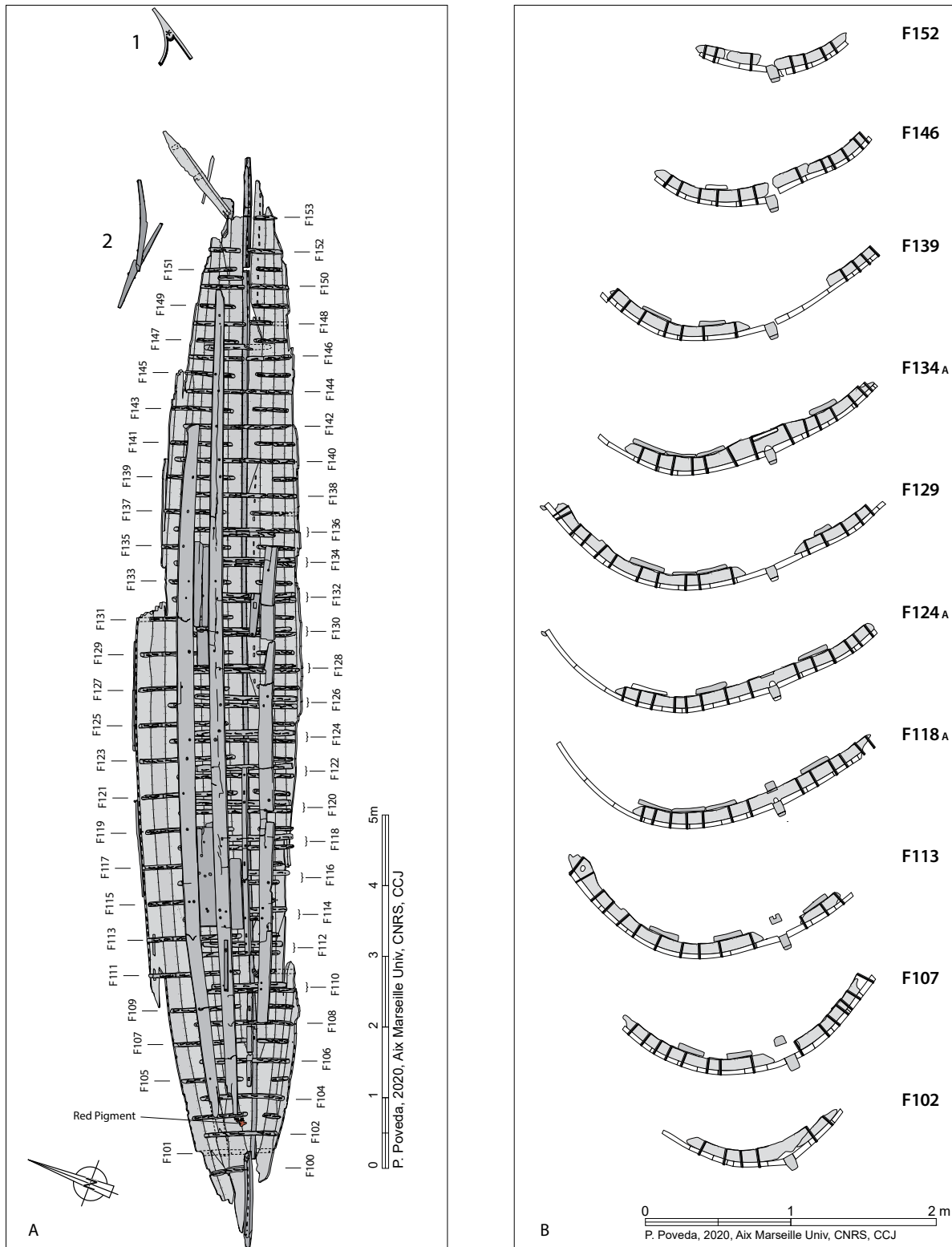


Fig. 3 Plan of the shipwreck of Phanagoria: 1) bronze casing; 2) fore-ram/*proembolion*; b) cross sections (drawing: P. Poveda, CNRS, CCJ)

1. Indications of the original shape of the ship

As the ship rested on its port side, this side was best preserved almost to the caprail (Fig. 3B). The transverse section at the main frame depicts a flat garboard with a round turn of the bilge. The longitudinal section shows a significant hog, which can be attributed to a post-depositional deformation phenomenon.

The stem, even if not preserved, had a concave profile as proved by the shape of the bronze casing. This element is 0.9 m long, 0.44 m high and weighs 15 kg. Two nails, whose holes are visible on the slightly curved arm, or cowl, attached it to the stem-post. A single nail secured the lower right arm to the keel.

A few other elements, found detached from the main hull not far from the bow, provide a considerable amount of information for the reconstruction of the original shape of the ship at the bow. These are a V-shaped floor-timber, 0.48 m wide and 0.45 m high, and two pieces made of oak (*Quercus* sp.). These two timbers are respectively 1.30 and 1.34 m long, and 55 mm thick. They are very similar in shape: a long, flat piece with a straight arm and a slightly curved arm. When placed side-by-side, the two timbers form a V-shaped structure and the individual nails match the holes in the opposite timber perfectly. It is suggested that this V-shaped structure was nailed to the outer part of the planking at the bow and capped the stem. In this configuration, this structure could be identified as a fore-ram/*proembolion*.

2. Iconographic comparison

A working hypothesis arose from the comparison between the longitudinal profile of the ship of Phanagoria and a graffito engraved in a wall of the House of Dionysus in the island of Delos Island, dated between 88 and 69 BCE when the house was abandoned after the sacking by the troops of Mithridates VI Eupator. The graffito, a ship propelled by 50 oars on each side, was identified by Capitain D. Carlini as a *hekatontore* (Bash 1987: 350–351; Morel-Deledalle, Pomey 1992: 30, 45) (Fig. 4). The shape of the bow with its prominent cutwater, the blunt-faced ram, and the *proembolion*, is similar to the one that we reconstructed for the Phanagoria ship even if the dimensions and the function of the two ships are not comparable.

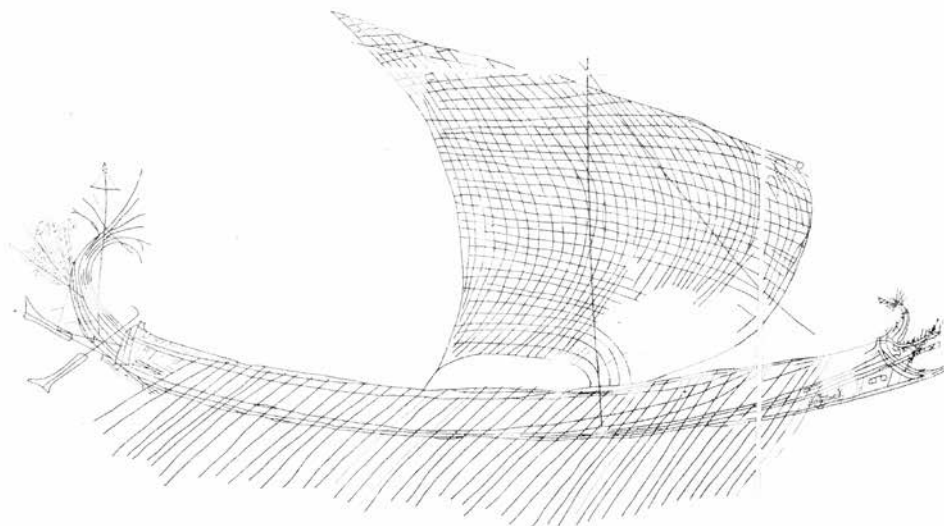


Fig. 4 Graffito of House of Dionysus (Delos, 88–69 BCE) depicting a *hekatontore* (drawing: Capitain D. Carlini, courtesy Musée national de la Marine, Paris)

Based on the shape and structure of the hull, the presence of both the bronze blunt-faced casing and the *proembolion*, we identified the Phanagoria wreck as the remains of a light sailing and rowing military ship, which must have proven to be very fast and manoeuvrable. Given its limited size, it does not fit into the category of the larger ships of the line. Instead, it must have been employed in minor war activities as a scout, or as a patrol ship. Its simple bronze casing was completely different from the three-finned rams discovered off the shore of Atlit (Israel, Hellenistic era; Casson, Steffy 1991), in Sicily at Aqualadroni near Messina (3rd c. BCE; Buccellato, Tusa 2013; Tisseyre 2014) or in the Egadi Archipelago (mid 3rd c. BCE; Tusa, Royal 2012; Tusa *et al.* 2021). We do not think it was intended to deliver a pounding blow to the enemy ships, but was placed to reinforce the cutwater.

3. The reconstruction process

Given the quantity and quality of the remains, we quickly considered the opportunity to attempt to reconstruct in 3D the original shape of the hull. It seemed to us that the port side was sufficiently well preserved in extension and that transversally its shape was relatively well preserved. However, the longitudinal profile of the wreck, with a significant hog, led us to question the appropriate method for assessing deformations and the amount of remodelling to match the original shape.

Given the high degree of accuracy of the documentation available – a complete underwater photogrammetric survey of the hull (Zhukovsky *et al.* 2013) and detailed 3D models of the recovered elements, all of which perfectly documented their shapes, revealing both deformations and cracks, as well as the exact position of each assembly element (pegs fixing tenons, nails, etc.) – we decided to reconstruct the Phanagoria ship through a hybrid scaled physical model, combining virtual and physical approaches. The use of hybrid scaled physical models is increasingly common in nautical archaeology, as recently demonstrated by the work carried out by the Norwegian Maritime Museum on the Sorenga 7 shipwreck (Falck *et al.* 2016).

In the Mediterranean, this approach is completely new and unprecedented.¹ It is worth noting that the high precision 3D documentation (i.e. the photogrammetry) and the 3D modelling of the remains, done with the software Rhinoceros, allow the construction of a physical scaled model following the ancient shell-first process, thus respecting the chronological order of placement of each element of the ship and the position of each assembly. In the case of Phanagoria, due to their good state of preservation, the frames were extracted from the 3D Rhino model of the wreck and printed. However, the modelling of the keel and the planking required a lengthy process that will be detailed in the following.

First, we modelled separately in Rhino all the elements of the wreck from the photogrammetry: the keel, the planks with their pegs for the tenons, the frames with their nails and treenails, as well as the ceiling and the keelson with their systems of assembly. Whether these elements were obtained by redrawing them or by just reworking the original mesh extracted from the photogrammetry, the goal is the same: to obtain a final 3D model of the remains in which all the elements are individualised and very accurate. The result is a complete 3D model of the remains which is not just a single mesh but composed by all the distinctive parts of the wreck.

For the planking, the idea was to obtain the developed plan of the flattened planks. To do this we used the 'UnrollSurface' command in the Rhinoceros 3D software, on the surfaces representing the inner faces of the planks. The position of the pegs, the position of the frames, and the position of the treenails are also marked and reported on the developed plan. These marks will be used later during the construction of the physical model to check the correct position and alignment of all the elements.

It is necessary to stress that this technique can only be applied to developable surfaces: a plank that owes its curvature partly to carving cannot be developed. Similarly, if the planks are torn, the result is a non-developable surface that prevents the use of this method. Fortunately for us, most of the strakes of the Phanagoria wreck were made from flat developable plank. Once this plan is generated, it is annotated before being printed at 1/10 scale and then glued onto cardboard from which each independent plank is cut.

For the frames, we used 3D printing, taking care to draw the holes corresponding to the assembly elements (treenails and nails) on the planking. Even if there is the possibility of having frames deformed in the transversal direction as demonstrated by previous studies (Tanner 2013: 33–34; 2020: 245–246), we estimated that the transverse shape of the port side of the Phanagoria wreck was quite undisturbed and very similar to the original.

Before beginning the reassembly of the pieces and construction of the physical model, we also had to find a technical solution that would allow a certain degree of freedom in terms of longitudinal curvature and height of the keel. This solution ensures the best possible match, i.e. all the elements fit together correctly. We designed a cradle that permitted adjustment of the height of the keel at three cross sections as well as the height of the bow and the curvature of the stern.

Mortises were carved in the thickness of the first planks and tenons inserted. The bow was temporarily held in place with a clamp. The assembly of the first five strakes, up to the turn of the bilge, did not pose any particular problems.

At this stage of the construction, the insertion of the bottom frames allowed both the cross shape of the bottom and the degree of rocker of the keel to be fixed. Indeed, it is known that increasing the keel rocker will flatten the central

¹ We have already reconstructed the shape of the highly distorted Roman ship Isola Sacra 1 following this hybrid approach, but the method used and the results are not yet published. On the ship see: Boetto *et al.* 2017; Boetto 2020: 260–265.

part of the boat, and decreasing the keel rocker closes the midship section (McKee 1978: 265–268). The height of the bow is then defined by looking for the best match between the shape of the bottom frames and the keel rocker.

The construction continued with the assembly of the successive planks and the insertion of the futtocks. To avoid unbalancing the hull, we also inserted the futtocks on the starboard side. These elements were reconstructed by symmetry to those on the port ones (Fig. 5).



Fig. 5 Detailed view from the prow of the inside of the model. The port side is on the right of the image (photo: L. Damelet, CNRS, CCJ).

When we reached almost the level of the caprail, the hull tended to have a more and more rigid, self-supporting shape, so we could fix the bow height. The keel rocker was determined by the whole structure. Towards the bow, the keel and strakes, which had been deliberately left longer than necessary, were then cut to the correct length determined by the best fit of the bronze casing, fore-ram/*proembolion* and V-shape frame. This validated the obtained shape of the bow (Fig. 6). Once completed, the physical model was recorded using 3D scanner (Artec Leo), thus accurately recording the resulting shape.



Fig. 6 General view of the completed model (photo: L. Damelet, CNRS, CCJ)

Conclusion

The reconstruction of the original shape of the Phanagoria ship was achieved through the use of a hybrid research process combining 3D and physical modelling. This research was based on the precise study and recording of the remains of the ship, the identification of ship components, the interpretation of all the available data, and comparisons with iconography. Given the preservation of the wreck's structures particularly on the port side, the hybrid process of reconstruction allowed the shapes and dimensions of the ship to be reliably defined (Fig. 7).

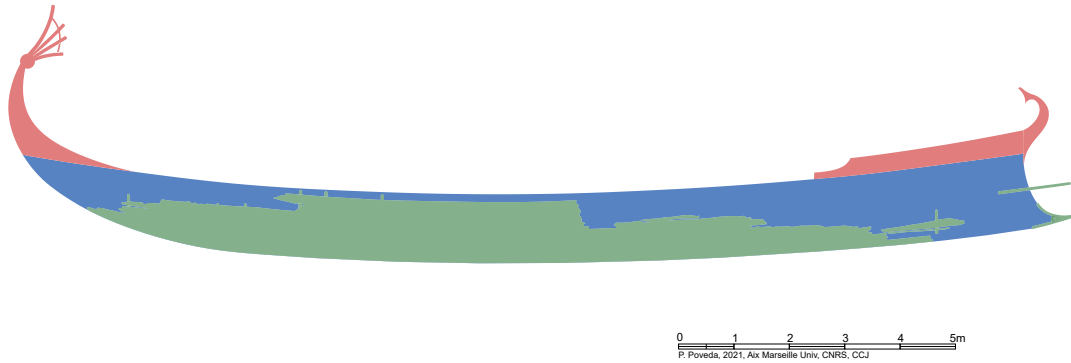


Fig. 7 Longitudinal profile of the ship highlighting the preserved part (green), and the various level of certitude of the reconstruction (blue probable reconstruction, red possible reconstruction) (drawing: P. Poveda, CCJ/CNRS)

With a length of 19.35 m and a mid-section width of 2.8 m, the length-to-breadth ratio of the ship of Phanagoria is close to 1:7, which is typical for oared long-ships, whereas merchant ships have a lower L/B ratio (1:3 to 1:4) (Fig. 8). The number of rowers could be estimated between 20 and 22, with two rowers per bench. This implies that the ship housed ten or eleven transverse beams used as rowing thwarts and supported by stanchions fitted in recesses carved in the keelson. The mortises still preserved on the keelson are spaced one meter apart and this distance corresponds almost exactly to the distance between oars (*interscalmium*) put in evidence in the archaeological records (Bockius 2012).

The next step will be the modelling of each element of the ship's structure, in particular the superstructures and the rigging and gearing. This will allow the displacement of the ship to be accurately calculated and its overall rowing and sailing performances to be studied.

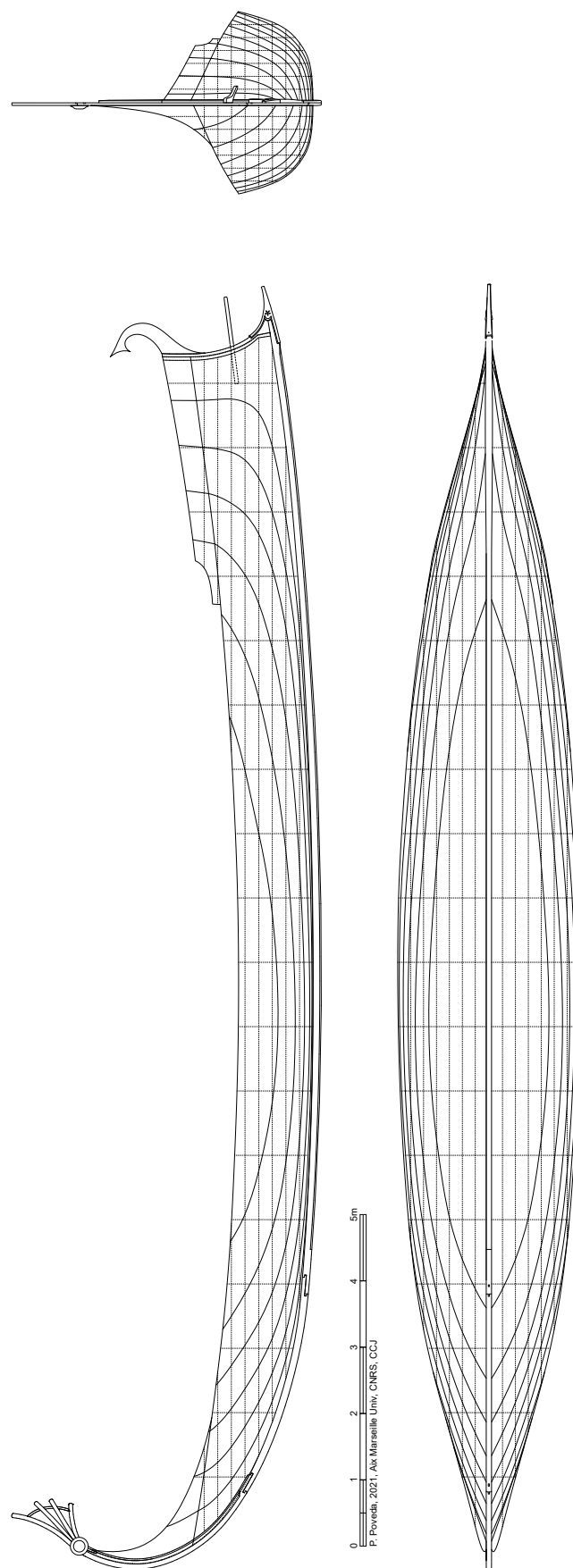


Fig. 8 Lines plan of the reconstruction (drawing: P. Poveda, CNRS, CCJ)

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Digital reconstruction hypothesis of the Roman-era fluvial barge from Kamensko, Croatia

Anton Divić – Giulia Boetto – Krunoslav Zubčić – Pierre Poveda

Abstract: The Kamensko barge sank to the bottom of the Kupa River sometime between the 1st and 3rd centuries AD. Its well-preserved remains, discovered in 2009 on the riverbed in the vicinity of Karlovac in Croatia, were excavated between 2015 and 2018. The quantity and quality of the obtained documentation allowed the reconstruction hypotheses of its hull shape, structure and technical system to be proposed and modelled through an exclusively digital approach, whose outlines will be presented in the text below.

Keywords: 3D reconstruction, flat-bottomed barge, Kupa River, nautical archaeology, fluvial navigation

1. The wreck

The Kamensko wreck is that of a flat-bottomed river barge from the Roman period, dated to between the 1st and 3rd centuries AD.¹ On its last journey it was transporting a cargo of several hundred construction bricks. Its remains, 2.1 m wide and 12 m long, are located on the riverbed of the Kupa River downstream of Karlovac in Croatia (Fig. 1). The remains consist of two massive bilge strakes, obtained by hollowing out two oak trunks, that form the sides and part of the bottom of the barge. Between them, two bottom strakes made from four planks are inserted.



Fig. 1 Position of the Kamensko site (map: V. Dumas, A. Divić)

A forward-placed rectangular longitudinal mast step has been preserved *in situ*, allowing for the identification of the surviving extremity as the bow of the barge. The barge is transversally reinforced by five pairs of frames attached to the

¹ According to AMS radiocarbon dating of two samples, one effectuated in Vienna Environmental Research Accelerator (40 BC–230 AD, 95.4% probability) and the other in Centre de Datation par le Radiocarbone in Lyon (82–234 AD, probability of 95.4%). The BC dates were not taken into account as brick production along the Kupa seems to have developed from 1st century onwards (for more details see Divić 2022a: 249–250).

hull by treenails. The strakes are assembled by numerous closely spaced iron clamps, driven both from the outside and inside of the hull. The barge presents interesting structural features that place it in close relation with several other Roman-era shipwrecks from the Danube hydrographical basin (Pomey, Boetto 2019; Boetto, Divić, Zubčić 2021; Divić 2022a; Divić 2022b).

The Kamensko wreck was excavated between 2015 and 2018 by a team from the Croatian Conservation Institute and the Centre Camille Jullian, making it the first fluvial wreck to be systematically researched in Croatia. Each stage of the excavation was accompanied by meticulous documentation in the form of measurements, drawings, general and detailed photographs, and 3D photogrammetric models used to generate orthographic images, plans and cross-sections.

2. The methodology

As well-stated by one of the forefathers of nautical archaeology, research and reconstruction are practically synonyms in the interpretation of shipwrecks (Steffy 1994: 214). This is also true for the Kamensko wreck, as the idea of the barge's original shape, structure, and technical system evolved constantly during the four campaigns of extensive fieldwork and many hours of post-excavation documentation and analysis. In addition to the study of the meticulously documented remains of the wreck, the original form of the barge was reconstructed through comparison with archaeological, iconographic, and ethnological parallels.

The reconstruction hypothesis of the Kamensko barge shape, structure, and technical system was, however, achieved through the application of an exclusively digital process following the latest approaches that are becoming standardised within the framework of nautical archaeology (Poveda 2012; 2015), in accordance with the established experimental boat and ship archaeology principles (Coates *et al.* 1995). The barge's architecture and technical system were three-dimensionally modelled in Rhinoceros 3D, a commercial 3D computer graphics and computer-aided design (CAD) software.

The first step in this process was the creation of a 3D CAD model of the preserved remains that would serve as the basis for the subsequent reconstruction (Fig. 2). This was achieved mainly through the use of georeferenced three-dimensional photogrammetric models, generated for every stage of the excavation, which served as a base layer for the CAD 3D modelling of the remains in the Rhinoceros software.



Fig. 2 Three-dimensional CAD model of the preserved remains of the Kamensko barge (CAD: A. Divić)

The information that could not be extracted directly from the photogrammetric models was supplemented by the fieldwork documentation: numerous measurements, sketches, plans, observations, and detailed photographs. This direct documentation proved to be an invaluable asset to the creation of the three-dimensional model of the remains and the subsequent reconstruction, which could not have been rendered solely on the basis of photogrammetric documentation. It is the abundance of high-quality documentation, combined with the high level of preservation of the barge, that has enabled the reconstruction of the hull shape, structure, and technical system with a good level of certainty.

3. Hull size and shape

As the remains of the Kamensko barge are preserved to a length of 12 m and the stern part of the vessel is missing, one of the greatest challenges in formulating the reconstruction hypothesis was determining the original length of the barge as well as its stern shape. In the absence of material remains that would allow for these elements to be reconstructed, parallels with similar vessels with a high level of preservation that operated in similar nautical spaces and in chronological relationship with the Kamensko barge were invoked.

For the reconstruction of the original length of the barge, two factors were taken into account. First is the ratio between the total length of the barge (L) and the distance measured between the recess for the mast and the bow (MR-BD). This approach was made possible due to the fact that both the mast step and the forward end of the Kamensko barge have survived *in situ* relatively intact, while the well-conserved and documented wrecks of other inland vessels from the Roman period have allowed parallels to be drawn between them.²

The barges taken into consideration are Arles-Rhône 3 (Marlier 2014), Bevaix (Arnold 1992a), and Zwammerdam 6 (de Weerd 1988), all documented and preserved almost in their original length with their mast steps preserved *in situ*. The dimensions of the three aforementioned Roman barges, as well as the L/MR-BD ratio, are presented in Table 1.

Barge	Length (m)	Beam (m)	Mast recess – bow distance (m)	L/MR-BD ratio
Arles-Rhône 3	31	3.07	9.16	1: 3.38
Bevaix	19.35	2.8	5.65	1: 3.42
Zwammerdam 6	20.4	3.4	6.05	1: 3.37
Average				1: 3.39

Table 1 Sample of three Romano-Celtic inland barges used to calculate an average ratio between the total length of the barges (L) and the distance measured between the recess for the mast and the bow (MR-BD).

As can be seen from the above-presented sample, the position of the towing mast does not seem to have differed greatly between these three Roman-era inland vessels belonging to different regional sub-groups that operated in different nautical transport zones across the Roman Empire. All three barges had their mast mortises positioned almost identically in relation to their extremities, approximately one-third of the total length from the bow and two-thirds from the stern.

Due to the good level of preservation of the Kamensko's bow and mast step, the same calculation can be applied to obtain a first hypothesis of the original length of the barge. The distance between the mast step mortise and the bow amounts to 4.86 m. When multiplied by the average mast L/MR-BD ratio of 3.4, this method allows us to propose 16.52 m as the first hypothesis of Kamensko barge original length.

This first length hypothesis can be evaluated by comparing the length/beam (L/B) ratio of some well-preserved inland barges from Roman period (Tab. 2) to the one obtained with the L/MR-BD ratio. Presenting a particular elongated shape suited to their navigation areas, with a L/B ratio much greater than their maritime counterparts, these slender, box-shaped vessels were built to facilitate their movement through often narrow canals and to reduce water resistance when hauled upstream. The preserved beam of the Kamensko barge (2.1 m), multiplied by the average L/B ratio calculated from a significant sample of Roman-Celtic inland vessels whose state of conservation and availability of publications allowed for a viable reconstruction of their original size, should allow for a validation or a mitigation of its above-reconstructed length.

² Masts of Roman inland vessels were rarely part of a sailing rig, but rather served as supports for cables used for towing, a particular method of upstream river navigation well documented in Roman archaeological and iconographic sources (Arnold 1992b: 84–85; Beaudoin 1994; Rieth 1998: 106–107; Boetto 2008; Marlier, Poveda 2014: 209–211). In contrast to the masts of the maritime sailing ships, which are rather placed slightly forward of amidships, the position of towing mast is dictated by this applied mode of propulsion, which requires a forward-placed mast, between the barge's centre of gravity and its bow, approximately at 2/3 of the hull length (Beaudoin 1994: 3; Rieth 1998: 106).

Vessel	Length (m)	Beam (m)	L/B ratio	Reference
Zwammerdam 2	23	2.8	1:8.21	de Weerd 1988
Zwammerdam 4	34	4.4	1:7.72	de Weerd 1988
Zwammerdam 6	20.4	3.4	1:6	de Weerd 1988
De Meern 1	24.6	2.6	1:9.4	van Holk 2011
De Meern 4	27	3.7	1:7.29	van Holk 2011
De Meern 6	10	1.6	1:6.25	van Holk 2011
Woerden 7	29.6	4.7	1:6.29	van Holk 2011
Lyon PSG 4	28	4.85	1:5.77	Guyon, Rieth 2011
Lyon PSG 7	40	5	1:8	Guyon 2010
Arles-Rhône 3	31	3.07	1:10	Poveda 2014
Bevaix	19.35	2.8	1:6.9	Arnold 1992a
Average			1:7.44	

Table 2 Sample of 11 Romano-Celtic barges used to calculate their average length/beam (L/B) ratio.

As seen on the sample of 11 Romano-Celtic barges, their length-beam ratio varies between 1:5.7 and 1:10, with the average ratio calculated at 1:7.4. In practical terms, this would mean that a 1-meter-wide vessel with 1:7.4 beam-length ratio would have the length of 7.4 m. When applied in the case of Kamensko, with its beam conserved in its entirety and measuring 2.10 m, this second hypothesis reconstructs the barge's original length to 15.62 m. Considering the median value of the two length reconstruction hypotheses, the original length of the Kamensko barge is therefore reconstructed to approximately 16 m (Fig. 3).



Fig. 3 Hypothetical reconstruction of the Kamensko barge navigating downstream during its last voyage (CAD: A. Divić, P. Poveda)

Parallels with the afore-mentioned barges (Tab. 1 and 2) were once again invoked for the reconstruction of the missing stern of the Kamensko barge. Although different in shape and size, and belonging to different shipbuilding traditions, most of these barges present a symmetrical shape, as do the majority of modern traditional fluvial vessels. In light of these considerations, and in particular due to the lack of the possibility to introduce any kind of evidence that indicate otherwise, the shape of the stern of the Kamensko barge has been reconstructed as a mirrored version of its bow.

4. The propulsion system

As is very often the case with ancient wrecks, the propulsion and steering systems of the Kamensko barge did not survive the wrecking and site formation processes and need to be reconstructed by deduction as well as through comparison and analogies with their counterparts documented in archaeological, iconographical and ethnographical sources.

The only surviving element of the Kamensko barge related to its propulsion is the mast step. However, what type of mast did it house? Was it a towing mast, a mast for hoisting a sail rig, or could both have been used? The idea of the use of sail on the Kupa was dismissed due to several reasons: the relatively narrow width of the river, which would hinder any manoeuvres; the morphology of the Kupa, presenting numerous meanders; the absence of prevailing winds; and no documented use of sail in the ethnological record.

The use of towing as an upstream propulsion method during the Roman period, on the other hand, has been well documented in contemporary sources. In addition to the well-preserved towing mast of the 1st century AD Arles-Rhône 3 barge (Marlier, Poveda 2014: 209), towing scenes are depicted on several low-reliefs such as those from Cabrières-d'Aigues (Cavalier 2008) and Igel (Béal 1999: 95–103), as well as immortalised by the writings of the 4th century poet Ausonius (*Idyllia* X, *Mosella*).

Some of the above-presented archaeological, iconographic, and written sources, reinforced by historical and ethnographical studies of 18th and 19th century navigation on the Kupa (Divić 2022a: 81–109), allow for the conclusion that the mast recess of the Kamensko barge housed a towing mast. With one or more towing cables attached to its masthead, the barge was propelled on its journey upstream by being pulled by a group of several men, or less likely pack animals, from the riverbank.

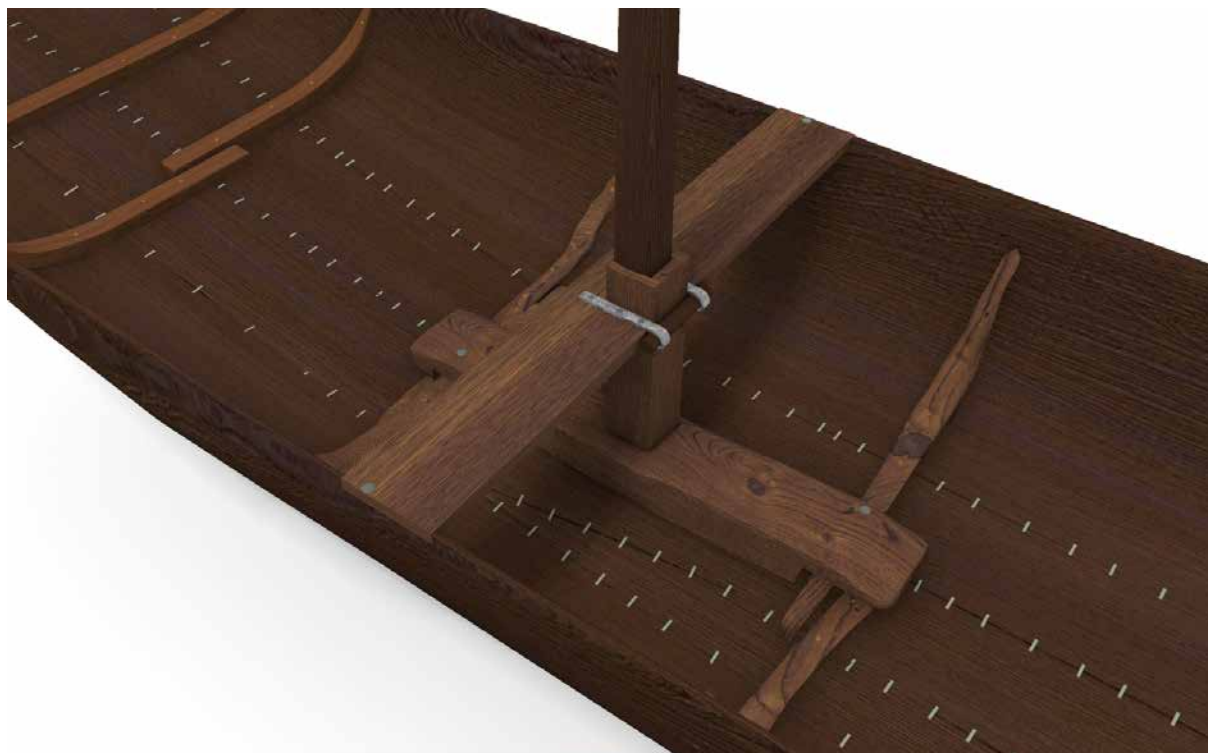


Fig. 4 Reconstruction hypothesis of the locking mechanism of the Kamensko mast ensemble (CAD: A. Divić)

The evidence that allowed us to reconstruct this propulsion system in more detail came in form of three rectangular notches imprinted into the upper face of the mast step. With a width of 3–4 cm and a length up to 15 cm, these notches are interpreted as traces of three planks that formed the structure to support the mast in place. Those would require a transverse support in the form of a beam, perhaps similar to the one recorded on the contemporary Zwammerdam 4 shipwreck (de Weerd 1988: 149, 152), whose secondary function would be to provide the barge with additional transverse support. This combination of direct evidence and archaeological analogies allowed the reconstruction of the Kamensko mast ensemble (Fig. 4) as a probable hypothesis.

5. The steering system

As no elements of Kamensko's steering system were preserved in the riverbed, a *possible* reconstruction (Pomey, Rieth 2005: 148; Poveda 2014: 40–41), based not on direct archaeological evidence but on parallels and analogies with other archaeological, iconographic and ethnographic sources, was effectuated.

In addition to the steering oars from Bevaix (Arnold 1992a: 95) and Arles-Rhône 3 (Marlier, Poveda 2014: 213–214), iconographic representations from the Roman period proved to be a trove of detail regarding the attachment and handling of these devices, in particular the detailed depiction from the 1st century Cologne stele (Arnold 1992b: 85). Reinforced by a number of ethnographic contributions that testify to the use an axially positioned steering oar within the Kupa basin (Divić 2022a: 101–109), the Kamensko steering oar has been reconstructed as such (Fig. 5).



Fig. 5 Reconstruction of the Kamensko steering oar and its attachment system to the stern (CAD: A. Divić, P. Poveda)

Such an axially positioned steering oar would have been attached with ropes to the stern of the barge and fixed in place in a way that would prevent any lateral movement, allowing for an axial rotation of its shaft. With its blade immersed, the steering oar would have been manipulated by the steersman through lateral movements of a tiller driven vertically through the shaft, thus ensuring the desired direction of the barge.

An axially positioned, stern-mounted steering oar would need to be supplemented with a stern platform which would facilitate its handling and provide the steersman with a better line of sight. The existence of such platforms is depicted on a majority of the above-mentioned low reliefs and has been deduced from the archaeological remains of Bevaix (Arnold 1999) and Arles-Rhône 3 (Poveda 2014: 226–228) barges. During downstream navigation, the stern steering oar could have been supplemented by an oar placed at the bow of the barge, as depicted on the Blussus stela and attested in the ethnological record (Divić 2022a: 108–109; Hefele 1896: 73).

6. Hydrostatic analyses

This digital reconstruction method allowed for the development of a complete reconstruction hypothesis which, in addition to its educational and presentational purposes, can primarily be used for scientific analyses: to simulate the cargo capacity, displacements, and evaluate the navigational capabilities of the ship within its area of navigation. Every architectural element has been modelled and had its respective material and characteristics assigned to it (type of wood and the corresponding specific weight), which allowed us a straightforward calculation of their volume and weight. This, in turn, led to a relatively simple calculation of the barge's displacements and tonnage, while the combination of the obtained data and the reconstructed hull lines allowed the generation of accurate hydrostatic analyses.

The hydrostatic analyses were calculated in Orca 3D, a naval architecture and marine design plug-in for Rhinoceros 3D software. These simulations were used to calculate the barge's light displacement, deadweight tonnage, and loaded displacement³ (Fig. 6).

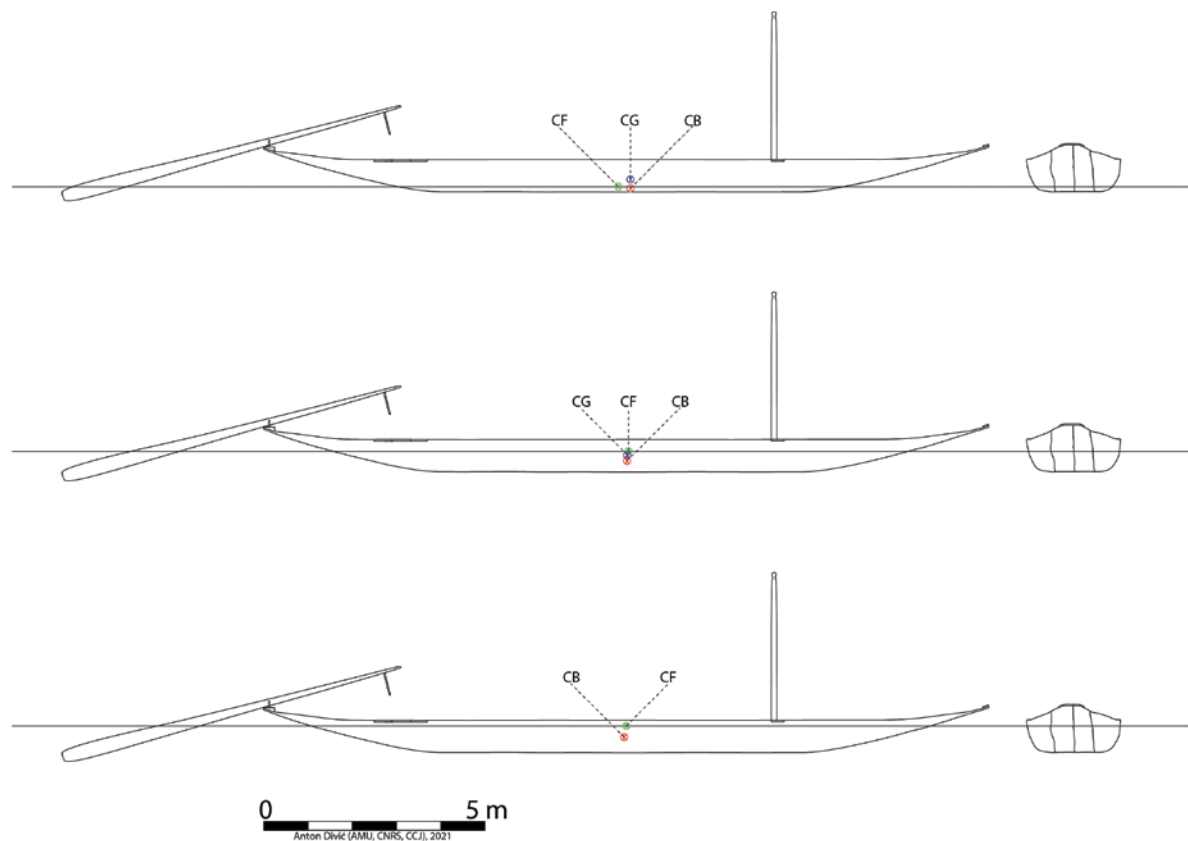


Fig. 6 Three levels of displacement of the Kamensko barge in accordance to the water level: light displacement (up); loaded displacement (middle); maximal displacement (down) (CAD: A. Divić, P. Poveda)

³ The 'Weight and Cost Reports' generated in Orca 3D for both light and loaded displacement of the Kamensko barge's hull reconstruction (including the hull's LCG's, TCG's, and VCG's) have been omitted from this publication due to spatial constraints, but have been included in the co-author's PhD thesis (A. Divić 2022b: 161).

With its reconstructed dimensions of 16 m in length, 2.1 m in width, and 0.70 m in depth, the 3D reconstruction allowed the volume of the barge's structural and assembly elements to be calculated at 2.45 m³. The combination of the volume of each of the barge's elements with the density of the woods used in the construction permitted us to evaluate the barge's light displacement to be 2.1 metric tons, with a draught of 0.10 m when sailing empty.

Although the majority of the barge's brick cargo remained preserved *in situ*, the aft cargo disposition was unknown due to the lack of archaeological remains; however, the reconstructed shape and volume of the hull allowed the complete cargo disposition to be reconstructed as well. As correctly assumed at the early stages of excavation, the barge transported approximately 600 bricks occupying a volume of 4.6 m³. With each brick weighing 11 kg on average, together with the 140 kg of dunnage in form of tree trunks and branches, the barge's deadweight tonnage at the moment of the wrecking was calculated to be 6.7 t.

The combination of barge's deadweight tonnage and its light displacement allowed for its loaded displacement to be calculated using the 'Hydrostatics & Stability Analysis' of the Orca 3D software. On its last voyage, the Kamensko barge is presumed to have had a displacement of 8.8 t, which would have resulted in a draught of 0.47 m, exactly 2/3 of the hull's total depth. The freeboard of 0.23 m would have allowed the barge to navigate without fear of flooding, thus eliminating overload as a possible cause of sinking as was envisaged in the initial stages of excavation.

Acknowledgments

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Visualising the ‘Big Ship’; The reconstruction of a 12th-century cargo vessel found in the harbour of Wismar

Massimiliano Ditta – Jens Auer

Abstract: At the ISBSA 15 in Marseille, the authors presented the preliminary results from the excavation of a Medieval cargo vessel in the port of Wismar (Germany), built from oak and pine sourced from western Sweden in the period AD 1184-1190. Since then, the full documentation of the wreck has been completed, and the timbers are currently undergoing conservation treatment. As the next step, a minimum reconstruction of the hull form was carried out to analyse the ship’s design and construction. This paper discusses the methodology used for the archaeological reconstruction and presents the results of the hull analysis. Finally, the Wismar ship is compared with contemporary ship finds intending to explore its place in the development of the sailing cargo vessel in the 12th and 13th centuries.

Keywords: Nordic Clinker shipbuilding, Early Medieval shipbuilding, Reconstruction, Baltic, Wismar

1. Introduction

This paper aims to present the minimum hypothetical reconstruction of the hull of the ‘big ship’ of Wismar, which was carried out to understand the displacement and provide a basis for comparing hulls with other contemporary vessels. Although the authors have already presented the site and the wreck’s construction features at ISBSA15 held in Marseille in 2018, and a more extensive article is forthcoming, a brief re-introduction of the hull is in order.

The Wismar wreck or ‘big ship’ of Wismar was one of three medieval shipwrecks found during construction work for the extension of the Wismar Seaport, one of the Hanseatic cities on the German Baltic coast. The wreck was excavated by archaeologists from the State Service for Culture and Monuments in Mecklenburg Western Pomerania in November and December 2017, and fully recorded in early 2018.

The 19.8 m long and 5.3 m wide preserved remains of a clinker-built vessel were deeply buried in soft sediment with a 20 to 25-degree list port side (Fig. 1). Altogether 17 strakes of outer planking were preserved *in situ* on the port side, and four strakes survived on the starboard side. Neither keel nor posts were found. Inside the wreck, 28 frame stations were preserved with their associated timbers. Apart from the intact keelson, stringers and part of the aft deck construction could be recorded.

The ship was built from oak and pine sourced from western Sweden and dated to AD 1184–1190 (Daly 2018). With riveted outer planking, in-laid caulking made of animal hair and the presence of *biti* and *biti*-knees, the wreck belongs to the Nordic clinker shipbuilding tradition of the early medieval period (Crumlin- Pedersen 2004; Bill 2009). Moreover, the construction shows striking similarities with several large 12th-century cargo vessels found in Northern Germany and Scandinavia.

2. Reconstruction methodology

2.1. From wreck to a working model

Following the excavation, the ship timbers were recorded by a team of four archaeologists over 37 days in January and February 2018, using the 3D annotated scans method (Van Damme *et al.* 2020). The timbers were cleaned, sampled and subsequently scanned with an Artec EVA structured light scanner. The resulting textured 3D models were

imported into Rhinoceros 3D, where they could be annotated. A written description and photographs of details were then added in order to compile the final catalogue entry for each timber.

The final output consisted of the annotated models, a 2D timber catalogue and 3D prints of all timbers on a scale of 1:20. The 3D-printed timbers were assembled into a so-called working model (Fig. 2), which primarily helped identify the position of the many dislocated timbers found in the site's surroundings. Moreover, as the model was assembled, it helped to understand the construction sequence of the vessel.

The model also became the basis for the proposed minimum reconstruction. Initially, the final working model was mounted over a frame that reflected the keelson's curvature, as the keel was absent as discussed below.

Prior to the placement on the frame, the model showed a pronounced longitudinal twist caused by the absence of the keel, endposts, and starboard side. Once mounted on the frame, with the floor timber aligned to follow the keel line, most of the twisting was removed but not completely eliminated. It should be noted that the final scale model represents a somewhat unique object. It is neither the original as-built version of the vessel nor its shape at the time of sinking, or even the wreck as found. Instead, the model represents an 'adjusted' post-deposition shape state, thus retaining some of the deformations in its shape due to its incompleteness and deposition circumstances.



Fig. 1 3D model of the fully excavated wreck on the seabed showing what remains of the vessel. Landesamt für Kultur und Denkmalpflege Mecklenburg-Vorpommern, Landesarchäologie (author: M. Ditta)



Fig. 2 The working model of the wreck on top of the excavation siteplan. Landesamt für Kultur und Denkmalpflege Mecklenburg-Vorpommern, Landesarchäologie (author: J. Auer)

2.2 From ‘adjusted’ model to minimum reconstruction

The ‘adjusted’ model was scanned again, first with an Artec EVA scanner to capture the overall shape and later with the Artec Space Spider to integrate the minute details not visible with the EVA. The resulting combined scans were processed into a meshed model and used as a starting point for the reconstruction. The 3D-printed model has a standard accuracy for the 3D printing technology employed (Selective Laser Sintering) of ± 0.3 mm for 100 mm, while the Artec EVA has an accuracy of 0.1 mm and a resolution of 0.2 mm. Thus, after scaling the model by a factor of 20, the model’s accuracy can be estimated at around ± 1 cm. The minimum reconstruction of the hull form was carried out in Rhino 6, where the meshed and texturised model was imported and scaled by a factor of 20.

The concept of minimum hypothetical reconstruction has been widely discussed and re-defined over the years. In this paper, we adopted the definition put forward by Tanner (2020: 237):

- A watertight envelope capable of floating and representing the vessel in a form capable of its intended function;
- A reconstruction that does not violate any of the archaeological evidence;
- Missing elements are replaced and/or repaired using contemporary comparative evidence.
- Basic hydrostatic calculations to provide an impression of the vessel’s potential capabilities.

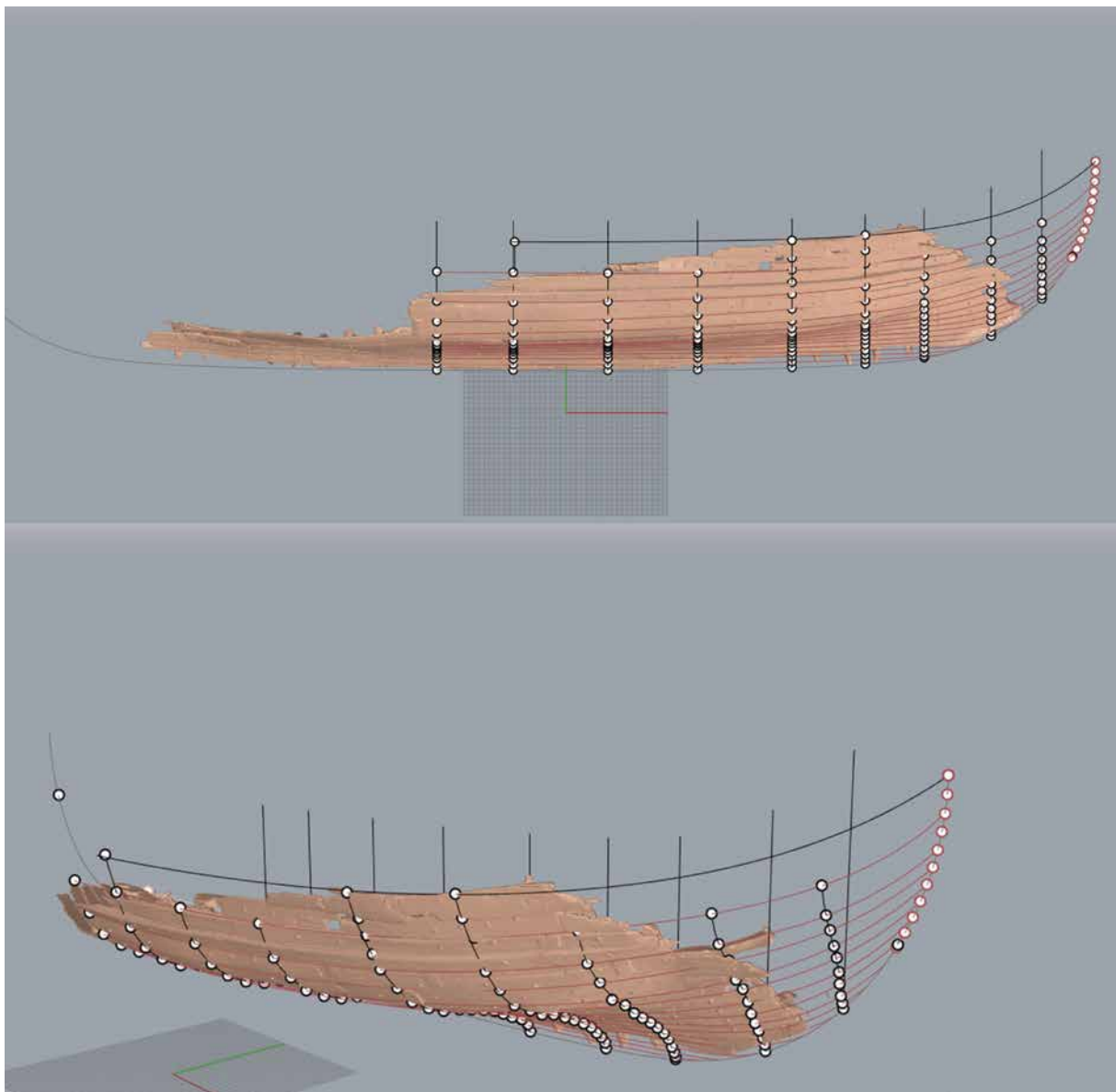


Fig. 3 Snapshot from a reconstruction step. The outer strake lines interpolated through points extracted from arbitrary stations (author: M. Ditta)

As already mentioned, the original scale model still had twists and distortions due to incomplete framing and the asymmetric quantity of materials recovered. These distortions can be categorised as global (Tanner 2020: 239–244), while more localised distortions were also present due to damaged and deformed planking. The correction of global distortions such as twisting and bending were possible using native Rhino commands. The main aim was to reconstruct a watertight envelope for analysis, which entailed creating a conventional lines plan for the exterior of the hull using the outer edge of the strakes. A series of arbitrary stations were created to correct locally deformed areas, and points were extracted for each edge of the outer strakes (Fig. 3). Consequently, the exterior strake lines were interpolated through these points and extended to the reconstructed endposts. Finally, the interpolated lines were faired and lofted, resulting in a watertight hull shell ready for basic hydrostatic calculations (Fig. 4).

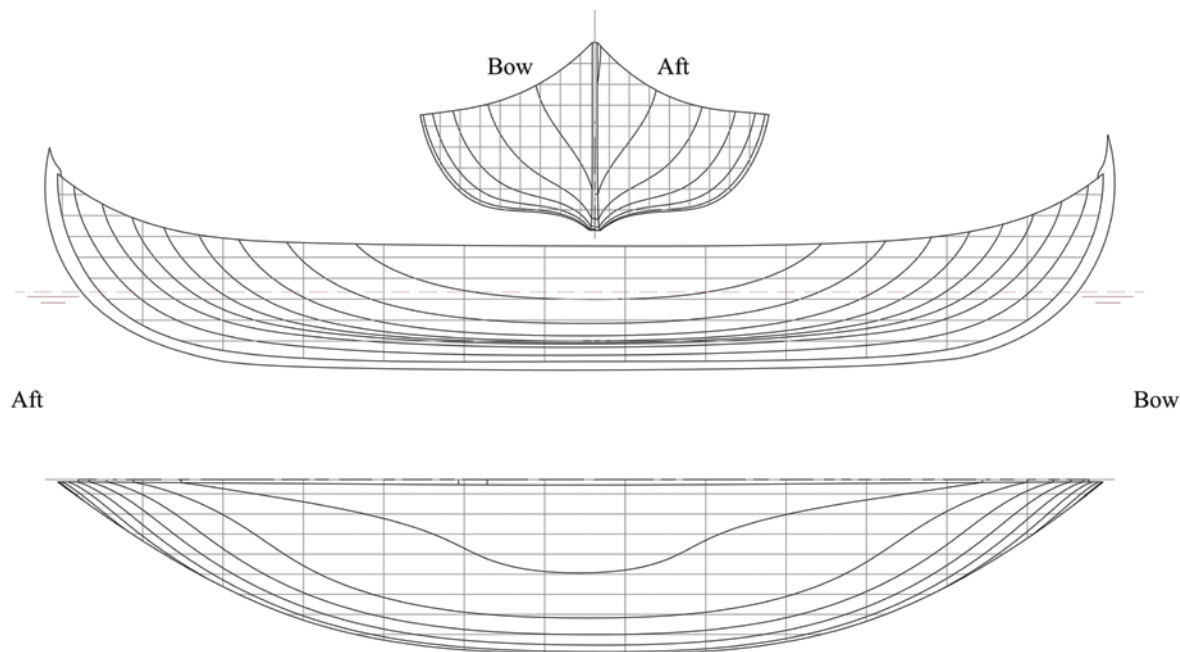


Fig. 4 The lines plan for the minimum hypothetical hull's reconstruction of the 'big ship' of Wismar is not to scale (author: M. Ditta).

The overall length is estimated based on the symmetry of the internal structural elements. The regular spacing between frames and the symmetrical breaks aft and fore the keelson imply an overall symmetrical arrangement. Therefore, the shapes of the keel and endposts had to be reconstructed based on indirect and comparative evidence. The keel was reconstructed with a moderate rocker, assumed by the shape of the 10-meter-long keelson. This massive timber is believed to have undergone relatively minor deformations and thus corresponds to the original curvature of the keel. A similar characteristic is also seen in the closely comparable Lynæs I ship (Englert 2015: 168–169). The upper moulded dimensions of the keel and thus the rabbet line for the garboard strake have been estimated based on the foot of the floor timbers, while the sided dimensions are based on the surviving keel of Lynæs, which is relatively shallow with 17 cm at midship. As typical for vessels built in the Nordic clinker tradition of the early medieval period, the Wismar ship was double-ended with round extremities. Both endposts were reconstructed symmetrically and based on the shape of the sternpost. The curvature is visible in the surviving wings (a specifically shaped wooden plank between the actual planking and the endposts) and the hood ends of the stern planking. Perhaps coincidentally, the radius of the sternpost appears to be 1/6 of the length between posts. The sheer-line follows the run of the 17th strake, the last strake, as indicated by the preserved in-wale.

3. What did the ship look like?

Before examining the details of the hull properties, a so-called 'visual' reconstruction is proposed here (Fig. 5) and discussed. This reconstruction aims to give an impression of the ship structures and arrangement resulting from the minimum hull shape reconstruction, the interpretation of the archaeological remains, and comparative sites.



Fig. 5 Visual reconstruction of the vessel based on the working model and available archaeological evidence (author: M. Ditta)

Fore and aft open decks: The deck construction of the vessel can be traced on the port side aft. Here, a preserved beam shelf and some oak standing knees provided the substructure for a half-deck. Moreover, the preserved structure indicates the existence of another, higher deck further aft, which might have been the helmsman's position. Although not preserved, a similar arrangement is expected for the vessel's fore section. Moreover, a hole on the port-side in-wale on the aft deck suggests the presence of a thole pin, which would allow rowing for manoeuvring in and out of sheltered and shallow areas.

Still, on the aft deck, a massive knee from limewood (*Tilia* sp.) probably served as a bearing for a windlass that extended across the entire width of the vessel. While this type of windlass bearing finds a comparison in the much smaller Elling Å ship (1163) (Bill 1997), a corresponding windlass for this type of arrangement was found in connection with the 'Big Ship of Bergen' dated AD 1187/88 (Christensen 1985: 180).

Through-beams: A 22 cm × 22 cm rectangular opening in the 16th strake at the aft deck's forward end indicates the presence of a through-beam. The beam would have notched under the upper stringer, which is confirmed by a recess in the timber. Further notches in this upper stringer imply the existence of at least three of such through-beams. Through-beams are known from the Bryggen excavations (Christensen 1985: 66), and at least two of these beams could be linked to the find context of the 'Big Ship of Bergen'. The largest beam found in Bergen had a square section of 20 cm × 20 cm. Moreover, the seal of the city of Winchelsea in England from the 13th century depicts a ship with striking similarities to the Wismar ship: A single-masted clinker-built vessel with a large windlass on the aft deck (Fig. 6) and three through-beams at the aft, amidship and fore of the vessel.



Fig. 6 Second seal of the corporation of Winchelsea from the early reign of Edward I 1272–1307 (SEC0025), National Maritime Museum, Greenwich, London

Another noteworthy feature is a smaller opening measuring 10 cm × 16 cm above the upper stringer and just aft of the through-beam. Its position above the deck and at the end of the keelson suggests that it served as a scupper-hole. A similar solution can be seen in the Kalmar V, a small merchant ship from the early 16th century. A hollowed-out beam, at the aft end of the keelson above the deck, led the bilge water to a circular scupper-hole in the ship's side. The gutter beam was associated with a primitive bilge pump (Åkerlund 1951: 74). The Wismar ship was probably equipped with a similar pump arrangement, as the position of the lowest two stringers in continuation of the keelson allows free access to the lowest point in the ship between the 22nd and 23rd frame stations.

Based on the curvature of the sternpost, it can be assumed that the ship was equipped with a quater rudder, as stern rudders are generally associated with straight sternposts. As seen in the Kalmar I wreck (Åkerlund 1951: 32), similar longitudinal beams may have ran between the through-beams. A preserved mast partner would have fit in such an arrangement and provided extra reinforcement to the mast. Moreover, a mast horn was fitted fore of the mast step, possibly to counter-act the pressure of the mast against the transverse structures.

4. Talking numbers

The minimum reconstruction resulted in a hull with a Length Overall (LOA) of 23.3 m, a maximum breadth of 7.6 m and a depth amidship of 2.7 m. In order to calculate the hull displacement at full load, the draft was established according to the Icelandic Grågås codex freeboard law. The codex is a collection of laws recorded as early as AD 1117 and used until the AD 1280s. The law states that the minimum freeboard of a cargo ship should be 2/5 of the depth of hull amidships (Morken 1980: 178). In the case of the Wismar ship, the resulting waterline is at 1.61 m and, perhaps not coincidentally, it corresponds with the lower edge of the first wale. The resulting displacement of the hull at the full-load waterline is ca. 89.5 t.

The length-to-beam ratio is 1:3, quite indicative of the cargo-carrying nature of the vessel. While the slightly hollow waterlines and the low Block Coefficient value (0.4) indicate good speed potential, the prismatic coefficient (0.6) might indicate a slightly higher resistance.

McGrail (1987: 195–198) suggested the use of simple form coefficients as a method of determining relative assessments of the capabilities of a boat. However, coefficients are relative values that tell little about a vessel's real-world operations and behaviour (Tanner 2020: 315). That is what we hope to investigate at a later stage with the seakeeping and stability analysis.

5. A brief comparative analysis

Although a detailed list and analysis of comparable vessels have been published elsewhere (Auer, Ditta 2023), a brief comparative analysis of the most closely related vessels is presented here. In terms of construction features, the Lynæs 1 wreck from AD 1140 (Englert 2015: 164) stands out as a very close comparison to the Wismar ship. The similarities range from the general layout of the vessel and the presence of carved planks with a characteristic cross-section (wales) and a w-shaped floor timber to the arrangement of the *biti* system. The remarkable correlation in the provenance of the oak timbers used for construction is another point both wrecks have in common (Daly 2018). While through-beams were not preserved in the Lynæs 1 wreck, these could have been present. However, considering the age difference of 40 to 50 years between the two ships, the features could also represent later phenomena. A marked difference between the two ship finds is the consistent use of pine for all long and straight elements in the Wismar ship. However, despite this difference, Lynæs 1 still looks like a direct predecessor of the Wismar ship.

The 'Big ship of Bergen' (Christensen 1985) should also be discussed here. The 'Big ship of Bergen' not only dates to the same period as the Wismar ship, but the few preserved elements of this vessel also show striking similarities. From the shape of the keelson to the presence of mast *bitar*, through-beams, and the construction of the windlass, the Bergen ship is a larger version of the Wismar ship. However, all preserved structural elements from the Bergen wreck are made of pine.

The Lynæs I wreck is reconstructed with an LOA of ca 25 meters and a maximum breadth of 6.5 m. The ship, significantly more slender than the Wismar ship, has an estimated total displacement of 75 t and a cargo capacity of 56 t, approximately 75% of its total displacement. While a thorough analysis of the bare hull's weight is

pending, preliminary calculations based on a similar estimation approach (75% of the total displacement) suggest a cargo capacity of around or over 67 t for the Wismar ship. This estimation considers the remaining bare hull weight of 21.5 t, which is presumed to be about 25% of the total hull, leading to an estimated full load displacement of 89 t.

Although not fully reconstructed, the Bergen ship is estimated to have an LOA of 27–30 m and a maximum breadth of ca 9 m. According to Christensen (2002), the ship had a cargo capacity of 120 t or ca 60 lasts and was meant for bulky but light cargo, like stockfish or timber.

Generally, a trend is noticeable in the L/B ratio, considering other vessels too. Ships predating the Wismar ships have a much higher ratio, a trend already underlined by Crumlin-Pedersen and Bill regarding size and cargo capacity. The Lynæs ship has an L/B ratio of 3.8 against the 3 of the Wismar ship and possibly also the Bergen ship, while the latest comparable vessel from 1265, the Falsterbro ship (Bill 1997), has a ratio of 2.4. Clearly, the trend relates to the increasing specialisation of ships for cargo transportation.

6. Conclusion and outlook

As suggested by Christensen (2002) and Englert (2015), ships such as Lynæs, Wismar and Bergen are well above what an ordinary *farmann* (a Scandinavian peasant trader) could afford to build, equip and maintain. The high-quality material used in the construction and the sheer amount of raw material needed indicate that these ships were commissioned and owned by someone high up on the social ladder, such as high clergy, magnates, or even kings. Interestingly, late 12th-century to 14th-century sources like the Icelandic Annales and English toll roll often mention the so-called *Buzer* (Christiansen 2002; Simiek 1979), a name used to define cargo ships stemming from Scandinavia. Their names suggest their ownerships, like the *Qgvaldsnesbuza* from the royal seat of Avaldsnes in Norway (Mundal 2017: 44) or the *Lysbúza* from the monastery Lysa in Norway (Simek 1979: 28). Thus, it is not difficult to imagine that ships like the ones from Wismar and Bergen were built to partake in the Atlantic trade. For example, the stockfish trade from Bergen was sufficiently developed even before 1200 to make it profitable and necessary to build such large ships (Christiansen 2002: 92). At the same time, the Danish dominance in the Baltic was reaching a peak over the areas around Lübeck and Wismar, providing new trade possibilities for professional merchants.

One thing is clear, Scandinavian shipbuilders from around the mid-1100s were able to build surprisingly large ships. Perhaps the pressure on shipbuilders to provide larger ships enticed the introduction of new construction features to reinforce the hull, such as through-beams (Bill 2002: 112) which are documented at least from the end of the 1100s. The size of Scandinavian-built ships continued to rise steadily until changes in the economy and societal organisation brought the trend to a close. When Hanseatic dominance reached its peak, it was their exceptional organisation of trade and a monopoly on essential goods, such as grain and salt, that gave German merchants an advantage rather than their cogs.

Further analysis of the reconstructed hull of the ‘Big Ship’ of Wismar is planned, including stability analysis and a tank test. First, we would like to estimate the vessel’s cargo capacity accurately and appraise its sailing capabilities over different weather conditions. The aim is to understand if the Wismar ship was built for long Atlantic voyages and how it would have performed at sea.

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Comparing and conceptualising reconstructions; The Barcode 6 revisited

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Abstract: When opening a small boat-building workshop at the Norwegian Maritime Museum in Oslo, Norway in 2009, the intention was to foster collaboration between academics and craft experts. Over the years, the workshop has facilitated the building of several reconstructions of archaeological boats. This paper presents a reflective analysis of the methodologies and outcomes involved in reconstructing the 1595 CE Barcode 6 boat, known as the *Vaaghals*, which was successfully launched in 2011. Both digital and practical methods are evaluated and discussed.

Keywords: reconstruction, model building, boat building, experimental archaeology, digital methods, exhibition

1. Introduction

Since 2004, the Norwegian Maritime Museum has conducted excavations in the old harbour of Oslo, Norway. From the 1960s onwards, more than 60 shipwrecks have been uncovered in the old harbour, together with extensive wharf constructions that are the remains of Oslo's historical harbour, dating back to Medieval times (e.g., Christensen 1973; Christensen, Molaug 1966; Gundersen 2012; Molaug 2012; Paasche *et al.* 1995; Vangstad *et al.* 2020). The vessels date back to the 14th century, with an undisputable majority from the 16th and 17th centuries. During this era, Oslo was expanding as a town for shipping, especially for timber trade destined for the European market (Figs 1 and 2).

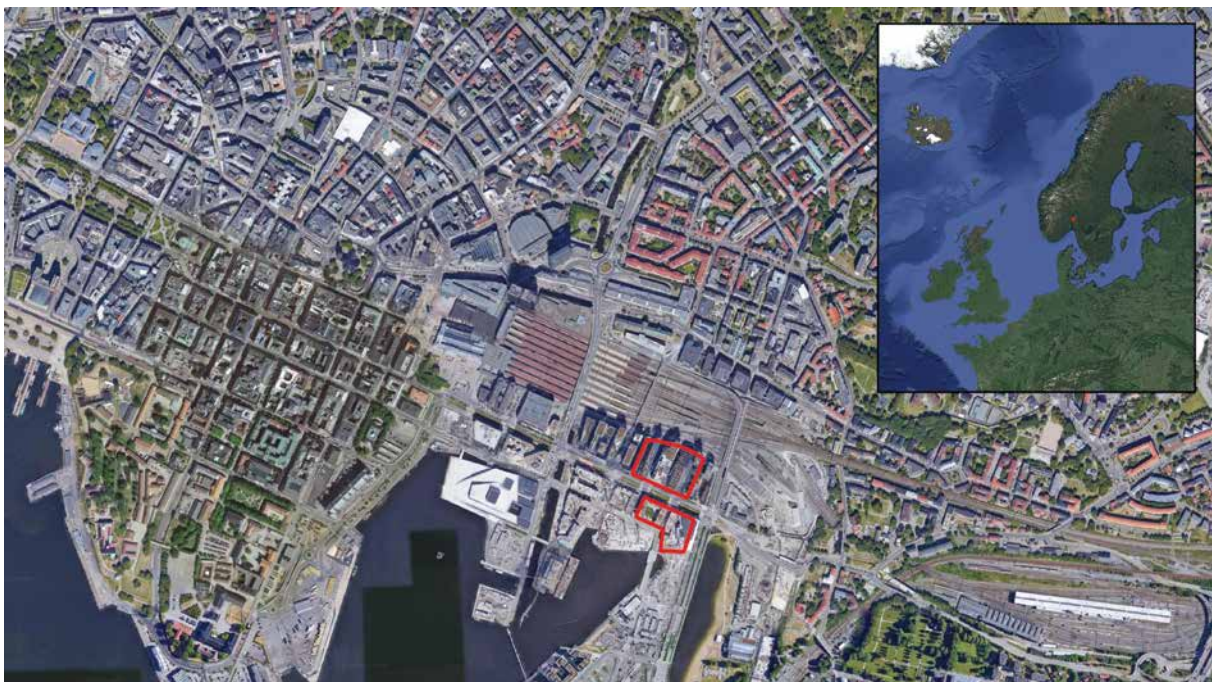


Fig. 1 The modern harbour of Oslo, Norway, with two excavations, the Barcode B11-12 (2008-2009), and the B3/B7 (2015-2016) (map: S. van Riel/NMM)



Fig. 2 Map showing results from the excavations, with harbour constructions and shipfinds. The Barcode 6 (after 1595 CE) vessel is marked with a red circle. Background map is from approximately 1700 (map: S. van Riel/NMM).

One of the vessels, the Barcode 6 (after 1595 CE) (Daly 2010), has received much attention, functioning as a ‘guinea pig’ in the museum’s required pursuit to build competence and knowledge in the areas of post-excavation documentation, conservation, reconstruction and exhibition (Falck, Egenberg, Vangstad 2014; Planke, Stålegård 2014; Hovdan, Sandvoll, Thome 2015; Sandvoll 2015; Vangstad *et al.* 2020). This paper intends to reflect upon our practices concerning documentation and reconstruction by examining the processes that culminated in building a so-called floating hypothesis, the *Vaaghals* (Eng: Dare Devil), in 2011 and the following exhibition of the original material in 2017.

These processes involved various experts, spanning from archaeologists, conservators, and ethnologists to boat builders and other crafts experts, as well as volunteers. Over the years, several representations of the boat have been produced, demonstrating some discrepancies. Since reconstructions have the ability to convince and present themselves as accurate, we wanted to investigate how the different methods of reconstruction can shed light on variation and diverse interpretations. Instead of blurring the fact that they differ, we tried to put the differences on the table, hoping to learn something that we could carry onward to new projects. The investigations made us conscious of how we create reconstructions and interpretations on different conceptual levels. On the one hand, through digital methods, we reconstruct to produce knowledge of technical features and abilities of a vessel, comparable to modern naval architecture. On the other hand, we reconstruct to understand crafts and practices, which can be conceptualised as the ‘patterns’ of building (Planke 2011; Planke, Øya, Heide 2022). These latter concepts touch upon the social aspects of building that create both continuity and change within communities of practice (Ravn 2020).

2. Reconstructions, experimental archaeology and interdisciplinarity

Reconstructions, in the shape of physical scale models, technical line drawings, and full-scale sailing hypotheses, have been considered vital tools within nautical archaeology for decades. The need for a minimum reconstruction of the often distorted and fragmented excavated material is obvious for creating an understanding of the outline and qualities of the vessel found. We are standing on the shoulders of years of practice, but as Crumlin-Pedersen and McGrail recommended in 2006, the advantages of working in interdisciplinary groups are key (Crumlin-Pedersen, McGrail 2006). The Barcode 6 is reconstructed through a dialogue between different sources and types of knowledge (Planke, Stålegård 2014), and the process can be described as hermeneutical, even phenomenological, as also discussed by Bischoff in her thesis on the reconstruction of the Oseberg ship (Bischoff 2020). So, instead of viewing the boat builder as a blank

slate that objectively can learn and apply the methods of the past, the boat builder's practical knowledge of the use of tools, material quality, dexterity, and work processes is viewed as a resource. While this is important, it is also vital that boat builders can interpret and are willing to accept that the tools and techniques of the past differ from their training. Ideally, this is the strength of academic training, and in this manner, boat builders and archaeologists can learn from each other's perspectives.

Interdisciplinarity in these projects also includes technical conservators who stabilise the timbers and, in the case of Barcode 6, shape the timbers in moulds before freeze-drying. To do this, the conservators must also be involved in the digital documentation and interpretation of the scale model. Specifying these three main groups of experts only touches the surface of what is needed to reconstruct, conserve, and exhibit an archaeological ship find. Still, for the purpose of this paper, they are the most crucial.¹

3. Excavation and post-excavation documentation

We will not focus on the methods for digital excavation and post-excavation documentation here. Since the excavation in 2008–2009 (Gundersen 2012; Vangstad 2012), the methods in use have been developed and refined. This also relates to the post-excavation documentation, where we, in 2020, converted from 13 years of using a FaroArm for contact digitising (Hocker 2003; Jones 2007, Nayling, Jones 2012; Falck, Egenberg, Vangstad 2013; Falck 2014; Falck, Fawsitt, Kerr 2016) to Artec Eva/Leo structured light scanners, adding annotations directly onto the scans (van Damme *et al.* 2020). In this paper it is the supplementary use of this primary documentation that is of main interest. We want to stress that using these digital methods has facilitated cooperation between the experts involved in the work. Where one could surmise that the use of digital tools limits cooperation, as it demands basic qualifications in the use of digital software, this has not been our experience.

4. The building of a scale model

When opening a small boat-building workshop at the Norwegian Maritime Museum in Oslo in 2009, the intention was to create a place where academics and craft experts could work together (Planke, Stålegård 2014: 359). Calling it a laboratory, the BoatLab, emphasised this as a space for testing, trial and error, and experimenting, with an openness to the crafts and practices of the past – the ways of doing things. A basic method for reconstructing archaeological clinker-built ship finds is to use the scaled 1:1-drawings to create the shell, making nail holes in the strakes fit in dialogue with the framing system (Planke, Stålegård 2014: 375; Bischoff 2020: 64). Generally, we have practised this using a combination of paper-printed 3D drawings glued to cardboard (strakes) and printed 3D models in plastic (frames and other structural timbers). We built the Barcode 6 model in scale 1:5, creating a large model. The scale offered some material resistance and the possibility for higher precision (Planke, Stålegård 2014: 367). We searched for fixed points in the boat, which we could reference for other more doubtful parts of the construction. We soon experienced that they were few. Even in a situation with approximately 80% of the material present, interpretation and negotiation were necessary before making decisions. Especially difficult was the lack of beams, not providing us with any certainty of beam widths.

We have listed five important experiences from the building of the scale model.

- In a cardboard model, there is much room for adjustments and 'kneading' within a hull shape, where individual parts fit together.
- Lack of beams significantly increases the uncertainties of the reconstructions. This point is essential, as a majority of the finds from Oslo lack beams and should also be viewed in relation to point 1.
- One plank can alter the rest of the hull shape. This single plank can potentially be out of its original shape or not even be present.
- The shape of the floor timbers changed from their first on-site documentation to the time of documentation in the lab.
- Lastly, a (minor) discrepancy will occur since post-documentation is done on wet, swollen timbers, while actual boatbuilding is done on dryer wood.

¹ Other important crafts include the production of tar, reconstruction and sewing of sails, rope making etc.



Fig. 3 The reconstructed boat on display at the head quarter of the DNB Bank in Bjørvika, Oslo, seen from the aft (photo: B. Kjølsevik/NMM)

5. The building of Vaaghals²

The model's main function was as a template for building the full-scale reconstruction. Using the same master builder, Lars Stålegård, for the model and the boat, created a valuable (and recommended) continuity in the work.

The reconstruction results from discussions and negotiations between the crafts persons, the documentation, the archaeological material, the archaeological context, and the building materials and tools in use. For the archaeologists involved in these negotiations, a whole new context for their interpretations is created. This is a practical context, a knowing how, not just a knowing what.

6. The exhibition

The vessel was intended for an exhibition in the new headquarters of the DNB Bank (Fig. 3). The importance of this version of the boat lies not in the naval qualities and capacities of the vessel but in the preserved materiality and outreach. The material is fragmented and distorted but stable through treatment in PEG and a vacuum freeze drier. We used the scale model's digital version to recreate each plank fragment's shapes, creating moulds that locked the timbers before entering the freeze-dryer. This made assembling the pieces in the exhibition workable, but without claiming that every fragment fitted perfectly. We found it interesting to evaluate how the exhibited vessel eventually differed from the other versions (Tab. 1). Compared to the cardboard model, the length of the vessel is less than 1% shorter, while its breadth shows roughly a 9% narrower version. Accurate overall measurements were difficult to achieve, considering the strakes were incomplete up to the gunwale. Test measures on strakes, before and after freeze drying, suggest that the shrinkage plays a lesser role in the differences than the adoptions done when assembling the material.

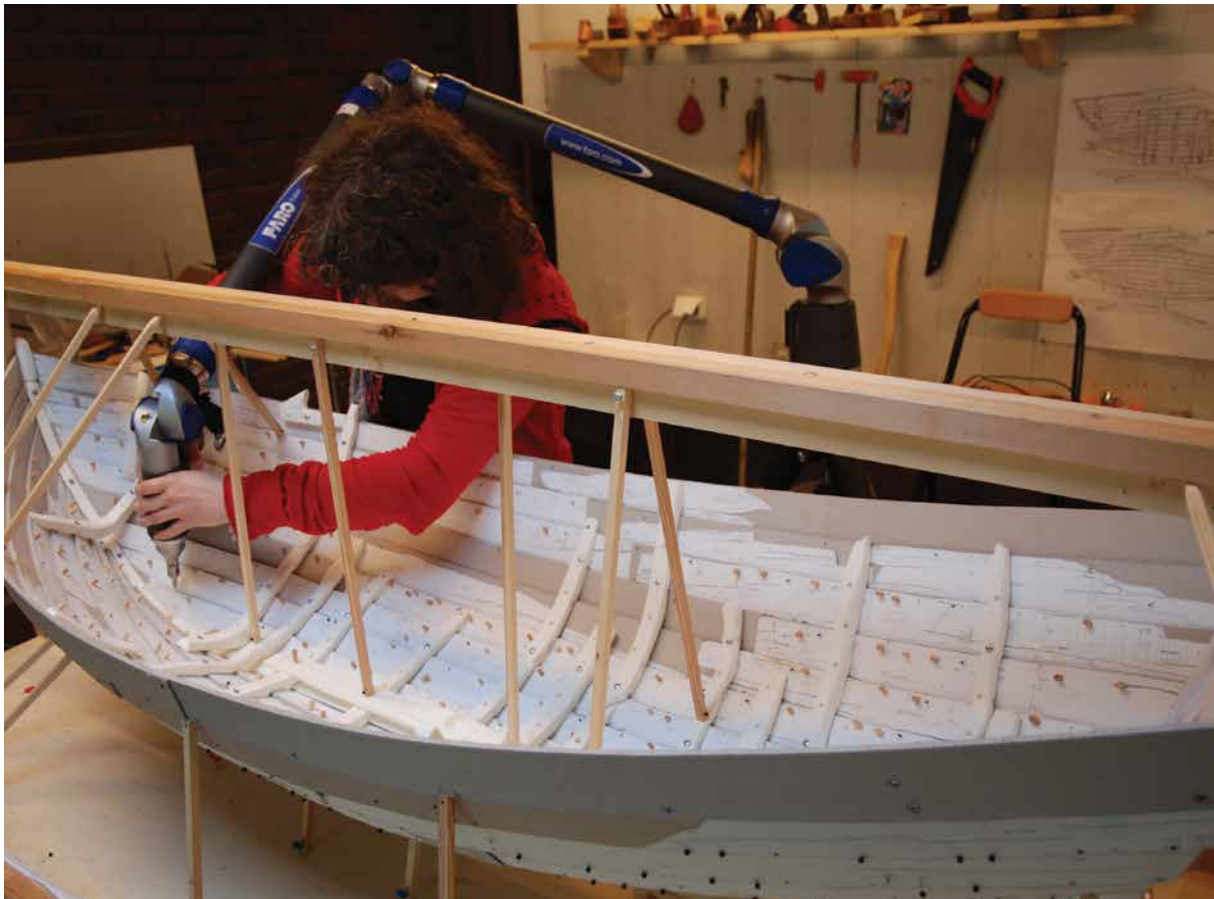


Fig. 4 Sarah Fawsitt is measuring the cardboard model using a FaroArm, back in 2010. Accuracy was complicated both by the method of contact digitising, and reaching certain parts of the hull with the measuring probe, especially in the bottom (photo: T. Falck/NMM).

² The work process is available at baatlaben.blogspot.com. The results are presented and discussed in Planke, Stålegård 2014. Both publications are in Norwegian.

7. Comparing the representations – identifying the discrepancies

7.1. The digital models

Two digital models were built in Rhino 3D to be run through Orca 3D.³ The first model was a hull based on a FaroArm recording of the physical 1:5 model (Fig. 4). This digital model will be referred to as the Barcode 6 model. The second model was based on a combination of photogrammetry and an Artec Leo 3D scan carried out on the physical full-scale reconstruction. Since the reconstruction has been named *Vaaghals*, the digital model of it will be referred to as the *Vaaghals* model. This method of digital model building and analysis in Orca 3D is based on the method developed by Pat Tanner (Tanner 2020).

The two models were remarkably similar, but there were some visible differences (Fig. 5). One reason for some of the differences lies within the recording and building of the Barcode 6 model. After the 1:5 scale model was recorded, there was an asymmetry to the digital model hull that was attributed to the method of documentation with a FaroArm probe. The probe could sometimes push the cardboard boat model out of shape when taking points. It was also challenging to record points in the lower areas of the hull. For this reason, it was decided to make a half model of the port side and allow Orca3D to mirror it in its analysis. Thus, the asymmetry was eliminated from the shape of the Barcode 6 model. The photogrammetry and scan have shown that the asymmetry was not necessarily just a product of the FaroArm documentation. With the more dependable scans, it was decided to adhere to the characteristics of the reconstruction and make a complete, asymmetric hull for the *Vaaghals* model. There are also other differences between the two models that cannot wholly be accounted for by mirroring the port side of the Barcode 6 model. While the differences in the hulls were slight, they were picked up by Orca 3D when the hydrostatic analyses of the two hulls were compared.

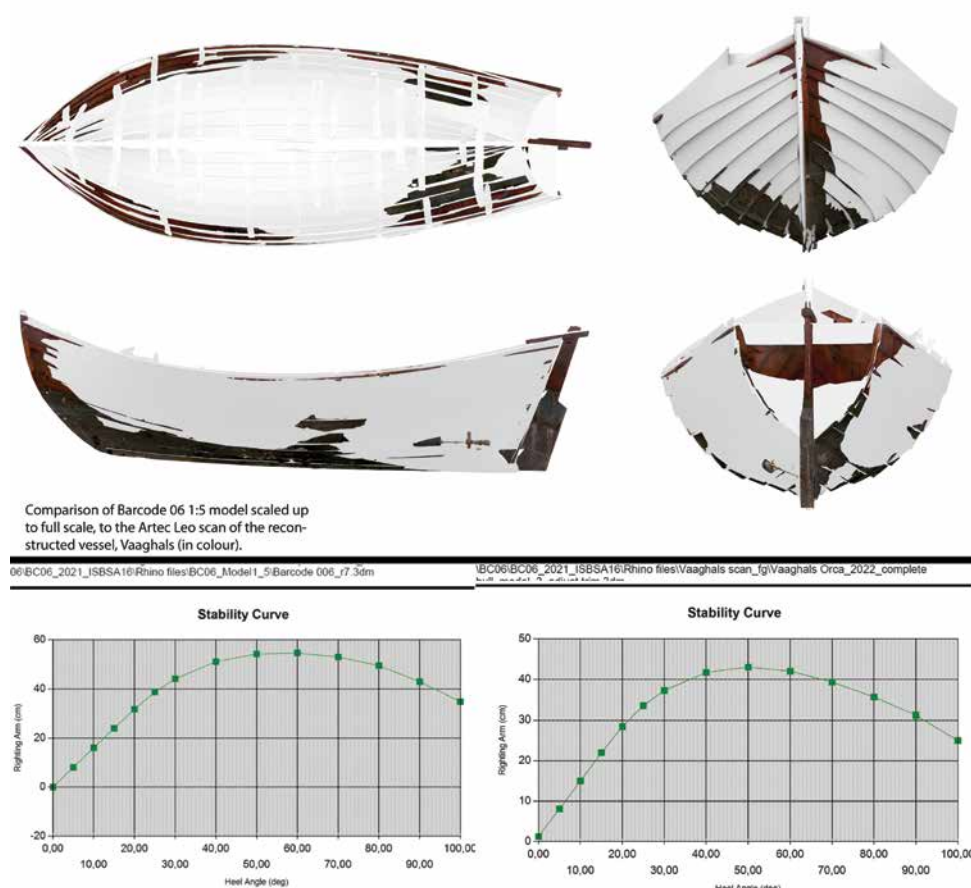


Fig. 5 Top: Comparison of Barcode 6 1:5 model (gray) scaled up to full scale, to the Artec Leo scan of the reconstructed vessel, Vaaghals (in colour). Bottom: Graphic display of stability curves for the two models (models: S. Fawsitt, K. Steen/NMM)

³ Orca 3D is a plug in for Rhino 3D for naval architects to perform hydrostatic analysis.

7.2. Orca 3D hydrostatic analysis.

For the hydrostatic analysis, two Orca runs of each model were done. Each model had identical loadings of 1- and 4-ton ballast (Tab. 2).⁴ The ballast was in point form and had an identical placement in each model. The Barcode 6 model had no heel due to being mirrored. The two models had slight differences in the overall dimensions and the subsequent waterline dimensions and waterplane value. There were slight differences in the hull coefficients, describing differences in the volume and area of the models. There were also differences in the volumetric centre of gravity, although slight. The stability curves produced by the hydrostatic analysis varied very little. The most significant difference was to be seen in the 4-ton loading between the Barcode 6 model and the *Vaaghals* model, where the symmetrical Barcode 6 model has a maximum righting arm of 55 cm at a heel angle of 60°. The asymmetrical *Vaaghals* model has a maximum righting arm of 43 cm at a heel angle of 50°, and a steeper drop off with an increase in the heel angle, although in both cases the models would have a freeboard of 0 at an angle of 20° heel. So, practically speaking, the difference in the righting arm and angle of vanishing stability are negligible. In conclusion, these slight variations in the interpretation of the Barcode 6 vessel have resulted in little variation in the resultant models, in as much as they can be interpreted by Orca 3D.

Overall dimensions (m)	Barcode 6 model	Vaaghals model	Exhibition
LOA	7.62	7.67	7.55
BOA	2.88	2.78	2.62
D	2.32	2.08	NA

Table 1 Overall dimensions of the representations of the boat. Length overall, breadth overall and depth (authors: S. Fawsitt, K. Steen, Ch. Rodum)

Barcode 6 model_1 t ballast				Displacement 2350 kgf			
Waterplane values [cm]	Vol. [m ³]	Wetted surface [m ²]	Overall dimensions [cm]	Waterline dimensions [cm]	Hullform coefficients	Centre of buoyancy [cm]	Centre of gravity [cm]
LCF: 247 cm	2.29	17.92	Loa: 762	Lwl: 644	Cb:0.263	L: 259.6	L: 0
TCF: 0			Boa: 288	Bwl: 215	Cp:0.543	T: 0	T: 0
VCF: 30.51			D: 232	T: 63	Cx: 0.484	V: 14.1	V: 53.22
Awp: m ²					Cvp: 0.405		
8.96					Cwp: 0.649		

Barcode 6 model_4 t ballast				Displacement 5350 kgf			
Waterplane values [cm]	Vol. [m ³]	Wetted surface [m ²]	Overall dimensions [cm]	Waterline dimensions [cm]	Hullform coefficients	Centre of buoyancy [cm]	Centre of gravity [cm]
LCF:249	5.21	26.86	Loa: 762	Lwl: 682	Cb: 0.332	L: 253.2	L: 0
TCF: 0			Boa: 288	Bwl: 255	Cp: 0.590	T: 0	T: 0
VCF: 57.7			D: 232	T:90	Cx: 0.563	V: 31,3	V: 30.19
Awp: m ²					Cvp: 0.466		
12.39					Cwp: 0.712		

⁴ *Vaaghals* is sailing with between 1500–2000 kg ballast.

Vaaghals Model_ 1 t ballast				Displacement: 2343 kgf			
Waterplane values [cm]	Vol. [m ³]	Wetted surface [m ²]	Overall dimensions [cm]	Waterline dimensions [cm]	Hullform coefficients	Centre of buoyancy [cm]	Centre of gravity [cm]
LCF: 245	2.28	11.59	Loa: 768	Lwl: 660	Cb: 0.277	L: 255	L: 254.6
TCF: 0.684			Boa: 278	Bwl: 204	Cp: 0.530	T: 0.827	T: -.275
VCF: 24.19			D: 195	T: 61	Cx: 0.523	V: 6.6	V: 48.46
Awp: m²					Cvp: 0.444		
8.394					Cwp: 0.623		

Vaaghals Model_ 4 t ballast				Displacement: 2343 kgf			
Waterplane values [cm]	Vol. [m ³]	Wetted surface [m ²]	Overall dimensions [cm]	Waterline dimensions [cm]	Hullform coefficients	Centre of buoyancy [cm]	Centre of gravity [cm]
LCF:253	5.21	27.23	Loa: 768	Lwl: 696	Cb: 0.331	L: 256.8	L: 256.8
TCF: -.781			Boa: 278	Bwl: 244	Cp: 0.575	T: -0.3	T: -.401
VCF: 53.1			D:195	T: 93	Cx: 0.575	V: 25.1	V: 25.7
Awp: m²					Cvp: 0.477		
11.746					Cwp: 0.693		

Table 2 Results from the hydrostatic analysis of the Barcode 6 and Vaaghals models with loadings of 1 and 4 t. The analysis is done in Orca 3D (author: S. Fawsitt)

8. Conclusion

The representations of the boat differ from each other, and we intended to reveal and investigate these variances. This way, we can understand which discrepancies are essential in that they alter the properties of the vessel. The hydrostatic analysis performed on the Barcode 6 cardboard and *Vaaghals* models identified differences, but these were interpreted as slight. This makes us believe that the pursuit to transform the results from the cardboard model into a sailing vessel has succeeded in bringing on similar qualities.

Just as important, the investigation is useful to evaluate and better understand our practices on a conceptual level. Following the building of *Vaaghals*, Planke and Stålegård (2014) discussed the methods from a craft perspective, raising questions about what they experienced as a processual and fragmented practice within experimental archaeology. While our digital methods and hydrostatic analysis help create measures that are comparable to other vessels' naval capabilities in a numeric manner, the craft perspective potentially establishes an understanding of the ideologies behind the structure and 'the ways of doing things'. We believe that both these perspectives are helpful, and in the future, we hope to more actively combine the methods so that they may strengthen each other. Through the practical use of *Vaaghals*, questions concerning the rather sharp bottom are one area where the digital methods and the practical perspectives, with great advantage, can work together to reconstruct and discuss variances. The same applies to the general problem of the lack of beams in the Oslo finds, which creates uncertainties concerning the beam widths.

The practical aspects of building, rebuilding, and use of sailing vessels need to be a core aspect and task for the reconstruction work within maritime and nautical archaeology (Fig. 6). Speaking from the experiences at the Norwegian Maritime Museum, the cooperation between experts in crafts and archaeology is required, and more research that allows this collaboration is therefore called for. The archaeological ship material from Oslo contains many vessels from quite a limited period. More full-scale reconstructions will make it possible to create a unique understanding of the principles behind the building of these vessels, stemming from a very dynamic time in history.



Fig. 6 The small cargo vessel, Vaaghals, has been rigged with one main square sail and one smaller sail in the fore. In the photo, the stability is tested by human force for the first time (photo: K. Steen/NMM).

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NAUTICAL ICONOGRAPHY AND ETHNOGRAPHY

The adoption of the sail in the Early Bronze Age Aegean (ca. 2550–2200 BC) and its impact on later Minoan, Aeginetan, and Mycenaean seafaring¹

Aleydis Van de Moortel

Abstract: This paper redates the adoption of the sail in the Aegean to ca. 2550–2200 BC – significantly earlier than previously thought. It argues that the sail was introduced first in the East Aegean and from there in the Central and West Aegean, reaching Minoan Crete only ca. 1900 BC. Sailing technology seems to have come from Egypt via the Levant to the Aegean in the context of the Early Bronze Age Anatolian Trade Network. This new maritime technology had a major impact on the Aegean in the Middle and Late Bronze Ages, facilitating the rise of Aeginetan, Minoan, and Mycenaean maritime trade networks.

Keywords: Bronze Age Aegean, seafaring, sailing ships, Kastri/Lefkandi I group, Anatolian Trade Network

It is widely believed that the Minoans of the island of Crete were the first people in the Aegean to adopt the sail, and that this happened towards the end of the Early Bronze Age (Basch 1987: 93–114; Wedde 2000: 76–80; Broodbank 2013: 353–354; Tartaron 2013: 51). It will be argued here, however, that new evidence places the first use of the sail in the Aegean much earlier, ca. 2550–2200 BC, and it first appeared not in Crete but in the East Aegean, i.e., the western Anatolian coast and its nearby islands, which was the most urbanized and technologically advanced part of the Aegean at that time (Şahoğlu 2005; Kouka 2013). The knowledge of the sail may have come from Egypt via the Levant to the East Aegean, and from there it spread to the Central and West Aegean. Only in the early Middle Bronze Age, ca. 1900 BC, is there hard evidence that it reached Crete. This technology transfer will be situated in the broader historical context of Early Bronze Age trade and human mobility. Finally, it will be briefly indicated how the adoption of the sail facilitated the rise of Aeginetan, Minoan, and Mycenaean maritime trade networks.

Our evidence for ships in the prehistoric Aegean is based mostly on about 400 two-dimensional images and boat models (Wedde 2000; Van de Moortel 2017). Actual boat remains are extremely few and do not give indications about their mode of propulsion (Van de Moortel 2012: 24). Before ca. 2550 BC, there is no evidence for the use of the sail in the Aegean. We have more than 150 boat representations from that era, most of which date to the Final Neolithic (Tel-avantou 2008a) and Early Bronze 2a phases (ca. 4500–2550 BC). Many representations show paddles or oars, and none have a mast or sail. It must be pointed out, however, that in spite of their large numbers, the geographical distribution of these boat images is limited to only ten sites, and only six of those representations do not come from the Cycladic islands: a Neolithic clay model was found at Tsangli, in southeastern Thessaly (Marangou 1991) and five Early Bronze I and II clay models derive from three different sites in East Crete (Fig. 1). Thus, large swaths of the Aegean have not produced boat images in these periods, even though we know that they were active in maritime trade. For instance, Troy and Limantepe (near modern Izmir, Turkey) were important harbor towns in the Early Bronze Age East Aegean, but have not produced a single boat representation. Thus, much information is missing from the archaeological record.

Most of these earliest boat representations are too rudimentary to tell us whether these boats were paddled or oared. However, a well-known clay model from Mochlos, probably dating to the Early Minoan (EM) II phase (Soles 2012: Fig. 12.14) is thought to have thole pins, and would thus have been oared. Thole pins may also be shown on an Early Cycladic (EC) II rock-cut boat from Korphi t’Aroniou on Naxos (Doumas 1965: Fig. 4). Until recently, there has been

¹ The absolute chronology of the Early Bronze Age Aegean is changing as the result of ongoing fieldwork. In this paper, I adopt the chronology proposed by Kouka, Menelaou 2018.

much debate about the identification of the extremities of EC II boats, because none of the then known boat representations showed steering oars to allow the identification of the stern (cf. Marinatos 1933: 182–185; Casson 1971: 31, 41; Basch 1987: 84–85; Wedde 2000: 35–39). In recent years, two rock-cut images of longboats with steering oars have been discovered at the EC II settlement of Vathy, on the island of Astypalaia, which clearly show that the steering oar is at the lower extremity, and that the higher extremity, which often carries an emblem, is the bow, thus finally laying this long-standing debate to rest (Fig. 2a-b; Vlachopoulos 2021: 104–107, 128, 130, Figs 27, 34).

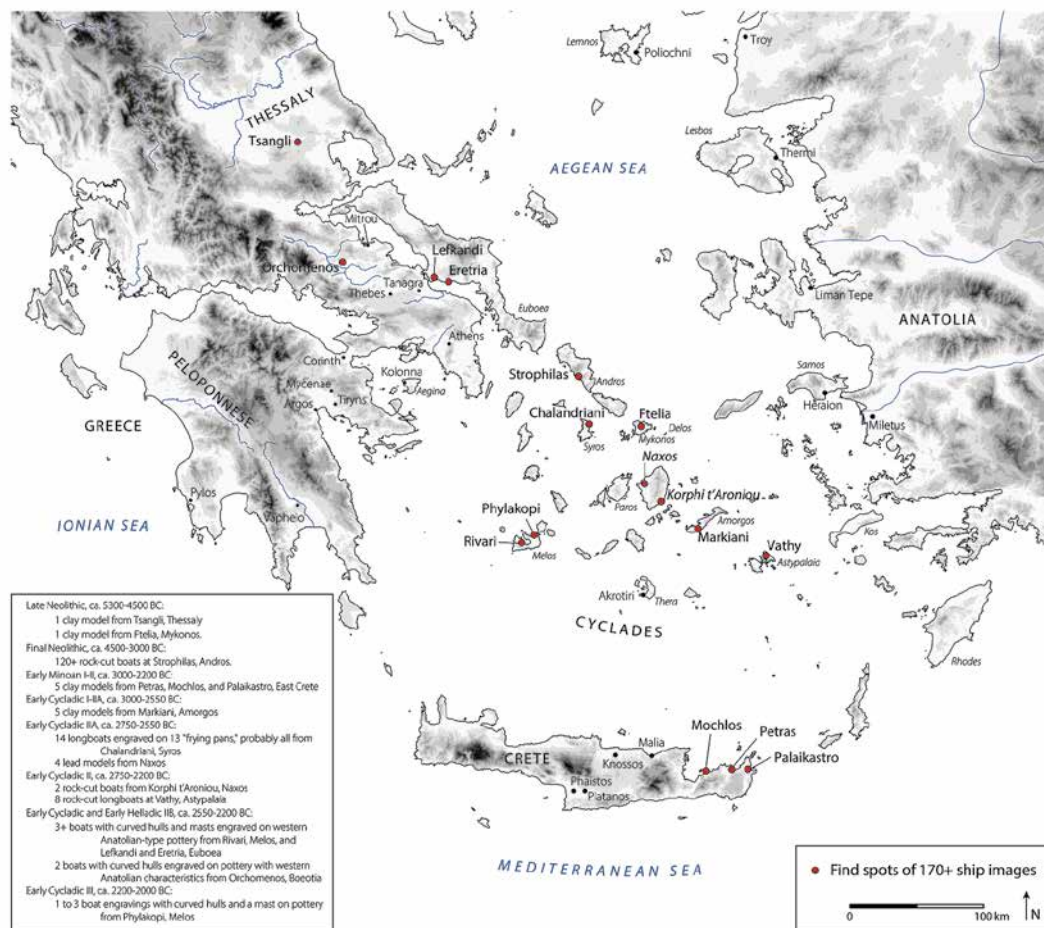


Fig. 1 Map of the Aegean with the geographical distribution of 170+ Late Neolithic and Early Bronze Age boat images with known provenance, ca. 5300–2000 BC (drawing: T. Ross)

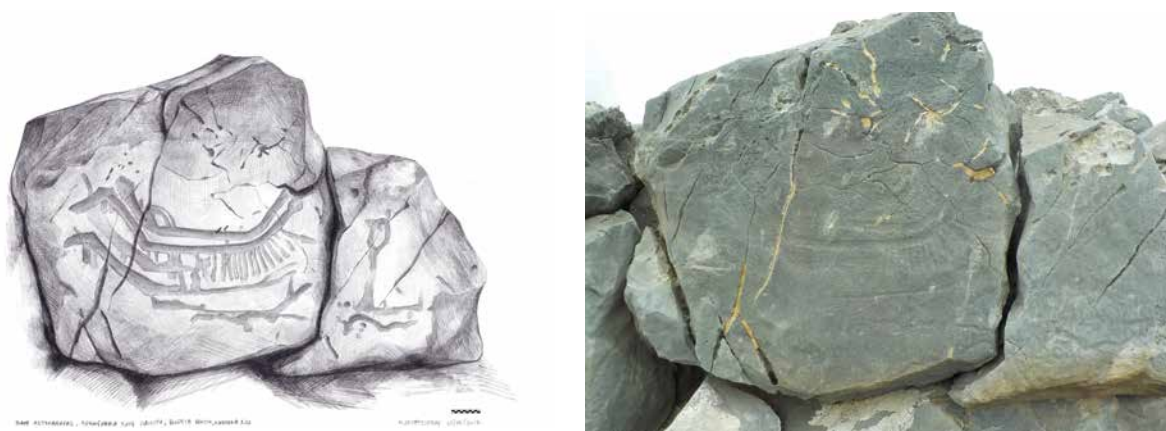


Fig. 2 2a) Three rock-cut flat-bottomed longboats at the EC II settlement of Vathy, Astypalaia, ca. 2750–2200 BC; the second boat has a triangular steering oar at its lower, righthand extremity, demonstrating without a doubt that the high extremity on these longboats was the bow. Fig. 2a (drawing: N. Sepetzoglou; Vlachopoulos 2021: 128, Fig. 27; courtesy of A. Vlachopoulos, Vathy Astypalaia Archaeological Project); Fig. 2b (photo: A. Van de Moortel)

The long-standing idea that the sail was adopted in Crete in the EM III phase, ca. 2200–2000 BC, was based on the presence of ship images with masts engraved on two Minoan seal stones that had no secure provenance. One seal was found at the East Cretan settlement of Palaikastro, embedded in wall plaster in a Late Minoan (LM) I context (Platon *et al.* 1977: 369, 377, No. 261b). The other seal did not come from an archaeological excavation, but was bought at the locality of Andromyloi, in East Crete (Van de Moortel 2017: 266, Fig. 2A; Platon *et al.* 1977: 369, 387, 410–411, No. 276b). Both seal stones have the shape of three-sided prisms, and were dated by Sir Arthur Evans to the EM III phase for several reasons: they were made of soft stones, they lacked hieroglyphic writing of the Middle Minoan (MM) I–II period, and they were of fine quality. To Evans, seals with such characteristics were associated with EM III pottery in the tholos tombs of southern Crete (Evans 1921: 117–118, 123–124, 195–196, Fig. 87; Anastasiadou 2011: 3). However, these tombs were in use for many centuries in the Early and Middle Minoan periods, and their material was notoriously mixed, with contexts not well documented. In 1956 and the 1960s–1970s, a workshop producing such three-sided soft-stone prism seals, mostly made of steatite, was excavated at the palatial settlement of Malia, in northeastern Crete, and its destruction dated to the MM IIB phase, roughly the early 18th century BC. This has prompted a number of scholars to question Evans' dating of those two ship seals. In 2000, Jean-Claude Poursat and Elsa Papatsaroucha redated both seals to the MM II phase, roughly 1850–1750 BC, because of their similarities in material, style, and imagery with seals from the workshop at Malia (Poursat, Papatsaroucha 2000: 265, Fig. 3a–c). Their dating is supported by Maria Anastasiadou in her 2011 comprehensive study of all three-sided soft-stone prism seals from Crete. She assigns those two ship seals to her Malia/Eastern Crete Steatite Group (Anastasiadou 2011: 101, 513–514, Fig. 47, Nos 87b, 90b).

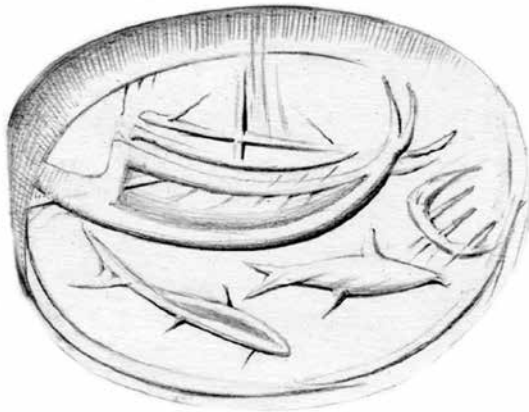


Fig. 3 Drawing of MM IA Late/IB seal from tholos tomb B at Platanos, Southern Crete, which provides the earliest secure evidence for a sail in Minoan Crete, ca. 1900 BC. L = 1.8 cm (drawing: courtesy of the Corpus der Minoischen und Mykenischen Siegel)

Some other seals with sailing ships were previously dated to the EM III/MM I transition, ca. 2000 BC (Kenna 1960; Wedde 2000: 332–333, Nos 703–801), but these have also been redated to the MM II phase by Poursat, Papatsaroucha, and Anastasiadou, including two with an unknown provenance in the Ashmolean and the Brooklyn Museum, which are assigned by Anastasiadou to the Malia workshop (Anastasiadou 2011: Pls 58–60, esp. Pl. 59, Nos 509b, 570a). With the downdating of all these seals to the MM II phase, the earliest well-dated evidence for the sail in Minoan Crete is a three-sided bone seal from tholos tomb B at Platanos, in southern Crete (Fig. 3), which has been dated by Christos Sbonias on the basis of its style to the transition from MM IA Late to MM IB, ca. 1900 BC – just before or at the time when the first palaces were built on Crete (Sbonias 1995: 101; Platon 1969: 330–331, No. 287; Wedde 2000: 333, No. 802). Many early Minoan sailing ships have rather bulky hulls, and it is reasonable to interpret them as specialized cargo vessels.

The construction of specialized sailed merchantmen at this time appears to reflect an increase in maritime trade and a shift from high value/low bulk cargoes to low value/high bulk cargoes. All this supports the thesis that an increase in maritime trade was an important economic driver that made Minoan elites wealthy and contributed to the rise of a hierarchical, palatial society. These early representations on Minoan seals are very small (1–2 cm as a rule) and do not show much detail of rigging, but the Late Cycladic I Miniature Ship Fresco from Akrotiri, on the island of Thera, includes much more detail, making it clear that the rigging of the depicted ships closely resembles that of Egypt (Doumas 1992, 69, Fig. 35; Casson 1975; Basch 1988; Wachsmann 1998, 96–99). Because of these close similarities, Basch's interpretation that Crete had adopted the sail from Egypt has been widely accepted, as Crete and Egypt had increasing trade contacts at that time (Basch 1988: 8–10; cf. Broodbank 2013: 341–347; Tartaron 2013: 53; see Wedde 2000: 76–80, 90–92 for a more complex borrowing route).

However, recently iconographic evidence has come to light that links the first appearance of the sail in the Aegean not to Crete but to the East Aegean. It shows beyond a doubt that the sail was known in the Aegean already in the Early Bronze Age, and this roughly in the third quarter of the third millennium BC. In 2008, Christina Televantou published images of potter's marks found on EC IIB (ca. 2550–2200 BC) shallow bowls from the cemetery of Rivari, on the Cycladic island of Melos. One of these potmarks is a schematic ship image with a mast (Fig. 4a; Televantou 2008b: 213–214, Fig. 21.14; Sampson, Fotiadi 2008: 218–219). In 2018, Sylvie Müller Celka reported the discovery

of similar potmarks on a wheel-finished shallow bowl from Lefkandi and a semi-coarse pottery fragment from Eretria, both located on the island of Euboea, and dating to the contemporary Early Helladic (EH) IIB phase (Fig. 4b-c; Müller Celka *et al.* 2018: 202–203, Fig. 10). All these potmarks are about 4 cm long and represent boats with curved hulls. It is important to note that all these boat engravings with masts occur on vases of the so-called Kastri and Lefkandi I groups, which have western Anatolian characteristics. Many of the bowls are wheelmade and their surfaces are plain or have been red to brown or black slipped and burnished. Their shape and surface finish is western Anatolian, as is the fact that they were wheelmade. They represent the earliest products of the potter's wheel in the Aegean (Choleva 2020: 15–20), and are part of an elite Anatolian eating and drinking set that was introduced into the Aegean presumably together with new elite commensal practices (Mellink 1989; Kouka 2013: 577).



Fig. 4 Potter's marks in the form of boats with asymmetrically curved hulls and masts on EC IIB and EH IIB shallow bowls and a vase with western Anatolian characteristics from (a) Rivari, Melos; (b) Eretria, Euboea; and (c) Lefkandi, Euboea (after Müller Celka 2018: 203, Fig. 10; courtesy of S. Müller Celka). These provide the earliest evidence for the use of the sail in the Aegean, ca. 2550–2200 BC.

The sail and the potter's wheel were not the only technical innovations coming from the East Aegean around 2550 BC. Tin bronze, or bronze made from an alloy of copper and tin, also was introduced into the Central and West Aegean at this time, whereas previously only arsenic bronze was known (Stos-Gale *et al.* 1984: 23). I have argued that also a new shipbuilding technology based on the principle of the expanded logboat was introduced at this time (Van de Moortel 2017). My hypothesis was based on the fact that these boat representations on Anatolian-type pottery are the first ones in the Bronze Age Aegean to show curved hulls, and their curvature is asymmetrical, which is a characteristic of the expanded logboat (Van de Moortel 2012: 24–25). One could rightly object that the potmarks are too rudimentary to provide certainty, but a much more detailed engraving on an EH IIB hybrid jug from Orchomenos, in Central Greece, which has a local shape but an Anatolian surface finish, shows a boat that resembles an Early Cycladic longboat, but with a bottom that is curving in a decidedly asymmetrical fashion, rising less towards the (high) bow than towards the stern (Fig. 5). Hulls with similarly asymmetrical curvatures are seen in later Aegean ship images such as the Miniature Ship Fresco from Akrotiri and MM and LM depictions from Crete (Van de Moortel 2012: 24–25, Fig. 3.8; 2017).

In view of the close similarities of the Late Bronze Age Aegean rigging with Egyptian rigging, I would hypothesize that the sail was not invented in the East Aegean but introduced via the Levant from Egypt, where the sail was first attested (Fagan 2004: 14; Van de Moortel forthcoming: note 62). Recent research has demonstrated that ca. 2600 BC a number of small regional trade networks in Anatolia coalesced into what Vasif Şahoğlu has called the Anatolian Trade Network (Şahoğlu 2005; 2019). This terrestrial and maritime network linked the Aegean coast through Anatolia to Mesopotamia overland, and to the Levant via a maritime route that ran along the south coast of Anatolia (Mellink 1989; 1993; Choleva 2020: 7, 8). This Anatolian Trade Network

brought new goods and knowledge from those eastern regions to the East Aegean, including the potter's wheel, which was invented in North Syria in the 4th millennium BC, and arrived in Cilicia and Troy by the early 3rd millennium BC. I would propose that also the knowledge of the sail, possibly together with the expanded logboat technology, was brought to the East Aegean from the Levant via the southern Anatolian maritime route.



Fig. 5 Paddled or oared longboat with an asymmetrically curved hull (max. pres. W = 7.5 cm) engraved on the handle of an EH IIB Boeotian askos from Orchomenos, Boeotia, ca. 2550–2200 BC; the two slanted lines above the hull do not belong to the ship but are part of the handle decoration (photo: A. Van de Moortel; courtesy of Chaironeia Museum).

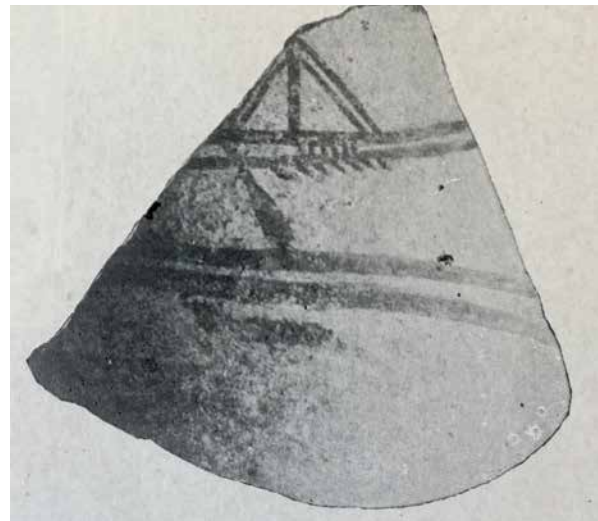


Fig. 6 Fragment of a two-handled jar (max. pres. L = 9.7 cm) from Phylakopi I or II with painting of a sailing ship with curved hull, EC III-Middle Cycladic, ca. 2100–1700 BC (after Edgar 1904: pl. XII.23; courtesy of Society for the Promotion of Hellenic Studies, London)

Current scholarship on the transfer of complex technologies emphasizes the need for prolonged and intense contact between teacher and apprentice (cf. Choleva 2020: 2–6). Where and how the adoption of the potter's wheel and tin bronzes happened in the Early Bronze Age Central and West Aegean has been a matter of debate. Some scholars (Davis 2001: 74; Kouka 2013: 577) have described these processes as local adaptations resulting from increased trade contacts between the East Aegean and the rest of the Aegean. Others (Rutter 2012: 73–79, Şahoğlu 2005: 352; 2019) have proposed that East Aegean migrants moved west and settled in other parts of the Aegean, bringing with them the new technologies. Şahoğlu has argued most forcefully for this hypothesis, and sees these movements as a westward extension of the Anatolian Trade Network. This migration hypothesis is supported by a recent study by Maria Choleva (2020) of the adoption of the potter's wheel, which provides strong evidence for mobility of East Aegean or Anatolian potters to the west. Much of the Anatolian-type pottery found in the Central and West Aegean has been made in local fabrics, including wheelmade vases. This observation had led scholars to conclude that these vessels had been made by local potters who had traveled east and learned to use the potter's wheel there. However, Choleva was able to demonstrate that this was not the case. She found that the potter's wheel was used exclusively for a small number of high-quality Anatolian-type drinking, eating, and serving vessels in the Central and West Aegean, and especially for shallow bowls, whereas local pottery shapes as well as many Anatolian-type vessels continued to be made by hand. What is more, the large majority of wheelmade Anatolian-type vases show a consistent *chaîne opératoire*, or production-step sequence, which includes using the wheel for joining coils, thinning the vessel walls, and shaping the roughout (Valentine Roux' Method 3: Roux, Courty 1998), whereas fewer vases display various *chaînes opératoires* using the wheel only for thinning and shaping (Roux' Method 2). These *chaînes opératoires* are mostly found at Lefkandi and Palamari (on the island of Skyros) and have links with the northeast Aegean and northwestern Anatolia. Given the difficulties involved in building and using the wheel, and the intense prolonged cooperation required for apprentices to learn the required cognitive and motor skills of a technique and *chaînes opératoires* that then were used only for a small subset of vases, Choleva argues, convincingly in my opinion, that the potter's wheel was introduced into the Central and West Aegean by mobile groups of northwestern Anatolian potters, most probably located at Lefkandi and Palamari, who eventually taught the new technology to local apprentices, possibly resulting in its spread to other Aegean settlements.

It is proposed here that the transfer of the new shipbuilding technology and the sail may have happened in much the same way. Given the very different boatbuilding principles and understanding of the properties of wood involved in the construction of expanded logboats and their multi-part descendants as compared to boats descended from ordinary logboats, I think it is likely that also this technology as well as the sail were introduced to the Central and West Aegean by traveling East Aegean boatbuilders. However, it is unlikely that there were large waves of East Aegean migrants into the Central and West Aegean, because there is too much continuity in local material culture and practices in those regions. Rather, we should envision small groups of people seeking their luck in the Central and West Aegean. Sometimes they traded or merged with the local population, and sometimes they created their own short-lived settlements, as I have argued for Kastri on the Cycladic island of Syros and for Panormos on Naxos (Van de Moortel forthcoming; cf. Bossert 1967; Angelopoulou 2014). The superiority of the expanded logboat design and the use of the sail would have made those East Aegean seafarers more mobile than the Central or West Aegean people using their traditional paddled or oared craft consisting of unexpanded logboats and their descendants, and this may have made the East Aegeans very successful also at raiding local settlements. One could compare their technological advantage to that of the Vikings in medieval northern Europe, who used the expanded logboat principle to build superior seagoing vessels that allowed them to be more mobile and carry out far-flung voyages of colonization as well as surprise raids in western Europe (Crumlin-Pedersen 1972; 2010: 49–51, 65–117).

By the Early Bronze 3b phase, starting ca. 2100 BC, the Anatolian Trade Network had collapsed, and so had much of maritime trade in the Central and West Aegean, breaking apart into smaller networks (Alberti 2012). Only three ship images are known from the EC III phase and Middle Cycladic period, and all come from Phylakopi on Melos (Fig. 6; Edgar 1904: 91, 104, 179, No. I 4, pls. V.8c, XII.23; Wedde 2000: 314, 316, Nos 416, 509; Van de Moortel forthcoming). Since they occur on local Cycladic-style vases, they suggest that curved hulls and the sail were now at home in the archipelago.

Two regions survived this collapse relatively unscathed, and in the vacuum thus created, they developed their own maritime trade networks. One was the small island of Aegina, near Athens, where the urban settlement of Kolonna in the course of the Middle Bronze Age (ca. 2000–1700 BC) established a maritime trade network reaching from the Saronic Gulf down to the East-Central Peloponnese and up to Thessaly through the Euboean Gulf, to judge by the distribution of its pottery (Gauss, Knodell 2020). Its ever-growing massive fortification walls as well as the presence of weapons and a helmet on two of its ship representations, painted on Middle Helladic II barrel jars from Stratum IX, dating ca. 1800 BC, indicate that Kolonna had the military and naval power to support its trade network (Gauss 2019: 66; Siedentopf 1991: 6b, 24–25, 45–46, 62, Pls 14, 35–38, Nos 75, 158, 162; Van de Moortel 2020: 323–325, Fig. 18.3). These painted Aeginetan ships have similarly asymmetrically curved hulls as the East Aegean and Cycladic ships, and thus would arguably have descended from expanded logboats.

The other region that took advantage of the Anatolian collapse was Minoan Crete, which from ca. 1900 BC onwards developed highly complex palatial societies that, to judge by the distribution of pottery and other cultural characteristics, were increasingly involved in maritime trade with the Greek mainland, the Cyclades, the southeastern Aegean, the Levant, and Egypt. This long-distance trade by the Minoans was made possible by their adoption of the sail and their construction of specialized cargo ships with rounded bottoms. Co-incidentally, Minoans also adopted the potter's wheel about the same time, ca. 1900 BC (Van de Moortel 2006: 328–329; Berg 2015: 19–23).

At the beginning of the Late Bronze Age, ca. 1700 BC, the rising power of Mycenae in mainland Greece arguably took over the Aeginetan trade network. Around 1450 BC, after the destruction of most Minoan palaces and settlements on Crete, Mycenaean elites also established control over Crete and the Minoan maritime trade network. The few ship depictions that we have from the Mycenaean palatial period, ca. 1370–1200 BC, including reassembled fresco fragments and a graffito from the palace of Pylos (Brecoulaki *et al.* 2015; Egan, Brecoulaki 2015), as well as a Linear B sign from Knossos, display mostly asymmetrically curved hulls comparable to Minoan and Cycladic hulls, which likewise must have descended from expanded logboats. These ships also have Minoan-type masts and rigging. However, some Mycenaean representations from the 13th century BC, such as small clay boat models with curved hulls from Tiryns and Tanagra, and an unpublished fragmentary fresco from Orchomenos (Aravantinos, Fappas 2015: 324; <https://www.mthv.gr/en/permanent-exhibition/mycenaean-period/#image-40>), testify to the existence of asymmetrical ships with a vertical stem and a curved stern comparable to the many well-known representations of Sea Peoples' ships from the 12th century BC Aegean (Van de Moortel 2017: 267–268, Fig. 4b; 2020). In spite of the relative scarcity of ship images, it is clear from the wide geographic distribution of Mycenaean pottery and the dispersion of Mycenaean cultural practices that with the aid of well-built ships descended from expanded logboats, and with the sail, Mycenaeans were able to develop the most intensive maritime trade network of the Late Bronze Age Aegean.

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Ship graffiti on the East Adriatic coast

Ita Praničević Borovac

Abstract: On the insular and coastal area of Dalmatia about thirty sites with ship graffiti from Antiquity to the end of the 19th century have been found. Three quarters of the graffiti are found on sacral edifices, with a lesser number found on profane buildings or on rocks above the sea. Particularly valuable are ship drawings from earlier centuries, that, due to the lack of other information from that period, present valuable visual data about historic vessels, providing insight into the daily life and the rational world of the earlier inhabitants of this part of the Mediterranean.

Keywords: ship graffiti, Dalmatian coast, historic ships, drawing, ex-voto

The inhabitants of the coastal and insular area of the indented Eastern Adriatic coast, have since time immemorial based their living on activities related to the sea – fishing and trade, salt production and trade, and shipbuilding of specific vessels adapted to local maritime conditions. The ancient ships that sailed the Adriatic are testified by material remains discovered on the sea bottom. These ships are mentioned and sometimes described in detail in written sources, but valuable visual information is also preserved in a number of visual and artistic representations, of which the so-called graffiti presented here are particularly interesting. The term graffiti, already accepted in archaeology and art history, denotes an informal quick and simple text or drawing, executed by carving or drawing by charcoal stick on a hard surface – wall of a building, on a rock, on wood or on ceramics – used by an individual or group to communicate a message in a spontaneous and honest way (Baird, Taylor 2011). Graffiti are considered to be direct historical sources, revealing thoughts and emotions of their creators ‘behind’ the representation, giving us an insight into daily life of coastal residents and seafarers (Basch 1978; Delouca 1996; Artzy 1999; Muscat 1999; Westerdahl 2013; Damiandis 2014; Champion 2015; Demesticha *et al.* 2017; Gonzales Gozalo 2017; Van de Moortel, Langdon 2017; Nakas 2021). Perceived as type of visual documentations, these drawings become more precious with their age, particularly when they date from an era that otherwise provides only scarce or even no information at all (Ray Martin 2001: 18, 134–137, Figs 122–125).

The following paragraphs provide a short overview of ship graffiti discovered until the present on the Dalmatian coast, their characteristics, time and context of appearance and possible interpretations of their meaning.

The interest for this phenomenon in Croatian science has developed rather recently – the first few texts mentioning them were published in the 1960s (Gušić-Fisković 1958; Fučić 1962; Kečkemet 1962; Petricoli 1968). In the last twenty years several papers about this topic have been published (Praničević Borovac 2001; 2002; 2005; 2016; 2021), and the number of newly discovered graffiti has increased as well. Research is still going on and new finds can be expected.

Along the coast and islands from Kvarner to Dubrovnik, from Antiquity until the end of the 19th century, there is a total of 32 sites, and as many of the sites contain several representations of vessels, the overall number of ships displayed exceeds 100 (Fig. 1).

Most of the drawings are found on sacral edifices: 25 sacral sites have been discovered to date. They are mostly town churches – among them are four cathedrals (Zadar, Trogir, Split, Dubrovnik), but also smaller churches on the edges or outside of settlements and even at distant, isolated sites such as open-sea islands. Two drawings were found on parts of monastery complexes (Badija – cloister, Živogošće – belfry). Seven drawings belong to non-sacral edifices and are situated on the walls of public buildings (Šibenik – jail, Dubrovnik – granary) or private houses (Drvenik, Korčula), and on a natural cliff above the sea (Senj, Viganj). In the towns of Zadar, Trogir, Split and Dubrovnik, several sites with graffiti have been found on various edifices dating from different periods.

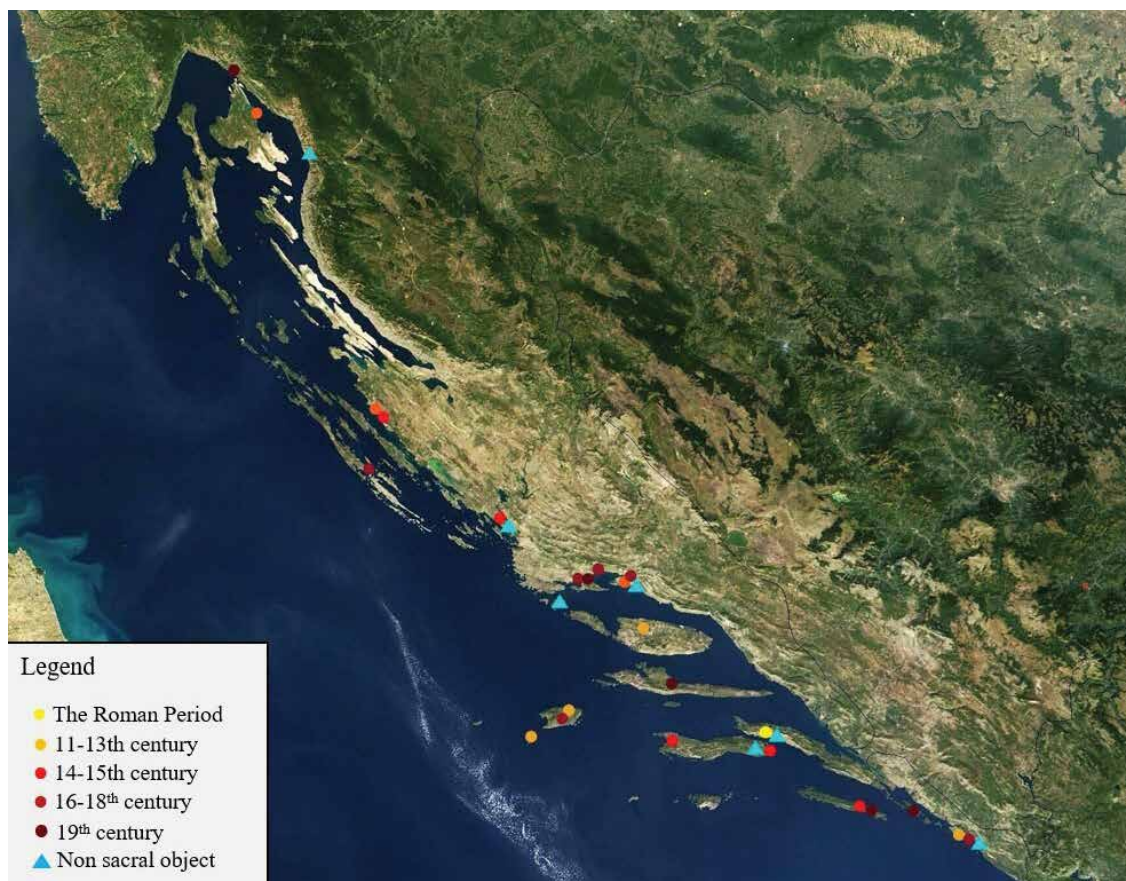


Fig. 1 Map of the Dalmatian coast with marked location of the sites where ship graffiti have been found (author: I. Praničević Borovac)

As spontaneous creation and quick execution are crucial features of this visual expression, it is not surprising that most of the registered drawings were made by inscribing the stone or plastered surface of an exterior or interior wall surface of a building with a sharp object. On two examples, the discovery of pigments indicates that after being inscribed, the graffiti were coloured (Krk, Split). About one third of the ships were drawn by charcoal (burnt stick), while a few of them were made by red lead – *minium* (Pb3O4,) used for colouring (painting) consecration crosses, which may facilitate the future dating of these drawings.

Dating graffiti is a particularly challenging task. There is no information about them in archival documents, and they are not mentioned in descriptions of the buildings where they were inscribed. The *terminus post quem* is certainly determined by the time of construction of the building, and in some situations, *terminus ante quem* can be ascertained based on detected reconstructions or alterations that modified the original space of the building and covered the drawings (thus preserving them until the present). The determination whether the drawing is simultaneous with the construction, or made at a later, or much later moment, is sometimes possible according to technical data about the material and type of construction – if the drawing was inscribed in fresh, first mortar it may be presumed that it was simultaneous with the building's construction. If, on the other hand, it was inscribed in a dry surface, then the estimated dating is based on other arguments.¹ A crucial element in determining the time when the graffito could have been made lies in the appearance of the ship itself, i.e. it is based on recognizing the type of vessel according to its shape and details – shape of hull, prow and stern, ship's equipment such as: number of oars, presence or absence of stern rudder, the number and inclination of the masts, shape of sail, etc. (Kozličić 1993).

The earliest representation of a graffito is on a cliff,² on the southern side of the Pelješac Peninsula, which together with the opposite, northern coast of Korčula Island creates the Pelješac Channel, since ancient times an area of dense sea traffic (Rapanić 1972). Drawings of two smaller ships can, with necessary caution, be dated to Antiquity, that is to the period of Roman administration, based on the appearance and proportions of the drawn boats and, their close

¹ For example, on the medieval church of St. Barbara on Šipan Island, built inland from the coast, several ship graffiti are engraved in mortar on the exterior side of the southern and northern wall, which are dated to the mid-19th century, as the year 1861 was also engraved into the mortar.

² As the drawing hardened during nearly two millennia, it can be considered a petroglyph.

similarity with the amber figurine of a ship with an oarsman from Nin dated to the 1st century (Suić 1969). Archaeological context – the discovery of a shipwreck of the Roman *navis oneraria*, at the sea bottom under the rock where the drawing stands, although not necessarily connected, confirms that this strait was frequently used in antiquity, but also dangerous for navigation which may indicate a possible motivation for the creation of this graffiti.

About 10 medieval sites yield very valuable representations dated from the end of the 11th until the end of the 15th century that have survived until the present date. In these centuries, when there are extremely few works of art with maritime motifs, and those vessels that are represented are most often a small part of a biblical scene, it is the graffiti that bring extremely important facts about the appearance of medieval ships. We find several types of so-called long ships designed for combat missions, as well as larger so-called round, merchant ships with three masts, and smaller merchants, with one mast holding a square sail.



Fig. 2 Graffiti of ships (about 20 x 30 cm) from the Dubrovnik cathedral, late 11th century photo: archive of the Maritime Museum Dubrovnik)



Fig. 3 Interior of the Early Medieval church of St. Luke on the island of Brač with a drawing (about 100 x 80 cm) of a ship on the west wall (photo: I. Praničević Borovac)

The earliest precisely dated medieval ship graffiti in Dalmatia date from the end of the 11th century. These are six drawings of long ships with a multitude of oars, each with one or two masts (Praničević Borovac 2001: 77–85) (Fig. 2). The drawings are small, inscribed into the plastered skin of a pylon by the apse of the pre-Romanesque Dubrovnik cathedral (Stošić 1988).³ Approximately at that time or at the beginning of the 12th century, graffiti of at least three ships, (very likely even more), were made in the small pre-Romanesque Church of St. Luke on Brač Island. Precisely inscribed in fresh mortar, of beautiful proportions and portraying clear details such as a stern rudder, two tilted masts with a triangular sail and fifteen oars, stands the portrait of a historic vessel known as the 'sagena' (Domančić 1960; Kozličić 1993) (Fig. 3). Of similar features, but drawn in charcoal and unfortunately not preserved in their entirety, graffiti of historic ships were discovered on Vis Island some twenty years ago, in the chapel of St. George, an early church of long existence, built on the seaside at the entrance to Vis harbour (Praničević Borovac 2001: 51–54), and in the only church of St. Sylvester, on the open-sea island Biševo (Praničević Borovac 2002).

The economic rise of harbour towns on the studied area of the Croatian coast, from the 13th to the 15th century, is reflected in graffiti of merchant sailboats discovered in the Romanesque chapel of St. George on Krk Island (Fučić 1962) (Fig. 4) and on the exterior stone surface of the old Split Cathedral (Praničević Borovac 2005). Additionally, maritime conflicts, including pirate incursions never lacking in this part of the Mediterranean, were documented by drawings in the interiors of sacral edifices – Stomorica Church in Zadar (Petricioli 1968), St. Vitus near Šibenik (Praničević Borovac 2001: 35–39), and SS. Cosmas and Damian in the interior of Korčula Island (Praničević Borovac 2001: 64–76).

³The dating is reliable and is based on archaeological research undertaken after the earthquake in 1979, which determined the sequence of construction and reconstructions of the Dubrovnik cathedral over more than a thousand years (Stošić 1988; Peković 1998; Vežić 2014).



Fig. 4 Engraved and painted drawing (about 120 cm) of a merchant sailing ship in the church of St. George, is land of Krk, 13th century (photo: I. Praničević Borovac)

The time of rapid changes that marked the new age from the 16th century onwards brought an extreme leap in artistic expression. That said, the increase in both the quantity and the versatility of art works produced, including the appearance of engraving techniques and the possibility of multiplying art templates (which, along with other types of graphic works, made *isolarii*, portolan charts and nautical charts widely accessible), seems not to have had influence on the appearance of ship graffiti. Sketchy and clumsy, yet skilful and detailed, drawings of sailboats, oared vessels and fishing boats were still incised or drawn on church walls, as well as on the walls of houses and palaces, jails, town granaries, and on the rocks rising above the sea.

Some 15 sites with ship graffiti from the 16th until the end of the 19th century have been discovered along the Dalmatian coast, with many of them displaying more than one vessel. Examples of such graffiti include (approximately in chronological order): a precise drawing in *minium* of a galley with a crew on a stone block of the wall of the cloister of the Franciscan monastery on Badija islet; a graffito at the entrance to the Pelješac Channel (Belamarić 1983); and an elaborate drawing of a galleon and another small sailboat in the interior of the parish church of St. Mary in Sali on Dugi Otok, a village of strong fishing and maritime tradition (Kečkemet 1962: 573). In the Trogir Cathedral of St. Lawrence graffiti can be seen in two locations, the result of two mutually unrelated acts of inscribing – a representation of a boat on the southern facade made in *minium* (Kečkemet 1962: 562), and a later graffito, recently discovered group of sailboats and horsemen drawn in charcoal in the apse. Not far from Trogir, in Kaštel Lukšić, on the interior side of the southern wall of the parish church dedicated to the Ascension of the Blessed Virgin Mary is a hardly noticeable small drawing of a small, oared vessel, shallowly scratched in dry mortar (Praničević Borovac 2021). Also, worth mentioning are two sites on the islands of Hvar and Mljet with several similar circumstances – graffiti of ships are incised on the outer side of the walls of the parish churches built in the last quarter of the 19th century (on the sites of earlier churches), in old settlements on the slopes of the hilly interior of the islands, far from the sea. On Hvar, façade on the Church of St. James in the village of Pitve displays graffiti of several larger and many smaller sailboats, and on Mljet the Church of St.



Fig. 5 Drawings of ships (about 20 cm), on the exterior of the church of St. Anthony the Abbot, island of Mljet, late 19th century (photo: J. Amadeo)

Anthony the Abbot in Maranovići clearly displays engraved boats (Fig. 5). Interestingly, not far from Maranovići, the chapel of St. Mary of the Hill had a drawing of a smaller sailboat made in *minium* on the facade of a small church, done in the same medium, and logically at the same time as the gothic consecration crosses dated to the 15th century (Gušić, Fisković 1958: 90). Unfortunately, the church has no roof and is in very poor condition, and the remains of the drawing are nearly completely faded.

Among the ship graffiti on non-sacral edifices – family houses or public buildings, some are still legible and in good condition, such as several drawings from the 18th century found in the cellars of the former Rector's Palace in Šibenik, an area that once served as prison (Bilić 2013: 178, Fig. 1). These drawings can be seen today in the basement of the Šibenik City Museum. Graffiti have also been found in the building of the former Dubrovnik granary that presently houses the Rupe Ethnographic Museum. The many graffiti there, textual and pictorial, are mostly from the 16th and 17th centuries including about a dozen sailboats drawn in charcoal (Fig. 6a) and the very skilful representation of a Dubrovnik carrack (Fig. 6b). The rocks along the Senj Podgorje, rising above a centuries-old dense maritime traffic route used by small boats on local trade routes as well as large merchant ships, yielded a considerable number of simple paintings of various motifs and different ages, among which are about a dozen representations of different types of ships – smaller, coastal sailboats, *grips*, large *naves* etc. (Glavičić 1975: 209–210, Figs 54, 56, 57).⁴

Some concluding thoughts at the end of this short overview:

- Ship graffiti are a valuable archaeological and historic source of information about the appearance and features of historic vessels. Each single drawing, at each site is unique, even when a certain drawing is part of a larger group – the final result is an authentic and original 'portrait' of a ship.
- Although there are some representations of larger galleys/dromons or larger merchant sailboats, representations of smaller boats are more prevalent, including fishing boats, warships, and merchant ships. The sizes of the drawings vary from the smallest of about ten centimetres to the largest ones whose longitudinal axis is one meter. However, smaller graffiti are more common.
- The authors of graffiti are unknown individuals, seamen, fishermen ... but certainly art amateurs whose 'art' reveals directness, naïveté, and fresh expression.
- The purpose of the graffiti is revealed by the site and way of execution. Those on the church walls are religiously motivated and are most often interpreted as an expression of lay piety, as a form of vow, gratitude for salvation from distress at sea, or as a 'drawn prayer'. However, other locations demonstrate that there are other motivations driving the artist to make the drawings. A sailboat drawn on the facade of a palace, could be an advertisement of availability; a graffito placed on the wall of a jail cell may be the reminiscence of happier days of free living, and still others may have been made of necessity while describing an event at sea or in harbour by means of an image, or even rendered just out of boredom etc.
- This phenomenon of drawing ships seems to be, from time immemorial, very widespread in all coastal areas, and the Eastern Adriatic is no exception. There must have been many more of these graffiti produced along the coastlines and islands of Dalmatia over the centuries comparison to the small number of graffiti preserved by coincidence and discovered to date.

⁴ According to scholars it may be concluded that these drawings were warnings of sites of accidents that should be avoided.

Studying this style of preserved history provides an opportunity to draw attention to the fragility of precious testimony from the past, reflected in their dilapidation (especially those executed in charcoal), and the need for their preservation.



Fig. 6 Ship graffiti in the City Granary Rupe in Dubrovnik, 17th century: a) graffiti of sailing ships, 15-30 cm (photo: A. Vukoja); b) graffito of argosy, about 40 x 50 cm

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Iran's last sewn boat? In search of the beach-seining *āmele* along the Persian Gulf coast of Hormozgan Province, Iran

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Abstract : Recent ethnographic fieldwork along the Persian Gulf coast of southern Iran by the lead author has located probably the last-known sewn vessel in the country – a disused, beach-seining boat known in Bandari as *āmele* (عامله) and Arabic as *‘āmila* (عامللة) in the village of Bostane, in Hormozgan Province. The research has also yielded new information about this type: its former distribution within Hormozgan is established, its function is elucidated, and aspects of its materials and terminology are documented for the first time. The work builds on previous work by the three co-authors documenting sewn vessels of the same type acquired from Iran by Qatar Museums, Doha, in 2012, and reported at that time as *baggāra* (Persian بگاره; Arabic بَغَارَة) on the basis of museum records.

Keywords: Persian Gulf, Iran, *baggāra*, *āmele*, sewn boat

1. Introduction

In this paper, we report the discovery of what is probably Iran's last-known sewn boat known in the local Bandari dialect of Persian as *āmele* (عامله) and in Arabic as *‘āmila* (عامللة)— and demonstrate the benefit of ethnographic collaborations with coastal communities to inform our understanding of nautical technologies. Sewn construction is a long-standing practice found until recently along Iran's Persian Gulf coast and around the neighbouring Arabian Peninsula, but which came to a rapid halt in these regions amid the emergence of the oil economy in the mid-twentieth century C.E. and the appearance of new boatbuilding technologies such as fibreglass. Indeed, this tradition was once widespread around the western Indian Ocean (Moreland 1939a; 1939b: 63–67; Hornell 1941: 60–61; 1942: 28–33; Hourani 1951: 92–93; Le Baron Bowen 1952: 202–210; Prins 1982; 1986: 64–94, 100–111; Adam 1985; Kentley 1985; 1996; Kapitän 1987: 135–148; 2009: 66; Kentley, Gunaratne 1987: 35–48; Shihab 1987: 41–58; Varadarajan 1995; 1998; Vosmer 1993; 2007: 236; 2019: 305; Prados 1996: 99; Flecker 2000: 199–200; 2001: 336–337; 2011: 101; McGrail 2001: 71–72; Agius 2002: 78–81; 2008: 138–140, 148–150; Camelin 2006: 103–108; Ransley 2009, vol. 1: 88–125, vol. 2: 10–127; 2012; Shaikh *et al.* 2011; Jansen van Rensburg 2016: 114–115; Burningham 2019; Dixon 2019; Fenwick 2015; 2019; Ghidoni 2019: 375; Shaikh 2019: 377; Staples, Blue 2019; Weismann *et al.* 2019). Today, however, it persists only in parts of India (Kentley 1985; 1996; Kapitän 1987: 135–148; 2009: 66; Kentley, Gunaratne 1987; Varadarajan 1995; Ransley 2009, vol. 1: 88–125, vol. 2: 10–127; 2012; Shaikh *et al.* 2011; Fenwick 2015; 2019; Shaikh 2019). Some survivals have, by now, been documented in detail (Vosmer 1997: 227–234; Shaikh *et al.* 2011; Fenwick 2015; 2019; Weismann *et al.* 2019). So too have a small number of archaeological finds (Blue *et al.* 2011; Belfioretti, Vosmer 2010; Ghidoni 2023). Yet, much of the associated intangible knowledge held by maritime practitioners – builders and fishers – has been lost with time.

In 2012, Qatar Museums (QM) acquired five small sewn vessels from the port of Bandar Lenge in Hormozgan, the most southerly of Iran's Persian Gulf coastal provinces; these were subsequently documented in Doha in 2019 by the secondary authors of this paper (Cooper *et al.* 2020). Their work on the structure of the boats – isolated in their museum context – left many questions unanswered, including geographical distribution, function, construction sequence, materials and linguistic terminology.¹ It is these lacunae that this paper, drawing on ethnographic methods, seeks to address.²

¹ The terminology presented in this paper is, unless otherwise indicated, from the Bandari dialect of Persian, which is centred on Hormozgan Province; much of it is shared with Arabic. Bandari is indicated by 'Bd.' in the text, Arabic as 'Ar.' and Persian as 'Pr.'

² Interviews were conducted by Shadi Kalantar in 2021–2022 while she was doing her survey on traditional vessels of Iran for her PhD thesis. John P. Cooper, Chiara Zazzaro and Alessandro Ghidoni contributed by designing the questions for interviews, methodology, further studies and writing. Additionally, even though interviews were translated from Arabic to Persian by Mr. Ebrahim Ahmadi, who was present during the interviews, further interpretations were done by John Cooper using the recorded interviews on video.

The results presented here were gathered through observation and interviews conducted in 2021-2022 by the lead author during fieldwork along a section of Iran's Persian Gulf coast within which the QM vessels had been acquired (Fig. 1). The survey formed part of her PhD research, which focused on Iranian watercraft traditions. It was also prompted in part by reports of a similar vessel to the QM boats having been seen in the village of Bostane, in western Hormozgan.³ This 'vessel' turned out to be a concrete sculpture, but during the lead author's resulting visit, she nevertheless identified the remnants of a sewn vessel in the village and interviewed Esmail and Abdollah Esmaili, two of the adult children of its late builder and owner, Mr. Mohammad Salem Esmaili (Fig. 2). Both in their eighties, the brothers provided much of the new information in this paper. The interview was conducted in Arabic and Persian (mostly in Bandari dialect) and video-recorded, and later translated into Persian by Ebrahim Ahmadi. Other interviews during fieldwork were conducted in Persian and are duly cited in the footnotes. While all four authors identified the broad topics of enquiry before the fieldwork began, the interviews were open-ended, allowing interviewees to offer insights into unanticipated areas.



Fig. 1 The survey area, from Asaluye in Bushehr Province to Biahi in Eastern Hormozgan. The green circle indicates where the sewn *āmele* was found; the blue circles where (nailed) *baggāras* were observed (image: S. Kalantar).

2. A tale of two coasts

Realisation within academic circles of the survival of any working sewn boats in the Persian Gulf region emerged only following the QM acquisitions in 2012. Identified by QM staff as *baggāras* (Arabic بَغَارَة) at the time of acquisition, these were reported as such in 2020 by Cooper *et al.* Focusing on the three best-preserved examples, Cooper *et al.* conducted a close investigation of the vessels' construction method and sewing and lashing systems, carried out 3D photogrammetry, and reverse-engineered construction and naval-lines drawings (Fig. 3). The survey revealed craft that were almost entirely sewn, following a stitching method that has been attested widely across the western Indian Ocean region over centuries – inboard stitches over wadding following a XIXIXIXI pattern, and outboard stitches recessed into vertical rebates (Hornell 1941: 62; Bowen 1952: 205; Chittick 1980: 301–303, Figs. 7, 8; Prins 1986: 100–111; Prados 1996: 102–103; Vosmer 1997: 231–234, Fig. 25; Camelin 2006: 105; Belfioretti, Vosmer 2010: 113, Fig. 6; Vosmer 2019: 308; Weismann *et al.* 2019). However, the QM vessels' garboard-to-keel stitching secured both the port *and* starboard garboard planks within the same stitching run, something that had previously been undocumented, adding to their significance (Cooper *et al.* 2020: 16–18). Also striking was their use of a thick, black coating outboard, provisionally identified as bitumen, and of an unidentified grassy material used inboard as overstitched wadding along the planking seams (Cooper *et al.* 2020: Fig. 12).

The scope of the QM work did not allow for materials analysis, for example to establish timber and plant-fibre species or the provenience of the bitumen used. Moreover, the situation of the study – in a museum collection on the Arabian coast, removed from the vessels' place of origin – precluded access to the communities that had created them, and hence to their geographical, social, and technological contexts. Equally, Cooper *et al.* had no access to information regarding their provenience beyond their year and location of acquisition. Nor could the project, perforce, offer any indication of the state of survival of any such craft in Iran itself.

³ This information was kindly provided by Dr. James Onley, Ms. Fatemeh Teimoorzadeh, and later by Mr. Masoud Shorouj and Mr. Ebrahim Ahmadi.



Fig. 2 The *âmele* of Bostane: (A) stitching of the keel; (B) the sewn and bitumen-coated hull planking; (C) planking and a frame from inboard, showing much damage to the stitching; (D) profile view – the length over all is 9 m and the beam 2.4 m; (E) Abdollah and Esmail Esmaili (first and second from left), sons and former assistants of the builder, together with Ebrahim Ahmadi (third from left), who introduced us to them, along with the lead author (right), in Bostane, 2021 (photo: M. Shorouj)

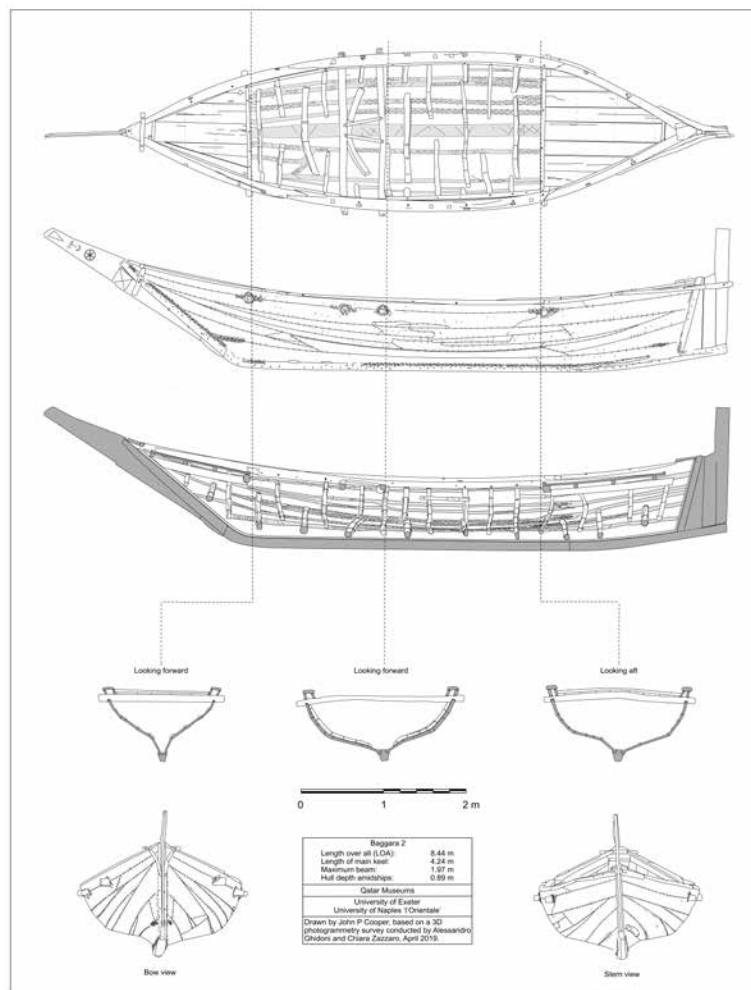


Fig. 3 Construction drawing of “*baggāra*” number 2 held by Qatar Museums, now re-identified as an *âmele* (drawing: John P. Cooper; from Cooper *et al.* 2020: 374)



Fig. 4 A concrete sculpture of an *āmele* in Bostane (photo: S. Kalantar)

3. Distribution – and a survivor

These lacunae were addressed by the lead author's 2020–2021 fieldwork. This focused on Hormozgan Province, where it covered 24 sites along the mainland coast, from Ziarat in the west to Biahi in the east, as well as the islands of Qeshm, Hendorabi, Larak and Lavan. It also visited the port of Asaluye in neighbouring Bushehr province (Fig. 1). Enquiries among local people in these locations established that boats of the type acquired by QM had once been common in an area of western Hormozgan bounded by Gorze in the west and Gashe in the east; the vessels in the QM collection had been acquired within this zone, at Bandar Lenge.

The potential of the village of Bostane, just west of Gashe, had first been brought to our attention by Dr. James Onley and Ms. Fatemeh Teimoorzadeh, who had sent to us a recent photograph of what turned out to be a concrete sculpture of one of these vessels in the main square (Fig. 4). It was a resulting visit there that revealed the only surviving vessel of this type encountered during the survey. This abandoned example was not as well-preserved as the three reported QM vessels. The hull was distorted; some frames and planks were broken or missing, and its cordage was highly eroded (Fig. 4). But it stands as the only known sewn vessel of any kind surviving in Iran: it was subsequently removed by the Institute of the Studies of Traditional Navigation and Lanj-Building to a boatyard in Kong for safekeeping. Plans for the conservation of the vessel are yet to be finalised.

Interviewees outside of the distribution range indicated above were often not familiar with this sewn-vessel type. For example, informants at Kong, further east, advised: “you should go [west] to Hasine... and Gorze to find them: we never had them in Kong.”⁴ It was also unfamiliar to people west of the distribution area, such as in the village of Chiruye. One informant there, on seeing a picture, said he remembered vessels of that shape in the village around fifty years ago, but could not remember whether they were nailed or sewn – they might therefore have been similar nailed vessels we discuss below.⁵ People on the islands were equally unfamiliar with the type, and with sewn fishing boats more generally. Informants on Larak told us that the nailed *jalkash* (Bd. جلکش), a boat with a structure that is largely similar to *āmele* (Fig. 6), had once been common on their island, and was still to be found on Qeshm, but not these sewn craft.⁶ Meanwhile, people on Hendorabi and Lavan islands did not have a memory of any vessel called *āmele* nor *jalkash*.

⁴ Interviews with Mr. Ali Bahri (Nakhoda Hamood), spring 2021, and Mr. Ali Mahmood Najarbashi, spring 2022, Kong.

⁵ Interview with Mr. Hasan Mozafarnia, winter 2021, Chiruyeh.

⁶ Interviews with Mr. Ali Vali (Ali Sheikh) and Mr. Ali Laraki, spring 2022, Larak.

4. When a *baggāra* is not a *baggāra*: definitions, differences, and complications

What quickly became apparent during the Hormuzgan survey was that local people refer to the sewn boats of the type found in the QM collection as *āmila* in Arabic or *āmila* in Bandari (Bd.) dialect, rather than the term *baggāra* that Cooper *et al.* reported in 2020 on the basis of QM information.^{7,8} Esmail and Abdollah Esmaili explained that the term *āmele*/*āmila* refers to a small fishing boat with a long and upright stern fin (Bd. *dom*; Ar. *fashīn*) and raking stempost: crucially, it is sewn and bitumen coated – just like the QM vessels. Moreover, the vessel was only used in beach seining for sardines (*hashīne*), since it was not structurally strong enough for other activities.⁹ Four rowers, from a crew of eight, would row the vessel from the beach for a short distance, deploying a small-gauged seine net as they go, before arcing back to shore to close the loop. The net would then be hauled onshore, rather than onto the boat.¹⁰

“In Bandari, the term *āmele* is given not only to the boat, but also to the seine net, and indeed even to the seining method itself. When in standard Persian (Farsi) the lead author asked children in Bostane village “Where are your fathers?”, they answered: “they went *āmele*”,¹¹ meaning “beach-seining”.



Fig. 5 The nailed *baggāra*: (A) an example at Ramchah in 2017; (B) the same vessel in 2022, having suffered significant damage; (C) one of two *baggāras* observed at Jask (preserved length 6.7 m; beam 1.2 m) (photos: S. Kalantar); (D) men at the stern of a *baggāra* in Jask in the 1970s (photo: courtesy of H. Heidari)

What, then, of *baggāra*, the term used by QM staff? Our informants said that this in fact applies to a different vessel, very similar in overall form to the *āmele*, but nailed rather than sewn, and not coated with bitumen. They said it is often also larger than the *āmele*, the hull of which is typically no more than 8 m in length, excluding the prow timber (Bd. and Ar. *saṭūr* (ساطور), although this was *not* the case for the surviving *baggāras* we observed. The *baggāra*'s hull is relatively rounded, but still with an angled, ‘rocker’ keel like that of the *āmele*¹² (Fig. 5A-D). The lead author observed three of these nailed craft in Hormozgan. One, abandoned at Ramchah on the south-eastern shore of Qeshm island, was well preserved when first observed in 2017 (Fig. 5A), but subsequently badly damaged during construction of a harbour (Fig. 5B). A further two, highly damaged, were noted in 2021 in the port of Jask in the eastern part of the province (Fig. 5C).

⁷ Interviews with Esmaili brothers, sons of the late builder of the surviving *āmele* in Bostane, and Majid Arang, grandson of the late owner, Spring 2021, Bostane.

⁸ Interviews with the Esmaili brothers and members of the Bostani family who owned the surviving *āmele* in Bostane, Spring 2021, Bostane.

⁹ Interviews with the Esmaili brothers and Bostani family, spring 2021, Bostane.

¹⁰ Interviews with the Esmaili brothers and Bostani family, spring 2021, Bostane.

¹¹ Pr. «رفتند عامله»

¹² Interview with the Esmaili brothers, spring 2021, Bostane.

The *āmele* and *baggāra* are not the only fishing craft of southern Iran with an angled ‘rocker’ keel. Another variant of the *baggāra* is the *jalkash* (Bd. جلكش), which occurs mainly on Qeshm island. Like the *baggāra*, it is nailed and has no bitumen coating; its prow and stern ‘fin’ are similar in over-all shape to both the *āmele* and *baggāra*, and its length is similar to the former. Its main difference to the *baggāra* is that it has no stem-head (Fig. 6). Meanwhile, on Qeshm, the terms *zārūqa* (Bd. زاروقه) seems to have been an alternative name for the *jalkash*: retired fishers said either that the two were identical or that the *zārūqa* was somewhat bigger.¹³

It should be noted that the terms we use are those used by Bandari-speaking informants, and our usage of them accords with our observations and interviews conducted along the wider Iranian coast of the Persian Gulf. Type names may well be applied differently on the Arabian coast, and to different vessel types, and may well be pronounced differently. The naming of mutually similar inshore fishing vessels in Iran and on the nearby Arabian coast has certainly exercised ethnographers such as Prins (1972–1974: 164), Vosmer (1997: 220), Agius (2002: 183–184) and Weismann *et al.* (2014: 418–420).



Fig. 6 The *jalkash* of Gambrun, island of Qeshm (length overall: 7.8 m; beam 2 m) (photo: S. Kalantar)

5. The builders and the building process

It became clear from our fieldwork that the well-known *āmele* builders of the region had by now passed away. We learned of builders formerly in Gashe and Bostane, the latter being Mohammad Salem Esmaili, whose sons Esmail and Abdollah we interviewed. They recalled that as teenagers they had helped their father build *āmeles* on ground directly in front of their house (Fig. 6E).

The broad construction of the *āmele* has already been discussed by Cooper *et al.* (2020) based on analysis of the QM vessels. The brothers’ description of a hull comprising five strakes resonates well with the QM vessels, albeit without the latter’s complex use of stealers, drop-strakes and graving pieces. So too does the brothers’ description of the framing configuration, which comprises pairs of half-frames (Bd. and Ar. *shalmūn*/شلمون) alternating with floor timbers (Bd. *atfe* (عطفه); Ar. *atfa* (عطفة)). The brothers also remarked that the design on the stem-head (*saṭūr*) of an *āmele* was unique to each builder: having inspected images of the three published QM boats, they concluded that none had been built by their father.

¹³ Interviews with Saleh Talenda and Hasan Tanide Nezhad, spring 2022, Iran, Qeshm.

The brothers were particularly helpful in providing names of the parts of the boats, as well as identifying the materials used in the construction process – neither of which topics Cooper *et al.* (2020) had been able to pursue. They identified the timber used for the keel (Bd. and Ar. *bīs* (بيس) and framing elements as *karat* (Bd. and Ar.; قراط), probably *Acacia nilotica*, and that of the planking as mango (Bd. *anba* (انبه) (*Mangifera indica*). Abdollah said the latter: “is porous and absorbs water, so the planks enlarge once the vessel is in the water and the gaps between the planks are filled.” The brothers said that the garboards are stitched to the keel using cordage made of *kambār* (كمبار), or coconut coir, a material widely used in western Indian Ocean sewn-boat construction (Hornell 1941: 60; Hourani 1951: 91–92; Bowen 1952: 203; Varadarajan 1993: 556; McGrail 2001: 72, 354; Agius 2002: 80; 2008: 148–149; Fenwick 2015: 390; 2019: 390–392; Vosmer 1997: 231; 2019). They said that the dowels used in, for example, edge-joining the hull planks and fastening the hood ends (Cooper *et al.* 2020: 11–20), were made of *bāskil* (باسكيل), which they described as a dense, bamboo-like material imported from India. The wadding – that is, the cushion of vegetal material laid beneath the stitching and along the seams inboard (Cooper *et al.* 2020: 16–20) – is made from a grass that Abdollah Esmaili called *nabakh* (نابخ), which we tentatively identify through linguistic translation as a grass of the genus *Bromus*. On coatings, the brothers confirmed that bitumen (Cooper *et al.* 2020: 21–23) – bought in the local market – was applied outboard, with shark-liver¹⁴ oil (Bd. *sīfe* (سيفه); Ar. *sīfa* (سيفة)) applied inboard.

6. Conclusion

This article has underlined the value of ethnographic research in enhancing our knowledge of artisanal watercraft and their contexts. The fieldwork conducted by the first-named author along the southern Iranian coast has enriched our understanding of the last surviving sewn-boat type of the Persian Gulf – correcting our understanding of its name, establishing its former distribution, and adding important detail regarding its materials and construction. The construction, technical features and building sequences of the vessels had previously been detailed by Cooper *et al.* on the basis of examples in the QM collection, where it was identified as a *baggāra*. However, the geographic and social context, as well as the intangible knowledge of these crafts, remained little understood.

The lead author’s ethnographic enquiry revealed that these vessels are in fact called *āmele* among the communities that made and used them, and that they were used only inshore, for beach seining. It has established their former distribution between the villages of Gorze and Gashe in the western part of Hormozgan province. Meanwhile, the insights of the sons of a former builder have enabled us to understand more about materials and construction of a vessel type that has become all-the-more important by virtue of being the last sewn boat type of the region.

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¹⁴ The brothers did not specify the species of shark, but the first author’s enquiries elsewhere on the northern coasts of the Persian Gulf and Gulf of Oman have previously identified whale shark (Bd. *kūli kar* (كولي كار)).

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The dugout canoe from São Tomé and Príncipe; The results of an archaeo-anthropological mission

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Abstract: The aim of this article is to present the findings of a research mission carried out in February 2020. The authors gathered evidence of the construction of wooden dugout canoes on the islands of São Tomé and Príncipe, with the goal of documenting and comprehending their manufacturing process, from the felling of the tree to their use on the water. This study analyses a very important element of the cultural tradition of an archipelago that is struggling to survive due to environmental problems, lack of interest from younger generations, and the introduction of fiberglass, a more durable and safer material.

Keywords: shipbuilding, maritime community, ethnoarchaeology, West Africa, Gulf of Guinea

1. Introduction

The conception of this paper began with a research trip carried out in February 2020 as part of the project *CON-CHA: The construction of early modern global cities and oceanic networks in the Atlantic: An approach via Ocean's Cultural Heritage*, a staff exchange project funded by the European Community, based on CHAM - Centre for the Humanities, Portugal, and a satellite project of the UNESCO Chair of Ocean's Cultural Heritage at the NOVA University of Lisbon.

The main objective of the archaeological mission was to assess the scientific potential of São Tomé and Príncipe's archaeological heritage, especially its maritime heritage. To date, no archaeological work has been carried out in the country and no articles have been published on the subject in the last 50 years, except for the very recent article published in *World Archaeology* (Mitchell, Lunn-Rockcliffe 2021). The authors have tried to develop the study of the canoes of São Tomé and to document and understand their manufacturing process, from the felling of the tree to their use on the water.

This article is about the experiences and observations the authors made during this mission, with the main objective of drawing attention to the daily life of communities living on the border between land and sea, where the beach is a fluid scenario and different ecosystems of people, animals, flora, canoes, tools, and necessities meet. It is in this context that this study appears: an analytical and comparative look at a forgotten island reality that struggles daily to survive and thrive.

2. Historical and geographical background

The archipelago of São Tomé and Príncipe lies in the Gulf of Guinea in the Atlantic Ocean, south of the equator (Fig. 1). The archipelago is of volcanic origin and consists of two main islands, São Tomé and the Príncipe, but also of several small islets. Its location below the equator line leads to two different climatic zones during the year. Between October and May is the time of heavy rainfall, violent thunderstorms, and high temperatures. Between June and September, we have what is known as *gravana*, characterised by dry weather and almost no rainfall (Frade, Correia da Costa 1956: 31–33).

As with other islands in the Gulf of Guinea, the natural wealth of the archipelago lies in its vegetation cover, true ‘lush gardens’ created by the abundant rainfall and the hydrographic network. In fact, São Tomé and Príncipe has one of the densest and most biodiverse forests in the world and was designated a World Biosphere Reserve in 2012 by UNESCO¹.

The island of São Tomé was discovered in December 1470 and Príncipe in January 1471. However, there are some authors who claim that the island of São Tomé was already inhabited when the Portuguese arrived (Santo 1979). The truth is that no evidence has been found on either São Tomé or Príncipe that points in this direction. If there was contact before the arrival of the Portuguese, no traces are known to date (Ambrósio 1984: 7). Settlement began in the 1480s, in a process very similar to that on the islands of Madeira, Azores and Cape Verde (Tenreiro 1961: 651). Over the years, the islands were cultivated with different agricultural crops (Brásio 1954). First it was sugar in the early 16th century, a result of the growing demand in Europe. Then coffee at the end of the 18th century and cocoa at the beginning of the 19th century (Agência Geral do Ultramar 1964: 21; Henriques 2000: 26). The society formed by Portuguese, foreigners, slaves, and freedmen went through different scenarios of socio-political tensions and rebellions (Seibert 2015: 110–111; Caldeira 2016: 18). The plantations were sites of constant tension between subjugates and subjugated. A few decades after the widely known Cadbury slavery case (Mateus 2018: 213–222), an episode occurred that led to the 1953 massacre of Batepá, a terrible day in the history of this land, caused by the Portuguese authorities (Rodrigues 2018: 30; Castaño 2012: 35). From this misfortune came the seeds of São Tomé and Príncipe’s independence, which was achieved in 1975.



Fig. 1 Geographic location of the islands of São Tomé and Príncipe in the Gulf of Guinea (from Google Earth Pro; January 8, 2021)

3. The archaeo-anthropological mission – Canoes

Any type of boat requires the combination of two factors: first, it must be able to float in all the circumstances in which it is to sail; second, it must move efficiently and in a controlled manner, either by human power, by paddles, or by the wind via sails (Muckelroy 1978: 216).

¹ For more information, please consult <https://en.unesco.org/biosphere/africa/island-of-principe>

Traditional canoes are not simply utilitarian objects; they shape the physical and cultural landscape of São Tomé and Príncipe and are present in various aspects of daily life. They are beings that accompany several lives and are assigned to different tasks. This statement is based on our direct observation and understanding, and examples such as those presented in Fig. 5 document this reality well. In São Tomé and Príncipe, as in many other parts of the world, fishing communities are often isolated and reserved. It can be challenging to gain insight into their way of life. Thus, the contact with the two fishing communities the authors dealt with was only possible through personal contacts, the type of data collected in this study. Our work in relation to this reality was to record several examples of traditional canoes. Maritime archaeology has found in ethnography the appropriate methodology to approach contemporary communities, their crafts, and their activities. This symbiosis arose from the need to record traditions, lifestyles and vessels that are fast disappearing.

During the mission, data collection was done through informal interviews where the authors talked to local fishermen and boat builders. The authors were able to observe the start of a canoe cutting operation in Quimpo and record two canoes: one in Porto Alegre and another in Santo António. The recording was done in three phases: identification and selection of the canoe to be recorded, securing permission and access to the canoe, and the recording itself, which consisted mainly of photogrammetry, detailed photography, and direct measurements. Post-processing of the photogrammetry and drawing was done using Agisoft Photoscan/Metashape and AutoCAD software (Fig. 2). The archaeological record process of the canoes involved the use of a camera, a scale, and an articulated meter. During the informal interviews, we uniquely take fieldnotes. The process of constructing a canoe, as described below, was based on direct observations and a few interviews.

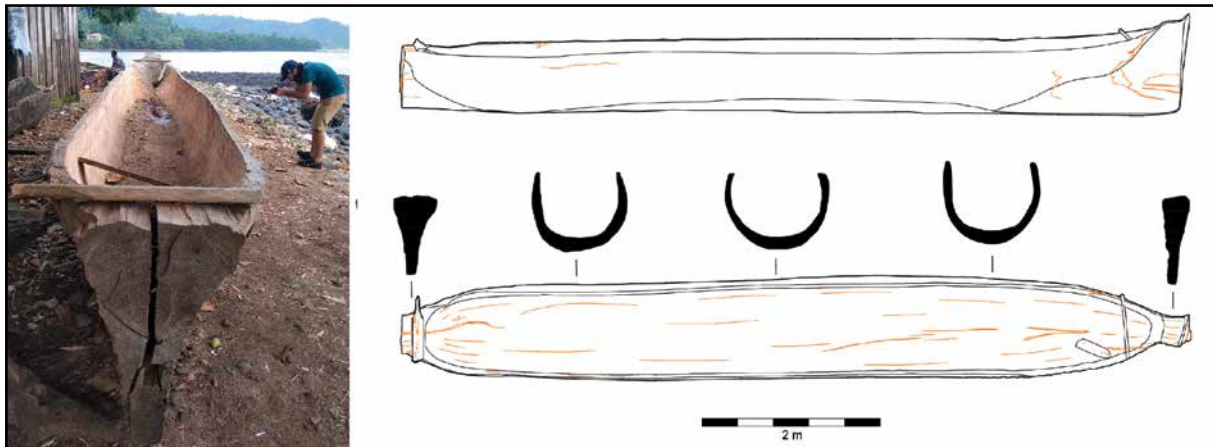


Fig. 2 On the left, photogrammetric record of the dugout canoe in Porto Alegre; On the right, the vectorial draw and sections of the same canoe after all the processing (photo: J. Baço)

The process of constructing a Santomean canoe begins with the selection of the tree to be used, which is always planned according to the lunar cycle, the best time being three days before or after the new moon. Before felling, the tree must be well studied: its girth, the position of the trunk and branches, the environment into which the tree will fall and the best route for transport. To cut down the tree, they first make a cut on the side of the tree where it is to fall, and another smaller cut on the opposite side, providing instability. After a few more small cuts, the tree finally gives way. Most of the time the transformation is done on the spot, but occasionally the branches and some unnecessary parts are cut off and the clean trunk is transported².

The carving is done in three phases (Fig. 3). First, the outline of the canoe is marked on the trunk with an axe (a). The canoes are carved so that their base is in line with the middle area of the trunk to avoid reaching the sapwood (b). Usually, the stern is at the base of the trunk and the bow at the top to take advantage of the morphology of the tree. In the past, several cuts were made with the axe in the trunk until the sapwood was reached, and then the remaining parts were chopped between the cuts (c) and (d). Currently, the outer parts are cut with a chainsaw and then the rest of the trunk with an axe (e). In the second phase, the remaining protrusions are removed, and the overall shape of the canoe is checked with a double bow or stern plate. In the third and final phase, the hull is dug out or hollowed out as the canoe continues to be shaped. As they approach the ends, they smooth the surfaces. At the same time, they check the thickness of the entire canoe, which should be about two fingers thick. The most common tools used in this process are machete, axe, hoe, plane, chisel, drill and nowadays also the chainsaw for larger cuts³.

² Personal information of Hélder, the only canoe builder in Porto Alegre (South of São Tomé Island).

³ Personal information of Lúcio, a canoe builder from Quimpo.

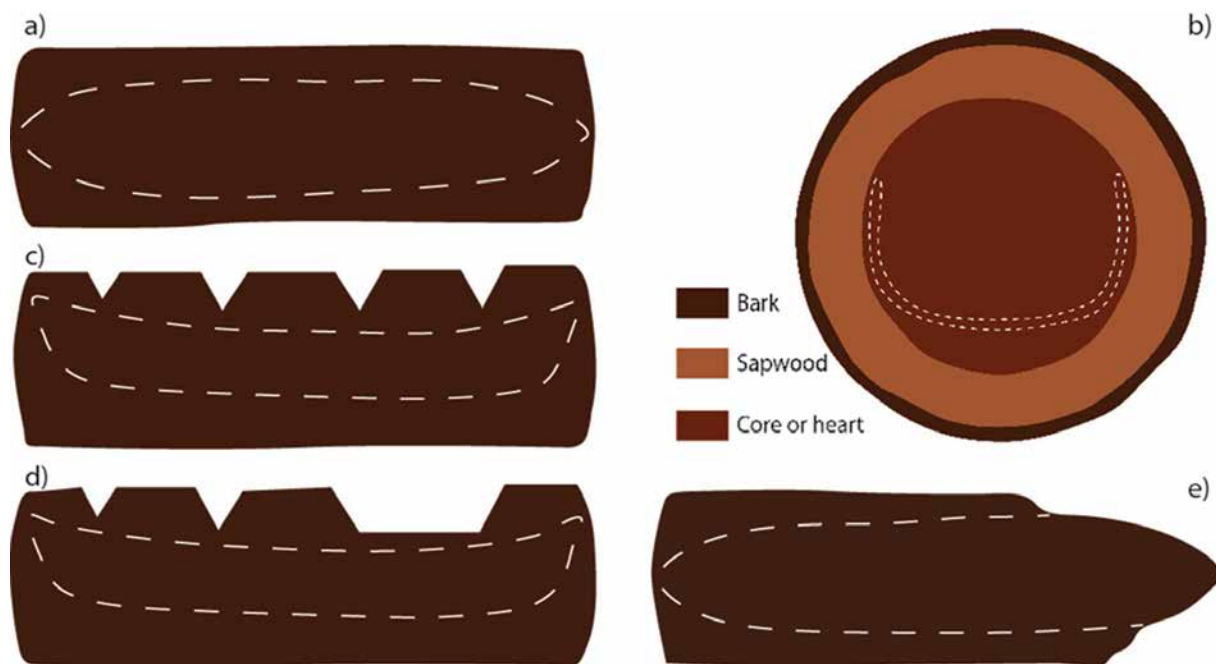


Fig. 3 Sequence of carving (adapted from Fuquen 2014)

The final touches are made in the villages. This stage is about reducing the thickness of the hull, especially on the outside, and smoothing it. It should be noted that the bottom should always be thicker than the sides, as wear and tear is greater both in the water and on land when towing. The bow is usually higher and tapered and the stern lower and wider. It can also be tapered or cut off, creating a sort of small straight stern plate. This change is more recent and is closely related to the introduction of outboard motors in the 1970s. Finally, the boats are launched, which is always a cause for celebration and ends in a big party with music, dances, and palm wine (Lima 1968–75: 171).

Repairs are made because the canoes naturally wear out over time or because they have suffered an accident. There are different types of repairs, but the most common are wooden moulds with tar reinforcement, the use of air chambers or tyre remnants, filling cracks with tar and some metal patches fixed with iron nails, or, nowadays, the use of pieces of plastic, small fibreglass sheets and white glue.

In Sao Tome and Principe, there are three standardised sizes of canoes: the smaller ones are 3 to 4 m long, the medium ones 8 to 10 m, and the largest canoes can be up to 15 m long. On average, however, they are 3.50 to 12 m long, 90 cm wide and 35 to 45 cm deep. In smaller canoes, the crew consists of a single person, maximum two. The larger canoes can be manned by up to eight people.

A first approach to identifying the tree species is to match the native creole or Portuguese name, the English translation and then the species. This is just an exercise based on observation and similarities: *Ocá*, Samauma, *ceiba pentandra guineensis*; *Acácia*, Acacia, *albizzia molucana*; *Fruta-pão*, Bread fruit tree *artocarpus incisa*; *Gôgô*, african crabwood, *carapa procera*; *Cedro Cheiroso*, Cedar, *cedrela odorata*; *Amoreira*, mulberry tree, *chlorophora excelsa*; *Jaqueira*, jackfruit, *artocarpus heterophyllus*.

The species of wood most commonly used locally for building canoes are samauma, acacia, breadfruit tree, african crabwood, cedar tree and mulberry. The trunks of samauma, the most commonly used wood, can grow up to 25 m high and allow the construction of up to four canoes. But even though it is the most commonly used wood, the canoes start to break after two or three years and have to be replaced with new ones.

There is no distinction between river, mangrove, or sea canoes, as they are versatile enough to operate in any of the water environments. The tasks that canoes perform range from fishing near or far from the coast, both during the day and at night, to transporting goods and even people. The lifespan of a river, sea or mangrove canoe is about two to three years, but if the wood is good, harvested at the right time and built with skill, it can be used for 12 or even 15 years. A canoe that travels mainly in salt water has a shorter lifespan as it is worn down by the combination of salt and sun.

Today, many Santomean fishermen use an outboard motor as a means of propulsion. However, as the purchase of an engine and its maintenance are very expensive for the economic circumstances of Santomean fishermen, there are still many who continue to use paddles. Some canoes even stretch sails made from burlap recycled from flour sacks, or nowadays from plastic bags. In Príncipe, there are problems in obtaining and maintaining engines and electrical parts, as these must be bought on the second-hand market in Nigeria or Angola. There is also a shortage of fuel on the island, which affects both fishermen and shipping authorities and endangers the safety and well-being of all.

4. The archaeo-anthropological mission – Communities and traditions

The canoes are a fundamental element in the life of the Santomeans, and many of the activities carried on are only possible through their use. Fishing, for which the use of a canoe is essential, generates the income of more than half the population, while the other half is divided between agriculture, the gathering of fruit and vegetables, and livestock breeding. Even those who pursue another type of activity also fish. There is a saying in the islands: “Every Santomean is a fisherman.”

Canoes are acquired in different ways: they can be bought, with all costs paid to the builder, or favours can be exchanged with the builder and the people he has to hire. The price can also be negotiated depending on the work the acquirer can do. Several people can also get together to buy a canoe and form a kind of cooperative, which then develops into a fishing society and shares the costs and profits. These cooperatives also take responsibility for families who lose their livelihoods for any reason.

The division of labour is clearly defined. The construction and repair of canoes is done exclusively by men. Fishing is almost exclusively done by men, at least the part that takes place at sea, and there are only very sporadic cases where women participate in the work. For example, some women have skills that can help the crew, such as being healers. As a rule, no woman goes out to sea alone, only in exceptional cases, such as when a husband is physically or mentally disabled and his wife gets permission from the community chief to take his place in the canoe. However, when the fish comes ashore, the women play a crucial role because they prepare, transport, and sell the fish. They are also the ones who put the fish to dry in the dryers built by the men (Fig. 4) and clean and preserve the fish.



Fig. 4 Fish dryer registered on the Island of Príncipe (photo: G. Lopes)

5. Final remarks

In some parts of the world, where dugouts are still used today, the construction process differs in small details, depending on the region (Smith 1970: 515; Muckelroy 1978: 127). Santomean canoes fulfil their many purposes in serving the communities, and some find new uses even when they have reached the end of their life at sea, either as a bench, a flower bed, a storage place, or simply as decorative objects in resort gardens (Fig. 5). In any case, they continue to shape the physical and cultural Santomean landscape.



Fig. 5 Different reutilizations of the Santomean dugout canoes (photos: G. Lopes and J. Baço)

The construction logic of Santomean dugouts has not changed significantly since the 16th century. This is indicated by contemporary written and iconographic sources for the Gulf of Guinea region (Smith 1970: 520; Sheves 1991: 49–50). Of course, there are minor technical changes, such as the use of new tools and mechanised means of transport.

Another change is the number of canoes built today, far fewer than in the past. This decline is related to the ecological concerns of the government and also of the population about the sustainability of the Santomean ecosystem. In Príncipe, for example, there is a forest management policy where only people with certain professions are allowed to fell trees (e.g. carpenters and canoe builders). If they do so, they have to plant four trees for every one they cut down. At the same time, it is becoming increasingly difficult to find good quality raw material near the villages because the forests have been over-cut for decades. Therefore, today one has to go further and further into the dense forest, which few want to do. At the same time, boats made of fibreglass have been introduced, which are more robust, durable and cheaper, and have gradually replaced the dugout canoes. And finally, the younger Santomeans seem to have lost interest in learning the techniques of this type of construction, either because they are looking for a job in another economic sector or because it is a knowledge that is considered obsolete. Of the three builders the authors spoke to, only one is passing on his knowledge. On the other hand, the fibreglass boat building workshop is very active and young people are employed.

As soon as it is possible, the authors want to return to São Tomé and Príncipe with several goals in mind: To participate in the construction of a canoe; to participate in a traditional fishing day on the sea and in the river or in the mangroves; to strengthen the relationships started in 2020 with the fishing communities through the aforementioned points, in order to deepen the knowledge of the mysticism and symbolism inherent in the entity of canoe and used by them; and to hand over all the data collected to these communities so that they preserve it, value it, and maintain their traditions.

Acknowledgments

We want to thank all the people that made this mission possible, namely Andreia Pinho Alves, Elísio Neto, Hilton Barros, Jorge Carvalho do Rio, Jovêncio, Abdulai, Hélder, Lúcio, José Assunção, Cláudio Cique, Manuel Mesol Tomé Lopes, Branca Moriés and Luís Sousa Martins.

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READING THE PAST – IMAGINING THE FUTURE (POSTERS)

3D digital study of the historic ship-model “ARIS” of Admiral Miaoulis from the 19th century – VHSS Project; Preliminary Report

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Georgios Tzavaras – Vasiliki Nikolakopoulou – Nikolaos Politopoulos –
Alexandros Tourtas

Abstract: The study of the ship-model of “Aris” of Admiral Miaoulis (Andreas Vokos) (1769–1835) was undertaken in the frame work of the VHSS project. The model was recorded and reconstructed by photogrammetry, laser scanning and conventional measurements. Although it was donated in 1933 (Benaki Museum/Athens), it is considered to have been built during the lifetime of the Admiral. It has a length of 64 cm and it is planked on the starboard side and unplanked on the port side. We propose that the model was built by a shipwright in a scale 1/75. The brig “Aris” was built around 1813 in the shipyards of the island of Hydra and became the flagship of the Greek fleet during the War of Independence.

Keywords: brig, ship-model, photogrammetry, laser scanning, Hydra, Admiral Miaoulis

1. The “VHSS” project

The study and 3D representation of the historic model of the brig “Aris” of Admiral Miaoulis was undertaken in the framework of the project VIRTUAL HISTORIC SAILING SHIPS-VHSS. The project aims to create 3D digital models of 19th century sailing ships based on contemporary 3D physical scaled models combined with drawings, old photographs, technical descriptions, and other contemporary artifacts from museums and archives. The project focuses on the appearance, the function and the construction of sailing ships. The results will be presented by means of virtual and augmented reality, during an exhibition at the Folklife and Ethnological Museum of Macedonia and Thrace in Thessaloniki in 2022. The project is a collaboration of the Institute of Mediterranean Studies (FORTH), the Department of Production and Systems Design Engineering (University of the Aegean), the Folklife and Ethnological Museum of Macedonian and Thrace, and the company TETRAGON. The project is funded by the EPAnEK 2014-2020 Operational Programme “Competition – Entrepreneurship – Innovation”.

2. The ship-model

The physical 3D ship-model of “Aris” is in the permanent exhibition of the Benaki Museum/Athens (Fig. 1). The model was donated to the Museum in 1933 by Stephanos Pesmazoglou, a descendant of the Admiral Andreas Vokos, better known by his nickname Miaoulis. According to the records of the donation, the ship-model was probably built in the era of the Admiral, in the first half of the 19th century. It has a total length of about 64 cm (external points). It is planked on the starboard side and unplanked on the port side. Parts of the inside structure of the model are visible and directly related to the structure of the real ship. The model represents many elements of shipbuilding of the vessels that were built about that period. However, elements of masts and rigging are noticeable absent. It seems that the person who build this model was focused specifically on the hull and its structure and he was confident only on the appearance of this part of the ship.

The model represents the hull of the brig “Aris” of the Admiral Miaoulis. The brig “Aris” was built around 1813 in the shipyards of the island of Hydra, which was a prominent shipbuilding and maritime center of the Aegean before the Greek War for Independence (1821–1830). Under the Ottoman authorities, in the early 19th century, Hydra had a large fleet of merchant ships occupied mainly in trade between the Black Sea and the Western Mediterranean. At the end of the 18th century, many ships of the Aegean islands were built abroad, but in the two earliest decades of the 19th century Hydra had its own shipyards and most of the ships of the island were built there. The model represents that period and reflects the shipbuilding technology of the Aegean boatyards. This is actually the era of the Greek war of independence and “Aris”, like many other merchant ships, was armed and took part in the war. She became the flagship of the Greek fleet during the War (1821–1830) and she was unregistered some time before 1834. The final disposition of the ship is unknown.

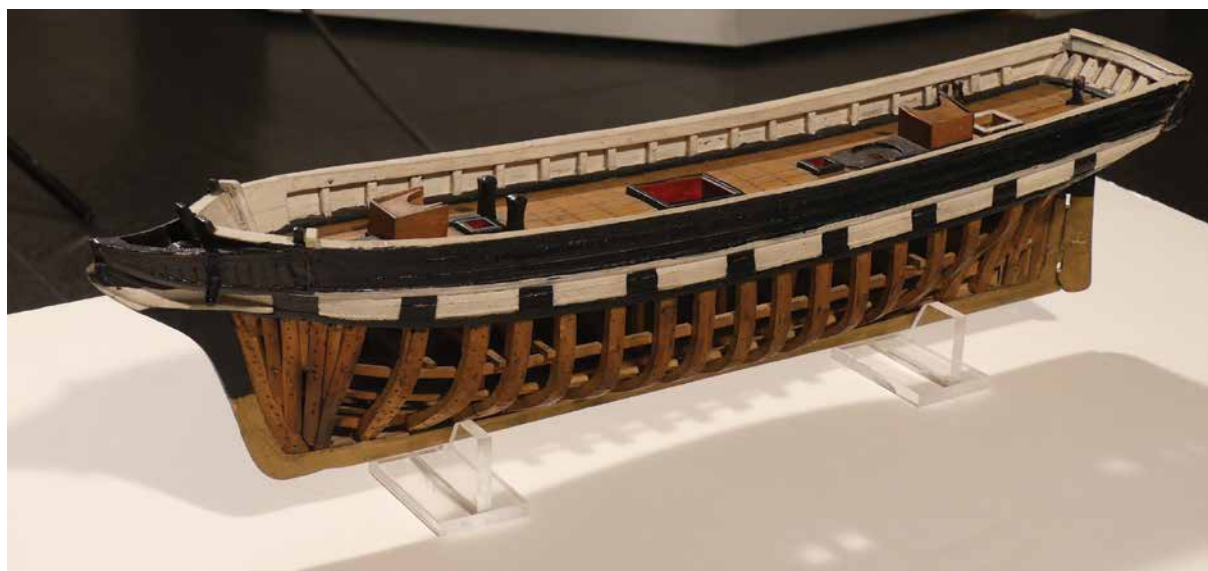


Fig. 1 The model of the brig “Aris” of Admiral Miaoulis, Benaki Museum (photo: K. Damianidis)

2.1. Photogrammetry

The ship-model was digitally reconstructed using the Structure from Motion (SfM) method, a photogrammetric and computer vision technique. The first task, 3D reconstruction, was carried out by two photogrammetric software programs, Agisoft and Meshroom. Both were used to perform intermediate steps of the SfM process such as calibration, image alignment, and depth estimation. Finally, Meshlab, an open-source 3D manipulation software, was used to correct and refine the initial 3D reconstructed model. The final model has a 0.1–0.2 mm pixel size and 355 images were processed in total. The digital camera used was Nikon D5300 Kit (AF-P 18–55mm VR). Through photogrammetric 3D reconstruction, the colored texture of the model and several surface details were captured, enriching the 3D scanned data¹

2.2. Laser scanning

In the second method the ship-model was scanned using the Creaform HandyScan 700 3D scanner which works based on laser triangulation, in conjunction with the VXelements software. Due to the size and detail of the model and the limitations of the hardware on site, a scanning strategy was devised, with numerous sessions, for optimal data acquisition. Special consideration was given to capture inside structural details of the model. A number of positioning targets were placed in order to ensure that each scanning session could successfully be merged with all the others later in the process, in case insufficient surface overlapping occurred. To further optimize the workflow as well as the end result of the digital model, a representative session of the model was first edited in the VXelements software so that the optimal scan parameters could be defined (resolution, optimization and decimation of the scan mesh). The selected method for merging the scanning sessions was ‘Surface best fit alternating with the ‘Target best fit’ to ensure accuracy of the model.

¹ Special acknowledgment to Andreas El Saeer, photogrammetry engineer.

Using the Geomagic DX software the digital model was oriented along a potential axis of symmetry and placed upright, to enable further processing. The working position of the ship-model was stabilized when the keel was theoretically horizontal and the level of the optimal symmetry was determined in upright position. Sections were extracted in order to produce the desired lines plan and 2D structural drawings. The sections were made every 50 mm, every 25 mm at the bow and stern part of the model in order to assist the drawing of the frames, and every 20 mm for the drawing of the water lines and bow and buttock lines, in order to support the 2D naval and structural drawings of the ship model.

2.3. Measurements with conventional methods

The digital recording of the ship-model was supplemented with some close observations of the structure and the use of some conventional measurements in some parts, especially inside the ship-model which was difficult to capture with digital methods. Furthermore, the thickness of some structural elements like the planks, the frames, the keel and the clamps were measured and further structural details were conventionally recorded in the inside part of the model.

The 2D drawings of the structure of the model were based both on extracted sections from the 3D digital models (laser scanning and photogrammetry) and on the conventional measurements by hand.



Fig. 2 The right side of the ship-model (orthophoto: V. Nikolakopoulou)

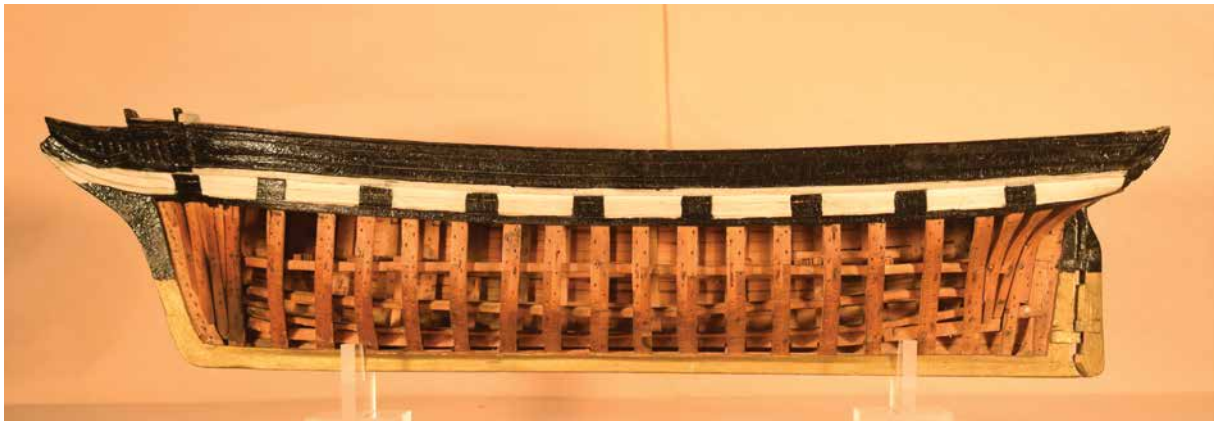


Fig. 3 The left side of the ship-model (orthophoto: V. Nikolakopoulou)

3. Study of the model

Several structural elements that imitate parts of the structure of the original ship appeared on the ship-model (Figs 2–5). However, the small size of the model put some limits to the realistic representation of the components of the original ship and gives uneven evidence for the study of the ships' structure. During the survey on the model, we had to discover whether the model was built according to a specific scale.



Fig. 4 The bow of the ship-model
(orthophoto: V. Nikolakopoulou)



Fig. 5 The stern of the ship-model
(orthophoto: V. Nikolakopoulou)

3.1. Dimensions and scale

The basic dimensions of the model, according to the digital measurements, are:

Total length: 64.2 cm;

Length on deck: 55 cm;

Length of keel (on the rabbet): 46.5 cm;

Maximum width (about the water line C and the frame no.11): 13.5 cm;

Total height: 14.9 cm;

Height from the keelson to the deck (underneath the deck and at the frame no. 10): 8 cm.

In the Historic Archive of Hydra, where the ship “Aris” was built and registered, there is a list of ships from the island that participated in the War of independence. “Aris” was registered in this list under the name of the owner Andreas Miaoulis. It is mentioned that captain of the ship was the son of Andreas Miaoulis and the length of the keel of the vessel was 38 yards (34.75 m). If we consider that the model in the museum was built in a particular scale then the length of 34.75 m should have some relation with the length of 46.5 cm (length of keel) on the model. Indeed, the length of 34.75 m could be represented in 46.3 cm if reduced on a scale of 1/75. This is very close to the 46.5 cm measured as the length of the keel of the model. Furthermore, the scale of 1/75 was a common way of analogical reduction of lengths, when the system of measurement in the Greek shipyards was that of the yard, the feet, the *parmak* (Ottoman unit of measurement equal to 31.57 mm) and the finger.

In this case if we consider that the model was built on a scale of 1/75, then the rest of the dimensions of the ship “Aris” of Andreas Miaoulis, could be derived from that model as following:

Length overall (on deck) = 41.25 m (118.68%);

Length of keel (at rabbet) = 34.75 m (100%);

Maximum width (about the water line C and the frame no. 11) = 10.12 m (29.12%);

Height from the keelson to the deck (underneath and at the frame no. 10) = 6 m (17.27%).

These dimensions and specifically the percentages of them are very close to the percentage dimensions of other brigs that were built in the first half of the 19th century (Damianidis 2014: 327; Delis 2014: 342; Tzamtzis 1987: 29).

3.2. The lines

The lines plan of the model that was produced from the digital records has seventeen frames, four water-lines, and three bow and buttock lines (Fig. 6). The model has some distortion, because of its age, especially at the bow. Thus, a lines plan was produced for each side of the model, and after some corrections a final lines plan incorporating both sides of the model was produced.

It seems that the shape of the hull is very carefully determined for the entire length of the model. The bow is wide on the deck but going further down, below the water line D, the frames become flared and give a moderately sharp entry. The middle part of the hull is fairly wide from the water line B up to the top. However, the body below water line B has a moderate reduction of the breadth and it gives a slightly wider V-shape bottom floor. It is remarkable that the maximum widths of the different water-lines are located in different vertical positions on the hull. The stern has the typical wide transom of the brigs of that period, and the deck remains considerably wide as far as the very aft part of the ship. Below water line C, the bottom of the stern becomes markedly narrow giving a fine run aft.

Considering that the model was built with frames and ‘planks’ like the building of real ships, it seems unavoidable that the model-maker used some kind of lofting technique, possibly from the original lines plan of the ship.

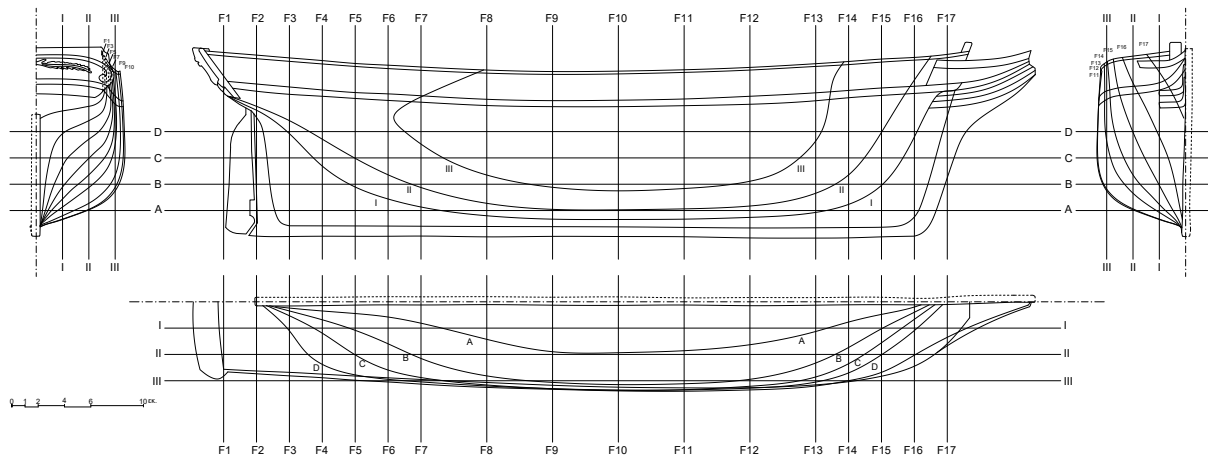


Fig. 6 The lines of the ship-model (drawing: G. Tzavaras, K. Damianidis)

3.3. Structural components

The structural components of the model can be dimensioned following the scale 1/75 of the whole model. The keel has a cross section 6.8×10.4 mm on the model, and that could be about 51×78 cm for the original ship (this large cross section of the keel it is not easy to be formed by a single tree trunk and probably indicates that it was consisted of at least a false keel, a main keel and a deadwood).

The model in the museum has 18 full double frames (Fig. 3) and six cant frames on the bow (Fig. 4) and another five cant frames on the stern (Fig. 5). The cross section of the double frames of the model is 9.1×5.4 cm. The double frames consist of 11 pieces (probably like the original ship) in a double row with an overlapping assembling of the joins (Fig. 7). The pattern of the pieces overlapping assembling “changes at the middle frames. The frames fore amidships have the floor timbers on the aft row of the double frames while the frames aft amidships have the floor timber on the fore row of the double frames. This structural detail, which is still in use in the Aegean boatyards, is another indication that the model-maker of this model was very familiar with the technical process in the shipyards. The model doesn’t represent the full number of frames that would be on the original ship. This is because of the scale of the model and perhaps the model-maker deliberately decided to reduce the number of frames on the model. However, he was able to produce other structural details that he considered critical and they are related directly to the construction of the real ship.

The stern has a transom (square stern) and several reinforcing components (Fig. 5), like counter timbers, taffrail, wing transom, fashion frame and filling transom pieces. This kind of stern for sailing ships was very common in the first quarter of the 19th century and later was replaced by the elliptical or counter sterns. The records about this kind of stern are limited in the Greek sources and the model is very valuable from this point of view.

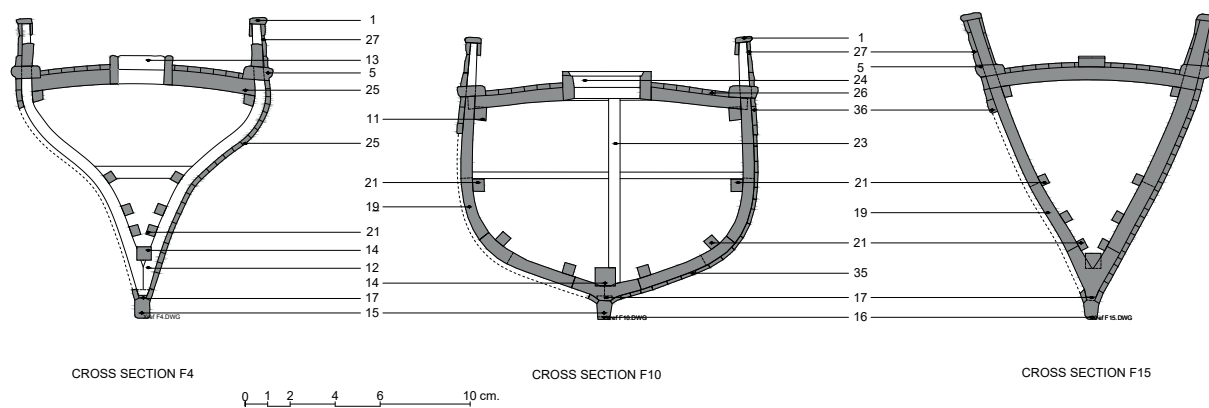


Fig. 7 The cross sections of the ship-model (drawing: G. Tzavaras, K. Damianidis)

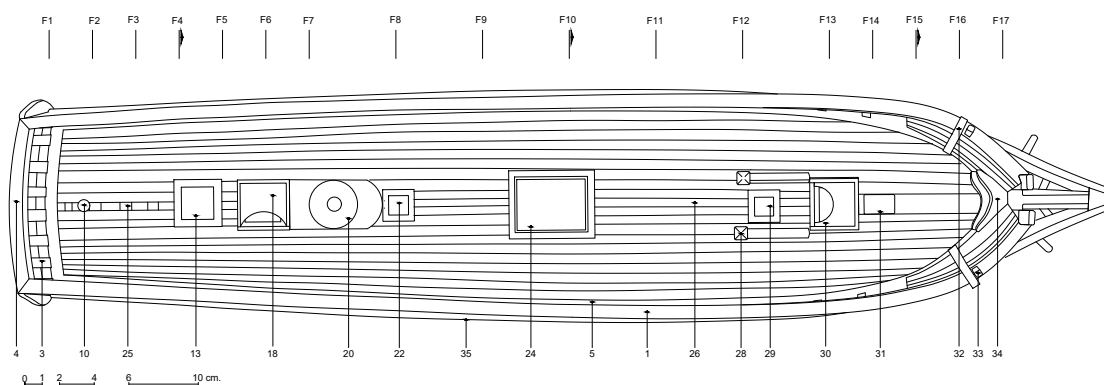


Fig. 8 The deck plan of the ship-model (drawing: G. Tzavaras, K. Damianidis)

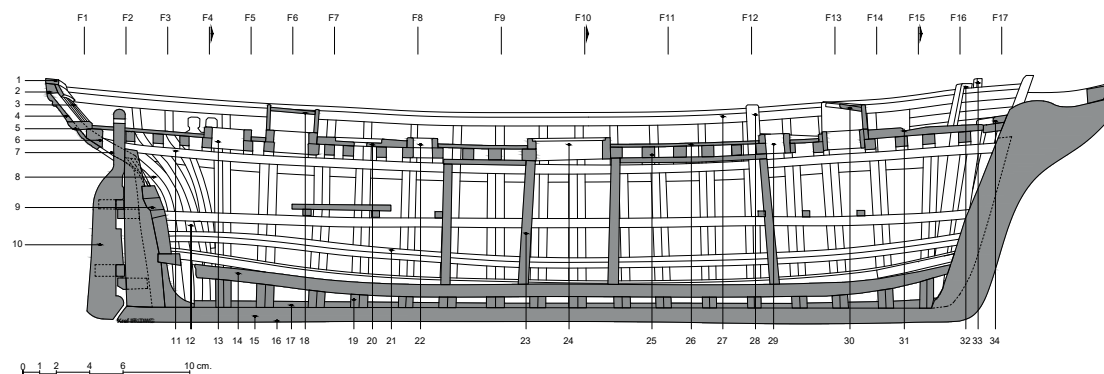


Fig. 9 The longitudinal section of the ship-model (drawing: G. Tzavaras, K. Damianidis)

1-taffrail, 2-gunwale stringer, 3-stern knee, 4- transom, 5-waterway, 6-wing transom, 7-counter timber, 8-fashion frame, 9-filling transom pieces, 10-rudder, 11-shelf, 12-cant frame, 13-aft hatchway, 14-keelson, 15-keel, 16-false keel, 17-deadwood, 18-aft ladderway, 19-double frame, 20-capstan bed, 21-clamp, 22-main mast cleat, 23-stanchion, 24-main hatchway, 25-beams, 26-deck planks, 27-gunwale, 28-riding bitt, 29-fore mast cleat, 30-fore ladderway, 31-recess for the bowsprit, 32-cathead, 33-timberhead, 34-knees, 35-planking, 36-wales

Several internal elements are visible inside the model, including the keelson, shelves, clamps, beams, and stanchions (Figs 3 and 7). The planking of the model (Fig. 2) on the one side consists of 22 strakes below the waterway and probably were deliberately decided to reduce the number of the strakes on this scaled model. Thickness of planking is about 1.5 mm which indicates a thickness of planking of the original ship about 11 cm (scale 1/75). There is a thinner planking on the gunwale and three slightly thicker planks (wales) below the waterway timber.

The arrangement of the deck is of particular interest (Fig. 8), because it seems that it represents specific real elements on it. These include the waterway timber and 19 rows of deck planks. At the bow the central deck plank is wider and it has a recess to support the bowsprit. In the same area there are catheads together with timberheads, the fore ladderway to the lower deck, the fore mast cleat and two riding bitts with supporting knees. In the middle part of the deck there are the main hatchway, the main mast cleat, and the capstan bed or step. At the stern there are the aft ladderway to the lower deck, the aft hatchway and the rudder. The transom on the stern is square with eight stern knees, taffrail and gunwale stringer.

Conclusion

The study of the model of the brig “ARIS” of Admiral Miaoulis casts some light on the structure and the form of the Mediterranean brigs, locally build during the early 19th century. The model of the ship seems simple but very carefully designed, with all lines of outstanding workmanship. There is a ‘full body’ on the fore part of the hull and a very flared shape on the aft part of the hull. It is probable that the shapes of the frames and the rest of the structural elements were produced with some kind of scaled lofting technique, imitating the construction of the ship. Although the deck arrangement seems simple, it includes all the main elements at the right positions. The study of the model of “Aris” of Admiral Miaoulis continues by comparing it with other models and drawings of contemporary brigs. We believe that this model is a construction made by a person who had experience building ships and might have been personally involved with the construction of brigs like “Aris”. This conclusion makes the model very valuable for the study of the Greek shipbuilding industry during the early 19th century. We would like to thank the Benaki Museum for the permission to study and publish the model of “Aris” of Admiral Miaoulis.

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Documenting a 20th century wooden vessel at risk: the AGIOS SPYRIDON project

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Abstract: *Agios Spyridon*, a 24 m long wooden vessel, was built in 1950, and operated in Cyprus as a trawler until 2004. Between the years 2005 and 2019 it remained on dry land, exposed to the elements. It suffered severe damages and the local authorities decided that it should be destroyed. To mitigate the consequences of its unavoidable loss, a project of controlled destruction took place in 2019, led by the University of Cyprus. Applying a rescue excavation approach, the vessel was fully recorded, using both conventional and digital methods. The project also included activities for raising public awareness for the protection of maritime heritage, as well as plans for future display of rescued components of the ship's hull and gear.

Keywords: Cyprus, wooden fishing trawler, controlled destruction, ship recording

1. Introduction. A brief biography of the trawler AGIOS SPYRIDON

The trawler *Agios Spyridon* (Άγιος Σπυρίδων) was built in 1950 in Crete. It was registered in Cyprus in 1954 and withdrawn in 2004, under the European program for fisheries protection, by the Cypriot Department of Fisheries and Marine Research¹ (NC 1). It was a 24 m long vessel of a type known as *karavoskaro* (Καραβόσκαρο) in the Aegean, used as both a merchant and fishing vessel (Damianidis 1998: 73–76, 103; Segditsas 1940: 237–238). *Agios Spyridon* was propelled by a diesel, eight-cylinder, Kelvin engine and rigged with two masts used only for fishing purposes. While in Cyprus, it changed owner at least three times and was involved in fishing activities in Cypriot, Lebanese and Egyptian waters (NC 1, NC 2, NC 4).

In 2005, after its retirement, the Cypriot Department of Fisheries allowed the Municipality of Polis Chrysochous to preserve and protect *Agios Spyridon* as a monument of vernacular maritime heritage. It was dry docked outside the marina at Latsi, Polis Chrysochous, on the northwest coast of Cyprus. The boat remained fully rigged, sitting on concrete blocks and supported on its sides with beams, without protection from the elements. As a result, the deterioration of the entire structure was a matter of time (Fig. 1). In 2018 the local municipality council concluded that the vessel had turned into a hazard and should be destroyed. The Maritime Archaeological Research Laboratory (MARELab) of the University of Cyprus took action at this point and put significant effort to raise funding for the vessel's protection. The efforts bore no fruit and a controlled destruction program was deemed the next best option. Thus, the *Agios Spyridon* project commenced in November 2019, and was funded by the Honor Frost Foundation, the Municipality of Polis Chrysochous and the Cypriot Department of Fisheries and Marine Research. It was conducted in collaboration with the Cyprus Institute, the company Blue Lines Shipbuilders, one of the oldest traditional shipwrights' families of Cyprus (NC 3), and a team of Greek specialists in wooden boat recording, led by Dr Kostas Damianidis. This paper discusses the approach that was adopted for the comprehensive documentation and the controlled destruction of the vessel.

¹ Cyprus Fleet Register on the Net (<http://ec.europa.eu/fisheries/fleet/index.cfm?method=Download.menu>, accessed on June 15, 2018).



Fig. 1 The Agios Spyridon on dry land: (a) in 2006 (photo: K. Damianidis) and (b) prior to the project's commencement in 2019 (photo: © University of Cyprus, MARELab)

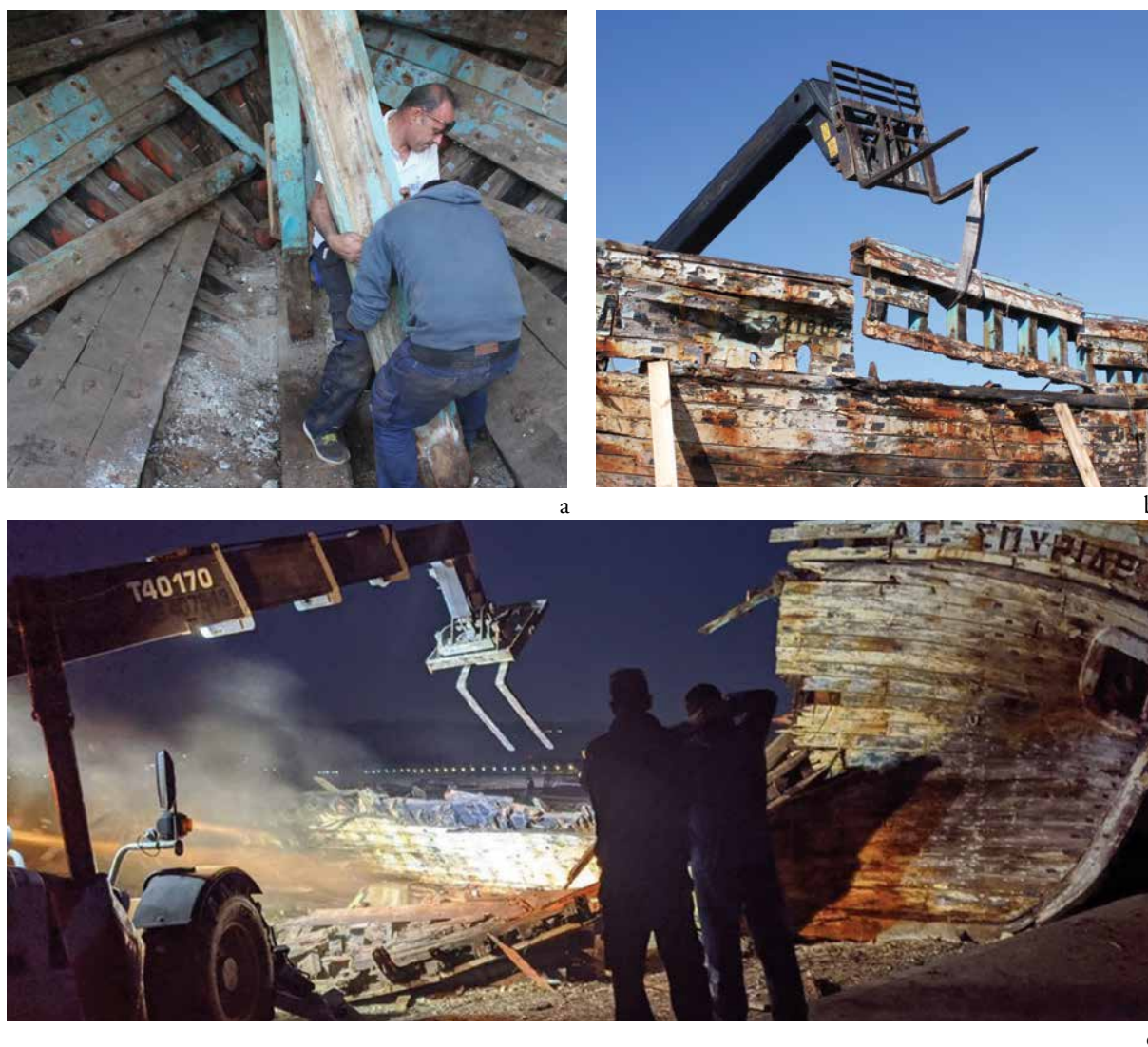


Fig. 2 Main phases of Agios Spyridon's controlled destruction a) Structural timbers being carefully disassembled. Cutting (b) and breaking (c) parts of the vessel using mechanical means and a telescopic handler (photo: © University of Cyprus, MARELab)



Fig. 3 The different methods of recording Agios Spyridon: a) Conventional measurements, b) Laser Scanning, and c) Photogrammetry

2. The Agios Spyridon project

The main objectives of the *Agios Spyridon* project were: (i) to preserve the structural, morphological and technological characteristics of the wooden vessel, through digital documentation, (ii) to select and preserve physically some of the key parts of the hull that could be useful for the study of the vessel, and (iii) to raise awareness about the preservation of nautical heritage.

Prior to any destruction, the vessel was recorded with laser scanning and a 3D model was created.² Fieldwork for the controlled dismantling lasted 15 days between November 28 and December 12, 2019, and was organized into three main phases:

- Removal of all superstructures, mechanical parts, fishing equipment and part of the deck, in order to expose the interior for recording;
- Full recording of the ship's interior;
- Removal of the characteristic parts of the vessel to be salvaged, and final destruction.

² http://ephemera.cyi.ac.cy/?q=Agios_Spyridon (accessed on April 14, 2022).

One of the main concerns was the selection of the technical methods and tools that should be used for the dismantling, considering the limited time available and the destructing character of the project. Three methods were used (Fig. 2): (i) careful dismantling of mechanical and fishing equipment, as well as parts of the vessel, with the use of hand tools, or electric cutting wheels for rusted bolts and joints; (ii) cutting and removing wooden parts of the vessel with the use of chain saws, and (iii) breaking large parts of the vessel with the use of a telescopic handler, by either pushing or pulling. This method was mainly used during the last phase of destruction, when the remaining parts of the vessel were considered already as disposal material.

Throughout the destruction process, the hull together with the mechanical and fishing equipment were photogrammetrically recorded, as they were gradually exposed. Alongside the photogrammetric documentation of the interior sections and details, many measurements were taken with conventional methods. Before the final destruction, the hull was also recorded with laser scanning (Fig. 3).

2.1. Morphometric digital documentation

Terrestrial Laser Scanning (TLS), using a phase-shift device, was selected as the most effective method for recording the boat's external and internal compartments. All morphological features were recorded in two phases, one during the pre-disturbance survey and one before the final destruction, almost at the end of the project. The main objective of the latter was to improve the first model with all the structural details that were exposed during the controlled dismantling, which were not initially visible.

A 4D database was created, consisted of two 3D models of 106 (March 2018) and 77 (December 2019) range maps, respectively. The difference in the overall number of stations was due to the dismantling progress and decreased complexity. The average resolution for the final point clouds is estimated to be 7 mm (X-Y).

An unavoidable difference was created applying a common pipeline after a TLS survey (Grussenmeyer *et al.* 2016). The latter was supported by aerial (2018) and terrestrial (2019) image-based campaigns, used to record and map high definition RGB values. The aerial survey was performed by the CyI USRLab using a DJi Inspire 2 drone. The computed photogrammetric camera network was hence spatially aligned with the TLS data to allow a detailed re-projection of colours on the vessel geometry.

The final 3D models of both seasons today available on the EpHEMERA database (Abate *et al.* 2017), were aligned in the same local reference system (Fig. 4) in order to: (i) perform a multitemporal comparison of the different epochs; (ii) analyse morphometric features of the lost structure, and (iii) extract architectural 2D drawings of the vessel.

2.2. Close-range (multi-image) photogrammetry

Close-range (multi-image) photogrammetric documentation was used to record parts of the boat during the pre-disturbance phase and as they were exposed, during its dismantling. The documentation proceeded as in an archaeological excavation, while the exact 'stratigraphic' sequence (matrix) of the boat was reconstructed in the post-processing phase, by merging the various recorded models. During this process, the laser scanning data was of essential importance, as the TLS point-cloud provided data for geo-referencing the photogrammetric point-cloud (Fig. 4). Additionally, this procedure allowed the combination, when and where necessary, of the two point-clouds (TLS and photogrammetric), thus creating a fully integrated system of 3D recorded data. The image data capture was done with both SLR (Canon EOS 550D with an 18–55 lens) and compact (Olympus TG-5) cameras; data were processed in Agisoft® Metashape (formerly PhotoScan).

2.3. Measurements with conventional methods

The 3D model of the vessel was blind in specific structural details due to the limited access in certain interior spaces. For these areas, mainly at the stern and the bow, the use of some conventional measurements and recording methods was necessary.

The team of architects used printed 2D sections of the TLS 3D model and filled by hand the structural details that were missing. Most of the conventional measurements were taken at the counter stern (inside and outside of the boat), at the interior space of the bow, and at several sections of the middle part of the structure. Key structural details were recorded on these sections, such as: the assembling of the frames, the resting of the beams on the clamps, and the joining arrangements of the hanging knees. The conventional measurements together with all the data from the 3D digital models were used to produce architectural 2D drawings of the vessel.

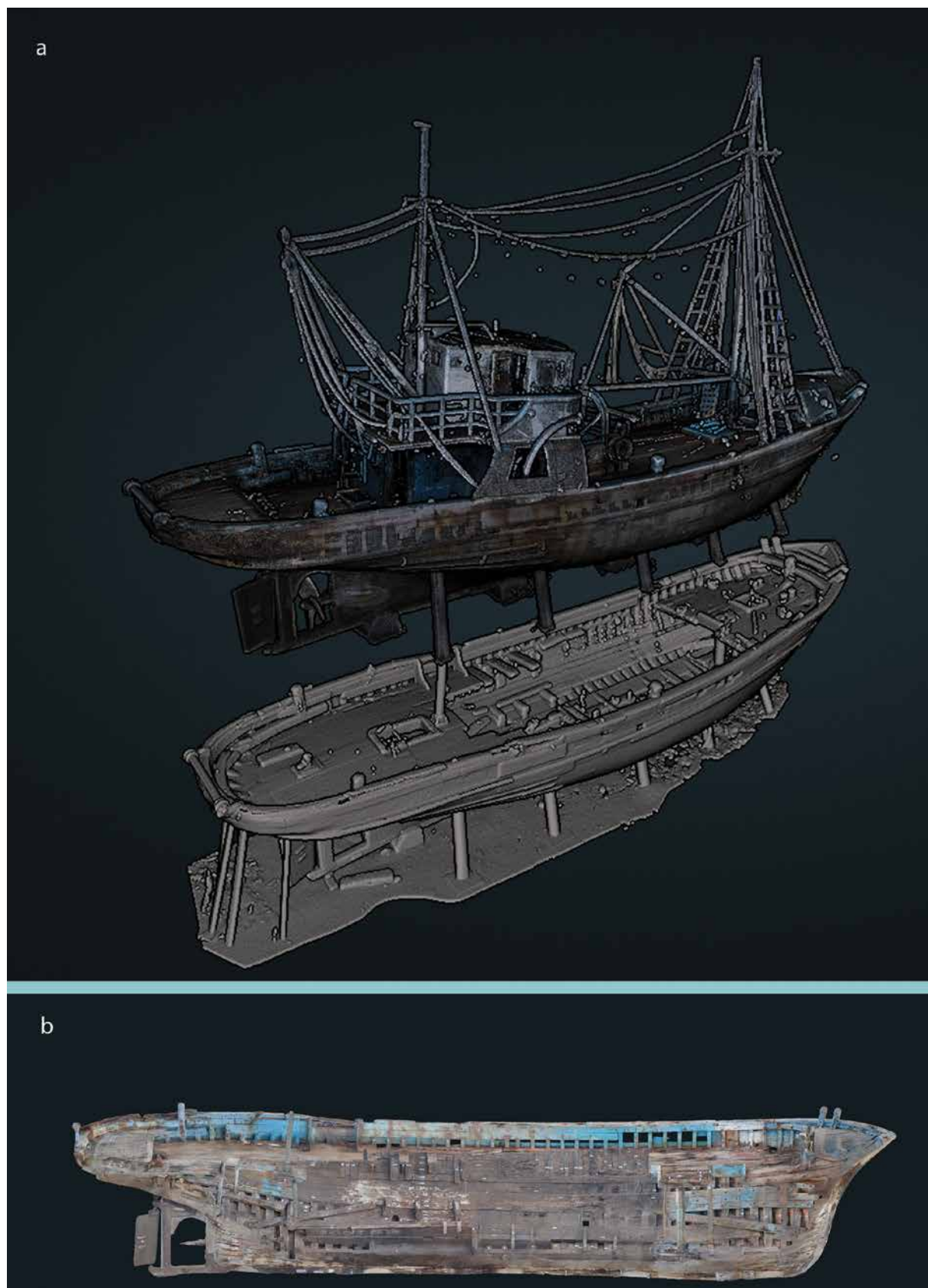


Fig. 4 The digital documentation of Agios Spyridon a) The TLS 3D models (© Cyprus Institute); b) A longitudinal section of the 3D model created from a combination of the TLS and photogrammetry point clouds (TLS © Cyprus Institute; Photogrammetry © University of Cyprus, MARELab)

3. Shipbuilding information

Agios Spyridon was one of the largest surviving wooden trawlers in Cyprus, and possibly in the eastern Mediterranean, and had preserved all fishing gear *in situ*, both on deck and in the interior. Its basic dimensions were recorded with accuracy during the project: overall length = 23.88 m; keel length = 18.8 m, maximum beam = 6.16 m; midship height = 3.26 m (Fig. 5).

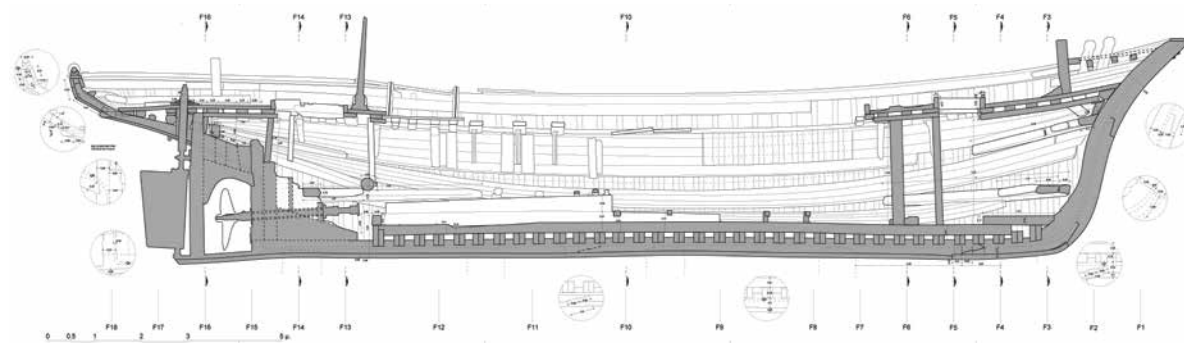


Fig. 5 Longitudinal construction section of the trawler *Agios Spyridon* (drawing: K. Damianidis, G. Tzavaras)

The vessel had, 49 full frames from the stem to the stern post. They consisted mainly of nine pieces each, including the floor timbers, the futtocks and the top timbers. The cross section of the double frames was approximately 12 × 24 cm and the single 12 × 12 cm. The last full frame on the stern was above the vertical stern post. This is a strong structural element that supports almost all the cant frames that were placed radially behind it.

On most of the transversal sections the keel had a cross section about 17–18 cm wide × 23 cm high and the false keel 17–18 × 9 cm. The rabbet had a width of 5.5 cm. Clamps had a thickness of 11 cm and the keelson had cross sections of 28 × 21 cm amidships. The cross section of the deck beams was about 9 × 15–28 cm and the deck planking had a thickness of 4.5 cm.

There were 12 hanging knees on each side of the vessel beneath the deck reinforcing the joints between some of the deck beams with the shelf clamp and the respective futtocks. The two main breast hooks were located on the bottom parts of the bow and the stern, together with their legs (i.e. separate timbers that were extended more than 4 m on top of the lower parts of the frames). They were made of natural curved logs with adequate angles and lengths. These, together with their legs were the main reinforcing components at the extremities of the vessel. The double frames were visible in some areas (cross sections of both pieces: 21–26 cm sided, 12–14 cm moulded). The average space between two successive frames was 19 cm, ranging from 16 to 21 cm.

The planking of the hull consisted of planks (5–5.5 cm thick), the wale below the waterway timber (9 cm thick), the bulwark planks (about 4 cm thick) and the plank sheer on the top of the planking (6 cm thick). Under the frames, the keelson, the sister keelsons, the limber strakes, the lower and the upper clamps, the legs of the breast hooks, and the shelves, had various thicknesses.

The elliptical stern of the vessel rested on the heavy axial structure of the lower part of the stern. The stern post consisted of two vertical pieces that stood upon the rear end of the keel. Aft of this stern post the axial structure extended with five vertical pieces; only the rear one was resting on an extension of the keel (9 × 18 cm) and the false keel (9 × 18 cm). Between the stern post and this vertical rear piece there was the opening for the placement of the propeller. Above the propeller opening, a wooden knee was fixed, and on top of it rested the other vertical pieces. Aft of this lower axial structure, there was the rudder hole and the metal rudder, were supported by two metal stays (bearings) and fastened on the axial structure. The aftermost complete frame of the skeleton together with 12 cant frames and the upper extension of the stern post comprised the skeleton of the elliptical stern. All of them were resting on the lower axial structure of the stern that is described above. The cant frames were placed radially around a centre that was located at the top of the rear pieces of the axial structure of the lower stern. They were placed at almost equal intervals, which at their top averaged 65 cm (46–69 cm). The cant frames were connected together with several curved pieces horizontally placed in a way that provided support to the structure of the aft deck and gunwale (Fig. 6).

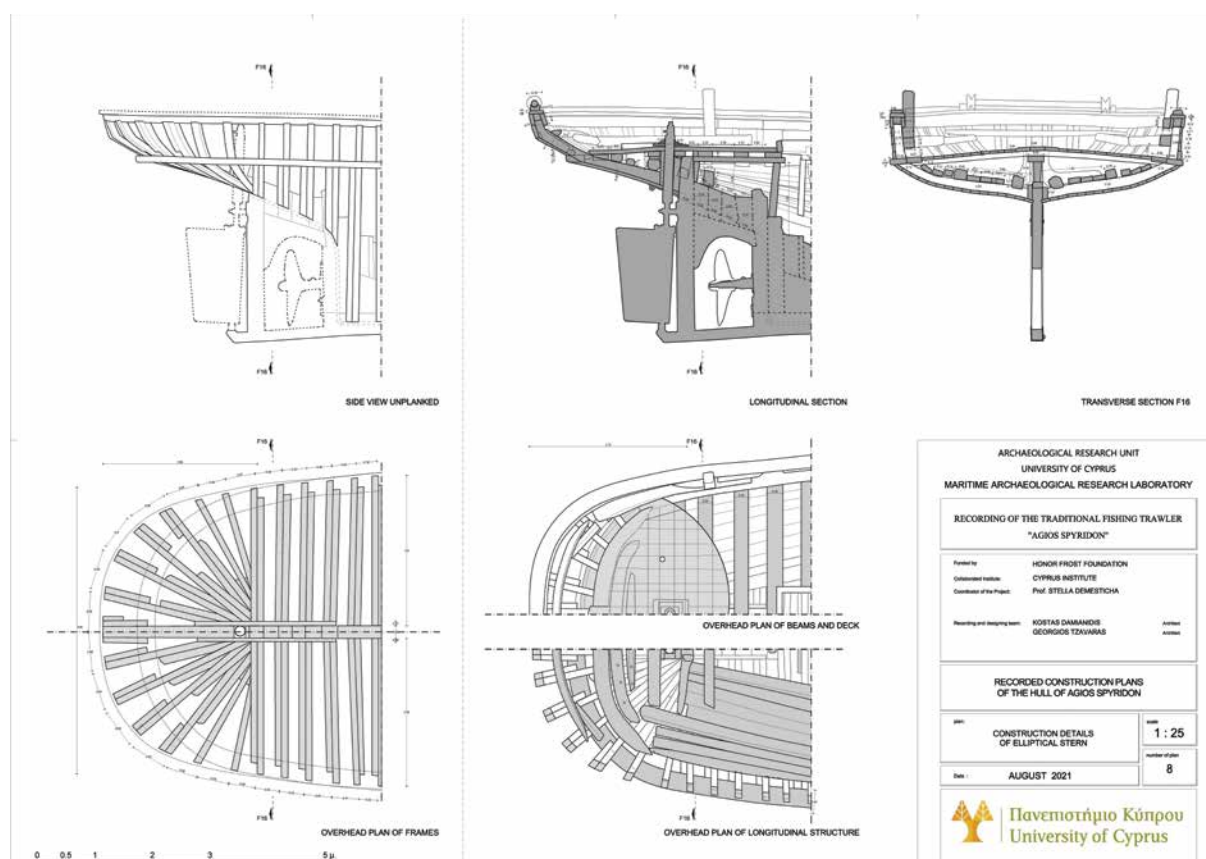


Fig. 6 Construction details of elliptical stern of the trawler Agios Spyridon (drawing: K. Damianidis, G. Tzavaras)

4. Large wooden vessels in danger: is controlled destruction a solution?

The project *Agios Spyridon* was the first experimental controlled destruction of a traditional vernacular wooden vessel in the Eastern Mediterranean. In this respect, it addresses some key issues regarding monuments of nautical cultural heritage (UNESCO 20013; Firth 2015). One of these issues concerns the role of legislation and how it combines with the support of local authorities for the protection of historic and traditional wooden vessels. In the case of *Agios Spyridon*, the attitude of the local council is revealing. The boat was initially perceived as a promising cultural heritage conservation project, and legislation was used positively for its protection. But over time, local authorities lost interest when they realized the amount of effort and resources that were necessary for its conservation. So, when the vessel failed to become an 'attractive' monument because of neglect, its destruction and removal from the town's waterfront was deemed the optimum solution and to the community's best interest, in terms of aesthetics and safety. A similar case in Greece concerned the *Eleni. P.*, a 24 m long Greek vessel of a type known as *perama* (πέραμα) (Damianidis 1998: 52–60). She was protected by law, but this was not enough to save her (Damianidis 2016: 22–24, 33). She was left dry docked, without any care, since the late 1990s, in a boatyard on the island of Salamis, Greece. The initial conservation plan was never materialised, because of bad management by the authorities, and in 2018, already in bad condition, the boat eventually collapsed.

The dilemma between the conservation of a vessel in danger and its controlled destruction is not a simple one, especially because the 21st century is the last phase of the long history of vernacular wooden vessels in the eastern Mediterranean (Damianidis 1996). Their gradual decommission and the lack of new wooden shipbuilding projects deprives these boats of their ethnological, technological and traditional context (Adams 2013: 22–26). No matter how extensively vessels are documented and studied, their withdrawal automatically removes an important part of the local cultural her-

³ UNESCO: Convention on the Protection of the Underwater Cultural Heritage, <https://unesdoc.unesco.org/ark:/48223/pf0000126065>, accessed on March 10, 2022.

itage stock. In balance, their protection and preservation allow for their recording and study and adds important chapters to the nautical history of the region. Preservation of large vessels on dry land, however, requires constant care and resources, otherwise it fails. The cases of *Agios Spyridon* and *Eleni P.*, discussed above, exemplify the fact that, apart from legislative measures, the role of local communities, hence public awareness, is imperative. For instance, it is possible that the sad fate of *Agios Spyridon* is related to a general lack of maritime literacy on the island of Cyprus (Nicolaou 2021).

Controlled destruction with full documentation can be the only mitigating solution, if/when preservation fails. The *Agios Spyridon* project tried to collect as much information as possible, but the physical remains of the boat are forever lost. The project followed a rescue excavation approach and tried to document pieces of the boat's technology, function and biography, all recorded with multimodal digital recording. Usually, archaeologists are trying to reconstruct a vessel from random preserved fragments. In this case, a methodology was developed to effectively do the opposite: record an entire structure in two weeks, while selectively salvaging sections and timbers, representative of a vessel to be destroyed. At the end of fieldwork, more than 100 construction parts of the *Agios Spyridon* were selected to be salvaged: pieces of the hull, mechanical and fishing equipment, rigging components, and personal belongings.

Along with the digital preservation of *Agios Spyridon*, the project focused on raising public awareness, to prevent the destruction of such vessels in the future. In order to get the local population actively involved and wishing to preserve as much of the material remains of *Agios Spyridon* as possible, artists and craftspeople were invited to select pieces from the ones not salvaged for further study, to give them a second life through creative reuse. An exhibition based on their work will be organized in the future.

The logistical difficulties and the challenges arising from the rescue character of the *Agios Spyridon* project notwithstanding, the added value of the recording approach discussed above was increased via a multidimensional use of the collected data, in a way that prolongs the vessel's life and contributes to the enrichment of the nautical cultural heritage of the region.

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EARLY MODERN PERIOD SHIPBUILDING (POSTERS)

The Sanguinaires C shipwreck, Corsica; An early 16th century clinker-built ship of northern origin

Éric Rieth – Marine Sadania – Hervé Alfonsi

Abstract: Discovered in 2005, the Sanguinaires C shipwreck is located near the Sanguinaires Islands in the Gulf of Ajaccio (Corsica). After two surveys, a multiannual program (2021–2023) has been implemented. The wreck is characterized by a stone mound (dolomitic limestone) covering the architectural remains of the hull. A secondary cargo of Pisan and Ligurian ceramics dating from the first part of the 16th century has been discovered. Excavation of the architectural remains, limited to the fore and aft ends of the keel, has brought to light several main features; the most important one, in the Mediterranean context, concerns the clinker structure of the planking.

Keywords: clinker-built, Corsica, 16th century, limestone cargo

1. Introduction

Discovered in 2005 during a survey conducted by the Drassm,¹ the Sanguinaires C shipwreck lies at a depth of 19 m on the Sanguinaires Islands in the north of the Gulf of Ajaccio (Corsica) (Fig. 1). After two surveys conducted under the direction of Hervé Alfonsi (ARASM/FFESSM)² and three excavation campaigns, a multi-year excavation programme (2021–2023) was implemented under the direction of Hervé Alfonsi in co-direction with Marine Sadania (Drassm), and in collaboration with Éric Rieth (CNRS)³ and Élisabeth Veyrat (ARKAEOS) (Fig. 2). The Sanguinaires C shipwreck is one of the major discoveries of the French coastline: it is clinker-built, and its cargo and equipment reveal new data on maritime trade in the early modern period (Fig. 3).

This article focuses on the presentation of the architectural remains. However, it is important to emphasise the richness and diversity of the material culture uncovered. The hull remains were covered by a cargo of dolomitic limestone, 17.40 m long, 12.40 m wide, and 2.80 m high (at its central part). This type of stone is found throughout the Mediterranean basin and was used for the manufacture of lime. The origin and destination of this limestone are the main interest regarding this cargo.

Among the on-board equipment, three wrought iron anchors with wooden stocks, which were not preserved, were observed on the site. The first is 3.54 m-long and was placed on the starboard fore extremity of the shipwreck, on the stone mound. Its diamond ring hints at a pre-16th century dating. Of two other anchors, one is 4.15-m-long. These anchors were found 10 m beyond the mound, on the same starboard fore extremity. Their position seems to indicate that they were dropped in a hurry, in case of an emergency. Numerous iron concretions were discovered in the vicinity of the shipwreck, some of which, following X-ray analysis, reveal the presence of artillery on board, which could have participated in the defence of the ship in a troubled maritime context. The exact number of artillery items is still uncertain. It could have also been used as ballast. Further investigation is needed on this subject.

The excavation of the shipwreck also revealed a collection of objects which were discovered in the space between frames, and bear witness to the daily life of the sailors. Small bone fragments, cooperage items, pewter containers, a wooden mallet, and an exceptional wooden compass cover – all provide valuable clues to life on board.

¹ Drassm: Department of underwater archaeological research, French Ministry of Culture.

² ARASM: Association for underwater research; FFESSM: French federation of study and underwater sports.

³ CNRS: National Center for Scientific Research.

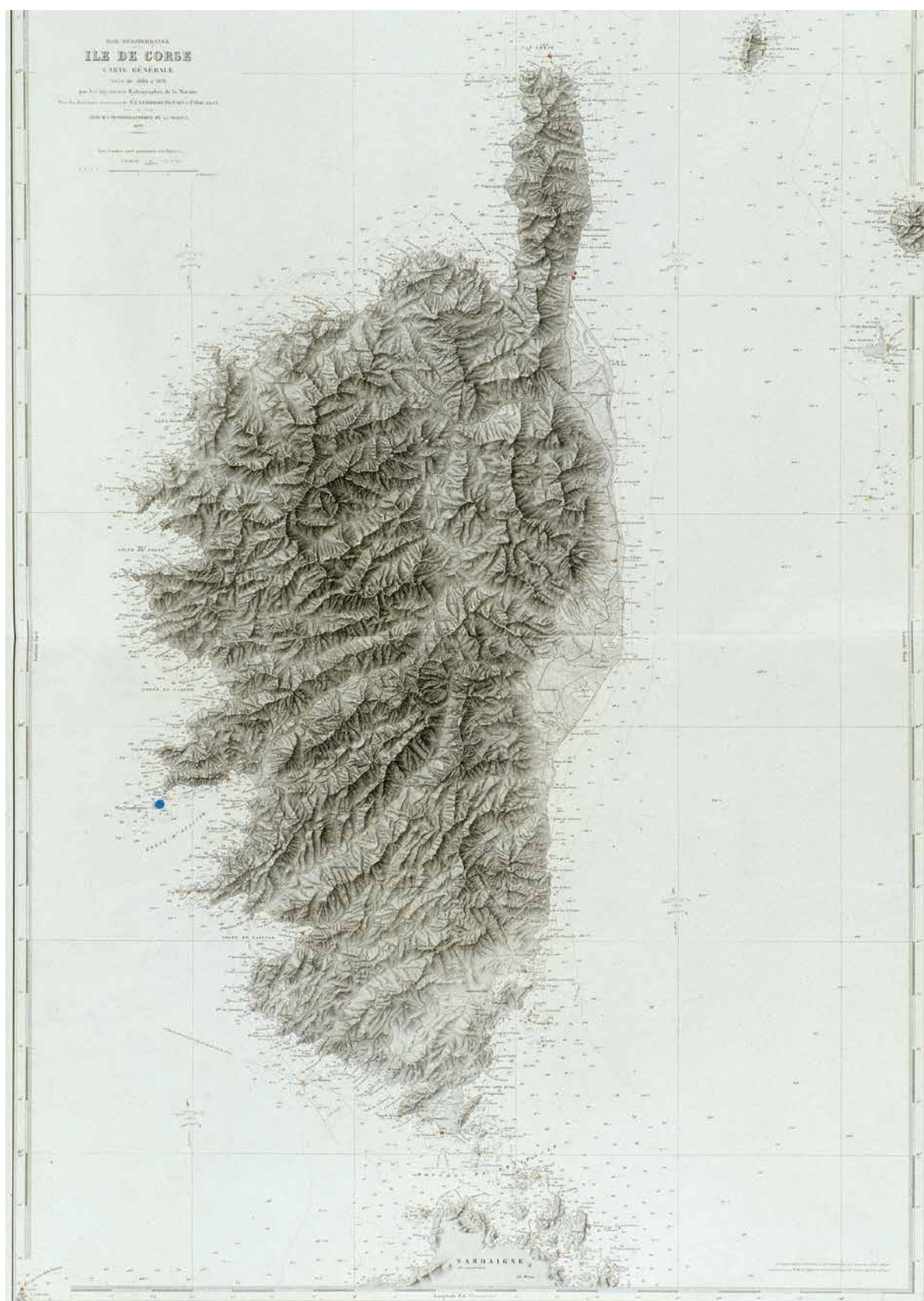


Fig. 1 Location of the wreck in Corsica (Hydrographie française, pl. 4993, © Musée national de la Marine/P. Dantec, Inv. B668)



Fig. 2 Aerial view of the Alfred Merlin, Drassm's ship, French Ministry of Culture (photo: T. Seguin, ARASM-Drassm)

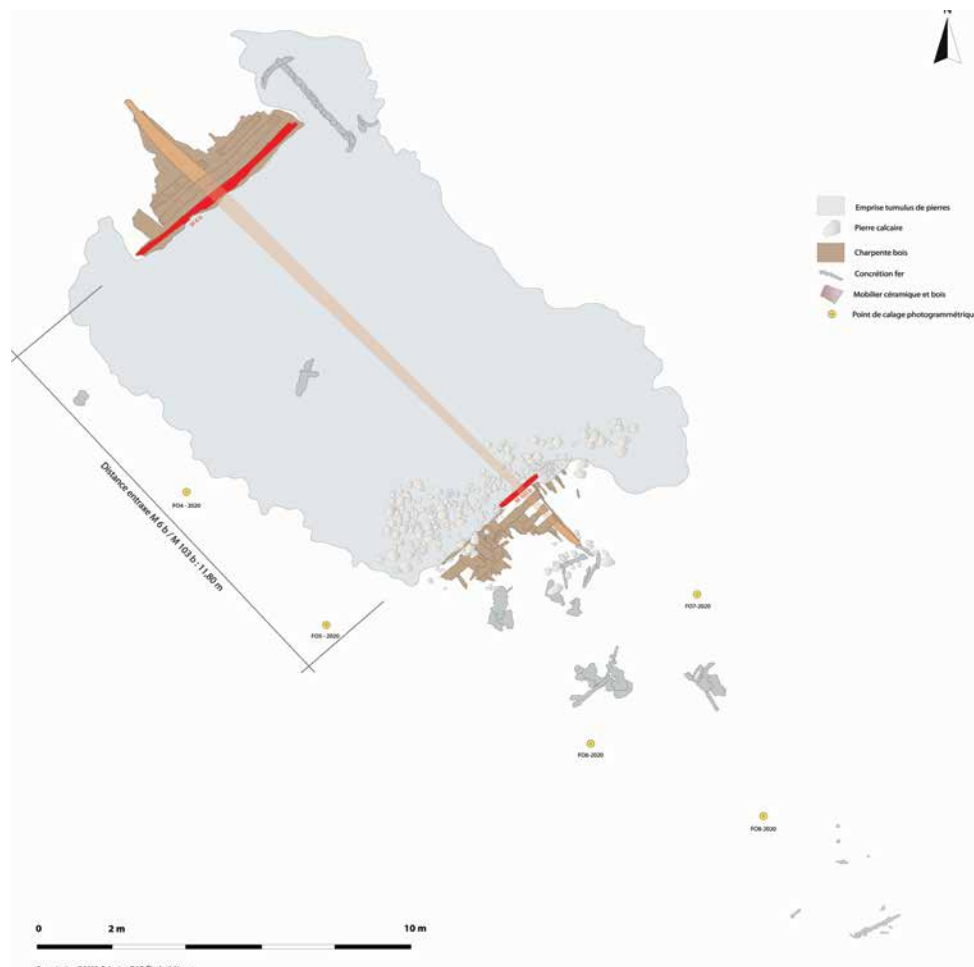


Fig. 3 Archaeological record of the wreck with the two excavation areas; the two pieces in red correspond to the presumed 'floor timber beams' (drawing: D. Peloso, Ipso-Facto)

In the centre of the stone load and around the site numerous ceramic items were found (Fig. 4); the majority corresponds to northern Italian production, including a large collection of Pisan *graffite a stecca* (open forms: cups and bowls). These ceramic items were made of red slipped clay and are covered on the inside with a green, brown, and colourless glaze. They are characterised by deep removals of dark-coloured earth made with a gouge. The outer surface is not glazed, but in most cases the upper part shows slip and glaze flows. They demonstrate a careful, high-quality decoration with several peripheral motifs, many of which refer to a sequence attributed by Marcella Giorgio (Alberti, Giorgio 2013: 137, 306) to the period 1530–1560. The Pisa region seems to be the origin of the undecorated monochrome cups that have been identified on the site. In addition, there is a collection of Ligurian ceramic items, earthenware represented by closed containers (three *albarelli* jars and a pill box), as well as some bowls with an orange glaze and incised decoration of the type *monochrome graffite a punta*. Among the decorated ceramic items there is a *polychrome graffito* bowl and a *gotico-floreal* plate, with monochrome blue decoration of the *alla porcellana* type, characteristic of Tuscan factories, probably Montelupo and datable between the last quarter of the 15th century and the second half of the 16th century (Berti 1998: 16). The *tegame* pot and the Frejus jar, found on the site, could be more of a ship's ware. Some shards of rim and jug sides attest to the presence of closed forms on board the ship. These ceramic items, present in small quantities on the site, are evidence of a secondary cargo of food and pharmaceutical containers⁴.



Fig. 4 Samples of ceramics from northern Italy (photo: F. Osada, ARASM-Drassm)

The excavation strategy for the architectural remains had to consider the previous excavation of the stone cargo. In this perspective, it was decided to carry out a methodical dismantling of the stone mound to try and understand the possible organisation and distribution of these stones in the hold⁵. Such a cargo raises the question of the risks of its partial displacement in case of severe weather and its consequences for the stability of the ship. Therefore, this was a major technical problem that the men responsible for loading the Sanguinaires C vessel had presumably been confronted with, and it was important to try and appreciate today. In these conditions, the strategy was based on a gradual approach to the loading and architectural remains, limiting itself to the removal of the north/forward of the hull (2018–2019) over a length of almost 3.60 m, and south/aft of the hull (2020–2021) over a length of approximately 2.20 m – two areas of the shipwreck where the height of the stones to be removed was lower than in the central part, in the area of the master frame. In total, therefore, the shipwreck was studied over a length of about 5.80 m, i.e. a little less than a third of the preserved length of the keel. This dimension, although small in relation to the extent of the preserved remains, is sufficiently representative to allow an initial sketch of the architecture of the Sanguinaires C ship.

⁴The main cargo was a load of dolomitic limestone. The secondary cargo hypothesis is based on the fact that nearly two hundred ceramic artefacts (NMI count) were unearthed, the majority of which were engobed *graffite a stecca* bowls that can only be considered as merchandise to be disposed of, and not as ship's crockery.

⁵ In 2021, the collaboration of divers from the French Navy's *Groupement de plongeurs-démineurs de la Méditerranée* made it possible to dismantle the upper part of the cargo in layers, with the support of several members of the archaeological team.

2. Architectural remains (Figs 5, 6)

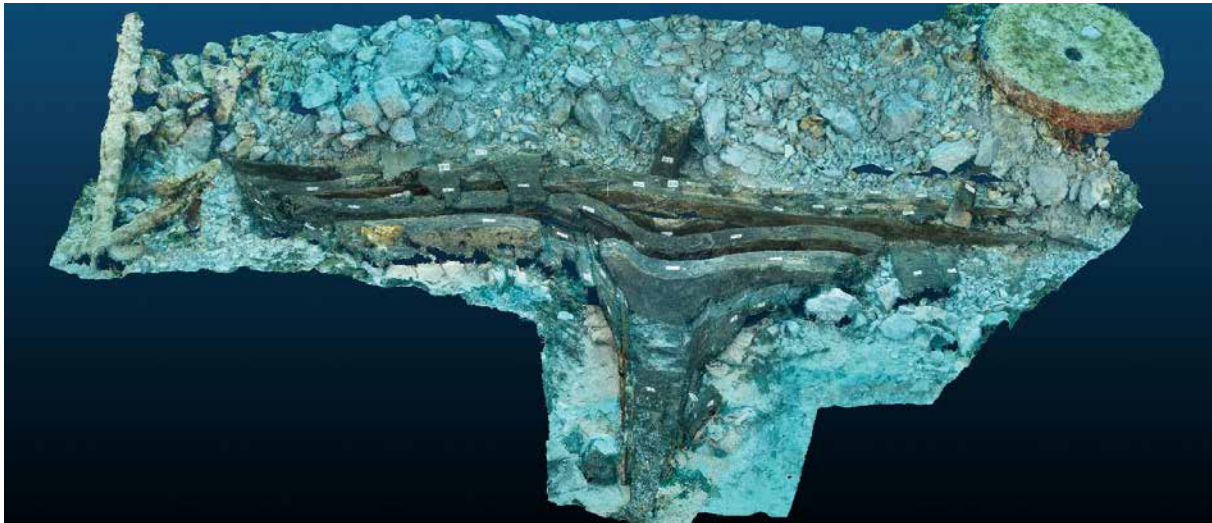


Fig. 5 The fore M 6 floor timber in the background is topped by the presumed 'floor timber beam' M 6b (authors: F. Osada, ARASM-Drassm & D. Peloso, Ipso-Facto)

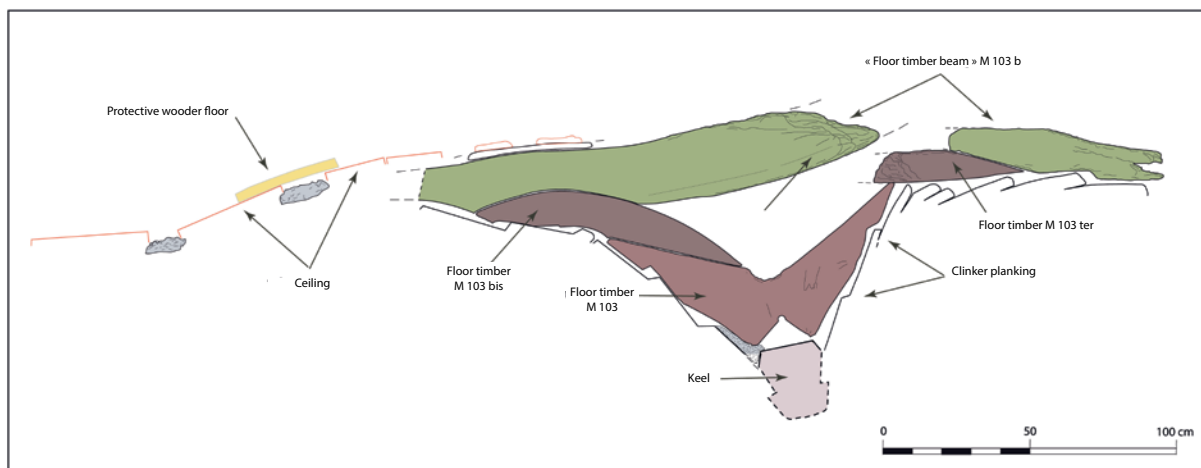


Fig. 6 Cross section at the level of the aft floor-timber M 103 with the presumed 'floor timber beam' (broken) M 106b (drawing: E. Veyrat, ARKAEOS)

2.1. Longitudinal axis

The oak keel is preserved over a length of 17.80 m. The fore extremity of the keel is preserved up to the base of the stem, however the aft extremity is destroyed. The regular reduction in the width of the last low strakes of the planking towards the aft end indicates that the stem probably originally extended to a length of maximum 1 m. A section of the aft part of the keel incorporating one of the garboards was taken to define its precise dimensions and morphology. Its section is trapezoidal: the width increases from nearly 19 cm at the aft end to 29 cm at 1.90 m from the aft end for an average height of 25.5 cm at the aft end. At the fore end, the keel dimensions appear to be much larger: the width varies from 30 to 52 cm at M 3 and M 4 frames and the average height is 42 cm.⁶ The keel has a 3-cm-deep rabbet whose profile evolves. The rabbet has a right angle in relation to a vertical garboard at the fore end and opens at the aft end in relation to a slightly sloping garboard.

An oak keelson, of which only the aft end was found at the level of floor timber M 104, was set on the upper face of the floor timbers. This extremity of the keelson is 18 cm wide and 24 cm high and is located at the front of floor timber beam M 103b.

⁶ No evidence of a counter-keel and a false keel was identified. Further observations of this fore part of the keel will have to be made to understand these differences in dimensions.

2.2. Clinker planking

The clinker planking of the Sanguinaires C shipwreck is one of its three main characteristics. The oak planks are between 21 and 33.5 cm wide. The average thickness of the planks is 3.4 cm, except for the garboard, which is thicker, at about 3.8 cm. The clinker strakes are joined together without any particular arrangement,⁷ with an average overlap of 7 to 12 cm. The assembly was carried out by means of iron rivets driven in from the outer face of the planks. The tip of the rivets was pressed onto a quadrangular iron rove with an average size of 2.8 cm on each side. Rivets and roves are only preserved as iron concretions. Their average interval is around 17.5 cm, with occasional more irregular intervals. A particularly important feature of the roves in relation to the ship's construction process was noted. During the dismantling of several fore and aft floor timbers for a detailed study on the surface, it was found that some of the roves were overlapped by these frames. This overlap is a clear indication that these floor timbers were placed after the lower part of the planking had been raised and assembled following the classic chronology of the longitudinal shell-first construction method. In the current state of progress of the excavation, however, it was not possible to observe whether this same arrangement of overlapping roves was evident at the level of the first futtocks. The sealing between the planking at the level of their overlapping and joining surfaces was carried out according to the luting method, as the planking rises, with a material based on braided cords of horsehair and/or sheep's wool. Each strake is made up of several planks joined together by means of a vertical flat scarf. A final characteristic of this planking is that the planks were fastened to the frames by means of 3 to 3.5 cm long treenails, some of which were wedged. Only the two garboards seem to have been fastened to the keel and the frames by treenails and iron carvel nails.

2.3. Frames

The oak frames are the second significant feature of the architecture of the Sanguinaires C shipwreck. The first aspect to be noted is the large sample of the frames, crotches, and floor timbers. Their typical sided is between 22 and 29 cm. This sampling of the frames is combined with an irregular room and space that ranges from 8.5 to 16 cm in the fore part and from 15.4 to 23 cm in the aft part. The crotches and floor timbers are extended by futtocks joined by a flat scarf. This was achieved by overlapping the end of the floor timber with its extension futtock. According to the traditional clinker architecture, the lower face of the frames has a series of notches of 4 to 5 cm deep on average intended for embedding the top of the lower strake at the level of its overlap by the upper strake. The second important aspect to be mentioned concerns the irregular morphology of the frames and the preservation of the bark on several crotches and floor timbers in relation to their minimal shaping. One of the questions is whether this is a technical choice intended to favour the sampling of the frames to the detriment of the quality of their shaping or, on the contrary, whether it is a constraint imposed by shipyard's supply problems.⁸ The third particularly revealing aspect of the frames concerns the relationship, or rather the lack of connection, between the base of the crotches and floor timbers and the keel. On the one hand, several frames do not rest on the keel, from which they are separated by few centimetres, and, on the other hand, they were not fastened to the keel by iron bolt or treenail. In other words, these frames appear to be 'floating' in relation to the longitudinal axis of the hull and only fastened to the planking by treenails. Obviously, these features were only identified at the level of the fore and aft end frames of the shipwreck. The question is whether this arrangement is found in the central part of the hull. One fact is certain: this lack of connection between the frames and the keel implies that they were installed after the planking was fitted to the bottom of the hull, at least in accordance with the shell-first construction method. One final aspect should be noted. Two forward floor timbers, M 5 and M 6a, have engraved marks on their north/front moulded face in the form of one horizontal and two vertical lines for the M 6a frame and one horizontal and four vertical lines for the M 5 frame. The nature of these engravings is unknown at present, maybe carpenter or merchant marks. Further excavation will perhaps allow us to propose a hypothesis of interpretation.

2.4. Floor timber beam

The third feature particularly revealing of the shipwreck's architecture relates to the M 6 fore frame and M 103 aft frame. A massive quadrangular transverse wooden piece⁹ rests on the upper ends of the two floor timbers and extends on the port and starboard sides, forming extensions. The lower sided face of this timber resting on the planking has a series of notches for fitting the clinker planks. The two transverse timbers are arranged roughly symmetrically in relation to the fore and aft ends of the keel and are separated by a gap of about 12 m which, probably may correspond to the length of the hold. These two transverse timbers seem to be very comparable to the *biti* of the Nordic clinker architec-

⁷ There were no sloping edges or grooves for the sealing material.

⁸ The frequency of the presence of bark on the crotches and floor timbers, as well as on other structural parts, seems to rule out the possibility of repairs.

⁹ The piece M 103b combined with floor timber M 103 is broken. Its quadrangular section measures on average 25 cm wide by 22 cm high. An interesting detail is that its moulded (south) face is regularly shaped, whereas its north face, facing the cargo, is in a rough state with its bark is still on.

ture which can be interpreted as a kind of ‘floor timber beam’ acting mechanically as transverse reinforcements of the bottom of the hull.¹⁰ This reference to the *biti* system and more broadly to the Nordic clinker architecture constitutes a major argument for the historical interpretation of the construction of the Sanguinaires C ship.

2.5. Ceiling

The frames were covered almost exclusively with oak ceiling planks which were attached to the frames by treenails and iron carvel nails. The irregular width of the ceiling (from 11 to 38 cm in the aft ceiling for example) and the typical thickness of the planks (between 3.5 and 4 cm) appear to be arranged at more or less regular intervals, forming as many openings as possible, and as many traps for archaeological material for the interest of archaeologists. This ceiling was covered by a protective wooden floor on which rests the load of stones with aggressive edges for the wood. These planks, made of Mediterranean conifers, have an average thickness of 2.8 cm and an irregular width of between 8 and 35 cm. They are fixed to the ceiling planks with iron nails. There is one main difference between the protective floor at the fore extremity and the one at the aft extremity: the fore one does not rest directly on the ceiling planks, but on wooden crosspieces placed on the ceiling planks, whereas the planks of the aft protective floor are in direct contact with the ceiling planks. A particularly important aspect is the almost systematic use of Mediterranean conifers for the protective floor. Unlike the oak ceiling planks, which can be interpreted as the original planking, the protective floor would appear to have been made later during the life of the ship in a Mediterranean port, and corresponds either to a repair of the bottom of the hull or to an arrangement designed more specifically to protect the ceiling planks from the stone cargo.

3. Conclusions

All the data collected from the excavated areas of the shipwreck converge to characterise the architecture of the Sanguinaires C as that of a clinker-built merchant ship. This architecture, in relation to the chronological context of the ship’s construction, which is probably close to the beginning of the 16th century, or even the end of the 15th century, is characterised by a particularly strong transverse framework based on thick frames with a reduced room and space. In the context of the Mediterranean shipyards characterised by a multi-secular frame-first carvel architectural tradition (since the end of the 5th–beginning of the 6th century in the eastern Mediterranean), the clinker shell-first architecture of the Sanguinaires C shipwreck appears, in the current state of research, to be an archaeological *unicum*, along with the Barcenoleta 1 shipwreck, Barcelona, Spain (Pujol i Hamelink *et al.* 2017: 283–289), which dates from the 1430s. This shipwreck, of which only part of one side is preserved, is linked to the north Iberian tradition of the clin.¹¹ Written sources attest to the presence of Basque ships in the Mediterranean in the late 13th/early 14th century. The most famous evidence is that of the *Nuova Universale* chronicle which mentions the presence of Basque ships (*cocche*) in the Mediterranean in 1304: “[...] di Bajona in Guascogna con loro navi, le quali si chiamavano cocche Baonesi ... e d’all hora inanzi i Genovesi e Vinitianti e Catalani usarono di navigare con le cocche [...]”. The Mediterranean written sources, on the other hand, do not seem to mention ships coming from northern Europe to the Mediterranean in the first half of the 16th century, the period corresponding to that of the sinking of the Sanguinaires C ship. However, several characteristics of the shipwreck in the form of authentic *architectural fingerprints* of historical dimension, such as the almost exclusive use of oak for the construction of the hull, including the keel, and above all the two floor timber beams reminiscent of the *biti*, tend to associate the architecture of the Sanguinaires C shipwreck with a Nordic rather than a north-Iberian origin.¹² The decisive argument should be provided, as dendrometric references allow, by analysis of the wood samples from the shipwreck which are currently underway.¹³ In the meantime, the closest comparison to the Sanguinaires C shipwreck appears to be that of Riddarholm (Sweden) dated to 1520/1527 (+/- 5 years) (Linberg 1985).

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¹⁰ Thanks to Morten Ravn and Mikkel Haugstrup Thomsen of the Viking Ship Museum in Roskilde and Emmy Kauppinen of the Medieval Museum, Stockholm for their comments, documentation and bibliographical contributions.

¹¹ Analyses (particularly of pollen from the moss used to seal the clinker planks) have revealed a north Iberian origin (Cantabrian-Basque coast) of these sealing materials.

¹² For example, the use of beech for the keel is considered as one of the architectural fingerprints of the north Iberian shipbuilding tradition.

¹³ Analysis by Frédéric Guibal (IMBE-CNRS) and Alba Ferreira Dominguez (Ipso Facto).

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Post medieval wreck in the bay of Sv. Nikola, island of Pag

Dino Taras – Ines Šelendić Taras

Abstract: The poster shows the results of a short investigation of a modern shipwreck in the bay of Sv. Nikola on the island of Pag. During the research the entire ship structure was excavated and subsequently documented, and a 3D model was created with the corresponding ortho image and drawing. The article provides basic data for the ship's construction and descriptions of relevant parts of its structure. Radiocarbon analysis of wood fragments was also carried out dating the sampled element of the hull most probably to 18th century. Furthermore, an overview of possible modern types of ships to which the ship structure from the site would belong is presented.

Keywords: Pag, Trabacollo, shipwreck, postmedieval

Geographical and historical context

The island of Pag is situated on the eastern Adriatic coast, between the Velebit channel and Kvarnerić (part of the Kvarner bay). It is surrounded by Vir, Olib, and Rab islands, and stretches parallel to the Velebit mountain range sitting across the channel. The surface area of 284.56 km² and length of 58.25 km makes it one of the largest Croatian islands (Faričić 2003: 47). The shipwreck was discovered in the bay of Sv. Nikola (Mikula – local name) situated on the eastern end of the gulf of Pag, near the strait of Paška vrata, as the last bay still inside gulf of Pag (Fig. 1, left side).

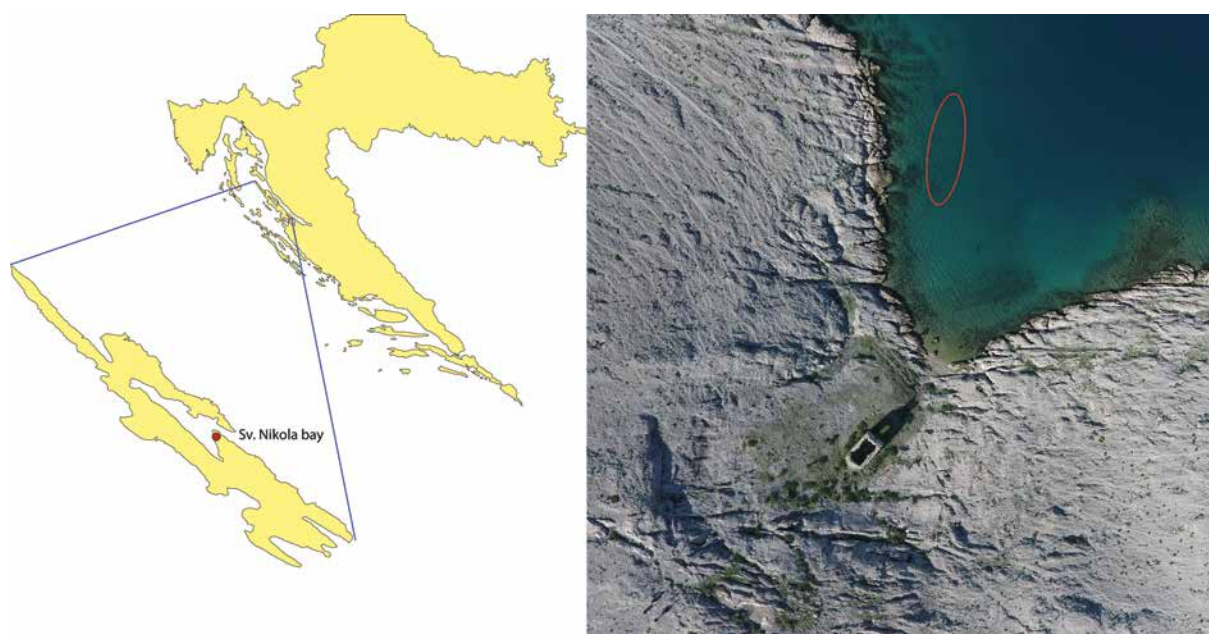
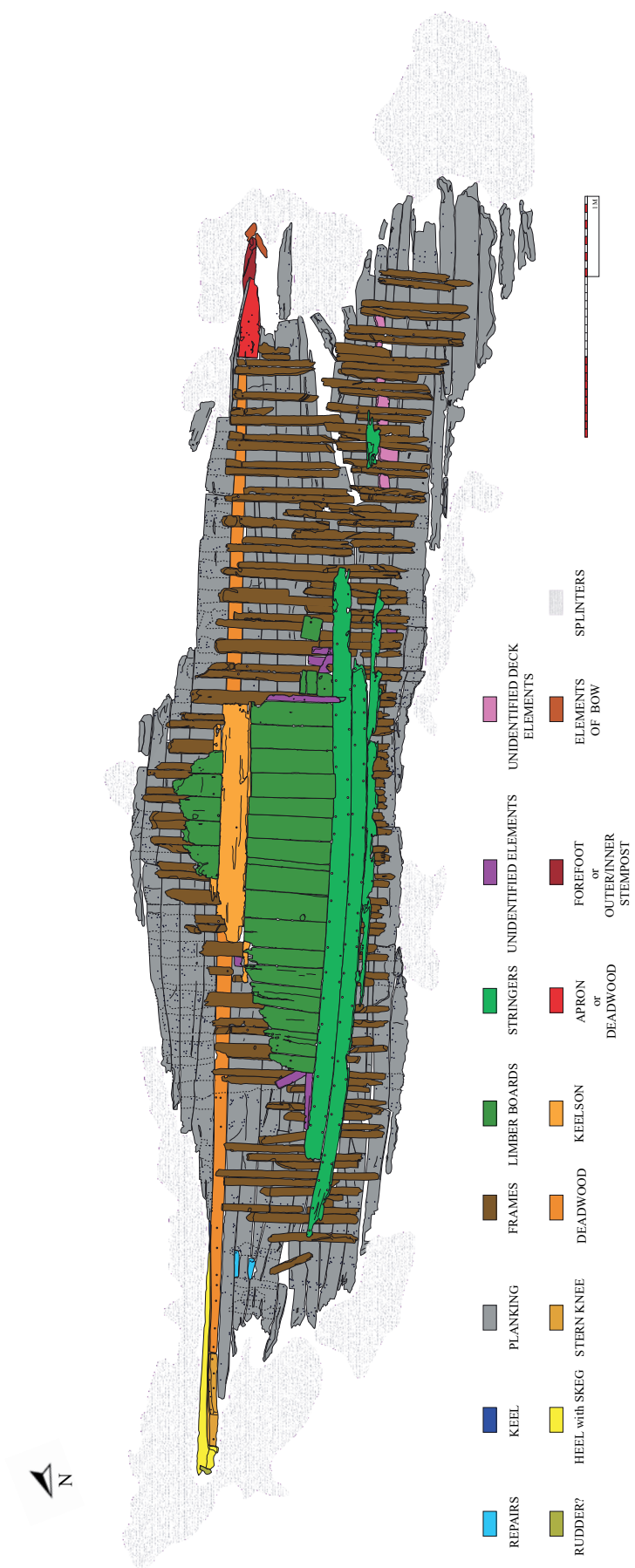


Fig. 1 Location of Pag island and the bay of Sv. Nikola with marked position of the wreck in the bay, with visible submerged remains of a jetty (drawing: D. Taras; photo: R. Maršić)

The bay shares its name with the remains of a small church – Sv. Nikola *in scalniza* – that is sitting on the slope above the beach. The church dates to the middle of 14th century, and can be compared to similar churches on Pag. The earliest mention of this building dates back to 1433 in connection with the communal allocation of lamp oil, and as a place where some type of tax (possibly customs duty?) was paid on the import of wine. Last mention of the church dates



back to 1823, when it was referenced as *dirocata* (dilapidated) (Hilje 2011: 155). Some interventions in the landscape are visible on the southern slope of the bay, facilitating easier access to the sea. The remains of a large jetty are visible beneath the surface of the sea on the northern side of the bay. This jetty protected the vessels in the small bay from north tramontane winds. A bit deeper towards the southwest at a depth of 4-5 m are the remains of the shipwreck that is discussed in this article. (Fig. 1, right side) The surrounding seabed is littered with post medieval ceramic finds dating to 17th century and beyond, ranging from luxury ceramic vessels made for serving a certain kind of food, ceramic forms which were involved in sugar production, even finds like *piedo di gallo*, which were used for separation of clay vessels in the furnace, in ceramics production.

2020 excavation

Almost parallel to the southern slope of the bay, at a depth between 4 and 5 m lie the remains of a ship discovered at the end of the 2019 research campaign. The objective of the 2020 excavation was, if circumstances allowed, to uncover the entire ship's construction. A grid comprising 17 quadrants was set following the grid established during the 2019 campaign. After cleaning the construction, a 3D model was processed and an orthoimage of the site was extracted. Only the basic measurements and descriptions of construction elements were recorded due to a relatively short research campaign, also taking into consideration the ship's dimensions. A small number of finds were recovered from the site: a few ceramic fragments and metal concretions, mostly nails. Following the end of the excavation, the entire site was covered, and the seabed was returned to its original state.

Ships' construction (Fig. 2)

The remains in the bay Sv. Nikola on the island of Pag span the length of 16 m, while the breadth measures 3.6 m amidships. The shipwreck rests on its keel, inclined to the better-preserved starboard side. The sided dimension of the upper surface of the keel measures from 4 cm to 19.5 cm, while its moulded dimension measures from 4 cm to 28 cm, where it was possible to measure. The outer planking consists of at least 54 strakes on both the port side (almost completely destroyed) and starboard side (partially destroyed). The planking width varies between 10 cm and 40 cm depending on the position of the plank. Some of the planks show butt scarfs. Two repairs have been identified in the planking system – RP1 and RP2. RP1 is an almost rectangular piece of planking, while RP2 is a triangular piece of planking. Both repairs are adjacent to the imprint of the frame F162, in the stern part of the ship (Fig. 3).

The transverse section includes a frame construction pattern which varies throughout the wreck, alternating between double floor timbers and a wider (double-sided) floor timber. The framing is comprised of 164 elements *in situ* and one displaced element, while the imprints of eight other missing frame elements are visible on the planking. At this stage of the research 32 groups were distinguished within the framing elements. In the keel area (amidships), the pattern is noticed in two narrow frames and one wider frame alternating. In fore and aft part of the ship, the framing elements patterns are less discernible. More research campaigns are required to take place in order to fully define the framing system. Furthermore, ceiling planks and the keelson need to be removed in order to fully study and comprehend the framing system (Fig. 2).

It is possible to establish the position of the stem and stern, as the wreck is oriented in the northeast – southwest direction with its stern on the northeastern side. The sternpost (Fig. 3) consists of the heel (K1) with triangle extension (skeg) which protected the rudder (Fig. 3). Upward from the skeg along the heel, a possible piece of rudder with a circular perforation is preserved (K3). Above the heel lies a piece of wood which might be characterized as a stern knee or deadwood (K4). Sitting atop the aft end of the keel and fore part of the heel is a longitudinal element which corresponds to deadwood (K5).

Due to a short research campaign, the bow (Fig. 4) was not completely excavated and defined. It consists of three elements: a triangular element, level with the frames, which might be considered as an apron or deadwood (K6), and two wooden elements which can currently be defined as parts of the stem (K7, K9). Disconnected from the bow end are two damaged wooden elements, which may belong to the bow construction.

The amidships area contains several longitudinal and transverse elements (Fig. 5). A longitudinal element that resembles a maststep (KS1) measuring 3.04 m in length (6.15 cm molded, 34-36 cm sided), sits above the keel line. Longitudinal timbers (KS2, KS3) were recorded next to the maststep, sitting on top of the frames, supporting the limber

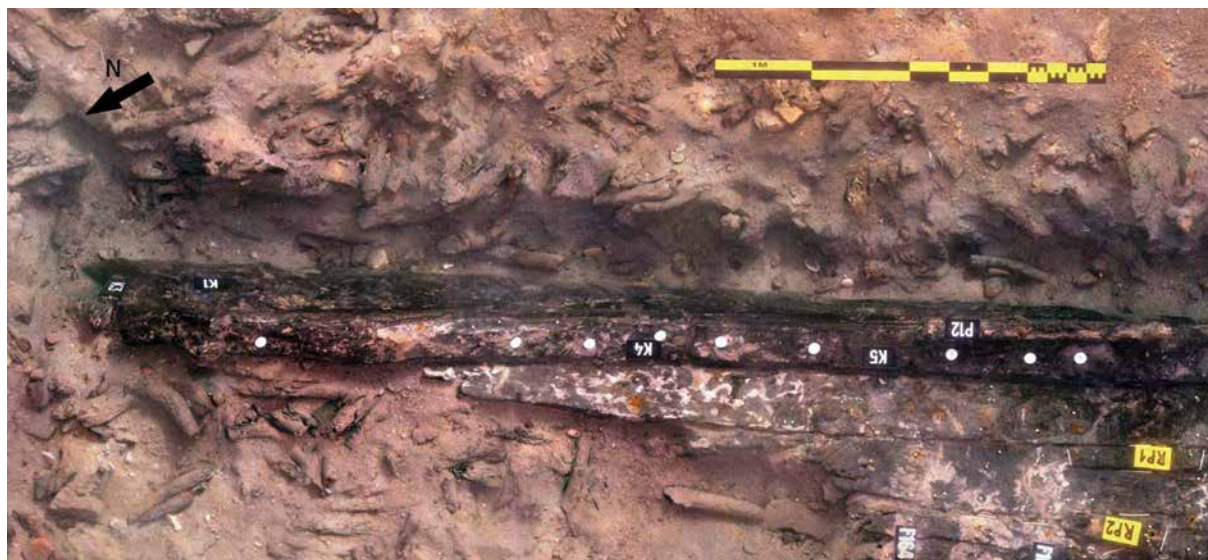


Fig. 3 Stern area with remains of sternpost and repairs (photo: D. Taras)



Fig. 4 Bow area (photo: D. Taras)

boards. Perpendicular to the keelson are limber boards extending to the port and starboard side (C1–C22, C28–C32) with keelson ends sitting on elements KS2 and KS3. These limber boards are not fastened to the construction. The width of the boards measures from 22.4 cm (C13) to 36 cm (C2). Their thickness ranges from 2.5 cm to 5 cm. Length of these limber boards measures from 102 cm to 113 cm. Furthermore, in the forward part of the amidships area three limber boards are visible, which are parallel to the keelson, on the starboard part of amidships (C26, C27 and a probably dislocated C25). These are much smaller than the aforementioned limber boards, and are divided from them by an unidentified transverse element (UM1).

Longitudinal elements adjoining the limber boards on the starboard side represent the remains of three stringers boards (C23–C24, C33). These measure 750 cm and 755 cm in length and 22.5 cm and 18 cm in width, respectively. Their thickness measures from 3.7 cm to 4.04 cm. An unidentified longitudinal element next to the stringer C23 sits atop the frames and beneath the limber boards, resembling (in function) the KS2 and KS3 elements adjoining the keelson. In the forward part of the amidships area a small, fourth piece of ceiling board (C34) is preserved with several unidentified constructive elements (UM5–UM11) (Fig. 6). These obliquely positioned boards were found wedged between the frames F4 and F20 on the starboard side. Some of these elements need to be excavated completely and document in detail in order to define them properly.

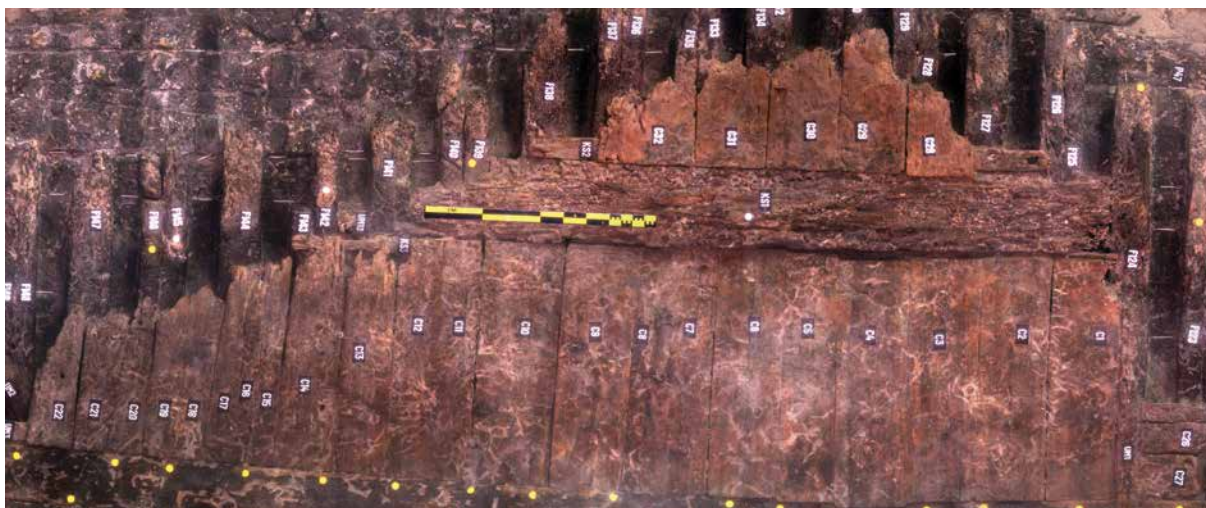


Fig. 5 Amidships area (photo: D. Taras)



Fig. 6 Unidentified constructive elements (UM5-UM11) (photo: D. Taras)

An area filled with large wooden splinters (most dense in the bow and stern area) surrounds the shipwreck. Those wooden splinters were also recovered during the removal of sediment from the ship's constructive elements. They may have been the cargo left on board as the ship sank or was scuttled. Also, it could have served as a sort of dunnage for the actual cargo (Figs 2–4).

Fastenings were noted and marked on the site. They were grouped in three categories: smaller fastenings connecting planking to the framing system (noted on both systems), larger fastenings detected on the keel, and larger fastenings detected on the ceiling boards. Due to the short campaign, a lot of data is missing, which will be recorded in possible subsequent campaigns.

Radiocarbon dating

One frame and one round wooden splinter were lifted from the site and sent to Radiochronology laboratory of Centre d'études Nordiques, Université Laval. In summary, the dates calibrated with IntCal20:

Round wooden splinter fragment is dated to 125 +/- 15 BP, with the following intervals: 1686–1733 (23%); 1805–1928 (72.5%) cal. AD;

Frame from the ship's construction is dated to 175 +/- 15 BP with the following intervals: 1665–1690 (18.1%); 1728–1785 (48,1%); 1794–1809 (8.8%); 1922–present (20.4%) cal. AD.

Combined dates (an average weight) are within following intervals: 150 +/- 11 = 1673–1697 (16.3%); 1723–1778 (28.8%); 1797–1814 (12.1%); 1837–1880 (14.3%); 1913–1944 (24%) cal. AD. These results point to the fact that the wood used to form the ship's frames could most likely be dated to the middle of 18th century, while the round wooden splinter is from a later date, that of 19th century.

Possible ship typology

Although the excavation was not finished, and not all the constructive details have been noted and documented, some of the characteristics of the sunk or scuttled boat in the bay of Sv. Nikola can be extracted from the available data. This was a vessel of at least 16 m long, with breadth of at least 7 m. In the analysis of first volume of Croatian Maritime Regesta there is a list of different types of ships and boats that sailed the Adriatic in the 18th century (Z. Podhraški Čížmek, N-M Brandl 2021). Out of 6479 vessels divided into 55 types, only few of them match the basic dimensions of our wreck: Checcia (length: 12–20 m, breadth: 4–7 m), Nava (length: 16–18 m, breadth: 6–8 m), Pielego / Pieleghetto (length: 11–28 m, breadth: up to 6 m), Tartana (length: 13–18 m, breadth: 5–7.5 m) and Trabaccolo (length: 12–30 m, breadth: 3–8m). According to the representation most common type in the first volume of the Regesta is Trabaccolo (1472 vessels, 22.72%), then the Pielego (1360 vessels, 20.99%), Tartana (870 vessels, 13.43%), while Nava (249 kom, 3.84%) i Checcia (55 kom, 0.85%) are rare occurrences (Z. Podhraški Čížmek, N-M Brandl 2021: 96, Table 1).

Trabaccolo (Trabakul, cro) is most common type of vessel in the first volume of the Regesta, and was built in a variety of sizes. Its' deadweight tonnage (DWT) ranges from 14 T to 200 T, height was up to 1.5 m, with a crew of 3–8 seamen. Common version had two masts with lugsails, was powered up to four oars and had a ships' boat in tow. Due to its characteristic Trabaccolo was used for trade and fishing purposes, and was a favourite trading ship in the Adriatic in the 18th century (Z. Podhraški Čížmek, N-M Brandl 2021: 105).

Pielego (Pelig, cro) is the second most common type of trading vessel in the first volume of the Regesta. Its DWT ranges from 15 T to 100T, height was up to 2.5 m with a crew of 3–6 seamen. Common version had two or three masts with lugsails and gaffs and was powered by up to four oars. Due to its characteristics, it had a lot in common with Trabaccolo, which was visible in its construction. Alongside trading it was also used for fishing, like the Trabaccolo (Z. Podhraški Čížmek, N-M Brandl 2021: 106).

Tartana is the third most common type of vessel in the first volume of the Regesta. It was also built in different dimensions, so the DWT ranged from 10T to 300 T with a crew of 4–20 seamen. Common version had 1–3 masts with lateen, square or lugsails, depending on the wind. This kind of versatility in the choice of sails depending on the wind made this type of ship very agile. It was used for cargo and passengers transport, but also for fishing. It had the option of mounting 6–14 cannons, as a warship (Z. Podhraški Čížmek, N-M Brandl 2021: 107).

Nava is one of the largest sailing ships of its time, with a DWT that ranges from 130 T to 800 T (for Naves from Pelješac DWT was 130–330 T) with a crew of over 20 seamen. It had 2–4 masts with square and lateen sail. This type of ship sailed and traded on the Mediterranean, even up to the northern seas. Aside from its role as a trading ship, Nava was also known as a warship (Z. Podhraški Čížmek, N-M Brandl 2021: 110).

Cecchia (Ćeća cro.) was a large sailing ship with a DWT ranging from 60 T to 230 T, and a crew of up to 16 seamen. It had 2–3 masts with a square, lateen or gaff sail, and was used as a trading vessel on the Adriatic, and Mediterranean also. In the registers it was often also identified as a Brigantine, due to its construction (Z. Podhraški Čížmek, N-M Brandl 2021: 114).

Concluding remarks

Although it is too early for definitive conclusions about the sunken or scuttled ship in the bay of Sv. Nikola, it could very well belong to a Trabaccolo, Pielego or a Tartan type of ship, with regards to its dimensions and the percentage of occurrences of aforementioned vessels in the first volume of the Registry. The short excavation campaign just uncovered the ships construction, and barely allowed a time to do the basic documentation and photogrammetry. It would seem that the cargo has been recovered after the wrecking, if the ship indeed was wrecked. Remains of possible cargo, or some sort of dunnage littered the shipwreck site around the ships construction. Nevertheless, the ship most probably belonged to the trabacollo class of vessel, as it was most common and favoured type of ship in 18th century, as mentioned above. It was a ship built for fishing and trade purposes. For the complete analysis of this site and the ship that sunk or was scuttled there a longer and more extensive archaeological research campaign is needed, as well as research in the state archives and historical sources concerning the Pag island.

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The *galea* Magna shipwreck – archaeological evidence and archival sources of a Venetian war galley of 1598

Andrea Podestà – Rita Auriemma – Fernando Zongolo

Abstract: Since 1999 and until 2021, numerous scattered remains of a presumed Venetian ship (weapons, coins, pottery, etc.) have been recovered from the shallow waters of the ‘trap-bay’ of Torre S. Sabina (Carovigno, Brindisi, Italy). Through extensive archival research and the study of the artifacts recovered, we were able to identify these finds as belonging to the *galea* Magna. On 11 November 1597, the *galea*, under the command of Marc’Antonio Magno, a Venetian *sopracomito* (ancient Venetian term for a noble commander of a galley), set sail from the island of Crete to Venice, following the common shipping route along the eastern Adriatic coast. A storm forced a change of route (Fig. 1) which, combined with the darkness of the night, caused the ship to run aground on the cliffs and sink at the entrance to the bay on 1 January 1598.

Keywords: galley, Marc’Antonio Magno, *galea* Magna, Torre Santa Sabina, shipwreck

1. Introduction

Torre Santa Sabina and, more precisely, the seabed of Baia dei Camerini has been, since the end of the 1960s, the scene of numerous underwater recoveries and, since 2007, the site of systematic underwater surveys and stratigraphic excavations conducted by the University of Salento in the broader framework of the research of seascapes archaeology in southern Puglia. In 2020–2021 this archaeological site was also the setting of a pilot intervention within the Underwater Muse project (Italy-Croatia CBC Program 2014–2020), due to the quality and variety of the finds in the bay. This latter can indeed be called a ‘supersite’, with its layers of events that are also significant markers of the evolution of the coastal landscape: cargos and hulls, but also remains of quarries and settlements (Auriemma 2014; 2015; Calantropio *et al.* 2021; Auriemma *et al.* 2022). One of the main objectives of the last 2020-2021 campaigns was to ascertain the attribution to a Venetian ship of several finds excavated during previous investigations.

2. Archaeological evidence

In 1999, close to the shore and at a depth of only 1.5-2 m, thanks to a joint intervention by the Central Institute for Restoration (ICR) of the Italian Ministry of Culture and the Ribezzo Museum of Brindisi, a metal object embedded in the sand was found. It was about 2.7 m long, curved and cylindrical in shape, attached to an unidentified wooden element, which was perhaps part of the longitudinal carpentry of a hull. The find was subsequently documented by photogrammetric filming during both the 2010 and 2021 excavation campaigns and left in situ (Fig. 2). Absolute dating, carried out at that time by CEDAD indicated a date range between 1320 and 1450. In the course of the various interventions, on the other hand, a number of weapons have been recovered: artillery projectiles (in iron and stone), an arquebus (muzzle-loading rifle), and mostly iron helmets (Fig. 3): about 23 examples of a particular type of *borgognotte* and one *cabbaset*, many of them overlapping and heavily concreted. They are presently being restored inside the ICR laboratory in Rome.

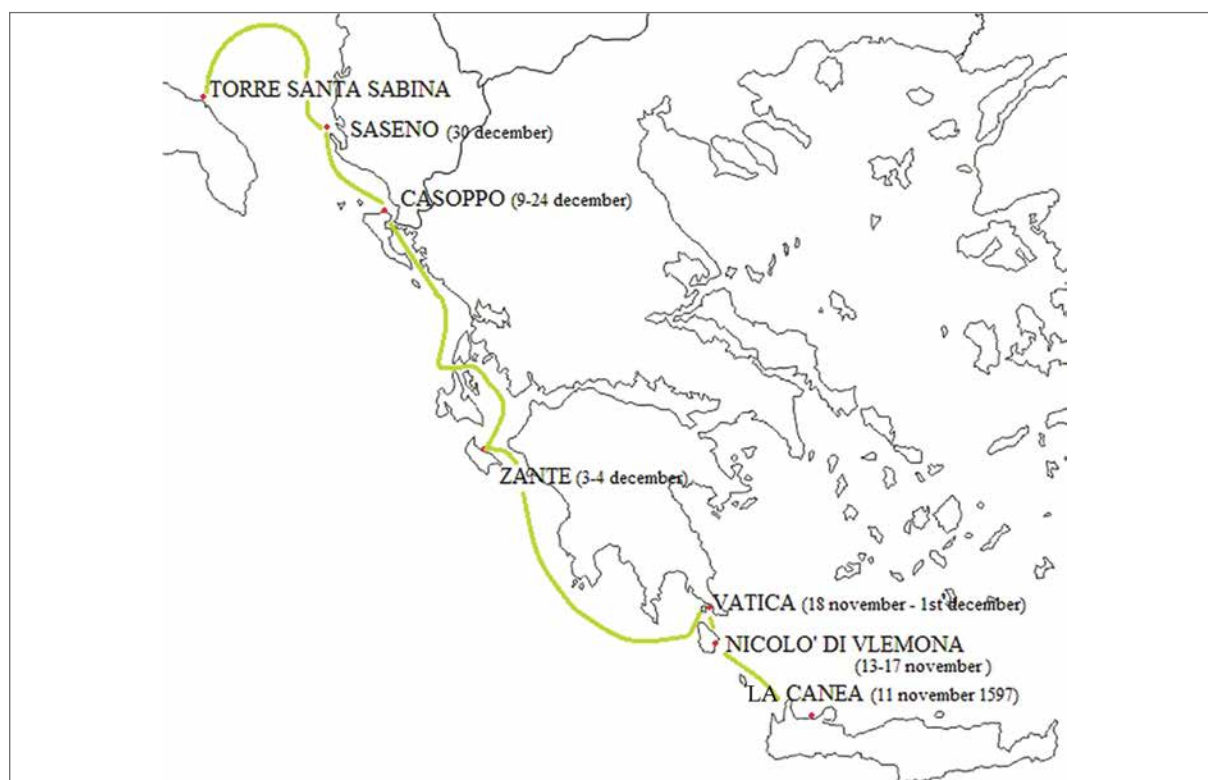


Fig. 1 Reconstruction of the route from the Venetian harbour of Chania to Torre Santa Sabina (author: A. Podestà)



Fig. 2 A metallic item attached to a wooden element not identified, maybe pertaining the longitudinal carpentry of a hull (elab.: L. Coluccia)

Over the years, several scattered fragments of archaeological finds have been recovered by Andrea Podestà and Fernando Zongolo: late 16th Century Italian glazed pottery (fragments of graffito pottery, apothecary vessels, plates, bowls, containers decorated with an armillary sphere motif (Fig. 4) and a probable fragment of Iznik pottery), glass fragments and several coins. During the 2011 campaign, a Venetian *Ducato* (Fig. 5) related to the period of regency of the Doge of the *Serenissima* Pasquale Cicogna (1585–1595) was recovered near the alleged naval item. This is a type of coin that, with minor variations, was in use for a century or more, with the winged Lion of St. Mark with its forepaw on the opened Book of Gospel on the left, the kneeling Doge on the right, holding the staff with cross and pennant at the top of the obverse and a full-length facing figure of St. Giustina, with palm branch and book, in the background; on the sides, two galleys at sea and a rocky island on the horizon and the value mark “124” *soldi* in the exergue of the reverse. Later, Podestà and Zongolo, after a storm, recovered and delivered to the Superintendence a pile of anonymous, largely concreted coins (Fig. 6), including a ten-gazette silver coin, called Lirone or Lirazza, (Venetian Law 1571, January 5) and a four-gazette coin (Venetian Law 1570, April 10).

In addition, during the 2020 campaign, an additional silver coin, yet to be restored and identified, was found near the aforementioned wooden element.



Fig. 3 A group of four corroded helmets a particular type of (borgognotte) overlapped and strongly concreted (photo: P. Pulli)



Fig. 4 From left to right: a fragment of a green and yellow glazed jar decorated with armillary sphere motif, a fragment of venetian *boccia* decorated with geometric shapes, fruits and leaf motif and two fragments of a white apothecary container (*albarello*) decorated with blue leaf motif (photo: A. Podestà)



Fig. 5 Silver coin (Reverse). Venice. Pasquale Cicogna (AD 1585 -1595). 124 Soldi (Ducato) type with a harbour scene behind St. Justina (photo: A. Podestà)



Fig. 6 Silver coins (heavily corroded) scattered on the seabed (photo: A. Podestà)

3. The historical fact

Years of research of archival records in epistolary correspondence from Naples and Dalmatia to the Senate of Venice in the Archivio di Stato of Venice and in the Vatican Apostolic Archive has finally made it possible to attribute those scattered fragments to a ship that was the protagonist of a long and troubled voyage. It was the year 1597, and on Tuesday, November 11, during the night of St. Martin's Day, Nicolò Donà, a 72-year-old patrician of the *Serenissima*, at the end of his tenure as Provveditor General and Inquisitor of the Kingdom of Candia, embarked for Venice from the port of Chania, a town on the northern coast of the island of Crete, on the wooden captain galley with convicts as rowers, "Veniera". The Veniera galley was followed by two slaves' galleys, the *galea* Magna and the Pisana commanded, respectively, by *sopracomiti* Marc'Antonio Magno and Francesco Pisani.

After the capture of three Barbary corsairs' ships (*fuste*) and other events, which forced Veniera to remain in the port of Corfu, on Monday, December 29, Donà sailed from Casoppo/Kassiopi bound for Dalmatia on the *galea* Magna, which became the captain galley, while the Pisana continued to serve as convoy galley.

Driven by the favourable sirocco wind, they reached the northern part of the island of Saseno, where the wind changed, coming from north-east, and the sea became so rough that they were unable to find a safe harbour despite several attempts. The waves broke with such force that they caused big damages to the *galea* Magna, and the two galleys lost sight of each other in the stormy sea, sailing separately towards Salento. The next day the *galea* Magna was close to the Apulian coast and the northeast wind suggested that they should get into port quickly.

Marc'Antonio Magno decided to sail to the safe harbor of Torre Guaceto (Cape Xiti), but the officers on board, not knowing the coast, mistook this place for Torre Santa Sabina, about 6 miles to the north. Upon reaching Santa Sabina, in the stretch of water to the east of the tower, the anchors were stranded, but in 1598, on Thursday, January 1, after the hour of Ave Maria (in the Roman time system, around midnight), the *grecale* wind caused the anchors to move on the sandy bottom and pushed the ship against the rocks, not far from the shore, causing it to sink. At the time, there were frequent landings there for embarking and disembarking; the Tower of Torre Santa Sabina did not have a guard, but local fishing families certainly did not hesitate to help strangers in distress inspired by the spirit of solidarity that has always characterized the seafarers.

We know that on that night the moon was two days past first quarter. Taking advantage of both the confusion and the illuminated sky, many rowers (convicts, *sforzati*) escaped, stealing valuables and money. We can assume this knowing that the galley was carrying a considerable amount of Venetian gold and silver coins.

As for the *galea* Magna, leaks in the bow quickly filled the hull with water and the deck quickly sank. Ironically, the seabed near those reefs was quite deep at the time, and had it not been for the inexperience of the sailors on board, who had no knowledge of those places, the galley would never have been wrecked.

The bow of the ship had remained high, supported by the rock on which it had collapsed. Superintendent Nicolò Donà only had to move to the front of the ship to avoid drowning and Councilman Tron with his wife and children and other people had also found a shelter in this small, not-yet-flooded space.

In the absence of the lifeboat, lost in navigation the previous day, there was no way out except to swim from that cramped, overcrowded and dark, wave-beaten place. As dispatches from Naples to the Senate confirm, some fighting occurred in a vain attempt to quell the revolt of the *sforzati* (convicts). There are reports of a *sforzato* from Mantua being wounded in the head by the galley's Comito (he was the highest non-noble officer who issued orders directly to the crew about when to row and when to sail). The *sforzato* in question attempted to escape after breaking a chest in the ship's desk, taking several large pieces of silver with him.

Some *sforzati*, who could not swim, remained in the bow, others saved themselves by swimming but at least a dozen lost their lives by drowning. On the morning of Friday, January 2, the Neapolitan Baron Agostino Caputo, feudatory of Carovigno, personally went to the aid of the Venetian nobles and hosted them in the Castle of Carovigno, about three miles from the site of the shipwreck. The generous help given to those *Serenissima* lords would be worth the granting of Venetian citizenship to the nobleman in 1599.

The kind aristocrat, however, once he realized the value of the ship's cargo, objected to the recovery of the Magna's cargo because he clearly wanted to take possession of part of the valuables. Indeed, according to the laws of the time, he would have been entitled to one-third of the goods recovered from the shipwreck.

The Superintendent General had lost his life savings in the sinking of the galley, and the other noblemen had also lost much of their wealth; the greatest damage had not been done by the sea, but by those who had tried to steal every item of value from the ship.

According to Donà's account, the shipwreck was due to the inexperience of the sailors on the galley. He then decided to file a complain against the Admiral Stamatello and the officers of the galley.

In the following days the sea returned ten bodies and several parts of the ship, destroyed by the waves, and dismembered by the violent blows against the rocks. The vessel was irretrievably lost, and the cargo was partly dispersed on the seabed and on the beach of the bay.

The nobleman Pietro Loffredo was the first to guard the recovered material, for which he was thanked for this by the Senate. Then a commissioner took daily and detailed notes of the finds.

On January 3, the vice-consul of Brindisi went to the site of the shipwreck, and on the same day Donà wrote to the Senate and to the Regency of Naples, where the notary Giò Carlo Scaramelli, aware of what had happened, reported the shipwreck and did his best to facilitate the recovery operations by convincing the Viceroy to have the Governors of Terra d'Otranto and Terra di Bari to issue the necessary orders. Around the middle of the month Baron Caputo left Carovigno in great secrecy to discuss in Naples his rights to the items recovered from the galley.

It should also be noted that at the time it was common practice to salvage from the wreckage even artillery, anchors and rigging, all items easily identifiable from the surface.

Harsh winter temperatures and storm surges certainly did not speed up the already complex recovery operations. Supervisor Marc'Antonio Magno personally supervised the recovery operations and interacted directly with the crew.

On Wednesday, January 21, the 13 galley guns, sails, and most of the equipment on board were recovered. The artillery had already been loaded and transported to Brindisi as was to be done with all the other equipment that was loaded onto a galley or a *Marcigliana* ship. The *sopracomito* and its crew were to embark on a galleon or a *Marcigliana*, while Donà was to embark on the *galea* Pisana.

On January 21 the ship appeared broken in the hull, so unrecoverable that it was the Donà's intention to sell it. But the hardships don't end here. The *galea* Pisana, once it broke away near the island of Saseno, continued sailing and reached the coast of Salento, where it escaped the fury of the waves near Otranto. The first letter containing news of the galley and addressed to the Regency of the Serenissima in Naples is dated Sunday, January 4. The galley had to drop some artillery en route to Apulia and, due to the stormy sea, it lost or damaged an antenna of the mast.

On January 20, the Pisana galley was still moored in Otranto due to bad weather and, although not *galea* fully repaired, it would head for Torre Santa Sabina to provide assistance to the *Provveditore* Donà and recover the *galea* Magna's public and private cargo.

After the Pisana hull has been repaired in early March, the castaways from the *galea* Magna embarked on the other galley, and set sail for Venice. Unfortunately, after arriving near the island of Mljet, the galley was driven for the second time by headwinds; a very strong bora wind blew it towards the opposite coast of the Adriatic.

On the night of Saturday, March 14, the mast also broke and the shipwreck could not be avoided; it occurred outside the port of Bari probably on the shoal called *u munde russ* or *Monterosso* (the red mountain).

Candia's Provveditor General, Nicolò Donà, spent more than two weeks in Bari, and on Sunday, April 5, having recovered his strength, he decided to continue his journey to Venice by land.

4. Conclusions

The analysis of numerous documents, compared with the archaeological testimonies, has produced conclusive evidence in terms of identification of the ship. In this respect, the correspondence with the Senate of the Venetian Republic of the high government official Giovan Carlo Scaramelli turned to be very useful.

The discovery provided information on the ship (master, passengers, crew, equipment, and hull structure), as well as on the story of the ship, its route (Fig. 1), and the reasons for its sinking. Several information about navigation and life aboard Venetian War Galleys in the late 16th century were also collected, thus completing the picture of the story of the *galea* Magna.

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RECENT DISCOVERIES AND AUDIT RESEARCH (POSTERS)

Potkamenica Cove shipwreck, island of Šolta, Croatia

Maja Kaleb

Abstract: The remains of a shipwreck located in the Potkamenica Cove on the island of Šolta were researched, documented and protected *in situ* in 2020, one decade after its discovery. The shipwreck is gravely devastated due to uncontrolled anchoring, but parts of the keel and one side of the ship with its belonging elements, planks and futtocks are partially preserved. The ship was built using the *shell-first* technique using the distinctive assembly method of tenon-and-mortise joinery. The sinking of the ship was dated in the 4th century by using the 14C AMS method and by the comparative analysis of movable archaeological material.

Keywords: Late Roman Period, Roman shipbuilding, mortise-and-tenon, Dalmatia, Croatia

1. Introduction

Šolta is one of the smaller islands of the Central Dalmatia region, presenting a highly indented shoreline (Fig. 1). Its administrative territory includes a number of islets and rocks. It gravitates chiefly to the city of Split, which had, and continues to have, the most significant impact on the development of the island and its inhabitants. Although we have no confirmation that the Greek polis of Olynthus colonised the island (Oreb 2012: 193) we do know that the island was referred to as Olynthus, meaning 'unripe fig' (Bezić 2012: 19), in the 4th c. BCE during the Greek colonisation of the Adriatic (Suić 1996: 196, 199). With the Roman incursion, and the concomitant Latinisation of toponyms, we see Šolta referred to as Solenta and by similar other names (Bezić 2012: 19–21). On the *Tabula Peutingeriana*, a cartographic itinerary showing the road network of the Roman empire, Šolta is shown as Iŷs. Solentij, i.e., *insula Solentii* (Faričić, Đuran 2012: 167). Numerous archaeological artefacts and architectural features - remains of economic and sacral character - bear witness to active life on Šolta. Along with the many traces of life on land, we also have a number of Classical Antiquity underwater archaeological sites (Vrsalović 2011: 122; Oreb 2012: 205; Bezak 2014: 570; Kaleb 2020; Kaleb 2021a: 13–14; Kaleb 2021b: 31–35) of various types (anchorage sites, loss or damage sites, and wrecks). Notable on the indented north side of Šolta is the Nečujam inlet, consisting of a number of coves: Šumpjivina, Potkamenica, Maslinica, Piškera, Supetar, Bok o' Supetra, Tiha vala and Bok od rata.

2. Discovery and research

2.1. Discovery and survey in 2009

Potkamenica is one of the coves to the west side of the Nečujam inlet. It is characterised by shallow water and the very good protection it provides against the most perilous of winds on eastern Adriatic coast: the north-easterly *bura* and the south-easterly *jugo*. An archaeological survey was performed in 2009 following a report and the discovery of a wreck. The investigation identified an antique period ship of the late Roman empire built using the shell-first technique and described the visible elements of the wooden structure (Radić Rossi 2010: 684–686).

2.2. Resurvey in 2019

The part of the cove with the remains of the ship was surveyed again in 2019. It was found that the wreck had suffered significant devastation in the intervening ten-year period and that there was a large quantity of destroyed and dislocated wood in the deeper part of the cove among the Mediterranean tapeweed (*Posidonia oceanica*) growing there. As the ship's structure was clearly threatened by a quantity of sediment insufficient to provide adequate cover, and by

the uncontrolled anchoring activity of many boaters, the decision was made to fully investigate, document, and adequately protect the wreck. The investigative work at the wreck site in Potkamenica cove in 2020 was the first systematic underwater archaeological excavation in the waters of Šolta island.

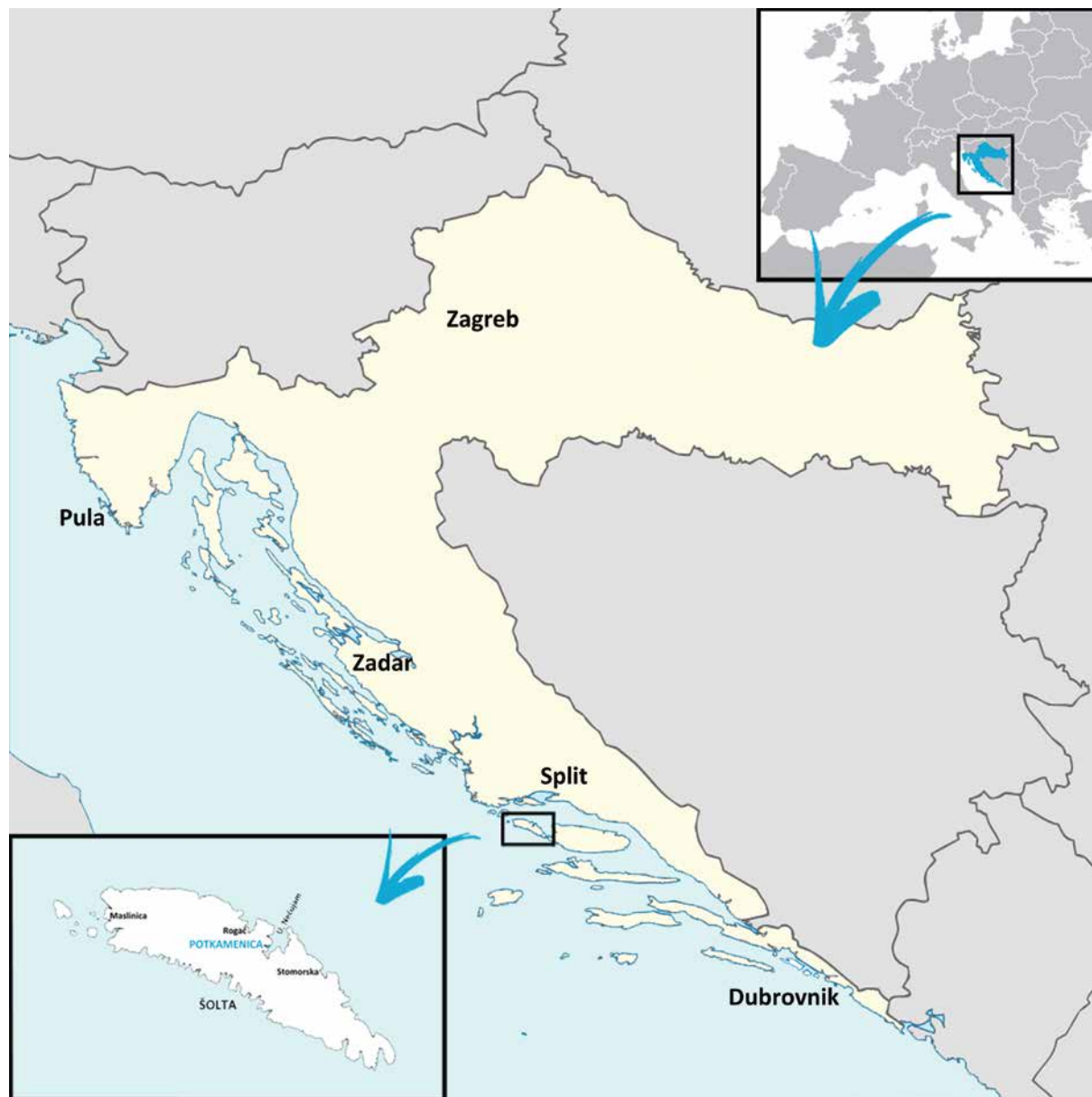


Fig. 1 Map of Croatia and Šolta Island with Potkamenica Bay (author: M. Kaleb)

2.3. Excavation in 2020

Following an underwater survey of the whole of the cove, our attention was focused entirely on the wreck site. It is located on the north side of Potkamenica cove, about thirty metres from the shoreline, on a gentle slope at a depth range of four to five metres. Prior to any intervention on the seabed the site area was video and photographically documented with underwater cameras for the production of a 3D model and a digital orthophoto mosaic of the condition as found. A grid with four fixed points and four 2 × 2 m metal grid sectors (trenches) was installed in order to facilitate the detailed documentation of all elements of the ship's structure. Upon completion of all preparatory work, the excavation and documentation methodology were agreed upon. It was followed by the start of archaeological excavation work which was assisted by a dredge with flexible reinforced tubes powered by a water pump. The surface layer of sediment was excavated to the level of the wooden material in order to identify the component elements. In areas where wood was not preserved the depth of the excavated layer was somewhat greater in order to ascertain if any material was present further down.

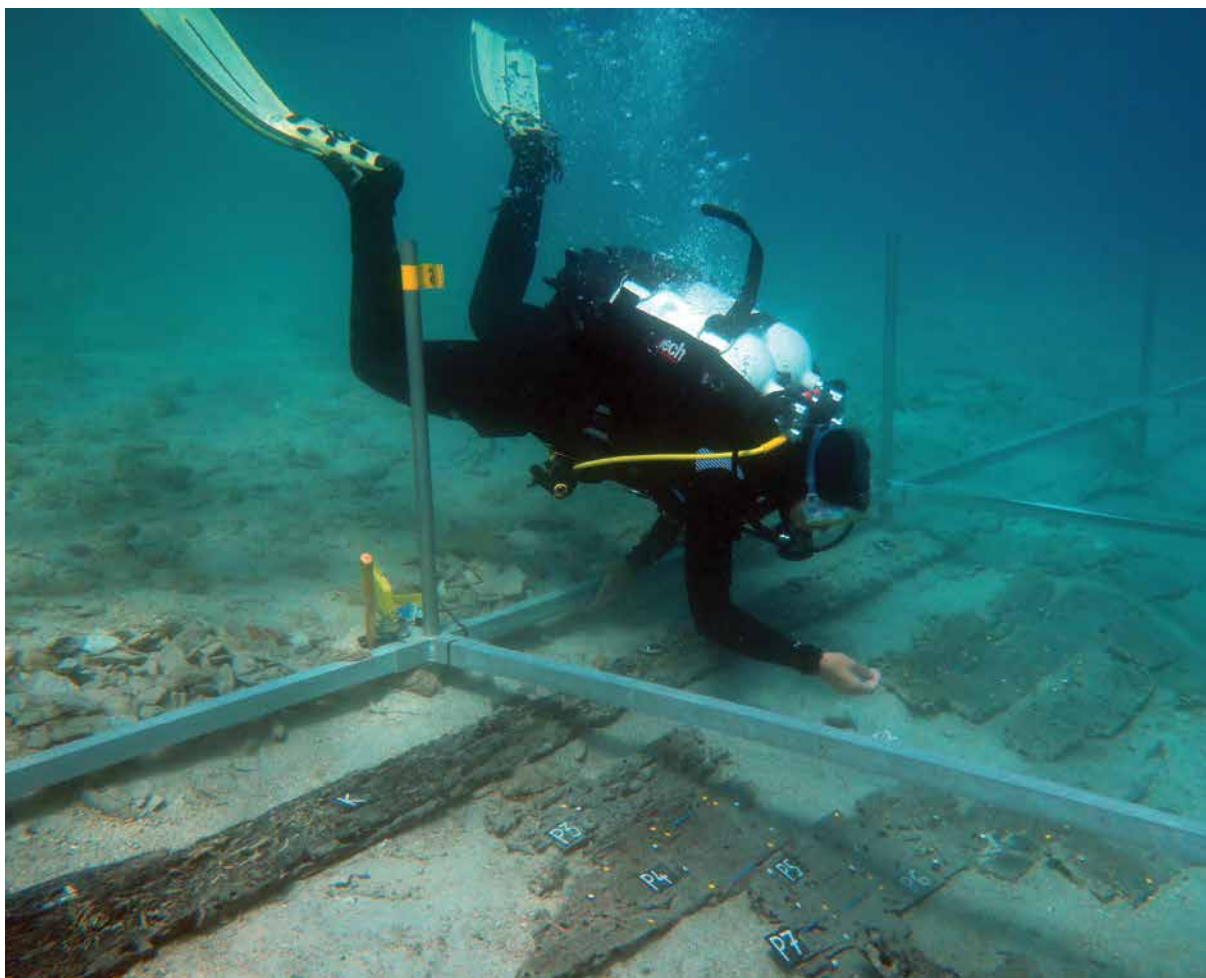


Fig. 2 Labeling of ship's structure before documenting (photo: R. Surić)

2.4. Documentation

The very meagre quantity of sediment – sand and rubble – meant that the surface of the ship's structure was very quickly revealed and identified. In situ labelling of the ship's elements was initiated upon the clearing of almost the entire area of the excavated trenches. The horizontal and transverse elements of the ship were labelled (Fig. 2) with white marker on rectangular PVC labels¹. The keel was designated with the letter K, with alphanumerical designators used to label the planks (P) and the frames and futtocks (F)². Joint elements were labelled with white and yellow markers. White was used to designate the treenails used to join frames with the outside planking, and yellow to designate the pegs used to lock mortise-and-tenon joints. Butt scarfs between planks were marked with blue wire. Once all the elements were labelled, the ship's structure was photographed in detail for the production of a 3D model. A total of 500 photographic images were made, then reviewed and processed for use in the Agisoft Metashape software. The produced result is a photogrammetric 3D model and a digital orthophoto mosaic of the site (Fig. 3). Along with the digital material we also insisted on the production of technical, i.e., hand-drawn documentation. A separate plan view was drawn for each trench, later merged as a complete field drawing of the wreck. The produced drawing of the remains of the wooden structure greatly facilitated the planning of the further course of excavation work. Three profile drawings of the preserved remains of the ship were also produced ahead of the placement of markings on the ship's structure.

¹ The film used for the labels is also known locally as *kalander*. Besides being reasonable in terms of its cost, this material is characterised by strength and durability. Black PVC film with a thickness of 0.23 mm was used.

² As a rule, F is used to designate a frame, while Fu is used to designate a futtock, however the poor condition of preservation at this wreck hampered a confident identification of the elements and their differentiation.

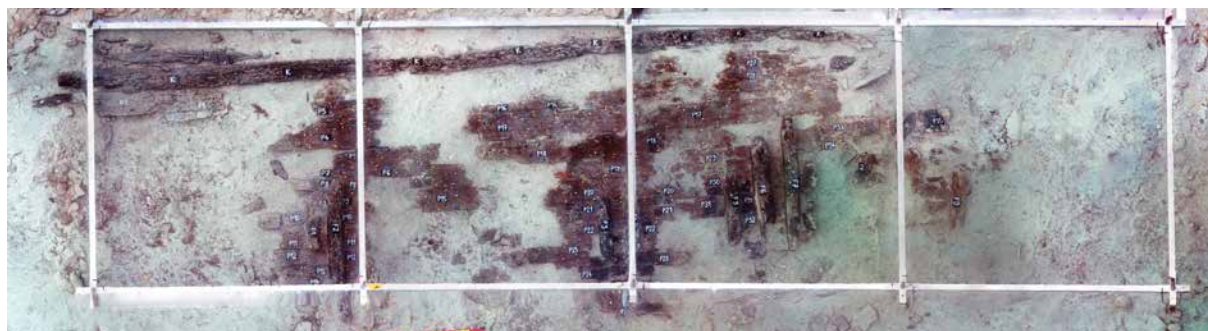


Fig. 3 Orthophoto model of ship's remains (author: R. Surić)

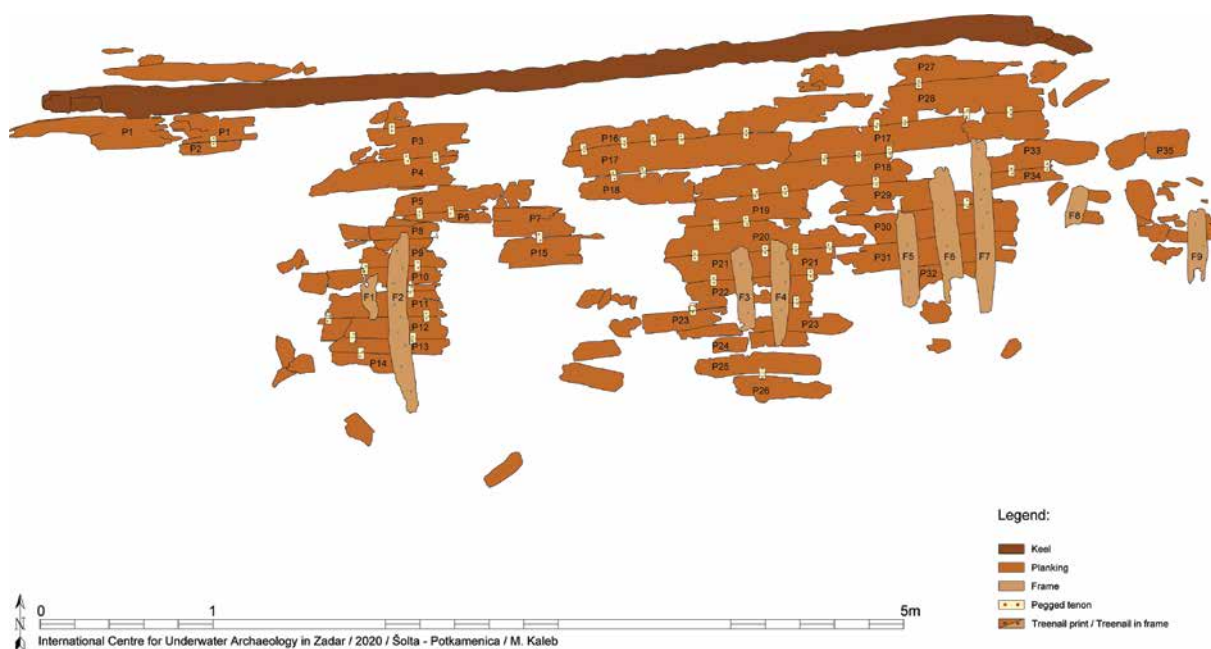


Fig. 4 Elements of wooden ship structure (drawing: M. Kaleb)

2.5. Remains description

The preserved part of the ship (Fig. 4) in the waters of Potkamenica cove cover a length of seven metres and width of 2.2 m. Most of the preserved remains of the outside planking and some of the futtocks were found in situ. The keel is in its proper place, but overturned. Small fragments of wood were observed around the wreck and at the bottom of a gentle slope about ten metres south from the centre of the site, but no confident determination could be made as to what part of the structural elements they were from. The very poor state of the remains of the ship's structure and the absence of some structural elements unfortunately means that no confident determination can be made as to which side of the ship has been preserved, or as to its alignment (stern and bow position).

3. Hull

The ship wrecked in the waters of Potkamenica cove was built using shell-first construction technique. The outside planking, consisting of planks laid edge to edge (carvel work) with mortise and tenon joints, was built after the keel and posts had been set. The ship's keel, made of oak (*Quercus sp.*), is preserved to a length of 5.9 m. The maximum preserved keel height (moulded dimension) is 18 cm, and the width (sided dimension) is 17 cm. The section is rectangular, with no visible rounding of the edges. The keel was not found in situ, rather overturned to the south with its topside lying on the garboard strake. Although it is likely that the garboard planks were joined to the keel by a system of mortise and tenon joints, as seen in the example of the Marausa wreck (Tiboni, Tusa 2016: 242) and the Monaco A wreck (Pomey, Kahanov, Reith 2012: 247), there are few material remains that might confirm this. At one end of the preserved part of the keel we see a scarf (Fig. 5), a joint used to connect two timbers or planks (Radić Rossi 2015: 445), e.g., two parts

of the keel, or the keel to the stem and/or the sternpost (Markovina, Ukalović 2010: 111). We know of a number of scarf variants (Markovina, Ukalović 2010: 111; Bernardi 1964: Figs. 15, 16, 17; Steffy 1994: 292–293), but the scarf joint most similar to the one at Potkamenica is seen on the Monaco A wreck in France (Pomey *et al.* 2012: 246, Fig. 14), with a three-part hook scarf locked with a large bolt.



Fig. 5 Keel scarf of Potkamenica shipwreck (photo: M. Kaleb)

3.1. Planking

The ship's planking consists of planks that are joined in rows to form strakes. We have only one partially preserved side at this wreck site, at which we have identified a possible twelve strakes. The widest plank (P28) has a width of 21.5 cm, while most of the others are about 16 cm wide. The average thickness of the planks is 3.8 cm. The longest plank (P17) measures 2.8 m. All planks subjected to xylological analysis were determined to be made of pine wood (*Pinus*), specifically black pine (*Pinus nigra*) or Scots pine (*Pinus sylvestris*), with the exception of one (P8) which is made from either Aleppo pine (*Pinus halepensis*) or stone pine (*Pinus pinea*). To the other side of the keel, towards the shoreline, we have only one very poorly preserved plank with thinned ends and degenerated form. Here and at some other zones of the wreck we see numerous perforations caused by naval shipworm (*Teredo navalis*) activity, and traces of burning.

3.2. Mortise and tenon joints

The planks are joined one to another with mortise and tenon joints. On the average the mortises in the planks are 6 cm wide, 6 to 8 mm thick, and 4 cm deep. A tenon averaging about 7.5 cm long and about 5 cm wide is inserted into a pair of facing mortises. The joint is locked with pegs averaging 35 mm in length gently tapered from 10 mm at one end to 8 mm at the other. All of the analysed pegs are made of black pine (*Pinus nigra*) or Scots pine (*Pinus sylvestris*). The average centre-to-centre distance between pegs is 17 cm.

3.3. Stability and cohesion of the ship

In the construction of this vessel the shipbuilders formed the outside planking after the keel, stem- and sternpost had been set, and then inserted the frames. Guided by the principles and methods of Classical Antiquity shipbuilding (Pomey 2004: 27–28) the primary structural elements providing stability and cohesion to the ship are the longitudinal elements, while the transverse elements (frames; floor timber, half frame, and futtock) served as reinforcement.

3.4. Frames and futtocks

A total of nine elements labelled F (frame) are in fact futtocks. As with the other structural elements, the state of preservation is very poor, such that assertions as to the original dimensions are uncertain at best. In all seven futtocks (F1–F7) were found in situ, while for two (F8–F9) the original position is uncertain as they are not connected with the main body of the structure. Traces of other frames and futtocks are evident as dark impressions on the preserved remains of the outside planking. We also see numerous treenails in rows set at relatively regular intervals on the inside face of the outside planking. The largest preserved futtock (F2) has a length of 1.04 m, while its maximum preserved sided and moulded dimensions are 10 cm. Five-sided and six-sided treenails with a diameter of 1.6 cm were used to attach the frames and futtocks to the planking. All the futtocks, and the treenails used to attach them, were made of oak (*Quercus sp.*).

3.5. Ship's fastening

Although metal nails were observed, documented and collected at the site, they were not observed in situ in the ship's structure. All of the recovered nails were made of iron. Radiographic (X-ray) images were taken of individual nails and of those in conglomerates. Most are well preserved at the core, although surrounded by a deposit of the various particles attached to the corrosion products produced by nails in seawater³.

3.6. Impermeability

The keel and planks are copiously coated on the inside with a black mass created from tree resin to protect the part of the ship below the waterline and to achieve the impermeability of the seams.

4. The result of radiocarbon dating

The xylological analysis (Fig. 6), which determines the type of wood, was carried out by Frederic Guibal from the Mediterranean Institute of Marine and Terrestrial Biodiversity and Ecology at Aix-Marseille University (France). Two samples taken for dating using the radiocarbon method were submitted for analysis to the Laboratory of Mass Spectrometry of the Centre for Physical Sciences and Technology (FTMC) in Vilnius (Lithuania). A sample from one of the planks (P7) of the outside planking was dated, following calibration, to the period between the years 123 and 247 with a 95.4% probability. Taking into consideration the necessary period for the drying of the felled timber⁴ and for the construction of the ship, it is likely that the ship that sank at Potkamenica set out on its maiden journey late in the 2nd or early in the 3rd c. Dating of a sample of a multifaceted treenail extracted from a futtock (F2) yielded a calibrated date with 95.4% probability from the mid-3rd to early 5th c. This result can be interpreted as indicating a repair, i.e., the replacement of worn or damaged elements with new elements, which was and remains a frequent practice in traditional wooden shipbuilding. With proper and regular maintenance, it is not unusual for ships to sail for several decades. The shipwreck in Potkamenica Cove lies just a few dozen meters from the north shore and upon excavation, it was revealed that the ship was devoid of cargo. Additionally, visible traces of burning were observed on the remains of the ship's structure, indicating a significant event in its history.

³ For more detail concerning this process, see Kaleb 2021c: 51.

⁴ Wood used for shipbuilding was dried at least two years, the time required for the moisture in the wood to evaporate. The process is done in a covered area that allows for a constant flow of air (Fréminville 1864: 345).

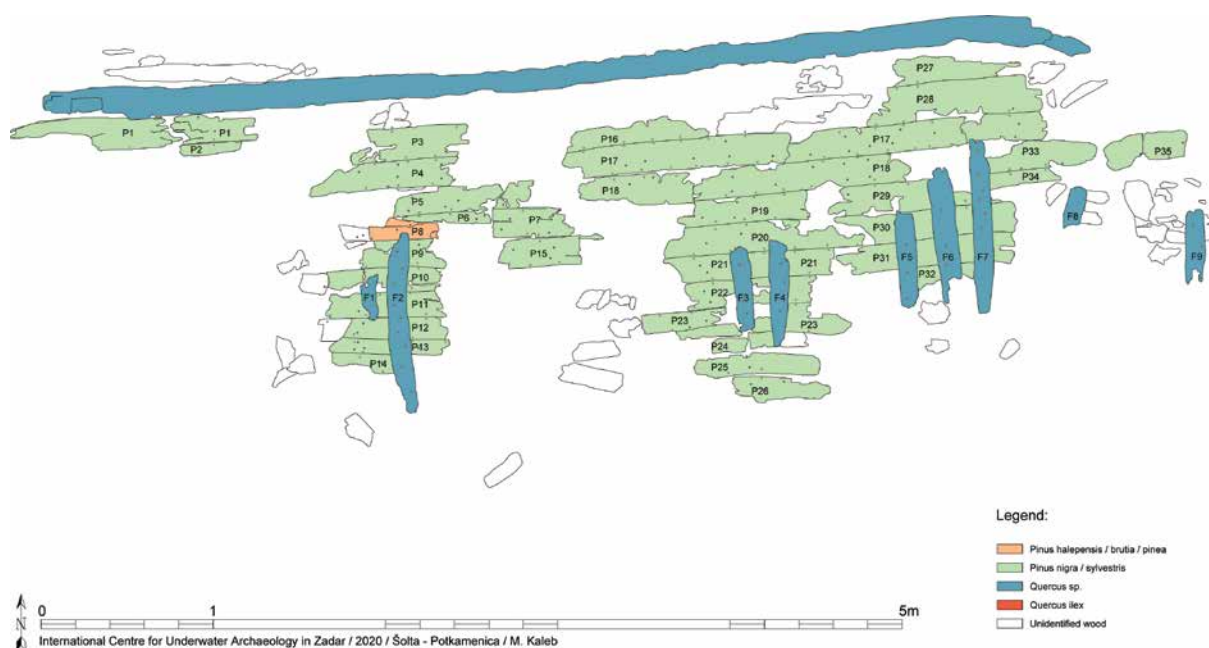


Fig. 6 Elements of wooden ship structure based on xylological analysis (drawing: M. Kaleb)

5. Other finds

Numerous sherds of antique period ceramic ware were found in the course of the excavation of the wreck and the survey of its immediate vicinity. These include various ceramic forms: table and cooking ware, transport packaging, and one ceramic sinker for a fishing net. The tableware includes several sherds from jugs and bowls, while the cooking ware includes fragments of pans and pots. Among the transport ware we see several amphorae forms originating from north African workshops. Found along with the ceramic ware were a number of iron nails, several ballast stones, and one section of rope. Based on the preliminary analysis of the ceramic material and the interpretation of the radiocarbon dating, we date this wreck to the 4th c.

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Condura Croatica – a revision of the structural drawings

Anita Jelić – Mladen Pešić

Abstract: Since 1994, two wooden boats known as *Condurae Croaticae* have been exhibited in the small Museum of Nin Antiquities. Over time, significant degradation has been observed on the wooden elements. This led to a comprehensive conservation-restoration procedure launched in 2017. During these works, a gap was noticed between the frames and planking measuring up to 5 cm, which led to a revision of the structural drawings of these vessels. With the help of new digital technologies and the creation of ship lines based on images, efforts were made to determine whether their current condition aligns with its first interpretation presented in the Museum.

Keywords: 3D scanning, 3D modelling, Nin, *Condura Croatica*, revision of drawings

1. Introduction

While extracting sand from the seabed, which was usually used as a building material, a sand miner from Privlaka extracted stones and traces of timber. He reported this unusual situation to the curator of the Archaeological Collection in Nin, underwater archaeologist Zdenko Brusić, who found a wooden boat at the very entrance to the port of Nin in his survey in 1966 (Brusić 1969: 443). Two years later, a wider search of the area near the first boat resulted in the discovery of another boat. The boats were situated at a depth of only 1.5 to 2 m under a pile of stones on the sandy seabed. Furthermore, they were found without the remains of cargo and equipment (Brusić 1969: 444). This pointed to the assumption that the boats were purposely scuttled to protect the entrance of the port of Nin from enemies in that period. The absence of any remains of cargo or gear made it impossible to ascertain the time of its use, and for this purpose a radiocarbon (^{14}C) dating of wood samples was performed. The completed analysis dated the boats to the middle of the 11th and beginning of the 12th century, i.e., to the High Middle Ages during the era of the native Croatian rulers (Brusić 1969: 443; Brusić 1978: 10–12).

In the 10th century, Byzantine Emperor Constantine VII Porphyrogenitus wrote that the Croatian navy at the time consisted of smaller *condura* ships and larger *sagena* ships (Kozlić 1991: 18). The *condura* ships had narrow hulls that were 7–9 m long and 1.5–2 m wide, and built with frames connected to the planks by treenails and iron nails. Over the course of history, they were known as the smallest but also very deadly warships. Apart from warfare and defence, they were also used for other purposes, such as fishing and the transport of people and goods. They were fast row boats and could be propelled by a sail when favourable winds blew. A specific feature of the hull's construction is the lack of a classic keel, replaced instead by a thicker keel plank. Instead of a classic keel, the boats had two parallel longitudinal beams on each side that ran along the outer part of the hull. These beams were used to stabilize it and maintain the boat's line while sailing, while also making the boats fast and agile. Moreover, due to the shallow stern, it is assumed that they were also used to pull them ashore (Brusić 1969; 1978: 8–10). Many similarities between the *condura* vessels and the boats found in Nin, such as a similar period of use, as well as length, width, specific hull construction and the presence of treenails, iron nails, and parallel beams, led the scholars to presume that those boats were the *condura* type. The boats were, therefore, named *Condura Croatica* and today they represent a unique example of the maritime tradition of the medieval Croatian rulers, which makes them exceptional and very valuable components of Croatia's cultural heritage.

2. Background

The boats were extracted from their marine environment in 1974 (Brusić 1978). The process of desalination, conservation, restoration and reconstruction of one of the boats followed (Jurić, Oguić, Vilhar 1991; Kozličić, Brusić 1991; Jurić, Sutlović, Vilhar 1997), after which both boats were exhibited in the Museum of Nin Antiquities, a department of the Archaeological Museum in Zadar (Fig. 1). However, due to the timber's sensitivity to the adverse microclimatic conditions to which the boats were exposed very soon after the conservation procedure, degradation was observed on the timber. This prompted the University of Zadar to conduct a collaborative analysis of wood samples with the University of Tel Aviv in 2008 and Texas A&M University in 2010. This analysis showed that the boats were made of oak (Radić Rossi, Liphschitz 2010: 263–264). Further analysis showed the impact of a number of chemical and physical processes due to the inadequate conditions to which the boats were exposed that degraded the structure of the wood (Šimičić, Vrgoč 2016). Based on these results, a comprehensive conservation and restoration procedure was initiated in 2017. The project receives funding through the Ministry of Culture and Media, and is implemented by experts from the International Centre for Underwater Archaeology in Zadar.

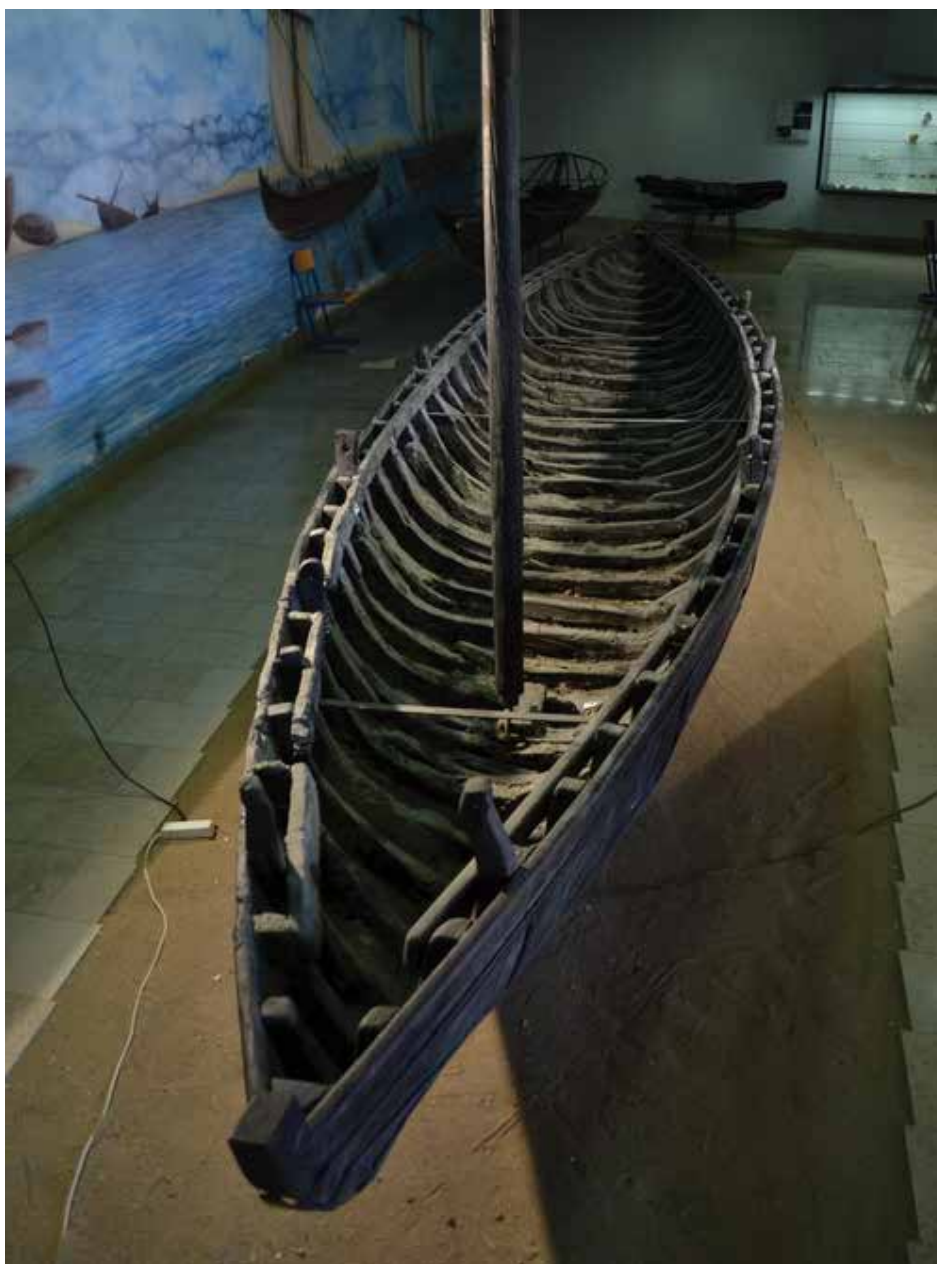


Fig. 1 The reconstructed boat (Nin MNS 2530), in the Museum of Nin Antiquities (photo: M. Ćurković Madiraca, ICUA)

A gap of 5 cm was observed between the planks and the frames during the process of conservation-restoration and cleaning of the boat structures. Since, so-called metal cradles in which the boats are exhibited were built according to measurements and designs made in 1974 (Jurić, Oguić, Vilhar 1991: 47–48), the possibility of the expansion of their wooden elements, which may have occurred when they sank, was most likely overlooked. The long-term impact of seawater on the structure of wood and the possible dimensional changes that occurred during the process of impregnation and drying of the wood also contributed to the aforementioned gap. Furthermore, the wood was irreversibly deformed by fluctuations in temperature and relative humidity in the exhibition room (Jelić 2023: 229) and mere force of gravity, especially on the wooden parts not supported by a metal cradle (Hauer *et al.* 2023: 50–51).

The need to revise the existing reconstruction was thus obvious, so digital documentation of the existing condition of the boats was done as part of the conservation and restoration process. With the help of new digital images and the construction of ship lines based on them, an attempt was made to determine whether the current condition of the *Condura Croatica* boats aligned with their original interpretation presented in the Museum.

3. Digital Documentation

The first step in digital documentation was a 3D scanning of the boats to obtain invaluable data about their length, dimensions and circumference, as well as their position points. The first 3D scan of the vessel structure was done prior to the start of PEG cleaning. The scanning and 3D model processing were done by Aero Photo 3D SLIC from Pula. After the initial scan, the wood remains underwent the complex conservation procedure. The main goal was to remove all PEG that was applied to the original wood and to get complete insight into the remains of the wooden elements, but also to understand the correlation between the original and reconstructed wooden elements that were added during first reconstructions. Upon completion of the cleaning process, new scans of the Nin boats were done. The 3D scanning was performed by a team from NITEH, Duga Resa, using a handheld scanner, i.e., a HandySCAN Black/Elite-Creaform scanner. Based on the data collected by the 3D scans, complete and detailed 2D technical documentation was compiled using existing ship lines as well as a complete 3D reconstruction with existing and missing parts of one of the boats i.e., the reconstructed boat (Nin MNS 2530)¹. The model was made by ViaKornel – an experienced studio involved in 3D modelling, prototype development and shipwreck reconstruction.

3.1. 3D modelling

The reconstructed boat (Nin MNS 2530), which was taken as the basis for making the 3D model, consists of original or archeological wooden elements but also additional wooden reconstructions of the missing parts. The original, archaeological component of the boat consists of the bottom section of the external planking with two longitudinal parallel beams and two thirds of the starboard. Inside the hull there are 24 incomplete frames and a mast step between frames 8 and 9. The boat's portside, missing parts of the starboard, bow and stern, along with nine frames (two on the bow and seven on the stern) were reconstructed during the 1970s and 1980s (Jurić, Oguić, Vilhar 1991).

During scanning process, special attention was accorded to the scanning of the original frames on which basis the reconstruction of the ship lines was planned and done. While creating a 3D model, the program highlighted certain irregularities. The program noted that individual frames do not follow the line of the model in their shape and it was not possible to fully fit them into the final projection (frames 6 and 9; Fig. 2). Due to their fragmentation, some frames provided insufficient information for their complete reconstruction (frames 11 and 16), while some were deformed and did not match the rest of the vessel contours (frames 5 and 21). Furthermore, some frames aligned more with the position of another frame, while some frames were used in the reconstruction of other frames (frame 15 used to reconstruct frame 21). The assumption is that parts of the wooden elements likely do not correspond to the newly made 3D model because the wood had dried and the frames had moved several centimetres back and forth compared to their original position and bending angle, as well as the lack of degraded parts in certain wooden elements (Budimir 2021).

Therefore, when making the reconstruction, only well-preserved original frames were taken as the basis for deriving the adequate line of the hull's shape. Certain corrections were made to adjust the position of the frames and optimize their shape in order to achieve a satisfactory visual and technical presentation of the hull's shape in 3D reconstruction (Budimir 2021).

¹ The boat that was scanned for the purpose of revision of the structural drawings in this article is inventoried in the Archaeological Museum in Zadar, Museum of Nin Antiquities, under number NIN INV BR MNS 2530. In the previous bibliography, this boat is also known as Nin 2. However, the written records and photo documentation of the work conducted by the International Centre for Underwater Archaeology in Zadar the same boat is referred to as Nin 1. Due to this unintentional name change, neither Nin 1 nor Nin 2 is used in the text in order to avoid further confusion.

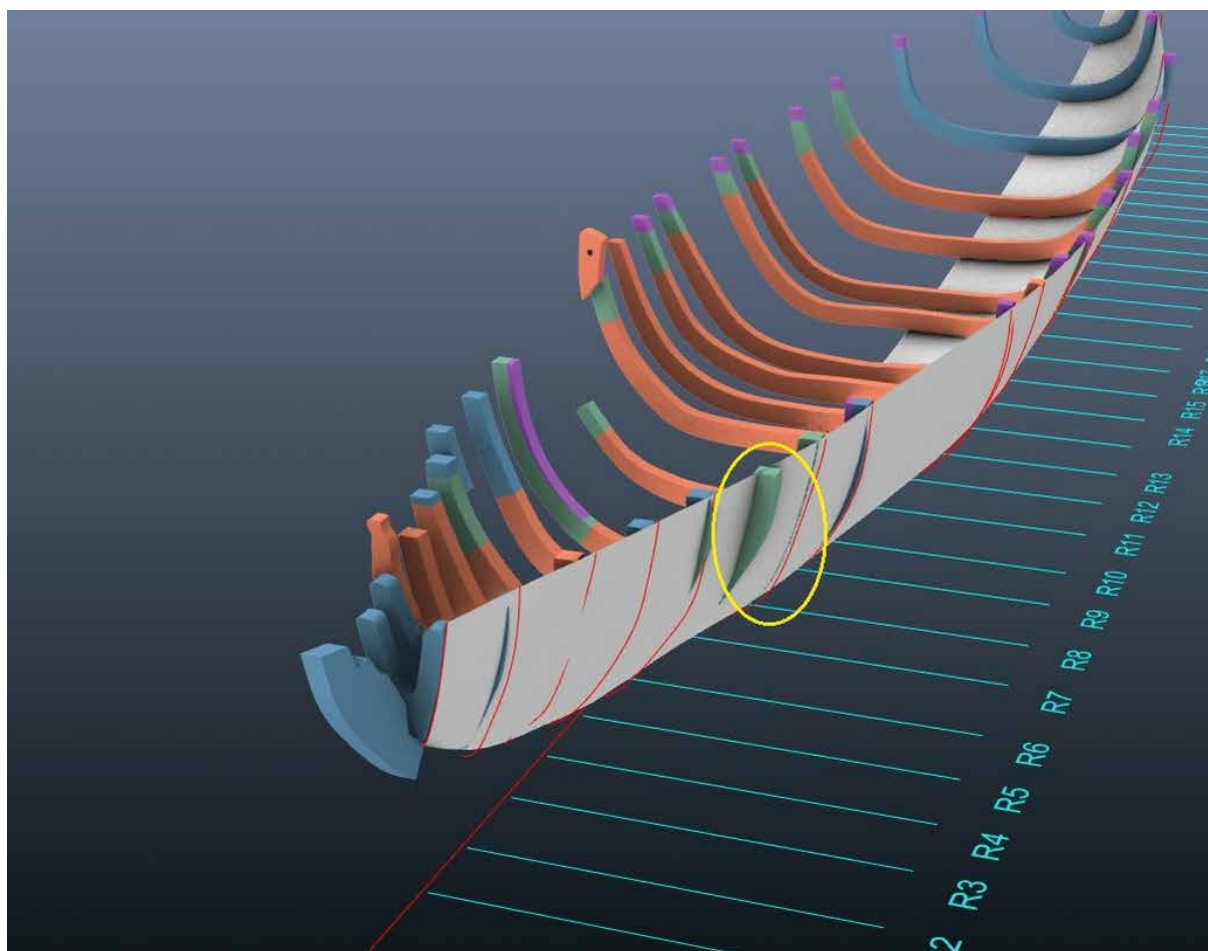


Fig. 2 Frame 6 does not adhere to the model line (model: N. Budimir, ViaKornel Ltd)

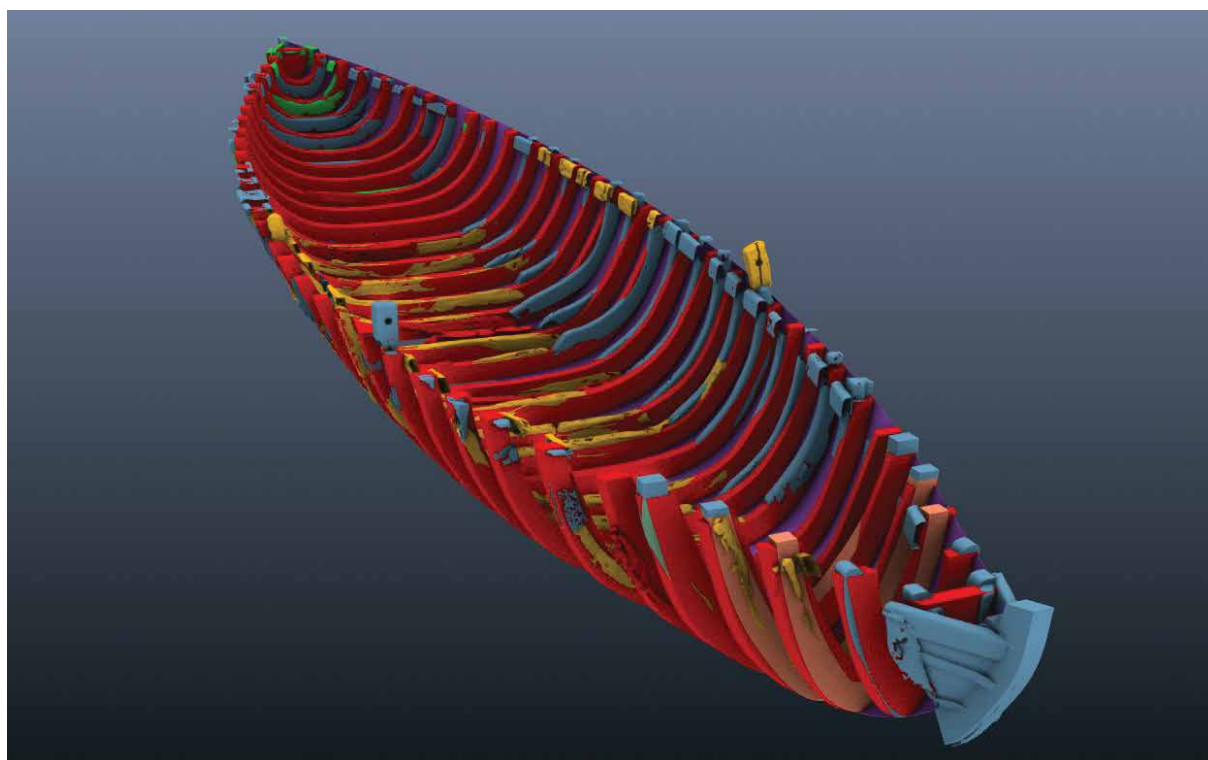


Fig. 3 Ideal reconstruction of the boat by 3D modelling (model: N. Budimir, ViaKornel Ltd)

Furthermore, because the stern end of the reconstructed boat (Nin MNS 2530) does not have preserved original parts, a compromise was reached between the original parts of the vessel's construction and reconstruction of the existing carpentry. Accordingly, individual frames of carpentry which best corresponded to the originally preserved lines of the frames were used in 3D modelling for the purpose of ideal reconstruction. As for other elements, such as the inner side plank, cleats and mooring elements, bow and stern loom and side beams, the original elements were used to make the model where they were available, and the model was supplemented based on carpentry reconstructions in those parts where original was missing. An ideal reconstruction of the vessel was obtained (Fig. 3) as result of 3D modelling, and the elements used were indicated in different colours i.e., yellow was used for the original preserved wooden parts, blue was used for the existing carpentry reconstruction, and red indicated the parts that make up the ideal line of 3D models (Budimir 2021).

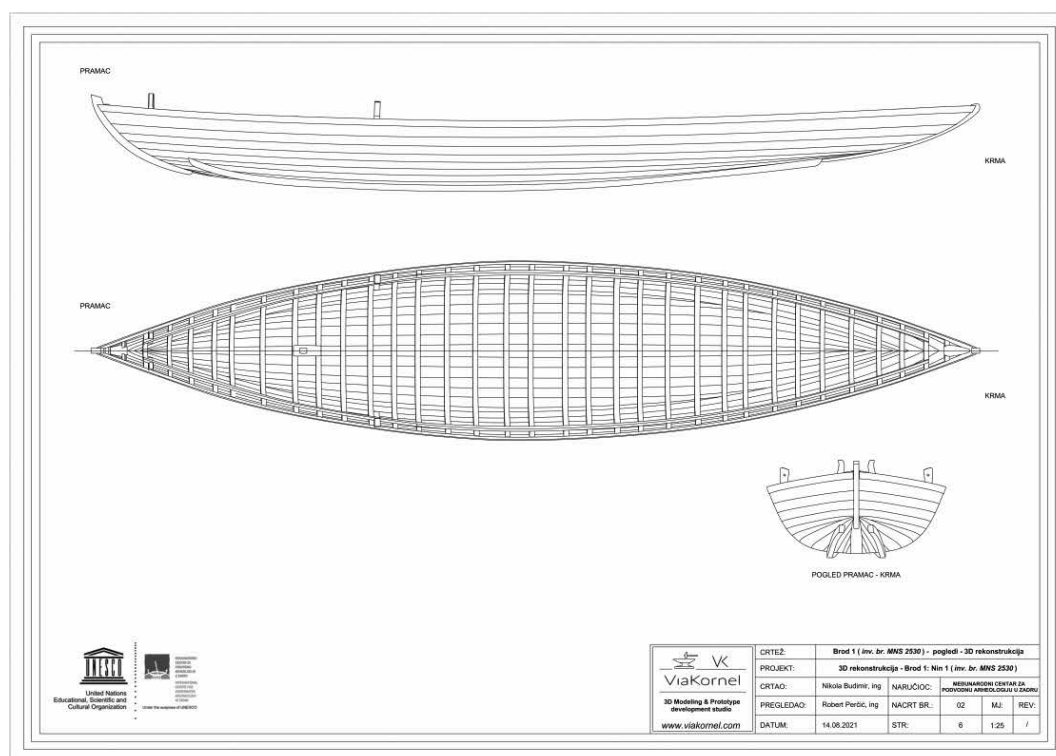


Fig. 4 Final drawings of the boat structure based on 3D modelling (drawing: N. Budimir, ViaKornel Ltd)

3.2. 2D documentation

Based on the information obtained by 3D scanning, 2D drawing documentation of the reconstructed boat (Nin MNS 2530) was compiled. A complete 3D reconstruction of the boat had to be done first to ensure that the 2D drawing documentation was accurate. This meant that within the 3D reconstruction, the missing elements of the vessel, as well as cracks, fissures or holes caused by marine organisms, cargo sludge, the marine environment or the conservation process had to be reconstructed. The creation of detailed 2D drawing documentation was possible after these irregularities were rectified. The 2D drawings clearly indicate which original elements were used to make the 3D model (Fig. 4). Since the 2D drawings are based on the 3D documentation of the current condition of the boat displayed in the Museum, the drawings represent only basic or introductory material for the possible future, more detailed analyses of vessel construction, and facilitate the comparison and revision of existing drafts of the boat lines (Budimir 2021).

Consequently, it became possible to compare the two drafts because the reconstructed boat (NIN MNS 2530) was documented before the aforementioned comprehensive conservation and restoration procedure was launched. Namely, in 2016 the studio Arheo Ko-op documented the then current condition of the reconstructed boat (NIN MNS 2530) by making 2D drawings. The boat was documented together with the metal cradle in which it is displayed (Fig. 5). A comparison of the 2D documentation from 2016 and the new drafts obtained by 3D documentation shows a noticeable difference in the shape of the boat. Since the metal cradle was probably built according to measurements made after excavation of boat from the seabed, when dimensional changes in wood due to various causes were most likely neglected, the shape of the boat is defined according to the shape of the metal cradle in which the boat is displayed.

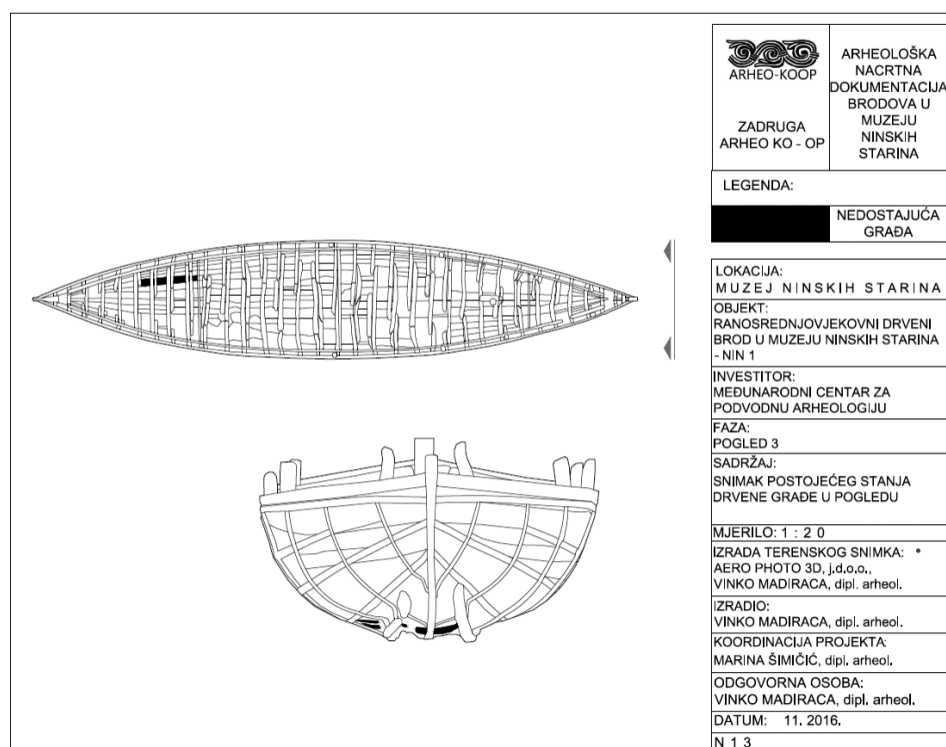


Fig. 5 Drawing of the reconstructed boat (Nin MNS 2530) with its metal cradle, made in 2016 (drawing: V. Madiraca, Arheo Ko-op)

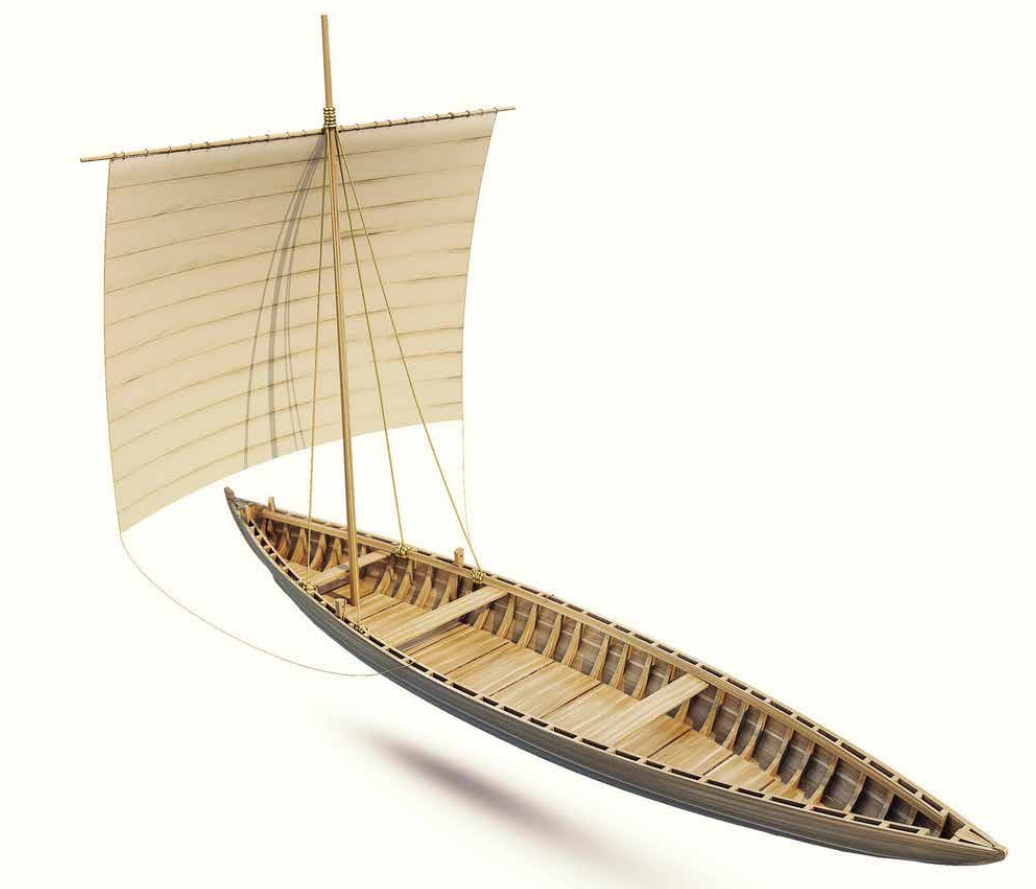


Fig. 6 Photorealistic image or rendering of the *Condura Croatica*, based on the model of boat Nin MNS 2530 (model: N. Budimir, ViaKornel Ltd)

Therefore, a comparison of the two bow-to-stern views shows that the shape of the hull is less rounded than thought. The 2D documentation obtained by means of the 3D documentation clearly shows that the bottom of the boat is flatter, its bilge is wider and its sides are straighter.

The aforementioned demonstrates that the size and shape of the metal cradle does not correspond to the shape of the boat's hull and continues to define and refer to an inaccurate and untrue line for the boat. There is an obvious need to present both vessels differently. This would provide better insight into the hull shapes as well as their construction, and the data obtained by 3D scanning can greatly simplify and accelerate the choice of how to display the boats – if a decision on their different presentation is ever made.

The final phase of this project was the creation of a photorealistic image or rendering of the *Condura Croatica*, during which the model was 'painted' and visualized entirely according to historical materials used in construction. In this case, it was about several varieties of oak (Radić Rossi, Liphshitz 2010: 263–264). The photorealistic image or rendering of the *Condura Croatica* was presented by the studio ViaKornel as a final result of 2D documentation and 3D modelling (Fig. 6).

4. Conclusion

3D scanning is a new technology which has also found its application in the documentation, recording and measurement of objects with great historical significance. The technology is efficient and accurate and has been selected as the contemporary method for documenting *Condura Croatica* boats. The benefits of documenting the current condition of boats by 3D scanning are multiple. With 3D scanning, the boats were archived in digital format and each piece was measured and documented without the need to touch or move them. By using 3D printing and laser cutting technology, it is possible to create and replace damaged or destroyed elements that are virtually identical to the originals.

Once documented in this way, 3D reconstructions, restorations or replicas of the boats based to the existing originals can always be made subsequently. Furthermore, the digital documentation of both boats has created an opportunity to display each boat more appropriately, which will better highlight their specific construction.

With 3D technology, the present ship lines were successfully reviewed and more accurate lines were obtained. The previously mentioned gap between the planking and frames was created not only due to the ill-fitting cradle in which the boat is exhibited, but also as a consequence of the wood drying and the frames moving a few centimetres back and forth from their original position. The bending angle of the frames due to drying and the absence of degraded parts in certain wooden elements also contributed to the aforementioned gap, as well as the different hull's shape. The revision resulted in an improved shape for the boat's structure and a corrected visual identity. The documentation materials may contribute to more detailed analyses of boat construction in the future.

Moreover, the accelerated development of augmented virtual reality applications can bring newly created and reconstructed technical 3D/2D materials closer to the public or museum visitors, shipbuilders and anyone interested in historical and traditional naval architecture. Augmented virtual reality applications can create a boat in the form of attractive virtual models and animations or as a virtual replica of the *Condura Croatica*, which can be presented in detail on the screen and thus combine technical documentation with modern digital technologies.

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Digital reconstruction of the Puck 3 wreck hull

Paweł Litwinienko

Abstract: The Puck 3 wreck is a 12th century clinker-built vessel, salvaged from the submerged remains of the medieval harbour in Puck, northern Poland, in 1990. Individual planks and other timbers were then passed on to the National Maritime Museum in Gdańsk for conservation. Following the procedures developed and used for the digital reconstruction of the other Puck harbour wreck, the longship P2, the timbers of the P3 cargo vessel were documented in 3D using the Faro Arm. This allowed for digital assembly of the individual timbers. On that basis a reconstruction of the complete hull was prepared and tested for hydrostatic properties.

Keywords: digital reconstruction, High Middle Ages, Slavic boat-building, lapstrake vessels

1. Introduction

The submerged medieval harbour in Puck, northern Poland (Fig. 1), has been studied since 1977, when it was discovered by a group of amateur divers. A logboat and four lapstrake vessels were found among the remains of complex harbour structure remains. Today, only two of them remain *in situ*, while the rest were salvaged. The logboat, dated to the 7th-8th centuries by ¹⁴C analysis and designated as Puck 4; numbers assigned in order of discovery, was recovered in 1989. Since then it has been safely stored in the regional museum in Puck (Litwin 1995: 140). Both salvaged lapstrake vessels, Puck 2 and Puck 3, are part of the collection in the National Maritime Museum in Gdańsk (NMM). The one-of-a-kind 10th-century longship Puck 2 was recovered in 2005. Over the past several years it has been conserved in PEG, digitally recorded, reconstructed and prepared for exhibition (see Pomian, Litwin 2009; Litwin 2021; Litwinienko, Różycki 2021). Two Puck wrecks are still *in situ*. Puck 1, interpreted as a 14th century coastal trader, was uncovered and partially documented in 1983. However, years of lying in shallow, littoral waters contributed to its further degradation. In 2019, poorly preserved, scattered timbers were collected by the NMM's diving team and secured underwater with geotextile. The last wreck, Puck 5, was found during the Puck 3 salvage operation in 1990 (Szulta 2002). It was uncovered, partially documented and dendro-dated to the 13th century (Ważny 2001: 68). The wreck remains *in situ* and is currently being investigated and studied by NMM archaeologists.

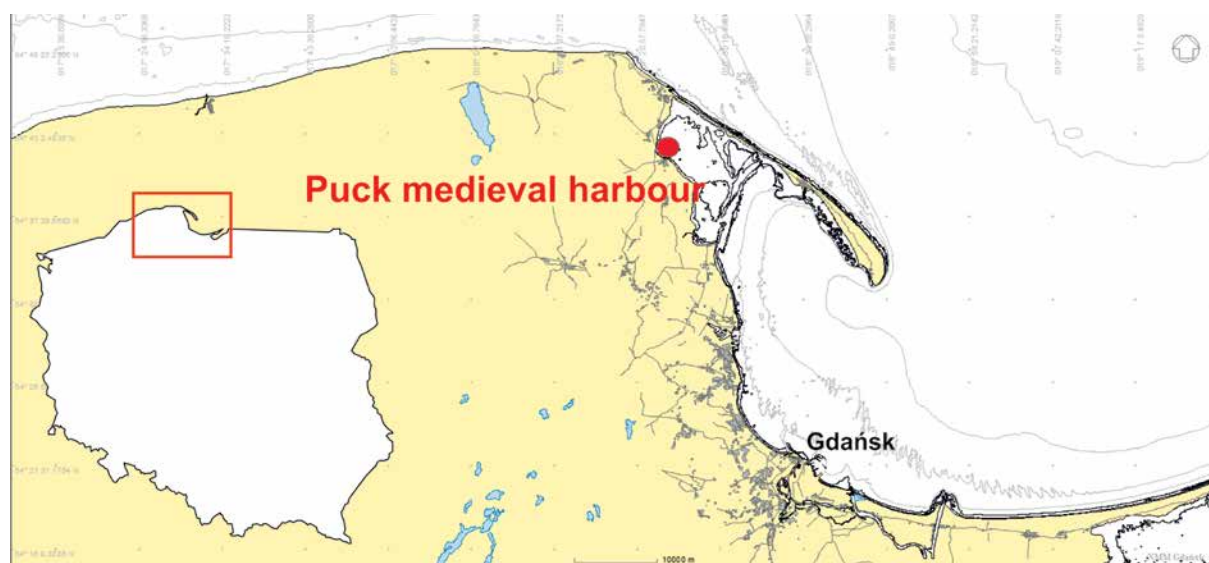


Fig. 1 Location of the Puck medieval harbour site (map: P. Litwinienko)

2. The Puck 3 wreck – discovery, salvage and conservation

The Puck 3 shipwreck was discovered in 1979 and its fore section was documented in 1983 during research conducted by W. Stępień (1984: 319). It was found in the western part of the site, 17 m south of the nearest recognisable harbour structure. The wreck, 11 m long and 3 m wide, lay in shallow waters, 1.5 m deep. It rested in an approximately W-E orientation, with its preserved bow facing west-north-west and submerged approx. 1.5 m into the seabed, while the midship was exposed, and thus prone to devastation. The wreck was covered with a layer of natural peat and no anthropogenic objects were observed within. In 1989, after a research hiatus lasting several years, it was decided to salvage the wreck, as it was observed that the exposed timbers were rapidly deteriorating (Szulta 2002: 77).

The wreck was fully examined and documented in 1990 by underwater archaeologists from Nicolaus Copernicus University in Toruń, while the NMM salvaged the wreck and assumed care of it for conservation, further study and future display. During the examination, apart from the actual wreck salvaged in several pieces, 86 loose structural elements were also extracted and passed on to the Museum (Szulta 2002: 77). Then the artefacts were documented (with drawings and photographs) and conserved with a PEG solution that was sprayed and brushed over the elements (Litwin 2021: 152). During the conservation process the wreck was studied to establish its chronology, identify the shipbuilding traditions employed during construction and define the best way to reconstruct it for exhibition purposes (Litwin 2000; Litwin 2021: 150).

Soon after its discovery, the wreck was carbon-dated to approximately AD 950 (Stępień 1984: 319). A total of fifteen dendro-samples were taken from the planking in subsequent years, which made it possible to set the wreck's chronology to the mid-12th century (after 1155). The dendro-provenance of the samples has still not been precisely defined – it most likely originated in the southern Baltic area, either in the vicinity of Gdańsk or Szczecin (Ważny 1999; Krąpiec, Ossowski 2003). The difference between the dating results may arise from the inadequate sampling of wood for radiocarbon dating or the bias in original interpretation (for an elaboration of inconsistencies between radiocarbon and dendrochronology results for dating clinker-built vessels see Ossowski, Krąpiec 1999).

3. The post-conservation digital documentation

In 2017, after documenting the Puck 2 longship (Litwinienko, Różycki 2021), the author, in cooperation with Janusz Różycki and Krzysztof Kurzyk from the NMM's Underwater Archaeology Department, began the digital recording of the conserved structural elements of the Puck 3 wreck, which was then being prepared for reconstruction in a specially designed cradle. Using the Faro ScanArm, a total of 95 artefacts were documented: keel, stem, five futtocks, 15 pieces of floor timbers, 11 knees, four thwarts (beams), two breast-hooks, two stem-planking connectors, 48 pieces of planking and six unidentified elements. 52 elements (mainly frames and floors) were laser scanned, while the rest (planking) was documented using a contact digitiser probe (see Jones 2015 for further reference). Next, the wireframe digital drawings were given surfaces and modelled into solid models used during the assembly of the digital model.

4. The wreck as found

Once documentation was completed, it became possible to assemble the individual elements in the digital model of the wreck in an attempt to recreate the as-found condition with the use of field data. The wreck is a clinker-built vessel built on a keel with almost half of the hull preserved, including the fore stem. The 8.39 m long keel has been almost entirely preserved; it is joined with a fore stem by a diagonal scarf fastened with a single large treenail. It is T-shaped in cross-section, which is 11 cm high and 17 cm wide at the widest part. Two rectangular (8 per 4 cm) grooves had been incised close to the scarf on the keel's upper surface, interpreted as being used to temporarily attach the garboard strakes to the keel and stem during the construction process using shipbuilding clamps (Litwin 2000: 263–264). This feature is present among several wrecks found in the Gulf of Gdańsk area, including Puck 2 and Orunia 3.

The fore stem is 2.3 m long and has some distinctive features in the form of extrusions for attaching the garboard strake, an oval hole in its lower part and a step for the second strake. The upper surface the stem has three rectangular grooves, such as those on the keel. A transition piece between the planking and the stem on both of the latter's sides was attached with nails in the form of a small plank formed by steps for the third and next planking strakes. The better-preserved port side transition piece is 1.6 m long and has steps for three strakes.

The planking has been preserved in good condition and to a considerable extent with up to six starboard and eight portside strakes. Most planking is still in large chunks of several planks are still connected to each other, with preserved moss luting. The moss species used was identified as *Drepanocladus aduncus*, which is common among early-medieval southern Baltic shipwrecks (Gos, Ossowski 2009). The planks, as well as other construction elements, are made of oak. They are approximately 2 cm thick and 20–25 cm wide. The longest complete (with both scarves) plank is 5.2 m long, while the shortest is only 1.7 m long. The strakes are clinker-laid with an overlap of 4 cm and joined with wedged wooden pegs 1.5 cm in diameter, placed every 10 cm. All strakes, except the sixth, are attached to the stem transition pieces; the sixth strake is shorter, as it terminates in a specially prepared step in the fifth strake, ca. 2 m from the stem. No traces of repair were identified on the planking.

The hull was reinforced with floor timbers, futtocks and knees. The floors, measuring approximately 7 cm sided and 10 cm moulded in section were fastened to the planking with treenails 3 cm in diameter and regularly placed every 1 m. Seven floors were preserved, including two V-shaped bow floor timbers. They covered six planking strakes on each side, being relatively flat in the midship. The lower surfaces of the floors had been shaped to fit with the lapstrake planking, with openings for the smooth flow of bilge water. Furthermore, five futtocks are preserved, extending the floors to the side in the vessel's midship; these were probably placed on floors no. 4, 5 and 7. The bow section was reinforced with two breast-hooks, connected to the planking with small pegs. Four rowing benches were preserved, including the one placed in the midship (2.9 m long) with an oval excision for the mast, as well as ten knees, reinforcing the sides above the benches.

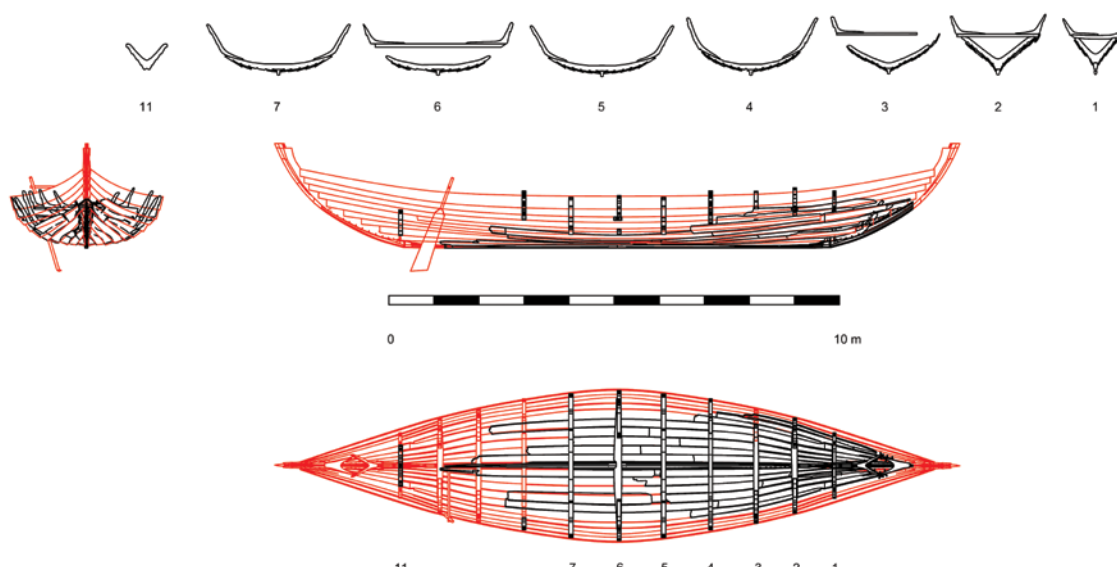


Fig. 2 Reconstruction drawing of the Puck 3 wreck, preserved timbers in black (drawing: P. Litwinienko)

5. Digital reconstruction of the hull

Digital reconstruction of the vessel's hull shape was done using Rhinoceros 5 software based on preserved elements, mainly the shape of the floor timbers and frames (Fig. 2). It was assumed that the ship was double-ended with a symmetrical bow and stern, which was common among medieval Southern Baltic vessels made in the Slavic shipbuilding tradition (see Litwin 2014: 31–22), and its widest floor was no. 6, with the bench and mast excision serving as the central frame. This central frame is situated 4.5 m from the preserved bow end of the keel, which after applying the assumed symmetry results in a 9 m total length for the keel (of which 8.4 m has been preserved). The preserved stem extends the hull 2.1 m forward (and, symmetrically, aft). After adding the reconstructed piece, shape of which was determined on the basis of the preserved curvature (approximate radius 3.6 m; see Litwin 2003: 262), this length increased to 3.1 m. The resulting overall hull length with stems is 15.2 m. The central rowing bench is 2.9 m long, and after adding its knees, the vessel's beam is 3.4 m. The bench does not rest on the floor timber itself, but rather on the reconstructed short frames that would make it higher and wider. The midship height of the ship is 1.1 m, while the stems rise 2.1 m above the keel. There would be ten planking strakes on each side. The total number of strakes is indicated by the height of the knees in the midship section. Nine planking strakes end on the stem and the sixth strake

ends on the fifth strake, which would increase the ship's beam. The overall reconstructed hull shape can be described as full; the ship is 1.6 m wide at the first frame, located at the stem.

The original hull shape was slightly distorted, most likely due to post-depositional processes that occurred while the shipwreck rested on the seabed covered by sediment. The bow section's V-shaped frames were apparently the sturdier pieces, as this part of the wreck is the least distorted, even though situated at the greatest depth. The distortion is most evident in the midship floor timbers, which had been flattened – floor no 7 was almost broken in half in the process. The keel is also slightly bent to the portside in its bow section, while its broken and eroded aft part, which lay above the sediment, juts upwards. It is unknown how and if the planking was distorted – after the conservation processes all planks are straight, their original and post-depositional curvature eliminated. In the digital reconstruction process, the distorted curvature of the midship floor timbers was altered to some degree to ensure the smoothness of planking which, as the hull was built shell-first, accounted for the original shape.

The ship is then a mid-sized (even though it is the largest of the early medieval Southern Baltic finds) transport vessel, 15.2 m long and 3.4 m wide, which gives it a beam to length (B:L) ratio of 1:4.47 (L:B 0.22). The vessel was most likely sail-propelled, as evidenced by the central beam. No mast step was found, however, as it was probably temporarily fastened to the floor timber. This type of mast step was found in several southern Baltic shipwrecks. The presence of frames and a simultaneous lack of benches on two floor timbers on both sides of the mast provided ample cargo space for transporting goods. The oars were probably used to manoeuvre during calm seas.

After modelling, the ship reconstruction was tested for hydrostatics in the Orca3D plug-in for Rhinoceros, using the methodology developed by Pat Tanner (Tanner 2020). Before calculations, it was necessary to prepare a simplified model of the hull, using the Orca Plate function, which enables the modelling of a hull's surface using control points placed alongside cross-sections. This surface was given weight, using the 'Orca Weight and Cost' properties tab: a model of each oaken construction element was given oak material density (800 kg/m³), hence the weight calculated by the software. The estimated lightweight displacement (empty hull with mast, with no provisions, ballast etc.) of the vessel is 1,554 kg. This empty hull sinks only 26 cm into the water, which is most probably the result of light planking, made of radially split oaken planks with a thickness of only 2 cm. This lightweight draft is similar to the result for Puck 2 (see Litwinienko, Różycki 2021, p. 311). As with the previously studied longship Puck 2, the medieval Icelandic Law (Tanner 2017: 173) was used to establish the minimum freeboard condition (F), according to the equation $F=2D/5$, which in this case equals 44 cm. The Puck 3 vessel fully loaded (achieving minimum freeboard) with ballast, provisions and a crew of 10 men (eight rowers, a helmsman and a lookout) displaces 8,934 kg of water and has a draft of 66 cm. The cargo capacity (including ballast, provisions and personal gear) of such a ship is 6,580 kg (approximately 6.5 t), while laden, with 50 cm of freeboard, the cargo capacity is 5,200 kg. The max heel angle, above which water pours into the open hull, is 15° in both loaded conditions, while the hull shows positive stability up to 25° of heel (Fig. 3). In order to achieve better sailing performance (higher freeboard and max. heel angle) the ship was probably loaded with even less cargo. The results of hydrostatic calculations are shown in Table 1.

Project	Lightweight	Loaded	Fully loaded
Length overall	15.2 m	15.2 m	15.2 m
Beam	3.4 m	3.4 m	3.4 m
Midship Depth	1.1 m	1.1 m	1.1 m
Waterline length/wet area	11 m/13.7 m ²	12.3 m/26.2 m ²	12.5 m/28.1 m ²
Displacement	1,554 kg	7,554 kg	8,934 kg
Draft	26 cm	60 cm	66 cm
Freeboard	84 cm	50 cm	44 cm
Crew number and weight	0	5 men = 800kg	5 men = 800 kg
Cargo, ballast, equipment, provisions, etc.	0	5,200 kg	6,580 kg
Max heel angle	35	15	15
LCB (measured from the bow)	7.62 m	8 m	7.85 m
VCB	17 cm	38.7 cm	42 cm
VCG	90 cm	64 cm	61 cm

Table 1 Results of Puck 3 hydrostatic simulations

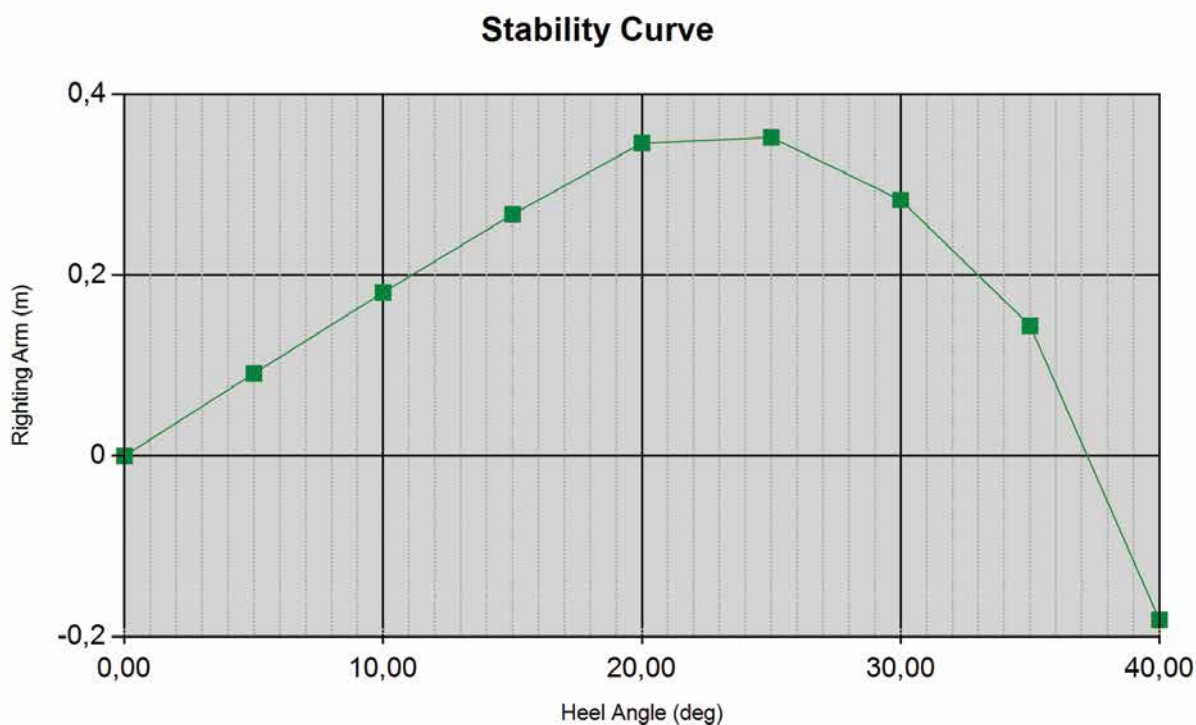


Fig. 3 The Puck 3 vessel stability curve in loaded state

6. Analogies and conclusions

The Puck 3 wreck seems to represent the typical southern Baltic (or Slavic) construction of a multi-purpose vessel that could be used for cargo transportation near the shoreline or for fishing. The wreck is very similar in its general proportions and construction features to at least four other wrecks dated to the 1150s–1200s and found adjacent to the Polish shoreline (Tab. 2).

Project	Puck 3	Czarnowsko 1	Charbrowo 1	Kamień Pomorski	Orunia 2
Dating	after 1155	after 1150s	after 1150s	after 1150s	after 1209
Length overall	15.2 m	13.76 m	13.2 m	12.1 m	11
Beam	3.4 m	3.35 m	3.3 m	2.7 m	2.27
Midship depth	1.1 m	0.85 m	1 m	1 m	0.87
Draft	66 cm	50 cm	-	65 cm	60 cm
B:L ratio	1:4.7	1:4.1	1:4	1:4.48	1:4.84
Cargo capacity	6.5 t (maximum)	5 t	6 t	5 t	3.5 t

Table 2 Shipwrecks dated to the latter half of the 12th century found adjacent to the Polish shoreline (data for wrecks other than Puck 3 after Filipowiak 2018: 97)

Of these four vessels, the Kamień Pomorski wreck, dated to the latter half of the 12th century, has recently been the subject of a published monograph that included its reconstruction (Filipowiak 2018). Both the Puck 3 and Kamień Pomorski ships are fairly similar, Puck 3 being proportionally longer and beamier (especially in the midship section), hence the greater cargo capacity of the former (Fig. 4). However, the stem from the Kamień Pomorski shipwreck has not been preserved, so it is probable that the vessel may have been longer. The Puck 3 wreck's shape is to some extent similar to the Skuldelev 3 shipwreck, interpreted as a Scandinavian local cargo-carrier used in safe and sheltered Danish waters. Its draft was calculated to 90 cm and cargo capacity to 4.5–5 t (Crumlin-Pedersen 2002: 195–243). The cross-sections of the bow and stern of both vessels are virtually identical; the greatest differences appear in midship, where the southern Baltic (Slavic) flat bottom of Puck 3 is clearly evident, as opposed to the prominent underwater

part of the Skuldelev 3 hull (Fig. 5). It seems that the Puck 3 vessel, the largest known southern Baltic wreck and the only one comparable to its Scandinavian counterparts, may have been used for local shipping in the sheltered waters of the Gulf of Gdańsk or, as there is a possibility of it originating from the Szczecin area, in the more turbulent open-sea areas of the Polish coastline.

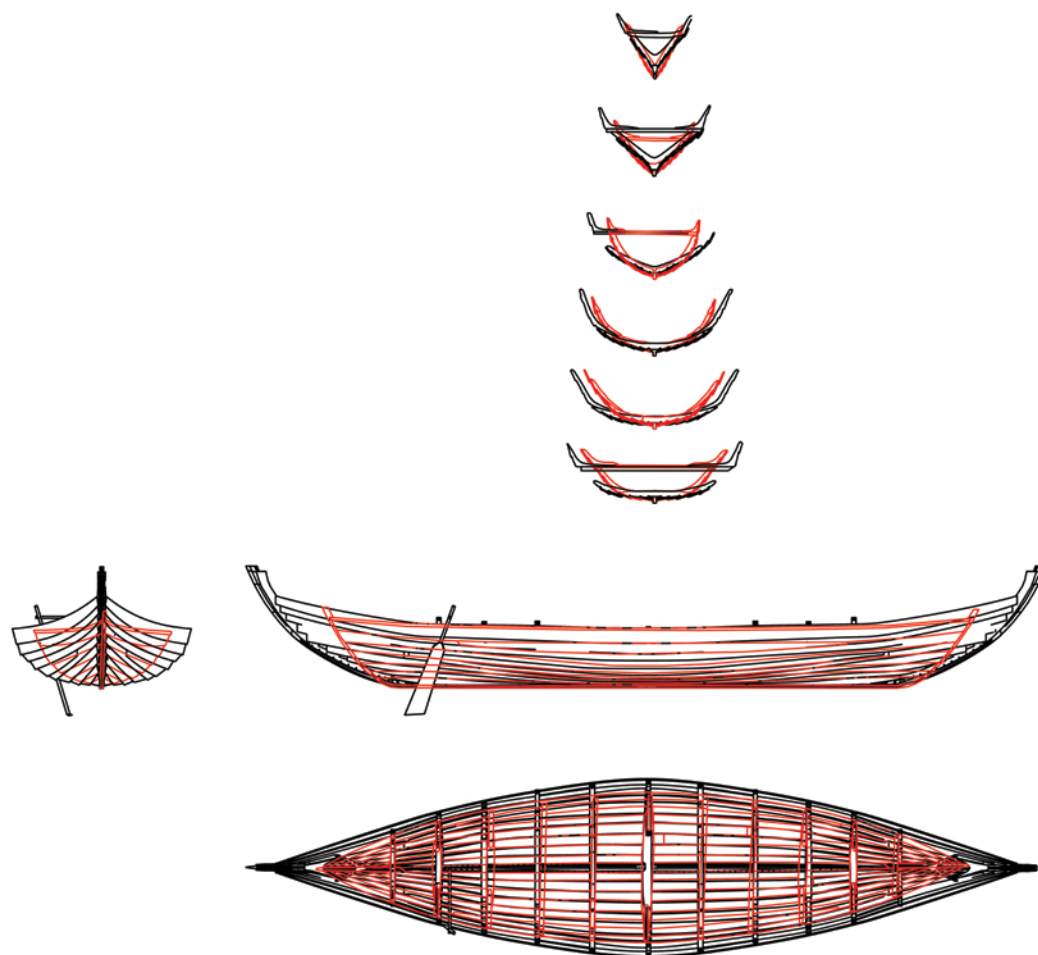


Fig. 4 Comparison of Puck 3 (in black) and Kamień Pomorski (in red) shipwrecks (Kamień Pomorski after Filipowiak 2018, digitised by P. Litwinienko)

The mid-12th century is considered the peak of Slavic maritime activity on the Baltic. This has been recorded in historical sources mentioning numerous raids by Slavic pirates against Danish and German towns and settlements, as well as the presence of Slavic traders in western Baltic ports (Ossowski 2016: 55). The historical sources mentioning maritime trade and warfare, written mostly by Danes and Germans, obviously focus on the western Slavs – the dukes of Pomerania and the Polabian pagans, leaving the Eastern Pomerania behind. Furthermore, the Baltic 12th century trade was dominated by Danish traders, with the main trade routes running from Lubeck and Schleswig east to Novgorod (Englert 2015: 21–23). However, the presence of several 12th century shipwrecks on the Polish coast, all of highly comparable form, cargo capacity and size not exceeding 15 m in length, may indicate the presence of a local trade route. These 12–15 m long multi-purpose vessels (Fig. 6) may reflect the scale of local exchange at a time of Danish dominance over long-distance Baltic trade, just a century before the rise of the Hanseatic League.

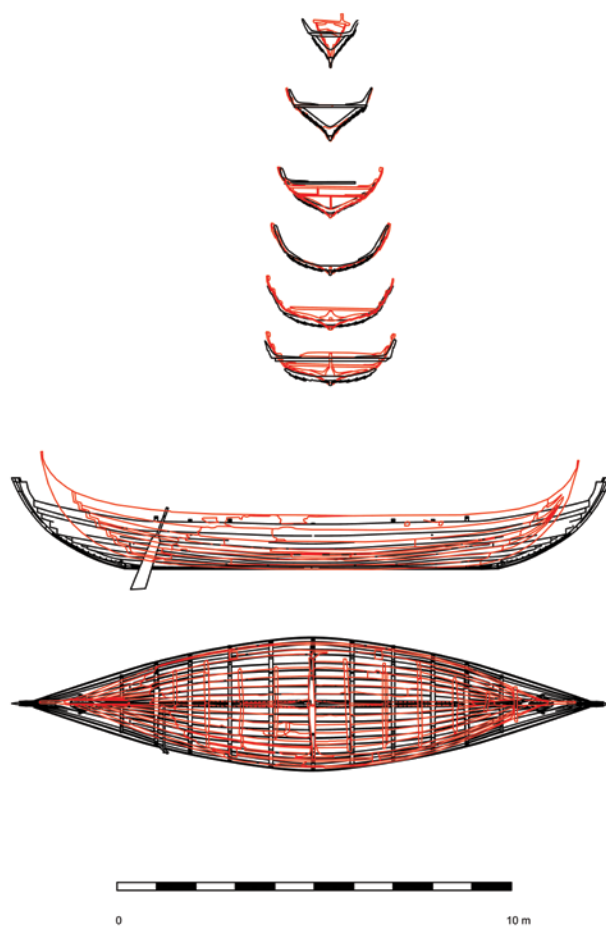


Fig. 5 Comparison of Puck 3 (in black) and Skuldelev 3 (in red) shipwrecks (Skuldelev 3 after Crumlin Pedersen 2002, digitised by P. Litwinienko)



Fig. 6 Three-dimensional visualisation of the Puck 3 local trader (author: P. Litwinienko)

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PHOTOGRAMMETRY AND REMOTE SENSING (POSTERS)

Photogrammetric techniques for 3D underwater record of the Late-Imperial Torre Santa Sabina's shipwreck

Luigi Coluccia – Rita Auriemma – Alessio Calantropio – Filiberto Chiabrando

Abstract: The possibility offered nowadays by the adoption of digital photogrammetry techniques allows one to virtually reconstruct the surveyed underwater assets to make them accessible also remotely, via visualization and dissemination platforms (online or offline). To improve the study of the documented cultural heritage artefacts and sites, it is crucial to adopt the right photogrammetric principles to achieve 3D metric products that are consistent and coherent with the real object of the survey. This paper is related to the photogrammetric survey of the late imperial era Roman shipwreck, located in 'Baia dei Camerini', Torre Santa Sabina (BR), Italy, in the framework of the project UnderwaterMuse (Italia-Croatia 2014–2020 Interreg Cooperation Programme).

Keywords: underwater archaeology, underwater photogrammetry, underwater museum

1. Introduction

This paper will examine some aspects related to the photogrammetric survey techniques of the beached wreck TSS 1 (Auriemma 2014: 156–166; 2015; Auriemma *et al.* 2022a), located in 'Baia dei Camerini' of Torre Santa Sabina, Brindisi (Fig. 1). It is a late imperial Roman wreck from the late 3rd-early 4th century that lies between 2.4 m and 3.4 m deep; its investigation and enhancement was one of the three pilot actions carried out in the framework of the international project UnderwaterMuse (Italia-Croatia 2014–2020 Interreg Cooperation Programme).

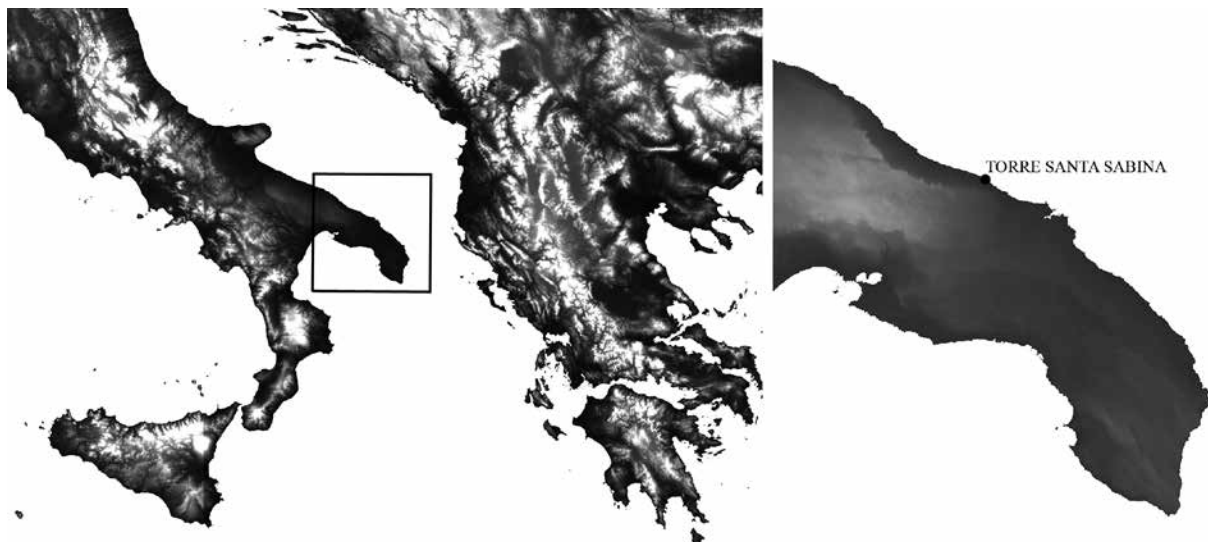


Fig. 1 Position of the site of Torre Santa Sabina

Based on our direct experience, we are fully aware that this contribution constitutes only a case study, not bringing anything new to underwater photogrammetry in general, but we nevertheless believe that it can offer some useful ideas in relation to photogrammetry in shallow depth contexts, where the ease of access suggests modifications to the appropriate intervention strategies.

In fact, contrary to what one might believe, the ease of access to a wreck at a very low depth poses a whole series of problems, mainly related to the quality of the operating conditions in the various stages of investigation development, from excavation to documentation.

It is evident that at these depths the stay in the water can be several hours, and theoretically, a lot more work could be done compared to greater depths, but the wave motion considerably reduces this possibility. It is necessary to constantly deal with poor visibility and the undertow's movement. This applies both to excavation and documentation operations, but also and above all, to the protection and conservation of the finds and the wooden structure of the hull, which must be constantly protected and ensured. Only on days of the calm sea will it be possible to obtain the maximum profit, and, at that point, the shallow depth represents an undoubted advantage.

The possibility offered today by the adoption of digital photogrammetry techniques allows us to optimize the times in the survey phases and to make the most of the calm days of the sea, even in low visibility conditions (on the photogrammetry see Calantropio, Chiabrando 2024 with bibliography, and Costa 2022 for the applications in low visibility contexts) .

For the same reason, the recording of topographical points must also be carried out in a calm sea, but the effectiveness of the measurement can only be achieved using some practical expedients, which the shallow depth allows for implementation.

The rods with antenna or prism, depending on whether they belong to GPS instrumentation or Total Station (TS), will hardly be able to be accurately maintained on the topographic point to be recorded if the operator does not step directly on the seabed. The experimentation of some supports capable of independently supporting the poles has allowed us to obtain satisfactory results with precision comparable to that obtained in land surveys.

The topographical and photogrammetric survey was carried out in an integrated form (underwater and UAV) and the research allowed us to obtain new advances in the acquisition and processing of underwater photogrammetry data in combination with the products achievable from drone shooting.

The salient phases of the work carried out will then be presented, starting with the photogrammetric processing carried out on archive images relating to the 2007 excavation campaign. Subsequently, we will move on to the description of the 2020 experiment focused on the photogrammetric acquisition of the aft part of the Roman wreck. This allowed the calibration of the survey and survey techniques of the 2021 campaign, also through the reconstruction of the new data with those of the survey carried out 14 years before this study. In conclusion, a preview of the photogrammetric survey carried out in the 2021 campaign will be provided (Calantropio *et al.* 2021).

Another aspect offered by photogrammetry, which will only be hinted at in this document, consists of the possibility of managing 3D models to compile augmented reality reconstructions of archaeological contexts, also accessible remotely via viewing and dissemination platforms online or offline (Costa *et al.* 2020 and Auriemma *et al.* forthcoming).

2. Underwater data acquisition and processing

The collection of underwater photogrammetric data was carried out in two successive campaigns carried out in 2020 on a small portion of the wreck (stern) and in 2021 on the entire surface affected by the remains of the Roman ship.

The underwater photogrammetric acquisition was performed using two digital cameras (Fig. 2), an Olympus Tough TG-6 and a Nikon Coolpix W300 (Capra *et al.* 2015), following both different acquisition schemes (nadir and oblique) useful for obtaining complete 3D and 2D documentation.

The cameras used can operate without underwater housing at a maximum depth of 15 m the first, and 30 m the second; thus, no additional housing was used during the acquisition phase. This also reduced image residuals and systematic patterns that are usually detected when dome ports are used (Menna *et al.* 2020).

Before capturing the images, some markers were placed on the sea floor around the wreck. The same markers were subsequently measured using a 4 m long pole and prism, shot with TS from the shore. Two divers manipulated the

prism to make it vertical before the TS measurements. After the first attempts conducted in the survey campaign of 2020, the difficulty of obtaining measurements with an optimal degree of precision emerged, which is why we worked to find a system that would allow obtaining an accuracy at least equal to, or if possible, less than one centimetre. Working in a shallow calm sea allowed us to use a practical expedient to achieve the desired result, a trestle stand of modular aluminium bars with plastic coupling joints, equipped with a central hole for housing the prism rod. The instrument can be adjusted by sliding two orthogonal planes on rails (Fig. 3). Once the rod was positioned inside the hole in the support and after having centred the marker with the tip, we proceeded with the levelling and orientation of the prism in the direction of the TS. The result obtained through the system described so far resulted in a deviation of less than one centimetre of tolerance. The use of trestle stands capable of autonomously supporting the prism pole allowed satisfactory results to be obtained, with an accuracy comparable to measurements taken on the ground.

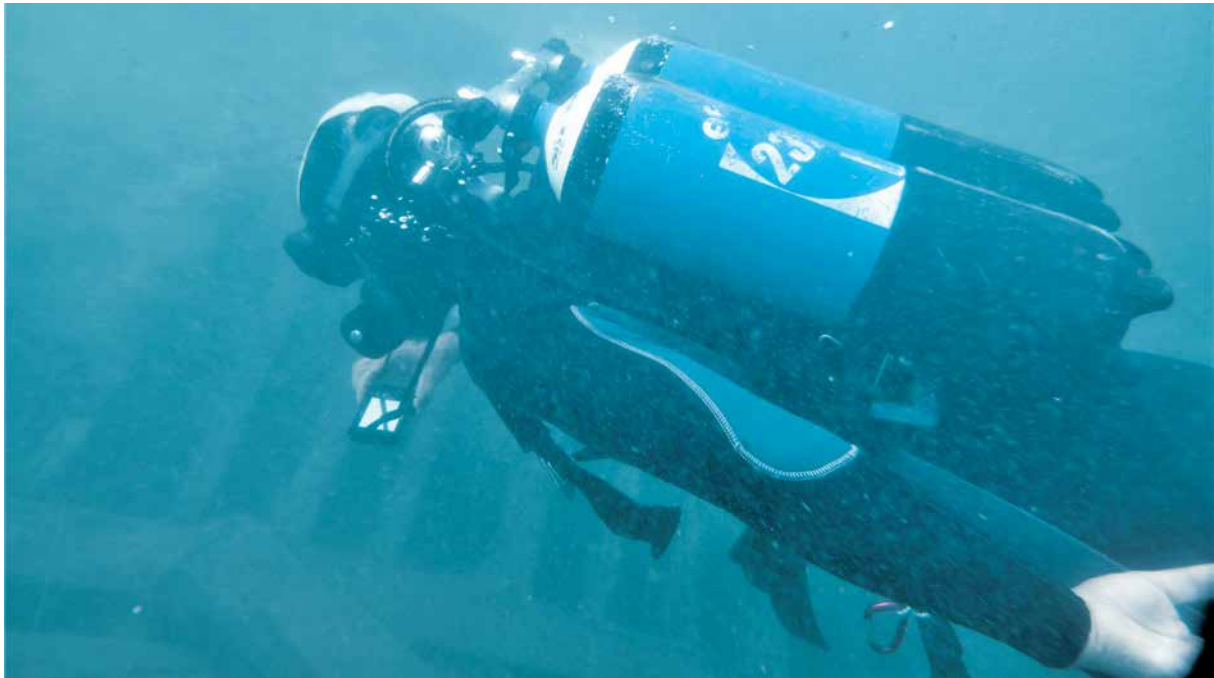


Fig. 2 Image acquisition phase during the underwater photogrammetric survey 2020 of the Roman shipwreck in Torre Santa Sabina (author: University of Salento, Department of Cultural Heritage)



Fig. 3 Topographic survey operations were performed to measure the position of underwater markers, also with the adoption of a pole-holder quadripod (author: University of Salento, Department of Cultural Heritage).

Recently the instrument market has introduced a new generation of more highly performing machines for GCP (Ground Control Point) detection of topographic markers. This GPS (Global Positioning System) is also waterproof and can make measurements with a tilt compensation of up to 30 degrees and more from vertical. However, for depths

like the one encountered in TSS 1, characterized by strong disturbances caused by currents and waves, it is always preferable to measure with TS and rely on a stand for fixing the rod which certainly allows work with greater precision. This was taken into account when assessing the accuracy of the survey and part of this work focused on assessing the quality of a photogrammetric 3D model generated via a free-mesh adjustment approach (followed by assigning a scale based on known distances). The 3D model developed following this method was compared with those generated using the previously collected data set.

The underwater photogrammetric datasets were processed using the software Agisoft Metashape 1.6.5. Following the software's operative workflow, images were oriented. A set of 5 previously measured points was used to provide correct georeferencing to the survey; in the end, dense point clouds, DEMs (Digital Elevation Model), and orthoimages were generated.

In both the 2020 and 2021 campaigns, before the photogrammetric survey a necessary archaeological procedure was applied for the characterization of the shipwreck via an operation that marked the most significant elements of the wreck using small portions of coloured electrical cables, some 'push-pin' thumbtacks, and plastic cards. Push-pins were also used to indicate where wooden nails were previously located. The same operative workflow of the first dataset was used. However, this time the 3D model was generated via a free-net adjustment, assigning a scale to the model via a least-squares adjustment on two scale bars placed in the surveyed scene. In this case, the camera calibration certificate of the previous dataset was used to provide an initial estimation of the camera's internal parameters.

To evaluate the quality of the two 3D models, the same portion (1 m²) of the two models was compared, performing a rigid roto-translation without changing the scale of the models. For point cloud management and analysis, the commercial software Leica Cyclone 3DR1 was used; the two clouds were aligned using the best-fit option of the above-mentioned software, allowing for a registration using the ICP (Iterative Closest Point) algorithm. This resulted in an average error of 2.8 mm and a standard deviation of 3.5 mm, measured via a C2C (Cloud to Cloud) comparison. The max value of detectable deviation was imposed at 2 cm.

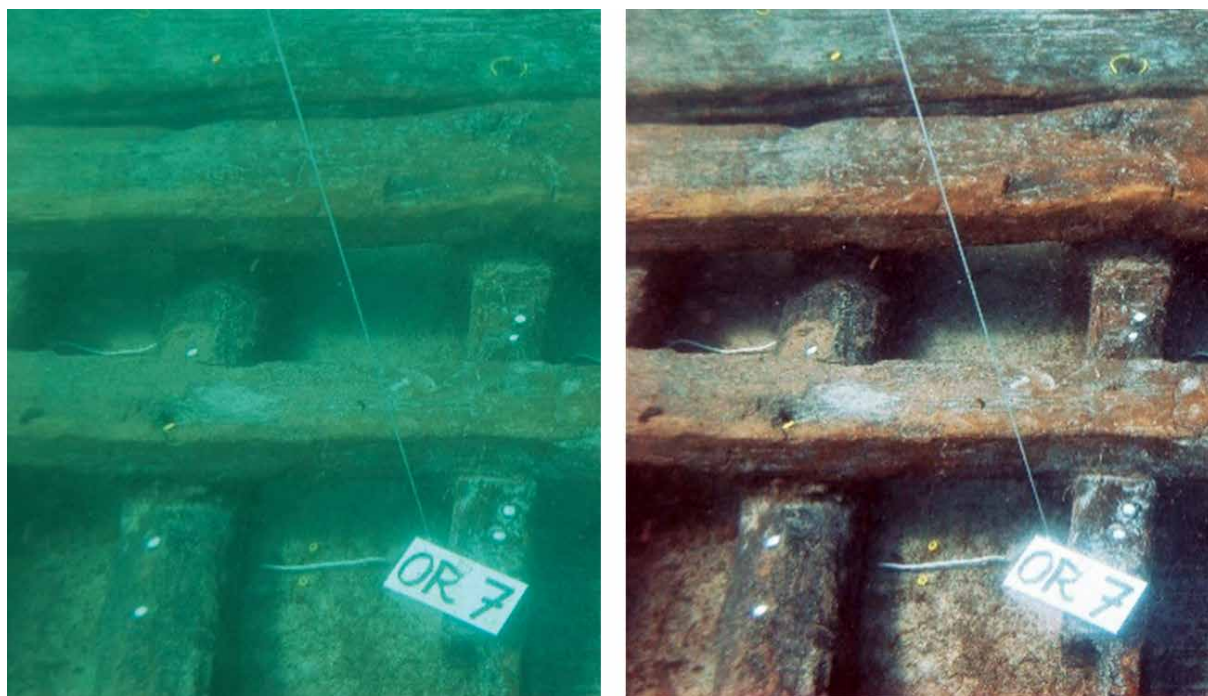


Fig. 4 Left: an image of the 2007 dataset before the radiometric correction; Right: the same image after applying the ACE (Automatic Colour Enhancement) filter (author: Calantropio 2023)

¹ <https://leica-geosystems.com/en-us/products/laser-scanners/software/leica-cyclone/leica-cyclone-3dr>.

3. Comparison with the 2007 survey

Given the importance of legacy data, it was interesting to compare data obtained and processing techniques followed in the 2020 acquisition campaign with a previous survey campaign performed in 2007 (Alfonso 2014). Images of the 2007 excavation campaign dataset were captured using a Nikon D50 (3008 × 2000 pixels) with underwater housing.

Since the acquired images suffered a severe chromatic aberration (Agrafiotis *et al.* 2017), a radiometric pre-processing was performed (Fig. 4) using the adaptation of the C code of the ACE (Automatic Colour Enhancement) image colour enhancement filter (Getreuer 2012), integrated into the Image Enhancement process tool of the i-MARECULTURE project.²

Because absolute georeferentiation data was not available, the operative workflow previously described (generation of a 3D model via a free-net adjustment) was followed, assigning a scale to the model via a least-squares adjustment on six measures obtained exploiting the metric rulers attached to the archaeological grid (Barker 1993), placed in the scene for performing the direct survey. To compare and relate the 2007 and the 2020 surveys, it was necessary to manually connect the two orthoimages on the same reference system, exploiting a small overlapping part. This made it possible to produce a complete orthomosaic and DEM to facilitate the understanding of the shape and extent of the wreck and plan future investigations (Fig. 5).



Fig. 5 Ortho imagery of the 2007 excavation georeferenced by the 2020 survey (author: Calantropio 2023)

4. Discussion and conclusions

Concerning the photogrammetric survey performed using UAS (Unmanned Aerial System), it was possible to document the wreck thanks to the generation of metric products (orthophotos, digital surface models and 3D models) obtained through photogrammetric techniques based on SfM (Structure from Motion) algorithms (Calantropio *et al.* 2021; Calantropio, Chiabrando 2024).

During the processing of the UAS data, an accurate assessment of the quality of the direct photogrammetric approach was carried out, using the two platforms. The proposed georeferencing method has shown that good results can be achieved with an autonomous PPK (Post Processed Kinematic) approach, even without measured GCPs.

In the first campaign of 2020, an essential part of the activities carried out in the underwater environment focused on the photogrammetric acquisition of the aft part of the Roman wreck, allowing both the understanding of the survey techniques to be used in the 2021 survey and the possibility of relating the new data to those from a survey carried out 14 years before this study. The results presented show that modern photogrammetric algorithms can provide a valid alternative to direct surveys in the documentation of the excavation phases of archaeological sites (Fig. 6).

² <https://imareculture.eu/downloads/project-tools/image-enhancement-process-tool/>.

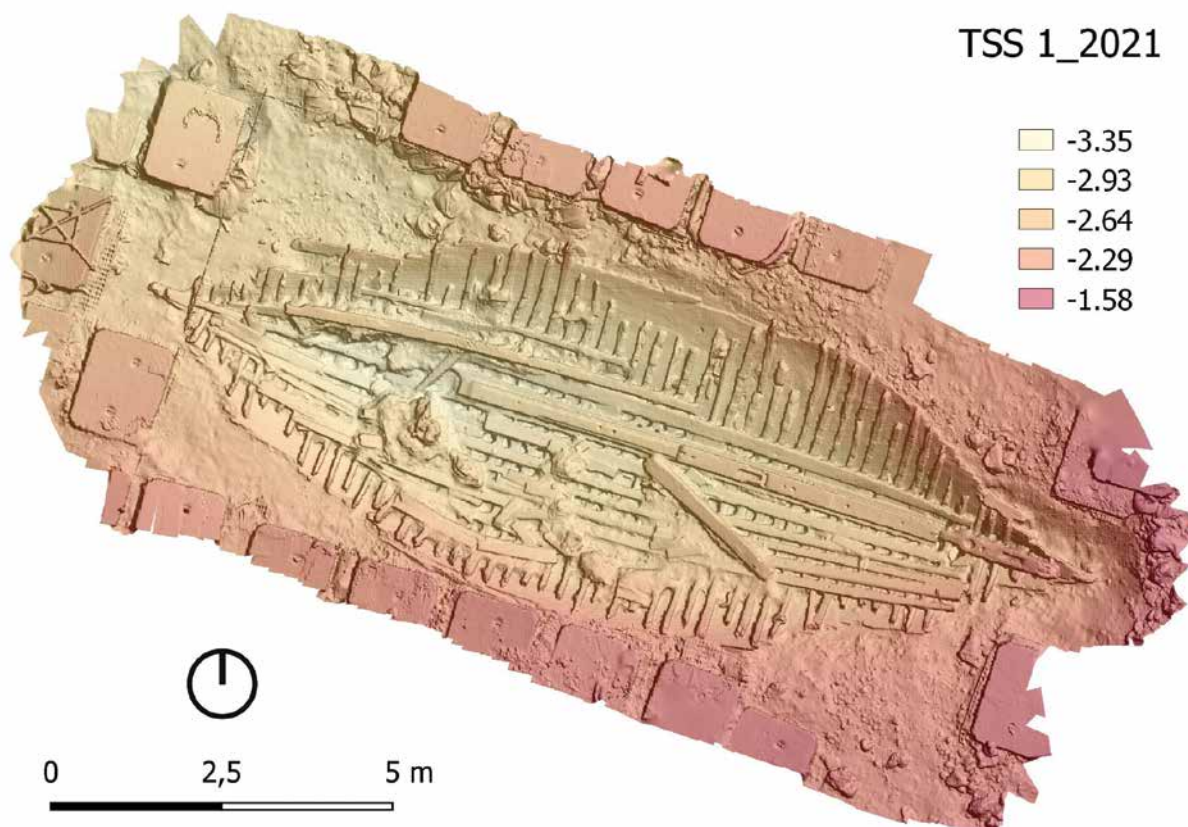


Fig. 6 DEM (Digital Elevation Model) of the TSS 1 shipwreck being processed
(author: Polytechnic of Turin - DAD, Laboratory of Geomatics for Cultural Heritage)

The use of digital photogrammetry techniques applied to the archaeological survey of underwater sites can constantly speed up survey operations without neglecting the quality and reliability of the data collected (Calantropio, Chia-brando 2024). The implementation of these procedures also offers better conditions for the operator involved thanks to the reduction of the overall dive time. The critical aspects of the application of this methodology are mainly related to the preliminary assessment of the camera calibration.

The execution of the survey in very shallow waters offers both advantages from the logistical point of view and some drawbacks in measuring the GCPs with traditional topographic methods. These aspects can be overcome by adopting simple fixing systems for the prism holder or GPS antenna rods. These are ballasted mobile stand trestles that can be locked in the desired positions when the operator is on the vertical of the topographic point with the pole.

As anticipated in the introduction, the 3D document base created can be used for virtual reality and augmented reality applications.

The three-dimensional reconstructions can be used for the study of naval architecture and to verify the hypothesis of restoration projects, recovery operations and enhancement of the wreck in the museum. It will also be possible to create immersive virtual tours able to allow the virtual use of the heritage (both naturalistic and cultural). These reconstructions can be exploited in museums, in underwater archaeological parks, in marine protected areas visitor centres and all regional networks of places of culture but also directly *in situ*, through interactive systems for the use of the underwater archaeological heritage, based on simple underwater tablets, connected to an antenna for reading the data recorded on tags placed near the archaeological finds. In this regard, we can cite the Italian realities of the Submerged Archaeological Park of Baia (see Gallo *et al.* 2012; Bruno *et al.* 2019; Davidde 2022) or the case of Grado 2 shipwreck (see Auriemma *et al.* 2022b; Auriemma forthcoming).

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The remote sensing survey off Malta – approaches to the mapping of an island's territorial waters

Timmy Gambin – Alberto Bravo-Morata Rodriguez

Abstract: The Malta Shipwreck Project, conducted by the University of Malta (UM), is aimed at surveying Malta's territorial waters, in order to create a map of archaeological remains located on the seabed. Since 2018, this work has been executed using an Autonomous Underwater Vehicle (AUV). Its main payload is an Edgetech dual-frequency (600/1600 kHz) Side Scan Sonar. Due to the capabilities of this particular AUV (stability and battery autonomy), it is able to produce images that are of much higher definition than traditional towed systems. Another advantage is the doing away with long turns associated with working with a 'towed fish'. In this paper the authors highlight the methodology established by the UM's team, with the aim of being able to document a site in detail from the discovery until verification stages.

Keywords: AUV, survey, remote, Malta, sonar

1. Introduction

Since 2005, the University of Malta (UM) has been carrying out the Malta Shipwreck Survey Project (MSP). The main aim of this project is to survey all of Malta's territorial waters, with the primary objective of creating an exhaustive archaeological map of the seabed. Such information facilitates the decision-making behind the management of Malta's underwater cultural heritage (UCH). This paper provides an overview of the approaches utilised in the context of the MSP.

2. Method

The approach used is that of conducting a 'blind' survey that involves the mapping of previously unexplored areas using the 400 or 450 kHz frequency sonar. This phase entails the use of broad parameters when it comes to the range of the sonar, and generally sees the sonar being 'flown' relatively high off the seabed in order to avoid potential obstacles and hazards that may be unmarked on navigational charts. Data from this initial phase area analysed and a target list is drawn up. Selected targets are subsequently surveyed using different parameters, which include a higher frequency (900 kHz or higher), shorter ranges, and the sonar being 'flown' closer to the seabed. This permits the acquisition of high-quality sonar imagery of selected targets.

3. Early work

Since 2005, the primary survey tool has been side scan sonar technology, a well-known and established method for archaeological mapping at sea (Quinn 2011). The approach, however, has differed over the span of the last two decades. Initially, the UM used towed systems – a Klein 3900 (455/900 kHz) system and an Edgetech 4125 (400/900 kHz) system. Both were utilised with a DT Marine winch with 500 metres of armoured cable. The towed systems worked well in waters down to approximately 160 metres, however, such depths required over 400 metres of cable deployment.

The main disadvantages are:

- The limitation of reachable depths due to cable length;
- The time needed to implement turns between survey lines;
- The quality of data is impacted by vibration from the cable as well as surface weather conditions;
- The possibility of gaps in the data due to surface traffic and interference with navigation.

Between 2014 and 2017 the UM collaborated in a number of projects with Vulcan Inc. and Harvey Mudd College, both of which provided the use of an Automated Underwater Vehicle (AUV) with a payload that consisted of a side scan sonar. The advantages of using an AUV over a towed system include:

- Significant time gains due to quicker turns between lines;
- Cleaner datasets due to the absence of cable vibrations and the interference of surface weather conditions.
- The disadvantages include:
- The cost of an AUV;
- Inability to see data through a live-feed (as one does with a towed set-up).

Exposure to AUV's over this four-year period resulted in the UM's purchase of an AUV, made possible through SINTEGRAM.¹ Since 2018, the UM has operated a Teledyne Marine Gavia Offshore Surveyor (Fig. 1).



Fig. 1 Teledyne Gavia Offshore surveyor AUV (photo: Teledyne Marine Technologies Incorporated)

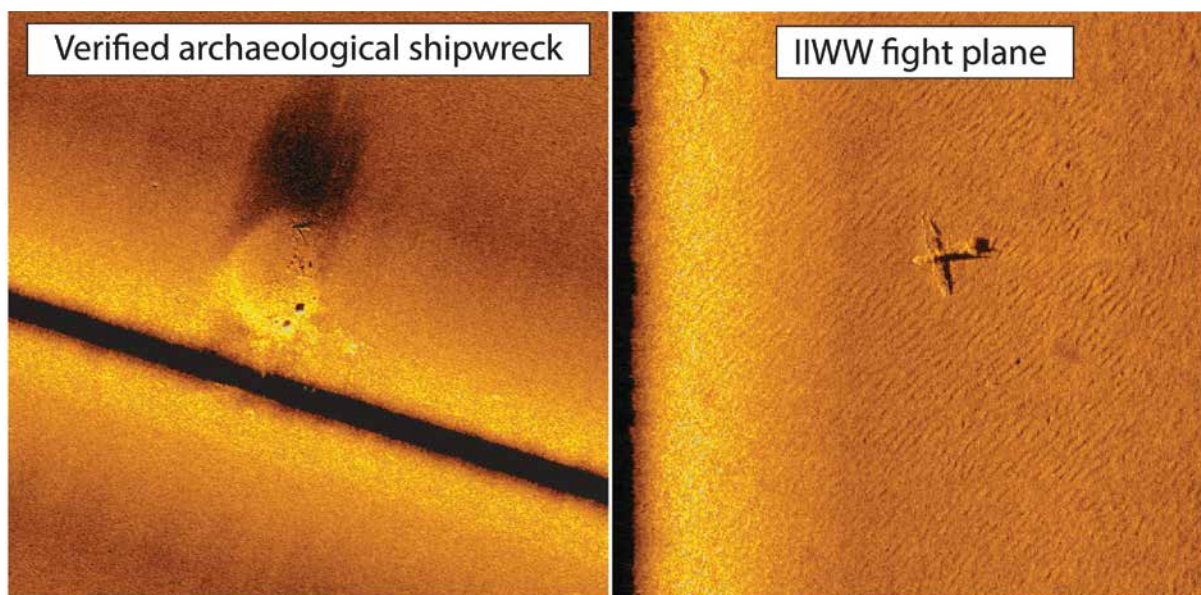


Fig. 2 Comparison between modern and ancient remains (Image: University of Malta)

¹ Operational Programme I - European Structural and Investment Funds 2014-2020 "Fostering a competitive and sustainable economy to meet our challenges" Project part-financed by the European Regional Development Fund - Co-financing rate: 80% European Union Funds, 20% National Funds.

The main payload is an Edgetech dual frequency (600/1600 kHz) side scan sonar, and a Blueview Multibeam MB2250 that is used for gap filling and backscatter.²

The autonomy of the AUV permits the team to plan missions of up to a maximum of eight hours, with surface management exclusively focused on tracking and being on standby in case of an emergency ascent and surfacing of the AUV. This differs substantially to surface tasks and responsibilities assigned whilst using a towed system.

The physical properties and capabilities of this particular AUV, which includes ease of operability, stability, and battery autonomy, has enabled the team to produce images that are of higher definition quality than traditional towed systems and in a shorter period of time. Therefore, the sonar imagery often permits the identification of targets without the necessity of deploying divers and/or remote operated vehicles (ROV), which is more common with modern wrecks, easily identifiable in comparison to ancient remains (Fig. 2).

This set-up allows the UM to survey an average of 5 km² on a typical working day. The number of days spent surveying depends mainly on budget, and on average the team achieves approximately 50 days at sea, surveying around 250 km² annually.

4. Using an AUV

An AUV is an autonomous robot that is used as a marine survey platform. For navigation purposes, the AUV integrates a Global Positioning System (GPS), navigation systems, and propulsion and direction modules, all of which are built into a robot vehicle. This is what enables the AUV to execute planned missions whilst simultaneously avoiding potential hazards and obstacles. A forward-looking sonar and a collision avoidance sonar ensure the AUV does not collide with submerged obstructions (cliffs, rocky outcrops, etc.). These systems allow the AUV to perform planned missions and to modify parameters when necessary. If the obstacle-avoidance is activated, the AUV is nevertheless able to return to its original survey mission after avoiding the obstacle.

Through the use of the dual frequency sonar integrated into the AUV, the UM is able to obtain geo-referenced 2D imagery of the seabed that provide highly accurate measurements of targets and features. The Blueview multibeam is used to capture data to fill the gap created by the nadir of the side scan sonar. The resulting 2D images allow for the extraction of information on aspects such as the geology of the area, the presence of cultural remains, or even fishing activities (Fig. 3).

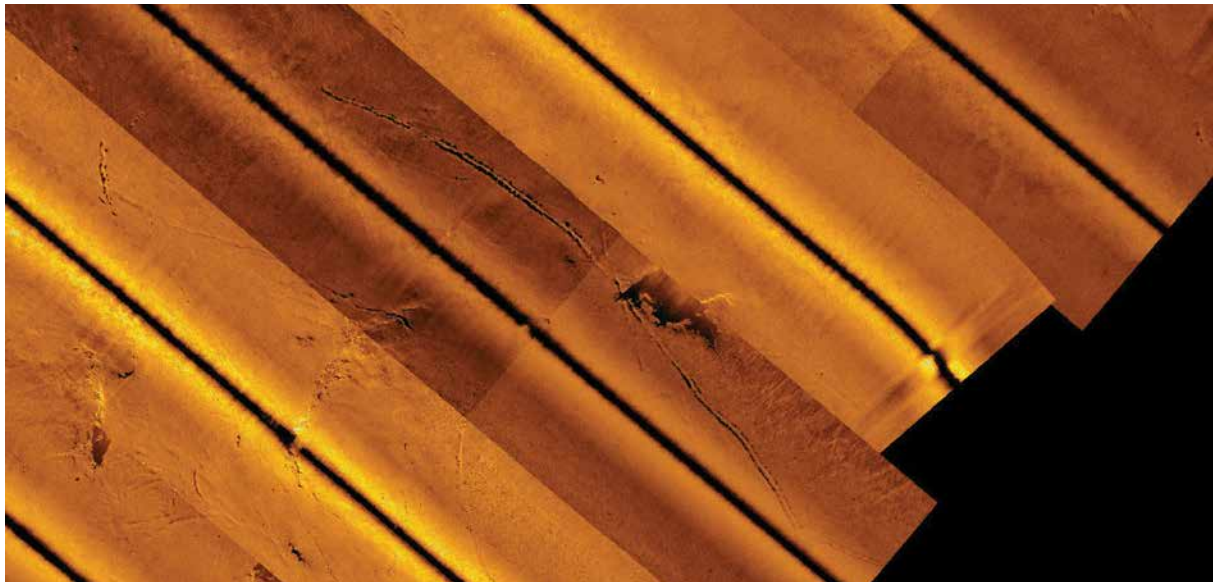


Fig. 3 Anchor marks over geology (image: University of Malta)

² <https://www.teledynmarine.com/en-us/products/Pages/gavia-mb-2250-gapfill-module.aspx> (accessed on April 7, 2022).

5. UM's methodology

The methodology employed by the UM follows a series of pre-defined steps that are aimed at locating, documenting, and identifying UCH with side scan sonar.

5.1. Selection of survey area

The selection of a survey area is based on work conducted in previous years, allowing the team to systematically continue its survey of Malta's territorial seabed. The location of potential areas of interest may, however, influence the choice of survey area.

5.2. Survey area

A 'blind survey' is a survey of a broad area of the seabed that is being captured for the first time. These surveys can be equated to field-walking techniques in terrestrial surveys. Data is captured systematically along pre-determined survey lines which result in the creation of a geo-referenced map revealing any potential cultural targets and anomalies for future research. The AUV is flown at a safe distance from the seabed in order to avoid any potential obstacles that may be unknown and unmarked on navigational charts. A height of between 10–13 m is maintained, allowing for safety considerations that do not interfere with the quality of data gathered (Fig. 4).

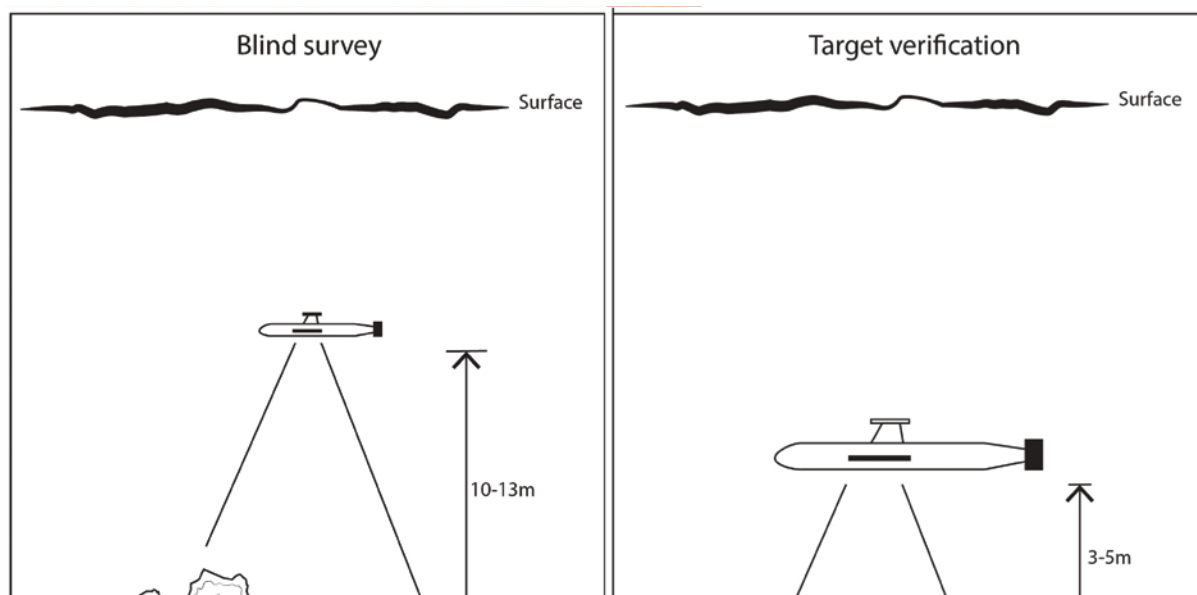


Fig. 4 Flying height of the AUV depending on the mission's configuration and objective
(author: A. Bravo-Morata Rodríguez, University of Malta)

5.3. Data processing

Once the survey is complete, data processing commences. Whilst many software packages are available, the UM utilises Chesapeake SonarWiz. Using this software, data is displayed visually, geo-referenced, and able to provide measurements and other verifications.

Data processing involves the evaluation of all individual survey lines, where targets, or 'anomalies', such as intact aircrafts and modern shipwrecks are immediately recognizable. Other anomalies, such as ancient shipwrecks, may be unrecognizable or harder to interpret (Fig. 2). In these cases, it is often experience with interpreting sonar data that allows researchers to differentiate between archaeological potential and for instance modern structures or geological features. Elements that are evaluated include sudden changes in the topography of the sea or reflectivity of objects that differ from the natural environment. In those cases where anomalies are flagged as being potentially of interest, a second survey phase is considered and then planned.

5.4. Remote inspections of anomalies

The survey of specific targets in high definition involves the planning of survey lines using the low-resolution images of the target from the initial blind survey. Using this approach, the alignment or longitudinal axes of the target can be matched to the new survey, where the number of lines and height of the AUV depends on the size of the target. However, the primary aim is to acquire data from both sides as well as from various angles.

The AUV is flown at a closer level to the seabed since the composition of the seabed is no longer an unknown variable due to the previous blind survey data (Fig. 4). The UM team is now able to plan a more precise pattern to be followed by the AUV, including elements such as proximity of survey lines, how close the target is to the sonar transducer, and how much area needs to be covered. Using this set-up, high-resolution data can be captured (Fig 5).

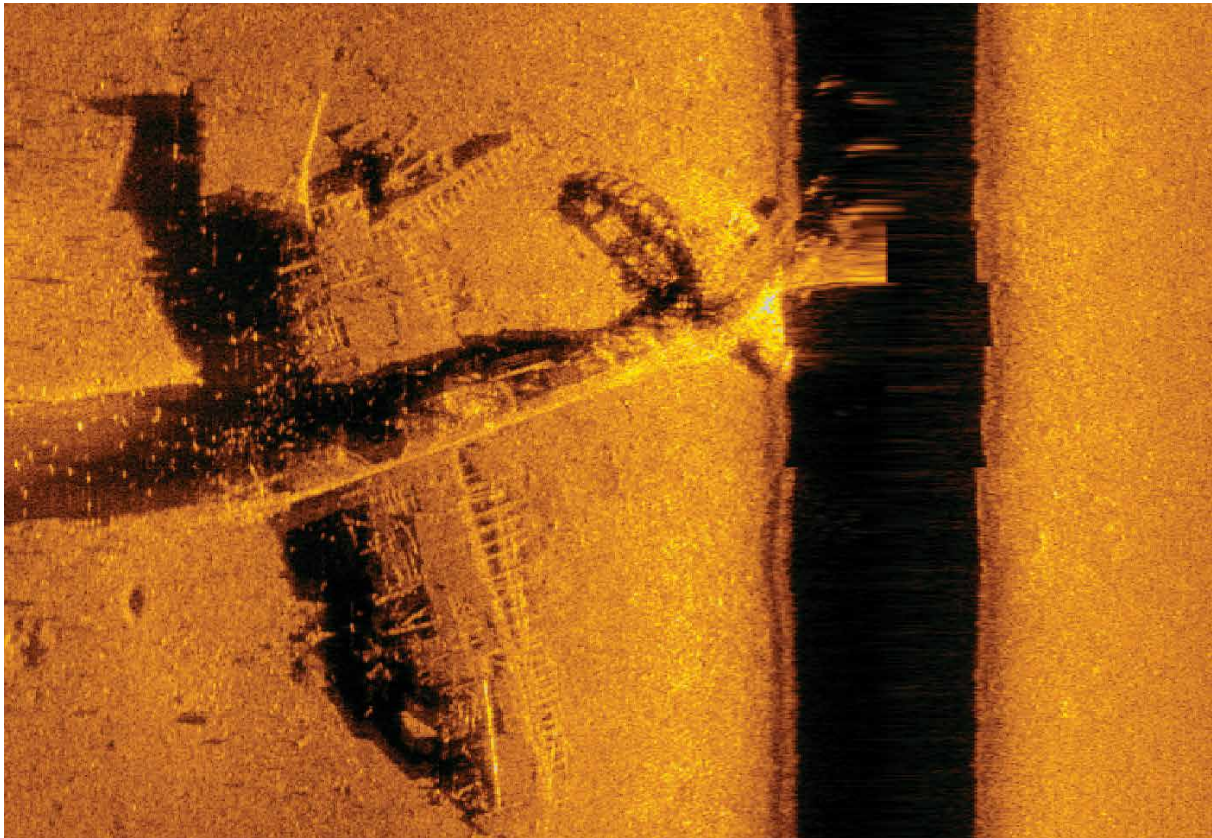


Fig. 5 Remains documented in high frequency (image: University of Malta)

5.5. Inspection of selected sites

Once these targeted surveys are carried out, a list of identifiable targets of potential archaeological interest is created. Depending on depth, size of target, budget, and equipment availability, decisions are made for further site inspection. For small sites up to a maximum depth of 120 m, the final inspection and documentation is carried out by technical divers (Fig. 6). This phase consists of gathering as much information as possible by documenting the site, confirming the importance of the target, and registering the site in the inventory of discovered sites.

Since 2015, the UM has been developing a 3D modelling process based on Structure from Motion (SfM) photogrammetry. Initially 4k video footage was used, however, today, full-frame mirrorless cameras that generate 24 megapixels still images are preferred. The cameras are coupled with powerful underwater lights that help balance colours in the images and provide light at depth. More recently, a diver propulsion vehicle (DPV) was adapted, where the lights and camera set-up are mounted onto the DPV. This configuration allows for the documentation of large and more complex wreck sites without compromising time spent at depth, often the most challenging and limiting factor. To-date the UM has recorded large wrecks up to a depth of 80 m. The resulting 3D models are used to study and identify wrecks, and are also used for public outreach purposes and publications.³

³ <https://underwatermalta.org/> (accessed on April 12, 2022).



Fig. 6 Diver documenting a site found with the AUV (photo: University of Malta)

6. Conclusion

Since 2005, the UM has surveyed approximately 30% of Malta's territorial seabed. Thousands of anthropic targets have been identified, a significant amount of which are of historic interest, including ancient wrecks, second world war ships, planes, submarines as well as conflict related items (UXO's). Of these, a considerable number have been documented in detail for further research and public outreach.

Utilising its current methodology, the UM is able to systematically survey approximately 150–250 km² annually. This approach will enable the entirety of Malta's seabed to be surveyed in a relatively short amount of time. The resulting geo-referenced data will enable the creation of dedicated database on Malta's UCH that informs on heritage management considerations.

The premise here is that effective management is based on knowledge-based decisions. Beyond the relevance to archaeological research and heritage management, is the relevance to other fields of research such as geology, oceanography, or fishing practices.

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NAUTICAL ICONOGRAPHY AND ETHNOGRAPHY (POSTERS)

The saint, the storm, and the ship: diving into the Corsican maritime ex voto

Hélène Botcazou

Abstract: This article presents a survey carried out in 2018 within the research framework of the author's defended PhD Dissertation, on the sailing trade coasters of the Corsican shores between the 16th and the 20th c. Few treaties and albums from the 18th and the 19th c. represent Corsican ships. A review of Corsican ex voto representations allows a look on the day-to-day coastal trade from the south of France or the northern part of Italy. The goal was to search for corresponding pictures from Corsica in the maritime ex voto curated in the churches and chapels of the island. This research led to the identification of a two-masted gondola ship that seems associated to the island.

Keywords: maritime history, maritime ex voto, nautical ethnography, Corsica

1. Introduction

A maritime ex voto (from the Latin *Ex Voto Suscepto*) can be a painting, or an object in relation to a maritime event, given to a sanctuary as a reward to God or a Saint. The donor generally survived a misfortune or an accident. He depicts it and sometimes describes the event in a dedication (Boullet, Boullet 1996: 9).

The gift can be offered by an individual or a group (the crew, some passengers) that make a pilgrimage and attend a religious service. The maritime ex voto can be made by the rescued themselves, or by a paid professional painter. One example is the case of some paintings from the corpus that have been made by members of the Roux dynasty from Marseille (Lepage, Rieth 1978; MacNairn 1987; Chadwick Forster Smith 1978; Brès 1883), a family from which several members have received the official title of *Peintre de Marine* that rewards the most careful and realistic depictions of maritime subjects (Fig. 1). Another famous professional painter of which some artwork was found in the Corsican chapels is Louis Gamain (1803–1871), who also offered a ship model of a little frigate, *La Louise*, to the son of Napoleon the third in 1858 (Patrimoine Nustrale 2018: 46).

But not everybody who is willing to offer an ex voto has such painting skills. Some paintings or models can present distortions, depending on the painter or drawer, or depending on what he wants to emphasize from the scene. It nonetheless constitutes a corpus of very high quality to improve our knowledge on the Mediterranean coasters, especially from the 19th century.

As Eric Rieth notes: “A comparative study allows us to isolate the elements that are technically illogical and to gather a kind of inventory of the distortions and the alterations, of which the most common are problems of perspective, strange ratios between the hull, the rigging and the characters, a simplification of the depiction” (Lepage, Rieth 1978: 31). On the other hand, the repetition of architectural traits on several stylistically different drawings allows assumptions on the presence or the morphology of architectural features.

The paintings can therefore inform us on numerous interesting points:

- on the architectural details of the ship,
- on the rigging of the ship,
- on the type of the ship, her name and the date of the event,
- on the maritime routes followed before the event, and the changing of the itinerary in adaptation to the event,
- on the emergency procedures followed during extreme weather conditions (caused by the waves, the winds or a broken element of the ship), and if it is the case, the location of the wrecking,
- on the cargo, the captain and the crew, the painter, and the donor.



Fig. 1 Maritime ex voto from the church of Lavasina, Brando, Corsica. In the dedication it is written: “Wish made by the crew of the brig-schooner *The Two Friends*, cap(tai)n Cesar Alfonsi, at 10 lieues from the Cape Corse, by a gale from N-N-W the 25th of January 1841, arrived at Calvi (Corsica) the same day”. On the other side we can read: “François Roux Hydrograph and painter of Marine, on the harbour, 23, Marseille. Make, sell and repair any kind of instruments, flags, maps and navigation instructions” (photo: H. Botcazou).

2. The 2018 survey¹

The 2018 survey's methodology relied on previous research elaborated by Sylvie Bénac in summer 1974 on the maritime ex voto of Corsica and in particular in the Cape Corse. Sylvie Bénac made an extensive inventory of all the maritime ex voto of the churches and chapels in this part of the island, which has the reputation to hold the most prominent maritime cultural heritage (Bénac 1975) (Fig. 2). A systematic study of the presence of maritime ex voto in the rest of the island is still to complete. A project of the General Inventory of Cultural Heritage of the French ministry of Culture, with the collaboration of the Petre Scritte Association, is currently being undertaken in this perspective².

The inventory made by Sylvie Bénac had two limits: the ships drawn or painted were sometimes only described as a ‘one’ or ‘two-masted ship’, and there were very few photographs taken of them. There was no idea of what was left of these churches and their ex voto 44 years later.

During our survey, some pictures and data on every maritime ex voto were taken, along with its precise description and state, and this information was later offered to the National Marine Museum in Paris, in order to complete their collection. But to enlighten the subject of research, there was the need to select specific maritime ex voto that were describing maritime events with sailing coasters depicted. In order to study the local coasters, the ships coming from the Atlantic coast (Giansily 2019: 53–62) were eliminated. The remaining corpus consisted mostly of paintings, watercolors, drawings, dioramas, and ship models. The majority of them were dated from the 19th century, and at least three others were from the 18th century. In total, 20 churches and chapels were visited; 76 ex voto were recorded; nine previously documented ex voto were not found.

¹ This study has been carried out with the collaboration of the LA3M laboratory (UMR7298, CNRS, Aix-Marseille University, France) and the IPSO FACTO Company. This work was co-directed by Nicolas Faucherre (LA3M, CNRS, AMU) and Eric Rieth (LAMOP, UMR 8589, CNRS, Paris 1 Panthéon-Sorbonne, Musée National de la Marine).

² Some ex voto are already recorded in a state database: <https://www.pop.culture.gouv.fr/>

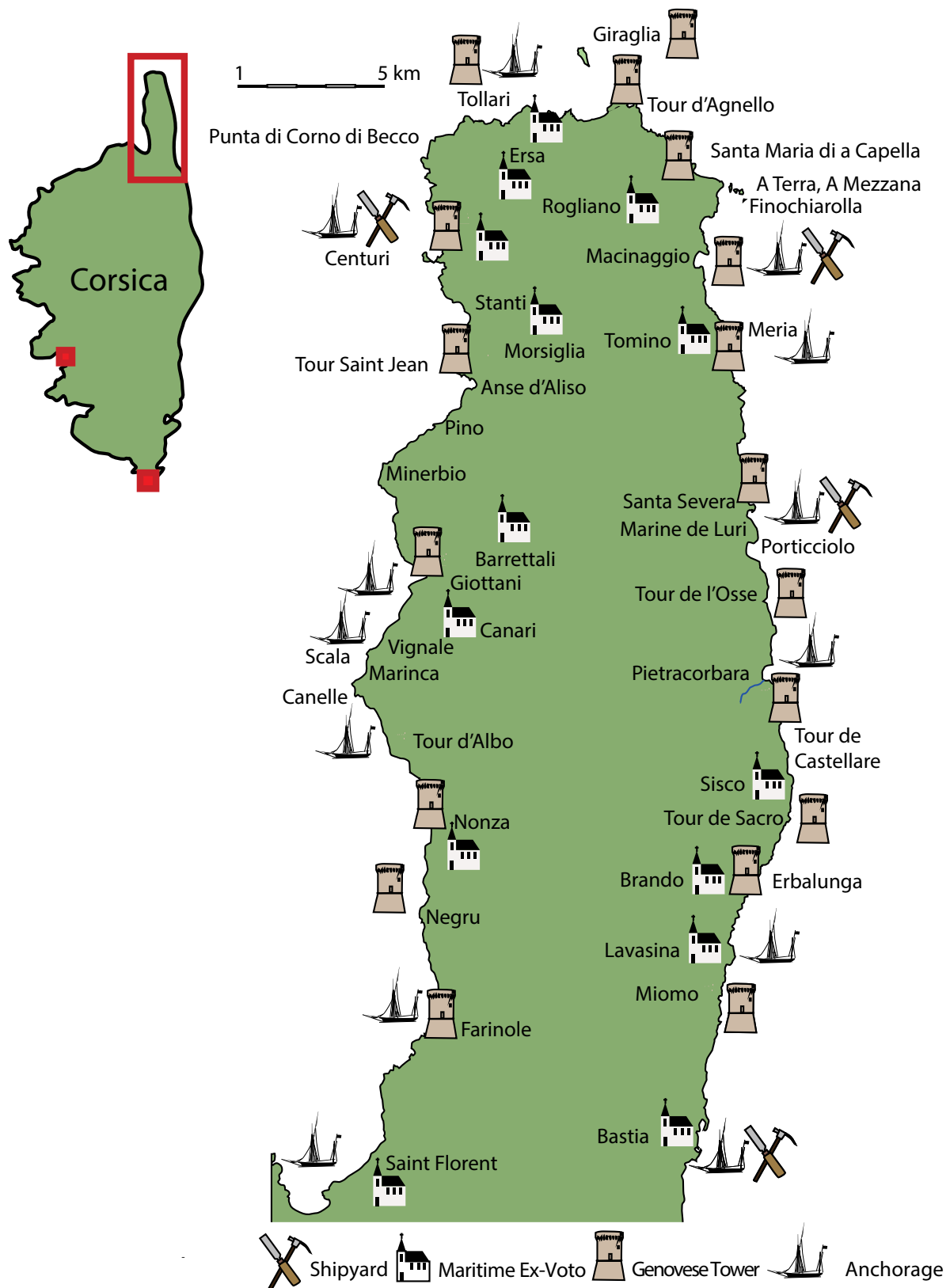


Fig. 2 Map of the visited churches (author: H. Botcazou)

In the 19th century, that is the period of the extreme majority of the corpus, 16 of the 79 ex voto are schooner-brigs (also called brigantines), ten are brigs and ten are schooners. Only two tartanes are depicted, although this was a ship type commonly described as the generally used coaster, at least in the south of France (notably in Languedoc and

Provence). However, six bovi and one leuto were found, two ship types from the same family that seem to have a more important local use. Three fishing dinghies are depicted as rowing boats, sometimes with a very short mast in the front of the hull (Fig. 3).

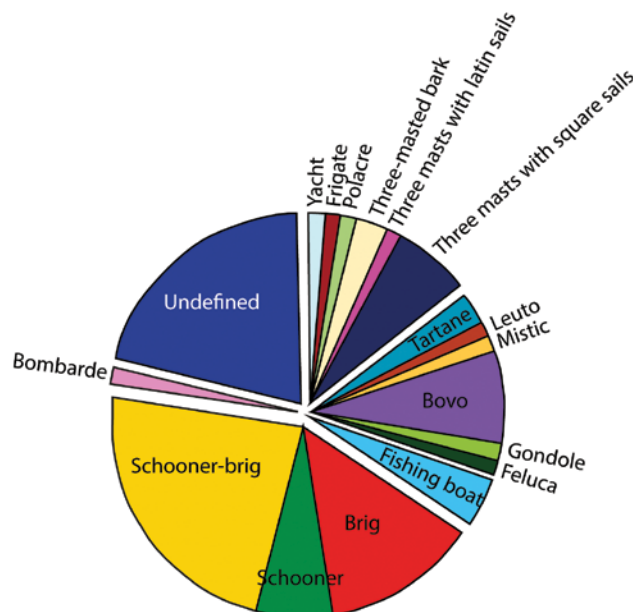


Fig. 3 Ship types found in 2018 (author: H. Botcazou)

3. Case study: An inquiry about a strange gondola

The gondola ship depicted in the Saint Erasmus Church in Ajaccio had a particular rigging compared to other common images of gondola ships (Fig. 4). This church shelters an important amount of maritime ex voto as it is known as the ‘church of the sailors’. Built in 1617, it is located at the heart of the historic center. It is an old Jesuit convent, closed during the French Revolution of 1789 and reopened in 1815, at the end of the reign of Napoleon I. It is then given as an oratory to the sailors’ religious brotherhood. A lateral chapel was already consecrated to the sailors in 1645 by Captain Giovanni Pietro Orto.



Fig. 4 Ex voto of the Gondola San Francesco, Ajaccio, Saint Erasm Chapel, Corsica (photo: H. Botcazou)

The ship has round shaped extremities, although the stern is slightly more slender. Two lateen sails seem to be set up for bad weather conditions. The foremast is placed very forward, and the main mast is in the middle of the hull. Another ship in the background is already pulled out of the sea and protected by a cover set up on the yard that has the same length as the ship. The ships could be pulled on the beach thanks to a hoist that is set up along the flanks of the hull with a bridle. The sails are not set up but rolled around the masts. The rudder of the gondola is lifted up and laid on the deck. One of the characters is holding the yard.

The dedication indicates: “The gondola called *San Francesco* from Ajaccio, led by Giuseppe Selli, traveling from Senetosa to Ajaccio, found in the Gulf of Campomoro a terrible storm from the East. By pure miracle we had the good fortune to land in the Cala of Giglio the 9th of July 1833.”³

The first mention of the gondola is dated from 1246 (Jal 1848, (new ed.) 1986: 6)⁴. Augustin Jal declares “The Genovese *neff* from the 14th and 15th centuries had three dinghies, as well as those from the 13th century: the *barque* or *chaloupe* (dinghy), the *laud* that replaced the *barque pariscalmé* and the *gondole* [...]” (Jal 1840: 393–408).

It is certain that this type of boat had been in use in Corsica anciently. Damien Broc found mentions of gondolas at Saint-Florent (Corsica) in the archives in 1518 (Broc Damien 2014: 297). Antoine-Marie Graziani also indicates that a gondola was used as a post and transport in his study on the 15th century building of the Genovese tower of Campomoro (Graziani 1997: 30).

In Corsica, this boat was traditionally used by fishermen to recover the famous red coral and also as a coaster for local trade. They were appreciated for their speed, as Tobias Smollett taught us in the story of his journey in France and Italy in 1765: “For my own part, I hired a gondola from hence to Genoa. This is a boat smaller than a feluca, rowed by four men, and steered by the patron; but the price was nine zequines, rather more than I should have paid for a feluca of ten oars. I was assured that being very light, it would make great way; and the master was particularly recommended to me, as an honest man and an able mariner” (Smollett 1806: 438).

In the beginning of the 19th c., gondolas constituted 5 to 10% of the Corsican registered ships according to Pierre-Jean Campocasso (Campocasso 2011: 343–359). Roberto Moresco wrote that it is a ship of 3 to 15 t, 7 to 10 m long and equipped with both oars and sails (Moresco 2015: 9–18). Jean-Christophe Liccia gives for this ship type a length comprised between 8 and 32 palmi (around 8 m) (Liccia 1998: 11–15).

In 1820, in order to harvest the red coral, the Corsicans are using gondolas of “6 to 12 tons, of which the shapes of the front and the back are identically elongated and they obey easily to the maneuvers with sails or oars [...] they are generally equipped with a crew of 8 to 12 men, including the apprentice”⁵.

Roberto Moresco described this boat as the most typical ship from Capraia Island in the 18th c. (Moresco 2015: 9–18). He indicates 60 to 70 boats of this type used from 1734 to 1737 and from 1742 to 1744. They are generally used for local trade, except for the smallest that are used for fishing. They could be bought in Corsica. They also could have been built from Corsican wooden timbers and assembled in Capraia. They had a sprit sail when rigged for fishing in Liguria. The mast was in this case placed at the very front of the boat.

In the 19th century, Carlo de Negri indicates 212 registered gondolas in 1867 in Elba Island which is more than the gondolas registered in bigger harbors like Genoa or Livorno (De Negri 1974: 200–202).

A dive in the iconographic collection of the *Bibliothèque Nationale de France* (BNF) made possible to have a glimpse of these gondolas in Corsica. A picture from the Roland Bonaparte collection shows them in the bay of Ajaccio in the late 19th c. They nonetheless seem to have a little lateen sail and not a sprit sail (Fig. 5).

On the other side of the Island, in the Cape Corse, some archive researches have been made (Luchetti 2010: 22–28). It gives us a good idea of the journeys these ships of very little tonnage were doing to trade goods from city to city in the Ligurian sea. *Le Rusé*, registered in Luri and of 14 t, had a charged waterline of 3 ft and 2 when unloaded. It was a ship that had a deck, and a crew of six men. Between the 28th of February 1789 and the 30th of January 1790, she went from Livorno to Macinaggio, from Rogliano to Genoa, From Genoa to Meria, from Rogliano to Marseille, from Livorno to Macinaggio.

³ *Gondola nominata San Francesco d'Ajaccio comandata da Giuseppe Selli partita dalle Senitose per venir in Ajaccio trovandosi nel golfo du Campomoro essendo un tempo fulminante da Lievante per pure miracolo ebbimo la fortuna d'abbordare in Cala di Giglio li nove Liuglio 1833.*

⁴ [Gondole], et doit avoir la devant ditte nave une bargue de cantier, Il bargues de pescalines, et une gondole (Belgrano, documenti, San Ludovico, p

⁵ *Ils [les Corses] arment à cet effet des gondoles de 6 à 12 tonneaux dont les formes de l'avant et de l'arrière sont pareillement élongées, lesquels doivent facilement obéir aux manœuvres soit à la voile, soit aux avirons [...]. Elles sont ordinairement équipées de 8 à 12 hommes, un mousse compris [...]*, in Bénac 1975. She quotes the Archives from the Port of Toulon, 19P231, 1828.

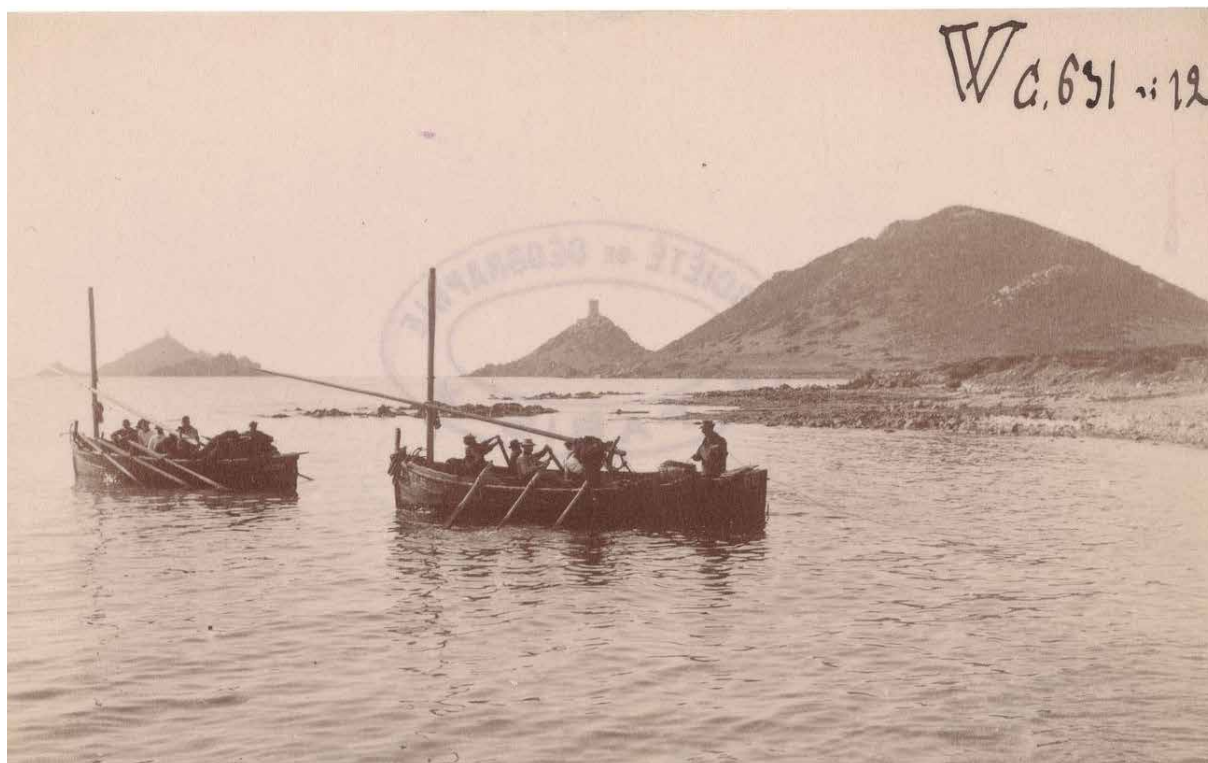


Fig. 5 Fishermen in front of the Sanguinaires islands (Ajaccio, Corsica) (Roland Bonaparte collection, 19th c., Gallica, Bibliothèque Nationale de France)

Some gondolas from Bonifacio draw another picture of the local trade that had importance in the south of the Island: smuggling. This narrow canal is dotted with ‘intermediary islands’, the Maddalena archipelago and the Lavezzi one. The Sardinian coast of Gallura was scarcely populated between Castel Sardo and Posada in the 18th c., excepting Terranova di Olbia that welcomed trading ships from Bastia and Capraia. This coast has numerous bays that are proper for a discreet unloading of illegal goods. The researches of Henri Marmonier on the archives of the Maddalena Islands give a testimony of the use of gondolas in this strategic military area that was at the same time an important shelter for people of both islands. *Doléances* letters⁶ indicate on the 27th of August 1783 that a Sardinian half-galea guarding the coast shot the *Sant-Antoine*, a gondola, and took her. The 5th of November 1841, Captain Oliveri, leading another gondola called *Sant Antonio*, filed a report to the maritime jurisdiction of Bonifacio because he just escaped a bombing from the Sardinians practically under the walls of the Corsican city. He was carrying cheese from Porto Torres (Marmonier 1896:1–41).

Sergio Spina has drawn a gondola on a beach from the end of the 19th c. that shows a vertical stem and stern. It is associated by Giovanni Panella and Carlo de Negri to fishing boats from the area of Liguria (Bellabarba, Guerrieri 2002: 108–113). The mast is situated in the first quarter of the total length. Two masts are interchangeable and two lateen yards can be set up depending on the weather. There is no deck in the central part of the hull. The sailors can sit on the beams to row. But none of the various declinations of these gondolas has two masts like in the ex voto of the Saint Erasmus Church of Ajaccio, Corsica. This drove the search for a locally designed boat.

On two old postcards of the same docks of Ajaccio respectively from the first quarter of the 20th century, ships can be seen with a shape similar to the *San Francesco* curated in the near church of Saint Erasmus. They have two masts with the front one settled near the stem. The ships are pulled out on the quay located under the citadel of the city.

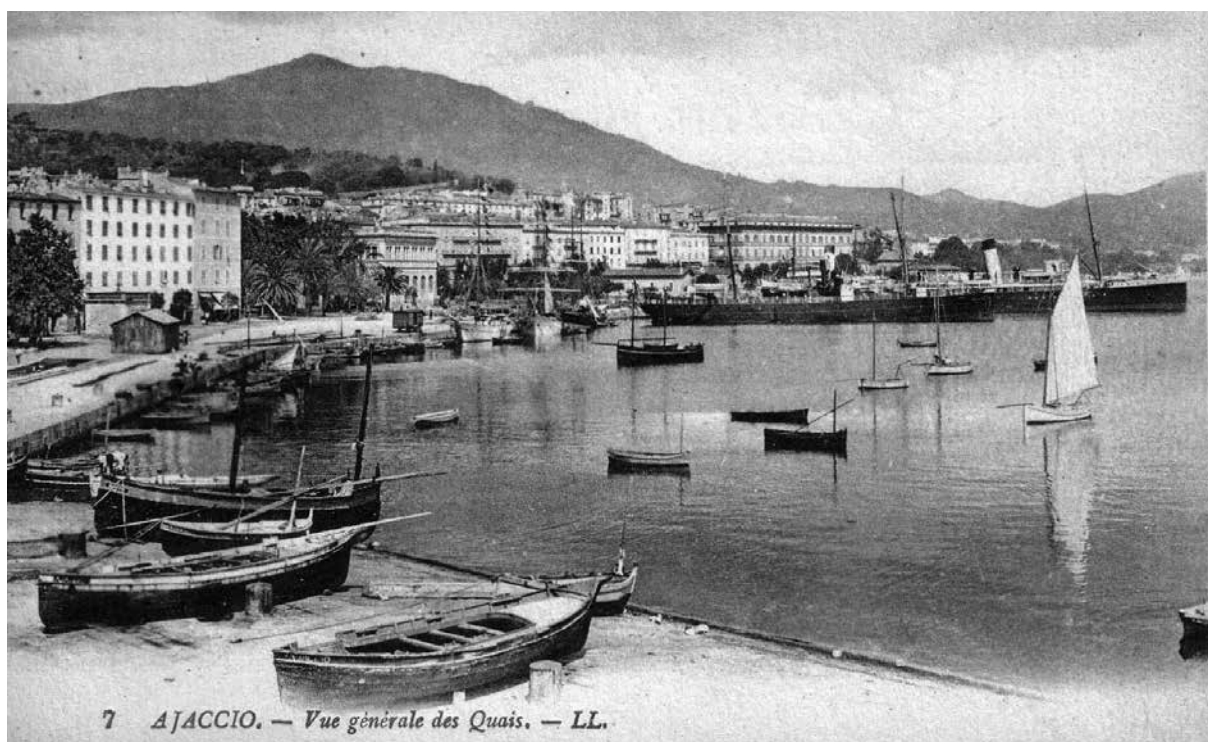
The two ships seem to have a slightly different rigging. One has a main mast higher than the front mast (Fig. 6), while in the other picture (Fig. 7), both masts seem to have the same height. Those pictures prove the use of these two-masted gondolas until the 1920’s in the city of Ajaccio. The first half of the 20th century corresponds to the disappearing of the sailing ships used for work (fishing and trade), and the very beginning of the presence of engines on board.

⁶ Letters of *doléances* are generally written in order to complain about something. The disadvantages resulting from a bad situation are described and explained in this kind of letter.



Source gallica.bnf.fr / Bibliothèque nationale de France

Fig. 6 Ajaccio, its harbour and its ships, press photography (photo: Agence Rol, between 1914 and 1921, Gallica, Bibliothèque Nationale de France)



7 AJACCIO. — Vue générale des Quais. — LL.

Fig. 7 Ajaccio – general view of the quays, L.L., first quarter of the 20th c. (personal archive)

4. Conclusion

It can be a difficult thing to establish a precise typology of small ships, especially in places that have several different culturally interlinked regions, like in the Tyrrhenian Sea, where the names of the ships fluctuate depending on the language used (French, Provençal, Corsican, Genovese, etc.). Each coastal population, separated by seas and mountains, but at the same time very close to each other, sometimes gives the same name to different types of ships, or different names to the same type of ship. The features associated to a specific type of ship also evolve over time. Moreover, it can be difficult to link written sources from the archives to pictures. This was however the goal of the author's PhD, to establish a nuanced catalog of the local adaptations of common types of coastal sailing ships found in the Tyrrhenian region, from the 16th c. to the beginning of the 20th century (Botcazou 2020). In total, 23 types of sailing coastal ships were studied in their multiple local declinations. Among other iconographical sources used to gather the needed information, the maritime ex voto are important testimonies as they give a picture and an associated description, and the dedications are written or dictated by the very person using the ship, in his own language. It is a good way to have a glimpse on the very locally used ships.

The example of the Corsican two-masted gondola illustrates perfectly the quality of the data that can be gathered thanks to the maritime ex voto. The gondola ship type had indeed already been studied on the island of Elba and on the Italian coast (Bellabarba, Guerreri 2002), but those two-masted types were not described. Searching for other examples of this type of boat, the author found two old postcards taken in the same city of Ajaccio, showing a similar ship. It can therefore be stated that the specific features found in the ex voto did not result from a bad interpretation. These two-masted ships may be a specific adaptation of the gondola ship-type in Corsica.

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Ship representations on Mycenaean pottery; A rare depiction of a shipwreck from Koukounaries on Paros

Stefanos Spanos

Abstract: A deep bowl from Koukounaries on Paros offers a rare representation of a ship. The vessel is depicted upside down, making it a unique depiction of a Mycenaean shipwreck. This Paros depiction may be compared to the representation of ships from Skyros and Tragana. The representation is more similar to shipwreck scenes such as the one on the north wall of the Great Temple of Medinet Habu. The possibility that the ship is an enemy ship will be discussed. Koukounaries had important overseas connections with the other Cycladic Islands, which lie at the crossroads of maritime trade with Asia Minor, Egypt, Syria, Cyprus and Crete.

Keywords: Koukounaries, ship representation, Lower Plateau, Paros, shipwreck

1. Introduction

Disasters on the mainland led to a radical change in the geopolitical map of prehistoric Greece. The destruction of the Mycenaean palaces forced the Mycenaean population on the mainland to migrate west, to the Ionian islands and Italy, and east, to the eastern Aegean basin. Residents of the devastated areas crossed the Aegean on their ships, heading to Crete and Cyprus, while others settled on the Aegean islands and the Cyclades (Spanos 2020: 79-80).

The excavations conducted by the Athenian Archaeological Society have brought to light evidence that immediately after the destruction of the Mycenaean centres in mainland Greece, around 1200 BC, a group of Mycenaean refugees fled to Paros, where they built a citadel at Koukounaries in the SW part of Naoussa Bay (Schilardi 1992: 637; 1998: 289; Karageorghis 1998: 130). A fortified hegemonic complex, its southern side protected by a wall, was erected atop a hill. A period of prosperity ensued, as indicated by various finds and the high quantity of painted pottery of the Late Helladic III C middle period. The archaeological dig (Schilardi 1984: 188–190; 1992: 633) revealed, inter alia, the presence of ivory, rock crystal, bronze (tools and weapons), lead, obsidian and steatite. The rare presence of a skyphos (deep bowl) with a representation of a ship was noted among the pottery of this period from Koukounaries. It is the subject of this paper.

2. The sherd from Koukounaries

In Koukounaries, excavations brought to light a high quantity of Mycenaean pottery (Schilardi 1979; 1984: 188–190; 1995: 485) during the excavation of the hegemonic complex on the Upper Plateau. A group of Mycenaean sherds was also discovered on the Lower Plateau, and examination showed that it is contemporaneous with the pottery of the hegemonic complex, since it dates to the Late Helladic IIIC middle period (Spanos 2005). Mycenaean pottery has also been found in other areas of Koukounaries, such as, for example, at the area of the Tombs (Spanos 2021a: 243–245).

The sherd K.1653/P.1243 (Fig. 1, 2) belongs to the pottery of the Lower Plateau (Spanos 2020, 81–84, 88, Fig. 1; 2021b, 100–104, Fig. 2, 3). The preserved piece is from the rim of a skyphos (deep bowl) (Furumark type, Shape 284) (Spanos 2020, 81). The outline of an upside down ship can be seen on the sherd's exterior. Part of the ship's bow has been identified; its deck is attached by a wide horizontal band. The bow is rendered upright in a vertical arrangement like a sigma. A thin horizontal line visible at the bottom of the bow may have belonged to a small projection that would have been the ship's ram. There are two lines in relation to the bow, which start from its lower section and are somewhat diagonally directed towards the sail. These may be the ropes that held the sail, shown here at full growth. The sail is

rendered in “realistically”, since the fabric is represented by parallel curved lines to indicate its swelling by the wind. The representation is a unique depiction of a wrecked Mycenaean ship. Some sherds from the Lower Plateau are noteworthy. Besides this sherd, others from the Lower Plateau are also important: a sherd from a bowl with a spiral, a sherd from a spouted cup with a cabbie decoration, kylikes, and other extant sherds.



Fig. 1 Representation of a shipwreck on the sherd of Koukounaries, like it is on the sherd (photo: S. Spanos)



Fig. 2 Representation of a shipwreck on the sherd of Koukounaries, turned upside down (photo: S. Spanos)

3. Ship representations of the Late Helladic III period

A brief overview of Bronze Age ship representations of the Late Helladic III period will contribute to a better understanding of this representation.

Ship representations of the Late Helladic III period belong to two groups: the Skyros and Tragana. The Skyros group is type V (Late Helladic IIIA-C) and the Tragana group is type VI (Late Helladic IIIB-C) of Wedde (2000: 54–56).

The first group took its name from a stirrup jar (Late Helladic IIIC) found on Skyros (Fig. 3). The vase bears a depiction of a ship on one side and an octopus on the other. The hull is flat, the bent stern is identified by the steering-oar, while the bow has a bird-headed stem. The sail is supported by a forestay and backstay (Vermeule, Karageorghis 1982: 145; Parlama 1984: 146–151; Wedde 2000: 54, No. 655). The representation is comparable to the ships from Pyrgos Livanaton of the Late Helladic III C middle period (Wedde 2000, 55–56, No. 6002–6003), and here we have a flat hull and a bow with decorated stem (animal head).

The other group got its name from a pyxis of Tragana (Fig. 4) (Late Helladic IIIC). The forestay reaches the chamber of the bow, the mast is balanced with three ropes and the backstay. The backstay is a lateral line behind the sail. The projection protrudes in front of the bow (Korres 1989: 177–202; Wedde 2000: 54–55, 86, No. 643; Kourouniotis 1914: 108–109). The stern carries the steering-oar. We have vertical lines between the bow and the stern, perhaps to indicate a deck. This set of lines also exists on representations on the larnax from Gazi, the stirrup jar from Asine and the stele from Dramesi. All three have a projection at the bow and a steering-oar (Wedde 2000: 55, 86, No. 608 (Gazi), No. 641 (Asine), No. 684 (Dramesi)). The Tragana ship resembles the ship from Skyros, but with a significant addition, i.e., the projection at the bow.

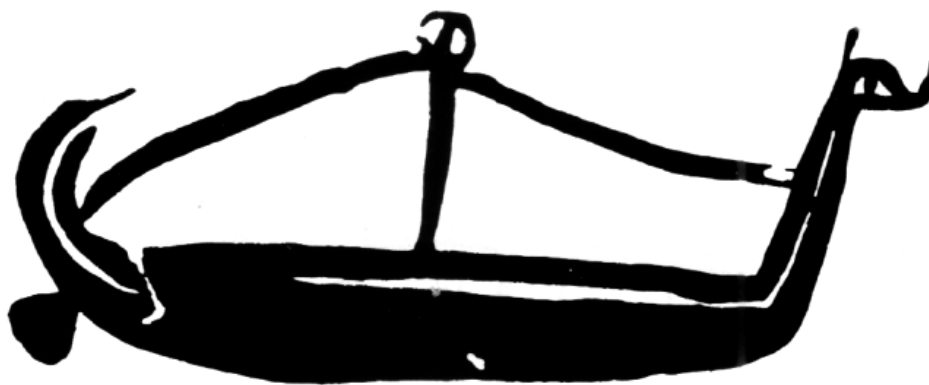


Fig. 3 Representation of a ship on a stirrup jar from Skyros (after Wedde 2000, 326, No. 655)

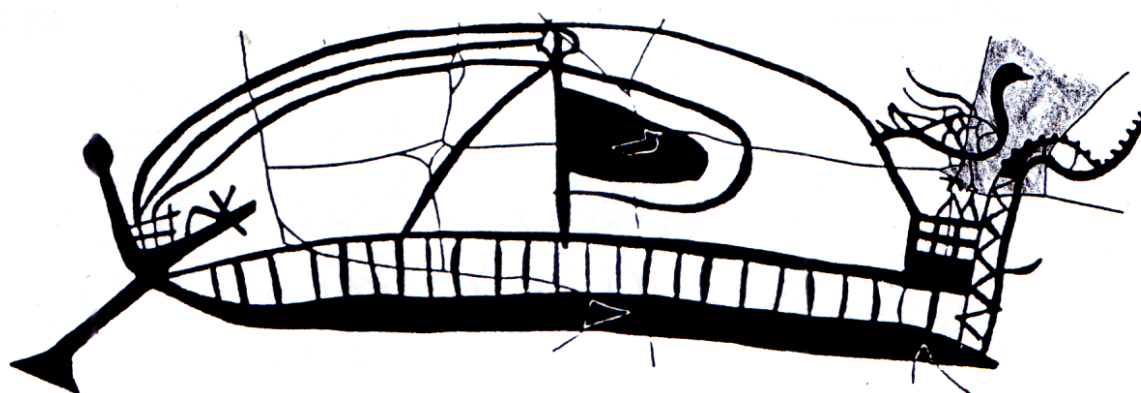


Fig. 4 Representation of a ship on a pyxis from Tragana (after Wedde 2000, 324, No. 643)

4. Discussion

The ship of Paros may belong to type VI (Late Helladic IIIB–C) rather than type V (Late Helladic IIIA–C), as it has a projection at the bow. The bow is bent, as it is in both of these groups. It seems that in the Paros depiction we have two ropes. One must be the forestay. This rope seems to end up on the mast, comparable to the Tragana and Skyros examples. The use of the second rope is unclear, i.e., whether it is tied to the sail or it is decorative. One of the Akrotiri ships of the Miniature Wall Painting has four ropes starting from the mast. Two of them reach the bow, while the other two that end in the cabin have rather decorative elements, circular objects and a crocus (Televantou 1994: 106–108). The sail is folded. On the Paros sherd, the sail is billowing in the wind, as are the representations from Tragana, Asine and Dramesi, which belong to type VI. The sail of the Dramesi ship is presented as an open rectangle, while the sail of the Asine ship is square and has lines. The Tragana sail is depicted as a solid (homogeneous) oval. The mast of the Dramesi ship is Y-shaped, with the sail tied to the right. Our sail is not rendered either empty or solid; its representation is convex, like the one from Tragana, with lovely curved lines to indicate the fabric. In the Asine drawing, the sail is covered with lines. The lines might indicate that it is made up of different pieces of fabric sewn together, or may be an artistic rendering of the sail's surface (Alexiou 1972: 94; 1973: 3–6). According to some speculation, long fabrics were used for the sail, reinforced with leather straps or something else (Marinatos 1933: 207; Kirk 1949: 131).

Another peculiarity in the Parian picture is that the ship is presented inverted (upside down) under the rim of the skyphos. It is a depiction of a wreck scene, as on the north wall of the Great Temple of Medinet Habu (Wachsmann 1998: 165–171). In that scene, the Egyptians are fighting against the Sea People. One of the Sea People's ships is depicted upside down (Fig. 5), i.e., capsized. The Miniature Wall Painting of Akrotiri contains a possible depiction of a naval battle (Fig. 6) (Televantou 1994: 65–67, 328, pl. 32; Marinatos 1974: G 150). On its northern part, two ships (P2-3) are portrayed one over the other on a very small surface. One of them (P3) does not appear to have suffered any damage to its fittings. The other ship's (P5) bowsprit is broken. In addition to the damage to the ships, seven naked men with

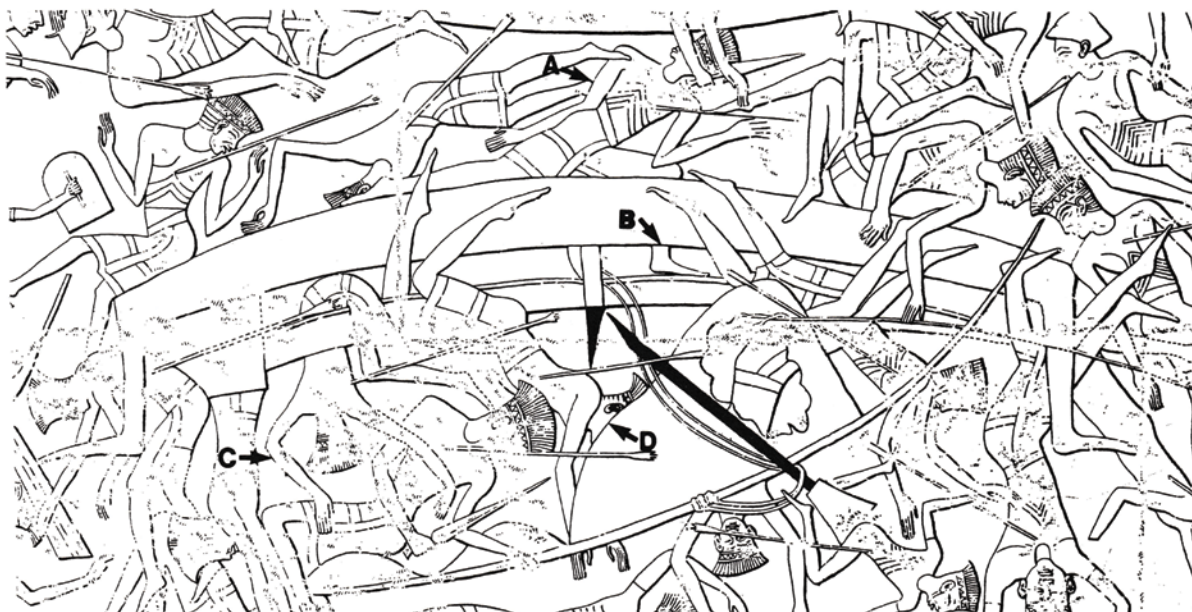


Fig. 5 Representation of a ship on the north wall of the Great Temple of Medinet Habu, the wreck scene (after Wachsmann 1998, 171, Fig. 8.14).



Fig. 6 Representation of a possible naval battle from the Miniature Wall Painting of Akrotiri (after Televantou 1994, pl. 32).

their weapons and shields are afloat in the sea. Sakellariou (1980: 150–152) claims that it depicts a celebration of *Navigium Isidis* rather than a naval battle, and also that the ship did not sink but was “offered” as a tribute to the sea. According to her, the naked men are not drowning but rather are swimmers. However, there are still some representations that, while not related to shipwrecks, seem to derive their theme from the sea and marine confrontations or raids. The rhyton of the Siege of Mycenae depicts a town enduring a naval attack, while naked men are at sea (Sakellariou 1975). The theme is repeated on the stone rhyton of Epidauros, as a town is again threatened from the sea. A part of the ship with its cabin has been preserved on the rhyton (Sakellariou 1971). Finally, on a dagger from Vafeio features a depiction of human figures in the water who are not swimmers but rather shipwrecked man survivors (Warren 1979: 126). Does the Paros representation show an enemy ship? The upside-down vessel on the wall in the Temple of Medinet Habu is a hostile ship. The Paros ship could be the ship of an enemy, perhaps a pirate vessel. Schilardi (1984: 200–201; 1992: 631; 1995: 499, 500) suggested that the destruction of Paros was caused by a hostile attack, but excluded an attack of the Sea People. Apart from these representations, battles are depicted on vases from Phylakopi (Vermeule, Karageorghis 1982: 114) and Pyrgos Livanaton (Dakoronia 2006: 23–29). A man with a spear is represented on one of the Phylakopi examples. Another sherd of the same vessel features a man on the bow of a ship. On the fragments of the Pyrgos Livanaton, warriors are shown fighting each other on ships. The form of the Pyrgos Livanaton ships resembles the Skyros ship (see above). On another fragment, a man is seen at sea (Dakoronia 2006: 26, Fig. 2). A likely shipwrecked man is depicted on a sherd from Athens (Vermeule, Karageorghis 1982: 114, x41). Late Bronze Ship representations have also been found on other Cycladic islands. Apart from Phylakopi, those from Siphnos (Televantou personal communication) and Amorgos are mentioned (Marangou 2002, 20, 21, Fig. 30). Apart from Late Bronze Age representations, depictions of naval battles and shipwrecks from the Geometric period have also been preserved (Morrison, Williams 1968: 34, 35, geom. 32, geom. 38, pl. 6e, Pl. 7a). In both cases, the ships are shown inverted. In the first image, the ship does not appear to have been damaged or at least this is not indicated, as is the case with the older ships of Akrotiri. A man floats with fish in the sea, while a second is swallowed by a large fish (Morrison, Williams 1968: 34, geom. 32, Pl. 6e). In the second representation, a shipwrecked man sits on the ship’s overturned keel (Morrison, Williams 1968: 35, geom. 38, Pl. 7a). This representation is similar to the representation of the Koukounaries ship that is reminiscent of the Geometric example. The ship is rendered inverted because the artist probably wanted to depict a shipwreck.

5. Conclusions

The representation of a ship from Koukounaries is vital evidence in the effort to reconstruct the history of the ancient citadel. The picture reflects the importance of marine life to the economic activity of its inhabitants. While evidence indicates that the citadel’s economy was based on the cultivation of olive trees and grapes, it is clear that Koukounaries was also engaged in trade, having established communication with other centres of the Aegean and the Southeastern Mediterranean. Metallic objects (see earlier) and other precious items made of ivory, rock crystal, steatite, obsidian, etc., found in Koukounaries show that it had significant overseas connections (Spanos 2020: 84–85; Spanos 2021: 247). Indeed, the Cycladic islands were at an intersection of maritime trade with Asia Minor, Egypt, Syria, Cyprus and Crete. It has been alleged that Mycenaean Paros exported wine, oil, honey and pottery, while importing other products and raw materials, mainly ivory, rock crystal, steatite, obsidian, etc. The ivory likely came from Syria or Egypt, steatite and rock crystal from Egypt or Crete, obsidian from Melos, bronze from Cyprus, etc.

Although the representation is fragmentary and it is not possible to determine whether it is a depiction of a shipwreck or a naval conflict and then shipwreck, the fragment suggests the importance of ships and seafaring to communications, commerce and the rise of the Mycenaean acropolis of Koukounaries.

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Reed and rush bundle rafts in Ireland - ethnographic and experimental nautical archaeology

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Abstract: Well into the 20th century, primitive watercraft, constructed of reeds, rushes, and other natural materials, persisted in use in the riverine midland regions of Ireland. While there is no known contemporary photographic evidence of these, some descriptions of various bundle rafts were collected by 19th Century Antiquarians, The Irish Folklore Commission (1935–1971), and by Folklorists in the Folklife Division of the National Museum. The last two decades have seen a renewed interest in the bundle raft tradition. A literature review was undertaken, known examples were examined, and some basic experimental archaeology was undertaken. The possible use of this archaic form of watercraft in prehistoric Ireland was considered.

Keywords: rush rafts, bundle boats, folklife – Ireland, work boats – Ireland

Introduction

Reed and rush bundle rafts and boats are usually associated with warm climates, but water reeds (*Phragmites Australis*), club rush (*Schoenoplectus Lacustris*), common or soft rush (*Juncus Effuses*) and bulrushes (*Typha latifolia*) thrive in the damp temperate climate of Ireland. The types of craft identified as having been constructed of club rush, water reed and other natural materials, are simple wading and swimming aids, round coracle type craft, larger square rafts and a rectangular raft built around a simple framework. All of these bundle type craft relied on the buoyancy of the material rather than hull displacement to float.

The most widely known of the bundle rush craft is the rectangular, boat shaped *Cliath Thulca* or ‘flood raft’ in use up to the 1930’s or later (O’Dowd 2015: 398). It was used to navigate the River Suck and the ‘Callows’, as the flood plain areas of the River Shannon and its tributaries are known. At least five known replicas of the *Cliath Thulca* have been built (Fig.1). Descriptions of several styles of bundle rafts were found in the folklore records and some of these rafts were recreated to see how they would perform.

The wider subject of the use of reed, rush and other bundle rafts has been covered in many scholarly works on maritime archaeology, such as Hornell (1946), Johnstone (1980), and McGrail (2001).

The Antiquarians and the Folklore Collectors

An early 19th Century Antiquarian travelling in the Lakelands of Fermanagh describes a form of rush craft: “In one place we were amused by seeing a man crossing to his fishing station, with no better mode of conveyance than a large bundle of rushes, on which he sat, moving it along by means of a small paddle” (‘E’ 1825: 199–210).

The Antiquarian William Wakeman wrote in 1866 that rush rafts were made in the lake districts of Fermanagh in the Northern part of Ireland. Wakeman gives us a reasonably detailed description of the raft: “cutting down four fairly – sized trees, generally of ash; these he forms into a quadrangle, lashing as sailors the corners, with ropes of straw or of hemp or even of leathern tongs. Over the figure thus constructed he attaches a few branches of timber, irregularly placed, and intermixed with branches; he then with a reaping hook cuts a number of armfuls of bulrushes and secures them to the framework; thus forming a raft or float...” (Wakeman 1866: 2) (Fig. 2).



Fig. 1 The Cliath Thulca or flood raft built in 1962 for the National Museum. It was based on a type used up to the 1930's on the River Suck (photo: © National Museum of Ireland).



Fig. 2 A 1.5 m² bundle raft. Similar to the description by antiquarian William Wakeman in 1866. The addition of a light framework made the raft more stable (photo: courtesy of R. Henshall).

In 1872 Wakeman writes “that until recently a kind of rude substitute for a boat was not uncommon upon the waters of the Erne ... It was composed of wreaths of bull rushes tied upon a frame or raft ... I myself have observed but one boat ... three years ago, upon the crannoged Lough of Coolmermer. Probably this rush-buoyed raft is the earliest kind of inland or fresh-water craft known to the primitive inhabitants of Erin” (Wakeman 1872: 74–76).

Agricultural and rural living practices in Ireland changed radically in the mid-20th century. Fortunately, the Folklife Division of the National Museum of Ireland and The Irish Folklore Commission were active in recording a way of life that was changing at pace. In 1935, The Irish Folklore Commission, later becoming the National Folklore Collection (NFC), started its work to study and collect information on Folklore and Folk traditions in Ireland.

Emyr Estyn Evans, a Welsh Geographer and Folklorist, noted in his book on Irish folklife that one of the more unusual boat types in the last century was the raft made of wreaths of bull rushes named a *curragh* (Evans 1957: 242).

Anthony T. Lucas, who was Director of the National Museum of Ireland from 1954 to 1976, had a keen interest in Folklife practices. In the early 1960’s he collaborated with The Irish Folklore Commission to circulate a questionnaire on the uses of hay, rushes and straw, (Ms. NFC 1962) and embarked on collecting artefacts in these materials for the National Museum.

James Delaney was a full-time collector with the Folklore Commission, based in the midlands. In the 1950’s, he came across the area of Derrycabill in a remote part of South Roscommon where rush rafts had recently been in use. In 1962, he brought the subject of rush rafts, in particular the *Cliath Thulca*, to the notice of Dr. Lucas at the National Museum. Local informant Patrick Gately arranged the building of a large 3.2 m example of the raft for the Museum. This was documented in a series of photographs by the National Museum, from which Fig. 1. is taken.

In 2000, the Senior Curator of the Folklife Division of the National Museum, the late Séamus Mac Philib, published an article in the Ulster Folklife Journal on rush bundle rafts, generating renewed interest in the subject (Mac Philib 2000).

The Engineers, Artists and Archaeologists

In 1997, Joseph Tully, a teacher of technology, constructed a rectangular coracle style hazel frame, to which he lashed bundles of rushes, for an historic re-enactment of a crossing of the fast-flowing River Shannon (Fig. 3). He found the raft difficult to handle, when compared to his experience of paddling skin covered coracles over the same stretch of water¹.

In 2000, Pádraig Ó’Duinnín, an engineer and experienced currach builder, built a 3.1 m *Cliath Thulca*. He used hazel rods for a framework, and reeds for bundles. The craft supported a number of passengers on a trial downstream voyage on the River Shannon.²



Fig. 3 The replica bundle rush craft built for the 1997 historical re-enactment crossing of the River Shannon (photo: courtesy of J. Tully, Kilcormick Community School, Ballinasloe)

¹ J. Tully, personal communication, 15 October 2021.

² P. Ó’Duinnín, personal communication, 10 October 2021.

In 2014 Gerardine Wisdom, an artist who works with natural fibres, built a raft using techniques observed in Lake Titicaca. Wisdom filled an elongated timber frame with compacted bundles of rushes to form the main body of the craft. The raft was extremely buoyant, and the very tight bundles took a few days to become waterlogged (Brennan 2014).

Possibly the largest contribution to the understanding of rush bundle rafts in Ireland was the research and experimental archaeology undertaken by Robert Henshall (2018) for his thesis in archaeology. A skilled offshore yachtsman, small boat sailor, and kayaker, he had the required broad skill base to construct and evaluate several examples of rush bundle rafts.



Fig. 4 A Floatation Ring made of rushes. Known as a 'curragh' (pronounced 'corra' in Ulster) it was used to teach children to swim (photo: © Museum Services, Fermanagh and Omagh District Council).

Swimming Aids

The National Museum has records of the use of swimming aids made of natural material including aids made from dried 'ellestrums', or yellow iris (O'Dowd 2015: 448). O'Dowd also gives an account from Ulster, where the titles '*swab*' and '*curragh*' describe a lifebuoy that is circular in shape. The swab had a protrusion, known as a beak, to lay one's chin on, and it also had a loop on each side for the arms so that the swimming aid revolved with the body. The Fermanagh and Omagh District Museum has an example of a floatation ring made of rushes (Fig. 4). In the National Museum collection there is a swimming aid from Co Cavan, consisting of a 2-metre-long rush bundle, bent into a horseshoe shape. Examples

are found in the Folklore Manuscripts from Mallow, where “bundles of reeds or rushes were tied with light ropes and used by persons swimming in the river” (Ms. NFC 2154: 91), and from Waterford, where 12 canes were simply tied together (Ms. NFC 2154: 175).

Lidström and Svanberg (2019) give an overview of rush (*Schoenoplectus Lacustris*) and reed (*Phragmites Australis*) swimming aids in Sweden, including a reference that Carl Linnaeus, in his 1737 *Flora Lapponica*, noted bundles of club rushes used as buoyancy belts in Småland. They also cite examples from Denmark, Germany, Switzerland, Austria, and Estonia.

Experimental Archaeology

Some experimental archaeology was undertaken, initially to try to reconstruct the examples of bundle rafts from the literature, and where successfully constructed, to make some basic assessment of the buoyancy, stability and manoeuvrability of the craft.

At least five different types of possible bundle rafts were identified from the National Folklore Collections (NFC). The folklore informants were between 60 and 85 (approx.) in 1962 and gave accounts of bundle rafts used within living memory on the River Suck. Square rafts constructed of sheaves of rushes bundled together, forming a raft of 1.2 m to 1.5 m², and approx. 0.60 m in depth, seem to be the most common craft used (Fig. 5). Some had a straw rope made into a handle at one end which facilitated the propulsion pole to be pushed through to anchor the raft in the mud (Ms. NFC 1573: 70–71). The first experiment by the author to recreate this model resulted in the raft folding in the centre due to lack of rigidity. Additional bundles of rushes in the base enabled this raft to hold the weight of a person but it was much more stable with the addition of a single longitudinal branch.



Fig. 5 A simple bundle raft, of no more than 1.5 m², without any framework. This is the most common type of bundle raft cited in the National Folklore Collections. Built by Robert Henshall (photo: D. Tully).

Two descriptions of round rafts were more difficult to interpret (Ms. NFC 1639: 274–276). The first, described as a coiled basket like a ‘swan’s nest’, was found to be too difficult to construct with the required diameter of coils to make a buoyant craft. The second used two crossed 1.5 m planks as guidelines, but the description was confusing to follow and was probably recorded by an observer rather than a practitioner.

The National Museum also has a record of a boat in the shape of a four-poster bed frame, filled with bundles of bull rushes, which was used on Lough Urlaur, County Mayo (Niland 1949), but no attempt was made to replicate it. Two other accounts describe rafts of large cubes 1.5 metres each side, but these were probably the rough rafts made by harvesters while collecting rushes. There were challenges building a craft where no partial or full example was available and interpreting some of the vague descriptions in the records.

There are various descriptions of the elongated *Cliath Thulca*, some with wicker frames and others where boards were added to protect the sides. Of the 1962 model Jim Delaney stated, “it rowed remarkable well, and was easily handled with a pair of oars ... Not a drop of water came through the reeds and the floor of the raft” (Delaney 1976: 19–29). As was found by Joseph Tully in his replica of a *Cliath Thulca*, the traversing of the River Shannon showed the lack of manoeuvrability in fast flowing water. It could indicate that reed and rush rafts (as found in Ireland), were probably confined to slow rivers, water meadows and lakes.

The author found making good cordage from natural materials much more challenging than collecting and bundling rushes together. Briars were difficult to handle, and split briars were found to be brittle. When a hide was available, leather thongs were the most rapidly made cordage. Straw rope was the easiest to make in large quantities but needed to be well made for immersion in water. Only a small sample of bog deal was available and not used in the reconstructions. In 2021, Henshall demonstrated to the author particularly strong cordage made from platting seasoned club rushes.

Discussion

Examples of bundle rafts still being made around the world are the reed Fassonis of Sardinia (Kriek 2022), the papyrus Tankwas of Lake Tana (Selmanta 2014), and papyrus canoes on Lake Chad (Immega 2012: 21–27). There are totora reed rafts on Lake Titicaca and Caballito de Totorá in Huanchaco, Peru, and Banana stalks are utilised for rafts in Kenya and elsewhere (Bockius, Eric 2015: 27–31). Other natural fibre rafts that were used into the 20th century were the Papyrella of Corfu (Tzalas 1995: 443), the flax and bulrush Mokihi of New Zealand (Best 2005: 195), and the Tule reed boats of California (Prodanovich 2022).

There are distinct similarities in bundle rafts around the world. A transfer of cultural practices is in no way suggested, but rather it seems to be a universally instinctive process for man to make bundles out of buoyant natural materials, and then to tie these bundles together to create a raft. At the 4th International Symposium on Boat and Ship Archaeology, Bonino stated “The passage from floats to rafts is simple, and takes advantage of the greater buoyancy obtained using the same number of bundles or logs, but distributed horizontally. This may have had its origins in the Mesolithic Period, along with the weaving of baskets and the building of huts and coracles” (Bonino 1988: 465).

A study is being carried out of the Clonfert Callows covering the period 1810 to the 1960’s, where farmers were moved into the Callows and had to adapt to subsistence living. During floods, boats were often kept tethered at the doorway as the only means of mobility (Cunniffe 2018). Lynch *et al.* (2011: 95) gives an account of a modern example of subsistence living and boat use in this wetland area by the last resident.

Mc Philib (2000: 7) suggested that Ireland was unique in Northern Europe, where a raft like the *Cliath Thulca* could be still made from living memory, and that this was probably down to an archaism in Irish material folk tradition. Ireland has been recognised as a repository of archaic folklife practices (Evans 2000: ix). The making of objects from natural materials was carried on in Ireland well into the 20th century (Shaw-Smith 2003; Hogan 2001).

Due to the bio-degradable nature of the bundle raft materials, none have survived in the archaeology record. Apart from Breen and Forsythe (2004: 147–148), little recognition has been given to the possible use of bundle rafts in Ireland by archaeologists. There have been a significant number of dugout boat finds, giving us direct evidence for the use of dugouts over a long period of time, back to the Neolithic (Fry 2000; Gregory 1997). Similarly, there is literary evidence for the use of skin boats going back over 2,000 years (Tully 2017: 206), and with the ethnographic evidence from Ireland and elsewhere bundle rafts should be given consideration for their possible use in earlier times.

Conclusions

The National Folklore records indicate that the *Cliath Thulca* and other bundle rafts were considered a temporary or seasonal craft. Most of the rafts seemed to have been constructions of simple bundles, more likely poled and paddled rather than rowed. While there were different styles of the *Cliath Thulca* they were probably 2 m or less in length, with a simple framework (Mc Philib 2008: 601). Henshall's (2018) rigorous interrogation of the primary sources found that there was no evidence for a *Cliath Thulca* type raft as large as the 3.2 m example in the Folklife Division collections.

One missing piece of information concerns how the rafts were dried out or stored between uses. It is possible that in those areas where rush and reed bundle rafts were required in winter flood times, raw material and cordage would probably have been stored to build a floating craft in a timely manner.

The craft constructed by Henshall and the author adhered to the descriptions in the records as far possible. The practical experimentation of building and floating the rafts filled some gaps in the knowledge of the subject and explained some of the more obscure descriptions in the records and anecdotal evidence.

The overall time and preparation required to build rush craft is less than that of a coracle. Construction of bundle rafts of the type found in Ireland requires fewer skills and resources than that needed to construct skin boats or dugouts, and as such they are likely to have been more numerous in earlier times. As referenced in the discussion and swimming aid sections above, the records show that flotation devices, in the form of rush and reed swimming aids and bundle rafts, were known throughout Europe and elsewhere. Rush and reed bundle rafts may therefore be worthy of more focussed study and consideration as a form of ancient transport for local mobility in Ireland, and the wider Northern European inland waterways.

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Fishing boats in El-Max

Yomna Osman

Abstract: El-Max is situated within the city of Alexandria, Egypt, a prominent coastal metropolis in northern Egypt. Specifically, it is located adjacent to the Mahmoudiya canal, which serves as a vital waterway connecting the Nile River to the Mediterranean Sea. This strategic location not only facilitates fishing activities but also underscores El-Max's historical significance as a maritime hub within the larger urban landscape of Alexandria.

El-Max region stands as a quintessential example of a geographic area deeply entrenched in maritime traditions, characterized by its rich fishing heritage and boat culture. This academic study explores the fishing heritage of El-Max, and examines the integral role of boats within El-Max's maritime ecosystem, highlighting their diverse typologies. By scrutinizing the craftsmanship behind boat construction and the socio-cultural rituals associated with boat ownership and usage, this research unveils the profound connections between boats and the identities of El-Max inhabitants.

Moreover, this research paper aims to document El-Max region as a local cultural heritage with its distinctive character. It highlights the importance of documenting the region in light of development projects undertaken by the state, which often involve significant alterations to El-Max area.

In conclusion, this paper emphasizes the urgency of documenting El-Max as a testament to its unique cultural heritage amid ongoing development pressures, the significance of fishing boats in El-Max extends far beyond their utilitarian function; they are emblematic of a deeply ingrained cultural heritage that binds together generations of coastal communities. As symbols of resilience, craftsmanship, and communal identity, these boats embody the rich maritime traditions of the region.

Keywords: El-Max, fishing, fishing boats, Alexandria, fishermen village, maritime traditions, coastal communities

Introduction

Ethnography represents a distinct approach within the realm of social research, albeit diverging somewhat from conventional methodologies in archaeology. This method draws upon a diverse array of information sources and involves immersive engagement with the community under study. Ethnographers actively participate in the daily activities of the community for varying durations, conducting observations, listening attentively, and posing inquiries to gain insights. They also gather recent data from the field to address pertinent research inquiries. The definition of ethnography varies depending on the specific context and objectives of the research. Within the domain of maritime archaeology, maritime ethnography serves as a valuable method for investigating maritime seafaring remnants, coastal settlements, and maritime tools. This approach entails gathering data from coastal residents and individuals with seafaring expertise. Detailed documentation of traditional maritime practices and boat construction methods enables researchers to discern evolutionary trends in boat designs and construction techniques over time (Hammersley 1983; Naidoo 2012; Agius 2019).

For instance, the prevalence of wooden boats has dwindled in modern times, with contemporary construction incorporating a variety of materials such as metal and fibreglass. As highlighted by McGrail in earlier writings, ethnographic studies continue to offer valuable insights for archaeologists by presenting diverse solutions to common challenges. Through the lens of ethnographic analogies, archaeologists can propose speculative reconstructions of incomplete artefacts and structures, hypothesize functions of ambiguous architectural elements, and elucidate the manufacturing processes of objects and structures. However, it is important to exercise caution when applying this approach to doc-

umentation. The tools utilized by contemporary craftsmen may not have served the same purposes in historical eras, necessitating careful consideration and contextual analysis. (McGrail 1984; Bowens 2011)

So, the disappearing maritime heritage in El-Max underscores the critical need for maritime ethnographic research in this coastal community. As rapid urbanization and modernization reshape the landscape of El-Max, traditional maritime practices and cultural heritage are facing unprecedented threats of extinction. This introduction sets the stage for understanding the urgency and importance of conducting ethnographic research to document and preserve the vanishing maritime heritage of El-Max.

El-Max, nestled along the shores of Alexandria, Egypt, has long been revered for its rich maritime heritage, deeply rooted in centuries-old fishing traditions and seafaring livelihoods. However, in recent years, this once vibrant maritime culture has been steadily eroding under the pressures of urban development, environmental degradation, and socio-economic changes. As a result, invaluable aspects of El-Max's maritime heritage, including boat craftsmanship, fishing techniques, and community rituals, are on the brink of disappearance.

In response to this looming crisis, maritime ethnographic research emerges as a crucial tool for safeguarding and celebrating the unique cultural identity of El-Max. By immersing themselves in the everyday lives of fishermen, boatbuilders, and coastal communities, ethnographers can uncover hidden narratives, oral histories, and indigenous knowledge systems that encapsulate the essence of El-Max's maritime heritage. Through participant observation, interviews, and archival research, ethnographers can document vanishing practices, record personal stories, and capture the intangible heritage woven into the fabric of daily life in El-Max.

In conclusion, the disappearing maritime heritage in El-Max necessitates urgent action to document, preserve, and revitalize its cultural legacy. Maritime ethnographic research serves as a potent tool for confronting this challenge head-on, offering a holistic approach to understanding, valuing, and safeguarding the intangible and tangible aspects of El-Max's maritime heritage.

El-Max

El-Max, situated adjacent to the Mahmoudiya Canal, is a community primarily comprised of fishermen. The canal, excavated in 1820 under the directive of Governor Muhammad Ali, served dual purposes: to channel water from the Nile to Alexandria and to facilitate maritime trade via cargo vessels. Functioning as a subsidiary branch of the Nile, the Mahmoudiya canal traverses Alexandria before reaching its terminus at the Mediterranean Sea. Due to its unique position, where Nile waters mingle with seawater, the marine ecosystem in this locale exhibits distinct characteristics.

Historically, the canal bore the name of Sultan Mahmud II, reflecting Egypt's status as part of the Ottoman Empire during the 19th century. This waterway played a main role in navigation and trade, contributing significantly to the region's economic and social fabric during that era.

The word "max" in the Arabic language dictionary means tax; perhaps this name is due to the function of the place in the past. Referring to the old maps, Al-Max area was on the western borders of the city, where there were some sources the presence of a wall for Alexandria city from the sea to the lake, and in later sources it is found as part of a port for goods where the Gulf of El-Max or the Gulf of Bab Al-Arab.

El-Max is one of the large areas in Alexandria governorate, which has historical and archaeological importance because of its forts and ancient lighthouses. It is also considered a local heritage area because of its different nature. Where there are fishermen's houses that wrap around a waterway that ends in the Mediterranean Sea in the so-called fishermen's village, in addition to the lighthouse and the houses adjacent to it and the fish market *all* these features gave the place a different character.

Fishermen village:

The Fishermen Village, or Qarya El Sayadeen, located in the El-Max area of Alexandria, Egypt, is a picturesque coastal settlement renowned for its vibrant fishing community and traditional maritime culture. The fishermen are affected by the marine environment surrounding them, and this appears in the way they decorate some of their homes in the fishermen's village.

The fishermen's village Qaryat El Sayadeen,, also referred to as 'the trench', is comprised of quaint residences inhabited by local fishermen, situated along the banks of the Mahmoudiya canal. This canal, constructed in 1820, served as a crucial conduit linking the Nile River to the Mediterranean Sea. Throughout the nineteenth century, it served as a vital artery for the movement of merchandise, underscoring its significance in facilitating trade and commerce in the region. The Fishermen Village has a rich history dating back centuries, with fishing being the primary livelihood for its residents. This coastal settlement has witnessed the ebb and flow of maritime trade and cultural exchanges, contributing to its unique identity. The residents of the Fishing Village adhere to time-honored fishing techniques passed down through generations. Fishing remains a central aspect of daily life, with fishermen setting out to sea in colorful wooden boats each day to cast their nets or lines.

The Fishing Village is a bastion of maritime heritage, preserving age-old customs, rituals, and folklore associated with seafaring life. Traditional songs, dances, and celebrations reflect the community's deep connection to the sea and its bountiful resources. Fishing is not only a cultural tradition but also an economic lifeline for the residents of the Fishing Village. The local economy relies heavily on the fishing industry, with fish being sold locally and distributed to markets across Alexandria (Fig. 1)¹.



Fig. 1 An old picture of Fishermen village before removing it (photo: Y. Osman)

The lighthouse residences

The lighthouse residences or The Al-Fanar housing area, or as it is called the cabins, are the area of the fishermen's houses in El-Max, adjacent to the lighthouse and the fish auction, is characterized by its direct proximity to the sea. These houses line the shoreline, offering unobstructed views of the Mediterranean and the bustling activity of the fish market. Perched on the edge of the coast, the houses stand as a testament to the close relationship between the fishing community and the sea. as fishermen prepare their nets and boats for the day's work, creating a vibrant atmosphere along the waterfront. Most of these houses are inhabited by fishermen as well (Fig. 2).

¹ All the pictures are taken by the researcher during the ethnographic interviews.



Fig. 2 The lighthouse residences (photo: Y. Osman)



Fig. 3 Fishing boat from Fishermen village (photo: Y. Osman)

Fishing boats

El-Max, a coastal community in Alexandria, Egypt, boasts a rich maritime tradition characterized by a diverse array of boats. Situated along the shores of the Mediterranean Sea and the Mahmoudiya Canal, El-Max is home to a vibrant fishing community whose livelihoods are intricately linked to the sea. This introduction provides an overview brief of the variety of boats found in El-Max, highlighting their significance to the local fishing industry and cultural heritage. People of El-Max are use boats for many purposes such as fishing and outing. The majority of boats in El-Max are purchased from workshops located in Mataria. These boats are predominantly small in size, constructed from wood, and equipped with motors. They typically feature a straight stern, slightly elevated bows, and are designed with onboard storage compartments (Fig. 3).



Fig. 4 Small boat in lighthouse area (photo: Y. Osman)



Fig. 5 Another type of small boat (photo: Y. Osman)

Similar types of fishing boats commonly seen in the fishermen's village are also found in the vicinity of the lighthouse, alongside various other types of vessels utilized for fishing purposes. These include:

- A small wooden boat designed to accommodate up to three individuals, equipped with a motor for swift transportation to fishing locations, followed by the use of paddles. Fishing is typically carried out using nets (Fig. 4);
- A triangular wooden boat, capable of carrying four individuals solely propelled by a motor, primarily used for net fishing of sardines (Fig. 5);
- A larger motorized boat employed in shrimp fishing, employing a method akin to trawling for catching shrimp (Fig. 6).

In the past, sailors relied on a variety of sailboats of different sizes, as the use of motors was not yet available during that time. Additionally, GPS technology was not accessible, and instead, sailors navigated using the stars or their prior knowledge of sea routes.



Fig. 6 The largest boat in lighthouse area (photo: Y. Osman)

Organization of fishing activities:

Each morning, all boats in El-Max embark on their fishing trips early. Each boat is equipped with a daily logbook, wherein fishermen are required to register their names before departing. Upon returning, fishermen leave these logbooks at the border guards' office, where officials ensure that all fishermen have safely returned.

Sometimes, boats are prohibited from sailing and fishing at sea due to adverse weather conditions. However, fishermen often find ways to circumvent these restrictions by using a large buoy to venture into the sea. Seated inside the buoy, the fisherman places the net on his legs and utilizes oars to row until reaching a suitable fishing spot. He then casts the net, although this method is fraught with risks. Nevertheless, the fisherman resorts to it out of necessity to provide for his livelihood (Fig. 6).

Destruction of the Fishermen village and the future destruction of Al-Fanar:

Unfortunately, the fishermen's village was dismantled as part of redevelopment efforts in 2018. However, fortunately, the area was documented prior to its removal through the utilization of ethnographic methodology. The fishermen's houses in the fishermen's village were removed from the area and relocated to other homes within the El-Max region. Despite this displacement, the fishermen continue their fishing activities in the sea. However, it's notable that the boats no longer dock within the canal (Figs 1–2).

In addition to plans underway to soon dismantle the fishermen's residences adjacent to the lighthouse as part of the Alexandria port development project.

Conclusion

This study is just a small part about the El Max area and the diversity of its fishing boats. In conclusion, the impending destruction of fishermen's areas signifies a significant loss of diverse maritime heritage in El-Max. The rich tapestry of cultural practices, traditional boat craftsmanship, and seafaring livelihoods that have thrived for generations are now at risk of disappearing forever. Urgent ethnographic research is imperative to document and preserve this vanishing maritime heritage before it is lost to future generations. By engaging with local communities, recording oral histories, and documenting traditional knowledge, ethnographers can ensure that the unique maritime heritage of El-Max is safeguarded for posterity.

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Shipyards in Egypt between antiquity, nowadays, and the future

Aya Mohamed Helmy

Abstract: Shipyards in Egypt played an extensive role in building the Egyptian civilization through the ages. Significant archaeological excavations at several sites in Egypt revealed remains of shipyards dating back to antiquity. By studying shipyards in Egypt nowadays in different environments, the ethnographic research revealed the main features of the Egyptian shipyards and the industry of shipbuilding. Shipyards reflect both the materialistic aspect represented in tools and material, and the cultural aspect represented in labourers and builders; therefore, studying the Egyptian shipyards illustrates a lot of evidence about the future outlook of the shipbuilding industry in Egypt.

Keywords: shipyards, shipbuilding, ship maintenance, shipbuilders, iron ships

1. Introduction

Sea and seafaring played an extensive role in building civilizations in the Mediterranean region, as the sea was an essential maritime highway for the Mediterranean people (Tilley 2004). Therefore, it is required to study ships and shipyards as well. Despite the scarcity of actual recognizable remains of shipbuilding sites, we depend on evidence such as the archaeological finds that refer to an existence of shipbuilding sites to provide us with knowledge on shipyards. Studying shipyards reveals evidence that supports the studying of ship construction and building techniques, as they illustrate a lot of information about the process of building from its very beginning, when a ship was just an idea and then transformed into a reality through wood and metal. Since Egypt has coastlines on the Mediterranean Sea, the Red Sea, and the River Nile, in addition to the Egyptian coastal lakes, the shipbuilding industry is a key player in all of the Egyptian civilizations through history.

This paper aims to present the Egyptian shipyards in antiquity and nowadays, in addition to their future outlook. It will also illustrate the main features of shipyards and discuss the differences and similarities between these features. Ethnographic research is the main methodology used in this study to define the characteristics of shipyards today, as well as the archaeological and historical evidence to read the past of shipyards and imagine their future. Three ancient shipyards and their archaeological evidence will be discussed: Tell Abu Saifi, Berenike, and Quseir Al-Quadim. These ancient sites will be compared to ethnographic research that has covered three modern shipyard regions with different environmental characteristics: Alexandria, Rosetta (Rasheed), and Burullus (Fig. 1).

2. Shipyards in antiquity

Maritime installations such as shipyards are considered as the interface between the land and the water. Therefore, the existence of shipyards is essential in Egypt as a country where people depended on the sea in many aspects of their life through history. Shipyards are not only sites for shipbuilding, but they also could be sites for routinely repairing and vessel maintenance. Another activity that took place in shipyards is ship dismantling to reuse timbers in the construction of new vessels, as this process required skilled labourers. The evidence of reused elements of ships that has been identified in shipwrecks and shipyards worldwide is a clear indication that ship dismantling was a well-known activity (Moser 2011: 839). It was common that shipyards were located in harbours, or near rivers that were deep enough to launch such large vessels (Moser 2011: 838). Many of the archaeological excavations around the Mediterranean generally, and in Egypt specifically, revealed indications of shipyards; the following are some examples of those excavated sites.



Fig. 1 Satellite image with the locations of studied sites (Google Earth Pro)

2.1. The site of Tell Abu Saifi

In North Sinai, an Egyptian survey has revealed remains of a shipyard that is dated back to the Ptolemaic and Roman eras. The site, called Tell Abu Saifi, lies 3 kilometres to the east of Suez Canal, near the Roman town of Sila (Hosny 2019). According to Dr Mostafa Waziri (the secretary General of the Supreme Council of Antiquities), the shipyard consisted of dry docks for shipbuilding and maintenance. The bigger dock, located to the east, was used for maintenance; it is 6 meters wide and surrounded by walls (Hosny 2019).

The excavation did not reveal the remains of the shipyard only; a lot of finds such as bronze and metal nails of different sizes and shapes, pottery, statues, and Nile fish bones were found. According to Hisham Hussein (North Sinai Antiquities Director), the remains of Nile fish bones that were found in the site is an indication that one of the old Nile branches used to run to the south of Tell Abu Saifi (Hosny 2019).

2.2. The site of Berenike harbour

The site of Berenike harbour lies on the Red Sea Egyptian coast. Berenike (modern Berenice) was an important port city on the Red Sea coast during the Ptolemaic and Roman Periods and for about eight centuries later (Sidebotham *et al.* 2008). The harbour was built by Ptolemy II (Philadelphus) in about 275 BC, and he named it after his mother (Wild, Wild 2001). The site is located about 825 km southeast of Suez, and 260 km east of Aswan. The site was excavated for fifteen seasons, from 1994 to 2001, then from 2009 to 2015, by a team from the University of Delaware and the University of California. During the excavations, the team discovered a sail fragment, reinforcing strip, and rings. These ship remains could be an indication of a site for shipbuilding or maintenance (Wild, Wild 2001).

2.3. The site of Quseir Al-Quadim

Another ancient site on the Red Sea coast is the harbour of Quseir Al-Quadim, that was known as Myos Hormos. The site lies about 8 km north of the modern town of Al-Quseir, about 500 km south of Suez, and rises to about 8 m

above sea level (Whitewright 2007). The early investigation at the site was from 1978 to 1982 by a team from Chicago University. The investigation was continued by a team from the University of Southampton between 1999 and 2003 (Sidebotham *et al.* 2008). During the excavations the team discovered some finds referring to shipbuilding and maintenance activity: nails, fragments of reused timbers, rigging and sail parts (Blue 2007). Additionally, the team discovered well-preserved finds of organic artifacts: a Roman deadeye with three holes dated to the mid to late 2nd century AD, various Roman sheaves from rigging blocks dated to the second half of the 2nd century AD, and a small fragment of a Roman sail dated to the late 1st or early 2nd century AD. Additionally, several brail rings made from wood and horn were excavated during every season of the survey (Whitewright 2007). These finds are considered clear evidence of shipyards.

3. Shipyards nowadays

Studying the Egyptian shipyards and their process of building today depended on ethnographic research to examine different regions with different environmental characteristics: Alexandria, Rosetta (Rasheed), and Burullus. The ethnographic research explored the role of shipyards nowadays and the different types of boats and ships that are built for different purposes. Egyptian people still depend on the sea in different aspects of their lives; consequently, the industry of shipbuilding remains an influential industry in Egypt today. Due to the differences between the studied regions and their environmental characteristics, there is a variety of vessels that are built. However, there are also some similar features in all the studied shipbuilding sites, in spite of the differences between the regions.

3.1. Alexandria

According to my ethnographic research with current shipbuilders and the owners of shipyards, for many years fishing was the main function in Alexandria. Most of the Alexandrian people were fishermen who depended on nets as a type of fishing. Therefore, it was essential for them to own fishing ships or boats. Thus, the earlier generations of shipbuilders used to build fishing boats and ships. Nowadays, Alexandrian people do not depend on fishing as a main activity anymore, and as a result the industry of building fishing ships in Alexandria is not as common as it used to be. Shipyards still exist in Alexandria, but today they are more famous for building luxury yachts. At local shipyards in Alexandria, shipbuilders depend on basic equipment during the process of shipbuilding (Fig. 2), even though they produce yachts in different sizes and various designs that are mostly used in tourism tours.



Fig. 2 A labourer uses a hammer in the process of shipbuilding in Alexandria (photo: A. M. Helmy)

According to interviews with shipbuilders in Alexandria, the quality of yachts depends on the type of timbers used; that is decided according to the budget of the shipowner. But, generally the process of shipbuilding requires more than one kind of timber. Based on the ethnographic research, and the interviews with the labourers and owners of shipyards, Alexandrian shipbuilders used to build most of the ships and boats by eye, as they don't rely on patterns, especially the old builders. Moreover, some fishermen used to build their own boats by themselves, depending on hand tools. The community of fishermen and shipbuilders in Alexandria proves that dealing with the sea is such an innate talent that all of them seem to have, thanks to the environmental characteristics of this city.

3.2. Rosetta (Rasheed)

Rasheed is a pioneering city in the industry of shipbuilding because of its unique location, as it is bordered by the Mediterranean Sea to the north, and the Rasheed Nile branch to the east. The industry of shipbuilding in Rasheed does not depend on small shipyards, instead this city has huge shipyards that are well equipped for shipbuilding and maintenance (Fig. 3). Based on interviews, through the ages the shipbuilders in Rasheed used to build different types of wooden boats and ships, but nowadays Rasheed is mainly famous for the industry of iron ships, especially those that are used for oil services, in addition to iron fishing ships.



Fig. 3 A side of the most famous shipyard in Rasheed (photo: A. M. Helmy)

According to the shipbuilders in Rashid, the industry of iron ships became known in the 1960s. However, wooden ships were still produced until approximately 2010 when ship owners decided to build iron ships, the whole industry in Rashid became dependent on iron except small boats manufacturing. The advantage of iron in this industry is that ships are maintained almost once every three years, conversely the wooden vessels are maintained twice a year, and they are left on land for almost a month to dry.

3.3. Burullus

The Egyptian lakes play an economic and environmental role that is not less important than the role of the Mediterranean Sea, the Red Sea, or the River Nile. Lake Burullus is one of the Mediterranean basin lakes. It is located to the east of Rasheed, bordered by the Mediterranean Sea to the north, and agricultural land to the south (Younis 2018). Lake Burullus is considered as the reason of life for most of the people who live in Burullus, as most of them are fishermen. Therefore, the main features of this town are boats that are used for net fishing in lake Burullus (Fig. 4).

Burullus icon of the town is characterized by sailboats with masts and sails that move depending on the direction of the wind (Fig. 5). However, making sails nowadays is not as common as it used to be, as according to the owners of shipyards in Burullus, some of them stopped making sailboats almost five years ago. And according to those owners of shipyards, this is based on financial reasons, since making sails and masts became expensive for the fishermen, therefore, they prefer boats that work with engines instead. Additionally, those boats with engines are much more practical as they do not move depending on the direction of wind. Although the industry of shipbuilding in Burullus depends mainly on small shipyards that are famous for producing flat fishing boats to sail in the lake, there are other shipyards in the town that build and maintain yachts and fishing ships with deep drafts that sail in the Mediterranean Sea.



Fig. 4 A fisherman on his boat in lake Burullus (photo: A. M. Helmy)



Fig. 5 Sailboats on the shore of lake Burullus (photo: A. M. Helmy)

4. The main features of the Egyptian shipyards

Regardless of the different characteristics of the studied regions, and the different types of vessels that are produced in the Egyptian shipyards, there are common features of the Egyptian shipyards that are obvious in both the material and cultural aspect.

4.1. The material aspect

The material aspect of shipbuilding is represented by the tools that are used in building all of the different types of vessels, and the available facilities in shipyards themselves as building and maintenance sites. The main characteristic of all the studied shipyards is that the tools are similar, whether hand tools or electric tools. The excavations of the ancient shipyards documented that the tools and materials in use did change over the centuries. This demonstrates

that shipyards had to evolve to serve the needs of the state and the sailors, thus the required skills of ancient shipyard workers must have changed as well. Today in the modern shipyards, the shipbuilders in Alexandria and in Burullus depend on the same basic tools to build wooden ships and boats. The studied shipyard in Rasheed is well equipped with more sophisticated tools that are used in the building and maintenance of iron ships, in addition to other facilities and equipment, such as trucks and lorries to transport metal. As a result, shipbuilders, labourers, and even the owners of the shipyards in Rasheed are specialized in working with tools and equipment that are used in iron work. This shows how the pace of shipyard change has accelerated in modern times to keep up with the changes in today's technology. Based on ethnographic research, the types of ships and the skills of Egyptian shipbuilders and shipyard workers are changing rapidly today to support new demands. Wood to iron, sails to motors, fishing to tourism; the material aspect of Egyptian shipyards must continue to modernize to survive, just as ancient shipyards did.

4.2. The cultural aspect

The cultural aspect is represented in the society of shipbuilders, labourers, and the owners of shipyards. The industry of shipbuilding does not just depend simply on shipbuilders. Each shipyard in Egypt includes specialized staff in different fields. Culture cannot remain static in the presence of changing technology. Skill sets may change. The process of shipbuilding goes through several stages that are not all about carpenters or builders. For example, luxury yachts must be provided with some services and divided into essential sections such as bedrooms, bathrooms, and kitchens, that depend on the size of each yacht. Fishing ships must contain sections such as rooms for the fishermen, and bathrooms. Moreover, all vessels must be well protected by caulking and painting. Therefore, the process of shipbuilding requires a group of technicians who are specialized in electricity, plumbing, caulking, and painting, etc. (Fig. 6).

The ethnographic research has revealed that too often workers move from one city to another to work at a shipyard at the request of their owner, or even due to lack of work opportunities in their home city. As a result, in one shipyard there could be a group of workers with different cultures and different backgrounds who spend several months work-



Fig. 6 Caulking a yacht by a labourer who specialized in caulking in Alexandria (photo: A. M. Helmy)

ing, talking, and also having their daily meals together. Workers will continue to move to find work as the location of demand changes. If wooden shipbuilding reduces at salt water shipyards, craftsmen may relocate to fresh water yards to remain employed, or perhaps they will retrain to other skills. These movements result in cultural mixing today; they must have caused cultural mixing in the past as well. This certainly leads to the exchange of cultures, traditions, and ideas. The education of present and future workers must reflect future expectations, not past needs.

5. The future outlook of shipyards in Egypt

The Egyptian shipbuilders totally respect their profession and realize the enormous importance of the industry of shipbuilding. Therefore, they do not stop working and believe this industry will remain just as important as it is now. Historically, the industry of shipbuilding in Egypt has been passed down through generations. In accordance with this ethnographic research, all the studied shipyards are dated back to the fathers and grandfathers of their current owners. Thus, the most common feature in the Egyptian shipyards nowadays is the presence of teenagers and children, who are the sons of the owners of the shipyards or sons of labourers. During the process of shipbuilding, they join the workers to watch, learn, and help as well (Fig. 7). As technology changes, some of the skills required to maintain older boats may become scarce. According to generations of shipbuilders, they will keep learning and continue to build wooden ships. However, the advancement of technology may increase the emphasis on formal education over the transfer of knowledge between generations of shipbuilders. Shipbuilding may increase the demand for technical education in Egypt. Regardless, shipbuilding sites should continue to exist in Egypt, and the profession of shipbuilding should not disappear in the future; on the contrary, it should continue developing.



Fig. 7 Children learn the function in Burullus (photo: A. M. Helmy)

6. Conclusion

Studying ships and their different types is complemented by studying the sites where those ships were built and repaired. Therefore, studying shipyards in Egypt as a country that is characterized by its coastlines illustrate a lot of information about the industry of shipbuilding in Egypt, and the society of shipbuilders. Also, by studying the remains of the Egyptian shipyards in antiquity and shipyards in Egypt nowadays we can anticipate the future outlook of the shipbuilding industry, shipbuilders, and the existence of shipyards. As the archaeological remains proved the importance of shipyards in antiquity, present-day ethnography shows that shipbuilders respect their function and teach it to the next generations.

There were shipyards thousands of years ago. They changed over time. There are shipyards today, that are changing right now. The rate of change seems to be accelerating. While in the past the transfer of shipbuilding knowledge emphasized generational transfer, technology today may increasingly emphasize formal education as shipyards continue to become more complex. The results of this research confirmed the impact of the shipbuilding industry in Egypt through history as a key player in building the Egyptian civilization, and supported the opinion of shipbuilders – especially the new generations – that their profession is not going to disappear, but will continue to evolve in the future.

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