Archaeology: Just Add Water

volume II

2019

ŚWIATOWIT Supplement Series U: Underwater Archaeology, vol. II

Financed by:
Polish Ministry of Science and Higher Education (959/P-DUN/2018)
Director of the Institute of Archaeology, University of Warsaw

Cover Photo: Humantay Lake, Peru 2016, by Przemysław A. Trześniowski
Back Cover Photo: Underwater Expedition IA UW at the 19th Archaeological Festival in Biskupin, Poland 2013, by Marcin Bartoszewicz

ISSN 2719-2997
ISBN 978-83-66210-03-5
Series DOI: 10.35538/uw.2719-2997
DOI of the volume: 10.35538/uw.2719-2997/978-83-66210-03-5

Typesetting and makeup: Aleksandra Chołuj, Małgorzata Mileszczyk, Magdalena Nowakowska
Print and binding: Elpil, Siedlce

„3rd Warsaw Seminar on Underwater Archaeology – zadanie finansowane w ramach umowy 959/P-DUN/2018 ze środków Ministra Nauki i Szkolnictwa Wyższego przeznaczonych na działalność upowszechniającą naukę”

Archaeology:

Just Add Water

Underwater Research at the University of Warsaw

WARSZAWA 2019

Preface

Dear Colleagues,

It is our great pleasure to present to you the second volume of the U Supplement Series of the "Światowit" periodical. To a large extent it is based on the papers presented during the *3rd Warsaw Seminar on Underwater Archaeology*, which took place at the University of Warsaw on the 17th and 18th of January 2019.

An efficient and prompt process of editing we owe to the funding from the Ministry of Science and Higher Education, grant no. 959/P-DUN/2018.

Organization of the Seminar and publication of the hereby volume was possible thanks to the co-operation with the Polish Chapter of the Explorers Club, in particular its President, Professor Mariusz Ziółkowski, and the Vice-President, Marcin Jamkowski, to whom we are deeply grateful.

We would also like to acknowledge and appreciate the support of the University of Warsaw, namely the Vice-Rector Ph.D. habil. Maciej Duszczyk, the Dean of the Faculty of History, Ph.D. habil. Małgorzata Karpińska, Professor UW, as well as the Director's Board of the Institute of Archaeology: Ph.D. habil. Krzysztof Jakubiak, Ph.D. Michał Starski, and Ph.D. Marta Żuchowska.

The special thank you we traditionally owe to the Diving Museum by the Warsaw Diving Club, especially the Museum's Curator, Karina Kowalska, and the Club's President, D.Sc. Grzegorz Kowalski, who have been supporting our activities for many years, and constantly guide and help us in numerous enterprises.

We would like to extend our gratitude to all the Authors and Reviewers, who have been extremely diligent and punctual to keep up with our strict deadlines.

During the editing of the volume we have received invaluable consultations in the matter of ancient languages by Tomasz Płóciennik and Ph.D. Joanna Wegner, who we would also like to thank with all our hearts. The post-editing process was successful due to the the kind assistance of Ph.D. Rafał Dmowski, who we owe enormous gratitude.

The whole book was once again skilfully supervised and managed by the one and only irreplaceable Ph.D. habil. Bartosz Kontny, Professor UW. Him we would like to thank for all the advice and help with difficult choices, as well as the dedication to the organizational matters, even though the really tight schedule.

Last but not least, we would like to thank all the Readers who have reached for the hereby volume. We sincerely hope you will enjoy the outcome of our efforts and wish you pleasant reading!

Aleksandra Chołuj

Małgorzata Mileszczyk

Magdalena Nowakowska

3rd Warsaw Seminar on Underwater Archaeology

3rd Warsaw Seminar on Underwater Archaeology held on 17th-18th of January 2019
at the University of Warsaw
(photos by: M. Sugalska)

Foreword

The volume, which we hereby present to our esteemed Readers, is the vivid proof that underwater archaeology at the University of Warsaw is doing more than well. It is the second publication in the ***"Światowit" Supplement Series U: Underwater Archaeology***, issued for now (and we hope this pace will be sustained!) with a frequency of a periodical. Within the book one might find i.a. the texts being an outcome of the international ***3rd Warsaw Seminar on Underwater Archaeology***, organized in the Institute of Archaeology, University of Warsaw. The Readers will discover here the articles presenting broad chronological and geographical range of issues: from the Prehistory until the Second World War, from Guatemala and Peru to Poland and Slovakia. We are trying to reflect this diversified character also by the choice of photographs on the cover.

The leitmotif of all this vast range of archaeological issues is **water**: realm bearing a magnificent symbolic character. Changing its colour (even during the day – from the blackness, through greyness, then blue, until the bloody-red at the sunset, turning again into black) and visibility, it has manifested also other features, which can be contemplated as signs of its animation, such as movement: horizontal (currents, waves, tides) and vertical (fluctuations of the surface). It was also the source of life quite literally, providing food and dihydrogen monoxide, essential for living.

Along with its whole mystery and dangerousness, water may also serve as a refuge (lake settlements from the early Iron Age) and a trade route, at the end of which there is a (hopefully) safe harbour. That is how underwater archaeology marches onto the land... Although, it is neither place nor time for the deliberation about the definitions of archaeology related to water environment; the discussion in this matter has lasted for many years, abound in more and more new terminological propositions, still being far from any resolutions. Whichever position we assume in the aforementioned debate, it is impossible not to notice that the symbolism, the rituals, and everyday casual activities essential for life and connected with water pass through each other, which is well-exemplified by the hereby volume. Objects lost during transportation and other kinds of exploitation of water basins, items put in the water as a matter of rituals, military aspects connected with watery environment, lake settlements, harbours, and trade – all of that and even more you can discover in *Just Add Water 2*. To all the Readers, who are going to immerse themselves into this topic, I wish a pleasant intellectual adventure and... good dives!

Bartosz Kontny

DOI 10.35538/uw.2719-2997/978-83-66210-03-5.pp.189-204

Shipwreck from Czersk. Excavation of the Large Vistula River Vessel from Medieval Times

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Abstract:

During the summer of 2018, remains of a wooden vessel were excavated and extracted near Czersk (Masovian Voivodeship, Poland). The recovered shipwreck is an example of the largest sailing vessel type used on the Vistula River in the pre-industrial era.

This paper shows the results of the recovery operation conducted by the State Archaeological Museum in Warsaw in cooperation with the Archcom company and the University of Gdańsk. Methods used during the documentation process allowed recording of the shipwreck site and timbers in a full 3D form. Thus, it was possible to refine the current knowledge about the ship itself and inland shipbuilding on the Vistula River. Furthermore, it is possible to reconstruct the original vessel's appearance, both in digital and physical form.

Keywords:

shipwreck, medieval shipbuilding, Vistula River, inland transport, documentation methods, Computer Vision Photogrammetry, 3D scanning

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Introduction

The archaeological investigations conducted so far show that large river crafts intended for navigation on the Oder and the Vistula Rivers started to be built and used in the 13th century A.D. The largest of them was *szkuta*, originally used on the Vistula for transporting grain. This type of vessel was a workhorse for carrying bulk commodities to Gdańsk until the late 18th century A.D. (Smolarek 1985: 174–177). However, until recently this kind of craft had been known only from written and iconographic sources. Luckily, in the summer of 2009 the first wreck of *szkuta*, dated to the medieval period, was successfully investigated in the old riverbed of the Vistula near Czersk, in Masovian Voivodeship.

The wreck was situated inside a small pond, which was in the past part of the riverbed (**Fig. 1**). The first archaeological research included the uncovering of the entire structure and the preparation of detailed *in situ* documentation. The hull had its original form preserved in 60%, with almost intact aft section (**Fig. 2**). The dendrochronological analysis revealed that the timbers used for the construction came from trees cut between 1478 and 1481 A.D. (Ossowski 2010: 107). The vessel was in use for almost 60 years before it was probably scuttled along the shoreline of the river. Having based on the field documentation, the first attempt to reconstruct the appearance of the ship has been made (Ossowski 2010: 108; Żrodowski 2010: 213–217). The total length of the vessel was estimated at up to 30 m with the original width of about 7–8 m.

After excavations, the rest of the hull was partially covered with sand and sunk again at its original location. It was meant to be fully recovered and documented in the next field season.

Preparation for Recovery

The fact of discovering the first large Vistula River vessel attracted the attention of the Regional Council of Masovian Voivodeship. Immediately after the first information came to light, the analyses of the possibilities for the ship's unearthing and its further exhibiting have begun. The State Archaeological Museum in Warsaw declared its willingness to undertake this task in cooperation with the National Maritime Museum in Gdańsk. Nevertheless, the recovery was limited at that time by the lack of appropriate conservation facility. None of the laboratories existing in Poland was able to handle conservation of such long shipwreck timbers. This forced the researchers to change both their priorities and the project schedule.

At that time the State Archaeological Museum in Warsaw proposed to build a new facility within the area of the Storage and Research Centre for Archaeological Finds, located in Rybno near Sochaczew (Masovian Voivodeship, Poland). With the financial support of the Masovian Regional Council, in the years 2011–2013 the old storage warehouses in Rybno were designated for future conservation laboratory of waterlogged archaeological wood. However, such large-scale work required major changes in the old facility's infrastructure. Besides, the whole storage house was located within the historical complex of the 19th century Rybno Manor, which caused some difficulties with construction works. The adaptation of the old warehouses was undertaken in 2012–2013. The conservation--restoration infrastructure was designed by Ph.D. habil. Małgorzata Grupa from the Nicolaus Copernicus University in Toruń (Grupa 2013). Having based on her concept, the facility was equipped with large tanks for storing and impregnation of waterlogged archaeological wood. Inside the main building a specially designed six-metre-long freeze-drying chamber has been built, where the conservation process of the wreck elements could have been finalized. Additionally, the building was equipped with a crane with lifting capacity of 1600 kg that was to carry the heaviest elements (**Fig. 3**).

During the first half of 2018, the facility was ready to receive the first elements. In August 2018 the Masovian Voivodeship Heritage Office approved the research programme for the wreck recovery and its conservation (Borkowski *et al.* 2018) and gave the State Archaeological Museum the green light for its excavation. All archaeological works were conducted under the supervision of Ph.D. Wojciech Borkowski and M.A. Witold Migal from the Museum. The recovery operation and documentation process were carried by the *Archcom* company, specializing in the excavation of historical shipwrecks. The scientific consultation of the project was entrusted to Ph.D. habil. Waldemar Ossowski – a Professor from the University of Gdańsk. The whole operation was financed by the State Archaeological Museum with the support of the Regional Council of Masovian Voivodeship.

Recovery Operation, 2018

Although the fieldwork of 2009 provided substantive data of the site, it was clear that the upcoming recovery operation required different approach in methods and logistics; few problems needed to be solved before the first shovel was to hit the ground.

One of the biggest issues was the limited space. Due to the agreement with the owners of the area, none of the undertaken actions should affect their apple orchard. It meant that the total area of archaeological works was limited to 2000 m^2, including 600 m^2 pond, where the wreck was situated. This required careful distribution of recovered sediment around the wreck as well as the deployment of the rest of the archaeological infrastructure (**Fig. 4**).

The second problem was the constant need for pond draining. As part of the old riverbed, the whole area was heavily affected by groundwater. Thus, constant pumping water out of the pond was required to keep its level at the minimum. Furthermore, the water had to be transported to a distance that would not have a negative impact on the nearby countryside. To minimize the problems, the whole operation had to be started when the water level of the pond was the lowest, which basically meant dry and hot period of the high summer season. In consequence, it led to another issue: the shipwreck had to be extracted as fast as possible to minimize the time of timbers exposition to the sun heat and their further deterioration.

The recovery operation was scheduled for the end of August and took 16 days. It was conducted by the team of five archaeologists from *Archcom* company with the assistance of four workers deployed by the State Archaeological Museum. Firefighters from the local volunteer units of Wojciechowice and Góra Kalwaria (Masovian Voivodeship, Poland) have helped with the pond drainage.

At the first stage, the pond was completely drained with the use of three motor pumps and kept at the lowest level for the whole excavation. The water was pumped out to the safe distance of 120 m from the site to an old drainage canal connected to Czersk Lake. Then, sand was manually removed from the shipwreck's structure. Due to the weather conditions, the wreck was constantly poured with fresh water to slow down the drying process.

The condition of the shipwreck corresponded to the state during previous works on site in 2009 (**Fig. 5**). The most deteriorated portion was its starboard side. Part of the midship section was missing and the remaining elements were heavily damaged, possibly by pond dredging. In the best state of preservation was the aft, originally covered by the thick layer of sand. On its port side, the elements of the structure were preserved up to the gunwale. However, a section of pine gunwale has fallen from its original location and had to be extracted from the site as first. The most deteriorated part was the forward section, where the structure of the upper parts was damaged or missing.

Site Documentation

The limited time frames for the recovery operation required time-saving methods of site documentation. The obvious choice was, therefore, the photogrammetry that allowed to generate good quality and precise site plans and thus to locate each timber from the original structure. Over the last decade, Computer Vision Photogrammetry was successfully tested on various archaeological sites and, in recent years, became a standard tool in the documentation of shipwrecks (Bednarz and Różycki 2017; van Damme 2015; Jones 2005; Yamafune 2016; Yamafune *et al.* 2017).

Prior to the documentation, each timber was labelled with coloured cattle ear tags with a pre-printed number sequence from 001 to 200. The labels were fastened with copper roofing nails. All tagged timbers were registered in the database with the information regarding their location and relation to adjacent wreck structures.

The recording process was based on aerial photography. All pictures were taken by the remotely controlled drone equipped with a digital camera with a twenty-megapixel sensor. The use of a drone speeded the whole recording process and prevented the contamination of timbers by stepping onto the cleaned surface of the shipwreck. For the project purposes, the site documentation was divided into three stages. During the first one, all *in situ* structures, including framing system and side planking, were recorded. The second phase included the documentation of the bottom of the hull with dissembled upper parts. It revealed all edge to edge connections between bottom planks and gave more information about the fasteners. The last phase was focused on recording the area after extraction of the timbers, where the other additional structures and objects were uncovered (**Fig. 6**). Each stage required 900–1600 photos with the resolution of 3992 × 2242 pixels.

Before the processing, all photos were first enhanced in *Adobe Lightroom*® for balance. The datasets were then imported to *Agisoft Photoscan*® where the photos were aligned to create 3D point clouds and finally generate 3D meshes with applied textures. All models were scaled with the use of 1 × 1 m cross-scale that was placed close to the recorded wreck's structures. All measurements were processed subsequently in the software. For the final corrections, additional ground control points were used. They were placed in various locations of the site. Coordinates of these points have been taken using the GPS-receiver: *Spectra Precision GNSS S60*, and converted to WGS-84 coordinate system.

The final output included three 3D models of each stage of shipwreck's disassembly, georeferenced, with enough quality to distinguish all the necessary construction details and features of all original timbers. All three layers were then integrated as flat orthogonal pictures and used to create a precise site plan (**Fig. 7**).

Timbers Extraction

The extraction was carried with the use of thirty-metre-long crane. The limited space on the archaeological site forced the researchers to access each shipwreck section from the single position of the crane. Prior to the lifting, each timber had to be detached.

However, the disassembly of the structure revealed another problem, i.e. the condition of the wreck itself. Its location within the pond in the low-oxygen environment created favourable conditions for wood preservation. Most of the timbers, originally covered by the thick layer of wet sand, survived almost intact, with just small traces of deterioration. Therefore, each iron rivet or treenail had to be dismantled and removed manually with care necessary to preserve fragile wooden material.

The lifting operation was combined with transport and divided into two phases. During the first one all framing elements and side planking were extracted directly to the truck. Most of the shipwreck parts were transferred in one piece. However, to fit on the truck, elements longer than 11 m had to be cut in half. In the second phase the whole bottom planking and the aft piece were extracted. All elements were transported over 100 km to the conservation facility in Rybno, where further documentation process has taken place.

Digital Recording of Timbers

In the foreword to his book, Richard Steffy says that wooden boats and ships are the most marvellous structures ever built by humankind (Steffy 1994: IX). With no doubt, none of other human-made crafts relies in such a strong way on the three-dimensional form, which defines its basic characteristics and capabilities. If the three-dimensional shape plays the main role in the ship’s construction, one should also try to use a spatial approach in its recording and analysing. The idea of digital three-dimensional studies of shipwreck structures has developed within the past few years, mostly due to improvement of computer techniques. The software environment is becoming much more accessible and friendlier for users not related to the architectural and engineering industry. The recording of *Newport Ship* (Jones 2005; Jones *et al.* 2013) or *Copper Wreck* (Żrodowski 2014) clearly showed that 3D scanning of individual timbers can deliver more detailed information about ship construction and help in the analysis and reconstruction of its original shape.

The documentation of the Czersk shipwreck was mostly based on the experience from archaeological excavations of two shipwreck sites related to the 1715 A.D. Swedish ship-barrier located in the entrance to Bay of Greifswald in North-Eastern Germany (Auer *et al.* 2017: 18–25). The recording process has been started by cleaning each timber from sediments and original waterproofing paint. Simultaneously, first interpretations and a general description were noted on timber sheets. Basically, the timber sheets delivered information about features that could vanish through the cleaning process (e.g. waterproofing materials, damaged and broken parts, repairs) and were used for the final description of the timber.

Cleaned elements were scanned with the *Artec Eva*® hand scanner (**Fig. 8**). The device, based on the structured light scanning technology, captures in high resolution the object's geometry and texture with all its features. The main advantages are no limit of the size of the scanned objects and small time-consumption needed for processing the data. In comparison with the Computer Vision Photogrammetry, a complete model can be processed even five times faster. Each object required two scans of both sides. The processing was performed with the use of *Artec Studio*® software, that enabled to merge into a single solid mesh both scanned surfaces.

Generated 3D models were further elaborated in the so-called annotation process. With the use of *Rhinoceros*® 3D software, each feature visible on the scanned timber was highlighted by the 3D contour applied directly on the meshed model. The contours were grouped into individual layers that represented different kinds of features, like fasteners, tool marks, wood science etc. (**Fig. 9**). The annotation process allowed recording a variety of complex timber details in a rapid and accurate way. For the paper prints of documentation, 3D models were put within flat layouts with generated technical viewports of each their face and cross-section (**Fig. 10**). The annotation was accompanied with the timber description, where complex information about the element, including data from paper timber sheets, was written on the timber description.

The collected data, including scans, annotated models, timber descriptions, and detail photo shots of structure features have been used to create a Timber Catalogue, considered to be a basic element of the recoding process (Castro *et al.* 2018: 61–62). Its compilation delivered a good foundation for further complex and complete analysis of the vessel construction.

The Project's Future

The complete documentation process does not fulfil all project objectives. A detailed 3D documentation of elements gives an opportunity for digital reconstruction with all missing or heavy damaged parts. This kind of reconstruction can provide more precise information about the ship's capacity, performance, propulsion, and overall appearance.

Simultaneously with the post-excavation works the conservation process has started. The presence of oversized elements requires enlargement of the facility, especially water tanks and a freeze-drying chamber where eleven-metre-long elements are to be kept. Another, much bigger warehouse for the timbers storage is planned to be built in 2019. Based on the programme calculation, the whole conservation process should be finished in eight years.

Detailed digital documentation allows replicating the missing elements and fitting them within the original wreck structures. According to modern principles of monument restoration, it is permissible to restore historical or archaeological objects to their original form and condition. From the very beginning of the project its goal was not only to save the wreck, but also organise an exhibition about Vistula boatbuilding traditions where the restored Czersk vessel would be the main attraction.

Literature:

Auer J., Grabowski M., van Damme T.

2017 *Excavation and Recovery of Wrecks Ostsee Bereich VII, Mönchgut Fpl. 63 (7070) and Fpl. 64 (7071) and in situ Protection of Wreck Fpl. 65 (7072) – Archaeological Diving Operation No. 3544–5409.01,* Schwerin, unpublished

Bednarz T., Różycki J.

2017 *Research of the Wrecks in the Gulf of Gdańsk Using Photogrammetric 3D Documentation*, (in:) J. Litwin (ed.), *Baltic and Beyond. Change and Continuity in Shipbuilding, Proceedings of the Fourteenth International Symposium on Boat and Ship Archaeology Gdańsk 2015*, Gdańsk, 27–32

Borkowski W., Grabowski M., Migal W., Paczkowski M.

2018 *Program badań archeologicznych Szkuty Wiślanej w Czersku,* Warszawa, unpublished

Castro F., Bendig C., Bérubé M., Borrero R., Budsberg N., Dostal C., Monteiro A., Smith C., Torres R., Yamafune K.

2018 *Recording, Publishing, and Reconstructing Wooden Shipwrecks*, "Journal of Maritime Archaeology" 13/1, 55–66

van Damme T.

2015 *Computer Vision Photogrammetry for Underwater Archaeological Site Recording in a Low--Visibility Environment*, (in:) F. Menna, E. Nocerino, S. Del Pizzo, F. Bruno, F. Remondino (eds), *The International Archives for the Photogrammetry, Remote Sensing and Spatial Information Sciences. Underwater 3D Recording and Modeling, 16–17 April 2015*, vol. XL–5/W5, Piano di Sorrento, 231–238

Grupa M.

2013 *Projekt wyposażenia pracowni konserwacji mokrego drewna archeologicznego*, Toruń, unpublished

Jones T.

2005 *Recording the Newport Ship: Using Three-Dimensional Digital Recording Techniques with a Late Medieval Clinker-Built Merchantman*, "INA Quarterly" 32/3, 12–15

Jones T., Nayling N., Tanner P.

2013 *Digitally Reconstructing the Newport Medieval Ship: 3D Designs and Dynamic Visualisations for Recreating the Original Hull Form, Loading Factors, Displacement, and Sailing Characteristics*, (in:) C. Breen, W. Forsythe (eds), *ACUA Underwater Archaeology Proceedings 2013*, Leicester, 123–130

Ossowski W.

2010 *Przemiany w szkutnictwie rzecznym w Polsce. Studium archeologiczne*, Gdańsk

Smolarek P.

1985 *Vistula Cargo Ships from the 16th–18th Centuries*, (in:) C.O. Cederlund (ed.), *Postmedieval Boat and Ship Archaeology, Proceedings of the Third International Symposium on Boat and Ship Archaeology in Stockholm in 1982*, BAR International Series 256, Oxford, 165–191

Steffy J.R.

1994 *Wooden Ship Building and the Interpretation of Shipwrecks*, Ed Rachal Foundation Nautical Archaeology Series, Texas

Yamafune K.

2016 *Using Computer Vision Photogrammetry (Agisoft Photoscan) to Record and Analyze Underwater Shipwreck Sites*, Ph.D. dissertation at the Texas A&M University, Texas, unpublished

Yamafune K., Torres R., Castro F.

2017 *Multi-Image Photogrammetry to Record and Reconstruct Underwater Shipwreck Sites*, "Journal of Archaeological Method and Theory" 24/3, 703–725

Żrodowski C.

2010 *Cyfrowa rekonstrukcja kształtu historycznych jednostek śródlądowych*, (in:) W. Ossowski, *Przemiany w szkutnictwie rzecznym w Polsce. Studium archeologiczne*, Gdańsk, 203–222

2014 *An Attempt to Create a Digital Reconstruction of the Copper Ship*, (in:) W. Ossowski (ed.), *The Copper Ship, A Medieval Shipwreck and its Cargo*, Gdańsk, 197–238.

Fig. 1 – The location of the shipwreck (elaborated by: M. Grabowski)

Fig. 2 – Preserved remains of the vessel excavated in 2009 (photo by: W. Ossowski)

Fig. 3 – Conservation facility in Rybno, near Sochaczew (photo by: W. Borkowski)

Fig. 4 – Aerial photography of the shipwreck site in 2018 (photo by: P. Stencel)

Fig. 5 – Uncovered wreck structures during the field works in 2018 with visible construction of the aft (photo by: M. Grabowski)

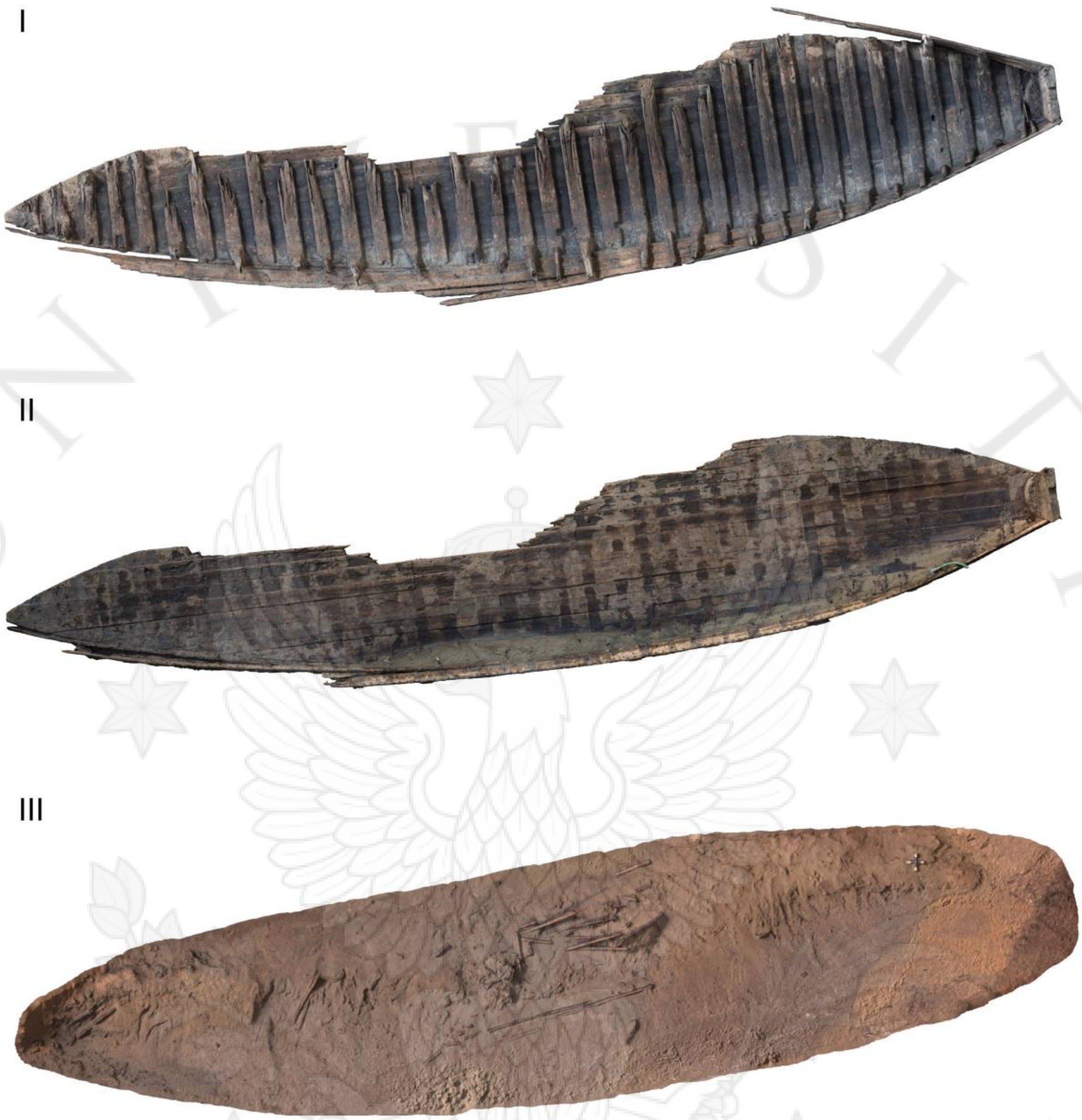

Fig. 6 – Orthogonal site documentation based on the Computer Vision Photogrammetry: I – *in situ* with all timbers attached, II – with disassembled frame stations and side planking, III – structures underneath the wreck (elaborated by: P. Stencel)

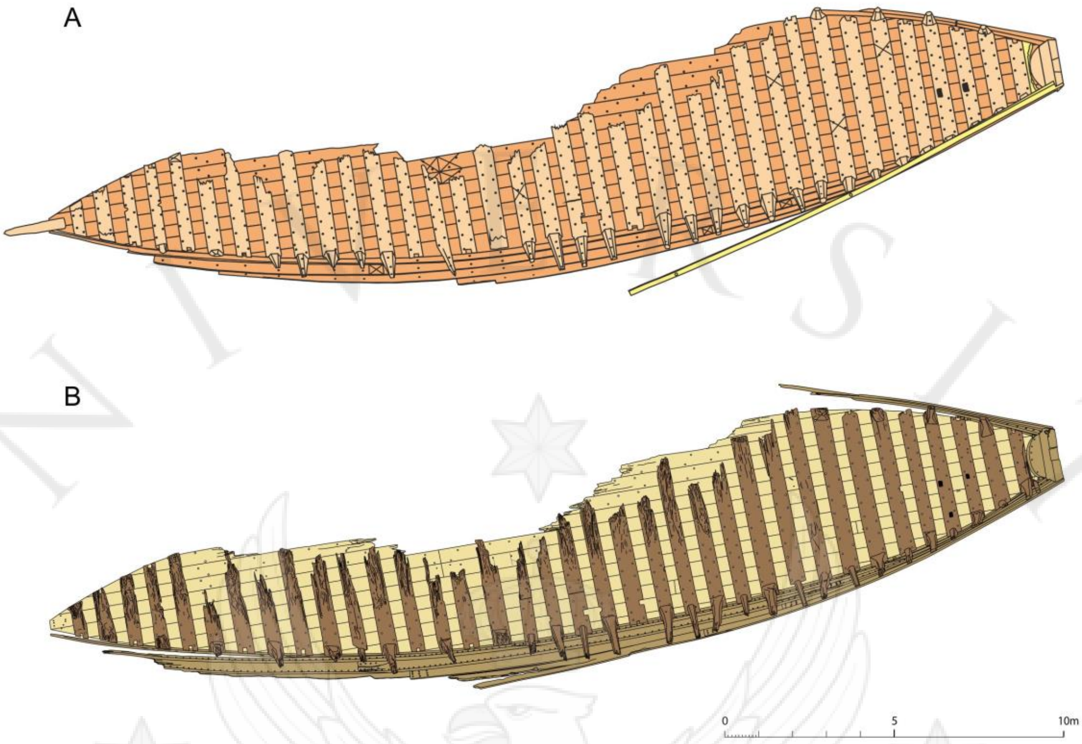

Fig. 7 – Comparison of the original site plan from 2009 [A] and site plan based on the Computer Vision Photogrammetry [B] (elaborated by: M. Grabowski, W. Ossowski)

Fig. 8 – Timber recording with the use of 3D hand scanner (photo by: M. Grabowski)

Fig. 9 – Processing of scanned timber in *Rhinocerros*® 3D software; visible features are 3D contoured and grouped in particular layers (photo by: M. Grabowski)

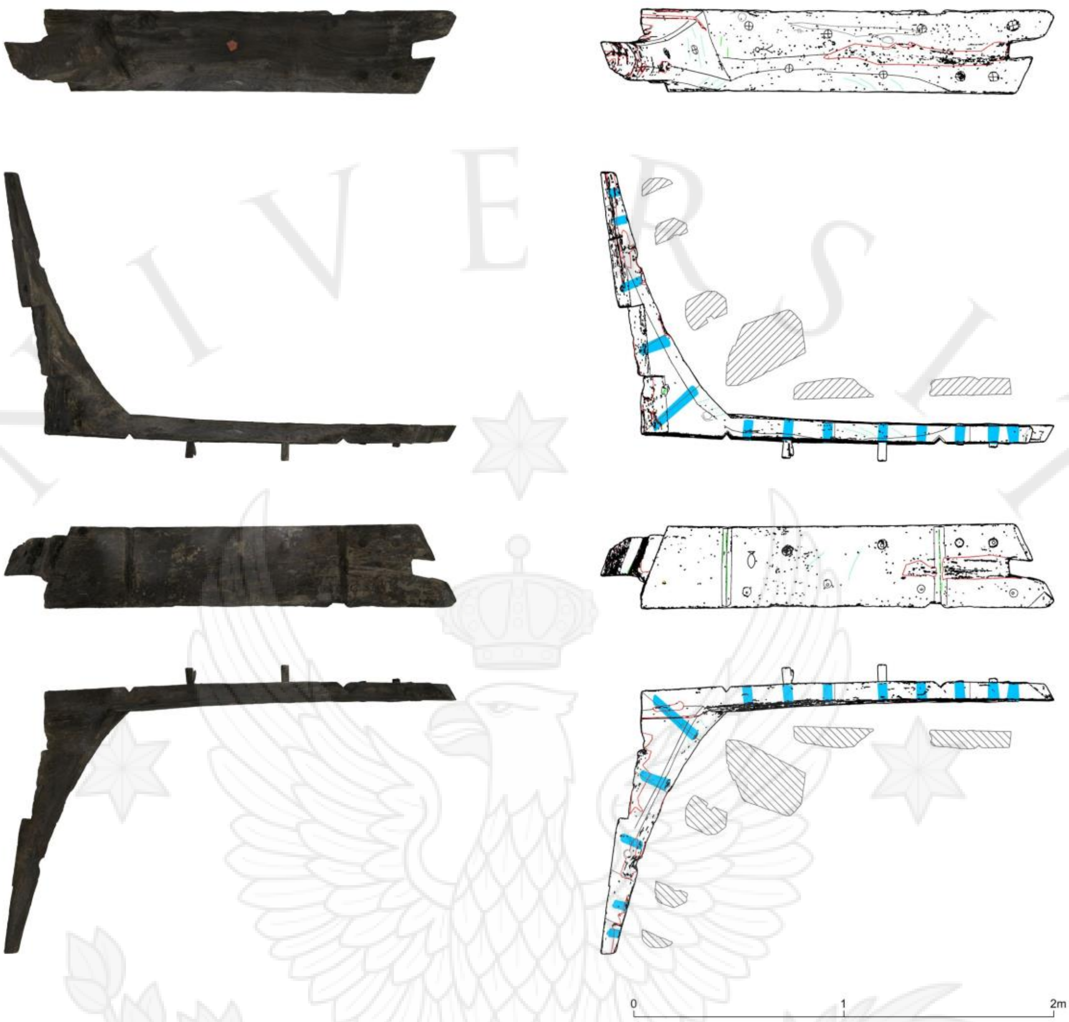

Fig. 10 – Scanned timber with original texture and its computer generated technical drawing with annotations (elaborated by: P. Kucharczyk)

Ministerstwo Nauki
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UNDERWATER EXPEDITION

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THE EXPLORERS CLUB
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ODDZIAŁ POLSKI

ISBN: 978-83-66210-03-5