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Ida Koncani Uhač, Giulia Boetto, Marko Uhač

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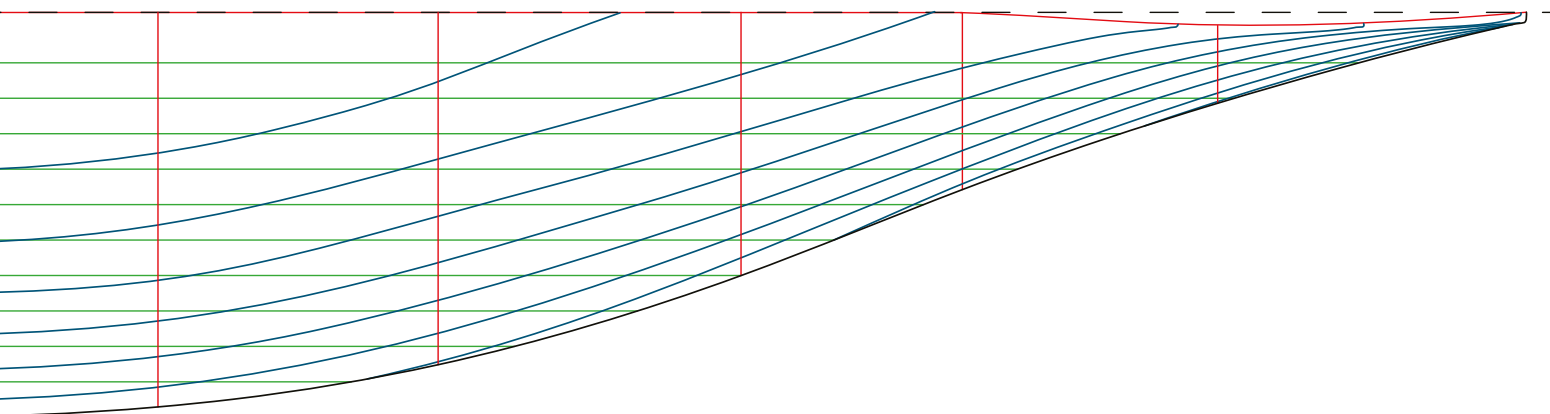
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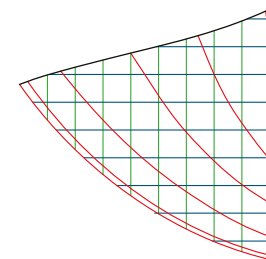
ZAMBRATIJA

Prapovijesni šivani brod

Rezultati arheološkog istraživanja, analiza i studija

Prehistoric Sewn Boat

Results of the Archaeological Research, Analysis and Study



Monografije i katalogi 33 • Arheološki muzej Istre
Uredili / Edited by: I. Koncani Uhač, G. Boetto, M. Uhač



ZAMBRATIJA



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Rezultati arheološkog istraživanja, analiza i studija

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Prehistoric Sewn Boat

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Ida Koncani Uhač - Giulia Boetto - Marko Uhač

Monografije i katalozi 33 / Arheološki muzej Istre
Pula 2019

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Predgovor

Foreword

Podvodna arheologija na području Istre ima tradiciju dugu više od 50 godina. Zadnjih nekoliko godina istraživanja su intenzivirana te su otkriveni i istraženi brojni podvodni arheološki lokaliteti iznimne vrijednosti. Treba pritom istaknuti pronalazak dvaju antičkih brodova u pulskoj luci, podvodne arheološke nalaze u Bijeci u Medulinskom zaljevu, bakrenodobno nalazište iz Zambratije te potopljeni brod iz Zambratije kod Umaga.

U svjetlu otkrića potopljenih šivanih rimskih brodova iz Pule, iz tiska je izašla monografija o prapovijesnom potopljenom brodu iz Zambratije, najstarijem šivanom brodu na Sredozemlju i jednom od najvažnijih otkrića na području Hrvatske u zadnjih desetak godina.

Potopljeni brod iz Zambratije pronašao je lokalni ronilac i ribar Christian Petretich u uvali Zambratija, smještenoj na sjeverozapadnoj obali Istre, u blizini Umaga. Zajedno s Nikijem Fachinom proslijedio je informaciju o nalazu Idi Koncani Uhač. Pregled i istraživanje lokaliteta provedeni su u razdoblju od 2008. do 2013. godine, pod vodstvom Arheološkog muzeja Istre te uz suradnju Ministarstva kulture Republike Hrvatske – Konzervatorskog odjela u Puli, Centra Camille Jullian Sveučilišta Aix Marseille, francuskog Nacionalnog centra za znanstvena istraživanja (CNRS) i francuskog Ministarstva europskih i vanjskih poslova. Po završetku istraživanja postavljeno je i zaštitno mrežište, koje štiti ovaj nalaz.

Brod iz Zambratije najstariji je primjer u potpunosti šivanog broda ikad pronađenog na Sredozemlju, a datiran je u vrijeme između zadnje četvrtine 12. i zadnje četvrtine 10. stoljeća prije Krista. Njegova arhitektonska rješenja i gradnja, tehnika šivanja i spajanja dijelova oplata, kao i sustav brtvljenja samog trupa nemaju paralela na širem području Sredozemlja. Zbog svega navedenog, brod iz Zambratije stoji na samim počecima “proto-histarske

The underwater archaeology in Istria has an over 50 years long tradition. During the last few years the research has been intensified, resulting in the discovery and investigation of numerous archaeological underwater sites of exceptional value. These valuable discoveries include the two Roman boats from the port of Pula, the underwater archaeological finds from Bijeca in Medulin Bay, as well as the Copper Age site and the sunken boat in Zambratija near Umag.

In light of the discovery of the sunken sewn Roman ships from Pula comes this monograph about the prehistoric sunken boat from Zambratija, which is not only the oldest sewn boat in the Mediterranean but also one of the most important discoveries in Croatia in the last ten years.

The Zambratija boat was found by the local diver and fisherman Christian Petretich, in Zambratija Bay, located on the northwestern coast of Istria, near Umag. Petretich, together with Niki Fachin, informed Ida Koncani Uhač of the find. The survey and research of the site were conducted from 2008 to 2013 under the direction of the Archaeological Museum of Istria, and with the cooperation of the Croatian Ministry of Culture – Conservation Department in Pula, the Centre Camille Jullian of Aix Marseille University and the French National Centre for Scientific Research (CNRS) within a program of the French Ministry for Europe and Foreign Affairs. Upon completion of the research, a safety grid was installed to protect the finding.

The Zambratija boat is the most ancient example of an entirely sewn boat ever found in the Mediterranean, as it has been dated between the last quarter of the 12th and the last quarter of the 10th centuries BCE. Its construction is unparalleled at this date, as is the sewing technique employed to assemble the planking and the

tradicije šivanja”, tradicije brodogradnje koja je preživjela do rimskog razdoblja i koja se razvila u takozvanu sjeveroistočnu jadransku tradiciju šivanja, o čemu svjedoče brojni brodovi datirani od 1. do 3. stoljeća, pronađeni na istočnoj obali Jadrana.

Brod iz Zambratije prezentiran je na brojnim znanstvenim skupovima diljem svijeta, a 2017. godine je realizirana i izložba “Zambratija – prapovijesni šivani brod”, koja je nakon Pule obišla i još uvijek obilazi brojne muzeje u Hrvatskoj i inozemstvu. Ova izložba je dobila nagradu Hrvatskog muzejskog društva i nagradu “Josip Brunšmid” Hrvatskog arheološkog društva za 2017. godinu.

Monografija koju imate u rukama sljedeći je važan korak u valorizaciji iznimnog nalaza potopljenog prapovijesnog broda iz Zambratije. Priređena je dvojezično, na hrvatskom i engleskom jeziku, pod uredničkom palicom Ide Koncani Uhač, Giulije Boetto i Marka Uhača. Na samom početku knjige se nalazi Predgovor i Uvod, a slijedi 14 članaka, koji su podijeljeni u pet glavnih poglavlja: I. Povijest istraživanja i metodologija, II. Brod, III. Datiranje i tehnologija brodogradnje, IV. Paleobotaničke analize, V. Kulturno-povijesni kontekst. Nakon članaka slijede Zaključna razmatranja, Rječnik, Bibliografija te bilješke o ukupno 17 domaćih i inozemnih autora.

Brod iz Zambratije i dalje leži na morskome dnu, na mjestu gdje je i pronađen, zaštićen od prirodnih i ljudskih utjecaja. Slijedi nam još jedan, ali ogroman, zaključni korak u ovom procesu započetom još 2008. godine – vađenje broda, njegova konzervacija i restauracija te konačno suvremena prezentacija jednog od najvažnijih arheoloških nalaza Istre i Hrvatske.

Darko Komšo
Ravnatelj Arheološkog muzeja Istre

system of wadding and laths used to render the vessel watertight. Due to all of the above, the Zambratija boat marks the very beginning of the Proto-Histrian sewing tradition, a shipbuilding tradition that persisted until the Roman period and developed into the so called north-eastern Adriatic sewing tradition, as evidenced by numerous boats dated from the 1st to the 3rd centuries CE, found on the eastern Adriatic coast.

The Zambratija boat has been presented at numerous scientific conferences, and in 2017, the exhibition titled „Zambratija – Prehistoric sewn boat“ was set up in Pula, after which it started its still ongoing presentation within many museums both in Croatia and abroad. The exhibition was given the award of the Croatian Museum Association, as well as the “Josip Brunšmid” Annual Award of the Croatian Archaeological Society for the year 2017.

The monograph that you have in your hands represents the next crucial step in the valorization of an extraordinary find – the sunken prehistoric Zambratija boat. The monograph is bilingual, featuring full text in both Croatian and English, and was issued under the editorial baton of Ida Koncani Uhač, Giulia Boetto and Marko Uhač. It starts with Foreword and Introduction, followed by 14 articles divided into 5 main chapters: I. History of Research and Methodology, II. The Boat, III. Dating and Shipbuilding Technology, IV. Paleobotanical Analyses, V. Cultural and Historical Context. The articles are followed by Concluding Remarks, Glossary, Bibliography, as well as notes on a total of 17 national and international contributors.

The Zambratija boat remains lying on the seabed where it was discovered, undisturbed by natural and human impact. What follows now is just one huge but final stage in this process that started back in 2008 – the removal of the boat, its conservation and restoration, and finally, a contemporary presentation of one of the most important archaeological finds both in Istria and Croatia.

Darko Komšo
Director of the Archaeological Museum of Istria

Uvod

Introduction

Podmorski arheološki lokalitet u uvali Zambratija, kojem je posvećena ova publikacija, datira u prapovijesno razdoblje. Radi se o jedinstvenom nalazu dobro očuvanog šivanog broda.

Samo otkriće i rezultati višegodišnjeg istraživanja prapovijesnog broda u Zambratiji otvorili su novo poglavlje u poznavanju arheologije broda na jadranskom prostoru.

Nakon saznanja o spomenutom lokalitetu, u ljeto 2008. godine u podmorju je obavljen stručni arheološki uviđaj. Zaključci koji su proizašli nakon prvog uviđaja ukazali su da se na morskom dnu, na dubini od oko 2 metra, ispod tankog sloja pijeska nalaze ostaci drvenog "šivanog" plovila. Analizama provedenim na uzorcima drva brod je datiran u prapovijesno razdoblje. Dobiveni datum podignuo je prašinu u domaćim i stranim arheološkim krugovima, a lokalitet je postao jedan od najznačajnijih arheoloških otkrića brodske konstrukcije, ne samo na Jadranu nego i na prostoru Mediterana.

U zadnjih nekoliko godina na sjevernom Jadranu provedena su arheološka istraživanja u kojima je istraženo nekoliko šivanih brodova. Među tim je nalazima brod iz Zambratije, koji datira u kasno brončano doba, zaslužio titulu najstarijeg u grupi istraženih brodova, dok ostali datiraju u rimski period. Samim time, pronalazak broda iz Zambratije svjedoči o kontinuitetu i snazi lokalne tradicije šivanih brodova, koju su brodograditelji pokoljenjima prenosili na mlađe naraštaje. Zahvaljujući tome, tradicija šivanih brodova na jadranskom prostoru održana je sve do razdoblja kasne antike i najvjerojatnije do ranog srednjeg vijeka.

Nakon otkrića, u razdoblju od 2008. do 2012. godine prikupljeni su razni arheološki podaci o brodskoj konstrukciji te su izvedene potrebne predradnje za sveobuhvatno predstojeće međunarodno znanstveno istraživanje, koje je uslijedilo 2013. godine. Vodeća

The underwater archaeological site in the Zambratija Cove, to which this publication is dedicated, dates back to the prehistoric era. It is a unique find of a well-preserved sewn boat.

The discovery, as well as the results of the multi-year research program on the prehistoric boat of Zambratija, has opened a new chapter of nautical archaeology in the Adriatic region.

Archaeologists carried out an initial underwater investigation in the summer of 2008. At a depth of around 2 m and under a layer of sand, the remains of a "sewn" vessel were revealed. The analyses of wood samples have shown that the boat dates back to the prehistoric era. The provided date drew much attention in archaeological circles at home and abroad and the site has become one of the most important archaeological wrecksites, not merely in the Adriatic, but throughout the Mediterranean.

In fact, in recent years, several sewn wooden boats have been excavated in the northern Adriatic Sea region. Among them, the Zambratija boat, dating back to the Late Bronze Age, wins the title as the earliest: the other excavated boats pertain to the Roman period. By that fact alone, the discovery of the Zambratija boat is proof of continuity and endurance of the local tradition of making sewn boats, which was passed down by shipbuilders from one generation to the next. As a result, the sewing technique in shipbuilding survived in the Adriatic region into the Late Antiquity and, possibly, until the Early Medieval Period.

Between 2008 and 2012, archaeological data was collected about the boat's structure, and the necessary preliminary procedures were put in place for a comprehensive, planned, international scientific research project, which took place in 2013. The Archaeological Museum of Istria has led the project throughout, and

institucija u istraživanju brodske konstrukcije svih tih godina bio je Arheološki muzej Istre, uz koji su se od 2013. godine u istraživanje uključili Ministarstvo kulture Republike Hrvatske - Konzervatorski odjel u Puli te Centar Camille Jullian, istraživački odjel Sveučilišta Aix Marseille i francuski Nacionalni centar za znanstvena istraživanja (CNRS) sa sjedištem u Aix-en-Provenceu.

Terenska i laboratorijska istraživanja brodske konstrukcije provedena su zahvaljujući novčanim sredstvima Ministarstva kulture Republike Hrvatske, Arheološkog muzeja Istre, Istarske županije – Regione Istriana, Grada Umaga, francuskog Ministarstva vanjskih i europskih poslova, francuskog Nacionalnog centra za znanstvena istraživanja (CNRS) i Sveučilišta Aix Marseille.

U svojstvu arheologa i studenata arheologije, u podmorskom terenskom istraživanju brodske konstrukcije sudjelovali su Ida Koncani Uhač (voditeljica istraživanja od 2008. do 2013.), Marko Uhač (2008. – 2012., suvoditelj istraživanja 2013.), Giulia Boetto (2011., suvoditeljica istraživanja, 2013.), Teodora Šalov (2008. – 2011.), Davor Bulić (2011., 2013.), Igor Miholjek (2013.), Niki Fachin (2008., 2010.) i Petar Krnjus (2013.).

U svojstvu restauratora u podmorskom istraživanju sudjelovali su Andrea Sarдоз (2011., 2013.) i Miran Erič (2010., 2011., 2013.).

Fotografi su bili Rok Kovačić (2010., 2011.) i Philippe Groscaux (2013.).

Topografsku izmjeru obavio je Vincent Dumas (2013.).

Ronioci i ostali suradnici na terenu, koji su svojim znanjem, različitim vještinama i radom pridonijeli realizaciji podmorskih arheoloških istraživanja u Zambratiji, bili su Christian Petretich (2008. – 2013.), Nikša Koncani (2008. – 2011.), Davor Uhač (2013.), Elvis Palčić (2013.) i Elvijo Brlobaš (2013.).

Institucije koje su svojim djelokrugom aktivnosti pridonijele istraživanju s hrvatske strane su Arheološki muzej Istre, Institut Ruđer Bošković u Zagrebu, Zavod za znanost o drvu – Šumarski fakultet i Botanički zavod Prirodoslovno-matematičkog fakulteta Sveučilišta u Zagrebu, a s francuske strane Centar Camille Jullian (CCJ) i Mediteranski institut za bioraznolikost i ekologiju mora i kopna (IMBE), oba iz Aix-en-Provencea, kao i Centar za radiokarbonsku dataciju iz Lyona, Laboratorij za mjerenje ugljika 14 (LMC14) Sveučilišta Paris-Saclay te Laboratorij masene spektrometrije i interakcije sustava Sveučilišta u Strasbourgu.

Tvrtke koje su također pridonijele istraživanju su laboratorij Beta Analytic (SAD), Archéobois iz Marseillesa (Francuska), Cadcon d.o.o. i Tehnomont d.o.o., obje iz Pule (Hrvatska), geodetske firme Constructa Geo d.o.o. iz Umaga (Hrvatska) i Geo Mataija d.o.o. iz Valice (Hrvatska), Harpha sea d.o.o. iz Kopra (Slovenija) i Neptun d.o.o. iz Pule (Hrvatska).

in 2013 was joined by the Croatian Ministry of Culture - Directorate for the Protection of Cultural Heritage - Conservation Department in Pula and the Centre Camille Jullian, a research unit of the Aix Marseille University and the French National Centre for Scientific Research (CNRS) based in Aix-en-Provence.

The field and laboratory investigations of the boat remains were conducted thanks to funding by the Ministry of Culture of the Republic of Croatia, the Archaeological Museum of Istria, Istria County - Regione Istriana, the City of Umag, the French Ministry for Europe and Foreign Affairs (MEAE), the French National Centre for Scientific Research (CNRS), and Aix Marseille University.

The following people participated in the underwater field investigations as archaeologists and archaeology students: Ida Koncani Uhač (director of investigation 2008 - 2013), Marko Uhač (2008 - 2012, co-director of investigation in 2013), Giulia Boetto (2011, co-director of investigation in 2013), Teodora Šalov (2008 - 2011), Davor Bulić (2011, 2013), Igor Miholjek (2013), Niki Fachin (2008, 2010), and Petar Krnjus (2013).

Andrea Sarдоз (2011, 2013) and Miran Erič (2010, 2011, 2013) participated in the underwater investigation as restorers.

The photographers were Rok Kovačić (2010, 2011) and Phillipe Groscaux (2013).

Topographic survey was conducted by Vincent Dumas (2013).

The following divers and other collaborators in the field contributed to the realization of the underwater archaeological investigations at Zambratija with their knowledge, varied skills and labour: Christian Petretich (2008-2013), Nikša Koncani (2008-2011), Davor Uhač (2013), Elvis Palčić (2013), and Elvijo Brlobaš (2013).

Institutions that contributed to the investigations within the scope of their activities, include: for the Croatian side, the Archaeological Museum of Istria, the Ruđer Bošković Institute - Zagreb, the Department of Wood Science - Faculty of Forestry and the Department of Botany of the Faculty of Science - University of Zagreb; for the French side, the Centre Camille Jullian (CCJ) and the Mediterranean Institute of Marine and Terrestrial Biodiversity and Ecology (IMBE) both of Aix-en-Provence, the Centre of Radiocarbon Dating of Lyon and the Laboratory of Carbon 14 Measurement (LMC14) of Paris-Saclay, as well as the Laboratory of Mass Spectrometry and Interaction of Systems - University of Strasbourg.

Companies that also contributed to the investigations within the scope of their activities are: Beta Analytic (USA), Archéobois from Marseilles (France), Cadcon d.o.o. and Tehnomont d.o.o. both from Pula (Croatia), the geodetic firms Constructa Geo d.o.o. from Umag (Croatia), Geo Mataija d.o.o. from Valica (Croatia),

U postterenskom i laboratorijskom istraživanju sudjelovali su Valérie Andrieu-Ponel, Giulia Boetto, Carine Cenzon-Salvayre, Armelle Charrié-Duhaut, Vincent Dumas, Axel Eeckman, Alba Ferreira Dominguez, Philippe Groscaux, Frédéric Guibal, Ida Koncani Uhač, Kristina Mihovilić, Christine Oberlin, Patrice Pomey, Pierre Poveda, Marko Uhač, Régine Verlaque i Stéphanie Wicha.

Nakon završetka istraživanja u 2013. godini, ostaci prapovijesne brodske konstrukcije su temeljito prekriveni te je iznad nalazišta postavljena zaštitna metalna mreža kako bi se spriječila eventualna devastacija.

Dok ne budu osigurani svi uvjeti za adekvatne konzervatorsko-restauratorske radove i suvremenu prezentaciju tog važnog nalaza, brod će ostati zaštićen u morskom okolišu.

Harpha Sea d.o.o. from Koper (Slovenia) and Neptun d.o.o. from Pula (Croatia).

Those involved in the post-excavation and laboratory investigations were: Valérie Andrieu-Ponel, Giulia Boetto, Carine Cenzon-Salvayre, Armelle Charrié-Duhaut, Vincent Dumas, Axel Eeckman, Alba Ferreira Dominguez, Philippe Groscaux, Frédéric Guibal, Ida Koncani Uhač, Kristina Mihovilić, Christine Oberlin, Patrice Pomey, Pierre Poveda, Marko Uhač, Régine Verlaque and Stéphanie Wicha.

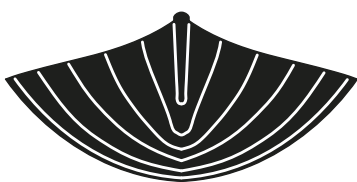
When the excavations were concluded in 2013, the remains of the prehistoric boat structure were thoroughly covered and a protective metal mesh was laid on the top of the site in order to prevent possible damage by natural or human impacts.

The boat will remain protected in its marine environment until all requirements for appropriate restoration and conservation, and contemporary exhibition have been met.

I.

**Povijest
istraživanja i
metodologija**

**History of
Research &
Methodology**



Zambratija – podmorski arheološki istraživački projekt

Zambratija – underwater archaeological research project

Ida Koncani Uhač, Marko Uhač

Uvala Zambratija nalazi se na pitomoj, nisko položenoj sjeverozapadnoj obali istarskog poluotoka. Na jugu je zatvara poluotok Sipar (rt Kaštel), dok je na sjeveru omeđena Crvenom uvalom (Sl. I.1, I.2).

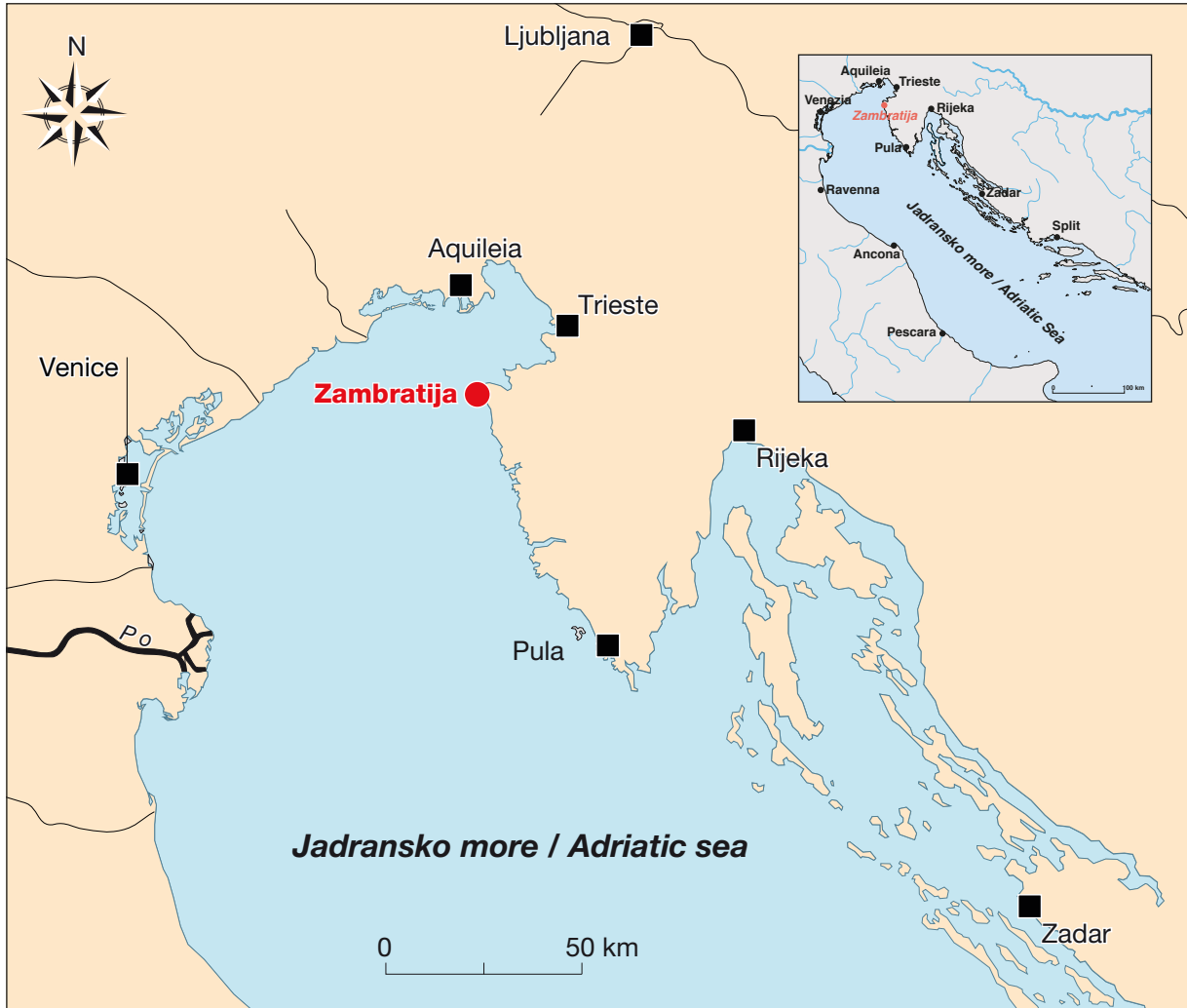
Potvrđeni arheološki nalazi iz Zambratije datiraju od ranog eneolitika preko antike do razdoblja kasnog srednjeg vijeka. Podmorje uvale čuva značajne, gotovo jedinstvene arheološke nalaze, čiji je pronalazak upotpunio povijesnu sliku o načinu života i običajima prapovijesnih stanovnika Istre (Sl. I.3, I.4).

U potopljenoj dolini uvale, uz sam obalni rub sačuvani su ostaci eneolitičkog naselja (Sl. I.5 – I.7) s ostacima kuća – sojenica izgrađenih s drvenim pilonima (Koncani Uhač, Čuka 2016, 2018). Dolina je od otvorenog mora bila odijeljena prirodnim vapnenačkim hrptovima (škojima), koji se u lokalnoj toponimiji nazivaju Plić i Zanestra (Sl. I.8, I.9). Na škojima su pronađeni pokretni arheološki nalazi koji ukazuju na kontinuitet naseljavanja od brončanog sve do rimskog perioda, kada su oni bili dio kopna (Sl. I.10). Na prirodnom vapnenačkom

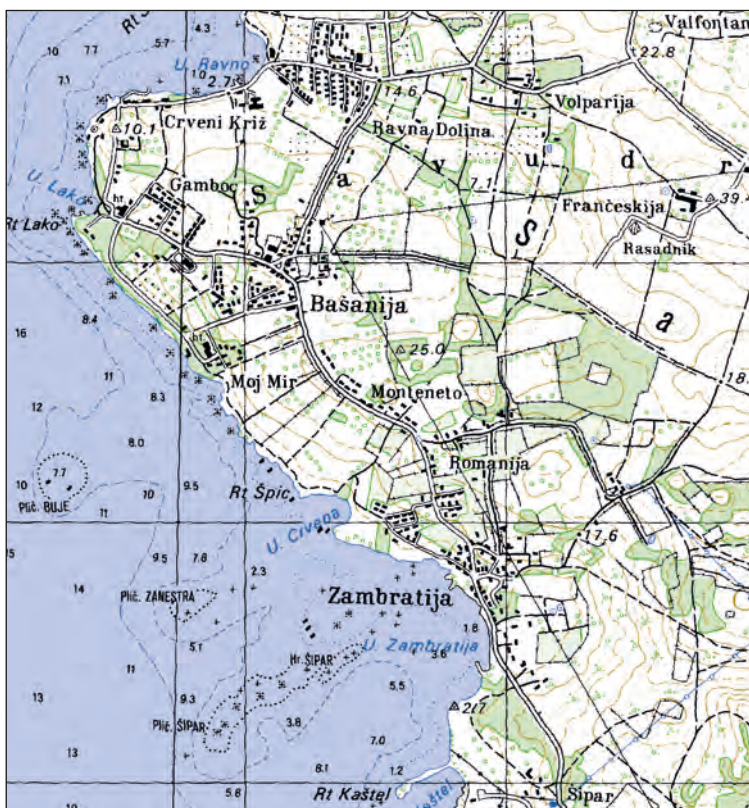
Zambratija Cove is located on the gentle, low-lying, north-western coast of the Istrian peninsula. It is enclosed by the Sipar peninsula (rt Kaštel) to the south and Crvena Uvala to the north (Figs I.1, I.2).

Archaeological remains in Zambratija date back to the Early Eneolithic, through the Roman period, to the Late Middle Ages. The seabed stores significant, almost unique archaeological remains that, once discovered, have added new pieces to the puzzle of understanding the way of life and customs of the prehistoric inhabitants of Istria (Figs I.3, I.4).

In the valley leading into the cove, near the shore, the archaeological remains of an Eneolithic settlement (Figs I.5 – I.7), with stilt houses built with wooden piles, were preserved (Koncani Uhač, Čuka 2016, 2018). The valley used to be separated from the open sea by natural limestone ridges (škoji), named Plić and Zanestra in the local toponymy (Figs I.8, I.9). Archaeological finds have been discovered on the ridges, indicating the continuity of human settlement all the way from the Bronze Age to



I.1
Položaj nalazišta u uvali Zambratija
 na sjevernom Jadranu
The position of the site in Zambratija
 Cove on the Northern Adriatic
 (izradila / made by: G. Boetto)



I.2
Područje uvala Zambratija - na jugu
 poluotok Sipar, na sjeveru Crvena
 uvala (topografska karta 1:25 000)
Map of the area of Zambratija Cove,
 peninsula Sipar on the south, Crvena
 uvala on the north (topographic map
 1:25 000)
 (izvor / source: Državna geodetska
 uprava RH)



grebenu koji se pruža prema zapadu obale ubicirani su i ostaci strukture koja je interpretirana kao rimska cesta (Sl. I.11), sačuvani u dužini od 72 metra.

the Roman period, when they were part of the mainland (Fig. I.10). A 72-metre-long structure interpreted as a probable Roman road (Fig. I.11) is preserved along the natural limestone reef that spreads towards the western side of the coast.

Otkriće broda i preliminarni radovi na nalazištu (2008. – 2010.)

Ostatke brodske konstrukcije pronašao je lokalni ronilac Christian Petretich iz Zambratije, koji je informaciju o postojanju lokaliteta povjerio prijatelju Nikiju Fachinu, studentu arheologije na Sveučilištu u Trstu i zaljubljeniku u kulturnu baštinu rodnog zavičaja. Fachin je zatim informaciju prosljedio podvodnim arheolozima, autorima ovih redaka.

Krajem srpnja 2008. godine, a nakon saznanja o postojanju potencijalnog arheološkog nalazišta s ostacima

Discovery of the boat and preliminary work at the site (2008-2010)

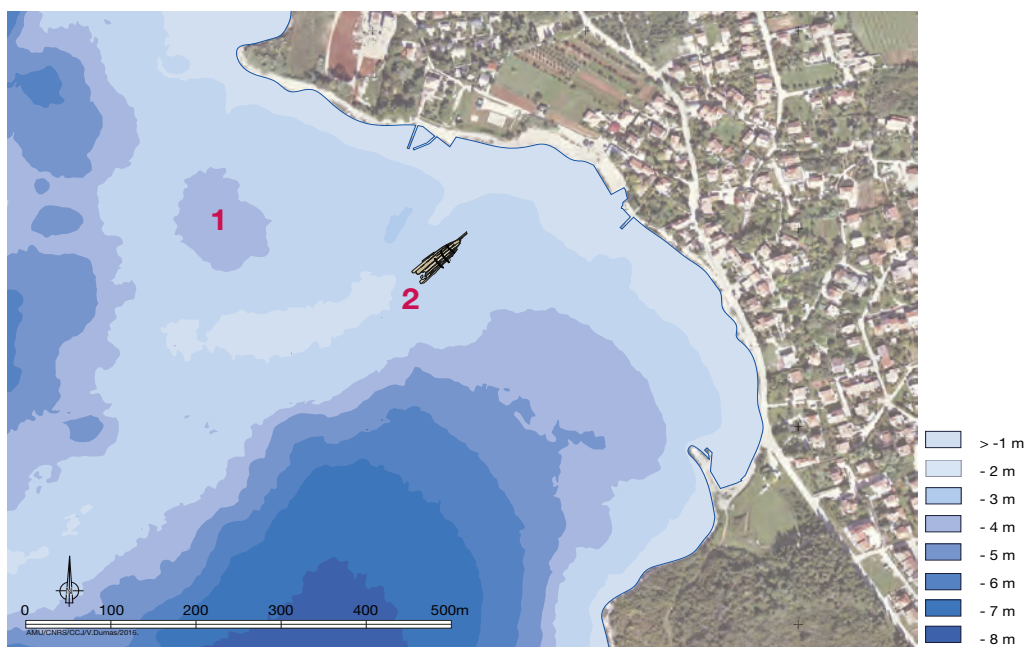
The site containing the boat remains was found by the local diver Christian Petretich from Zambratija, who shared the information about its existence with his friend Niki Fachin, a student of archaeology at the University of Trieste and an enthusiast of the cultural heritage of his native land. Fachin then forwarded the information to underwater archaeologists, the authors of these lines.

After being made aware of a potential underwater wrecksite, at the end of July of 2008,

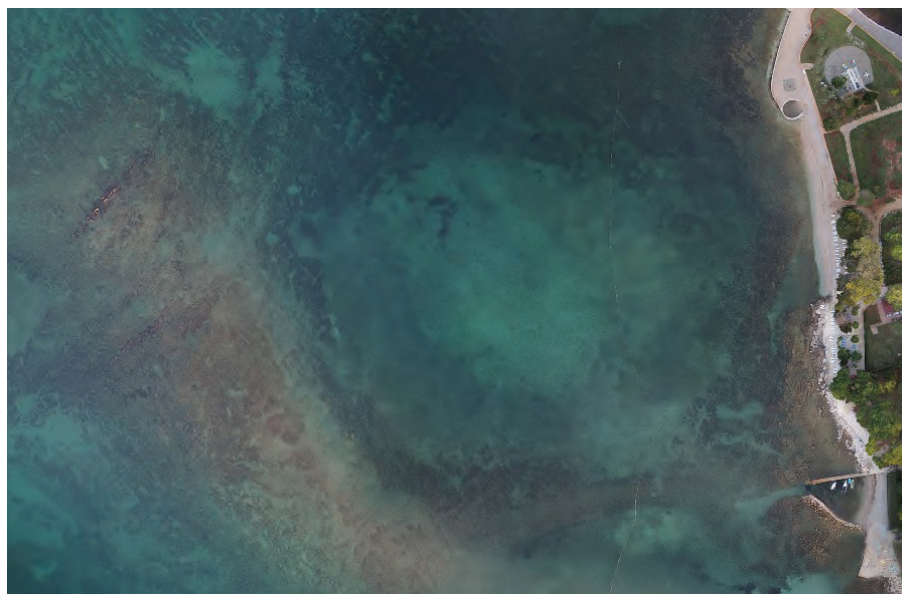


I.3
 Uvala Zambratija, pogled iz zraka
 Zambratija Cove, aerial view
 (fotografija / photo by: Aerofoto 3D)

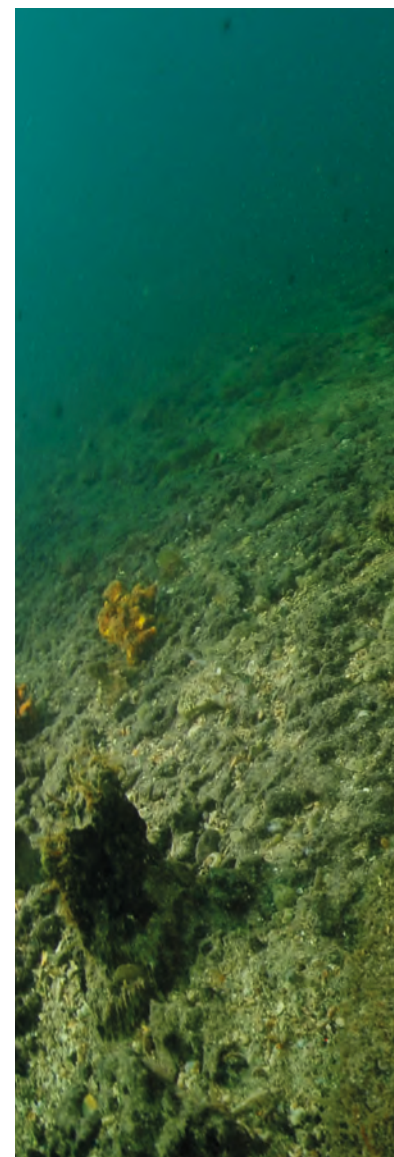
I.4
 Karta s prapovijesnim arheološkim lokalitetima u uvali Zambratija (1: eneolitičko naselje, 2: brod)
 Location of the prehistoric archaeological sites in the Zambratija Cove (1: Eneolithic settlement, 2: boat)
 (izrada / made by: V. Dumas)



I.5
Ortoto snimka prapovijesnog
naselja u potopljenoj dolini
**Orthophoto of the prehistoric
settlement located in a natural
geological depression**
(fotografija / photo by: J. Benjamin)

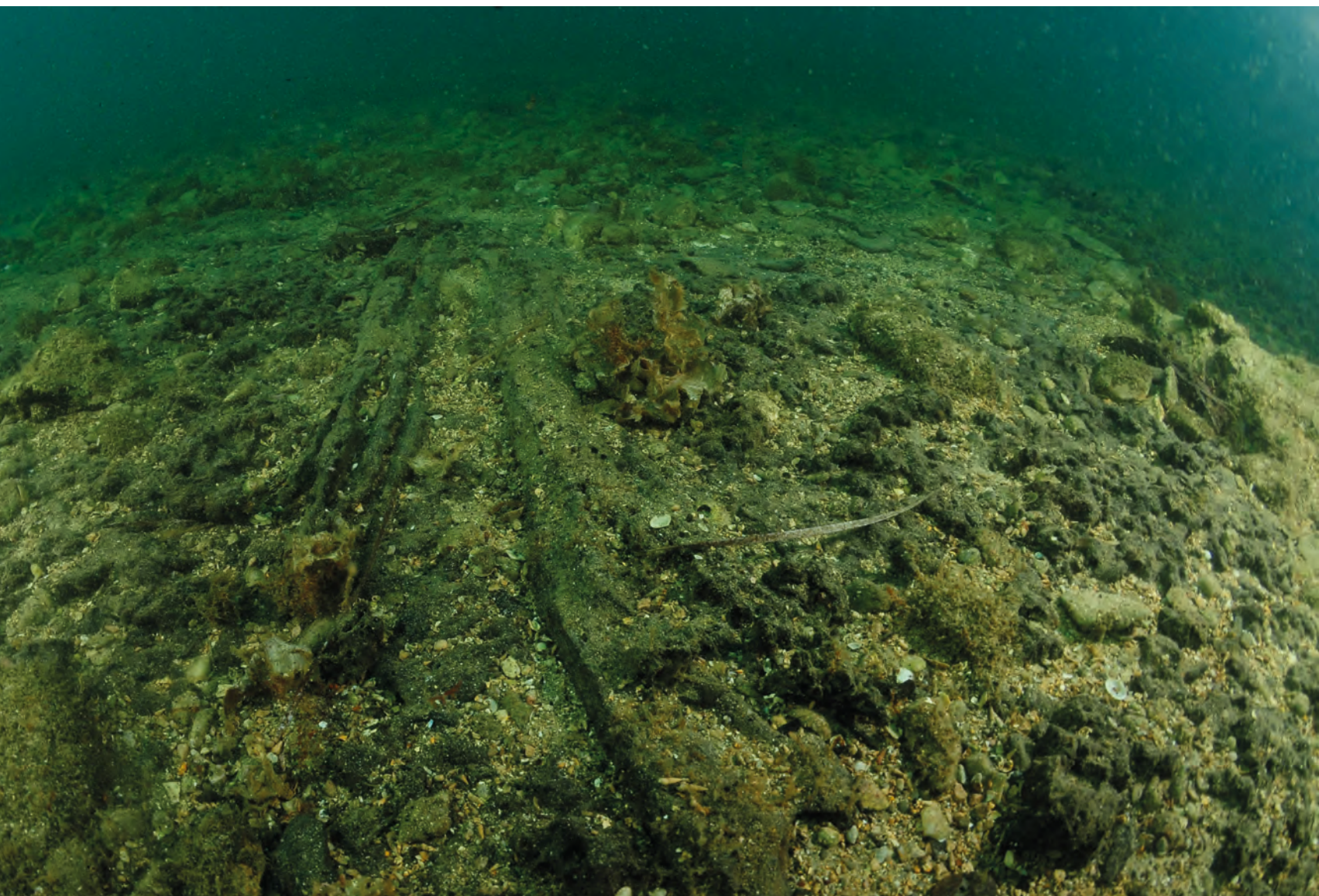


I.6a



I.6b

I.6 a,b
**Pogled na pilote koji su bili dio
konstrukcije sojenica eneolitičkog
naselja (6a: pilon koji proviruje iz
morskog dna; 6b: pogled na drvene
ostatke sačuvane u horizontalnom
položaju)**
**View of the pile dwelling Eneolithic
settlement**
(6a: pile protruding from the
seabed; 6b: view of the wooden
remains preserved in horizontal
position)
(fotografija / photo by: R. Kovačić)



I.7 a,b

Keramički predmeti pronađeni na nalazištu eneolitičkog naselja u Zambratiji (7a: rekonstruirano cjedilo, koje je vjerojatno korišteno u procesu prerade mlijeka, fotografija: V. Juhas; 7b: šalica za piće, fotografija: I. Koncani Uhač)

Ceramic finds from the Eneolithic settlement in Zambratija Cove (7a: reconstructed sieve probably used in the processing of dairy products, photo by: V. Juhas; 7b: drinking cup, photo by: I. Koncani Uhač)

I.7 a



I.7 b





I.8
Zračna snimka uvale Zambratija
Aerial photo of the Zambratija Cove
(fotografija / photo by: L. Damelet)

brodske konstrukcije, u podmorju uvale Zambratija obavljen je stručni arheološki uviđaj. Zaključci koji su proizašli iz tog uviđaja ukazali su na postojanje ostataka drvenog plovila (Sl. I.12), koji su se nalazili u plitkom moru (na dubini od 2,2 do 2,5 metara), na udaljenosti oko 150 metara od obale, prekriveni tek tankim slojem pijeska i ponegdje morskom travom. Ostaci broda su uslijed djelovanja valova bili otkriveni na površini od 1,5 x 0,8 m. Djelomično je bilo vidljivo jedno brodsko rebro te pet platica, međusobno spojenih tehnikom šivanja.

To je bio prvi nalaz šivane brodske konstrukcije u podmorju Istre, koji je naveo na promišljanje o podrijetlu i starosti broda, preliminarno ga vezujući uz tada poznate antičke nalaze s područja sjevernog i srednjeg Jadrana (Koncani Uhač 2008, 2009).

U razdoblju od 2008. do 2010. godine na nalazištu su prikupljeni uzorci drva radi određivanja apsolutne starosti radiokarbonskom metodom te analize vrste drva¹.

Bez arheološkog sondiranja obavljena su mjerenja, izrađena je tehnička dokumentacija, obavljeno je fotografiranje te je izrađen fotogrametrijski snimak vidljivih dijelova broda (Sl. I.13, I.14).

¹ Tijekom svih godina terenskog podmorskog istraživanja u Zambratiji, kao i općenito na području Savudrije, djelatnici Lučke uprave Umag-Novigrad su nam uvijek izlazili ususret pri rješavanju tehničkih u radu na području lučice Zambratija. Osobito zahvaljujemo Sergiu Stojniću i lučkom nadzorniku Francu Vidonisu.

archaeologists carried out a survey of the seabed of the north-western part of Zambratija Cove. The results revealed the remains of a wooden vessel (Fig. I.12) in shallow water (2.2-2.5 m), around 150 m from the shore, covered with just a thin layer of sand, and sporadic seaweed. The wreck was exposed over a 1.5 x 0.8 m area due to wave action. A frame and five sewn planks were partially visible.

At that point, it was the first sewn-plank wreck found in the sea around Istria, which led to the origin and date of the boat being considered further; up to that point it had been linked to the known Roman-period finds from the northern and central Adriatic (Koncani Uhač 2008, 2009).

From 2008 to 2010, wood samples were collected for radiocarbon dating and wood species analysis¹.

Measurements were taken without excavation, technical documentation was compiled, and photographic and photogrammetric records were made of the visible boat parts (Figs I.13, I.14).

Radiocarbon dates for the boat were provided first in 2009 by the Laboratory for Low-level Radioactivity of

¹ Throughout the years of the underwater exploration of Zambratija site and the Savudrija region, the employees of Umag-Novigrad Port Authority have always kindly assisted us with solving technical issues for our work in Zambratija harbour. We wish to give our special thanks to the Mr. Sergio Stojnić and the Port Supervisor, Mr. Franco Vidonis.



I.9
Zračna snimka uvale Zambratija, pogled na vapnenački greben i poluotok Sipar prema jugu
Aerial view of Zambratija Cove, the limestone reef and Sipar peninsula towards the south
(fotografija / photo by: L. Damelet)



I.10
Zračna snimka područja uvale omeđenog prirodnim vapnenačkim hrptovima (škojima)
Aerial view of the area of the cove bounded by natural limestone ridges (škoji)
(fotografija / photo by: L. Damelet)



I.11a



I.11b

I.11 a,b

Ostaci strukture interpretirane kao rimska cesta (11a: pogled iz zraka, fotografija: J. Benjamin; 11b: pogled na istraživanu strukturu u 2015. godini, fotografija: I. Koncani Uhač)

The remains of the structure interpreted as a Roman road (11a: aerial view, photo by: J. Benjamin; 11b: view of the investigated structure, 2015, photo by: I. Koncani Uhač)

I.12

Brodski ostaci otkriveni 2008. godine

The remains of the boat as discovered in 2008 (fotografija / photo by: I. Koncani Uhač)



I.12

I.13

Geodetsko snimanje točaka na nalazištu u 2008. godini

Geodetic recording of the site in 2008 (fotografija / photo by: T. Šalov)



I.13

Prvi rezultat radiokarbonskog određivanja starosti broda je 2009. godine u Laboratoriju za mjerenje niskih radioaktivnosti Instituta Ruđer Bošković u Zagrebu. Radiokarbonska analiza uzorka brodske platice (P3), izvedena tehnikom C 14 (Z4195), pružila je rezultat apsolutne starosti od 2535 ± 60 prije sadašnjosti, kalibriran između 810. i 480. godine prije Krista (vjerojatnost 91,9%). Naknadno je, 2013. godine, navedeni institut korigirao rezultat apsolutne starosti iste platice u 2950 ± 65 ,

the Ruđer Bošković Institute in Zagreb. The radiocarbon analysis of a sample (code Z4195) from plank P3 estimated the date at 2535 ± 60 , with a calibrated range of 810-480 BCE (with 91.9% probability). Subsequently, in 2013, the same institute re-calibrated the result of the same plank to 2950 ± 65 , with a calibrated range of 1264-1056 BCE (with 68.2% probability).

kalibriran između 1264. i 1056. godine pr. Kr. (vjerojatnost 68,2%).

Ta je datacija upućivala na jedinstvenost broda iz Zambratije u kontekstu poznatih nalaza šivanih brodova na Jadranu.

U tom je razdoblju obavljena i prva analiza vrste drva od kojeg je izrađen brod. U Zavodu za znanost o drvu Šumarskog fakulteta u Zagrebu napravljena je analiza uzorka koji je pripadao letvici iznad sljubnica platica te je utvrđeno da je riječ o drvu roda jela (*Abies Mill.*). Također je napravljena analiza uzorka platice, kojom je utvrđeno da pripada drvu roda brijest (*Ulmus L.*).

U cilju fizičke zaštite lokaliteta od morskog djelovanja, ali i ljudskih utjecaja, ostaci broda su prekriveni pijeskom i geotekstilom te su iznad toga položene dvije željezne armaturne mreže kojima je prekrivena površina od 12 x 8,80 m (Sl. I.15, I.16). Mreže su usidrene na osam betonskih blokova, čime je omogućeno da se pojedine stranice mrežišta mogu podizati ili otvarati za potrebe budućeg istraživanja.

Probno istraživanje u 2011. godini

U svibnju 2011. u laboratoriju Beta Analytic napravljena je analiza uzorka platice (P3) AMS metodom (Beta-296186), pri čemu je utvrđen rezultat apsolutne starosti od 2860 ±30, kalibriran između 1120. i 930. godine pr. Kr. (vjerojatnost 95%), koji se dijelom poklapa s korigiranim rezultatom Instituta Ruđer Bošković.

This date pointed to the Zambratija boat being unique among the known archaeological finds of sewn vessels in the Adriatic.

At that time, the first wood species analysis of the boat was conducted, as well. The Department of Wood Science – Faculty of Forestry at Zagreb University analysed the sample of a lath found covering the seams, and determined that it belonged to the fir genus (*Abies Mill.*). A plank sample was analysed too, which showed that it was made of elm (*Ulmus L.*)

To protect the site against marine and human impacts, the wreck was covered with geotextile, on the top of which two iron meshes were laid reinforcing the protection, providing a 12 x 8.80 m covered area (Figs I.15, I.16). The meshes were anchored with eight concrete blocks so that the sides of the meshes could be lifted or opened to allow access for future research.

The 2011 trial excavation

In May 2011, an analysis was conducted on a plank sample using the AMS technique (Beta - 296186) by Beta Analytic, providing the absolute date of 2860±30, with a calibrated date range of 1120-930 BCE (95% probability), which overlaps the corrected result obtained by the Ruđer Bošković Institute.

I.14

Ekpa s istraživanja obavljenih u 2008. godini (slijeva nadesno: N. Koncani, D. Sficco, T. Šalov, N. Fachin, I. Koncani Uhač, nedostaju: Ch. Petretich i M. Uhač)

Research team in 2008 (left to right: N. Koncani, D. Sficco, T. Šalov, N. Fachin, I. Koncani Uhač, not shown: Ch. Petretich and M. Uhač) (fotografija / photo by: Ch. Petretich)

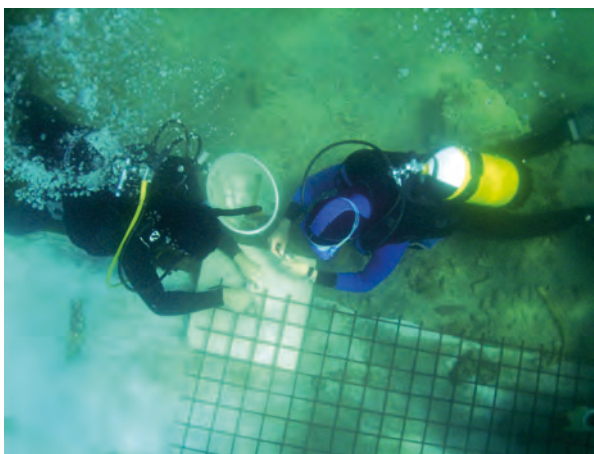




I.15a



I.15c



I.15b

I.15 a,b,c
 Postavljanje zaštitne mreže iznad
 ostataka brodske konstrukcije u
 2010. godini
 Positioning the protective net
 over the remains of the hull in 2010
 (fotografija / photo by: M. Uhač)

U rujnu i listopadu 2011. provedeno je arheološko sondiranje na manjoj površini olupine, radi prikupljanja arheoloških podataka koji su trebali ukazati na dimenzije, očuvanost i nautičke osobitosti nalaza, tj. na generalno stanje brodske konstrukcije (Koncani Uhač 2011).

Logistička baza za istraživanje bila je pozicionirana na sjevernoj strani zaljeva, na udaljenosti od oko 150 metara od lokaliteta (Sl. I.17). Nakon pripremnih istraživačkih radova, s nalazišta je prvo uklonjen geotekstil te je postavljeno metalno kvadratno mrežište unutar kojeg je bilo obavljano istraživanje uz pomoć vodenih sisaljki (Sl. I.18 – I.23), ne bi li se olakšao rad na nalazištu. Kvadratna mreža je pokrivala površinu od 4 x 6 metara. Bila je podijeljena na 6 kvadranta veličine 2 x 2 m, koji su bili označeni slovima od A do F, dok je svaki kvadrant bio dodatno podijeljen na četiri podkvadranta (1-4). Istraživanje je provedeno na jugozapadu unutar A1/A2/A3/A4 te B1/B2/B3/B4, gdje su bili vidljivi ostaci oplata broda, te unutar E1/E2 i F1/F2, gdje je pretpostavljeno postojanje intaktnog dijela broda (Sl. I.24, I.25).

Gornja površina brodske konstrukcije bila je prekrivena morskom cvjetnicom (*Cymodocea nodosa*), čije je korijenje uraslo i u sam trup (Sl. I.26, I.27).

In September and October 2011, a trial trench was excavated on a small section of the wreck to establish the dimensions, the state of preservation and structural features of the find, that is, to ascertain the general condition of the boat structure (Koncani Uhač 2011).

The research logistic base was located on the northern side of the cove, approximately 150 m from the site (Fig. I.17). Once the preliminary work was done, the geotextile was removed first and then an aluminium grid was assembled to define the trench and facilitate work on the site using water dredges (Figs I.18 – I.23). The grid covered a 4 x 6 m surface area. It was divided into six 2 x 2 m quadrants labelled A to F, each further divided into four sub-quadrants (1 to 4). The investigation was conducted in south-western sub-quadrants A1/A2/A3/A4 and B1/B2/B3/B4, where planking remains were visible, than E1/E2 and F1/F2, where the rest of the vessel remains were presumed to exist (Figs I.24, I.25).

The upper surface of the boat structure appeared to be covered with sea grass (*Cymodocea nodosa*), the roots of which had partially penetrated the boat structure itself (Figs I.26, I.27).

Na nalazištu je istraženo šest stratigrafskih jedinica. Stratigrafske jedinice SJ 4 i SJ 5 su naknadno izjednačene kao jedna (Sl. I.28, I.29).

Površinski sloj SJ 1 je predstavljao površinski sloj sastavljen od pijeska, kamenja i morske cvjetnice (*Cymodocea nodosa*) te sporadičnih ulomaka rimske keramike (keramičkog pršljena i trbuha amfore).

SJ 2 se odnosila na čitavu istraženu drvenu brodsku

In the investigated area, six stratigraphic units were identified. The codes SU4 and SU5 identify two identical units (Figs I.28, I.29).

The upper-most layer SU1 was composed of sand, stones, sea grass (*Cymodocea nodosa*), and sporadic sherds of Roman ceramics (a ceramic weight and a sherd of the body of an unidentified amphora).

Layer SU2 is the wooden boat structure. It lay at



I.16

Pogled na zaštitno mrežište s betonskim blokovima iznad nalazišta broda

View of the protective net with concrete blocks over the site of the boat
(fotografija / photo by: L. Damelet)



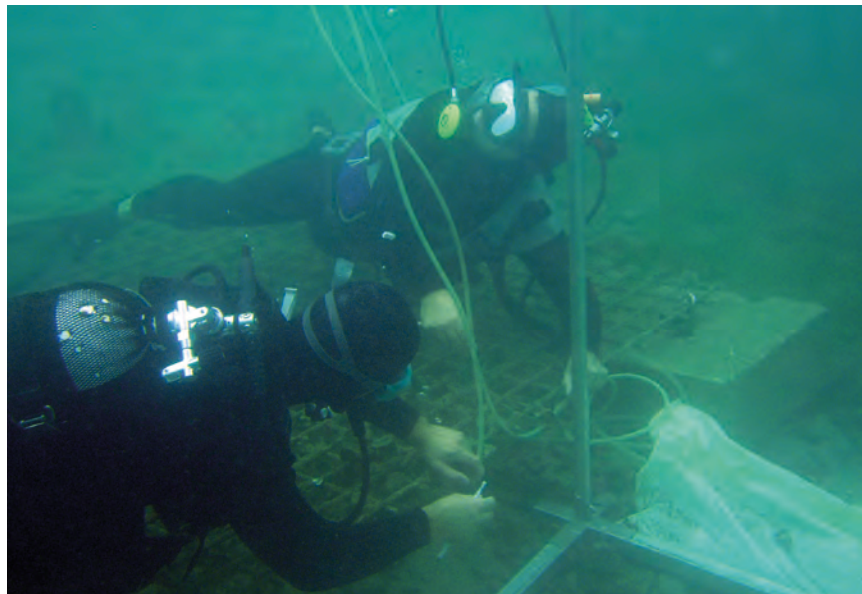
I.17

Radna baza u 2011. godini, pripreme prije urona
The research base in 2011, preparations before diving
(fotografija / photo by: T. Šalov)



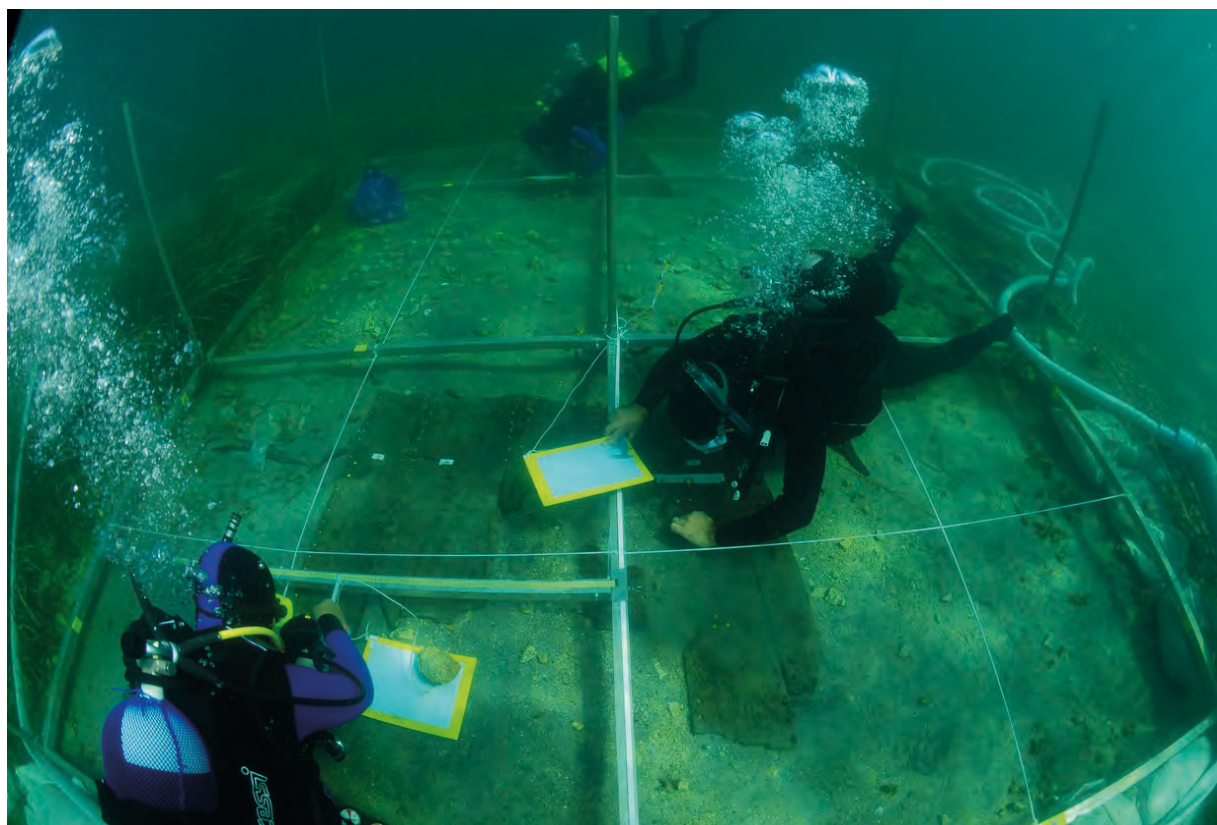
I.18

I.18
Radna baza u 2011. godini,
montiranje mrežišta za istraživanje
The research base in 2011,
assembling the grid
(fotografija / photo by: T. Šalov)



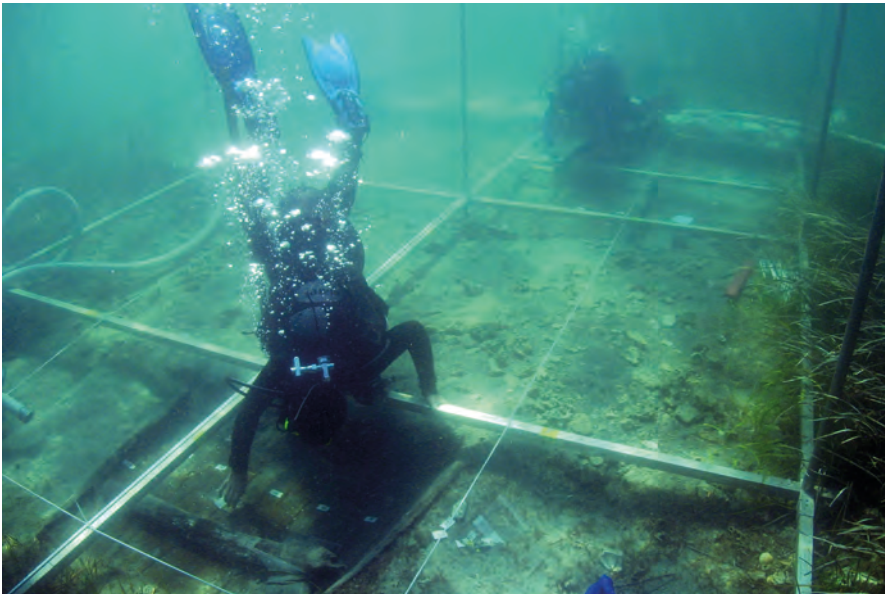
I.19

I.19
Niveliranje mrežišta na morskom
dnu, istraživanje u 2011. godini
Levelling of the grid on the seabed
in 2011
(fotografija / photo by: I. Koncani
Uhač)



I.20

I.20
Analiza i istraživanje brodskih
ostataka u 2011. godini
Analysis and survey of the hull
remains in 2011
(fotografija / photo by: R. Kovačić)



I.22

I.22
Analiza i dokumentiranje brodskih ostataka u 2011. godini
Analysis and documentation of the hull remains in 2011
 (fotografija / photo by: I. Koncani Uhač)

I.23
Pogled na nalazište s mrežištem, 2011. godina
View of the site with the grid in 2011
 (fotografija / photo by: R. Kovačić)



I.23

konstrukciju, dokumentiranu na dubini od -2,20 do -2,50 m te je bila djelomično vidljiva na površini morskog dna.

SJ 3 je predstavljao rahli sloj u unutrašnjosti i izvan brodske konstrukcije. Sloj je tamnosive, gotovo crne boje, sastavljen od pijeska, školjaka, sitnog kamenja te organskih ostataka vidljivih prostim okom. Dubina na kojoj je istražen bila je od -2,24 do -2,31 m.

SJ 4/SJ 5 se nalazio direktno ispod SJ 3, na dubini od -2,32 do -2,39. Predstavljao je kompaktan sloj tamnosive

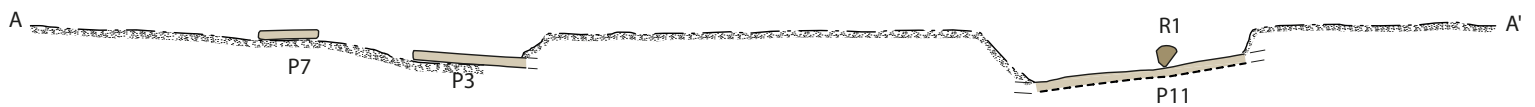
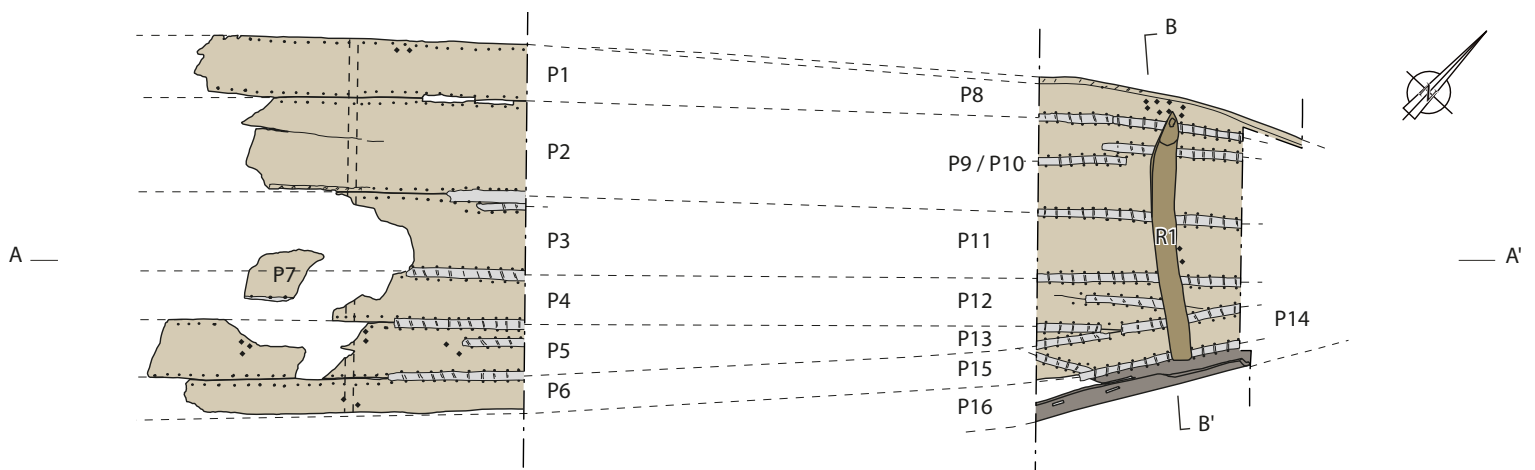
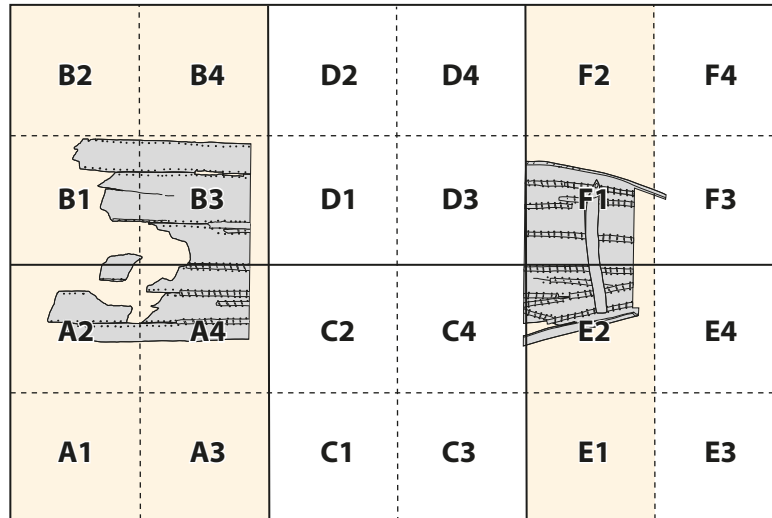
a depth between -2.20 and -2.50 m, and was partially visible on the surface of the sea bottom.

Layer SU3 was a loose layer that covered the boat structure. This layer was dark grey, almost black, composed of sand, shells, tiny stones and organic remains visible to the naked eye. It lay at a depth between -2.24 and -2.31 m.

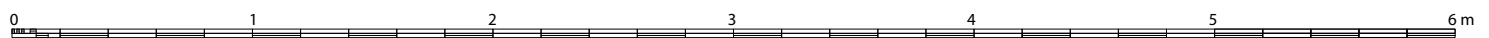
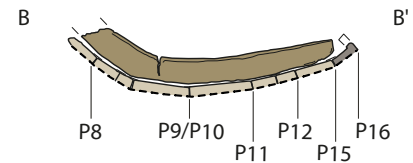
Layer SU4/SU5 was found directly below the layer SU3 at a depth between -2.32 and -2.39 m. It had a

I.24

Kvadratna mreža s istraženim dijelovima broda u 2011. godini
 Square grid with investigated elements of the boat in 2011
 (izradila / made by: G. Boetto)



- | | | |
|---------------------------|--------------------------------|---------------------------------|
| oplata / planking | letvica / lath | začepljene rupe / plugged holes |
| rebro / frame | tragovi šivanja / sewing trace | |
| završni voj / sheerstrake | mali drveni čavao / peg | |



T. Šalov, M. Uhač, G. Boetto/2011

I.25

Dijelovi broda istraženi u 2011. godini
 The boat elements investigated in 2011
 (crtež / drawing by: T. Šalov, M. Uhač, G. Boetto)



I.26

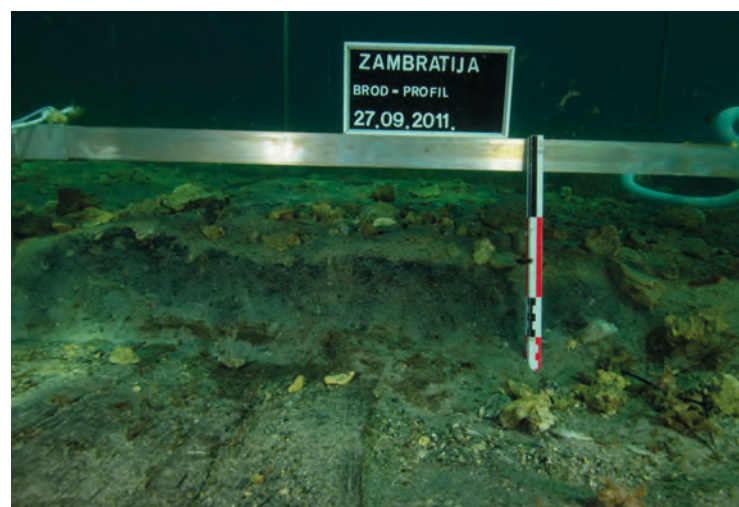
I.26
Uklanjanje morske cvjetnice
iznad nalazišta, 2011. godina
Removing the sea-grass roots
in 2011
(fotografija / photo by: I. Koncani Uhač)

I.27
Pogled na nalazište
View of the site
(fotografija / photo by: R. Kovačić)

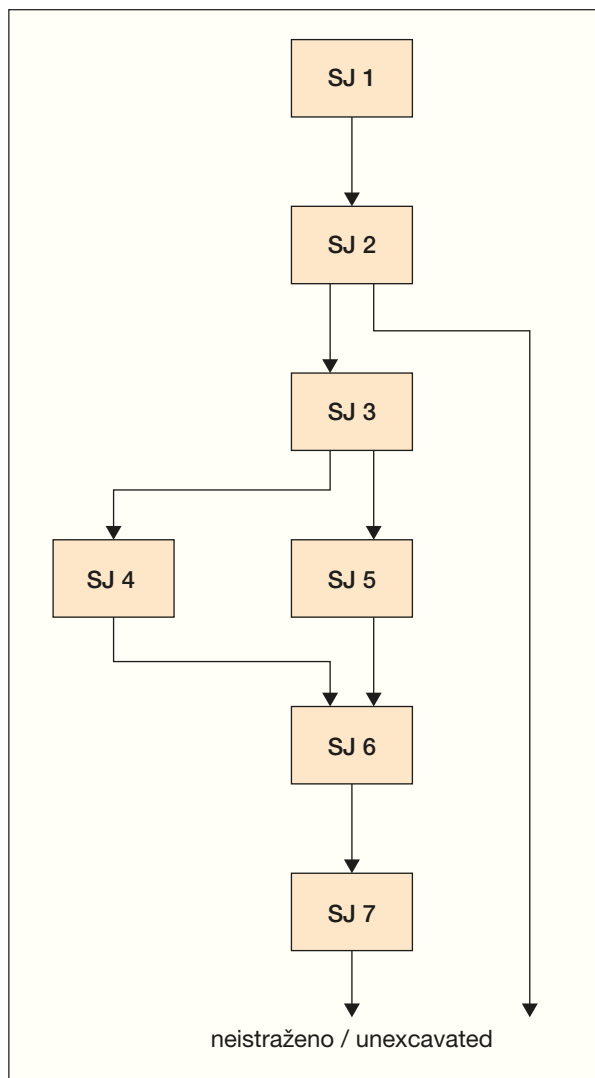
I.28
Slojevi iznad drvene brodske
konstrukcije
The layers above the boat
structure
(fotografija / photo by: R. Kovačić)



I.27



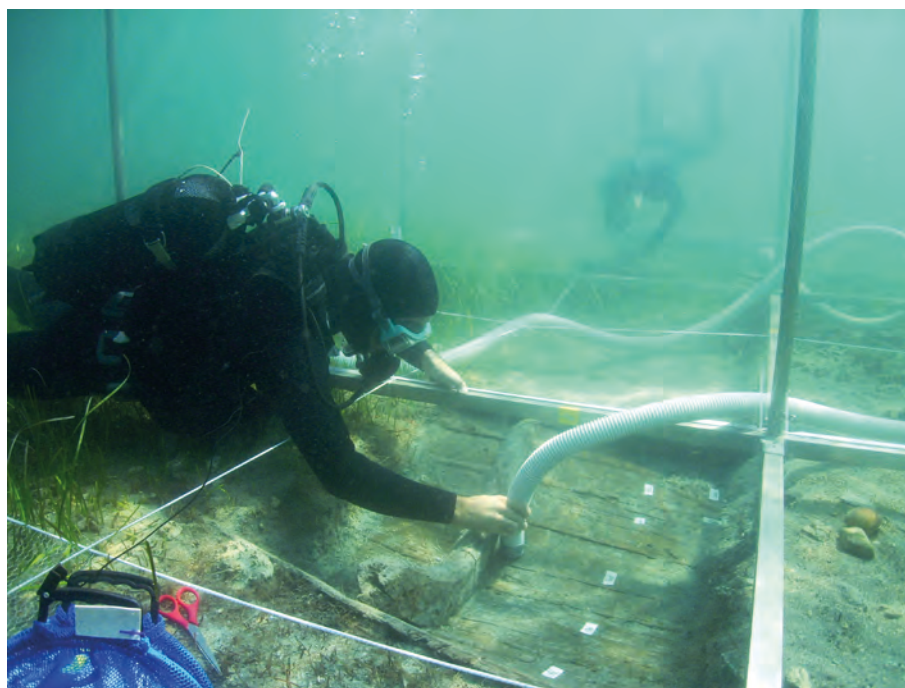
I.28



I.29

I.29
Stratigrafija nalazišta
Stratigraphy of the site
 (izradila / made by: I. Koncani Uhač,
 oblikovanje / design by: D. Tomić)

I.30
Fino čišćenje broda unutar
 kvadranta F1 i E2
Fine cleaning of the boat in
 quadrants F1 and E2
 (fotografija / photo by: I. Koncani
 Uhač)



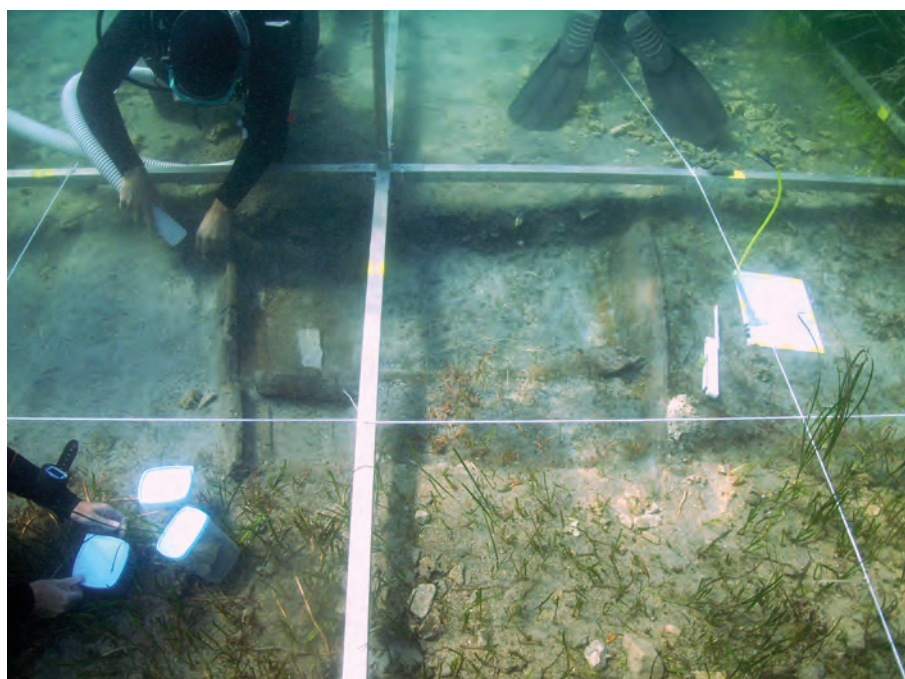
I.30



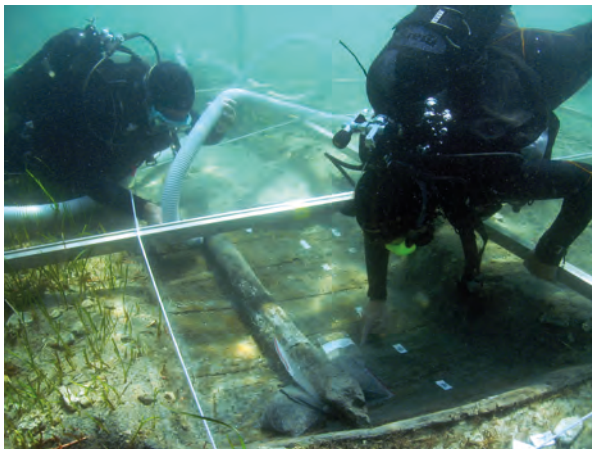
I.31

I.31
Uklanjanje sedimenta iznad dijela
 konstrukcije unutar kvadranta E2
Removing the sediment above the
 boat structure in quadrant E2
 (fotografija / photo by: R. Kovačić)

I.32
Fino čišćenje brodske konstrukcije
 i uzorkovanje sedimenta
Fine cleaning of the boat structure
 and sampling of the sediments
 (fotografija / photo by: R. Kovačić)



I.32



I.33

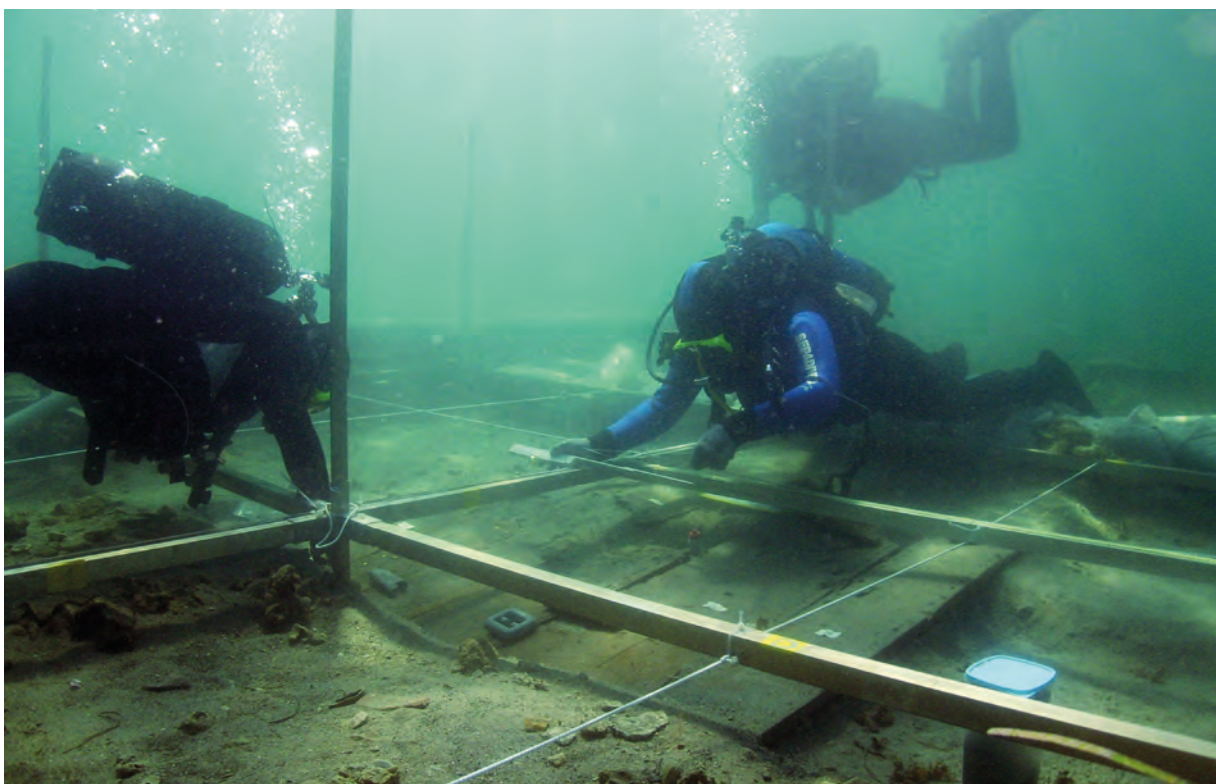


I.34

I.33
Fino čišćenje i analiza brodske konstrukcije u 2011. godini
Fine cleaning and analysis of the boat structure in 2011
(fotografija / photo by: I. Koncani Uhač)

I.34
Crtanje broda u 2011. godini
Drawing the boat elements in 2011
(fotografija / photo by: I. Koncani Uhač)

I.35
Crtranje broda u 2011. godini
Drawing the boat elements in 2011
(fotografija / photo by: I. Koncani Uhač)



I.35

I.36
Ekpa na istraživanju u 2011. godini (slijeva nadesno: M. Uhač, T. Šalov, Ch. Petretich, G. Boetto, I. Koncani Uhač, M. Erič, R. Kovačić, nedostaje: N. Koncani)
Research team in 2011
(left to right: M. Uhač, T. Šalov, Ch. Petretich, G. Boetto, I. Koncani Uhač, M. Erič, R. Kovačić, not shown: N. Koncani)
(fotografija / photo by: R. Kovačić)



I.36

boje, sastavljen od glinastog sedimenta. Dokumentiran je u unutrašnjosti i izvan brodske konstrukcije.

SJ 6 je bio kompaktan sediment koji se nalazio direktno ispod SJ 4/SJ 5; sastavljen od pijeska, u kojem su bili prostim okom vidljivi ostaci biljaka (grančica, lišća). U istraženom sloju pronađena su dva sitna ulomka keramike i jedan sitni kremenit odbitak.

Naposlijetku, SJ 7 nalazio se direktno iznad brodske konstrukcije, na dubini od -2,40 do -2,46 m. Sloj je bio sivosmeđe boje i u njemu su prostim okom bili vidljivi tragovi organskog materijala.

Zbog krhkosti pojedinih drvenih dijelova broda,

compact composition, a dark grey colour, and it was composed of a clay sediment. It was explored both in within and the outside of the boat structure.

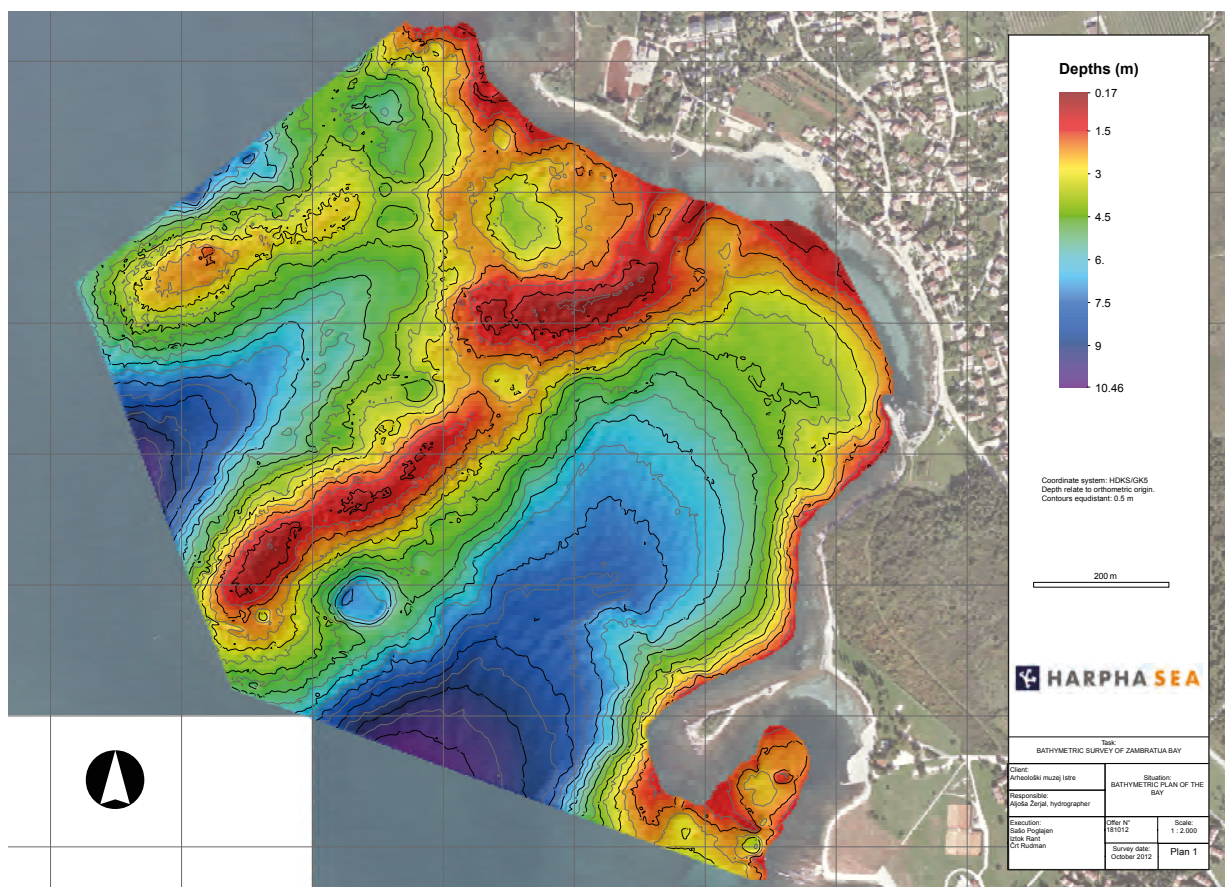
The compact layer SU6, situated directly below SU4/SU5, was composed of sand in which the remains of plants (branches, leaves) were seen. In this layer two undiagnostic small sherds of ceramic and one small piece of flint were also found.

Finally, layer SU7 was situated immediately above the boat wooden structure at a depth between -2.40 and -2.45 m. It was grey-brown and it contained traces of organic remains visible to the naked eye.

I.37
Izrada batimetrijske snimke u 2012. godini, plovilo s multibeam uređajem
The bathymetric survey in 2012, boat with multibeam sounder
(fotografija / photo by: I. Koncani Uhač)



I.38
Multibeam snimka morskog dna u uvali Zamratija
Multibeam scan of the seabed in Zamratija Cove
(izrada / made by: Harpha sea d.o.o)



uklanjanje sedimenta se obavljalo uz pomoć namjen-ski izrađenih vodenih sisaljki s priključenim fleksibilnim cijevima manjih profila. Na taj je način omogućena pre-ciznost pri radu te je regulirana odgovarajuća snaga usisavanja, u cilju minimalnog utjecaja na drvene elemen-te broda. Ronjenje je obavljano u parovima (ukupno pet parova dnevno), u smjenama od po dva sata. Brodske letvice i drugi nestabilni drveni elementi bili su učvršćeni žicom od nehrđajućeg čelika, a za označavanje pojedinih elemenata brodske konstrukcije upotrijebljeni su inoks čavli i plastične oznake. Brodska rebra su zbog svoje gotovo neutralne plovnosti bila opterećena vrećicama s pijeskom. Istraženi ostaci broda na terenu su bili ručno iscrtani, dok je crtež broda naknadno obrađen u računal-nom programu Adobe Illustrator (Sl. I.30 – I.36).

Podaci o nalazištu, dobiveni nakon arheološke kampanje u 2011. godini, ukazali su na činjenicu o postojanju jedinstvenog prapovijesnog broda (Koncani Uhač, Uhač 2014b; Koncani Uhač *et al.* 2017a, 2017b; Boetto 2016; Boetto *et al.* 2014, 2017) te su utjecali na odluku hrvatskih istraživača da se pokrene suradnja s inozemnim stručnjaci-ma koji su usko specijalizirani za istraživanje brodskih konstrukcija. Zbog toga je u 2013. godini ugovorena me-đunarodna znanstvena suradnja između Arheološkog muzeja Istre u Puli (AMI) i Centra Camille Jullian (CCJ).

Due to the fragility of some wooden boat parts, the sediments were removed with a specially constructed water pump to which small-diameter flexible hoses were attached. This enabled precise work to be car-ried out using a suitable suction supply, thus minimizing adversely affecting the wooden boat elements. Diving was organized in pairs (5 pairs in total per day), in 2-hour shifts. Wooden laths and other loose wooden elements were fastened to the hull with stainless-steel wire, while stainless-steel nails and plastic tags were used for label-ling the boat's structural elements. The boat frames were ballasted with sandbags to avoid their displacement due to their neutral buoyancy. The wreck parts were plotted by hand (Figs I.30 – I.36) while plans were subsequently processed with Adobe Illustrator software.

The results of the 2011 archaeological campaign indi-cated the presence of a unique prehistoric boat (Koncani Uhač, Uhač 2012; Koncani Uhač, Uhač 2014a; Boetto *et al.* 2014, 2017), and that fact influenced the decision of the Croatian researchers to establish a cooperation agreement with foreign experts highly specialized in boat and ship archaeology. Therefore, in 2013, interna-tional scientific cooperation between the Archaeological Museum of Istria in Pula (AMI) and Centre Camille Jullian (CCJ) was established.

I.39
Zaštitna metalna kutija u izradi
Protective metal box being made
(fotografija / photo by: M. Uhač)



I.40

Radna baza za istraživanje u 2013. godini

Research base in 2013

(fotografija / photo by: Ph. Groscaux)



Batimetrijsko snimanje i izrada zaštitne kutije u 2012. godini

U 2012. godini, na površini od ukupno 100 hektara, od Crvene uvale na sjeveru do Sipra na jugu, tvrtka Harpha Sea d.o.o. izradila je batimetrijski snimak podmorja uvala. Za snimanje je korišten sustav GPS RTK s *multibeam* sonarom, koji u podmorju omogućava rezoluciju do 0,1 m. Sonar koji je ugrađen u plovilo (brodica dužine 4,5 m) tijekom plovidbe bilježi zvučne valove u paralelnim linijama, a navođen je preko GPS sistema. Batimetrijom je u potpunosti registriran reljef dna uvala od dubine -0,5 m do -10 m (Sl. I.37, I.38).

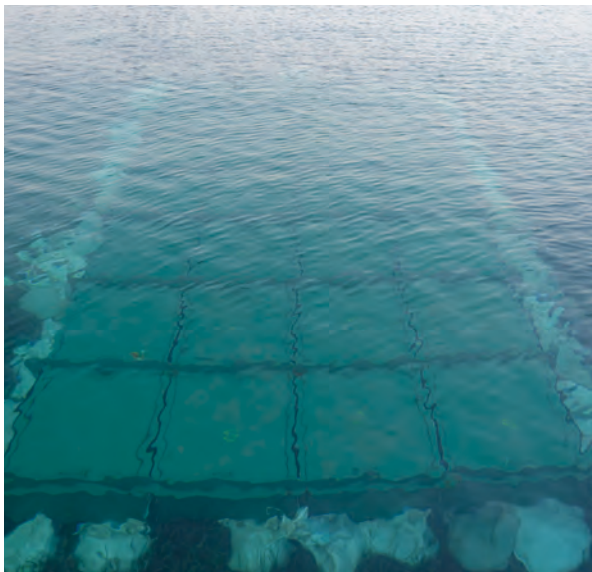
Tijekom vremena provedenog na lokalitetu postalo je jasno da postoje određene opasnosti koje bi mogle ugroziti cjelovitost nalaza, osobito tijekom arheološkog istraživanja. To su primarno otvorenost zaljeva Zambratija te izloženost gotovo svim vremenskim nepogodama, ali i moguće nekontrolirano ljudsko djelovanje, s obzirom da se lokalitet nalazi u neposrednoj blizini kupališta. Slijedom navedenog te zbog potrebe za višednevnim istraživanjem brodske konstrukcije, odlučeno je da se izradi namjenska zaštitna metalna kutija i pozicionira iznad područja istraživanja, ne bi li se zaštitila drvena brodska konstrukcija.

Ideja o zaštitnoj kutiji inspirirana je istraživanjem brodoloma Mazarrón 2 u Puerto de Mazarrónu u Španjolskoj (Neguerela *et al.* 2004), dok je projekt zaštitne metalne

The 2012 bathymetry survey and the construction of a protective box

In 2012, the firm Harpha Sea d.o.o. performed a bathymetric survey of the cove seabed, covering a surface of 100 hectares from Crvena Bay in the north to Sipar in the south. The survey was conducted using a GPS RTK system with a multibeam sounder providing an underwater resolution of up to 0.1 m. The sounder, situated on the surface of the research vessel (a 4.5 m long survey boat), recorded sound waves in parallel lines during navigation, and was supported by a GPS system. The bathymetry enabled the entire landscape of the cove seabed, from the depth of -0.5 m to -10 m, to be recorded (Figs I.37, I.38).

During the time spent on the site, particularly during the archaeological excavation, it became clear that certain risks could affect the integrity of the site, thus endangering the wooden structures if exposed during another excavation campaign. These risks primarily stemmed from the aspect of Zambratija Cove being open to almost all weather conditions, but also from possible uncontrolled human activity, as the site is located in the immediate vicinity of the swimming area. Therefore, as complete excavation of the site would require several days of work, it was decided that a box should be built and placed around the excavation area to protect the wooden structures while the work was carried out.



I.41



I.42



I.43

I.41
Zaštitna kutija sastavljena je na morskome dnu oko olupine
Protective metal box assembled on the seabed around the wreck
(fotografija / photo by: Ph. Groscaux)

I.42
Istraživanje unutar zaštitne kutije u 2013. godini
The excavation inside the protective box in 2013
(fotografija / photo by: Ph. Groscaux)

I.43
Otvaranje metalnih ploča kutije za potrebe istraživanja
Opening the metal plates of the box for daily research
(fotografija / photo by: Ph. Groscaux)

I.44

Pogled na zaštitnu kutiju i brodsku konstrukciju

View of the protective box and the boat structure

(fotografija / photo by: Ph. Groscaux)

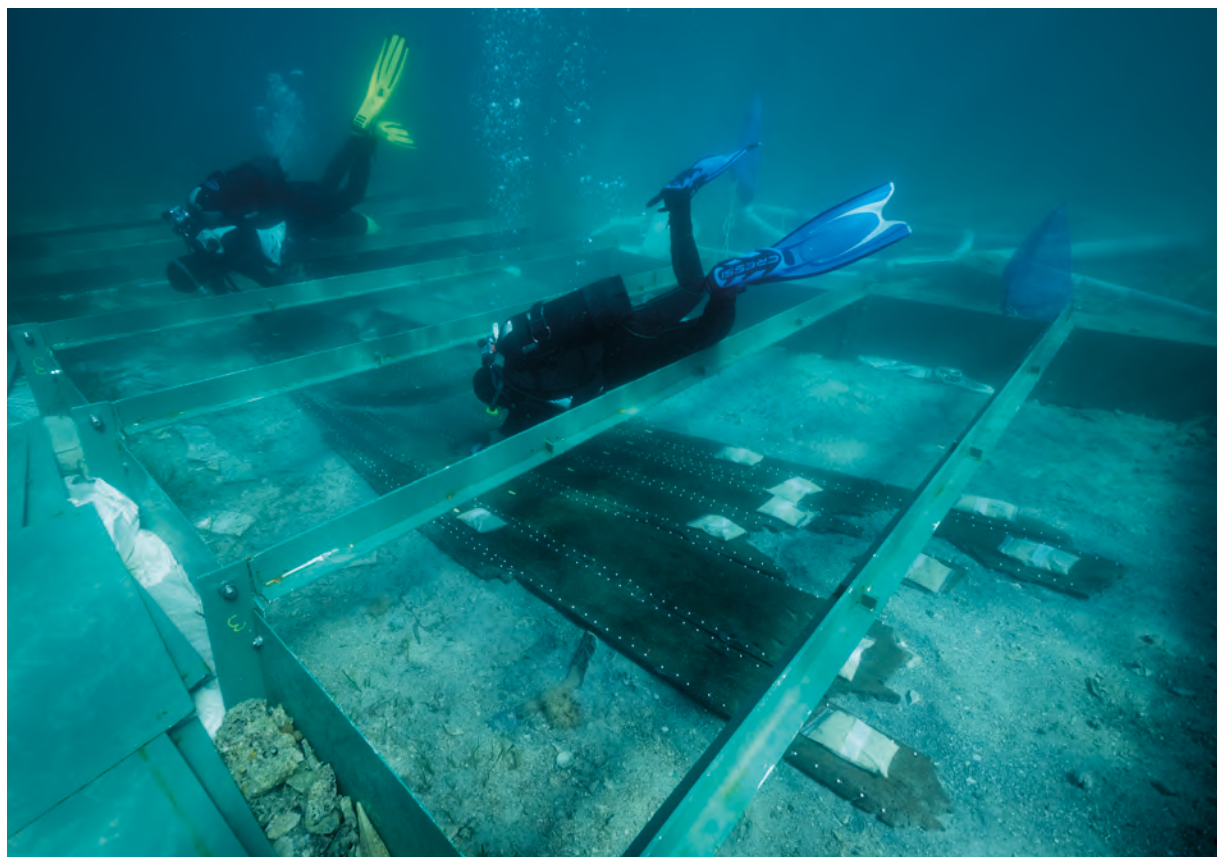


I.45

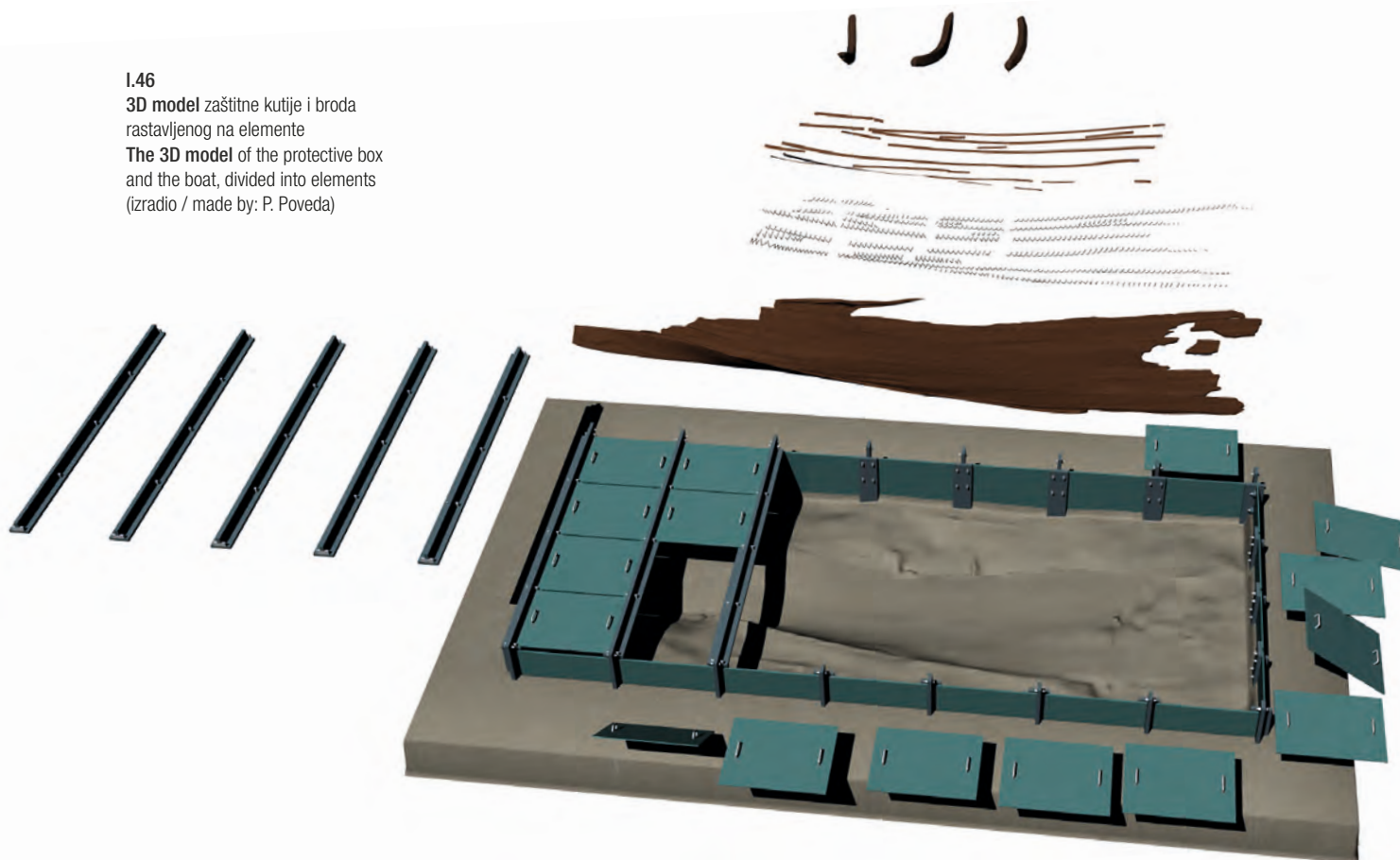
Pogled na brodsku konstrukciju bez brodskih rebara

View of the boat with frames removed

(fotografija / photo by: Ph. Groscaux)



I.46

3D model zaštitne kutije i broda
rastavljenog na elementeThe 3D model of the protective box
and the boat, divided into elements
(izradio / made by: P. Poveda)

kutije bio rad tvrtke za kompjutorski inženjering u brodogradnji, projektiranju i konstruiranju Cadcon d.o.o.² Radi lakšeg rukovanja, pojedinačni dijelovi kutije bili su projektirani na način da njihova težina ne prelazi više od 50 kg. Dimenzije zaštitne kutija iznosile su 7 x 4 m, a visina joj je iznosila 0,5 m. Zaštitna kutija je izrađena od tzv. brodskog čelika, ukupno projektirane težine 1740 kg (Sl. I.39). Montažno-demontažna zaštitna metalna kutija izrađena je u tvrtki Tehnomont d.d. u Puli.

Istraživanje u 2013. godini

Tijekom kolovoza i rujna 2013. godine na nalazištu je provedeno sveobuhvatno terensko istraživanje (Koncani Uhač, Uhač, 2014b; Koncani Uhač *et al.* 2017a; 2017b; Boetto 2016; Boetto *et al.* 2014; 2017). Ono je s razlogom održano u ljetnom razdoblju (Sl. I.40), ne bi li se umanjila mogućnost nepovoljnih vremenskih prilika koje bi utjecale na intenzitet istraživanja, kao i na sigurnost brodske konstrukcije.

Prije početka istraživanja u lučicu Zambratija je iz Pule dovezena zaštitna metalna kutija. Dijelovi kutije potom su u više navrata prevoženi radnim brodom na lokalitet,

This box was inspired by the one used during excavation of the shipwreck Mazarrón 2 in Puerto de Mazarrón in Spain (Neguerela *et al.* 2004), while the protective metal box was designed by Cadcon d.o.o.², a digital engineering company specializing in the field of shipbuilding, design and construction. To enable easy handling, each part of the box was designed to weigh less than 50 kg. The protective box dimensions were 7 x 4 m, and it was 0.5 m high. It was made of the so-called “shipbuilding steel”, with a total design weight of 1,740 kg (Fig. I.39). This prefabricated protective metal box was built by Tehnomont d.o.o., Pula.

The 2013 excavation

Between August and September 2013, a comprehensive field investigation of the site was conducted (Koncani Uhač, Uhač 2014b; Koncani Uhač *et al.* 2017a, 2017b; Boetto 2016; Boetto *et al.* 2014, 2017). The archaeological excavation was carried out in the summer (Figs I.40) to minimize the possibility of adverse weather conditions that could affect both the ability of the team to dive regularly and the safety of the boat structure.

Before starting the investigation, the protective metal box was delivered from Pula to Zambratija harbour. The parts of the box were then transported by boat to the site

² Osobito zahvaljujemo tvrtki Cadcon d.o.o. na izrađenom projektu.

² We wish to give our special thanks to the company Cadcon d.o.o. for the construction design.

I.47

Uklanjanje morske trave koja je urasla u brodsku konstrukciju
Removing the sea grass which has grown into the boat construction
(fotografija / photo by: Ph. Groscaux)



I.47



I.48

I.48

Fino čišćenje vodenom sisaljkom
Fine cleaning with water dredge
(fotografija / photo by: Ph. Groscaux)



I.49

I.49

Arheološki radovi na nalazištu
Archaeological activities on the site
(fotografija / photo by: Ph. Groscaux)



I.50

I.50

Arheološki radovi na nalazištu
Archaeological activities on the site
(fotografija / photo by: Ph. Groscaux)

I.51

Označavanje tehničkih detalja broda
Marking the structural elements of the boat
(fotografija / photo by: Ph. Groscaux)



I.51



I.52

Označavanje tehničkih detalja na oplati radi izrade fotogrametrije
Marking the stitching holes between planking for photogrammetry
(fotografija / photo by: Ph. Groscaux)

nakon čega je ona bila sastavljena na morskom dnu, oko brodskih ostataka³. Te su radove izveli profesionalni ronjoci, uz rukovodstvo i nadzor arheologa. Nakon što su uz bočne stranice kutije dodatno postavljene vreće s pijeskom, započelo se s arheološkim istraživanjem. Ono je trajalo ukupno tri tjedna, a gornje plohe zaštitne metalne kutije su se po potrebi otvarale i zatvarale (Sl. I.41 – I.46).

Unutar kutije prvo su podvodnom sisaljkom očišćeni dijelovi koji su istraženi 2011. godine, odnosno s njih je uklonjen sloj pijeska i geotekstil. Nakon toga se pristupilo uklanjanju izrasta morske rese te samom istraživanju na neistraženom dijelu (Sl. I.47, I.48).

Cjelokupna istražena brodska konstrukcija bila je dobro očuvana. Uz svakodnevnu izradu fotodokumentacije primarno je izrađen crtež s ciljem označavanja pojedinih konstruktivnih dijelova te organiziranja rada na lokalitetu kao i bilježenja prvih mjerenja i opažanja (Sl. I.49, I.50). Radi bolje preglednosti dokumentacijskih crteža i snimaka korištene su igle s plastičnom glavom, koje su postavljene na postojeće rupe i utore - igle s bijelom glavom su korištene za rupe za šavove (Sl. I. 51, I.52), a one s crvenom glavom za rupe od vezanja rebara za oplatu). Alfnumerički su označeni svi konstruktivni dijelovi broda (platice i rebra), uz pomoć ispis-trake i čavlića od inoksa. Mjerenja detalja brodske konstrukcije obavljena su direktno na trupu broda (Sl. I.53 – I.55). Svi detalji brodske konstrukcije su fotografirani, a na nalazištu su obavljene dvije faze digitalne fotogrametrije radi izrade dva 3D modela sačuvanih ostataka broda - jedan sa, a drugi bez brodskih rebara.

U cilju kvalitetnije analize, brodska rebra izvučena su na kopno te su isti dan nakon obavljene analize, mjerenja i fotografiranja vraćena u unutrašnjost broskog trupa (Sl. I.56).

Tijekom istraživanja dijagnosticirani su pojedini specifični detalji, dok su svi dijelovi brodske konstrukcije temeljito analizirani. Također su uzeti različiti uzorci brodskih elemenata za određivanje vrste drva i radiokarbonskog datiranja. Prikupljeni su uzorci biljnog materijala koji je služio za osiguravanje vodonepropusnosti, kao i uzorci premaza za kemijsku analizu sastava i podrijetla.

Brod je po okončanju istraživanja slojevito zatrpan pijeskom te je dodatno zaštićen željeznom mrežom. Uklonjene su plastične oznake i čavli s broskog trupa, kao i žica od nehrđajućeg čelika koja je učvršćivala pojedine elemente (letvicu i druge nestabilne dijelove). To je učinjeno zato da ne bi došlo do njihove korozije, koja bi mogla ugroziti stanje očuvanosti drvene konstrukcije. Iznad letvica broda je također postavljeno malo pločasto kamenje, radi osiguravanja krhkih brodskih dijelova.

³ Prijevoz metalne zaštitne kutije (u elementima) iz tvrtke Tehnomont do lučice u Zambratiji (dijelovi su spušteni u more) obavljen je kamionom-dizalicom obrta za prijevoz tereta „Cukon“, nakon čega su elementi radnim brodom Elvisa Palčića prevezeni iznad lokacije.

in several rounds and, finally, the box was assembled on the seabed around the wreck³. The work was carried out by professional divers, led and supervised by archaeologists. Once the sides of the box had been further secured around the site with sandbags, the archaeological investigation began. During the excavation, which lasted over three weeks, the top of the metal box was opened and closed every day, when necessary (Figs I.41 – I.46).

Inside the box, the areas investigated in 2011 were cleaned with a water pump first, then the layer of sand and the geotextile were removed. The sea-grass roots were cut and removed, and the excavation continued in the zones not previously investigated (Figs I.47, I.48).

The entire excavated boat structure was in good condition. Alongside a daily photographic record, drawing was essential to document the individual timbers, as well as organizing work on the wreck and recording the initial measurements and observations (Figs I.49, I.50). Drawing pins with plastic heads were used to mark the visible features - pins with white heads were used for stitching holes between planks (Figs I.51, I.52), while red pins marked holes for lashings joining the floor-timbers to the planking to help those drawing under water and to make them more easily visible in the photographs. All structural parts of the boat (planks and frames) were marked with alpha-numeric codes printed on plastic labels and secured to the wood with stainless-steel nails. Measurements of the boat were taken directly from the remains (Figs I.53 – I.55). Photos of all features were taken, and digital photogrammetry was used to create two 3D models of the preserved remains, one before and the other after the removal of the frames.

To study the frames more fully, they were recovered, measured and photographed, and re-installed inside the hull on the same day (Fig I.56).

During the investigations, certain specific features were analysed, while all parts of the boat structure were recorded in detail. In addition, samples were collected to determine the wood species and for radiocarbon dating. Vegetal material used to seal the plank seams and the waterproofing pitch found on the hull were also sampled for chemical analysis to determine their composition and origin.

Once the excavation was concluded, the boat was covered with layers of sand and additionally protected with a steel mesh. The plastic labels, pins and stainless-steel wire fastening certain elements (the laths and other loose parts) were first removed from the hull. These elements were removed to avoid corrosion that could endanger the condition of the timbers. Small flat stones were placed on top of the laths to secure these

³ The dismantled protective metal box was transported from Tehnomont company to Zambratija harbour and lowered into the sea by the “Cukon” company crane truck. Once in the sea, it was transported to the location by Elvis Palčić’s work boat.

I.53
Mjerenje trupa
Measuring of the hull
(fotografija / photo by:
Ph. Groscaux)



I.54
Proučavanje arhitektonskih ostataka broda
Examination of the architectural remains
of the boat
(fotografija / photo by: Ph. Groscaux)





I.55
Izmjera ostataka brodske konstrukcije
Measuring of the boat structure remains
(fotografija / photo by: Ph. Groscaux)



I.56
Rebrenice prilikom vađenja iz mora
Floor-timbers once removed from the sea
(fotografija / photo by: Ph. Groscaux)

Oko broda su dodatno postavljene vreće s pijeskom te je unutar njega nanesen sloj pijeska. Zatim je iznad trupa položen geotekstil, na čijim je rubovima položeno kamenje te je potom opet iznad svega nanesen sloj pijeska. Nakon uklanjanja zaštitne kutije, iznad lokaliteta su stavljene tri zaštitne željezne mreže, koje su pričvršćene na postojećih osam betonskih blokova. Iznad mreža je položeno kamenje prikupljeno u blizini lokaliteta, čime je stvoren kameni nasip koji se blago izdiže iz pješčane okolice. Zaštitna metalna kutija je u dijelovima izvučena radnim brodom i dopremljena na obalu.

Kroz iduće tri godine radilo se na obradi znanstvenih podataka, analizi drva, izradi 3D modela brodske konstrukcije sa i bez rebara, kao i 3D modela rebara te rekonstrukciji brodskih linija.

Izložbe

Rezultati istraživačkog projekta na brodu u Zambratiji prezentirani su 2017. godine izložbom i pratećim četverojezičnim katalogom pod nazivom "Zambratija. Prapovijesni šivani brod / Prehistoric Sewn Boat / Una barca cucita preistorica / Un bateau cousu préhistorique".

fragile boat parts. The boat was surrounded by sandbags, while the inside of the boat was filled with a layer of sand. Subsequently, the hull was covered with geotextile, fixed with stones around the edges, and another layer of sand was spread over the whole site. When the protective box was removed, the site was covered with three protective steel meshes fastened to the eight previously placed concrete blocks. Stones, collected near the site, were laid on the mesh, thus creating a stone heap, rising slightly above the sandy surrounding. The protective metal box was pulled out onto the shore in parts by the work boat.

Over the following three years, the scientific data collected was processed, the wood was analysed, 3D models of the boat structure (with and without frames) were made, and an initial reconstruction of the hull lines was produced.

Exhibitions

The results of the research project on Zambratija boat were presented in 2017 with the exhibition accompanied by a four-language catalogue titled "Zambratija. Prapovijesni šivani brod / Prehistoric Sewn Boat / Una barca cucita preistorica / Un bateau cousu préhistorique".

**ZA
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JA**

Arheološki muzej Istre
ima čast pozvati Vas na otvorenje izložbe
ZAMBRATIJA – PRAPOVIJESNI ŠIVANI BROD
(Ida Koncani Uhač, Giulia Boetto, Marko Uhač)
Pula, Galerija C8, Carrarina 8
Petak, 7. srpnja 2017. u 12 sati

Il Museo archeologico dell'Istria
ha il piacere di invitarvi all'inaugurazione della mostra
ZAMBRATIJA - UNA BARCA CUCITA PREISTORICA
(Ida Koncani Uhač, Giulia Boetto, Marko Uhač)
Pola, Galleria C8, Via G. Carrara 8
Venerdì, 7 luglio 2017, alle ore 12

I.57

Izložba „Zambratija – Prapovijesni šivani brod“, pozivnica
Exhibition “Zambratija - Prehistoric Sewn Boat”, invitation
(izradio / made by: D.Tomić - Kadar)

U 2018. i 2019. godini izložba je postavljena u drugim gradovima u Hrvatskoj (Arheološki muzej u Zagrebu; Muzej grada Šibenika, Arheološki muzej u Zadru, Muzej grada Umaga, Galerija Eugena Kumičića u Brseču, Dubrovački muzeji), u Francuskoj (Musée d'Histoire i Mucemu Marseju), Sloveniji (Pomorski muzej „Sergej Mašera“ u Piranu) i Italiji (Salone degli Incanti u Trstu) (Sl. I.57-I.59).

U 2018. godini izložba je dobila nagradu Hrvatskog muzejskog društva, dok su projekt i izložba nagrađeni Godišnjom nagradom „Josip Brunšmid“ Hrvatskog arheološkog društva.

In 2018 and 2019, the exhibition moved to other cities in Croatia (Archaeological Museum in Zagreb, City Museum of Šibenik, Archaeological Museum in Zadar, City Museum of Umag, Galerija Eugen Kumičić in Brseč, Dubrovnik Museums), France (Musée d'Histoire and Mucem in Marseilles), Slovenia (Maritime Museum “Sergej Mašera» in Piran) and Italy (Salone degli Incanti in Trieste) (Figs. I.57-I.59).

In 2018, the exhibition was given a Croatian Museum Association award, while the project and exhibition received the “Josip Brunšmid” Annual Award of the Croatian Archaeological Society.

I.58 a,b,c

Izložba „Zamratija – Prapovijesni šivani brod“, postav u galeriji „Žitnica Rupe“, Dubrovački muzeji
 Exhibition “Zamratija - Prehistoric Sewn Boat”, set up in the gallery “Rupe Granary”, Dubrovnik Museums

I.59

Plakat „Zamratija – Prapovijesni šivani brod“
 Poster “Zamratija - Prehistoric Sewn Boat”
 (izradio / made by: D.Tomić - Kadar)



I.58 a



I.58 b



I.58 c



**ZA
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JA**

*Prapovijesni
šivani
brod*

*Prehistoric
sewn
boat*

*Una
barca
cucita
preistorica*

*Un bateau
cousu
préhistorique*



Izložba / Exhibition / Mostra / Exposition
GALERIJA C8 7.7. - 3.9. 2017.
Carrarina 8, Pula



Digitalna fotogrametrija nalazišta

Digital photogrammetry of the site

Vincent Dumas, Giulia Boetto

Od 1960-ih godina potreba za vjerodostojnim nacrtima podmorskih arheoloških ostataka potaknula je razvoj metode bilježenja podataka fotogrametrijom, koja je bila prilagođena prirodi nalaza, brodskom teretu i ostacima broda u podvodnom okruženju. Početni pokušaji su se bazirali na upotrebi filma stereoskopskog fotoaparata (Dumas *et al.* 2015, 127-130).

Primjena digitalnih fotoaparata i detaljna razrada postupka za stvaranje oblaka točaka preko guste epipolarne korelacije (Hulo 2010) napravila je preokret u metodologiji arheološkog dokumentiranja, kako u kopnenom, tako i u podvodnom okruženju. Osim toga, smanjenje troškova tehnike, sve veća snaga računala i razvoj sve većeg broja komercijalnih računalnih programa ili onih nastalih u slobodnom računalnom svijetu, ovu su tehnologiju učinili pristupačnom u svakom pogledu.

U sklopu toga, od 2008. godine skupina nautičkih arheologa iz Centra Camille Jullian nastoji razviti sustavnu i lako održivu metodu dokumentiranja na osnovi primjene digitalne fotogrametrije, a koja je u skladu s

Since the 1960s the need for reliable plans of underwater archaeological remains has led to the development of photogrammetric recording methods that are capable of being used on both cargoes and hull remains in an underwater environment. Initial attempts were based on the use of stereoscopic film cameras (Dumas *et al.* 2015, 127-130).

The move to digital cameras and the elaboration of the procedures necessary to generate point clouds using dense epipolar correlation (Hulo 2010) have revolutionized methods of archaeological planning in both dry and wet conditions. Moreover, the reduction in the cost of the materials required, increased computing power, and the development of an increasing number of commercial software packages and freeware programs have rendered this technique within reach on all levels.

Within this context, from 2008 the nautical archaeology team from the Centre Camille Jullian committed to developing a coherent and easily reproducible method suited to its own research needs for producing

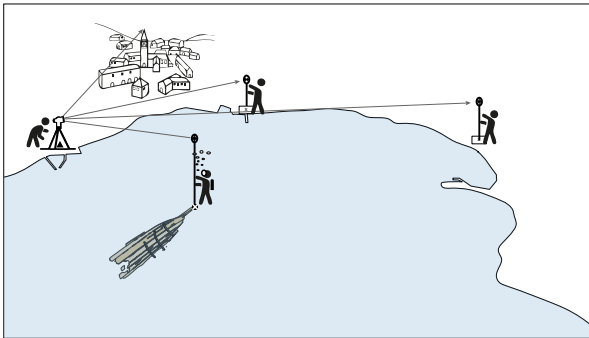
problematikom njezina istraživanja (Dumas 2011; 2012; Dumas *et al.* 2015).

Tome u prilog iznijet ćemo različite faze dokumentiranja broda iz Zambratije.

Položaj nalaza

Istraživačka kampanja tijekom 2013. godine rezultirala je otkrivanjem sačuvanih dijelova strukture broda (na površini od otprilike 6,5 m²). Zahvaljujući maloj dubini nalazišta (2,2-2,5 m) te blizini obale (oko 150 m), nalazište je georeferencirano uz pomoć totalne stanice. Za izmjeru je odabran planimetrijski sustav projekcije MGI/Balkans, zona 5. Izmjera je obavljena prema tršćanskom mareografu (Dumas 2011, 121-124).

Zbog pješčanog morskog dna u koje nije bilo moguće postaviti dugotrajnije fiksne točke oko broda, odlučeno je da se one postave na brodsku konstrukciju. Ove fiksne točke mjerene su s obale korištenjem prizme koja je bila postavljena na teleskopski štap (Sl. I.60, I.61).



I.60
Shematski prikaz postupka topografskog bilježenja podvodnih ostataka s obale
Diagram showing the procedure for recording the topography of the underwater archaeological remains from the shore
 (crtež / drawing by: V. Dumas)

Priprema olupine

Prije fotogrametrijskog dokumentiranja (faza mjerenja), brodski dijelovi su detaljno očišćeni od svih preostalih elemenata (sedimenti i alge) koji bi mogli prekriti katkad slabo vidljive detalje (sljubnice platica, elementi spajanja, tragovi alata, oznake brodograditelja). Najkrhkiji elementi, kao što su jelove letvice koje su prekrivale sljubnice platica, bili su učvršćeni inoks spojka. Tim je postupkom omogućeno zadržavanje letvica na mjestu, a ujedno

site plans using digital photogrammetry (Dumas 2011, 2012; Dumas *et al.* 2015).

Here, we first describe the various stages of the planning process carried out on the Zambratija wreck.

Site location

The 2013 excavation season uncovered all the preserved timbers (about 6.5 m²). As the site is in shallow water (2.2-2.5 m) and near to the shore (about 150 m) the position of the site could be recorded using a total station. The MGI/Balkans zone 5 projection was chosen to georeference the site. The Trieste record was referred to for heights above sea-level (Dumas 2011, 121-124).

As the sandy seafloor did not allow stable fixed points to be placed around the wreck, they were placed directly on the hull. These fixed points were measured by using a prism on an extensible pole viewed from the shore (Figs I.60, I.61).



I.61
Georeferenciranje olupine Zambratija totalnom stanicom prema fiksnim točkama na obali
Georeferencing the Zambratija wreck from fixed points on land using a total station
 (fotografija / photo by: Ph. Groscaux)

Preparing the wreck

Before starting the photogrammetric planning process (data acquisition phase), the wooden structures were carefully cleaned of all residues (sediments and seaweed) that might mask difficult-to-see details (planking joints, fasteners, tool marks, and carpenters' marks). The most fragile parts, such as the fir laths that covered the plank seams, were reinforced using stainless-steel staples. This allowed the laths to be held in place, preventing

su izbjegnuti rizici od klizanja ili pomicanja uslijed različitih snimanja. Očišćeno je i područje 50 cm oko ostataka brodske konstrukcije.

Za potrebe snimanja postavljene su dvije vrste oznaka: u prvoj su svi arhitektonski elementi imali alfa-numeričke oznake (Pomey, Rieth 2005, 99-102), dok se druga koristila za označavanje manje vidljivih detalja poput sljubnica platica ili elemenata spajanja.

Za prvi tip označavanja odabrane su žute plastificirane etikete s crnim tekstom (ispisane na etiketirki tipa Dymo) koje su vidljive i na 3D teksturiranim modelima¹ i na ortofotografijama. Te su oznake bile dobro pričvršćene za brodsku konstrukciju inoks čavličima ne bi li se spriječilo njihovo pomicanje tijekom faze snimanja, što je moglo dovesti do pogrešne izmjere modela.

Elementi spajanja označeni su pribadačama različitih veličina i boja, ovisno o vrsti spoja². Takvo označavanje ujedno omogućava i optimiziranje 2D ili 3D grafičkog prikaza, jasno određujući položaj i vrstu spojeva.

Privremeno mrežište

Privremeni lokalni koordinatni sustav, izrađen je postavljanjem metalne pravokutne mjerke, usmjerene prema magnetskom sjeveru uz sjeverni kraj brodske konstrukcije.

Druga pravokutna mjerka je postavljena na južnom dijelu, ne bi li se omogućila sigurnost u slučaju nedovoljnog preklapanja te kako bi se mogla provjeriti izmjera i nagib. Zatim su, horizontalno te paralelno s uzdužnom osi trupa broda, postavljene dvije fotoskale ne bi li se, s jedne strane, provjerila točnost mjerila modela, te s druge strane, kako bi to poslužilo kao mjerna referenca različitih fotomozaika generiranih iz fotogrametrijskih modela (Sl. 1.62).

Ovakvo privremeno mrežište omogućilo nam je dobivanje fotogrametrijskog modela u mjerilu, usmjerenog prema magnetskom sjeveru i u odnosu na horizontalnu os.

Faza fotografske dokumentacije

Ovu je fazu obavio fotograf koji je, uzimajući u obzir svjetlosne uvjete i zamućenost, izabrao najbolje moguće uvjete vidljivosti. Sve osobe iz istraživačkog tima su prije fotografiranja napustile nalazište, da bi se izbjegao rizik od zamućenja tj. pomicanja sedimenta.

Za snimanje je korišten profesionalni digitalni fotoaparat³ s vodootpornim kućištem s bljeskalicama

1 3D teksturirani modeli su površinski modeli isprepleteni u tri dimenzije izrađeni na osnovi digitalnih fotografija.
2 Najčešće su korištene pribadače u bijeloj i žutoj boji. Budući da se lokalitet nalazi na maloj dubini, za ovo snimanje su korištene i pribadače u crvenoj boji.
3 Fotoaparat Nikon D700, opremljen senzorom punog formata od 12 megapiksela i fiksnim žarišnim duljinama od 24 ili 20 mm.

them from slipping or moving while the photographic record was being made. A zone about 0.5 m around the wreck was also cleared.

Two series of labels and markers were used: the first tagged each element of the timber structure with an alpha-numeric code (Pomey, Rieth 2005, 99-102); the second marked difficult-to-see details, such as scarfs in the planking, or fasteners.

For the first type of labelling, plastic-coated yellow labels with black lettering (printed with a Dymo-type labelling machine) were used, which were visible on the texture-rendered 3D models¹ and on the orthophotographs. These labels were fixed to the structure with small stainless-steel nails to prevent them from moving during the data-gathering phase, which could jeopardize the correct calculation of the model.

The assembly system was marked using drawing pins and tacks of different sizes and colours for different features². This also meant the accuracy of the 2D plan and 3D models could be optimized while allowing the precise position and types of fasteners to be recorded.

Temporary grid

A temporary, site-specific, coordinate system was materialized using a metal set square horizontally positioned and aligned to magnetic north, placed to one side of the wreck, near its northern limit.

A second set square was also installed to the south to guard against problems caused by insufficient overlap and to check the scale and inclination. Two photographic scales were placed horizontally and parallel to the main axis of the hull remains both to check that the model is correctly scaled and to serve as a visual metric reference on the various photo mosaics generated from the model (Fig. 1.62).

This temporary grid allowed us to produce a scaled photogrammetric model, oriented to magnetic north, and with a horizontal axis.

Data acquisition phase

Data acquisition was carried out by a photographer who took account of light and turbidity to select the best possible conditions in terms of visibility. The rest of the team left the site to avoid causing disturbance (movement of items or particles).

A professional-standard digital camera³ in a waterproof housing with flashlights on articulated arms was

1 The 3D textured models are 3D mesh surface models rendered using the appropriate digital photographs.
2 The most commonly used colours are white and yellow. As the site is shallow, we also used red.
3 A Nikon D700, equipped with a full format, 12 mega pixel sensor and 24 and 20mm fixed focal lengths.



I.62

Olupina spremna za izmjeru.

Jedna od dvije metalne pravokutne mjerke, usmjerena prema magnetskom sjeveru, i dvije fotoskale postavljene za potrebe izrade 3D modela

The wreck prepared for survey.

One of two metal set squares, oriented to magnetic north, and two photographic scales are placed around the wreck to aid calculation of the 3D model

(fotografija / photo by: Ph. Groscaux)



I.63
Fotografiranje olupine za izradu
 fotogrametrijskog modela
Photographic documentation of
 the wreck for the photogrammetry
 (fotografija / photo by: V. Dumas)

postavljenima na pomične zglobove (Sl. I.63). Prvo je fotograf procijenio približnu rezoluciju snimaka s obzirom na senzor aparata, udaljenost predmeta snimanja i primijenjene žarišne duljine. Taj rezultat omogućio mu je da odredi površinu dohvata kamere te tako procijeni broj potrebnih fotografija za pokrivenost područja istraživanja. Ta je procjena uzela u obzir preklapanje od 60 % pojedine fotografije.

Ukupno su obavljena dva snimanja, prije i poslije podizanja rebrenica, u cilju dopune 3D modela unutarnje oplate broda.

Dokumentiranje brodskih rebrenica

Radi izrade modela odlučeno je da se rebrenice broda u Zamratiji izvade s nalazišta, kako bi ih se bolje proučilo na kopnu. S obzirom na nedostatak vremena te složenost oblika rebrenica, nisu izrađeni crteži na plastičnoj foliji (debeli plastični folija ili acetatni film) u mjerilu 1:1⁴ već je primijenjena metoda fotogrametrije. Radi cjelovite

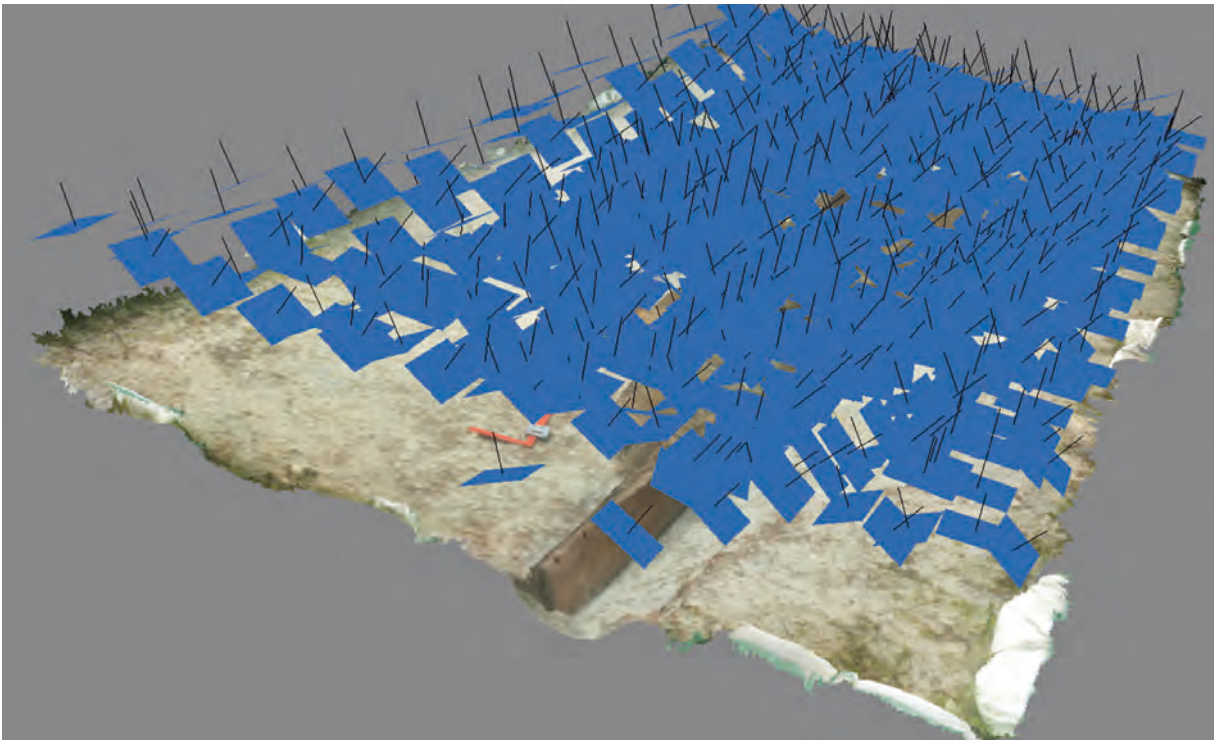
⁴ Sustavi mjernih ruku opremljenih mjernim ticalima koji omogućavaju 3D bilježenje kontura predmeta i njegovih karakterističnih linija vrlo su krhki i ne odgovaraju u potpunosti našim uvjetima rada (Ravn *et al.* 2011, 232-249; Kocabaş 2012, 1-15; Ranchin 2014, 58-60; Marlier *et al.* 2017). Prilikom dokumentiranja nije bila moguća upotreba prijenosnog skenera zbog nedostatnih financijskih sredstava.

chosen to take the photographs (Fig. I.63). Firstly, the photographer selected the approximate picture resolution according to the camera's sensor, the distance from the object, and the focal setting. These allowed the photographer to calculate the area covered by each image and thereby estimate the approximate number of images required to cover the zone to be recorded. This figure is calculated including a 60% overlap of each image. Finally, two complete series of photographs were taken, before and after the boat's frames were removed in order to complete the 3D model of the wreck's planking.

Recording the floor-timbers

At Zamratija we chose to raise the floor-timbers to study them on dry land. As there was little time and they had complex shapes, we chose not to trace them at 1:1 scale on transparent film (plastic or acetate)⁴. Instead, we used photogrammetry and, in order to have all faces of the timbers recorded, a minimum of two sets of data

⁴ Systems using measuring arms which allow a 3D record of the edges of an object are fragile and not suited to our working conditions (Ravn *et al.* 2011, 232-249; Kocabaş 2012, 1-15; Ranchin 2014, 58-60; Marlier *et al.* 2017). It was not possible to use a portable scanning device due to lack of funding.



I.64
Vizualizacija pozicioniranja
 snimaka upotrijebljenih za izradu 3D
 modela ostataka
Diagram showing the position of
 individual views used to build the 3D
 model of the wreck remains
 (izrada / made by: V. Dumas,
 Ph. Groscaux)

izmjere dijelova rebrenice sa svih strana, bila su potrebna najmanje dva dokumentiranja za pojedinu rebrenicu. Ova dva oblaka točaka spojena su kako bi se dobio bazni teksturirani 3D model. Interpretativni crtež kasnije je obrađen u računalnom programu CAO (Rhinoceros®).

Dokumentiranje kompaktnih i cjelovitih dijelova broda iz Zambratije predstavljalo je određeni problem. Naime, slomljene rebrenice i rebrenice složenijeg oblika zadavale su poteškoće prilikom rukovanja, što je dovelo do značajnih promjena u njihovoj geometriji te posljedično i do problema prilikom slaganja 3D modela.

Modeliranje gustom epipolarnom korelacijom

Za izradu 3D modela ostataka broda iz Zambratije korišten je program Photoscan (Agisoft), koji je dobro prilagođen analizi strukture i oblika broda. Naime, taj program omogućava stvaranje georeferentnog oblaka točaka u boji i fototeksturirane mreže. Proizvod se zatim može koristiti za izradu ortofoto planova (JPEG i GeoTIFF), oblaka točaka ili 3D modela koji se mogu eksportirati u više 3D formata (PLY, OBJ, VRML, Collada, PDF).

Za izradu prvog modela napravljeno je 618 snimaka prostorne rezolucije od 0,001 m/pixel, uz fiksnu žarišnu duljinu od 20/f2.8 mm na visini snimanja od 1,25 metara (Sl. I.64). Gustoća dobivenih točaka je 18.259 točaka po kvadratnom metru.

Drugi je model izrađen istim uređajem uz prostornu rezoluciju od 0,0008 m/pixel. Za izradu drugog modela

were recorded. These two point clouds were then used together to build a basic textured 3D model. An interpretative drawing of the framing was made later with the help of a CAO program (Rhinoceros®).

Recording the compact and solid pieces raised from the Zambratija wreck posed a specific problem. By contrast, the fractured frames, and those with more complex shapes proved difficult: when moved to obtain information for each of their sides, their shape altered significantly, making it difficult to match up the different parts when building the 3D model.

The dense epipolar correlation model

Photoscan (Agisoft) was chosen to calculate the 3D model of the Zambratija wreck because it was well adapted to the analysis of boat structure and shape. The program allows a coloured and georeferenced point cloud and a photo-textured mesh to be created.

These can then be used to produce orthophoto plans (JPEG and Geo TIFF) as previously established, point clouds, or 3D models, which can then be exported in a variety of 3D exchange formats (PLY, OBJ, VRML, Collada, PDF).

For the first photogrammetric series, 618 pictures were taken, providing a spatial resolution of 0.001 m/pixel, with a fixed focal length of 20/f2.8 mm, taken at a distance of 1.25 m (Fig. I.64). The density of points obtained was 18,259/m².

The second passage was carried out with the same

bilo je potrebno manje snimaka (546) jer nije bilo rebrenica. Dobivena gustoća točaka slična je prvoj: 18.986 točaka po metru kvadratnom (Sl. I.65).

Obim 3D modela

Mrežasti 3D model (Sl. I.66) ostataka broda iz Zambratija teksturiran je korištenjem neobrađenog fotogrametrijskog modela na kojem su vidljive prethodno postavljene oznake strukturalnih karakteristika broda (Sl. I.67).

Stvaranje shematskog 3D modela broda⁵ predstavlja prvi korak u postupku razumijevanja i rekonstrukcije izvornih oblika proučavanog broda (Sl. I.68). Pojedinačni dijelovi (kobilični element, rebrenice, oplata i spojni elementi) zasebno su iscrtani temeljem mrežastog modela nakon što je završena njihova zadovoljavajuće kvalitetna snimka, što nije bilo uvijek moguće za određene složene sisteme brodskih spojeva.

Ovaj je pročišćeniji prikaz čitljiviji i predstavlja osnovu za rad i promišljanje te donosi velik broj informacija

5 Svi sačuvani dijelovi ponovno su iscrtani na osnovi glavnih linija vidljivih na mrežnom 3D modelu.

set up for a spatial resolution of 0.0008 m/pixel. Fewer pictures were necessary (546) because the floor-timbers had been removed. The point density achieved was similar to that of the first series: 18,986/m² (Fig. I.65).

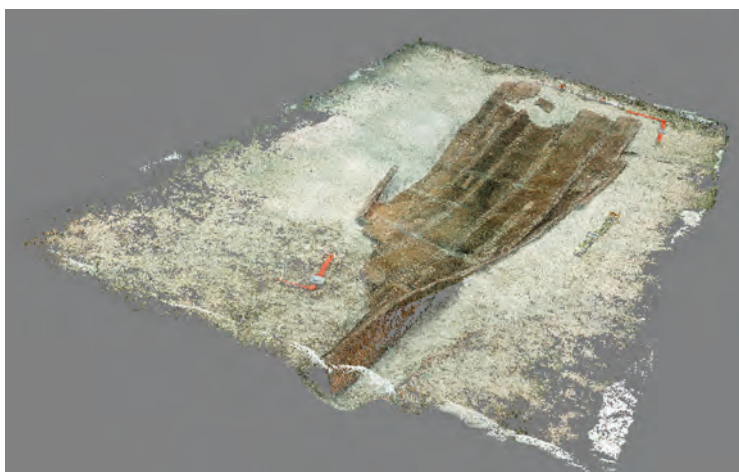
The range of 3D models

The 3D mesh model (Fig. I.66) of the Zambratija wreck was texture rendered using the raw photogrammetric model, in which the various labels used to mark the different preserved structural characteristics of the vessel are visible (Fig. I.67).

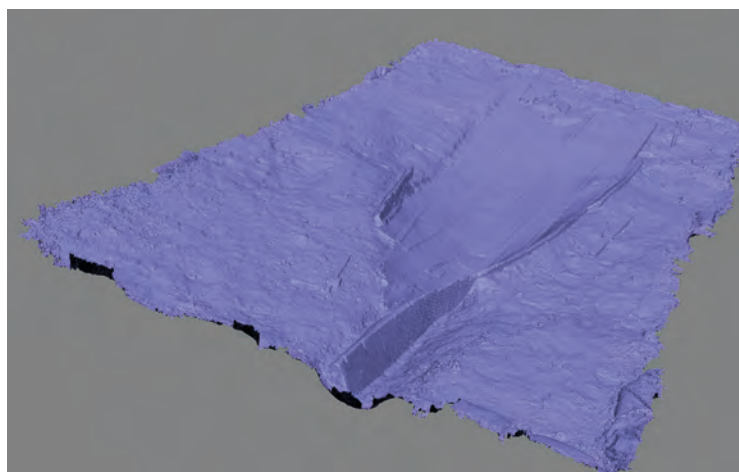
The creation of a schematic 3D model of the remains⁵ is the first stage in the process of understanding and reconstructing the original shape of a boat (Fig. I.68). Each piece (keel-like timber, frames, planking, and fasteners) was redrawn separately using the mesh model once a sufficiently complete record of each element was made, which was not always possible for certain complex systems of fasteners.

This simplified representation is more easily read

5 All of the preserved timbers were redrawn within the main lines recognized in the 3D mesh model.



I.65



I.66



I.67

I.65

3D oblak točaka

The 3D dense point cloud

(izrada / made by: V. Dumas, Ph. Groscaux)

I.66

Mrežasti 3D model

The 3D mesh model

(izrada / made by: V. Dumas, Ph. Groscaux)

I.67

Detalj mrežastog i teksturiranog 3D modela

Detail of the textured 3D mesh model

(izrada / made by: V. Dumas, Ph. Groscaux)

do kojih je prije bilo teško i naporno doći. Osnovna mjerenja (duljina, širina, debljina) mogu se obaviti mnogo preciznije i jednostavnije na ovakvom modelu nego na izvornome nalazu u moru. Obrada mjera je automatska, a mjerenja (primjerice razmak između malih drvenih čavala) se mogu primijeniti na sve vidljive elemente na modelu. Pa ipak, kako je prethodno navedeno, i dalje postoji potreba za obavljanjem brojnih zapažanja direktno na nalazištu, za vrijeme istraživanja.

Naposlijetku, 3D model izrađen fotogrametrijskim snimanjem poslužio je kao temelj za izradu prve hipoteze 3D digitalne rekonstrukcije izvornih oblika broda iz Zambratije.

and represents a base for future work and reflection. It contains a great deal of information that was previously difficult and laborious to obtain. Measurements (length, width, and thickness) are much more precise and more simply taken from the model than directly from the wreck under water.

The computation of volumes is automatic and the calculation of average spacings, such as between the pegs that wedge the stitches in place, can include all the visible examples in the model. However, as has been noted, there is still need for a number of observations to be made directly from the hull during the excavation.

Finally, the 3D model built from the photogrammetric survey of the remains was the basis for the first attempt at a 3D digital reconstruction of the original shape of the Zambratija boat.

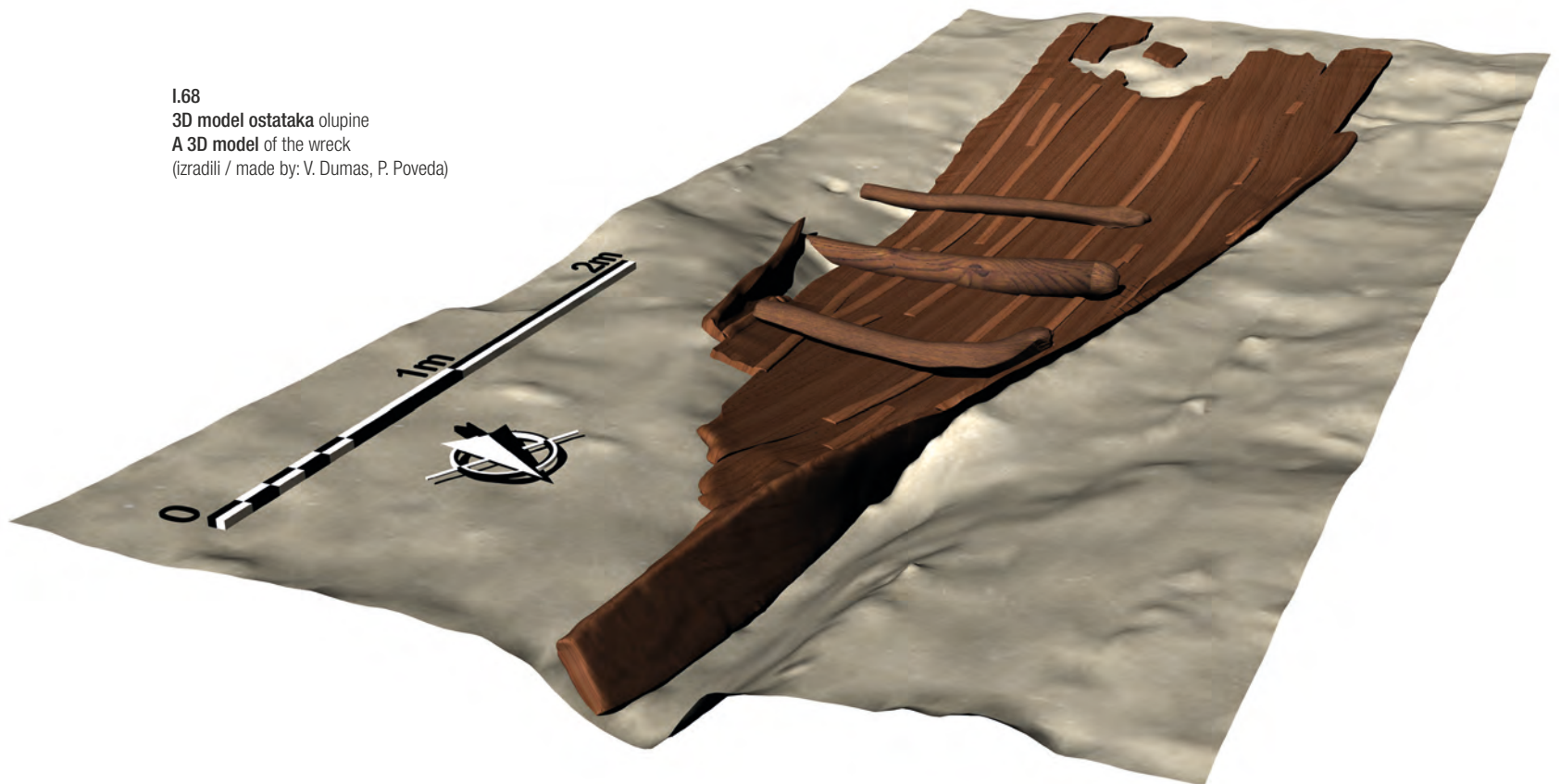
Grafička rekonstrukcija

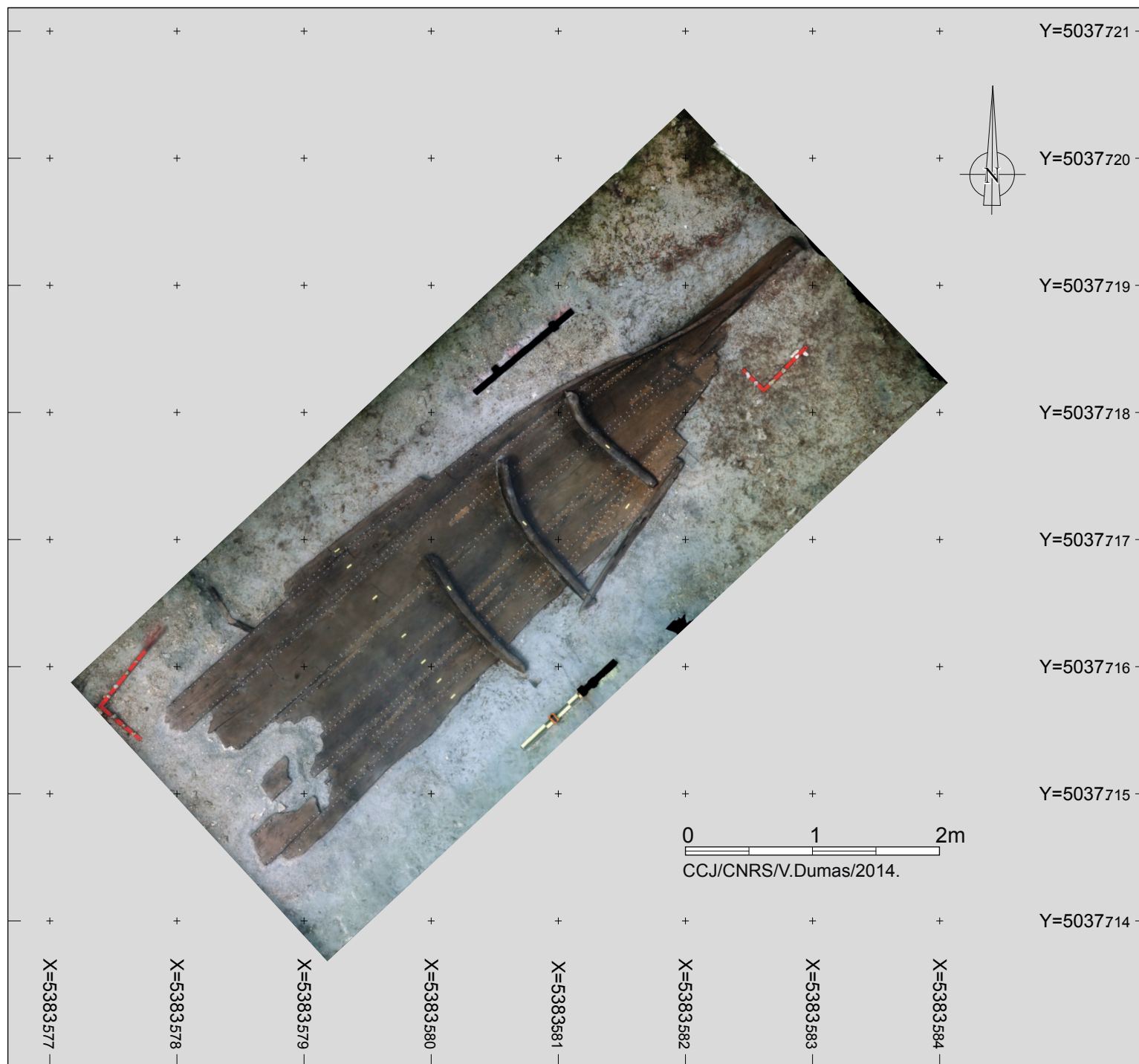
Premda trodimenzionalno modeliranje postaje nezaobilazan element u postupku proučavanja i rekonstrukcije, konvencionalni prikazi u dvije dimenzije (tlocrti, presjeci) i dalje ostaju nezaobilazni za znanstvene potrebe, kao i za primaran način ilustracije te usporedbe proučavanih olupina.

Graphical reconstruction

Although 3D models have become an inescapable stage in the analysis and reconstruction process, conventional 2D representations (plans and sections) are still the primary means of illustrating scientific reports and comparing wrecks that have been studied archaeologically.

1.68
3D model ostataka olupine
A 3D model of the wreck
(izradili / made by: V. Dumas, P. Poveda)





I.69
Ortofoto broda Zamratija
Orthophoto of the Zamratija boat
 (izradili / made by: V. Dumas, Ph. Groscaux)

Za izradu tlocrta korišten je ortofoto snimak brodske konstrukcije (prostorne rezolucije 0.002m/pixel) izrađene u računalnom programu Photoscan (Sl. I.69).

Na početku je odrađen prvi dio posla u programu CAD (AutoCAD) za potrebe georeferenciranja različitih ortofotografija i automatskog slaganja više različitih podatkovnih slojeva, uz korištenje njegovih brojnih opcija za crtanje.

Radi izrade finalnog modela te dobivanja rezultata koji bi bio što sličniji crtežu crtanom rukom, snimak je zatim

For plans, an orthophoto has been used (resolution 0.002 m/pixel) for the wrecksite generated directly using Photoscan software (Fig. I.69).

An initial attempt was made using a CAD program (AutoCAD), in order to use its capability of georeferencing the various orthophotos, which allowed different layers of data to be overlaid automatically, and to benefit from its powerful drawing tools.

In order to finalize the results and obtain drawings closer to those drawn by hand, the plan was then

eksportiran u program za vektorizaciju koji se temelji na upotrebi Bezierovih krivulja, poput Illustratora (Adobe).

Poprečni i uzdužni presjeci načinjeni su na osnovi trodimenzionalnog modela primjenom računalnog programa Rhinocéros®, koji može raditi i na bazi oblaka točaka i na bazi poligonalnih mreža. Ti su presjeci zatim ubačeni u Illustrator, kako bi ih se upotpunilo podacima koji su prethodno zabilježeni na skicama rađenim tijekom istraživanja.

Zaključak

Upotreba gustog oblaka točaka za dokumentiranje i modeliranje ostataka broda iz Zambratije omogućila je izradu kvalitetne dokumentacije, s jednakom razinom preciznosti kakva bi se mogla postići na kopnenom nalazištu.

Predmetni fotogrametrijski plan bio je presudan ne samo za izradu standardizirane grafičke dokumentacije, nego i kao potpora analizi arhitekture broda. Trodimenzionalni model ostataka broda nastao iz fotogrametrije bio je osnova za rekonstrukciju izvornog oblika i strukture broskog korita te njegovog pogona, koji zasad nema analogija na širem geografskom području.

Računalni programi:

<http://logiciels.ign.fr/?-Micmac,3>
<http://www.123dapp.com/catch>
<http://www.photomodeler.com/>
<http://www.agisoft.ru/>

exported to a vectorizing program based on Bezier curves, such as Illustrator (Adobe).

Transversal and longitudinal sections were created from the 3D model using Rhinocéros®, which is able to utilize both the point cloud and the polygonal mesh. These were then exported to Illustrator to be annotated with data marked on sketches made directly on site.

Conclusion

In conclusion, the use of the dense point cloud for the plan and the model of the Zambratija wreck remains enabled us to produce a high-quality record with the same level of precision that could be obtained for a terrestrial structure.

The photogrammetric plan was not only fundamental in producing a standard graphic record, but also supported the structural analysis of the boat. The 3D model of the remains generated from the photogrammetric survey served as the basis of the proposed reconstruction of the shape and structure of the hull and the propulsion system of this boat that is currently without parallel.

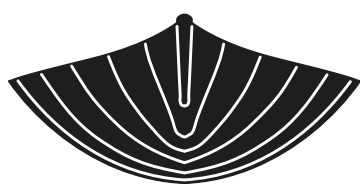
Computer programs:

<http://logiciels.ign.fr/?-Micmac,3>
<http://www.123dapp.com/catch>
<http://www.photomodeler.com/>
<http://www.agisoft.ru/>

II.

Brod

The Boat



Brodaska konstrukcija

The hull structure

Giulia Boetto, Marko Uhač, Ida Koncani Uhač

Olupina je orijentirana u smjeru sjeveroistok - jugozapad, dok je očuvani kraj trupa okrenut prema plaži. Kada je potonuo, brod je nalegao na istočni bok, koji je stoga ostao očuvan sve do završnog voja, za razliku od slabije očuvanog zapadnog boka (Sl. II.1 – II.3).

Ostaci trupa sačuvani su u dužini od 6,7 m te najvećoj širini od 1,6 m. Brod se sastoji od izdubljene osnovne monoksilnog stila, pet vojeva na istočnoj i dva voja na zapadnoj strani te tri rebrenice.

Nizovi zaptivenih rupa na oplati, koje su vjerojatno bile dio sistema za učvršćivanje rebara, identificiraju položaj još tri rebra. Ovo je dodatno potvrđeno tamnijim tragovima i otiscima baze rebara u paklinom premazanom unutarnjem dijelu trupa.

Opis brodskih ostataka

Uzdužni osni element

Jedan drveni komad (P2) izrađen od brijestovog trupca (*Ulmus* sp.), čiji je promjer veći od 40 cm, upotrijebljen je za izradu uzdužnog osnovnog elementa plovila (Sl. II.4). Na presjeku glavnog rebara plosnat je, debljine 3 cm, dok mu prema sjevernom kraju broda debljina doseže 21-23 cm (Sl. II.5 – II.7).

Širina mu se pak postupno mijenja od 39 cm u sredini do 6 cm na sjevernom kraju broda, mogućem pramcu

The wreck is oriented NE - SW with one preserved end of the hull pointing towards the beach. When the vessel sunk, it came to rest on one side, thus the western side is poorly preserved while the eastern side survives up to the sheerstrake (Figs II.1 – II.3).

The hull remains measure 6.7 m in length and 1.6 m in width at the widest section. The wreck consists of a carved logboat-style base, five strakes of planking on the eastern side and two strakes on the western side, as well as three floor-timbers.

The position of three more frames has been identified by rows of plugged holes on the planking that were probably part of the system used to attach the frames. Some dark traces on the wood, and evident marks left by the base of the frames on the interior layer of pitch, also clearly indicate the position of frame stations.

Description of the remains

The longitudinal axial element

A single piece of wood (P2) obtained from the trunk of an elm (*Ulmus* sp.) with a diameter of more than 40 cm constitutes the longitudinal axial element of the vessel (Fig. II.4). At the main frame, it is flat, and 3 cm thick, while towards the north end its thickness increases to 21-23 cm (Figs II.5 – II.7).

It narrows from 39 cm in the centre to 6 cm at the northern extremity, perhaps the bow, where the log is



gdje je trupac zašiljen. Tragovi alata poput sjekire ili tesla vidljivi su na unutrašnjoj površini. S arhitektonskog i strukturalnog gledišta neupitno je da je ovaj osnovni uzdužni element imao ulogu kobilice.

Na udaljenosti od 7,6 cm od sjevernog kraja kobiličnog elementa uočene su dvije horizontalne rupe pravokutnog presjeka (široke 1,3-1,5 cm i visoke 2-2,8 cm), međusobno razmaknute 19 cm (Sl. II.7). Rupe su vjerojatno služile za spajanje drugih drvenih dijelova na kraju kobiličnog elementa. Brodski element koji nedostaje je vjerojatno bio izrađen iz jednog komada drva i u njega su se umetali krajevi vojeva.

Oplata

Od brodskih ostataka, uz uzdužni osni element očuvane su još dvije platice na zapadnoj (P1 i P8) te pet platica (P3-P7) na istočnoj strani broda (Sl. II.4). Platice su u prosječne debljine 2,8 cm (prosječno od 1,9 cm do 3,3 cm). Njihova širina varira od 13,5 cm (P7) do 24,6 cm (P1). Svi ovi dijelovi napravljeni su od brijesta.

carved to a sharp point. Some tool marks, either made with an axe or adze, are visible in the inboard surface. This major longitudinal timber plays, from an architectural and structural point of view, the role of a keel.

At a distance of 7.6 cm from the keel-like timber's northern end, two horizontal holes, rectangular in section (1.3-1.5 cm wide and 2-2.8 cm high) and spaced 19 cm apart, have been noted (Fig. II.7). These were probably used to assemble another timber on top of the pointed end of the keel-like timber. This missing timber was probably carved from a single piece of wood to hold the ends of the strakes.

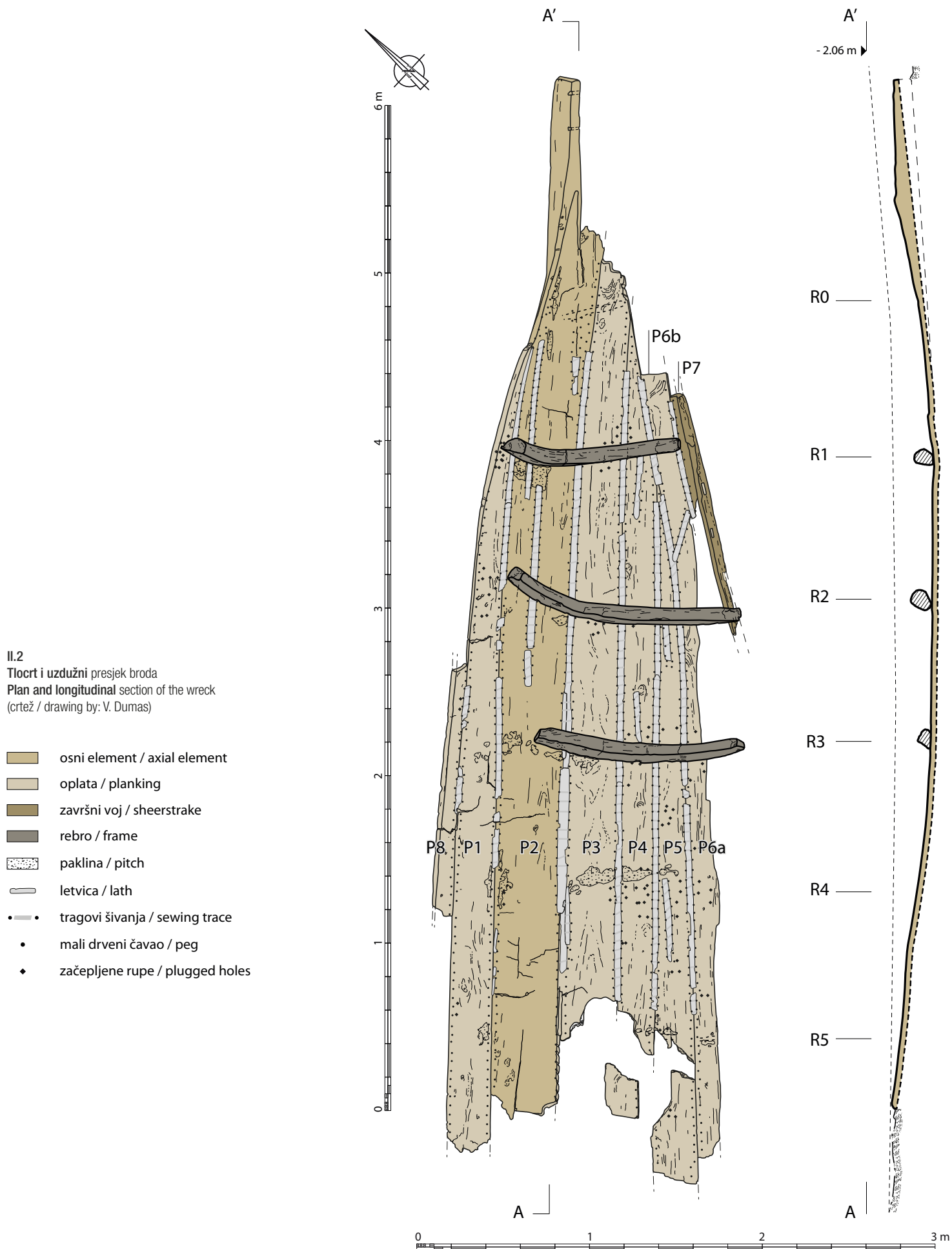
The planking

Two strakes on the west side (P1 and P8) and five strakes on the east side (from P3 to P7) are also preserved (Fig. II.4). The planks are 2.8 cm thick on average (range 1.9 cm to 3.3 cm). Their width varies between 13.5 cm (P7) and 24.6 cm (P1). All are made of elm.

II.1

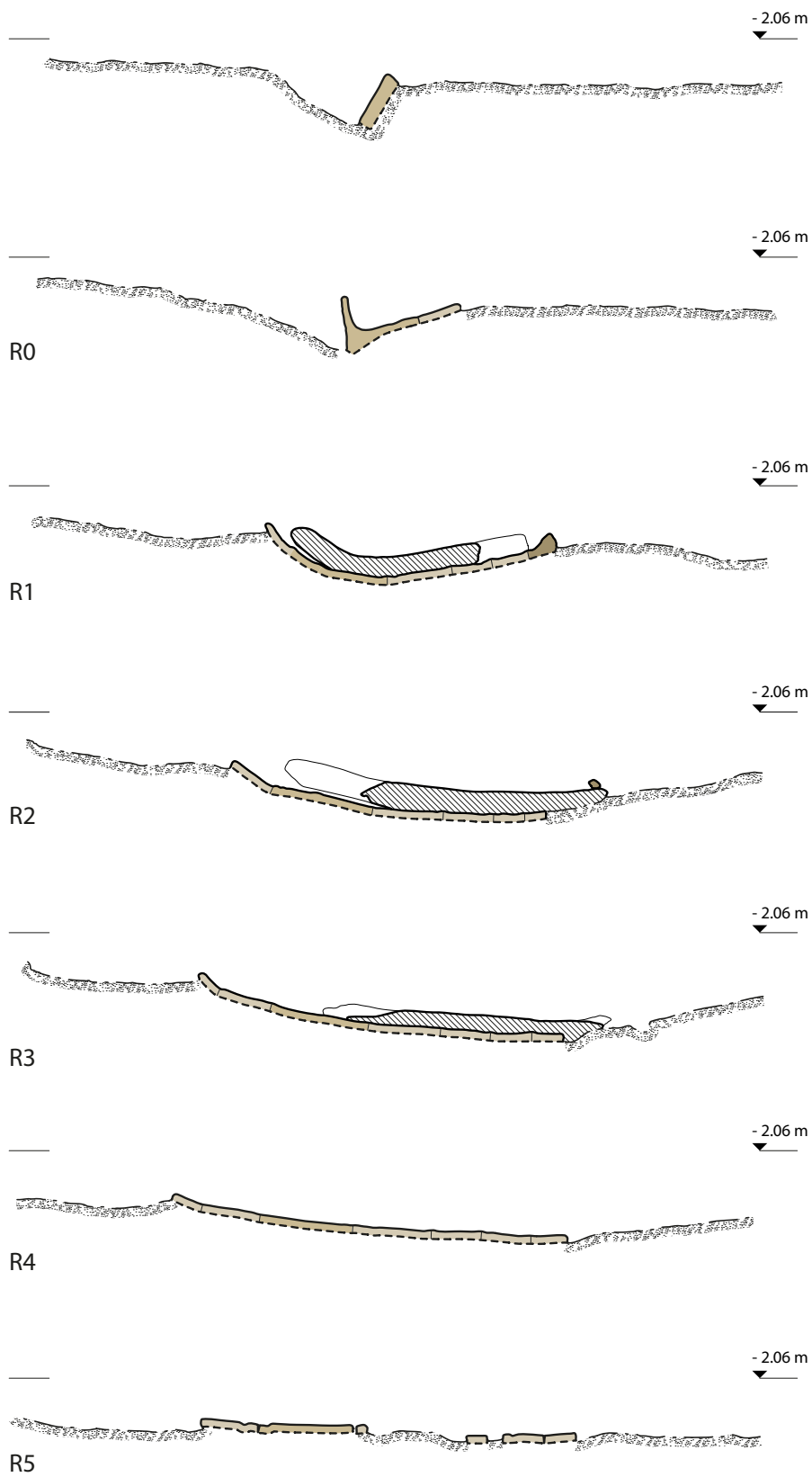
Pogled na brod sa sjevera. Dva kvadranta i dva foto mjerila su postavljena oko ostataka broda radi izrade fotogrametrije

View of the wreck from the north. Two quadrants and two photographic scales are positioned around the wreck remains for the purposes of photogrammetric survey (fotografija / photo by: Ph. Groscaux)

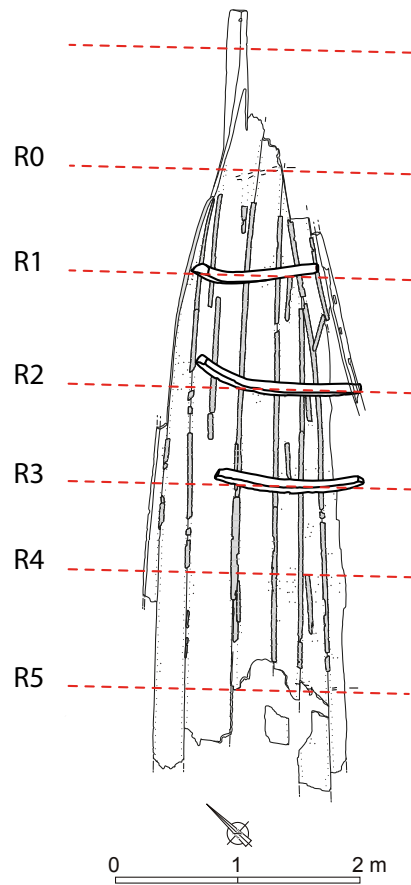


zapad / west

istok / east



II.3
Poprečni presjeci
Cross sections
(crtež / drawing by: V. Dumas)



Drugu (P4) i treću (P5) platicu karakterizira šiljati dio na sjeveru. Ovi su mrtvi vojevi korišteni kako bi se suzila oplata na oštrm kraju broda. Četvrti voj sačinjavaju dvije platice (P6a i P6b) povezane kosim ključem.

Peti, gornji voj (P7) predstavlja završni voj broda (Sl. II.8 – II.10). Ima oblik L-profila orijentiranog prema unutrašnjosti trupa, a debljina mu iznosi od 3 do 4,3 cm. Ovaj obrađeni element L-profila ima dva (moguće i tri) utora pravokutnog oblika, dužine 4,5 cm i 7 cm te širine 1,3 cm i 2,5 cm. Funkcija ovih pravokutnih utora još nije poznata (Sl. II.10), a razmak između njih iznosi 20 cm. Mogući treći utor nalazi se na južnom kraju, a od prethodnog je udaljen 23 cm.

The second (P4) and the third (P5) strakes are characterized by a pointed end to the north. These stealers were used to reduce the planking at the pointed end of the boat. Two planks (P6a and P6b) connected with an oblique scarf compose the fourth strake.

The fifth and upper strake (P7) is the sheerstrake (Figs II.8 – II.10). It has an L-shaped section oriented towards the interior of the hull and is 3-4.3 cm thick. This carved L-shaped timber has two (possibly three) rectangular, open mortises, the function of which is still uncertain (Fig. II.10). The mortises are, respectively, 4.5 cm and 7 cm long, 1.3 cm and 2.5 cm wide, and are spaced 20 cm apart. The possible third mortise at the southern end is placed 23 cm from the previous one.

Sustav spajanja oplata

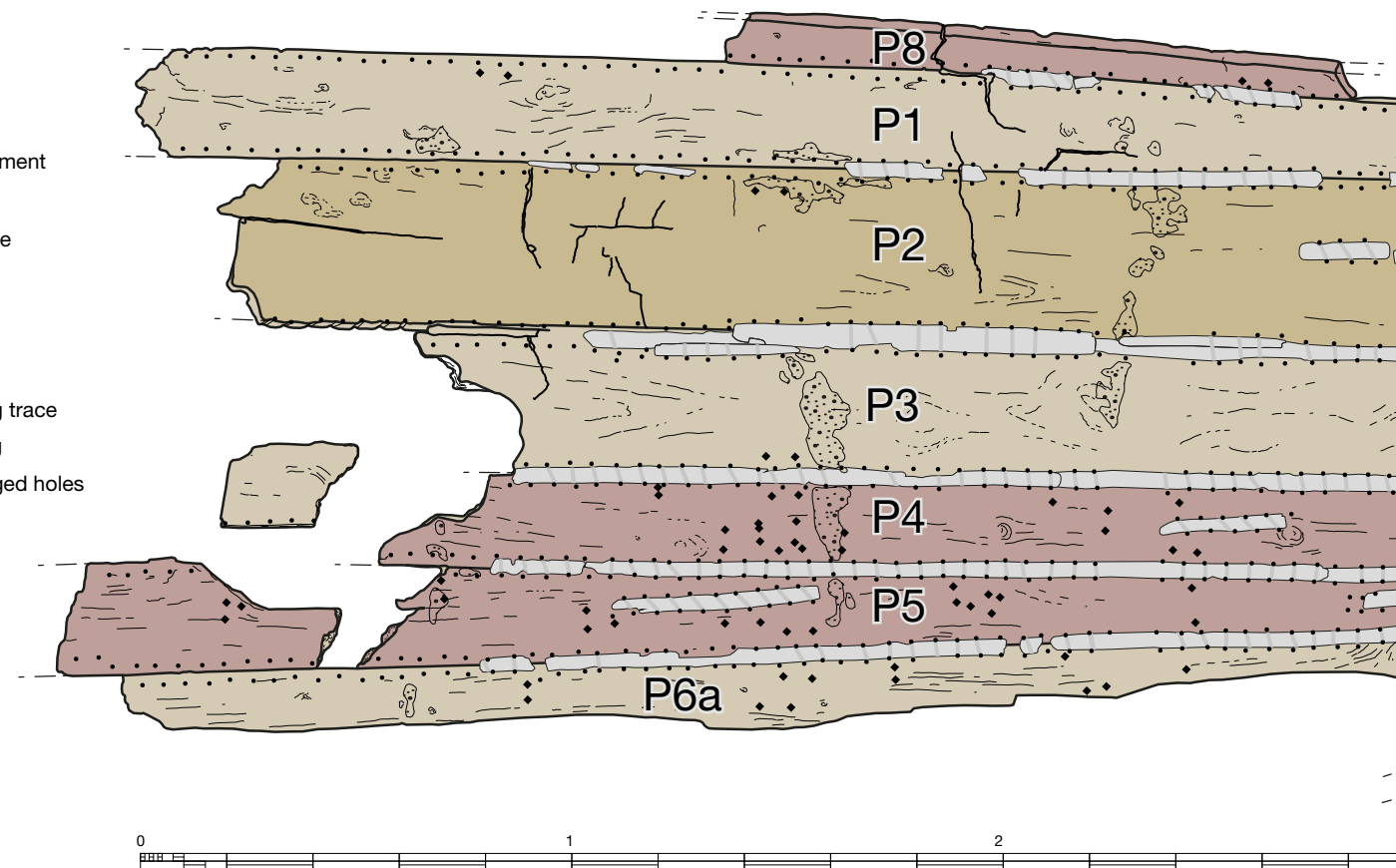
Vojevi položeni stično međusobno su spojeni uzdužnim sustavom šivanja (Sl. II.11, II.12). Šavovi, izvedeni od biljnih vlakana, nisu očuvani, ali se jasno vide njihovi tragovi na letvicama položenim preko sljubnica platica, a koje pripadaju sustavu vodonepropusnosti broda. Dvije

The system for assembling the planking

The strakes, which are flush-laid, are assembled using a longitudinal sewing system (Figs II.11, II.12). The stitches were made of vegetal fibres but have not been preserved. Instead, traces left by the cord are clearly visible on laths, placed over the seams before the planks

II.4
Brodsko oplata
The planking
(crtež / drawing by: V. Dumas)

- osni element / axial element
- oplata / planking
- završni voj / sheerstrake
- mrtvi voj / stealer
- paklina / pitch
- letvica / lath
- tragovi šivanja / sewing trace
- mali drveni čavao / peg
- začepljene rupe / plugged holes



vidljive tamnije linije, s razmakom od 7 mm do 1 cm, omeđuju svjetliju traku na kojoj se nalazila ligatura od nekadašnjih šavova.

Na bočnim sljubnicama platica nema tragova njihovog predspajanja korištenjem tipli. Međutim, moguće je da će se, nakon vađenja broda iz podmorja, proučavanjem uočiti navedene značajke.

Šivanje je izvedeno jednostavnim rubnim šavom (uzorak ///), a šavovi prolaze kroz rupe izbušene ukoso, dijagonalno prema sljubnicama platica (nisu okomite) (Sl. II.13, II.15, II.16). Kut šivanja je promjenjiv, ali su šavovi paralelni, s međusobnim razmakom od 2 do 4,5 cm.

Vanjski rubovi platica su zakošeni radi upuštanja ligature unutar sljubnica platica (Sl. II.14, II.18). Svaka rupa za šav sastoji se od dva ili tri žlijeba napravljena konkavnim dlijetom ili svrdlom (Sl. II.17). Upravo stoga presjek ovih rupa nije kružni već ovalan (promjera od 1 do 2 cm).

Mali drveni konusni i zašiljeni čavli, od jedan do tri po rupi, zaptivali su šavove (Sl. II.19, II.20). Čavli su izrađeni rasijecanjem stabljika mekog drva, poput joha (*Alnus* sp.) i topole (*Populus* L.), i imaju polukružni ili trokutasti presjek. Dugi su 2,2-2,7 cm, široki 6-8 mm, debeli 3-5 mm), a zabijani su s unutrašnje strane trupa, s prosječnim

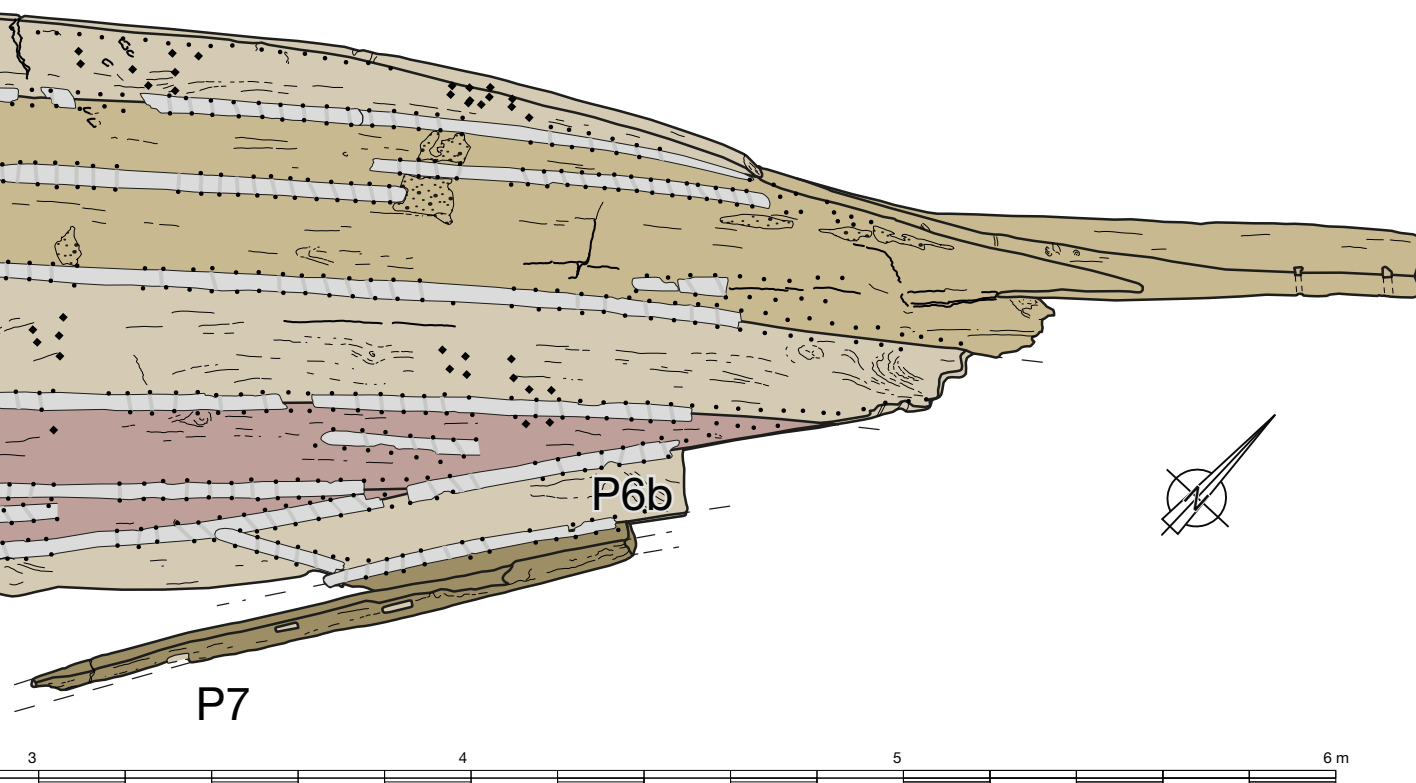
were sewn together to make the vessel watertight. Two dark lines, spaced 7 mm to 1 cm apart, flank a lighter zone where a ligature ran.

No evidence of pre-assembly of the planks using dowels was seen along the visible plank edges. However, it is possible that once the boat is recovered from the seabed, such features might be found.

The sewing consists of simple over-edge stitches (/// pattern) going through oblique stitch holes cut diagonally, rather than perpendicularly, to the plank edges (Fig. II.13, II.15, II.16). The angle of the sewing isn't regular, the angle of the stitches varies while they remain parallel to each other. The stitches were spaced 2 to 4.5 cm apart.

The external plank edges are chamfered to allow the passage of the ligature without it protruding (Figs II.14, II.18). Each stitch hole is composed of two or three grooves carved with a gouge or a drill (Fig. II.17). For that reason, the section of these holes isn't circular but oval and measures around 1 to 2 cm in width.

Small tapered and sharpened pegs, at least one to three for each stitch hole, locked each stitch in place (Fig. II.19, II.20). The pegs, obtained from splitting



II.5

Šiljati sjeverni kraj kobličnog elementa, pogled sa sjevera
The pointed northern end of the keel-like timber viewed from the north
(fotografija / photo by: Ph. Groscaux)



II.5

II.6

Tragovi alatki vidljivi na unutrašnjoj površini šiljatog sjevernog kraja
The woodworking marks visible on the interior surface of the pointed northern end
(fotografija / photo by: Ph. Groscaux)



II.6



II.7

II.7

Detaljan prikaz para horizontalnih rupa izdubljenih na šiljatom kraju kobiličnog elementa

Detailed view of the pair of horizontal stitch holes carved in the pointed end of the keel-like timber
(fotografija / photo by: Ph. Groscaux)

II.8

Završni voj L profila i središnji dio broda, pogled sa sjevera

The L-shaped sheerstrake and the central part of the wreck from the north
(fotografija / photo by: Ph. Groscaux)



II.8

II.9

Završni voj L profila i rebrenice R2 i R1
The L-shaped sheerstrake and the floor-timbers R2 and R1
(fotografija / photo by: Ph. Groscaux)

II.10

Četverokutni utori na gornjoj strani završnog voja L profila. Na fotografiji se s desne strane vidi gornji kraj rebrenice R1
The pair of rectangular holes carved in the upper face of the L-shaped sheerstrake. On the right side of the image, the top end of floor-timber R1 is visible
(fotografija / photo by: Ph. Groscaux)



II.9



II.10



II.11

Brodski vojevi od P3 (vrh) do završnog voja L profila P7 (dno). Vidi kosi spoj voja platica P6a i P6b te popravak pukotine u sredini platice P4. Bijele oznake nalaze se na pozicijama malih drvenih čavala koji su zaptivali rupe za šavove

The strakes from P3 (top) to the L-shaped sheerstrake P7 (bottom). Note the diagonal scar in the strake joining planks P6a and P6b, and the repair of a crack in the middle of plank P4. The white drawing pins indicate the position of pegs locking the stitches in place (fotografija / photo by: Ph. Groscaux)

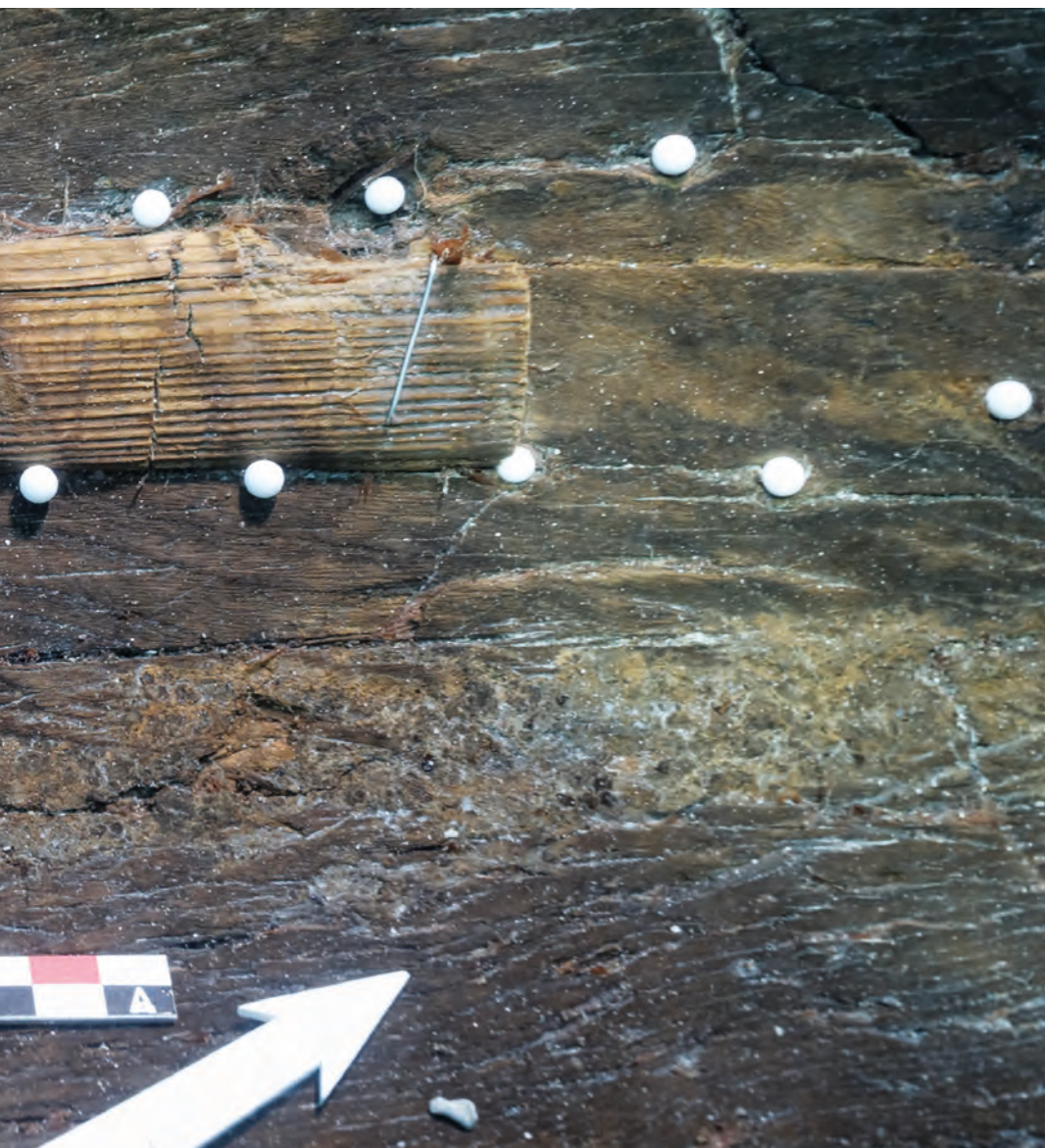


razmakom od 6 cm od centra do centra čavla (između 4 i 8 cm). Razmak od ruba platica (sljubnice platica) je nepravilan, između 1,3 i 2 cm.

Tanka letvica od jele (*Abies alba*), širine 3-4 cm, položena je preko sljubnica prije šivanja radi učvršćenja sloja nepovezanih biljnih vlakana (Sl. II.11, II.12, II.21). Ovaj sloj napravljen je od nepovezanih biljnih vlakana. Pronađena biljna vlakna se mogu dovesti u vezu s morskom travom (*Cymodocea nodosa*) te, u manjoj mjeri, s mahovinom (*Neckera crispa*). Postoji razumna sumnja da je morska trava izvorno bila korištena kao materijal za postizanje vodonepropusnosti. Naime, korijenje ovih morskih biljaka prekrilo je brodsku konstrukciju i ušlo ispod letvice, zbog čega ga je prilikom istraživanja oplate bilo potrebno ukloniti.

softwood stems such as alder (*Alnus* sp.) and poplar (*Populus* L.), are semi-circular or triangular in section. They are 2.2-2.7 cm long, 6-8 mm wide, and 3-5 mm thick. They were driven from the inside of the hull at an average spacing (centre-to-centre) of 6 cm (range 4 to 8 cm). The distance from the edge of the planks is irregular and measures 1.3-2 cm.

Thin laths, 3-4 cm wide, made of fir (*Abies alba*), were placed over the seams before sewing to hold wadding (Figs II.11, II.12, II.21). Under the lath, some loose vegetal fibres were found mostly belonging to sea-grasses (*Cymodocea nodosa*) and, to a minor extent, to moss (*Neckera crispa*). Reasonable doubt exists about whether the sea-grass remains were part of the original material used for waterproofing. The roots of these marine plants covered the wooden structures and entered



II.12

Detalj tragova od ligature na letvici postavljenoj preko sljubnica platica
Detail of the marks left by ligature on the laths placed over the seams
 (fotografija / photo by: Ph. Groscaux)

Neke pukotine na oplati (P4 i P5) i na kobiličnom elementu P2 također su bile popravljene jednakom tehnikom šivanja, kao i jednakom metodom brtvljenja i osiguravanja vodonepropusnosti plovila (Sl. II.2, II.22). Teško je ustanoviti jesu li ovi popravci napravljeni tijekom izgradnje broda ili za njegova radnog vijeka.

Između kobiličnog elementa P2 i platice P3 dvije letvice se preklapaju, što jasno ukazuje na popravke.

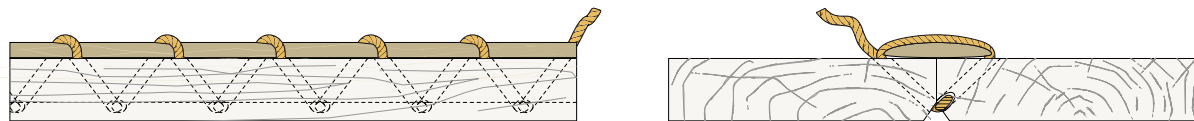
Pored letvica i umetnutog sloja biljnih vlakana, vodonepropusnost je dodatno osiguravao i zaštitni premaz paklinom na čitavoj unutarnjoj strani trupa.

under the laths making it necessary to cut during the cleaning of the hull.

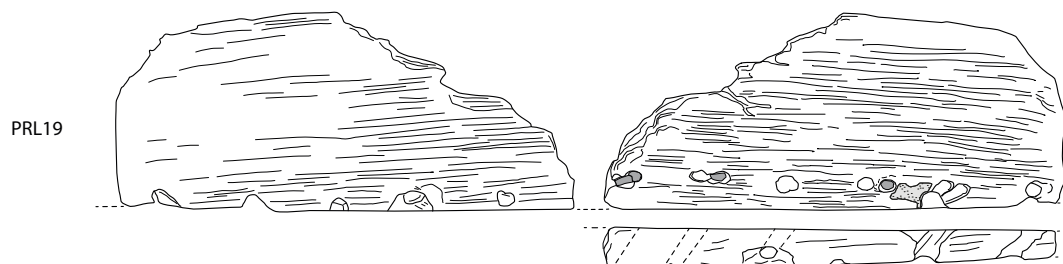
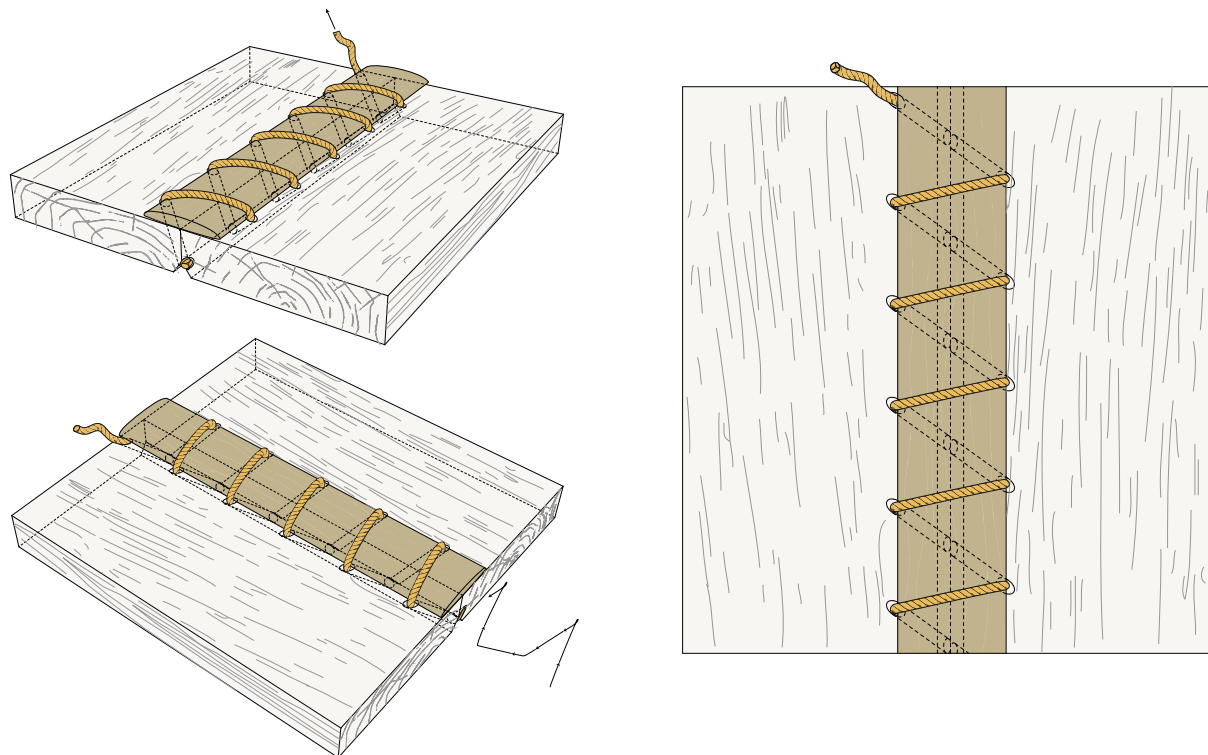
Some cracks in the planking (P4 and P5) and the keel-like timber P2, were repaired using the same sewing technique and the same system of wadding and ensuring the watertightness of the vessel (Figs II.2, II.22). It is difficult to know if these repairs were done during the construction or later during the working life of the boat.

Between the keel-like timber P2 and plank P3, two laths are superposed at some points, clearly indicating repairs.

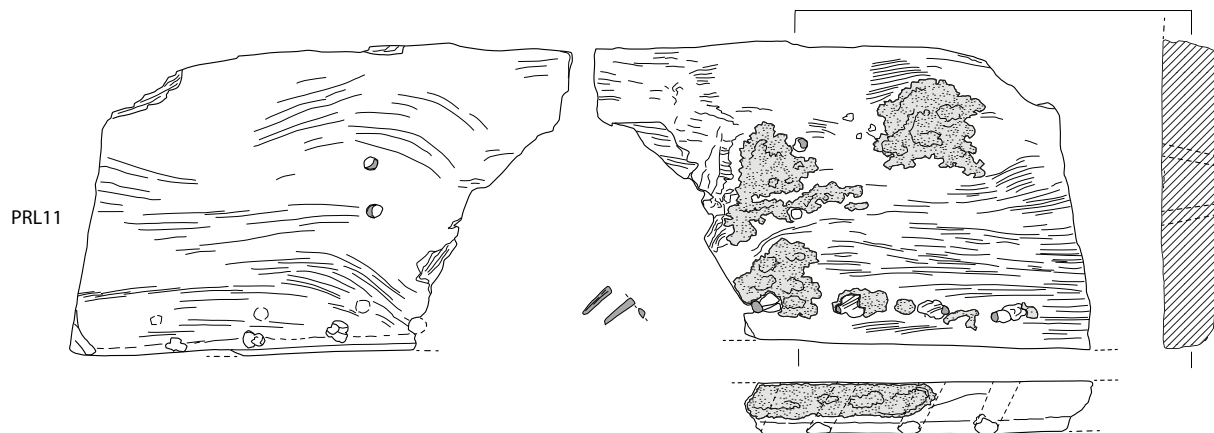
In addition to the laths and wadding, an interior coat of pitch ensured the hull was watertight.





Il.13
Aksonometrijska rekonstrukcija
 sistema šivanja oplata
Axonometric reconstruction of the
 sewing system used for the planking
 (crtež / drawing by: P. Poveda)



Il.14
Dva ulomka oplata, PRL19 i
 PRL11, izvađenih s nalazišta
Two planking fragments, PRL19
 and PRL11, recovered from the
 seabed
 (crtež / drawing by: G. Boetto)



0 10 20 cm
 © G. Boetto / CCI / CNRS / 2016

 mali drveni čavao / peg
 paklina / pitch



II.15
Pogled na slomljeni kraj kobiličnog
 elementa P2 sa zakošenim rupama
 za šavove
View of the broken end of the
 keel-like timber P2 with oblique
 holes for stitches
 (fotografija / photo by: Ph. Groscaux)



II.16
Detaljni prikaz žljebova koji čine
 rupu na fragmentu platiće PRL19
Detail of the grooves composing a
 stitch hole on plank fragment PRL19
 (fotografija / photo by: Ph. Groscaux)

II.17

Detalj unutrašnjosti fragmenta platice PRL11 s duguljastim rupama. Vidljiva je prisutnost žućkaste pakline koja se koristila za zaštitu trupa

Detail of the interior of the plank fragment PRL11 showing the oblong stitch holes. Note the presence of yellowish pitch used to protect the hull
(fotografija / photo by: Ph. Groscaux)



II.18

Detalj zakošenog ruba platice PRL11

Detail of the outboard chamfered edge of plank fragment PRL11
(fotografija / photo by: Ph. Groscaux)





II.19

II.19
Detalj malog drvenog čavla koji je služio za zaptivanje šava, na fragmentu platiće PRL19
Detail of a peg used to lock the stitching on plank fragment PRL19
 (fotografija / photo by: Ph. Groscaux)

II.20
Mali drveni čavli za zaptivanje rupe šava
Pegs used to lock a stitch
 (fotografija / photo by: Ph. Groscaux)

II.21
Ulomak letvice s ostatkom biljnog materijala koji je korišten za osiguravanje vodonepropusnosti sljubnica
Fragment of a lath with remains of the vegetal fibres used for waterproofing
 (fotografija / photo by: Ph. Groscaux)



II.20



II.21





II.22
Pogled na popravak pukotine u sredini kobličnog elementa P2
View of the crack repairs in the middle of keel-like timber P2
(fotografija / photo by: Ph. Groscaux)

Rebra

Tri rebrenice (R1, R2 i R3) pronađene su *in situ*, a identificirana je pozicija još tri rebra, jednog na sjeveru (R0) i dva na jugu (R4 i R5) (Sl. II.23). Istočna strana rebara očuvana je do vrha, dok je njihov zapadni dio samo dijelom očuvan (Sl. II.24 – II.26).

Rebrenice su široko razmaknute (oko 83 cm u prosjeku) i imaju trapezoidni presjek (prosječne širine 8,4 cm i prosječne visine 11,3 cm) s uskom donjom stranom i zaobljenim širim gornjim dijelom (Sl. II.27). Dvije rebrenice su izrađene od johe (*Alnus* sp.) (R1 i R3), a treća (R2) od drva divlje kruške (*Pyrus communis* L.).

Donja strana rebrenica je ravna i oblikovana tako da odgovara unutrašnjoj strani oplata (Sl. II.28). Neki od vidljivih malih tragova na donjoj strani vjerojatno su nastali kontaktom između rebrenice i letvica.

Pored toga, na donjem dijelu rebrenica nalaze se slivnice koje omogućavaju protok kaljužne vode. Rebrenica R1 ima jednu kvadratnu slivnicu (široku 2,6 cm i visoku 1-1,6 cm) (Sl. II. 29 – II. 32), dok rebrenica R2 ima dvije trapezoidne slivnice koje su međusobno razmaknute 16 cm (široke su 3 cm, a visoke 1,1-1,8 cm) (Sl. II. 33, II.34). Na rebrenici R3 nisu bile izrađene slivnice.

The frames

Three floor-timbers (R1, R2 and R3) were found *in situ*, and traces of three additional frames were identified, one at the north (R0), and two at the south (R4 and R5) (Fig. II.23). The tops of the eastern arms are preserved, while the western arm is broken (Figs II.24 – II.26).

Widely spaced (around 83 cm on average), these floor-timbers have a trapezoidal section (8.4 cm wide, 11.3 cm high on average) with a narrow foot and a rounded, wider upper surface (Fig. II.27). Two of these frames (R1 and R3) are made of alder (*Alnus* sp.), while the third (R2) was obtained from a wild pear tree (*Pyrus communis* L.).

The lower face of the floor-timbers is smooth and shaped to match the inner surface of the planking (Fig. II.28). Fine marks visible on the lower face may have been produced by friction between the frames and the laths.

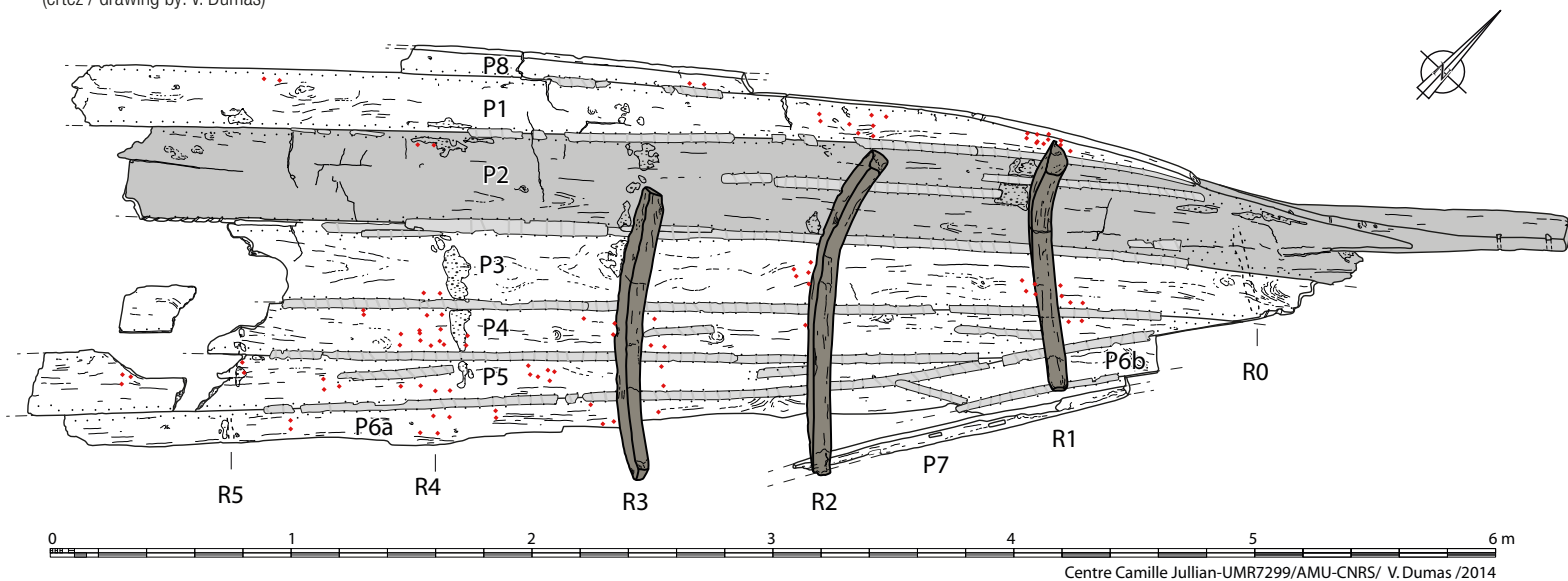
Additionally, the foot of each floor-timber was carved with limber holes, allowing the circulation of bilge water. Floor-timber R1 has a single quadrangular central limber hole (2.6 cm wide, 1-1.6 cm high) (Figs II.29 – II.32), while floor-timber R2 has two trapezoidal limber holes spaced 16 cm apart and 3 cm wide, 1.1-1.8 cm high (Figs II.33, II.34). No limber holes are present in floor-timber R3.

II.23









Brodsko rebra

The frames

(crtež / drawing by: V. Dumas)



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- | | | | |
|---|--|---|--|
|  rebrenica / floor-timber |  osni element / axial element |  paklina / pitch |  tragovi šivanja / sewing trace |
|  začepljene rupe / plugged holes |  oplata / planking |  letvica / lath |  mali drveni čavao / peg |



II.24
 Pogled s juga na tri sačuvane rebrenice
 View from the south of the three preserved floor-timbers
 (fotografija / photo by: Ph. Groscaux)

II.25
Potpuno sačuvani istočni kraj
rebrnice R1
The complete eastern end of
floor-timber R1
(fotografija / photo by: Ph. Groscaux)



II.25

II.26
Uništeni zapadni kraj
rebrnice R1
The broken western end
of floor-timber R1
(fotografija / photo by: Ph. Groscaux)



II.26



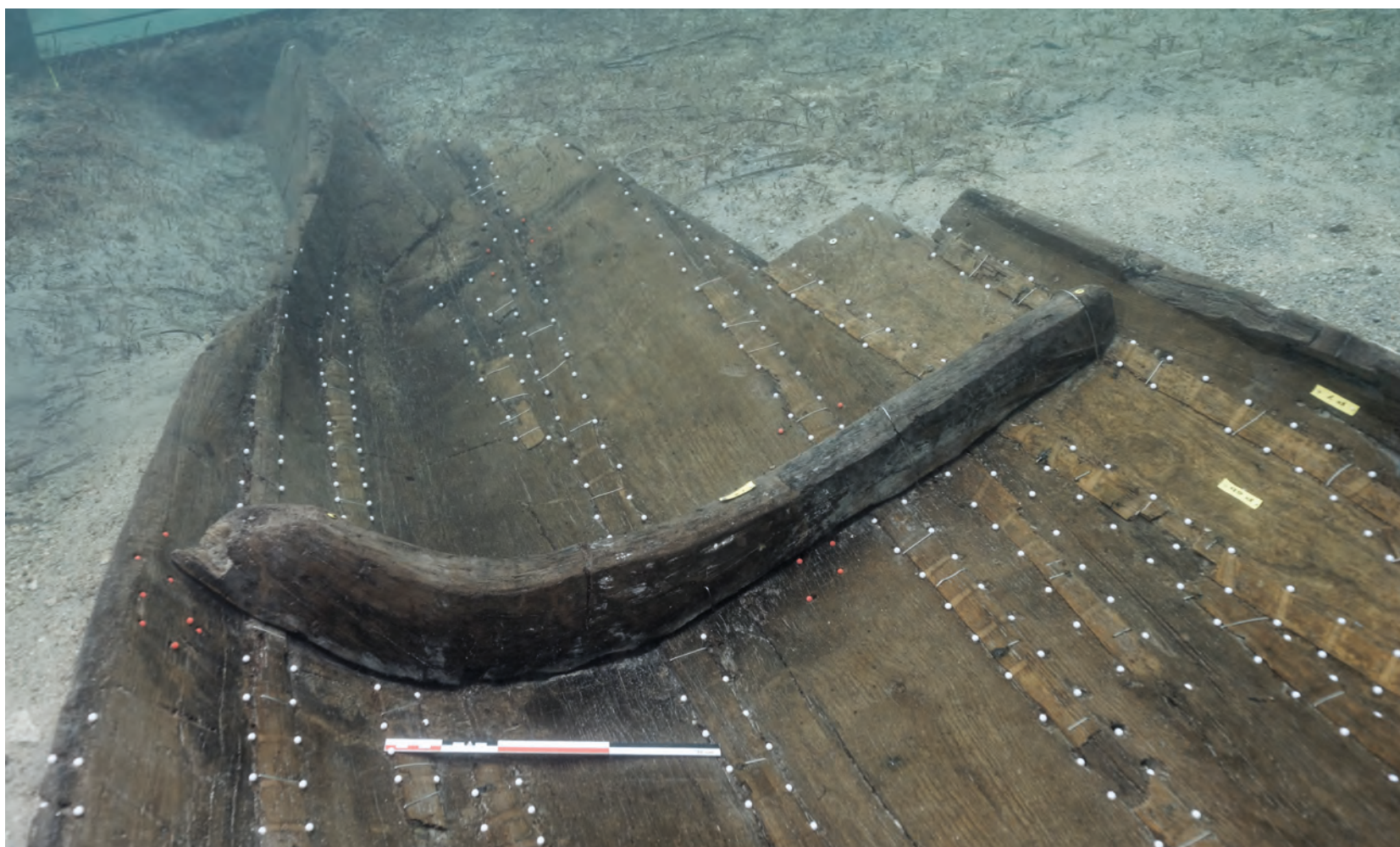
II.27



II.28

II.27
Trapezoidni presjek s uskom bazom i zaobljenom gornjom površinom rebrenice R1
The trapezoidal section with a narrow foot and rounded upper surface of floor-timber R1
 (fotografija / photo by: Ph. Groscaux)

II.28
Tragovi obrade drva na bočnoj strani i bazi rebrenice R1
Woodworking marks on the side and foot of floor-timber R1
 (fotografija / photo by: Ph. Groscaux)



II.29

II.29
Pogled s juga na rebrenicu R1
View from the south of floor-timber R1
 (fotografija / photo by: Ph. Groscaux)

II.30
Četverokutna središnja slivnica
rebrenice R1
The quadrangular central limber
hole of floor-timber R1
(fotografija / photo by: Ph. Groscaux)



II.30

II.31
Četverokutna središnja slivnica
rebrenice R1
The quadrangular central limber
hole of floor-timber R1
(fotografija / photo by: Ph. Groscaux)



II.31

Površina rebrenica je pažljivo obrađivana i vidljivi su mnogobrojni tragovi alata, vjerojatno sjekire (Sl. II.28, II.31). Upotreba dlijeta i drugih sječiva potvrđena je za potrebe izrade slivnica (Sl. II.32, II.34).

The surface of the frames is carefully worked and many tool marks left by the axes used are evident (Figs II.28, II.31). The use of chisels and other cutting blades is attested in particular for fashioning the limber holes (Figs II.32, II.34).

Spajanje rebara za oplatu

Rebrenice nemaju rupe za čivije, čavle ili šavove što znači da su izvorno bile privezane za oplatu sustavom vanjskog vezivanja. Ove ligature, koje se nisu očuvale, prolazile su kroz koso probušene rupe u platicama,

Fastening the frames to the planking

The floor-timbers lack holes for treenails, nails or stitches, and were originally lashed to the planking. The lashings did not survive, but are indicated by holes cut obliquely through the planks and pegs that locked them in place



II.32

II.32
Tragovi obrade na četverkutnoj
 središnjoj slivnici rebrenice R1
Woodworking marks on the
 quadrangular central limber hole of
 floor-timber R1
 (fotografija / photo by: Ph. Groscaux)



II.33

II.33
Pogled s juga na rebrenicu R2.
 Dvije slivnice su vidljive na njenom
 dnu
View from the south of floor-timber
 R2. The two limber holes are visible
 at its base
 (fotografija / photo by: Ph. Groscaux)



II.34

II.34
Par četverkutnih slivnica na
 rebrenici R2
Detail of the pair of rectangular
 limber holes of floor-timber R2
 (fotografija / photo by: Ph. Groscaux)

II.35

Fragment platice PRL11 s vidljivim rupama za šavove i parom rupa u sredini za vezanje rebra

Plank fragment PRL11 showing the stitch holes near the edge and a pair of holes used for lashing the frame in place at its centre

(fotografija / photo by: Ph. Groscaux)

II.36

Detalj para zakošenih rupa na unutrašnjoj površini platice PRL11, korištenih za vezanje rebra

Detail of the pair of oblique holes used for lashing the frame in place on the interior surface of plank fragment PRL11

(fotografija / photo by: Ph. Groscaux)

a zatim su zaptivene malim drvenim čavlima (Sl. II.35 – II.38). Uzduž rebrenica su identificirane koncentracije probušenih rupa (Sl. II.23), ali bez detaljne analize oplate nije ih moguće rekonstruirati, barem ne prije no što se platice podignu s morskog dna. Ipak, dislocirani komad oplate (PRL19) koji je bio izvađen s morskog dna na sreću ima očuvan jedan par rupa kroz koje je prolazila ligatura. Unutarnji promjer ovih rupa (8 mm) je malo veći od vanjskog promjera (6-7 mm), tako da je razmak između ovog para rupa s unutarnje strane platice 2,4 cm, a vanjske 3,5 cm. Vezivanje je izvedeno jednostavno, a izvana rupe nisu povezane utorom koji štiti ligature.

Sustav vezivanja rebrenica potvrđen je prisutnošću žlijeba u obliku slova V, dubokog 5 mm, a vidljivog na vrhu rebrenice R3. Također su tijekom istraživanja primijećeni slabo vidljivi križni tragovi preko rebrenica, koji su nestali ubrzo nakon što je drvo otkriveno.

(Figs II.14, II.35 – II.38). Groups of plugged holes in the planking were observed along the frames (Fig. II.23), but the reconstruction of the lashing pattern is not possible without a more detailed observation of the wooden remains, which will be possible only after the planks are raised from the seabed. Nevertheless, the displaced plank fragment (PRL19), which was retrieved from the seabed, fortunately retained a pair of lashing holes. These holes have an inboard diameter (8 mm) slightly bigger than the outboard diameter (6-7 mm), so the space between them is 2.4 cm inboard and 3.5 cm on the outboard face of the plank. The lashing seems to be very basic, and on the outer face the holes are not joined by a groove that would protect the lashing.

The lashing of the frames is confirmed by a groove with an open V section, and a depth of 5 mm, visible near the top of the floor-timber R3. Some other faint traces, not easily visible, that appeared to mark a cross over the frames, unfortunately vanished as soon as the wood was uncovered.

II.35



II.36



Princip konstruiranja, proces gradnje i arhitektonski tip

Nema sumnje da se princip konstruiranja broda pronađenog u Zambratiji temelji na konceptu ljuske za strukturu i formu trupa. Vojevi determiniraju formu broda, a rebra imaju sekundarnu ulogu unutar brodske strukture. Proces gradnje podrazumijevao je da se prvo oformi ljuska, što je ujedno i jedini proces koji je omogućavao uzdužno šivanje oplata¹.

Plovilo iz Zambratije najstariji je primjer u potpunosti šivanog broda ikad pronađen u Mediteranu, a datiran je u vrijeme između posljednje četvrtine 12. i posljednje četvrtine 10. st. pr. Kr. Njegova arhitektonska rješenja i gradnja, tehnika šivanja i spajanja dijelova oplata, kao i sustav vodonepropusnosti samog trupa, također nemaju paralela na širem području Mediterana.

Arhitekturu broda Zambratija karakteriziraju sljedeće značajke:

- izrezbaren kobilični element;
- oplata, uključujući završni voj L-profila te stično položena i spojena uzdužnim šivanjem;

¹ Za različite koncepte principa i metodu gradnje te arhitektonske tipove vidi Pomey 2004a; Pomey, Rieth 2005, 29-33 te Pomey *et al.* 2012, 2013.

Construction principle, building process and architectural type

There is no doubt that the construction principle used for the Zambratija vessel is based on a shell concept for the hull structure and shape. The strakes determine the boat's shape, and the frame plays a secondary role in the boat's structure. The building process is shell first. Indeed only a shell-first process is compatible with longitudinal sewn planking¹.

The Zambratija vessel is the most ancient example of an entirely sewn boat ever found in the Mediterranean, as it has been dated between the last quarter of the 12th and the last quarter of the 10th centuries BCE. Its construction is unparalleled at this date, as is the sewing technique employed to assemble the planking and the system of wadding and laths used to render the vessel watertight.

The architectural type of the Zambratija boat is characterized by:

- a carved keel-like timber;
- planking, including a carved L-shaped sheerstrake,

¹ For the different concepts of principle and method of construction and architectural types, see Pomey 2004a; Pomey, Rieth 2005, 29-33; and, finally, Pomey *et al.* 2012, 2013.

II.37

Vanjska strana fragmenta platice PRL11 s rupama za šavove, koji završavaju na zakošenom rubu platice, te par rupa za vezivanje brodske rebra

The outer side of plank fragment PRL11 showing the stitch holes ending in the chamfered plank edge, and the pair of holes for lashing the frame in place (fotografija / photo by: Ph. Groscaux)

II.38

Detalj para zakošenih rupa na unutrašnjoj površini platice PRL11, korištenih za vezanje rebra

Detail of the pair of oblique holes used for lashing the frame in place on the outside surface of plank fragment PRL11 (fotografija / photo by: Ph. Groscaux)



II.37



II.38

- rebra koja se sastoje od široko razmaknutih rebrenica trapezoidnog presjeka, uske baze i zaobljene široke gornje strane, vezana za oplatu;
- zaobljeni središnji poprečni presjek trupa; uzdužni presjek s blagim povišenjem prema zašiljenom kraju.

Velika znanstvena važnost broda Zambratija leži u njegovoj osebujnoj konstrukciji. U naravi, to je primjer rane faze građenja brodova platicama, koji vuče porijeklo iz monoksila dograđenim vojevima. Umjesto uobičajene kobilice ili središnje ravne platice, uzdužni osni element ovog broda izdubljen je od debla brijesta, što izravno upućuje na monoksilni izvor. Međutim, ako promatramo cijeli oblik kobilicnog elementa s njenim ravnim središnjim dijelom, vidljivo je da ovaj brod ima izvor u razvijenom monoksilu s dograđenim vojevima.

Brod Zambratija svjedoči o razvoju brodova s izgrađenom oplatom iz monoksila. Njegov kobilicni element služi kao strukturalna baza za dogradnju oplata vojevima od brijesta. U ovoj fazi istraživanja ne možemo odgovoriti na pitanje je li monoksilni kobilicni element izdubljen u svoju formu ili je umjetno proširen savijanjem stranica uz pomoć vatre i vode. To ostaje otvoreno za buduća istraživanja.

Iako se čini da je većina malih zaptivenih rupa povezana s vezivanjem rebara i oplata, neke su od njih također mogle biti korištene za kontroliranje debljine, što predstavlja tipičnu karakteristiku proširenih monoksila (Van de Moortel 2003, 184-185).

S druge strane, tehnika šivanja koja je korištena za spajanje oplata i s njom povezan sustav vodonepropusnosti također nema paralela i karakteriziraju ih sljedeće odlike:

- koso izbušene rupe usmjerene dijagonalno na rubove platica, koje završavaju u zakošenju vanjskog ruba sljubnica;
- jednostavan nepravilan rubni uzorak šivanja (///);
- drvene letvice korištene za učvršćenje sloja biljnih vlakana;
- mali drveni čavli koji zaptivaju šavove;
- zaštitni premaz paklinom koji štiti trup broda.

Zbog svih ovih karakteristika konstrukcije, tipa gradnje i rane datacije, brod Zambratija može se smatrati arhetipom tradicije šivane brodogradnje na prostoru Jadrana. Tehnika izgradnje broda šivanjem preživjela je sve do kasne antike odnosno ranog srednjeg vijeka, kako potvrđuju nalazi šivanih brodova na prostoru Italije, od ušća rijeke Po do Akvileje, na području rijeke Ljubljanice u Sloveniji te u Hrvatskoj, gdje je u Istri (Pula) i u Dalmaciji (Caska i Zaton) pronađeno osam takvih brodova, datiranih u vrijeme između 1. i 2. stoljeća.

- flush-laid and assembled by longitudinal sewing;
- frames composed by widely spaced floor-timbers, trapezoidal in section, with a narrow foot and a rounded, wider upper surface, that were lashed to the planking;
- a rounded mid section, and a gentle longitudinal rise to a pointed end.

The high scientific value of the Zambratija boat lies in its unusual construction. It is, in fact, an example of an early stage of planked boatbuilding, which originated in extended logboats. Instead of a traditional keel or a flat central-plank, it has an axial element carved from an elm trunk, a direct descendant of a logboat. But, considering the shape of the keel-like timber on the whole with its flat mid-section, this boat type has its origins in a developed, extended logboat.

Indeed, the Zambratija boat testifies to the development of plank-built boats from logboats. Its keel-like timber serves as a structural base for the planking, made by the addition of elm strakes. At this stage of research, the question of whether the logboat keel-like timber was entirely carved into shape or whether it was expanded, that is, widened by artificially bending out the sides using fire and water, remains open and requires further research.

Although most of the small plugged holes seem to be related to lashing the frames in place, some of them could have been used as gauges: holes used to check the thickness of the base are typical features of expanded logboats (Van de Moortel 2003, 184-185).

On the other hand, the sewing technique employed to assemble the planking and the waterproofing system, is also unparalleled and is characterized by:

- oblique stitch holes cut diagonally to the plank edge and ending in a chamfer along the outboard plank edge;
- a simple irregular over-edge sewing pattern (///);
- wooden laths to hold wadding composed of vegetal fibres;
- pegs to lock each stitch in place;
- a coat of pitch to protect the hull.

Due to these construction characteristics, the type of assemblage, and the early date of the boat, the Zambratija boat could be considered an archetype of the sewn-boat traditions found in the Adriatic geographical zone. Sewn construction techniques survived until the Late Roman-Early Middle Ages, as demonstrated by the discovery of a series of sewn boats in Italy, from the Po delta to Aquileia, in the river Ljubljanica in Slovenia, and in Croatia where eight wrecks dated from the 1st to the 2nd centuries CE were found in Istria, in Pula, and in Dalmatia, at Caska and Zaton.

Zaključak

Na kraju druge kampanje istraživanja broda Zambratija, prikupljeno je mnogo podataka što je omogućilo inicijalnu detaljnu analizu strukture trupa. Ipak, ovo istraživanje otvorilo je i mnoga pitanja na koja će se moći odgovoriti tek daljnjim dobro isplaniranim istraživanjima koja uključuju i vađenje svih ostataka broda te analiziranjem istih u laboratoriju.

Takva buduća istraživanja pomogla bi u istraživanju sustava vodonepropusnosti broda u smislu utvrđivanja prisutnosti materijala za brtvljenje unutar sljubnica ili utvrđivanja prisutnosti premaza paklinom na vanjskoj strani trupa ili na zakošenim vanjskim rubovima platica u kojima se nalaze šavovi.

Također, nova istraživanja omogućila bi cjelovitu analizu drva, ne samo zbog preciznijeg datiranja konstrukcije, već i s ciljem da se bolje prouče faze gradnje od debla do završenih arhitektonskih dijelova. Također bi bilo moguće detaljno proučiti tragove alata korištenih pri gradnji. Nadalje, analiza unutarnje strukture drva i, preciznije, njegovih medularnih zraka i uzdužnih ćelija pomogla bi da se napokon odgovori na važno pitanje – je li brod Zambratija baziran na proširenom monoksilu ili ne².

Na kraju valja zaključiti da otkriće broda u uvali Zambratija čini polazišnu točku za istraživanje porijekla i razvoja platicama građenih brodova na Mediteranu. On je potpora teorijama Basila Greenhilla (1976) i njegovog prethodnika Jamesa Hornella (1974) o porijeklu brodova građenih platicama iz četiri izvora primitivnih plovila (splav, brod od kože, brod od okorine i monoksil).

Plovilo iz Zambratije pruža prvi arheološki dokaz o ulozi monoksila kao temelja prema razvoju brodova građenih platicama na sjevernom Sredozemlju te osobito sjeveroistočnom Jadranu³.

Conclusion

At the end of the second season of excavation of the wreck, a large amount of data has been collected providing an initial detailed study of the hull structure of the Zambratija boat. However, this study has also raised a series of new questions that only further programmed research that will incorporate the recovery of the entire remains of the vessel and their analysis in the laboratory, will be able to answer.

Future research would enable the waterproofing system to be investigated further, such as the presence or absence of luting material between the seams, or whether an outer coat of pitch covers the outboard face of the planking and the plank-edge chamfers in which the sewing runs.

Also, future research would permit a complete study of the wood, not only to obtain a precise date for the construction, but also to better study the boatbuilding phases from log to finished pieces. It would also be possible to study in detail marks left on the wood by the tools used for this work. Moreover, the study of the internal structure of the wood, and more precisely its medullary rays and longitudinal cells, would finally help in answering the crucial question of whether the Zambratija boat is or is not based on an expanded logboat².

In conclusion the discovery of the Zambratija wreck constitutes a milestone in the study of the origin and development of plank-built boats in the Mediterranean. It follows the theories of Basil Greenhill (1976) and, before him, of James Hornell (1946), about the derivation of fully plank-built boats from in four primitive watercrafts (the raft, the skin boat, the bark boat, and the logboat).

The Zambratija vessel provides the first archaeological evidence of the logboat's role as a root in the development of fully planked boats in the northern Mediterranean and, more particularly, within the north-eastern Adriatic maritime area³.

2 Analiza drvenih ostataka broda iz Utrechta (997. god., Nizozemska) omogućila je A. Van de Moortelu (2003, 185-188, sl. 28.5-7) da ga identificira kao prošireni monoksil koji predstavlja primjer brodogradnje u prijelaznoj fazi između monoksilnih konstrukcija i izgradnje brodova u cijelosti od platica.

3 Zanimljivo je napomenuti da je upotreba monoksila te monoksila s dograđenim vojevima tradicija koja se zadržala na hrvatskoj obali kroz razdoblje srednjeg vijeka te sve do današnjeg vremena. Ova plovila, korištena za ribolov, najčešće su se nazivala *ladva*, *lada* ili *copul* (Radić Rossi 2009, 134-136).

2 The study on the wooden structure of the Utrecht ship (997 CE, The Netherlands) allowed A. Van de Moortel (2003, 185-188, fig. 28.5-7) to identify it as an expanded logboat, reflecting a building tradition at an intermediary stage between logboat construction and the production of fully plank-built vessels.

3 It's interesting to note that the use of logboats and, then, of extended logboats, persisted along the Croatian coast throughout medieval till modern times. These vessels, used for the purpose of fishing, were usually called *ladva*, *ladja* or *copul* (Radić Rossi 2009, 134-136).

Preliminarno istraživanje tragova alata

A preliminary study of tool marks

Axel Eeckman

Zahvaljujući odličnoj očuvanosti, na brodu Zamratija još su uvijek vidljivi brojni tragovi alata na nekoliko drvenih elemenata. Uvid u te tragove omogućila su određena preliminarna opažanja na temelju analize fotografija koje je izradio Phillipe Groscaux u 2013. godini tijekom druge istraživačke kampanje. Istraživanjem odabranog alata, svojte drva i morfologije debla, može se steći uvid u korištene metode obrade drva i tehnike izgradnje broda, kako bi ih se smjestilo u njihov specifični geografski, kulturološki i vremenski kontekst (Lavie 2013).

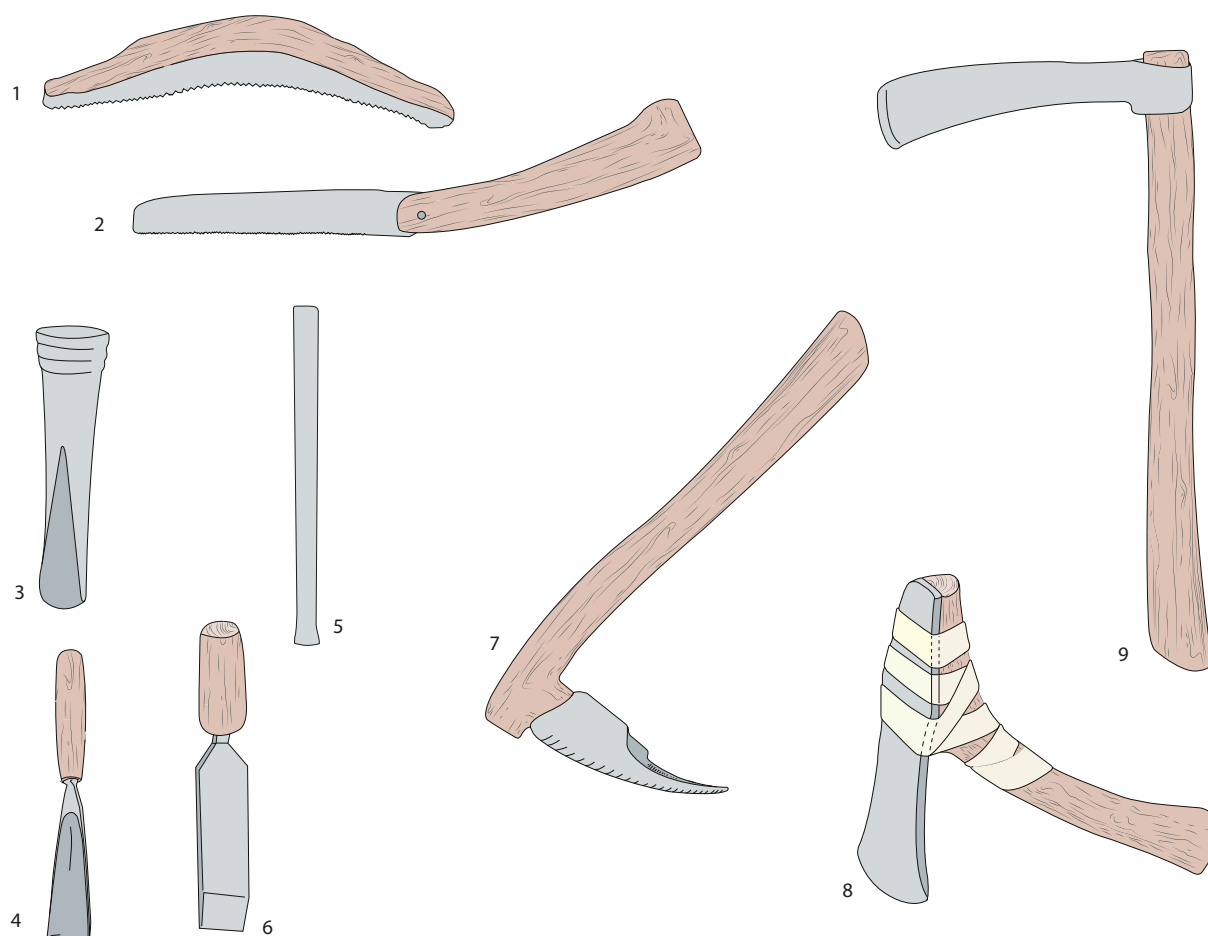
Detaljno istraživanje pronađenih tragova alata na brodu Zamratija od posebnog je interesa jer je na taj način moguće predložiti ne samo vrste alata korištenih za različite dijelove konstrukcije i njihovih spojnih elemenata (Sl. II.39), nego i odrediti jesu li upotrebljavane brončane ili željezne oštrice, a to su informacije koje bi mogle biti od pomoći za točnije određivanje vremena izgradnje broda¹. Dobiveni podaci mogli bi se usporediti s pronađenim tragovima alata na pilonima i drvu sojenica koje se nalaze u blizini i koje su bile u upotrebi od početka bakrenog do početka brončanog doba (Benjamin *et al.* 2001, 194-195; Koncani Uhač, Čuka 2016) ili s tragovima alata uočenim na drugim, kasnijim brodovima pronađenima u istoj geografskoj regiji, a sve kako bi se opisala lokalna brodograditeljska tradicija primijenjena u izradi broda iz Zamratije.

¹ Prelazak s bronce na željezo je *de facto* uzrokovao promjenu u morfologiji alata (obliku, veličini i oštrici) koja je se odražava u tragovima koji su ostali u obrađenom materijalu (Goodman 1964, 8). Povezivanje alata s kronologijom utvrđene vrste omogućilo bi potvrđivanje razdoblja izgradnje broda.

As a result of the excellent preservation of the Zamratija boat, a large number of tool marks are still visible on the various timbers. This allows a number of preliminary observations based on the analysis of the photographic record created by Philippe Groscaux during the second excavation season in 2013. The study of the tools, wood species and morphology of the tree trunks selected allows the woodworking methods to be investigated and the boat construction techniques employed to be defined in their specific geographic, cultural and temporal context (Lavie 2013).

A detailed study of the tool marks found on the Zamratija wreck would be of particular interest as it might allow not only the types of tools used for the different structural parts and their fasteners to be suggested (Fig. II.39), but also to determine if bronze or iron blades were used, which might help to refine the dating of the boat's construction¹. The results obtained could be compared with tool marks found on posts and wood from the pile dwellings located nearby used from the Early Eneolithic to the beginning of the Bronze Age (Benjamin *et al.* 2001, 194-195; Koncani Uhač, Čuka 2016), or with tool marks seen on other more recent boats found in the same geographic region, in order to describe the local boatbuilding tradition of the Zamratija vessel.

¹ The move from bronze to iron has *de facto* caused a change in tool morphology (shape, size, and blade), which is reflected in the marks left in the worked material (Goodman 1964, 8). The ability to link the tools to an established type-chronology would allow the period in which the vessel was built to be confirmed.



II.39

Alati za obradu drva u upotrebi između bakrenog i željeznog doba: 1-2: pile; 3: dlijeto uvučeno u dršku; 4: konkavno dlijeto; 5: ravno dlijeto iz kvadratne šipke; 6: dlijeto s ravnim sječivom; 7: tesla s konkavnom oštricom; 8: tesla s ravnom oštricom; 9: sjekira

Woodworking tools used between the Bronze Age and the Iron Age: 1-2: saws; 3: socketed gouge; 4: tanged gouge; 5: chisel formed from squared bar; 6: tanged chisel; 7: adze with concave cutting edge; 8: adze with flat cutting edge; 9: axe (crtež / drawing by: A. Eeckman)

Ciljevi, metode i ograničenja

Cilj preliminarnog ispitivanja tragova alata bio je utvrditi potencijale ove vrste istraživanja brodske konstrukcije Zambratija (Eeckman 2017). Znatnije ograničenje je predstavljala okolnost da su korišteni samo neizravni izvori (fotografije, nacrti u mjerilu, karte i presjeci) i da, osim u rijetkim slučajevima², nije bilo moguće izravno pregledati drvene ostatke. Naime, vrlo je teško, ako ne i nemoguće, provoditi takvo istraživanje bez izravnog promatranja ostataka. Opće fotografije mogle su se iskoristiti, ali uz određene poteškoće, jer informacije koje one sadrže variraju ovisno o kutu i svjetlu.

Rezultati

Osni kobilni element

Osni element od brijesta P2 jedan je od rijetkih dijelova koji je pružio informacije o načinu na koji je deblo obrađeno te njegov položaj u izvornom trupcu budući da je

² Analizirali smo dvije izvađene platice PRL11 i PRL19, i uzorkovano rebro R3a.

Objectives, methods, and limits

The preliminary examination of the tool marks was aimed at establishing the potential of this type of study for the Zambratija wreck (Eeckman 2017). A major limitation was that only indirect sources (photographs, scale drawings, plans, and sections) were used without being able, except in rare exceptions², to examine the wooden remains directly. In fact, it is very difficult – if not impossible – to carry out such a study without direct observation of the remains. The general photographs could be used but with some difficulty as the information contained varies according to the angle and lighting used.

Results

The axial keel-like timber

The axial elm timber P2 is one of the rare pieces that provided information about how it was worked and its position in the original tree trunk, as a transverse section

² We were able to examine the two raised hull planks PRL11 and PRL19, and the sampled frame R3a.

fotografiran poprečni profil na sjevernom kraju (Sl. II.40). Ta je slika, koja nažalost nije ni centrirana niti paralelna s profilom, ipak omogućila utvrđivanje jezgre u sredini debla, čime se potvrđuje da je P2 izrađena od raspolovljenog debla. Budući da za potrebe ovog istraživanja nije izrađena dodatna dokumentacija, nije moguće pružiti detaljne podatke o korištenim alatima.

Unutarnja ploha P2 neravne je površine (mikroreljefi) s jasnim znakovima obrade. Oblik vidljivih tragova upućuje na to da su napravljeni zakrivljenom oštricom ravnih strana, širine od otprilike 3 cm (Sl. II.41). Mjerenja su obavljena na osnovi fotografije na kojoj su prikazani tragovi i referentno mjerilo. Uzeti su u obzir samo najmanje deformirani tragovi. Budući da se čini da udarci sjekire nisu paralelni s površinom obrađenog drva, sjekira je vjerojatno imala širu oštricu. Na obje strane središnje linije broda vidljive su dvije serije tragova usmjerenih od sjevera prema jugu, koji otkrivaju redoslijed obrade. Drugi tragovi učinjeni navedenim alatom jasno su vidljivi na spoju kobiličnog elementa i voja sa zapadne strane (P1).

of the northern end was photographed (Fig. II.40). This image, which is neither centred nor parallel to the section unfortunately, nevertheless enabled the heartwood at the centre of the tree trunk to be identified, which confirms that P2 was sculpted from a half-trunk. As the different faces of this timber were not recorded specifically for this study, it is not possible to give details of the tools used.

The internal face of P2 has an uneven surface (micro-relief) with evident signs of having been worked. The shape of the visible marks suggests they were made with a straight-sided curved blade measuring on average 3 cm (Fig. II.41). The measurements were taken from a photograph showing both the marks and a reference scale. Only marks considered the least deformed were taken into consideration. However, as the axe blows do not appear to be parallel to the surface of the worked timber, the axe probably had a wider blade. Two series of marks oriented from the north towards the south are visible on either side of the centreline of the boat and reveal the order in which they were cut. Other traces made with this tool are clearly visible where the timber is joined to the first side strake to the west (P1).

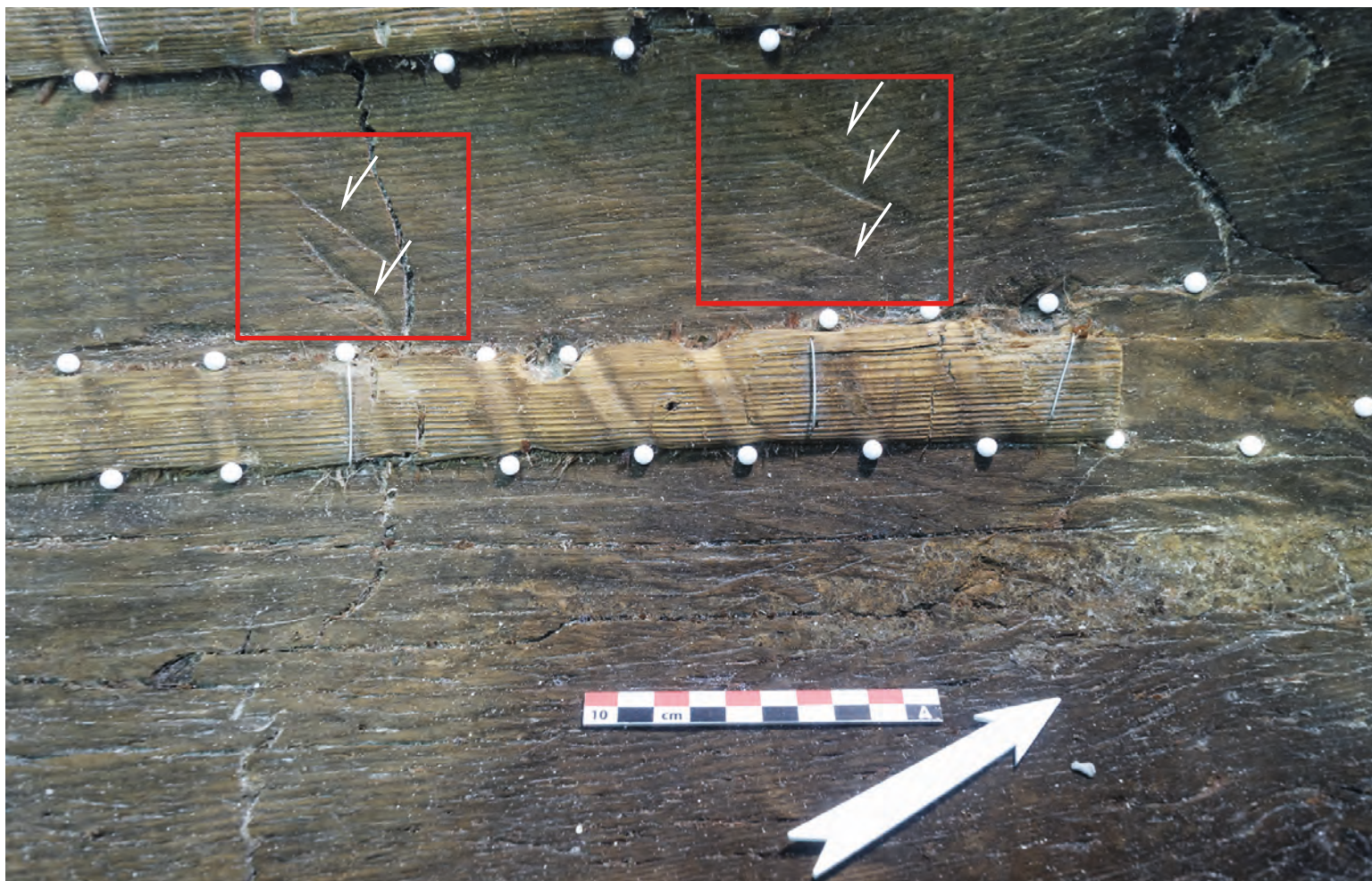
II.40

Okomiti dio sjevernog kraja P2. Bijele isprekidane crte označavaju godove i ukazuju na to da je kobilični element oblikovan od raspolovljenog debla

Transverse section of the north end of P2. The white dotted lines mark the tree rings and show that the keel-like timber was shaped from a half-trunk

(izradio / made by: A. Eeckman)





Rupe za šavove

Rupe za šavove, koje su korištene za spajanje vojeva oplate, vidljive su na južnom rubu P2 i na uzorku PRL11. Rupe tvore višebrojni kanali (dva ili tri) na unutarnjoj strani te na izlazu, na zakošenom donjem vanjskom uglu. Prije bušenja označene su rupe vodilje, koje su određivale položaj ovih rupa. Alate korištene za izradu kanala teško je identificirati jer je moguće da je njihov oblik promijenjen uslijed šivanja, zaptivanja drvenim čavlima, odnosno uslijed dugotrajnog ležanja brodske konstrukcije pod vodom.

U rupama za šavove nema vidljivih znakova upotrebe konkavnog dlijeta, koji uglavnom ostavlja zaobljene konkavne tragove (Grenouiller 1993, 166), ili svrdla, koje obično ostavlja okrugle rupe s tragovima navoja po stranama i na dnu, ovisno o obliku završetka svrdla (Grenouiller 1993, 175-176). Međutim, s obzirom na to da se konkavno dlijeto ne zabija okomito u vlakno drva, osim spontano u svrhu izrade rupe vodilje, teza o svrdlu čini se najvjerojatnijom, posebno jer se tim alatom rupe mogu vrlo brzo izbušiti.

The stitch holes

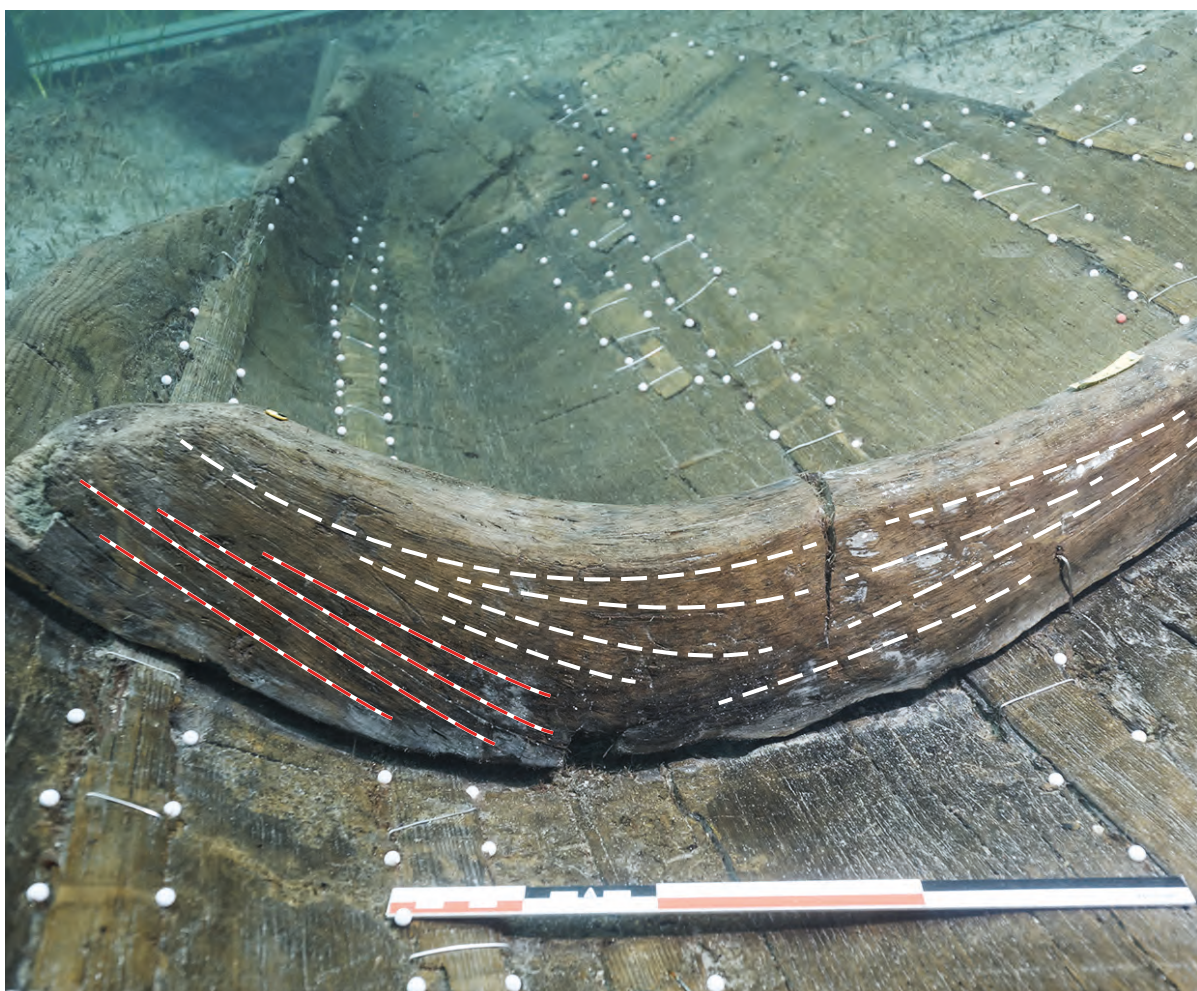
The stitch holes used to fasten the planking strakes together are visible at the southern edge of P2 and on sample PRL11. The holes have multiple entries (two or three) on the internal side and exit at the chamfered lower external corner. Pilot holes for these channels could have been drilled, or their positions marked before being drilled properly. The tools used to cut the channels are difficult to identify as their shapes could have been altered by the passage of the ligatures, driving of the pegs, and the wreck's long period under water.

No trace of the use of a gouge, which leaves more-or-less rounded concave marks (Grenouiller 1993, 166) or a drill, which usually leaves round holes with traces of the flutes on the sides and the bottom depending on the shape of the end of the bit (Grenouiller 1993, 175-176), is visible inside the stitch holes. However, as a gouge is not used perpendicularly to the grain of the wood, except in a spontaneous manner to make a pilot hole, the hypothesis of the drill seems the most plausible, especially as this tool permits holes to be pierced very rapidly.

II.41

Unutarnje lice P2 s tragovima sjeckire. Bijele strelice ukazuju na smjer udaranja alatom o površinu

The inboard face of P2 has marks left by an axe. The white arrows indicate the direction in which the tool hit the surface (izradio / made by: A. Eeckman)



II.42

II.42

Vlakna drva od kojeg je izrađena rebrenica R1. Bijele isprekidane crte označavaju prirodnu zakrivljenost vlakana. Crvena isprekidana crta označava ravna vlakna. Ta dva elementa ukazuju na upotrebu zakrivljene grane ili debla s račvastom bazom

The wood grain of floor-timber R1. The white dotted lines mark the natural curve of the wood grain. The red dotted line marks more linear wood grain. These two elements show the use of a curved branch or trunk with the base of a fork (izradio / made by: A. Eeckman)

II.43

Detalji gornjeg kraja rebrenice R1 s paralelnim brazdama uzrokovanim upotrebom pile. Bijele crte ocrtaavaju tragove alata

Details of the top end of floor-timber R1 with parallel striations caused by the use of a saw. The white lines outline the tool marks (izradio / made by: A. Eeckman)

II.44

Detalji rebrenice R3 s tragovima koje su posljedica obrade sjekirom. Bijele strelice ukazuju na smjer udaranja sjekirom

Detail of floor-timber R3 with traces left from being worked with an axe. The white arrows indicate the direction in which the axe struck (izradio / made by: A. Eeckman)

Rebra

Nekoliko mikrotragova vidljivo je na trima očuvanim rebrenicama. Tragovi upućuju na to da je barem posljednja faza oblikovanja ili završne obrade izvedena teslom zakrivljenog oštrog ruba i zaobljenih uglova. Tragovi obrade vrlo su blizu jedan drugome (50 mm) i upućuju na to da su rebrenice pažljivo završno obrađene.

Zakrivljeno vlakno drva, vidljivo na rebrenici R1 izrađenoj od johe, ukazuje na upotrebu zakrivljene grane ili debla koje se pri dnu račvalo (Sl. II.42). Njen gornji kraj je ispunjen paralelnim brazdama nastalim upotrebom pile čija se vrsta ne može utvrditi (Sl. II.43). Duljina lista pile i smjer piljenja nisu poznati.

Na rebrenici R3, za razliku od ostale dvije, uočeni su tragovi sjekire (Sl. II.44). Tragovi bi mogli ukazivati na to da su rebrenice u početku bile obrađivane sjekirom, a zatim dovršene teslom.

The frames

Several micro marks or facets are visible on three of the preserved floor-timbers. They indicate that at least the last stage of shaping or finishing was carried out with an adze with a curved cutting edge and rounded corners. The cut marks are very close together (50 mm apart) and indicate the timbers were carefully finished.

The curved wood grain visible on floor-timber R1, made of alder, indicates the use of a curved branch or trunk at the base of a fork (Fig. II.42). The top end has parallel striations as a result of the use of a saw, the type of which cannot be established (Fig. II.43). The length of the saw blade and the direction of sawing are not known.

Floor-timber R3 presents, in contrast to the other two, axe marks (Fig. II.44). The marks could indicate that the floor-timbers were initially worked with an axe and finished with an adze.

Slivnice

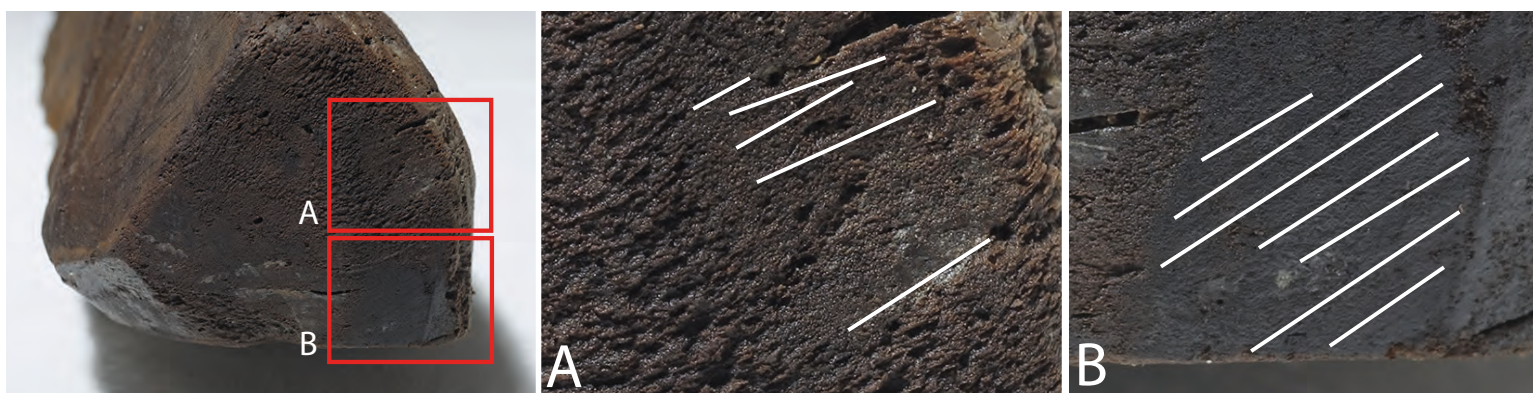
Slivnica na rebrenici R1 lagano je zakrivljenih strana, a na jednoj su strani vidljiva dva traga nastala oštrim alatom. Vrh je konveksan i u sredini se vidi brazda, što znači da je rebrenica doradivana kako bi se dobio željeni profil. Drugi vidljivi tragovi su ravni, što odgovara jednoj strani oštrice. Na temelju tih opažanja moguće je zaključiti da su upotrijebljena dva alata: tesla s ravnom oštricom, koja je služila za grubu obradu slivnice i dobivanje općenitog profila, te vrlo malo konkavno ili ravno dlijeto koje je služilo za završnu obradu (Sl. II.45).

R2 sadrži dvije slivnice, svaku s drukčijim tragovima (Sl. II.46, II.47). Na bočnim stranama jedne slivnice nalazi se nekoliko ravnih brazdi nastalih dljetom ili teslom ravne oštrice (Sl. II.46). Širina tragova alata iznosi 3 cm. Izmjerena vrijednost manja je od širine slivnice, tako da se ovdje radi o veličini korištene oštrice. Štoviše, dimenzije alata slične su dimenzijama upotrijebljenim za izradu slivnice u rebrenici R1. To ukazuje na upotrebu istog

Limber holes

A limber hole on floor-timber R1 has lightly curved sides, on one of which two marks made by a sharp tool are visible. The top is convex and has a central ridge, which shows the timber was reworked to achieve the desired profile. Other rectilinear marks are visible that correspond to one side of a blade. From these observations it is possible to conclude that two tools were used: an adze with a straight blade to rough out the limber hole and work the general profile, then a very slightly curved gouge or chisel to finish it (Fig. II.45).

R2 has two limber holes each with different marks (Figs II.46, II.47). One has several straight ridges on its side faces made with a chisel or flat-bladed adze (Fig. II.46). The width of the marks made by this tool is 3 cm. This measurement is less than the width of the limber hole and therefore is the size of the blade used. Moreover, the dimensions of the tool are similar to that used to make the limber hole in floor-timber R1. This



II.43



II.44

II.45

Detalj sa slivnice rebrenice R1 koji pokazuje način izrade. Bijele strelice ukazuju na smjer upotrebe alata. Brojevi (1 do 4) ukazuju na redoslijed tesanja drva teslom. Slova (A i B) ukazuju na tragove koji su naknadno nastali uporabom dlijeta. Crvena isprekidana crta ocrtava tragove nastale zadnjim udarcima dlijeta

Detail of the limber hole of floor-timber R1 illustrating how it was cut. The white arrows indicate the direction in which the tools were employed. Numbers (1 to 4) indicate the order the cuts were made with an adze. The letters (A and B) show the marks made afterwards with a chisel. The red dotted line outlines the marks left by the last chisel blows (izradio / made by: A. Eeckman)



alata ili na to da su oblik i veličina tesli dostupnih u alatnom kompletu graditelja bili standardni³. Na gornjoj se plohi nalaze dva lagano konkavna traga koji se preklapaju i završavaju u uklonjenom materijalu od polovine njihove dubine. Ti tragovi upućuju na višestruke udarce i alat po kojem se udaralo čekićem, a vjerojatno se radi o blago konkavnom dlijetu s oštricom 1 cm širine i barem 2 cm dužine. Stoga je riječ o različitom alatu od onog koji je upotrijebljen za izradu bočnih ploha.

Bočne strane druge slivnice (Sl. II.47) sličnog su oblika, ali predstavljaju zrcalni odraz bočnih ploha prve slivnice. Podudarajući oblici zasigurno su izrađeni istim alatom. Zrcalno odraženi profili slivnica R2 mogli bi značiti da je tesar promijenio položaj u odnosu na rebrenicu kada je radio na njima. Drugim riječima, pokreti su bili drukčiji od pokreta pri izradi drugih uočenih slivnica. Čini se da je korišten alat bio tesla s konkavnom oštricom. Središnje udubljenje vidljivo na gornjoj plohi, popraćeno s nekoliko paralelnih brazdi, te drugi svijetli tragovi upućuju na završnu obradu. Obrada rebrenice počela je od bokova te izvana prema unutra. Potom je s gornje plohe otrgnut dio drva. Obrada slivnice u ovom slučaju razlikuje se od ostalih.

³ To odgovara lijevanim oštricama iz bakrenog doba (Singer 1956, 607).

shows that either the same tool was used, or that the shape and size of the adzes available in the boat builder's toolkit were standard³. The upper face has two superimposed, slightly concave marks, ending in torn material from half their depth. These marks indicate that several blows were made and suggest a tool struck with a hammer, probably a very slightly curved gouge with a blade nearly 1 cm wide and at least 2 cm long. This is, therefore, a different tool from that used on the side faces.

The other limber hole has side faces (Fig. II.47) that are similarly shaped but mirror the first. Their matching shapes were certainly formed by the same tool. The mirrored profiles of the R2 limber holes could signify that the carpenter changed position in relation to the floor-timber between working on them. In other words, the gestures used are different from those for the other limber holes noted. The tool used appears to have been an adze with a concave blade. A central indentation visible on the upper surface accompanied by several parallel ridges and other light traces suggest finishing work. The timber was worked starting from the sides, from the outside inwards. A chip was then torn from the upper face. The working of this limber hole is distinctly different from the others.

³ This corresponds to the cast blades of the Bronze Age (Singer 1956, 607).



II.46

Detalj s jedne od dviju slivnica rebrenice R2 koji pokazuje način izrade. Bijele strelice ukazuju na smjer upotrebe alata. Brojevi (1 do 9) ukazuju na redosljed udaraca teslom u drvo. Slova (A-C) ukazuju na tragove konkavnog dlijeta koji su nastali neposredno nakon toga. Crvena isprekidana crta ocrta tragove nastale upotrebom konkavnog dlijeta

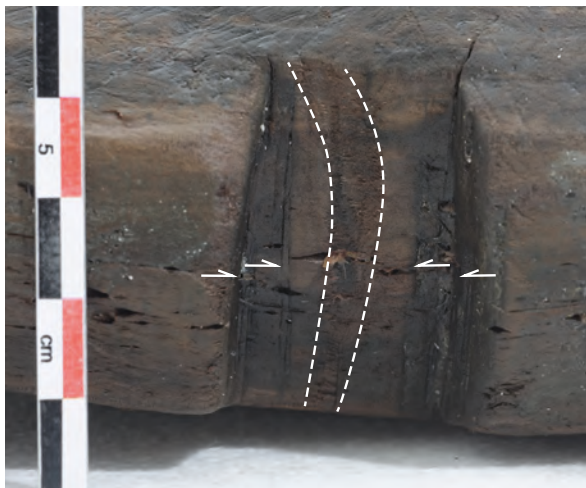
Detail of one of the two limber holes on floor-timber R2 illustrating how it was cut. The white arrows indicate the direction in which the tools were used. The numbers (1-9) indicate the order the blows were struck with an adze. The letters (A-C) indicate gouge marks made next. The red dotted line outlines the marks left by the use of the gouge (izradio / made by: A. Eeckman)

Zaključno, čini se da su slivnice izrađene teslama ili dlijetima ravnih oštrica (R1) te teslama konkavnih oštrica (R2), dok je završna obrada izvedena ravnim i konkavnim dlijetima.

Zaključak

S obzirom na poteškoće pri analiziranju tragova alata na temelju neizravnih podataka te na to da bi ova vrsta istraživanja bila detaljnija da su rebrenice izravno analizirane, posebno one s morskog dna, ovo istraživanje smjernica je za budući rad i njime je omogućeno postavljanje preliminarnih teza o postupcima izgradnje broda Zambratija.

Iz ovog preliminarnog i djelomičnog istraživanja tragova alata proizlazi da je sjekira bila glavni alat korišten pri oblikovanju kobiličnog elementa i rebrenica. Tesla je korištena za završnu obradu i tesanje slivnica, koje su dovršene dlijetima i šiljcima. Moguće je da je konkavno dlijeto korišteno za označivanje rupa vodilja za rupe za šavove, koje su vjerojatno izbušene svrdlom. Valja istaknuti da se čini da nisu sve slivnice izrađene istim alatima ili istim pokretima, što upućuje na pretpostavku da je na izgradnji broda radilo nekoliko brodograditelja različite vještine.



II.47

Detalj s druge slivnice rebrenice R2 koji pokazuje način izrade. Bijele strelice ukazuju na smjer udaranja teslom s konkavnom oštricom. Materijal između isprekidanih crta je oštećen

Detail of the second limber hole of floor-timber R2 illustrating how it was cut. The white arrows indicate the direction in which an adze with a concave cutting edge struck. The material between the dotted lines was torn (izradio / made by: A. Eeckman)

In conclusion, the limber holes seem to have been made with adzes or chisels with flat blades (R1) and adzes with concave blades (R2), while finishing work was carried out with chisels and gouges.

Conclusion

Keeping in mind the difficulties of analysing tool marks from indirect data, and that this type of study would be improved if the timbers were examined directly, preferably once raised from the seabed, this study can serve as guideline for future work and it has allowed some preliminary hypotheses concerning the procedures used for the construction of the Zambratija boat.

From this preliminary and partial study of tool marks, it appears that the axe was the main tool used to shape the keel-like timber and the frames. An adze was used for finishing and for cutting the limber holes, which were finished with chisels and gouges. A gouge may have been used to make pilot holes for the stitch holes, which were likely drilled with a bit. It should be underlined that not all of the limber holes appear to have been cut with the same tools or the same gestures. This could signify that several carpenters with various levels of technical competence worked on the construction of the boat.

Preliminarna rekonstrukcija

Preliminary reconstruction

Pierre Poveda, Giulia Boetto

Nalaz brodske konstrukcije iz uvale Zambratija značajan je zbog više razloga. Datacija broda, stanje očuvanosti drva te posve jedinstvene značajke arhitekture i načina gradnje čine ga jednim od zanimljivijih i znanstveno izdašnijih nalaza s obzirom na tekuću problematiku i istraživanja na polju arheologije broda na Mediteranu.

Međutim, jedinstvenost njegovih karakteristika izuzetno je otežala rekonstrukciju izvornog izgleda broda. Nepostojanje arheoloških materijalnih paralela ili drugih usporedivih izvora (ikonografski prikazi, pisani izvori, etnografski primjeri) čini svaki pokušaj rekonstrukcije osobito zahtjevnim, a njegov krajnji rezultat izrazito hipotetskim. U ovom su kontekstu ostaci broda jedina osnova na kojoj se može bazirati preliminarna hipoteza rekonstrukcije njegove forme. Srećom, brod Zambratija s tog aspekta ima nekoliko bitnih prednosti, jer sačuvani ostaci uključuju i određene temeljne arhitektonske elemente uz gotovo 30 posto sačuvanih izvornih dijelova broda. Sačuvan je jedan od krajeva te završni voj koji definira visinu vodene linije. Osim toga, tri rebrenice omogućile su rekonstrukciju izvornih poprečnih presjeka. To predstavlja važnu informaciju u postupcima evaluacije i korekcije deformacija nastalih postdepozicijskim

The Zambratija wreck is remarkable for more than one reason. The dating, the exceptional state of preservation of the wood, and the unique construction of the boat and its assembly system make it one of the more interesting and rewarding finds in view of current paradigms and research perspectives within Mediterranean nautical archaeological research.

Nonetheless, the unique character of the vessel made the reconstruction of the original boat particularly difficult. The absence of archaeological parallels, or any comparable material of other sorts (iconography, written evidence, or similar ethnographic examples), make any attempt at reconstruction particularly demanding and the results distinctly hypothetical. In this context, the remains themselves constitute the only evidence on which to base a preliminary hypothetical reconstruction of the shape of the boat. Luckily, the Zambratija wreck also has considerable advantages in this respect. The remains include the boat's fundamental structural elements, and about 30% of the original boat is relatively well preserved. One of the ends is preserved, along with the sheerstrake, which defines the vessel's waterline. Moreover, the three floor-timbers gave the hull's



II.48
 3D model ostataka
 3D model of the remains
 (izradili / made by: V. Dumas, P. Poveda)

procesima. Kao doprinos predmetnim pozitivnim činjenicama, možemo pridodati i metodu dokumentiranja primijenjenu prilikom istraživanja, koja je omogućila isctavanje vrlo preciznih planova, na osnovi kojih se obavljala rekonstrukcija izvornog plovila.

Metode rekonstrukcije

Cjelovito i iscrpno proučavanje nekog plovila zahtijeva ekstenzivna istraživanja, započevši od same olupine, a sve s ciljem izrade hipoteze rekonstrukcije izvornog plovila. Riječ je o složenom radu u kojem su poznata ograničenja u najmanju ruku jednako brojna koliko i nepoznata. Izrada rekonstrukcije uvjetovana je dugim i detaljnim istraživačkim protokolima i predstavlja važan izvor informacija kad je riječ o proučavanju plovidbenih karakteristika i mogućnosti te funkciji drevnih plovila.

Različita istraživanja provedena od 1960-ih godina u Danskoj (Centar za pomorsku arheologiju, Roskilde), Sjedinjenim Američkim Državama (Sveučilište Texas

cross section. These are important indications used to evaluate and correct the deformations the wood has undergone during the long period it was buried. In addition to these positive points can be added the recording methods used at Zambratija that have allowed a very accurate plan to be drawn, which was used as the basis of the reconstruction of the original boat.

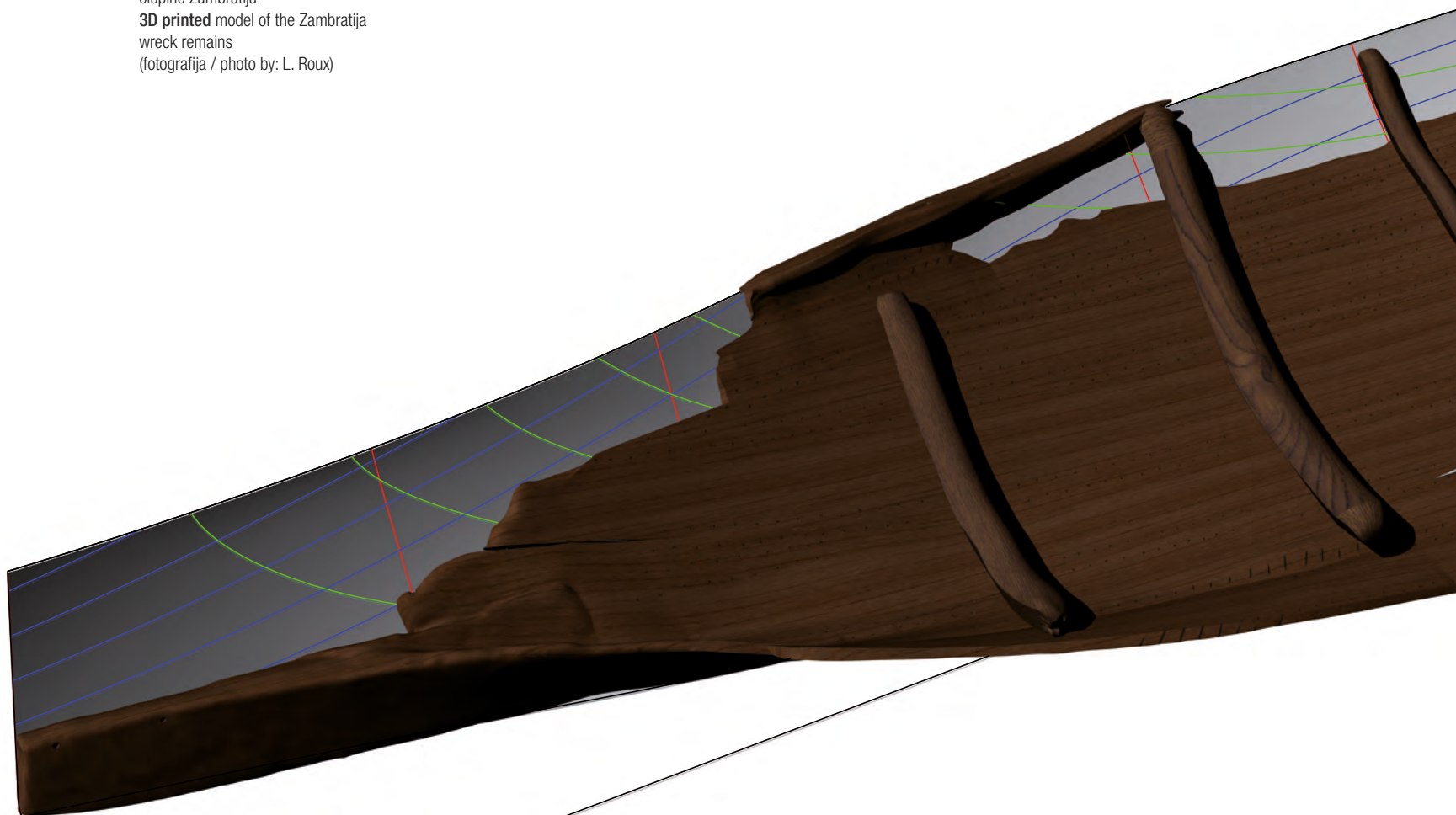
Reconstruction methods

A complete and exhaustive study of a vessel requires extensive research, starting from the wreck itself, with the objective of producing hypothetical reconstructions of the original boat. It is complex work in which the known constraints are at least as numerous as the unknown factors. Guided by long and meticulous research protocols, a reconstruction of an ancient ship is an important source of information used to examine the vessel's seaworthiness, sailing capabilities, and function.

The various experiments undertaken since the 1960s in Denmark (Centre for Maritime Archaeology, Roskilde), in America (Texas A&M University and the Institute for

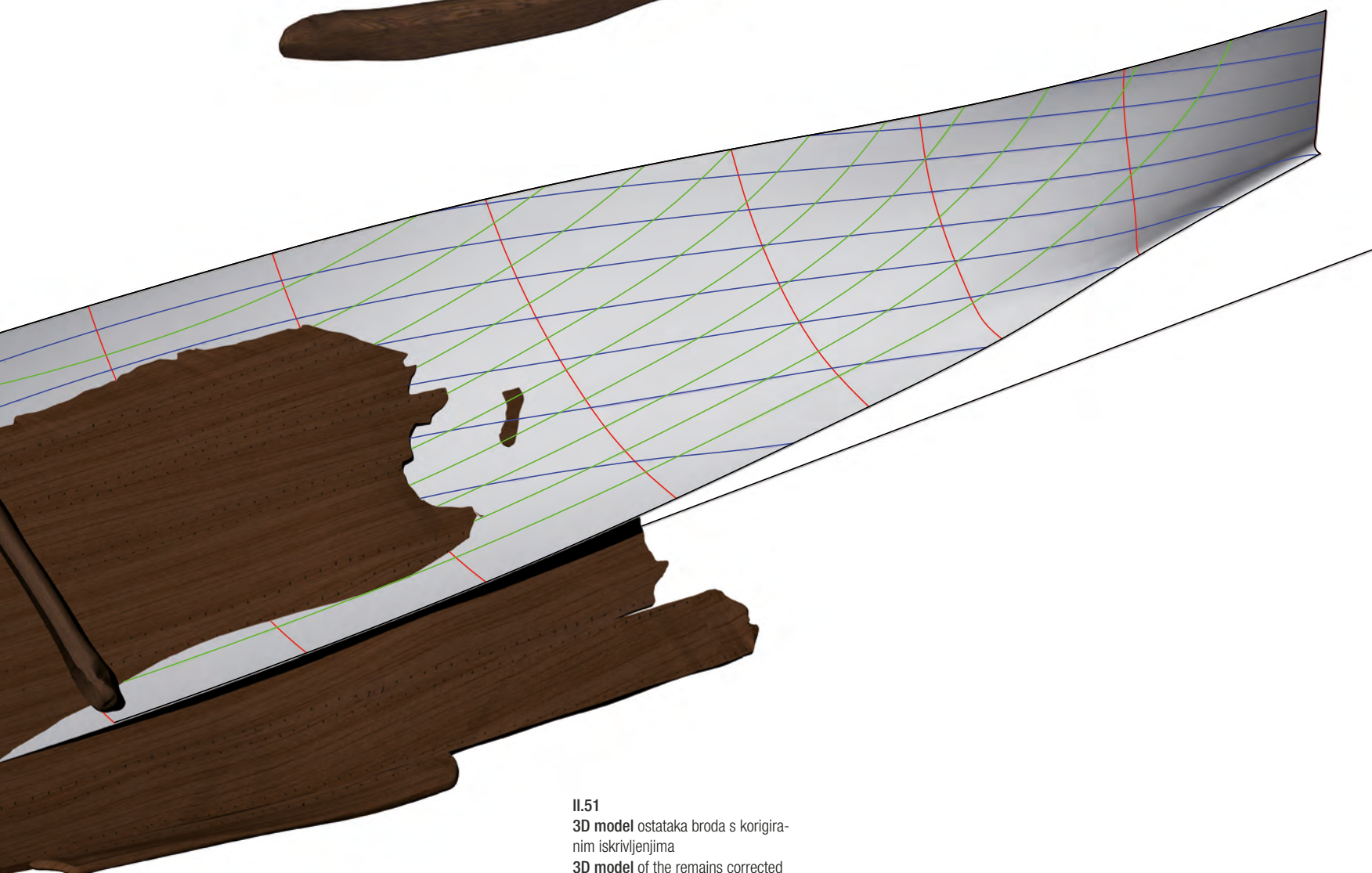


II.49
Isprintana 3D maketa ostataka
olupine Zamratija
3D printed model of the Zamratija
wreck remains
(fotografija / photo by: L. Roux)





II.50
3D model očuvanih rebara
3D model of the preserved frames
(izrada / made by: P. Poveda)



II.51
3D model ostataka broda s korigiranim iskrivljenjima
3D model of the remains corrected for distortions
(izrada / made by: P. Poveda)

A&M i Institut za nautičku arheologiju, College Station) ili Francuskoj (Centar Camille Jullian, Sveučilište Aix-Marseille, CNRS, Aix-en-Provence), omogućila su razvoj metoda rekonstrukcije koje su dobro prilagođene proučavanjem plovilima (Steffy 1994; Pomey, Rieth 2005; Poveda 2012, 2015).

Kroz modeliranje brodskih ostataka *in situ*, izradu studijskih maketa (od drva ili drva i kartona) te hipotetskih rekonstrukcijskih modela razvijen je proces analize ostataka te rekonstrukcije nedostajućih dijelova brodova. Posljednjih petnaestak godina ovakva se vrsta istraživanja uvelike izmijenila, s obzirom da sve značajnije mjesto zauzima informatička oprema koja se koristi u različitim fazama pri postupku rekonstrukcije. Olupina Zambratija također nije iznimka te ovdje iznesena pretpostavka o rekonstrukciji predstavlja rezultat gotovo isključive upotrebe alata za trodimenzionalnu virtualizaciju.

Fotogrametrijsko snimanje broda isprva je omogućilo izradu prvog 3D modela, pokazujući vrlo jasno položaj svih brodskih ostataka u prostoru. Premda je riječ o pravoj trodimenzionalnoj fotografiji nalazišta, iz takvog prvog 3D modela ipak nije bilo moguće međusobno razlikovati pojedine arhitektonske dijelove. Stoga je bilo potrebno prethodno izvesti remodeliranje na osnovi kojeg su kasnije razlikovani različiti dijelovi arhitekture broda te je njima rukovano odvojeno i po želji. Na temelju tog drugog modela nastojali smo rekonstruirati izvornu formu broda (Sl. II.48).

Na olupini Zambratija istodobno su primijenjene dvije metode rekonstrukcije kako bi se mogao usporediti njihov rezultat. Jedna je tehnika posve računalna, dok se druga temelji na kombiniranoj upotrebi virtualnih i fizičkih modela. Međutim, ograničenja koja nameće vrsta plastičnog materijala, 3D ispisa sačuvanih ostataka broda u mjerilu 1:10 (Sl. II.49), nisu dopustila da ovo istraživanje urodi konkretnim rezultatom. Stoga smo svoju pretpostavku razvili isključivo putem računalno baziranog istraživanja (Sl. II.50, II.51).

Od olupine do broda

Detaljnim proučavanjem ostataka utvrđene su jedinstvene karakteristike plovila Zambratija. Oblik rebrenica, kao i njihov položaj u odnosu na središnji element, derivat monoksila (P2), omogućili su određivanje uzdužne osi broda (Sl. II.52). Ta os je također omogućila opažanje forme nalaza i kuta nalijeganja, kao i iskrivljenost brodske oplate koja se značajno otvorila u svom sjevernom dijelu. Vojevi P1 i P8 mogu se uspraviti kako bi se prilagodili obliku rebrenica, ne bi li se dobio kut jednak kutu oplate na suprotnom boku (P3 i P4). Stoga brod izgleda kako ima vrlo zaobljeni poprečni presjek.

Nadalje, produžavanjem sačuvanih vojeva prema krajevima broda omogućava se nekoliko rješenja.

Nautical Archaeology, College Station), or in France (Centre Camille Jullian, Aix-Marseille University, CNRS, Aix-en-Provence), have enabled reconstruction methods that are well suited to studying such vessels (Steffy 1994; Pomey, Rieth 2005; Poveda 2012, 2015).

Through the use of models of the remains as found, study models (in wood, or wood and cardboard), and hypothetical reconstruction models, a process for analysing the remains and representing lost parts has been established. For the past 15 years or so, however, this type of study has been greatly modified by the increasing use of digital technology in the different steps in the reconstruction process. The Zambratija wreck is no exception and the hypothetical reconstruction presented here is the result of the almost exclusive use of 3D virtualization tools.

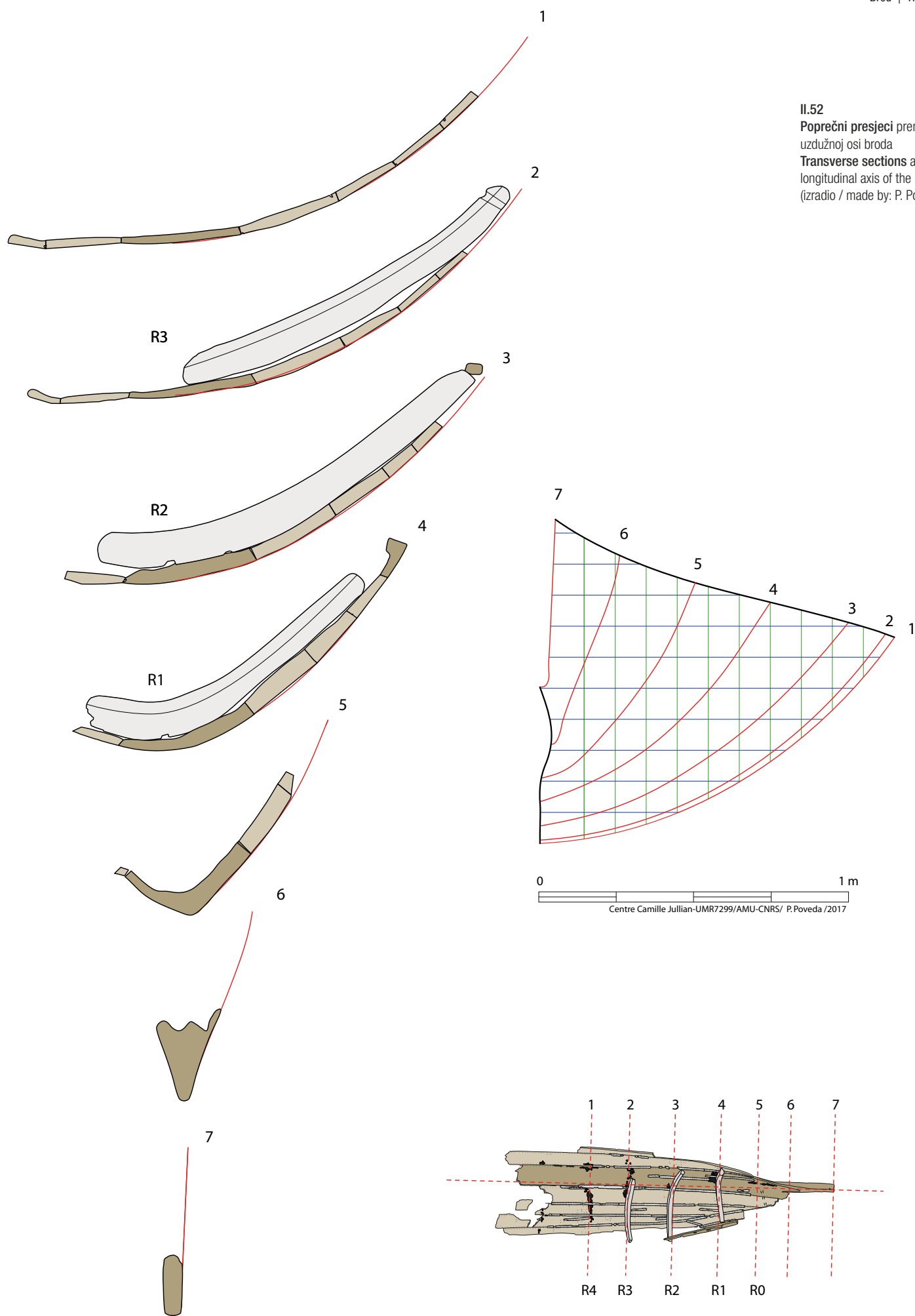
The photogrammetric record of the wreck initially allowed the creation of a preliminary 3D model that gave the precise position of the remains in space. The first model was a true 3D photographic image, but it did not allow individual timbers to be distinguished from each other. Remodelling was necessary to be able to separate and manipulate individual parts of the structure of the vessel at will. From the second model onwards the aim was to find the original shape of the boat (Fig II.48).

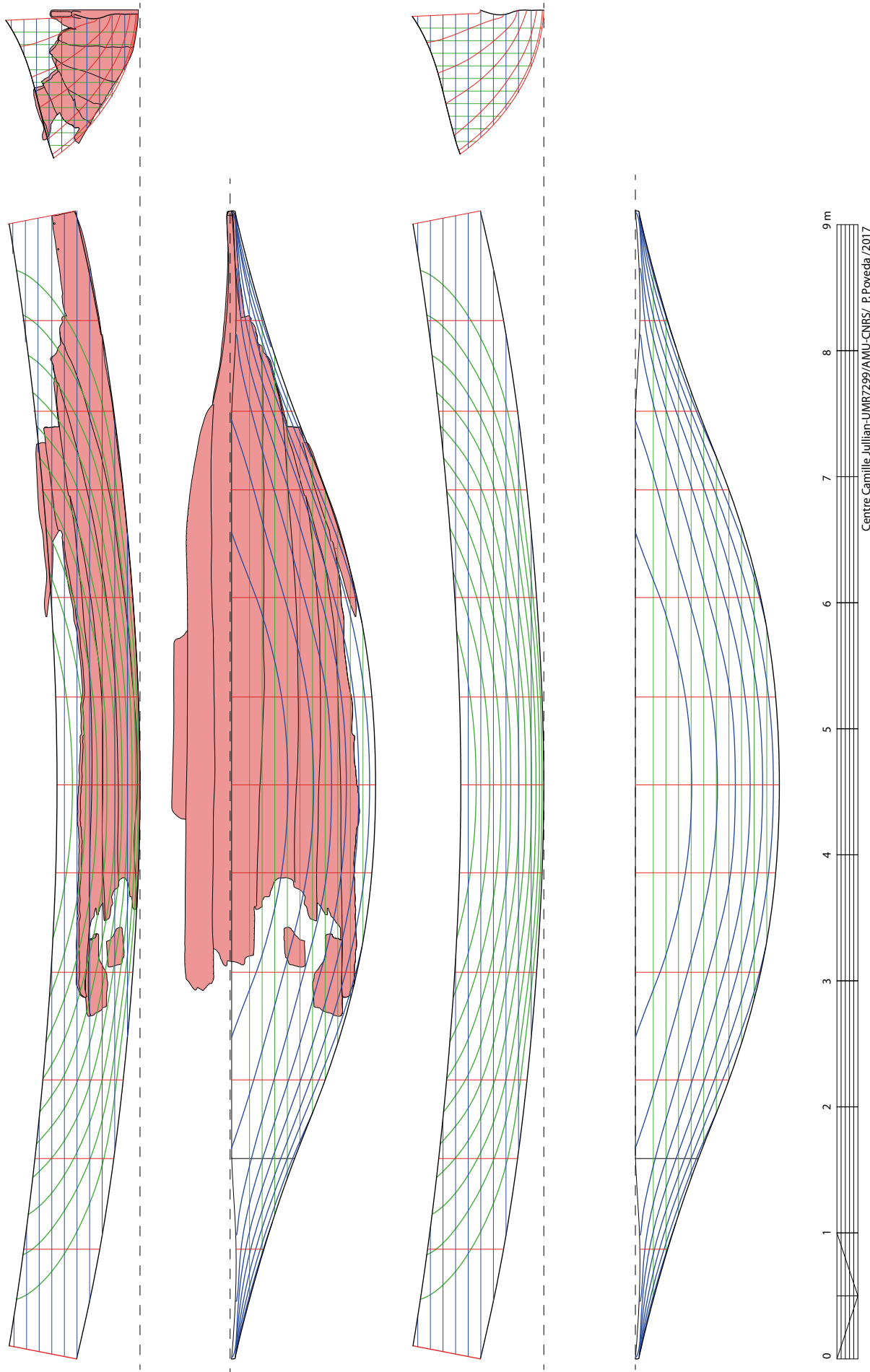
For the Zambratija wreck, two methods were employed simultaneously in order to compare results. One of the techniques is entirely digital, while the other is based on the combination of virtual and physical models. Constraints imposed by the plastic material used for the physical model, however, in this case the preserved parts of the wreck were 3D printed at 1/10th scale (Fig. II.49), did not permit this aspect of the research to produce conclusive results. Only the digital-based research was used for the reconstruction proposed here (Figs II.50, II.51).

From wreck to boat

Intensive study of the remains allows us to assess the unique characteristics of the Zambratija vessel. The shape of the floor-timbers and their position in relation to the central timber, a P2 logboat derivative, provides a coherent longitudinal axis (Fig. II.52). This axis also allows the form of the deposit and angle at which the wreck lay to be discerned, and thus the distortion of the planking that appears to have opened out on the northern side. Strakes P1 and P8 can be pulled up to match the shapes of the floor-timbers, forming an angle equal to that of the planking on the opposite side (P3 and P4). The boat can thus be seen to have a very rounded cross section.

II.52
Poprečni presjeci prema
uzdužnoj osi broda
Transverse sections along the
longitudinal axis of the boat
(izradio / made by: P. Poveda)





II.53
Prva hipoteza forme trupa
First hypothesis of the hull shape
(izradio / made by: P. Poveda)

9 m
8
7
6
5
4
3
2
1
0
Centre Camille Jullian-UMR7299/AMU-CNRS/ P. Poveda /2017

Prije svega, što se tiče sjeverne strane, sa sigurnošću je moguće iscrtati koherentnu shemu oplate temeljenu na korištenju mrtvih vojeva za sužavanje forme broda prema njegovim krajevima, na mjestu nižih vojeva (P3, P4 i P5). Oni su s gornje strane povezani cjelovitim vojem (P6), koji je i sam okrunjen završnim vojem L-profila (P7). Nadalje, čini se da se najšira točka broda, glavno rebro, može smjestiti u dijelove očuvanog trupa, budući da je uočeno blago sužavanje vojeva od položaja rebra R5. Posljedično, možemo racionalno pretpostaviti da očuvani sjeveroistočni dio konstrukcije odgovara četvrtini cjelokupnog broda.

Prethodno navedeni elementi o jedinstvenim značajkama ovoga broda, kao i zaključci koji proizlaze iz analize njegovih ostataka, navode nas, dakle, na postavljanje hipoteze koja nam se učinila najjednostavnijom, tj. simetriji lijevog i desnog boka te simetriji jednog i drugog kraja broda od njegovog najšireg dijela. Slijedom navedenog, zrcalno simetrično smo prvo preslikali rekonstruiranu četvrtinu boka, a potom i nasuprotnih krajeva.

Zaključak

Rekonstruirano plovilo duljine je 9,11 m, širine 2,28 m te visine 0,66 m na središnjem dijelu trupa (Sl. II.53). Poprečni profili broda su vrlo oblog presjeka, s uskim krajevima koje čini masivan i vertikalni pramčani i krmeni dio. Uzdužno, brod ima vrlo izraženu krivulju ili luk, kojeg prati i linija završnog voja, što brodu daje uzdignuti izgled.

Zaključno, na ovom stupnju istraživanja ostaju otvorena različita pitanja, osobito kad je riječ o krajevima broda, tj. kako su vojevi spojeni za masivne krajnje drvene elemente te o načinu upravljanja i sustavu propulzije broda. Sva ta pitanja morat će biti predmetom neke naknadne studije.

Furthermore, extending the preserved strakes towards the ends allows a number of findings.

First, for the northern side it is possible to reconstruct with some certainty a coherent planking plan based on the use of drop strakes to narrow the shape of the boat towards the ends for the lowest strakes (P3, P4 and P5), that are topped by a complete strake (P6), in turn capped by the L-shaped sheerstrake, P7. A slight narrowing of the strakes from frame R5 suggests the widest point of the boat, the midship frame, is within the preserved part of the hull. Therefore, we reasoned that northeastern part of the wreck equates to a complete quarter of the boat.

The unique character of the vessel and the analysis of its remains led us to propose the simplest hypothesis: a boat that was symmetrical both to port and starboard and fore and aft of the widest part. We could, therefore, mirror the preserved quarter first to reconstruct the opposite side, and then the opposite end.

Conclusion

The reconstructed vessel is 9.11 m long, 2.28 m wide, and 0.66 m deep amidships (Fig. II.53). The transverse profile is very rounded with narrow ends formed by the massive vertical timber at the bow and the stern. The longitudinal profile has a pronounced curve or rocker, matched by the sheerline, giving the boat a crescent shape.

In conclusion, at present several questions remain open, like the ones regarding the unusual ends or precisely, how the strakes were fastened to the massive end timbers, as well as those concerning the boat's steering and propulsion systems. These questions should be looked at again in the future.

Eksperimentalna izrada sekcije broda

Experimental construction of a boat section

Marko Uhač, Ida Koncani Uhač

Iako su podmorska arheološka istraživanja broda omogućila uvid u arhitekturu brodske konstrukcije, to ipak nije bilo dovoljno za potpuno razumijevanje tehnologije obrade drva i spajanja elemenata te procesa gradnje.

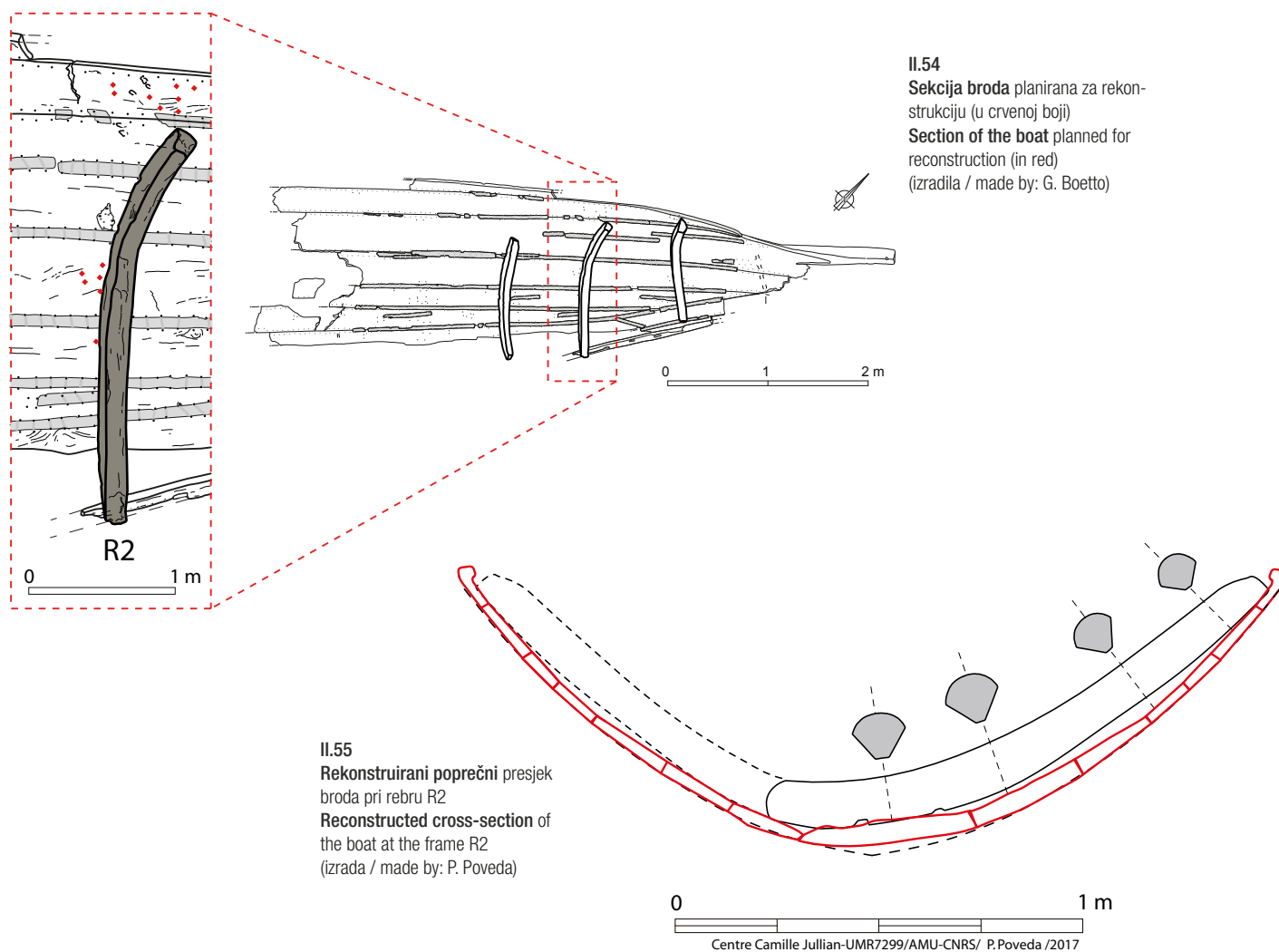
Plovilo je tijekom podmorskih istraživanja u potpunosti istraženo s njegove gornje tj. unutarnje strane trupa, a uvid u vanjsku stranu bio je moguć jedino na sačuvanom kraju broda te na dva ulomka platica koji su izvađeni radi laboratorijskih analiza. Prilikom istraživanja broda nisu obavljene sistematske analize drva *in situ* niti su provedena dendrološka uzorkovanja. U trenutnoj fazi istraživanja to je utjecalo na izostanak saznanja o pojedinim detaljima, kao što su izbor i transformacija drva, je li osni trupac za potrebe izrade kobličnog elementa bio proširen ili nije, jesu li bile prisutne tiple za prethodno spajanje, koja je vrsta šavova korištena za spajanje oplate te koliko je bio efikasan sustav vodonepropusnosti trupa.

Saznanja o tim važnim karakteristikama koje se tiču izgradnje trupa te procedurama primijenjenim u brodogradnji moguće je dobiti isključivo vađenjem broda iz mora. Detaljna analiza brodske konstrukcije u laboratoriju omogućila bi u tom slučaju dobivanje podataka za razumijevanje određenih tehničkih rješenja koja su bila

Although the underwater archaeological explorations of the wreck have provided insight into the architecture of the boat structure, they were not enough to fully understand the woodworking and fastening technologies and construction process.

The inner side of the hull was completely examined, while the outer side was inspected only on the preserved end and on two plank fragments raised for the purpose of laboratory analyses. The boat was not subjected to systematic analyses of the wood and no dendrological sampling was carried out. At the current stage of the research important questions such as the selection and transformation of wood, whether or not the axial element was expanded to form the keel-like timber, the presence of pre-assembly dowels, the type of stitching used to fasten the planking and the effectiveness of the system used to render the hull watertight, remain unsolved.

Important information concerning the construction of the hull and the procedures used in building the boat can be obtained solely by removing the boat structure from the sea. A detailed hull analysis executed in a laboratory environment would provide the data needed to understand the technical solutions used to construct the boat (e.g. whether the keel-like timber was expanded or not?).



II.54

Sekcija broda planirana za rekonstrukciju (u crvenoj boji)

Section of the boat planned for reconstruction (in red)
(izradila / made by: G. Boetto)

II.55

Rekonstruirani poprečni presjek broda pri rebru R2

Reconstructed cross-section of the boat at the frame R2
(izrada / made by: P. Poveda)

primijenjena u postupku izgradnje broda (tj. da li je kobilični element bio proširen ili ne?).

Za potrebe izložbe „Zambratija. Prapovijesni šivani brod / Prehistoric Sewn Boat / Una barca cucita preistorica / Un bateau cousu préhistorique” te inspirirani radom na modelima u mjerilu 1:1 (Steffy 1994; Pomey 1999; Marlier 2003; Pomey, Poveda 2018), tijekom 2016. i 2017. godine okušali smo se u izgradnji eksperimentalne sekcije brodske konstrukcije¹.

Za rekonstrukciju je odabran poprečni presjek rebra R2 budući da je u tom dijelu očuvana većina konstruktivnih elemenata broskog trupa (Sl. II.54). Naime, kako je brod nalegao bokom na morsko dno, njegova oplata je jedino u tom segmentu ostala očuvana od kobiličnog elementa P2 do završnog voja L profila P7. Četiri platice sljubljene stično i spojene šivanjem preko letvica također su ostale očuvane.

Na osnovi digitalne fotogrametrije koja je napravljena tijekom terenskog istraživanja 2013. godine, prve 3D

For the purposes of the exhibition “Zambratija. Prapovijesni šivani brod / Prehistoric Sewn Boat / Una barca cucita preistorica / Un bateau cousu préhistorique” and inspired by working on 1:1 scale models (Steffy 1994; Pomey 1999; Marlier 2003; Pomey, Poveda 2018), during 2016 and 2017 we tried to build an experimental replica section of the boat structure¹.

A cross-section at the frame R2 was selected for reconstruction since most of the structural elements of the hull were preserved in this part (Fig. II.54). Namely, as the boat rested with one side on the seafloor, it is only in this segment that the planking has been preserved from the keel-like timber P2 to the L-shaped sheerstrake P7. Four flush-laid planks originally joined by sewing over laths were also preserved.

Based on the digital photogrammetry performed during the 2013 on-site exploration, the first 3D reconstruction of the original boat shape was carried out at the Centre Camille Jullian. This reconstruction was based on

¹ Na izradi sekcije broda radili su autori i Christian Petretich, uz prisustvo drugih članova udruge Savudrijska batana / Batana Salvorina, na čelu s predsjednikom Davorom Rašinom. Članovi udruge pomogli su u aktivnostima kod obrade drva. Replika broda izrađena je u prostoru Zajednice Talijana Savudrija / Salvore u Bašaniji, zahvaljujući susretljivosti predsjednika Silvana Pelizzona.

¹ The authors and Christian Petretich from Savudrijska batana / Batana Salvorina Association built the section of the boat. The association provided its assistance with woodworking activities. The boat section was built in the headquarters of the Italian Community of Savudrija / Salvore in Bašanija, kindly offered to us by its chairman Silvano Pelizzon.

rekonstrukcije izvorne forme broda izvedene su u Centru Camille Jullian. Ova rekonstrukcija počiva na dvije činjenice: razumljivoj simetriji poprečnog presjeka te hipotezi o simetričnosti pramca i krme izvornog plovila. Iako je zapadna strana broda bila samo djelomično očuvana, forma pojedinih nesačuvanih vojeva rekonstruirana je na osnovi onih očuvanih na istočnom boku.

Nakon računalne obrade, za izradu 3D modela su isprintani pojedini sastavni dijelovi u mjerilu 1:10. Vojevi su zatim ručno sastavljeni šivanjem najlonskom niti kroz prethodno izbušene rupe na izvornim pozicijama. To je zahtijevalo finu preciznost u rukovanju te strpljivost pri izradi, ali nažalost rezultati su bili parcijalni. Naime, zbog malih dimenzija i neprimjerenosti materijala za printanje, tj. radi njegove krutosti, nije bilo moguće rekonstruirati izvorne brodske linije ručnim modeliranjem. Ipak, ovaj fizički model omogućio je vizualizaciju očuvanih ostataka broda u tri dimenzije te je na izložbi poslužio kao koristan didaktički primjer brodskih ostataka *in situ*.

Zahvaljujući računalnoj obradi te modelu rekonstruiranih brodskih linija, bilo je moguće izraditi točnu rekonstrukciju forme i dizajna u dijelu presjeka pri rebru R2 te preliminarnu rekonstrukciju arhitektonskih elemenata broda (Sl. II.55). Dužina sekcije planirane za izradu bila je 90 cm, tj. 1/10 od rekonstruirane izvorne dužine broda. Rekonstruirana širina trupa je 201 cm.

Odabir drva za izradu sekcije

Primarna zadaća prije izrade sekcije bila je dobava adekvatnog drva. U skladu s mogućnostima pokušali smo pribaviti izvorno drvo koje je korišteno pri izradi broda: brijest (*Ulmus* sp.) za platice, prirodno zakrivljenu johu (*Alnus* sp.) ili grane divlje kruške (*Pyrus communis* L.) za rebra, jelu (*Abies alba*) za letvice, topolu (*Populus* sp.) i johu za male drvene čavle (Sl. II.56 – II.58).

Ovo drveće u Istri raste u dvije različite zone, primorskoj i planinskoj. U konzultaciji sa stručnjacima iz Hrvatskih šuma² te uvidom u vrste drveća koje rastu u Motovunskoj šumi, utvrđeno je da u dolini rijeke Mirne danas nije moguće naći drvo svojte joha ili kruška adekvatne zakrivljenosti kakvu ima rebrenica R2. Slijedom tih okolnosti, s lagersa Hrvatskih šuma, uz pomoć prethodno izrađene krivulje rekonstruiranog poprečnog presjeka broda pri rebru R2 u mjerilu M 1:1, odabrano je bjelogorično drvo koje je imalo takve karakteristike, a to je hrast lužnjak (*Quercus robur*).

Daske brijesta (*Ulmus* sp.) nabavljene su od tvrtke Quercus d.o.o. u Livadama³, međutim nije poznato iz kojeg dijela Hrvatske potječu.

2 U pronalazačenju adekvatnog drva pomogli su nam djelatnici Hrvatskih šuma iz Uprave šuma Podružnice Buzet – Šumarija Buzet, na čemu im najsrdačnije zahvaljujemo.

3 Pri izboru nam je pomogao Franco Franzutti, kojemu na tomu najljepše zahvaljujemo.

two facts: the implicit symmetry of the cross-section and the hypothesis of an original symmetrical shape of the bow and stern extremities. Although the western side of the boat was only partially preserved, the shape of individual non-preserved strakes was reproduced based on the preserved strakes on the eastern side.

Once the data was processed, a 1:10 scale model of the preserved parts of the wreck was printed with a 3D printer. The strakes were then sewn together using a nylon thread through holes previously drilled on their original positions. The work required great precision and patience, but gave only partial results. Due to the small scale of the model and the rigidity of the material, the reconstruction of the original boat lines by manual modelling was not possible. Still, this physical model enabled a visualization of the preserved boat remains in three dimensions and therefore served as a useful didactic exhibit of the boat remains.

With the help of computer processing and using the model of the reconstructed boat lines, it was possible to make an accurate reconstruction of the shape and design of a section of the boat at frame R2 and a preliminary reconstruction of the architectural elements of the boat (Fig. II.55). The length of the section planned for construction was 90 cm, which is 1/10 of the reconstructed original length of the boat. The reconstructed hull width is 201 cm.

Selection of wood for the construction of the section

The first task before making the section was to find adequate wood. To the best of our ability we tried to find the same wood as used in the original boat construction: elm (*Ulmus* sp.) for planking, naturally curved alder (*Alnus* sp.) or pear (*Pyrus communis* L.) branches for frames, fir (*Abies alba*) for laths, poplar (*Populus* sp.) and alder for the pegs locking the stitching (Figs II.56 – II.58).

These trees grow in two different zones in Istria, one located by the coast and the other in the mountains. After having consulted the experts from Hrvatske šume d.o.o. (the Croatian Forestry company),³ and been given an insight into the Motovun forest stand, it has been confirmed that alder and pear species with suitable curvature for building the R2 frame could not be found in the Mirna River valley. Consequently, an alternative deciduous species that met the required characteristics, namely oak (*Quercus robur*), was chosen and a timber selected using a 1:1 template².

Elm planks (*Ulmus* sp.) were purchased from the warehouse of Quercus d.o.o. in Livade³. However, their exact provenance within Croatia is unknown.

2 We are very grateful to the employees of the Buzet Regional Office (Buzet Branch of Hrvatske šume Forest Administration) for helping us find suitable wood.

3 Special thanks to Franco Franzutti who assisted us in wood selection.



II.56



II.57



II.58

II.56

Motovunska šuma, u potrazi za drvetom johe za izradu rebrnice
Motovun forest, searching for alder for the construction of the floor-timber
 (fotografija / photo by: I. Koncani Uhač)

II.57

Traženje adekvatnog drva uz pomoć šablone
Searching for adequate wood using a template
 (fotografija / photo by: I. Koncani Uhač)

II.58

Čičarija, kalanje jelovih trupaca za izradu letvica
Čičarija, splitting the fir trunks for making the laths
 (fotografija / photo by: I. Koncani Uhač)

Jelove letvice (*Abies alba*) prvotno smo pokušali izraditi od sirove jelove građe na lokaciji u Račjoj Vasi na Čičariji⁴, što se pokazalo zahtjevnijim nego što smo očekivali. Naknadno smo pomnim odabirom polusuhih, industrijski piljenih jelovih dasaka sa skladišta Arheološkog muzeja Istre uspjeli izdvojiti nekoliko komada od kojih smo ručnom i strojnom obradom izradili letvice adekvatne za izradu sekcije broda.

Za sustav spajanja sekcije odabran je konop od industrijske konoplje, imajući u vidu da izvorni konop nije sačuvan pa njegov sastav i izrada nisu determinirani. Za izradu 300 malih drvenih čavala koji su služili za zaptivanje rupa od šavova sekcije, poslužili smo se industrijski pregotovljenim štapićima od drva bukve, umjesto da ih ručno izrađujemo od johe i topole.

Naposljetku, paklinu smo prvotno pokušali dobiti s područja NP Paklenica, od jednog od zadnjih

⁴ U pokušaju izrade letvica pomogao nam je poznavatelj Čičarije Igor Zaharija, kojemu ovom prilikom od srca zahvaljujemo.

We initially tried to make fir laths (*Abies alba*) from raw fir material at a location in Račja Vas in Čičarija⁴, which turned out to be more demanding than we expected. Subsequently, through careful selection of semi-dry, industrially sawn planks from the warehouse of the Archaeological Museum of Istria, we were able to extract several pieces from which we produced, by hand and machine processing, laths adequate for the section of the boat.

For the assembly system, a rope made of industrial hemp was chosen, taking into consideration that the original rope is not preserved so its composition and manufacture could not be determined. The three hundred pegs to fasten the stitching were obtained from prefabricated beech sticks rather than making them manually from alder and poplar.

Finally, we tried to obtain pitch for coating the

⁴ We thank Igor Zaharija, who knows Čičarija mountain very well, for providing help in the first stage of making laths.

tradicionalnih proizvođača u Hrvatskoj, ali nažalost bez uspjeha. Zatim smo dvije vrste pakline, tamnu od borovine (*Pinus* sp.) i svijetlu od jelovine (*Abies*), naručili od tvrtke DCC iz Bordeauxa, Francuska.

Obrada drva i proces izgradnje

Nakon odabira drva započeta je izrada sekcije (Sl. II.59). Zbog ograničenja vremenom, kao i izostanka studije o alatima koje su koristili prapovijesni brodograditelji, upotrijebili smo moderne alate (blanje, bušilice, pile i dr.), ručno ili električno pogonjene (Sl. II.60).

Za oplatu je korišteno ukupno 12 platice i dva završna voja L profila. Platice su obrađene piljenjem i blanjanjem te su prilagođene prosječnoj debljini izvornih platice. Kako je brod građen po principu „prvo ljuska“, koji je jedini kompatibilan s uzdužno šivanom oplatom, prilikom izrade sekcije prvo je položena kobilična platica, a zatim ostatak oplate prije umetanja rebra. Naime, bilo nam je, isto kao i prapovijesnim brodograditeljima, nemoguće spojiti platice uzdužnim šivanjem ako je rebro bilo postavljeno na kobilični element prije ugradnje oplate.

reconstructed section from one of the last Croatian traditional producers operating in Paklenica National Park region, but, unfortunately, without success. So we ordered two types of pitch from the company DCC from Bordeaux, France, a dark one made from pine (*Pinus* sp.) and a white one made from fir (*Abies*).

Woodworking and construction process

Once the wood was selected, the construction of the section was underway (Fig. II.59). Due to time constraints and in the absence of a study of the tools used by prehistoric shipbuilders, we used modern tools (planers, drills, saws, etc.), manually or electrically operated (Fig. II.60).

In total, 12 planks and two L-shaped sheerstrakes were built for the planking. The planks were sawn and then planed to match the original thickness of the planking. As the construction of the boat was based on a “shell first” building process, which is the only one compatible with longitudinally sewn planking, the keel-like timber was laid first, followed by the rest of the planking before finally inserting the frame. In fact, it would be impossible for us, as it was for the ancient boatbuilders, to connect the planks using continuous longitudinal sewing

II.59
Priprema za izradu sekcije
Preparing for the construction
of the section
(fotografija / photo by: I. Koncani
Uhač)





Kako smo gradili samo malu sekciju broda, bilo nam je neophodno služiti se vanjskom nosivom strukturom za ugradnju bočnih platice, što ne bi bilo potrebno da smo gradili cijeli šivani brod, kojem bi u tom slučaju trup bio samonosiv.

Bočne platice su slagane stično na osnovi vanjske nosive konstrukcije bazirane na rekonstruiranoj krivulji poprečnog presjeka. Zbog međusobnog boljeg prijanjanja sljubnica platice tijekom radova, zaključili smo da one moraju biti malo zakošene, što je izvedeno blanjanjem. Taj tehnički detalj na istraživanjima nije bio u potpunosti utvrđen budući da oplata nije demontirana, ali je vjerojatno bio primijenjen. Platice su također (kao i izvornici) u donjem dijelu sljubnica bile zakošene (zaobljene), radi upuštanja konopa unutar sljubnica platice (Sl. II.61).

Nakon obrade se naizmjenice obavljalo bušenje za potrebe šivanja. Prvotno smo s bušenjem krenuli iz unutrašnjosti trupa prema donjem vanjskom rubu platice, ali je zbog nepreciznosti izrade tj. nemogućnosti preciznijeg bušenja - u smislu izlaska rupe točno na vanjskom zakošenom dijelu platice - zaključeno da se ono može lakše i preciznije obavljati obratno, tj. izvana prema unutra. Na uzorku platice izvađene s nalazišta moglo se uočiti da su rupe s vanjske strane manje (4-5 mm), pravilnije i preciznije izvedene, dok one s unutarnje strane imaju ljevkast izgled, s više mogućih izlaza rupa (1 i više).

Ne bismo li omogućili usmjerenost rupa i šava, prvo smo izbušili rupu od vanjskog zakošenog ruba platice prema njenom unutarnjem gornjem licu. Tada smo na osnovi pozicije i kuta rupe bili u mogućnosti bušiti pridruženu rupu na susjednoj platici, poštujući zadani smjer i kut. Prosječni izvorni kut bušenja, koji smo težili rekonstruirati, bio je 54 stupnja. Rupe su se s vanjske strane oplata morale točno poklapati, da ligature ne bi stršale izvan oplata i da bi bile zaštićene od mogućih mehaničkih oštećenja.

Izrada letvica za osiguravanje vodonepropusnog

if the frame was placed on the keel-like timber before the planking was installed.

Since we were only building a small section of the boat, it was necessary for us to use a cradle to support the side planks. This would not be the case if we were building a whole sewn boat, in which case the hull would be self-supporting.

The side planks were arranged in a flush-laid fashion on the external support following the reconstructed cross-section curvature. To achieve a close fit of the planks the edges were planed at a slight bevel. This detail has not been observed on the wreck as the planking was not dismantled, but was most likely the case. As in the original boat, the planks were also chamfered in the outer corner of the edges to allow the ropes to be inserted inside the seams (Fig. II.61).



Parallel to woodworking, drilling was performed for sewing purposes. The holes were drilled from the inside of the hull towards the lower outer edge of the plank, but due to the inability to drill precisely since the exit hole was intended to be on the chamfered outer angle, it was concluded that the drilling could be performed more easily and more precisely in the opposite direction, i.e. from the outboard inwards. The sample of the plank taken from the site showed that the holes on the outside were smaller (4-5 mm), more correctly and accurately made, while on the inside multiple channels were visible (one and more).

In order to facilitate the alignment of the holes and stitch, first we drilled a hole from the outer chamfered edge towards the inner face of the plank. Then, based on the position and angle of the hole, we were able to drill the associated hole in the adjacent plank following the correct direction and angle. We tried to copy the average original angle of the drilled holes, which was 54 degrees. The holes on the outer side of the plank had to

II.60

Eksperimentalne alatke za izradu rupa na oplati
Experimental tools for drilling holes on the planking
(fotografija / photo by: I. Koncani Uhač)

II.61

Priprema za spajanje platice
Preparing for the joining of the planks
(fotografija / photo by: I. Koncani Uhač)

II.62
Obrada letvica
Making the laths
(fotografija / photo by: M. Uhač)



II.62

II.63
Proba šivanja platica
Practising plank sewing
(fotografija / photo by:
T. Draškić Savić)



II.63

II.64
Šivanje oplata
Sewing the planking
(fotografija / photo by: M. Račan)



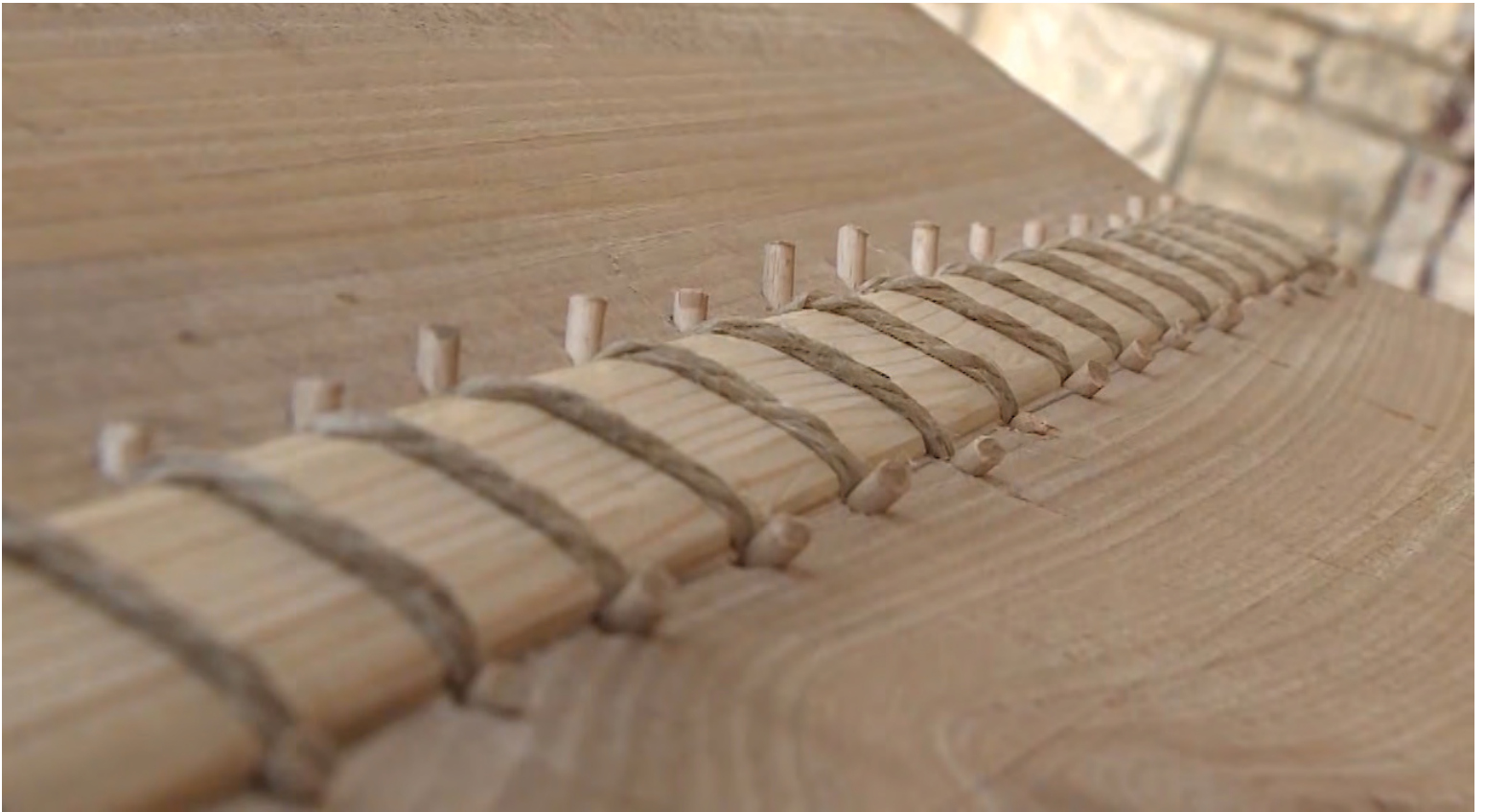
II.64

materijala pokazala se puno zahtjevnijom nego što smo očekivali. Naime, radijalnim rasijecanjem jelovog trupca dužine 1,5 m nismo uspijevali kalati letvice tanje od 10 mm te dužine veće od 50 cm. Tomu bi mogao biti razlog neadekvatno odabrana sirovina ili vjerojatnije naše neiskustvo. Budući da u suprotnom ne bi bilo moguće nastaviti pokus, odabrali smo izrezati letvice od industrijski piljenih dasaka (Sl. II.62). Letvica je potom položena iznad sljubnica platica bez stavljanja brtvila za osiguranje vodonepropusnosti, jer je interpretacija vlakana još bila u tijeku - tada još nisu bile završene analize o korištenju morske trave i/ili mahovine odnosno nekih drugih biljnih materijala kao i materijala za osiguranje vodonepropusnosti sljubnica.

Radi lakšeg šivanja prvo je isprobano sukanje vrha konopa i njegovo umakanje u paklinu, ali smo naposljetku pribjegli jednostavnijem rješenju korištenjem bakrene igle (Sl. II.63, II.64). Prethodno su pripremljeni

be exactly matched in order to prevent the ligature from protruding and to protect it from mechanical damage. The aim of such accuracy was also the desire to reconstruct the original stitch morphology.

Finally, making the laths that made up the waterproofing system of the boat proved to be more demanding than expected. We tried to radially split the 1.5 m long fir-log, but we were not able to obtain laths thinner than 10 mm and longer than 50 cm. This could be the result of the use of an unsuitable raw material or, more likely, our inexperience. Since it was not possible to continue the experiment, we preferred to cut laths from machine-sawn planks (Fig. II.62). The laths were then laid above the seams without installing the waterproofing material, since the interpretation of the fibres was still ongoing and the analyses of the use of seagrass and/or moss or other plant materials for waterproofing were not yet completed.



II.65

II.65
Detalj sašivene oplate
Detailed view of sewn planks
(fotografija / photo by: M. Račan)



II.66

II.66
Sekcija u radu
Section in progress
(fotografija / photo by: I. Koncani Uhač)

II.67

Tesanje rebra

Carpentry work on the frame
(fotografija / photo by: I. Koncani
Uhač)



mali drveni čavli dužine do 3 cm, koji su po zatezanju konopa zabijani u rupe pojedinog šava (Sl. II.65). Jednostavno rubno šivanje iziskivalo je oko 4 metra konopa po dužnom metru sljubnica platica. Nakon kraćeg uhodavanja šivanje je teklo relativno brzo i jednostavno (Sl. II.66).

Nakon izgradnje oplata pristupili smo ugradnji rebra. Kao što smo ranije naveli, na osnovi šablone odabrano je drvo adekvatnih dimenzija i zakrivljenosti, koje je zatim motornom pilom ugrubo modelirano. Sljedeća faza bila je njegova obrada u cilju dobivanja trapezastog presjeka sa zaobljenom gornjom stranom, uz uklanjanje kore. Ručno tesanje i blanjanje električnom blanjom tražilo je dosta preciznog rada i vremena (Sl. II.67). Osobita pažnja usmjerena je na dodir rebra i sljubnica tj. letvice, u cilju što boljeg prianjanja baze rebra na oplatu te radi očuvanja letvice. Ugrađivanjem rebra te njegovim vezivanjem za svaku drugu platicu dobivena je poprečna krutost modela, tj. spoj svih ugrađenih elemenata (Sl. II.68 – II.71).

Nakon izgradnje sekcije obavljeno je završno premazivanje paklinom na bazi crnogorice. Trup je izvana premazan tamnom paklinom od borovine (*Pinus sp.*), a iznutra (Sl. II.72, II.73) svijetlom paklinom od jelovine (*Abies*). Polovica sekcije ostavljena je neobojena, sa svim radioničkim oznakama, radi stjecanja boljeg uvida u kompleksnost procesa izrade.

For ease of sewing, first we tried to twist the tip of the rope and to dip it into pitch, but eventually resorted to a simpler solution of using a copper needle (Figs II.63 – II.64). Small wooden pegs, up to 3 cm in length, have been pre-prepared and, after tightening of the sewing, were hammered into the hole of each stitch (Fig. II.65). The simple overedge sewing required approximately 4 m of rope for 1 m of seam. After a short initial training, the sewing was done relatively quickly and easily (Fig. II.66).

After finishing the planking, the frame was inserted. As noted earlier, a piece of wood of suitable dimensions and curvature was selected by using a template, and then roughly shaped with a chainsaw. The next phase involved processing to remove the bark and obtain a trapezoidal cross-section with a rounded upper side. Manual carpentry work and planing with an electric planer took a lot of precision work and time (Fig. II.67). Special attention was paid to fitting the frames to the planking to prevent damage to the laths. The transverse rigidity of the model was obtained by fastening the frames to every other plank, which joined all the elements (Fig. II.68 – II.71).

Finally, the section was coated with conifer-based pitch. The hull was coated with dark pine (*Pinus sp.*) pitch on the outside, while a white one from fir (*Abies*) was applied on the inside (Figs II.72, II.73). Half of the section was left uncoated in order to show all working marks and thus offer a better insight into the complexity of the design process.



II.68
Vezivanje rebra za oplatu
Lashing the frame to the planking
(fotografija / photo by: M. Račan)



II.69
Pogled na vanjsku oplatu i rupe za vezanje
View of the exterior side of the planking and the holes for lashing the frame
(fotografija / photo by: M. Račan)



II.70
Pogled na rebro vezano za oplatu
View of the frame lashed to the planking
(fotografija / photo by: M. Račan)



II.71

II.71
Učvršćivanje rebra za oplatu
Fastening the frame to the planking
(fotografija / photo by: M. Račan)



II.72

II.72
Premazivanje trupa paklinom
Coating the hull with the pitch
(fotografija / photo: M. Račan)

II.73
Premazivanje vanjske strane trupa paklinom
Coating the exterior side of the hull with the pitch
(fotografija / photo by: M. Račan)



II.73

Zaključak

Skromno znanje u početnoj fazi projekta, vezano uz izbor, dobavu i obradu adekvatne drvene građe, nije nam omogućilo rekonstrukciju pojedinih elemenata broda na identičan način kao što su to činili nekadašnji brodograditelji. Taj je problem bio osobito izražen pri nabavi johe za izgradnju rebra. Naime, mogućnost nabave tog drva svedena je na samo jedan izvor (tvrтка Quercus d.o.o. u Livadama), a usto niti jedna sirovina nije odgovarala krivulji rebrenice R2. Stabla johe smo intenzivno tražili na području Motovunske šume, ali problem je predstavljao pronalazak adekvatno zakrivljenog drva. Naglašavamo također problem dobave jelovine, koja danas raste oko 60 km od vjerojatnog mjesta izgradnje broda tj. od uzmorskog pojasa, te teškoće pri njenoj obradi za izradu letvica.

Izradu predmetne sekcije obavili smo za 100 radnih sati, s prethodno pregotovljenom drvnom građom. Brzina izrade određenih elemenata konstrukcije bila je višestruko veća jer smo koristili električne alate. Primarna zadaća izrade sekcije u mjerilu 1:1 bila je omogućavanje opipljive prezentacije dijela broda široj publici, što nam je, sudeći prema reakcijama posjetitelja izložbe, i uspjelo.

Izradom ove sekcije samo smo se površinski dotakli vještina potrebnih za izgradnju broda. Jasno je da bez podizanja brodske konstrukcije iz mora i njene temeljite analize zasad ne možemo pružiti većinu odgovora vezanih uz pitanje kako je na prijelazu iz brončanog u željezno doba Istre izgrađeno ovako kompleksno plovilo.

Izrada sekcije u mjerilu 1:1 potvrdila je i da je za znanstveno istraživanje potrebno specifično znanje u smislu odabira sirovine i tehnika obrade drva, a koje su prapovijesni brodograditelji očito posjedovali.

Ipak, određena saznanja vezana uz potrebu zaključenja bokova strana platica radi njihova kvalitetnijeg sljublivanja, iskustvo stečeno pri bušenju rupa u cilju njihovog poklapanja te mjerljivost utrošenog materijala i vremena opravdavaju energiju uloženu u izradu ove sekcije broda.

Conclusion

Our lack of knowledge at the start of the project, related to the selection, supply and processing of adequate wood, prevented us from reconstructing certain boat elements exactly as they were built by the ancient shipbuilders. This issue was especially evident when trying to procure alder for the construction of the frames. Specifically, the choice of the wood was reduced to only one source (Quercus d.o.o. in Livade), where no raw material corresponded to the curve of the frame R2. We searched intensively for alder trees in the area of the Motovun forest, but the major problem was finding a log with adequate curve. Obtaining fir, which today grows about 60 km away from the probable place of the boat construction, i.e. from the coast and processing that fir for the manufacture of laths, was especially arduous.

We spent 100 hours working on the construction of the section concerned, by using pre-finished timbers. The construction of certain elements was speeded up due to the use of electrically powered tools. The main purpose of creating a 1:1 scale section was to produce a tangible presentation of a section of the boat for a wider audience, and judging by the reactions of the visitors of the exhibition it has been successful.

By building this section, we only superficially touched on the skills needed to build a boat. Clearly, without lifting the boat structure out of the sea and analysing it thoroughly, we cannot at this time provide most of the answers related to the question of exactly how it came to be that such a complex vessel was built in the period of transition from the Bronze Age to the Iron Age in Istria.

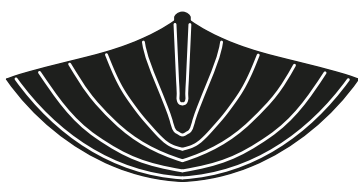
The construction of a 1:1 scale section demonstrated that for research we require specific knowledge in terms of material selection and woodworking techniques, which ancient shipbuilders obviously possessed.

However, realizing the need for bevelled plank edges to ensure a tight fit, the experience gained of drilling closely matching holes, and quantifying the material and time required justify the energy invested in making this experimental boat section.

III.

**Datiranje
i tehnologija
brodogradnje**

**Dating &
Shipbuilding
Technology**



Datiranje

Dating

Frédéric Guibal, Christine Oberlin,
Alba Ferreira Dominguez, Giulia Boetto

Budući da na lokalitetu nisu pronađeni keramički ili drugi predmeti povezani s ostacima olupine, a na temelju kojih bi se konstrukcija mogla datirati tipološkom metodom, datiranje je provedeno dendrokronološkom analizom i metodom akceleratorne masene spektrometrije (AMS), kako bi se pokušala odrediti starost brodske konstrukcije.

Neki od prikupljenih uzoraka sinkronizirani su na kalibracijskoj krivulji ^{14}C primjenom metode *wiggle matching*.

Dendrokronologija je primijenjena kako bi se pokušalo odrediti vrijeme sječe stabala korištenih za izradu različitih dijelova brodske konstrukcije.

Sječa je vrijeme smrti stabla, što je biološki događaj najbliži upotrebi drva, a time i izradi broda (Guibal, Pomey 1998, 427). Utvrđivanjem sličnih nizova godina na različitim komadima drva omogućuje se njihova sinkronizacija, koja pak omogućuje relativno datiranje. Sinkronizacija različitih uzoraka temelji se na uočavanju podudarnosti između godina koji predstavljaju različite kronologije, kao i na statističkoj podudarnosti utvrđenoj primjenom parametarskih i neparametarskih ispitivanja na numeričku seriju (Baillie 1982, 31-32; Guibal, Pomey 1998, 425-428, 2003).

Za dobivanje apsolutne starosti, podudarnost serije godina iz svakog uzorka i referentne kronologije određuje se istim postupkom. Referentna se kronologija određuje polazeći od živih stabala (znači od godine u kojoj je stvoren zadnji god i kada su, stoga, poznati svi godovi) i sinkronizirajući serije njihovih godina s progresivno mlađim uzorcima. Datiranje dendrokronološkom analizom zahtijeva dostupnost regionalne referentne kronologije vrste drveća čija se starost određuje.

U slučaju da nisu pronađene podudarnosti, mogu se provesti ispitivanja uz pomoć AMS-a na nizu godina

As no ceramic or other artefacts that could provide typological dating for the wreck were found in association with the remains, dendrochronological dating and AMS mass spectrometry were carried out to attempt to date its construction.

Some of the samples taken were synchronized on the ^{14}C calibration curve using wiggle-matching.

Dendrochronology was used to attempt to provide dates for the felling of the timbers used in the different parts of the boat's construction.

Felling is when the tree died, which is the biologic event closest to the use of the wood and therefore the construction of the boat (Guibal, Pomey 1998, 427). The identification of similar tree-ring sequences on different pieces of wood allows them to be synchronized, which allows relative dating. The synchronization of different samples relies on finding a visual match between curves representing different chronologies and a statistical match, using parametric and non-parametric tests, to the numeric series (Baillie 1982, 31-32; Guibal, Pomey 1998, 425-428, 2003).

To obtain an absolute date, the same process is used to match the tree-ring series for each sample to a reference chronology. The reference chronology is made by starting from living trees (so the year in which the last tree-ring was formed, and therefore all the rings, is known) and synchronizing their tree-ring series with samples of progressively earlier dates. Dendrochronological dating requires a regional reference chronology to be available for the species of wood to be dated.

Where no match is found, it is possible to carry out a series of AMS dating tests on the tree-ring sequence

jednog komada drva čiji su uzorci jednako vremenski udaljeni jedan od drugog. Tako dobiveni rezultati se nakon sinkronizacije na kalibracijskoj krivulji ^{14}C , primjenom metode *wiggle matching* (Pearson 1986, 295-296), mogu iskoristiti za poboljšanje preciznosti radiokarbonskog datiranja, a time i za određivanje starosti dendrokronološke serije.

Dendrokronologija

Nakon rezanja, poprečna ploha svakog uzorka očišćena je britvicom radi bolje vidljivosti godova. Osnovna serija širine godova izmjerena je uz preciznost od 1/100 mm, pomoću mjerne tablice LINTABB6®RinnTech i sustava TSAP koji je izradio Rinntech (Heidelberg, Njemačka).

Podudarnosti među serijama mogu se odrediti statističkim testovima kojima se mjeri matematička korelacija između dvije serije koje se uspoređuju (program TSAPWin®) i vizualnom usporedbom promjena u širini godova na vremenskoj krivulji.

Prije određivanja podudarnosti među različitim drvenim dijelovima, standardizirane su širine godova. Standardizacija omogućuje smanjenje niskih i srednjih frekvencija u osnovnim serijama, koje su osobito prouzročene općim povećanjem širine godova koje se događa protekom vremena te oblikom debla, čime dolaze do izražaja promjene nastale tijekom godina (visoke frekvencije) koje se mogu naći u dendrokronološkim serijama.

Širine godova sirovog drva standardizirane su metodom normalizacije (org. Corridor method) (Durost 2005; Lambert 2006) i transformacijom na E indekse prema Besançonu (Lambert, Lavier 1992, 127).

U pogledu izmjerenih godova, iz dva je uzorka dobiven samo mali broj: 59 za PRL11 i 64 godova za PRL19 (Sl. III.1). Zbog tako malog broja nije bilo moguće utvrditi godinu sječe, a s obzirom na to da taj uzorak nije reprezentativan, nismo uspjeli izvesti pouzdana tumačenja iz serije¹. Štoviše, nepresutnost sličnih godova na dvije uzorkovane rebrenice značilo je da se ne mogu podudarati.

Nisu pronađena podudaranja s referentnom kronologijom, odnosno sa serijom čija je starost već određena, a razlog tomu može biti činjenica da u bazama podataka nema dostatnih zapisa o brijestu².

Zasad serije godova iz ostataka broda Zambratija nisu datirane. Međutim, studija je omogućila dodavanje navedenih kronologija brijestova u baze podataka koji se odnose na hrvatsku obalu.

from a single piece of wood where samples are temporally equidistant from each other. The results obtained in this way, once synchronized on a calibrated ^{14}C curve by wiggle-matching (Pearson 1986, 295-296), can be used to improve the precision of the radiocarbon dates and therefore to date the dendrochronological series.

Dendrochronology

After being cut, the transversal face of each of the samples was cleaned with a razor blade to improve the visibility of the rings. The elementary series of ring widths was measured with a precision of 1/100 mm using a LINTABB6®RinnTech measuring table and the TSAP system made by Rinntech (Heidelberg, Germany).

Inter-series matches can be established using statistical tests that measure the mathematical correlation between the two series being compared (TSAP Win® program) and visual comparison of temporal curve variations of the tree-ring widths.

Before looking for matches between different timbers, the tree-ring widths were standardized. Standardization allows low and middle frequencies to be reduced in an elementary series, notably caused by a general decrease in the width of rings with age and the shape of the tree trunk, and thus accentuates inter-annual variations (high-frequencies) that are found in all the series.

The raw tree-ring widths were standardized using the Corridor method (Durost 2005; Lambert 2006) and the transformation to E indices following Besançon (Lambert, Lavier 1992, 127).

In terms of the rings measured, the two samples provided only a small number: 59 for PRL11 and 64 rings for PRL19 (Fig. III.1). This low number of rings did not allow the felling year to be established and, taking into account that this sample is not representative, we were not able to make reliable interpretations from the series¹. Moreover, the absence of similar rings in the two timbers sampled meant they could not be matched to each other.

No match could be found with a reference chronology, that is, a series that is already dated, possibly because elm is not a very well recorded species in the available databases².

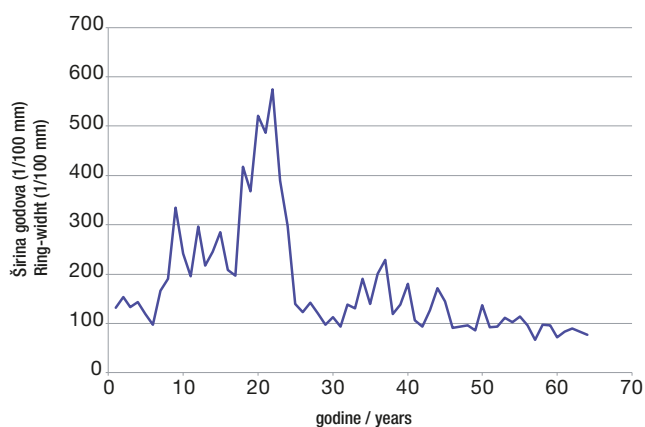
At present, the tree-ring series for the Zambratija wreck have not been dated. However, the study allowed these chronologies for elm to be added to the database for the Croatian coast.

¹ Za pouzdane rezultate potrebno je barem 15 uzoraka, od kojih svaki ima barem 60 godova.

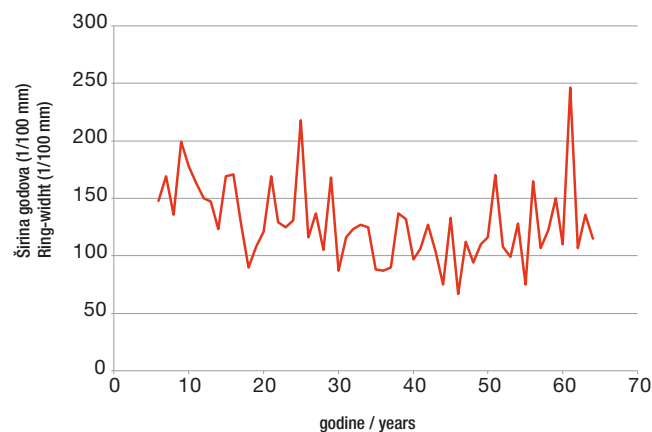
² Najpotpunija serija brijestova nalazi se u Mediteranskom institutu za bioraznolikost i ekologiju mora i kopna (IMBE). Druge podudarnosti tražit će se u budućnosti u lokacijski bližim serijama, posebno u Sloveniji.

¹ Reliable results require at least 15 samples each with at least 60 tree rings.

² The most complete elm series is kept by the Mediterranean Institute of Marine and Continental Biodiversity and Ecology (IMBE). Other matches will be looked for in the future in the more local series, particularly from Slovenia.



— odvojeni fragment platice PRL 11
disjointed fragment of plank PRL11



— odvojeni fragment platice PRL 19
disjointed fragment of plank PRL19

III.1

Neobrađena krivulja promjena širine godova iz fragmenata oplata PRL11 i PRL19

Raw curve of variation in tree-ring widths from planking fragments PRL11 and PRL19

(izrada / made by: A. Ferreira Dominguez)

Radiokarbonsko datiranje

Osim radiokarbonskog datiranja koje su proveli Institut Ruđer Bošković iz Zagreba 2009. i 2013., te laboratorij Beta Analytics Inc. iz Miamija, mi smo za potrebe analize tehnikom AMS, uz pomoć programa Artemis CNRS-a, uzeli četiri jednako vremenski udaljena uzorka iz nizova godova jedne rebrenice (PRL11), odnosno konstantni broj zasebnih godova (Sl. III.2)³. Rezultati su pokazali starost između 1288. pr. Kr. i 1056. pr. Kr., za koje je utvrđeno podudaranje na kalibracijskoj krivulji ¹⁴C primjenom metode wiggle matching⁴, ali oni nisu pružili precizan kronološki interval zbog ravnine na kalibracijskoj krivulji, koja se odnosi na razdoblje od 1210. do 1140. pr. Kr. (Sl. III.3). Naime, fluktuacije u proizvodnji ugljika u stratosferi dovele su u nekim razdobljima do ravnine u količini ¹⁴C u materijalima koji sadržavaju ugljik. Zbog toga nije bilo moguće točnije odrediti starost (Evin, Oberlin 2005, 113).

Ipak, uzorak PR11 za radiokarbonsku analizu tehnikom AMS, koji je uzorkovan s mjesta najbližeg rubu debla⁵ (radi približnog određivanja vremena sječe stabla od kojeg je izrađena oplata broda) datira iz razdoblja između 1268. i 1056. pr. Kr., što je slično vremenu koje je odredio Institut Ruđer Bošković iz Zagreba 2013. godine (Sl. III.2).

Radiocarbon dating

In addition to radiocarbon dating carried out by the Institut Ruđer Bošković in Zagreb in 2009 and 2013, and by Beta Analytic Inc. in Miami, we took four temporally equidistant dating samples from the tree-ring sequences from a single timber (PRL11), that is, a constant number of rings apart, for AMS within the Artemis programme of the CNRS (Fig. III.2)³. The results gave dates between 1288 BCE and 1056 BCE that have been matched on the ¹⁴C calibration curve by wiggle-matching⁴, but they did not provide a very precise chronological interval because of the plateau in the calibration curve that affects dates in the period 1210-1140 BCE (Fig. III.3). In fact, fluctuations in radiocarbon production in the stratosphere have led to plateaux in the quantity of ¹⁴C in carbon-containing materials at some periods. For this reason, no tighter dating could be obtained (Evin, Oberlin 2005, 113).

Nonetheless, AMS radiocarbon sample PR11 taken closest to the edge of the trunk⁵ so it could provide an approximate date for felling of the tree used for the boat's planking, gave a date between 1268-1056 CE, which is a similar date to that obtained by the Institut Ruđer Bošković of Zagreb in 2013 (Fig. III.2).

3 Četiri uzorka pripremljena su u Lyonu u Centre de Datation par le Radiocarbone (UMR 5138 Archéométrie et Archéologie), a ¹⁴C mjereno je akceleratorom ARTEMIS, UMS 2571, Laboratoire de Mesure du Carbone 14 (LMC14), Saclay, Francuska.

4 U praksi je cilj bio datirati uzorke prikupljene u sklopu jasno definirane kronologije (uzorci su uzimani sa svakih 3-5 godova), koja bi se potom mogla iskoristiti za datiranje niza godova primjenom kalibriranih istovjetnih starosti određenih ugljikom ¹⁴C i Bayesijske teorije (Ramsey *et al.* 2001, 384-385).

5 Code Lyon-12425 (SacA43735).

3 The four samples were prepared by the Centre de Datation par le Radiocarbone (UMR 5138 Archéométrie et Archéologie) at Lyon and the measurement of ¹⁴C was carried out using the accelerator ARTEMIS, UMS 2572, Laboratoire de Mesure du Carbone 14 (LMC14), Saclay, France.

4 In practical terms, the aim was to gain dates from the samples taken within a clearly defined chronology (each sample was taken every 3-5 rings) which could then be used to place the tree-ring sequence in time using the calibrated ¹⁴C dates par and Bayesian theory (Ramsey *et al.* 2001, 384-385).

5 Code Lyon-12425 (SacA43735).

Zaključak

Zbog nedostatka konačnog rezultata koji su pokušali dobiti različiti laboratoriji primjenom metode *wiggle matching* i radiokarbonskog datiranja, pomoću metode AMS-a (Sl. III.2), prihvaćaju se datacije dobivene u laboratoriju Beta Analytics Inc. koje su rezultirale kalibracijskim intervalom 1120. - 930. god. pr. Kr. Slijedom navedenog, brod Zambratija izrađen je u razdoblju između zadnje četvrtine 12. i početka zadnje četvrtine 10. st. pr. Kr.

Ti rezultati potvrđuju da je ovaj vrlo rijedak brod zasad najstariji poznati primjerak u potpunosti šivanog broda u Sredozemlju. Nadamo se da će potpuno dendrokronološko istraživanje očuvanih ostataka broda iz Zambratije, ako se nastavi, pružiti precizniju dataciju.

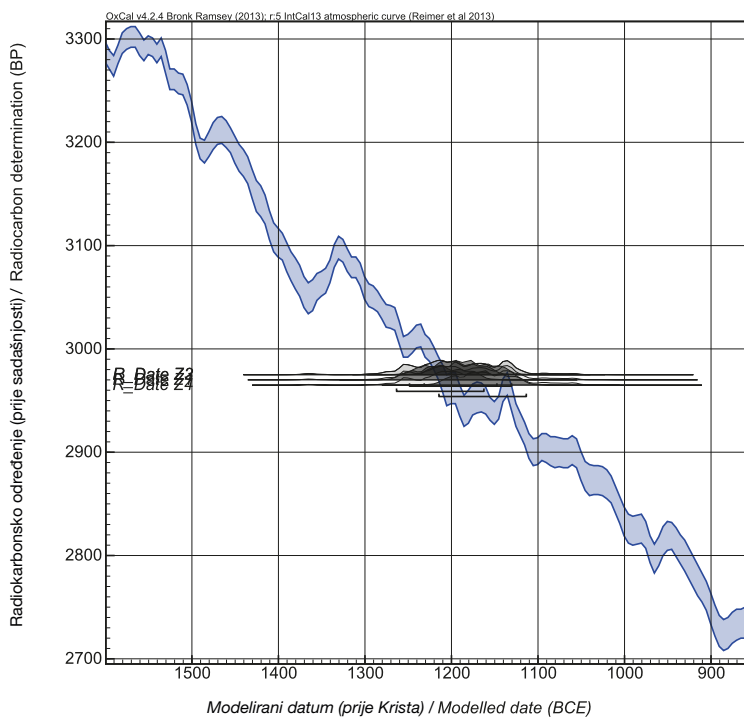
Conclusion

On account of the lack of a conclusive result from the attempts at wiggle-matching and the ^{14}C AMS dating carried out by different laboratories (Fig. III.2), we retain the dates provided by Beta Analytics Inc. which give a calibrated interval of 1120-930 BCE. This places the construction of the Zambratija boat between the last quarter of the 12th and the beginning of the last quarter of the 10th centuries BCE.

These results confirm that this very rare boat is, at present, the earliest-known example of an entirely sewn boat in the Mediterranean. It is hoped that the full dendrochronological study of the preserved remains of the Zambratija boat if research is continued, will enable a more precise date to be proposed.

laboratorij / laboratory	godina analize / year of the analysis	uzorak laboratorijska oznaka / sample laboratory number	prosječna radiokarbonska starost / conventional radiocarbon age	kalibrirani rezultati / calibrated result	vjerojatnost / probability
Ruđer Bošković (Zagreb)	2009, 2013	Z-4195, B626	2950 ± 65 BP	Cal BCE 1264 - 1053	68,2 %
Beta Analytics Inc. (Miami)	2011	Beta-296186	2860 ± 30 BP	Cal BCE 1120 - 930	95 %
Centre de datation par le Radiocarbone (Lyon)	2015	Lyon-12422 (SacA43732)	2970 ± 30 BP	Cal BCE 1281 - 1076	94,8 %
Centre de datation par le Radiocarbone (Lyon)	2015	Lyon-12423 (SacA43733)	2975 ± 30 BP	Cal BCE 1288 - 1108	93,6 %
Centre de datation par le Radiocarbone (Lyon)	2015	Lyon-12424 (SacA43734)	2975 ± 30 BP	Cal BCE 1288 - 1108	93,6 %
Centre de datation par le Radiocarbone (Lyon)	2015	Lyon-12425 (SacA43735)	2965 ± 30 BP	Cal BCE 1268 - 1056	95,4 %

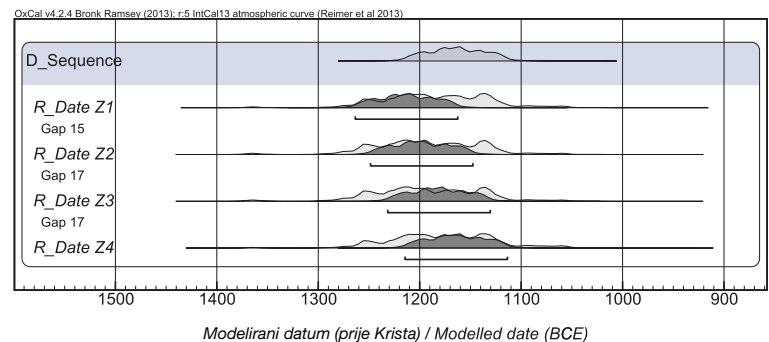
III.2
Radiokarbonske datacije
(neobrađeni i kalibrirani podaci)
Radiocarbon dates
(raw and calibrated dates)



III.3

Prikaz datacija uzoraka platice PRL11, dobivenih radiokarbonskom analizom s pomoću AMS-a, na radiokarbonskoj kalibracijskoj krivulji

Projection of the ^{14}C AMS dates obtained for the sample from the PRL11 plank on the radiocarbon calibration curve (izrada / made by: F. Guibal, Ch. Oberlin)



Identifikacija drva

Wood identification

Alba Ferreira Domínguez, Giulia Boetto,
Frédéric Guibal, Carine Cenzon-Salvayre

Tijekom dviju istraživačkih kampanja, u 2011. i u 2013., na olupini je prikupljeno ukupno 28 uzoraka drva. Oni su analizirani radi identifikacije vrste drva koje je bilo upotrijebljeno za izradu različitih dijelova brodske konstrukcije.

A total of 28 wood samples were taken from the Zambratija wreck during the two excavation seasons in 2011 and 2013. The samples have been analysed to identify the wood species used for different parts of the boat's structure.

Metode

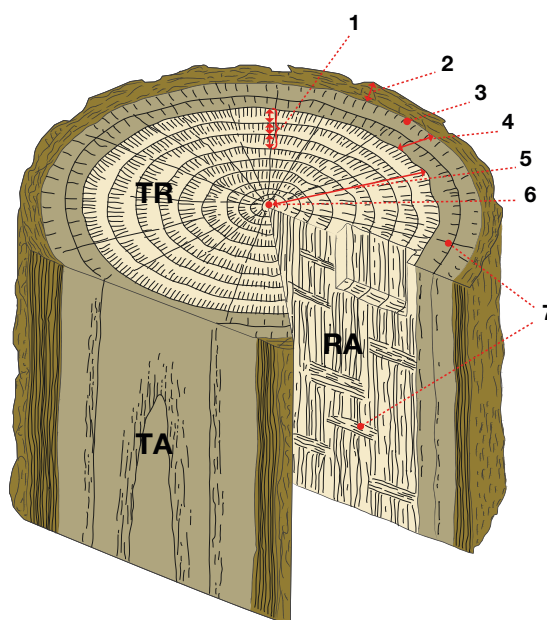
Tanki uzorci tri različita usmjerenja (poprečni, uzdužni i radijalni) (Sl. III.4) izrezani su ručno, žiletom, i to svaki uzorak pojedinačno, te su montirani na stakalce. Za identifikaciju uzoraka korišten je mikroskop i anatomski atlas drva (Sl. III.5)¹ (Jacquiot 1955; Jacquiot *et al.* 1973; Schweingruber 1978, 1990.).

Methods

Thin sections in three planes (transverse, tangential, and radial) (Fig. III.4) were cut by hand with a razor blade for each of the samples and then mounted on slides. A microscope and an atlas of wood anatomy were used for their identifications (Fig. III.5)¹ (Jacquiot 1955; Jacquiot *et al.* 1973; Schweingruber 1978, 1990).

III.4

Referentni smjerovi i presjeci drva: poprečni presjeci (TR), radijalni presjeci (RA) i uzdužni presjeci (TA)
Wood grain direction and reference planes: transversal (TR), radial (RA), and tangential (TA)
(izradio / made by: P. Poveda after Kaennel, Schweingruber 1995, 463)



1. Godovi / Rings
2. Kora / Bark
3. Kambij / Cambium
4. Meko drvo / Sapwood
5. Tvrdo drvo / Earthwood
6. Srčika / Pith
7. Sržne trake / Rays

¹ Pri radu su korišteni optički mikroskopi Olympus BH-2 (40x i 1000x) i Olympus CX41 (40x i 1000x), zajedno s digitalnim fotoaparatom Olympus PEN Lite E-PL3.

¹ Optical microscopes Olympus BH-2 (40x and 1000x) and Olympus CX41 (40x and 1000x) were used, coupled with an Olympus PEN Lite E-PL3 digital camera.



III.5
Anatomska identifikacija drva
 mikroskopskim ispitivanjem
Microscopic examination of wood
 samples for anatomical identification

Rezultati

Analiza uzoraka drva otkrila je uporabu pet taksonomskih vrsta (Sl. III.6): brijest (*Ulmus* sp.) (Sl. III.7), joha (*Alnus* sp.) (Sl. III.8), divlja kruška (*Pyrus communis* L.) (Sl. III.9), topola (*Populus* sp.) (Sl. III.10) i jela (*Abies alba*) (Sl. III.11).

Sve platice (osam vojeva) izrađene su od brijesta. Brijest je također identificiran kod dva odvojena ulomka platica (PRL11 i PRL19) koji su pronađeni izvan brodske cjeline. Od tri sačuvane rebrenice, dvije (R1 i R3) su napravljene od johe, a jedna (R2) od drva divlje kruške. Osam analiziranih malih drvenih čavala koji su zaptivali rupe za šavove izrađeno je od dvije vrste drva: topole i johe. Šest analiziranih letvica položenih preko sljubnica platica izrađeno je od drva jele (Sl. III.12).

Rasprava

Upotreba drva za izradu brodske konstrukcije ukazuje na homogenost pri odabiru vrste za oplatu, dok odabir drva za rebra pokazuje određenu heterogenost (Sl. III.12, III.13). Homogenost ukazuje na važnost oplata pri izgradnji broda napravljenog po principu «prvo ljuška» (Pomey, Rieth 2005, 30-31).

Među upotrijebljenim vrstama nalaze se vrste drva

Results

The wood analysis revealed the use of five taxa (Fig. III.6): elm (*Ulmus* sp.) (Fig. III.7), alder (*Alnus* sp.) (Fig. III.8), wild pear (*Pyrus communis* L.) (Fig. III.9), poplar (*Populus* sp.) (Fig. III.10) and fir (*Abies alba*) (Fig. III.11).

All of the planks (eight strakes) were made of elm. Elm was also identified for the two disarticulated plank fragments (PRL11 and PRL19) found beside the wreck. Of the three preserved floor-timbers, two (R1 and R3) were made of alder and one (R2) of wild pear wood. The eight pegs used to lock the stitches in place that were analysed were cut from two wood species: poplar and alder. Fir was identified for the six lath samples placed over the plank seams and held in place by the sewing (Fig. III.12).

Discussion

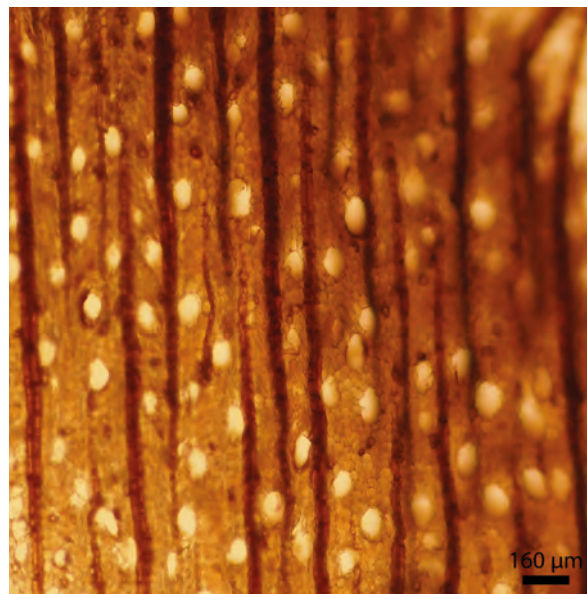
The planking of the Zambratija boat was very homogeneous while the framing is more varied (Figs III.12, III.13). This homogeneity illustrates the importance of the planking in 'shell-first' ship construction (Pomey, Rieth 2005, 30-31).

The wood used includes high-quality species such as elm (Giordano 1980, 184; Venet, Keller 1986, 141;

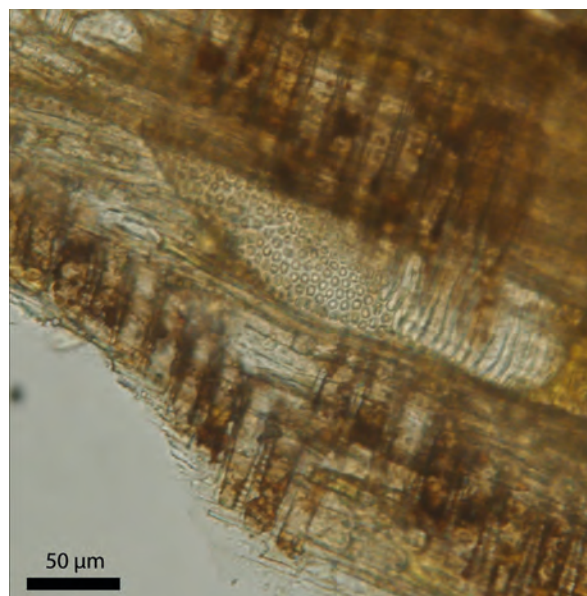
crnogorično drvo resinous tree	bjelogorično drvo deciduous tree
<i>Abies</i> sp.	<i>Ulmus</i> sp.
	<i>Alnus</i> sp.
	<i>Pyrus communis</i> L.
	<i>Populus</i> L.

III.6

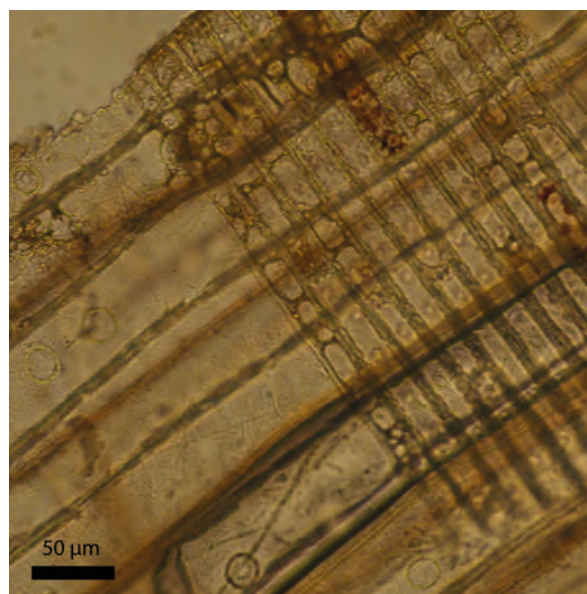
Vrste drva identificirane na olupini Zamratija
Wood species identified on the Zamratija wreck



III.9



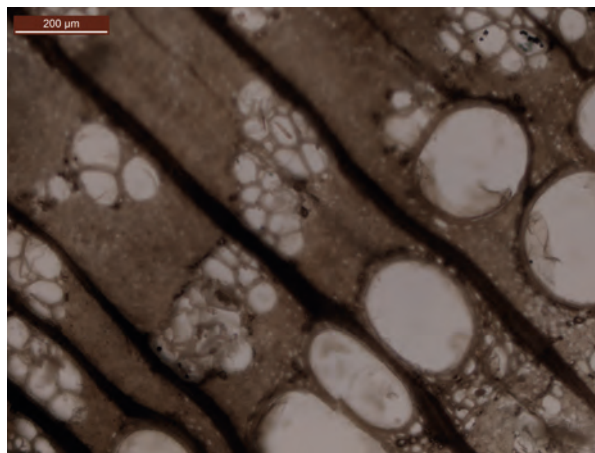
III.10



III.11

III.7

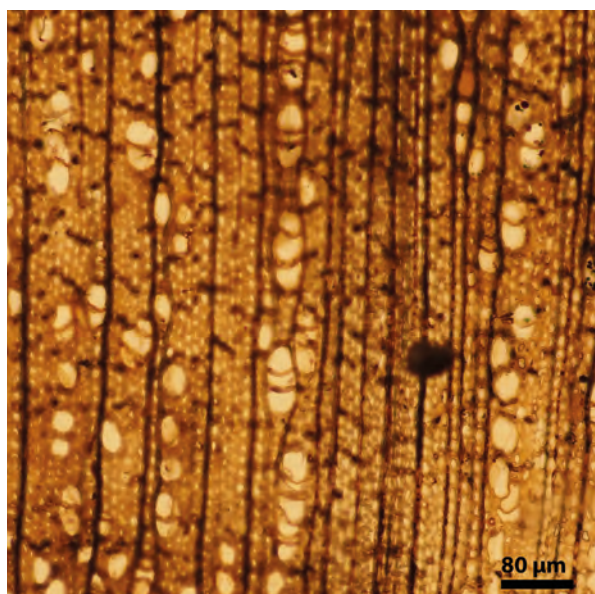
Poprečni presjek brijesta
(*Ulmus* sp.) uzorka P3
Transverse section of elm
(*Ulmus* sp.) from sample P3
(fotografija / photo by:
C. Cenon-Salvayre)



III.7

III.8

Poprečni presjek joha (*Alnus* sp.)
uzorka R1-PRL16
Transverse section of alder (*Alnus*
sp.) from sample R1-PRL16
(fotografija / photo by: A. Ferreira
Dominguez)



III.8

III.9

Poprečni presjek divlje kruške
(*Pyrus communis* L.) uzorka R2-
PRL17
Transverse section of wild pear
(*Pyrus communis* L.) from sample
R2-PRL17
(fotografija / photo by: A. Ferreira
Dominguez)

III.10

Radijalni presjek topole
(*Populus* sp.) uzorka PRL14
Radial section of poplar
(*Populus* sp.) from sample PRL14
(fotografija / photo by: A. Ferreira
Dominguez)

III.11

Radijalni presjek jele (*Abies* sp.)
uzorka PRL9
Radial section of fir (*Abies* sp.)
from sample PRL9
(fotografija / photo by: A. Ferreira
Dominguez)

visoke kvalitete, poput brijesta (Giordano 1980, 184; Venet, Keller 1986, 141; Rival 1991, 62), te vrste koje su poznate po dobroj izdržljivosti u vlažnoj sredini, kao što je joha (Giordano 1980, 184-185; Venet, Keller 1986, 127; Rival 1991, 70-71). Obično se za izgradnju oplata upotrebljavaju crnogorične vrste koje zbog svoje elastičnosti omogućavaju savitljivost potrebnu prilikom oblikovanja u skladu s postupcima gradnje «prvo ljuska».

Izgleda da je izbor brijesta možda, pored lokalne dostupnosti, povezan i s potrebom za deblima velikog promjera, osobito za izradu kobiličnog elementa.

Upotreba brijesta (koji ima izrazito gusta, debela i međusobno isprepletana vlakna) za izgradnju oplata plovila, nije bila česta na zapadnom Mediteranu². Međutim, na Jadranu se brijest gotovo sustavno upotrebljavao za izgradnju šivanih brodova. Ostaci broda Pula 1, pronađeni u antičkoj luci Pule i datirani u vrijeme 2. - 3. stoljeća, jasan su primjer navedenoga (Boetto *et al.* 2014; 2017)³.

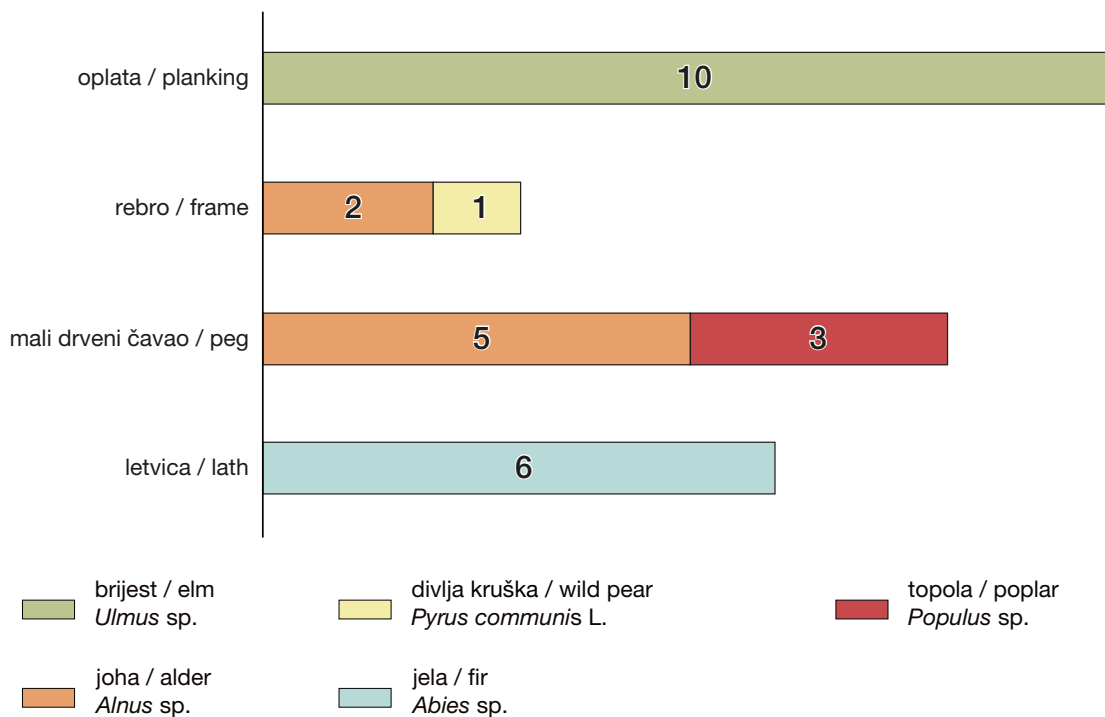
Nasuprot tomu, upotreba kruške, tvrdog drva vrlo uskih godova, koje je osobito traženo u stolarstvu (Rameau *et al.* 1989, 553), mnogo je rjeđa u brodogradnji.

Rival 1991, 62), and those reputed for their resistance in wet conditions such as alder (Giordano 1980, 184-185; Venet, Keller 1986, 127; Rival 1991, 70-71). Commonly the resinous species are more often used for boat planking, because their elasticity provides the flexibility necessary to shape the planks in the 'shell-first' construction process.

It is likely that the choice of a deciduous species is based not only on local availability, but also the need for trunks with a relatively wide diameter, particularly for the sculpted keel-like timber used for this vessel.

The use of elm, which has extremely dense, thick and interwoven fibres, is not very widely used for planking of vessels in the Western Mediterranean². In the Adriatic, however, this species was used almost systematically for the construction of sewn-plank boats. The Pula 1 wreck, found in the ancient port of Pula and dated to the 2nd-3rd century, is another fine example (Boetto *et al.* 2014, 2017)³.

Pear, a hard wood with a very fine grain that is highly prized for cabinet making (Rameau *et al.*, 1989, 553), is much more rarely seen in boat construction.



III.12

Dijagram koji pokazuje relativnu prisutnost vrsta drva identificiranih na ostacima olupine Zambratija s obzirom na različite brodograđevne dijelove

Diagram showing the relative frequency of the wood species identified in the Zambratija wreck remains by structural element

2 Primjer je brod Madrague de Giens (Hyères, Francuska, 70-65 god. pr. Kr., Guibal, Pomey 1998, 433).

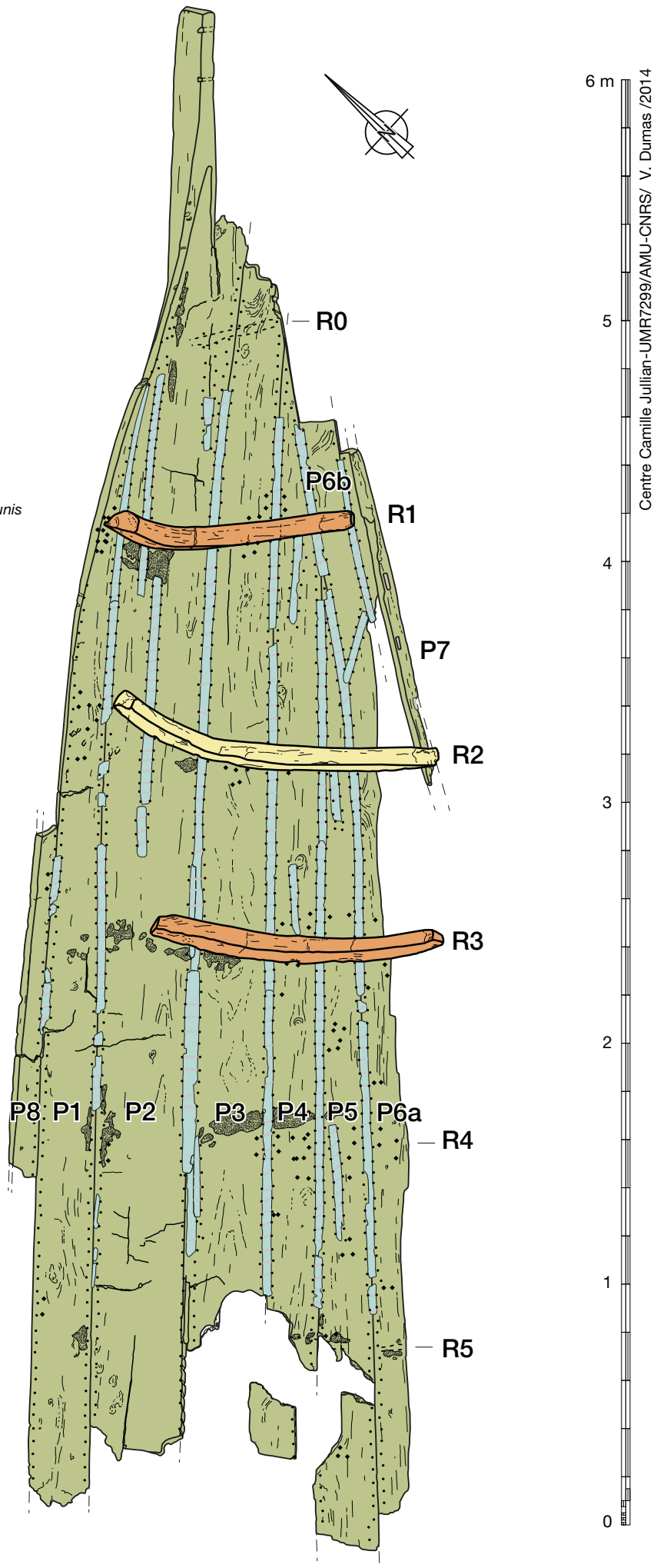
3 Brijest je upotrijebljen za izradu oplata 11 brodova na sjevernom Jadranu: Cavanella d'Adige (Motta di Cavanella d'Adige, Rovigo, 2.-1. st. pr. Kr., Tiboni, 2009, 2017), Comacchio (Ferrara, 1. st. pr. Kr., Castelletti *et al.* 1990, 150); Stella 1 (1. st., Palazzolo dello Stella, Udine, Castro, Capulli, 2016, 32); Aquileia 1 i 2 (uglavnom 1. st. i 2. - 3. st., Canale Anfora, Akvileja, Beltrame, Gaddi 2013, 298 i 301); Lido di Venezia 1 i 2 (1. - 2. st., Venice Lido, Beltrame 2002a, 356 i 368); Padova (2. st., Padua, Beltrame 2002a, 366); San Francesco del Deserto (rimski, Venecijanski zaljev, Capulli, Pellegrini 2010, 265); Santa Maria in Padovetere (Comacchio, Ferrara, 5. st., Beltrame, Costa 2016) i Cervia (7. st., Ravenna, Beltrame 2002a, 359).

2 For example the Madrague de Giens wreck (Hyères, France, 70-65 BCE, Guibal, Pomey 1998, 433).

3 Elm is also used for the planking of 11 other North Adriatic wrecks: Cavanella d'Adige (Motta di Cavanella d'Adige, Rovigo, 2nd-1st century BCE, Tiboni 2009, 2017), Comacchio (Ferrara, 1st century BCE, Castelletti *et al.* 1990, 150), Stella 1 (1st century CE, Palazzolo dello Stella, Udine, Castro, Capulli 2016, 32), Aquileia 1 and 2 (respectively 1st and 2nd-3rd century CE, Canale Anfora, Aquileia, Beltrame, Gaddi 2013, 298 and 301), Lido di Venezia 1 and 2 (1st-2nd century CE, Venice Lido, Beltrame 2002a, 356 and 368), Padova (2nd century CE, Padua, Beltrame 2002a, 366), San Francesco del Deserto (Roman, Venice lagoon, Capulli, Pellegrini 2010, 265), Santa Maria in Padovetere (Comacchio, Ferrara, 5th century CE, Beltrame, Costa 2016), and Cervia (7th century CE, Ravenna, Beltrame 2002a, 359).

- brijest / elm / *Ulmus* sp.
- joha / alder / *Alnus* sp.
- divlja kruška / wild pear / *Pyrus communis*
- jela / fir / *Abies alba*

III.13
 Raspostranjenost vrsta drva
 Distribution of the wood species
 (izradio / made by: V. Dumas)



Trenutno je kruška identificirana jedino na rebru brodske konstrukcije Baie de l'Amitié (Francuska, druga polovina 1. st., Wicha 2002; Wicha *et al.* 2003, 235; Wicha, Girard 2006, 114).

Naposljetku, drvo joha i topole je zbog svoje elastičnosti odabrano za izradu malih drvenih čavala kojima su zaptivane rupe za šavove (Rameau *et al.* 1989, 441 i 807). Jela je, pak, sigurno odabrana zbog mogućnosti rasijecanja pri izradi tankih letvica (Rival 1991, 40-41).

Da zaključimo, dobiveni rezultati ukazuju na uporabu vrsta dostupnih u blizini obale, u okolišu bogatom vodom, koji karakteriziraju močvare i obalne lagune. Samo je jelu, planinsku vrstu, trebalo tražiti u šumama udaljenijim od obale. Još i danas, sve vrste drva potvrđene na brodu Zambratija rastu u obalnom dijelu Istre, osim jele koja je prisutna na manje od 60 km od obale (Bačić 2005).

At present it has been identified only as a frame in the Baie de l'Amitié wreck (France, second half of the 1st century CE, Wicha 2002; Wicha *et al.* 2003, 235; Wicha, Girard 2006, 114).

Finally, alder and poplar may have been chosen for the pegs used to lock the stitches in place for their flexibility (Rameau *et al.*, 1989, 441 and 807), while fir could have been selected because it is easily split into thin laths (Rival 1991, 40-41).

In conclusion, the results of this analysis reflect the use of wood that was locally available near to the coast, in a rich freshwater environment characterized by marsh and coastal lagoons. Only fir, a mountain species, would have grown in forests at higher altitudes at some distance from the coast. Today, all the species used for the Zambratija boat can be found along the Istrian coast, except fir which can be found less than 60 km inland (Bačić 2005).

Identifikacija materijala korištenih za vodonepropusnost broda

Identification of waterproofing materials

Stéphanie Wicha, Régine Verlaque

Sustav vodonepropusnosti broda Zambratija odlikuje upotreba rahlih snopova biljnog materijala kojim su obložene sljubnice oplata, prekrivene tankim letvicama od jelovine (*Abies alba*). Ovaj sistem je pričvršćen uzdužnim šavovima.

Dva ulomka letvica na kojima je bilo ostataka biljnog materijala prikupljeni su 2011. za potrebe daljnje analize (Sl. III.14 – III.17).

Metode

Biljni materijali korišteni za vodonepropusnost odvojeni su od letvica pod binokularnim mikroskopom (Leica M26). Nekoliko biljnih fragmenata uzorkovano je pincetom, poprskano bojom *iodinegreen* ili fuksinom te preneseno na mikroskopsko staklo u glicerolu. Uzorci su promatrani pod svjetlosnim mikroskopom (Olympus CX41). U cilju utvrđivanja vrste, anatomije i/ili epiderme fragmenata korišten je referentni atlas drvne anatomije (Schweingruber 1990; Cappers, Bekker 2013), a morske trave uspoređene su sa sušenom referentnom kolekcijom Marsejskog herbarija (MARS) pri Sveučilištu Aix-Marseille.

The waterproofing system used for the Zambratija boat is characterized by the use of loose bundles of vegetal material placed over the planking seams covered by a thin lath of fir (*Abies alba*). This assemblage is secured by the longitudinal sewn seams.

Two fragments of laths bearing residues of the vegetal materials were recovered in 2011 and were sampled for analysis (Figs III.14 – III.17).

Methods

The vegetal materials were separated from the laths under a binocular microscope (Leica M26). Several vegetal fragments were sampled with tweezers, stained with iodine green or fuchsine, and then mounted on slides in glycerol. The samples were observed by light microscopy (Olympus CX41). To identify their species, anatomy and/or epidermis, fragments were compared with a reference atlas of wood anatomy (Schweingruber 1990; Cappers, Bekker 2013), and sea-grasses with the dried reference collection of the Marseille herbarium (MARS) at Aix-Marseille University.

III.14

Prikaz unutarnje plohe fragmenta letvice prekrivene biljnim vodonepropusnim materijalom
View of the inner face of a lath fragment bearing the vegetal waterproofing materials
(fotografija / photo by: Ch. Durand)



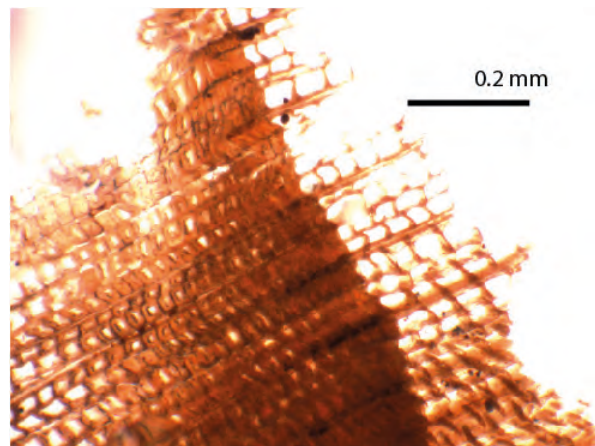
III.14

III.15

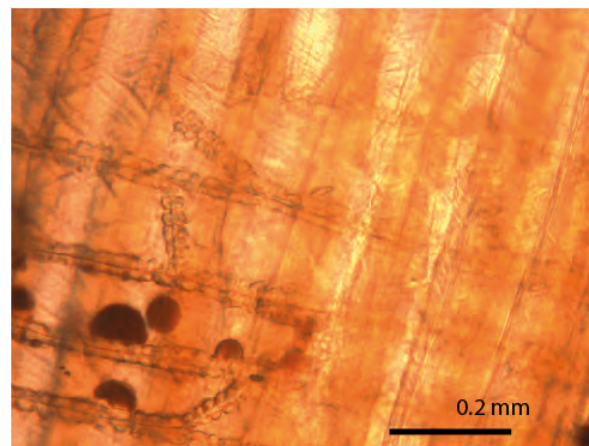
Detaljni prikaz rahlih snopova biljnih materijala s letvice
Detail view of the loose vegetal materials on the lath
(fotografija / photo by: Ch. Durand)



III.15



III.16
Identifikacija letvice: jela (*Abies alba* Mill.), transverzalno presječena
Identification of the lath: fir (*Abies alba* Mill.), transversally cut
 (fotografija / photo by: S. Wicha)



III.17
Identifikacija letvice: jela (*Abies alba* Mill.), radialno presječena
Identification of the lath: fir (*Abies alba* Mill.), radially cut
 (fotografija / photo by: S. Wicha)

Rezultati i rasprava

Na temelju makroskopskog promatranja, u uzorcima se mogu razabrati dvije vrste materijala. Prvi je tamne boje, dok je drugi svjetliji s dobro očuvanim svojstvima (Sl. III.18). Tamni elementi su stanice i fragmenti jele (*Abies alba*, *Abietaceae*, Sl. III.19). Njihova prisutnost mogla bi se objasniti na dva načina: ili se radi o razgrađenim dijelovima letvica ili o piljevini nastaloj prilikom rezanja letvica, koja je namjerno korištena kao dio materijala za osiguranje vodonepropusnosti.

Što se tiče svijetlih elemenata, utvrđeno je da se radi o morskim travama (spermatofitima) (Sl. III.20 – III.23). Premda je morske spermatofite vrlo teško morfološki odrediti, promatranjem epiderme njihova je identifikacija lakša. Svi fragmenti pripadaju travi *Cymodocea nodosa* (Ucria) Asch. (*Cymodoceaceae* Vines), koja je rasprostranjena u mirnim, plitkim vodama Sredozemnog mora, na pješčanom ili muljevitom tlu. Ta vrsta ima duge, uske listove (400 x 4 mm), stanice tanina, nema puči i ima brojna ispupčenja na sekundarnom korijenju. U uzorcima su prisutni različiti dijelovi biljke (rukavci lista i lišće): Sl. III.20, III.21; korijenje: Sl. III.22, III.23).

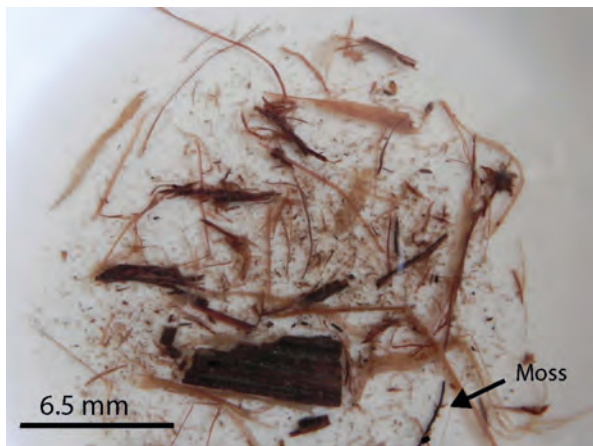
Premda je *Cymodocea nodosa* jedna od najuobičajenijih vrsta morskih trava u Sredozemnom moru i ima je u izobilju, u Jadranskom moru je duž južne i sjeveroistočne obale prisutnija *Posidonia oceanica* (L.) Delile, dok su *C. nodosa* i *Zostera noltei* Hornem jednako rasprostranjene, a *Z. marina* L. ograničena je na sjevernu obalu (Gamulin-Brida 1965; Damiani i dr. 1988; Buia, Marzocchi 1995.). Na primjer, *C. nodosa* najčešći je spermatofit u Tršćanskom zaljevu (Simonetti 1973.).

Results and discussion

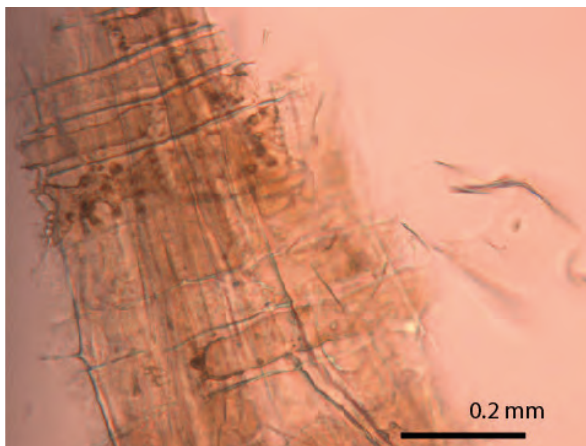
Through macroscopic observation, it is possible to discriminate two kinds of components. The first is dark in colour, while the second is lighter with well-preserved features (Fig. III.18). The dark features are cells and fragments of fir (*Abies alba*, *Abietaceae*, Fig. III.19). Two hypotheses could explain their presence: either they are degraded parts of the laths, or they are residual fragments from cutting the laths that were deliberately used within the waterproofing material.

The light elements were identified as sea-grass plants (Phanerogams) (Figs III.20 – III.23). Whereas morphological determination of marine Phanerogams is very difficult, epidermis observation makes identification easier. All the fragments belong to *Cymodocea nodosa* (Ucria) Asch. (*Cymodoceaceae* Vines), which is widespread in the calm, shallow waters of the Mediterranean Sea, on sandy or muddy soils. This species has long, narrow leaves (400 x 4 mm), tannin cells, lacks a stomata, and has numerous protuberances on the secondary roots. The presence of different parts of the plant is attested in the samples (sheaths and leaves: Figs III.20, III.21; roots: Figs III.22, III.23).

Although *Cymodocea nodosa* is one of the most common and abundant sea-grass species in the Mediterranean, in the Adriatic Sea *Posidonia oceanica* (L.) Delile is more commonly present along the southern and north-eastern coasts, while *C. Nodosa* and *Zostera noltei* Hornem are evenly spread, and *Z. marina* L. is confined to the north coast (Gamulin-Brida 1965; Damiani *et al.* 1988; Buia, Marzocchi 1995). For example,



III.18



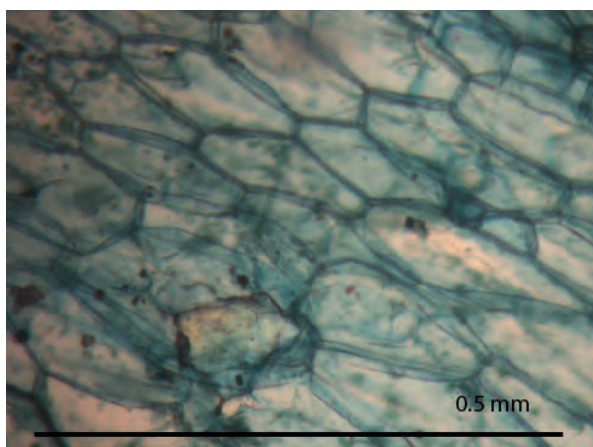
III.19

III.18
Makroskopski prikaz pojedinih komponenti sustava vodonepropusnosti

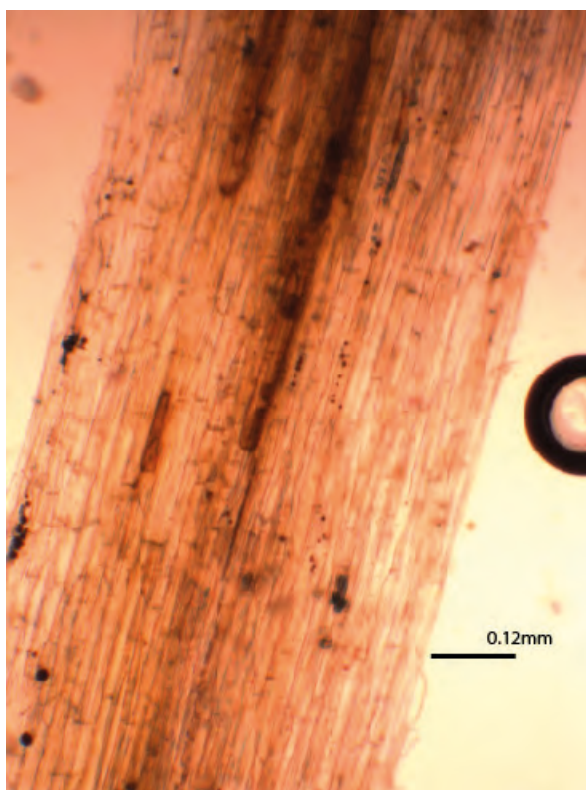
Macroscopic view of the loose components of the waterproofing (fotografija / photo by: S. Wicha)

III.19
Identifikacija fragmenta jele (*Abies alba*), radijalno presječne, iz materijala upotrijebljenih za vodonepropusnost

Identification of a fragment of fir (*Abies alba*), radially cut, from the elements used for waterproofing (fotografija / photo by: S. Wicha)



III.20



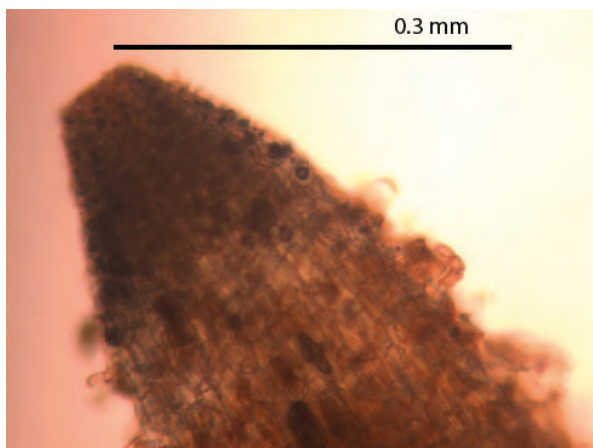
III.21

III.20
Rukavac biljke *Cymodocea nodosa*
Sheath of *Cymodocea nodosa* (fotografija / photo by: S. Wicha)

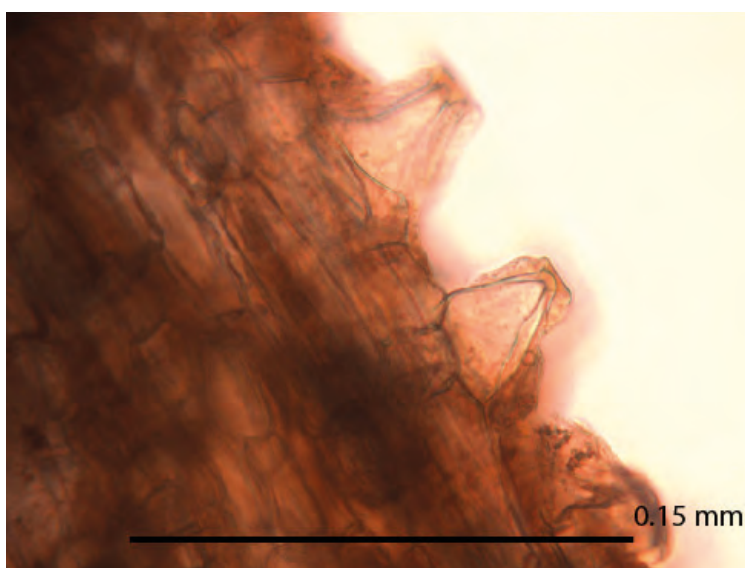
III.21
List biljke *Cymodocea nodosa*
Leaf of *Cymodocea nodosa* (fotografija / photo by: S. Wicha)

III.22
Korijen biljke *Cymodocea nodosa*
Root of *Cymodocea nodosa* (fotografija / photo by: S. Wicha)

III.23
Korijen biljke *Cymodocea nodosa*
Root of *Cymodocea nodosa* (fotografija / photo by: S. Wicha)



III.22



III.23

III.24

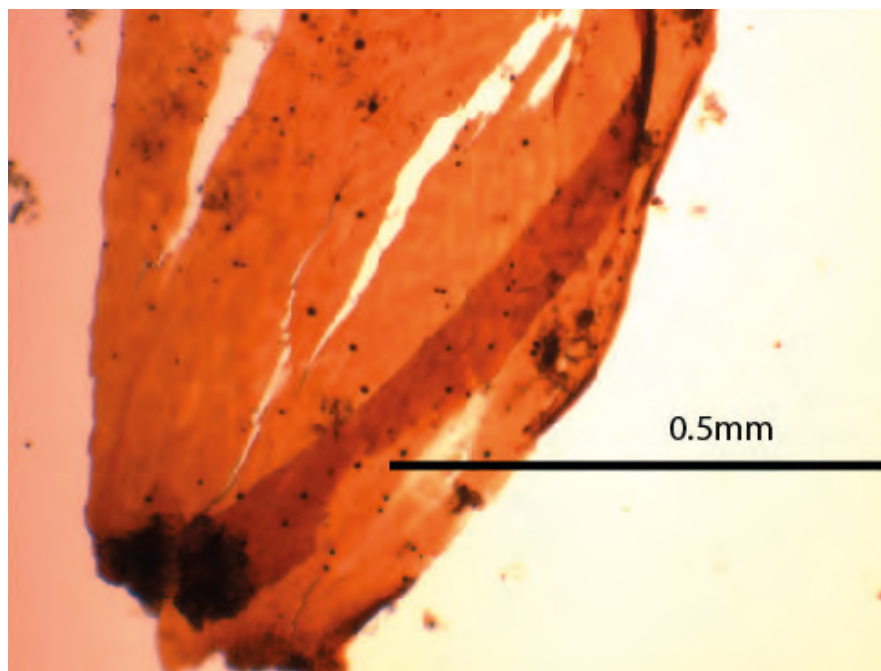
List mahovine, moguće vrste

Neckera crispa

Leaf of bryophyte, possibly

Neckera crispa

(fotografija / photo by: S. Wicha)



Ujesen se na plažama mogu naći izbačene velike količine uvelog lišća te slomljenih podanaka korijenja sa snopovima lišća trave *C. nodosa* (Mateo 2010.).

Na kraju, identificirani su i stručci s nekoliko malih listova (Sl. III.24). Struktura i epiderma lišća upućuje na to da pripadaju mahovini, moguće vrsti *Neckera crispa* (Sabovljević 2006.). Mahovine se nalaze u različitim habitatima pa se stoga mogu naći skoro svugdje, osim u morskom, preslanom i presuhom okolišu (Delvosalle 1965.).

Zaključak

Mikroskopska analiza materijala za vodonepropusnost pronađenog na brodu Zambratija, pokazala je prisutnost triju elemenata: drva, morske trave i mahovine.

Dok se drvo (*Abies alba*) vjerojatno može pripisati ostacima obrade letvica, upotreba mahovine ukazuje na specifične tehnološke odabire na koje su utjecale značajke ovih materijala i njihovu dostupnost u blizini mjesta izgradnje broda.

Mahovine, kao što je *Neckera crispa*, korištene su za osiguranje vodonepropusnosti u tradiciji izgradnje brodova zasnovanim na ravnom dnu. Ta tradicija je

C. nodosa is the most frequent Phanerogam in the Gulf of Trieste in the north Adriatic Sea (Simonetti 1973). In autumn, dead leaves and broken rhizomes with leaf bundles of *C. nodosa* can be carried on to the beaches in large quantities (Mateo 2010).

Finally, a rachis with several small leaves was also identified (Fig. III.24). The structure and epidermis of the leaves suggest it belongs to a moss (Bryophytes), probably *Neckera crispa* (Sabovljević 2006). Bryophytes occupy a variety of habitats and are, therefore, found almost everywhere, with the exception of marine, too salty, and too dry environments (Delvosalle 1965).

Conclusion

Microscopic analysis of the waterproofing recovered from the Zambratija boat revealed the presence of three constituents: wood, sea-grass, and moss.

While the wood (*Abies alba*) probably corresponds to the use of residues from the manufacture of the laths, the use of moss identifies specific technological choices dictated by the characteristics of this material and by its availability in the vicinity of where the boat was built.

Mosses, such as *Neckera crispa*, are commonly used as waterproofing materials in the Continental and Northern European bottom-based shipbuilding traditions

tipična za kontinentalnu i sjevernu Europu, a poznata je od galo-rimskog razdoblja i traje do danas (Argant i dr. 2000; Pomey, Rieth 2005, 197; Bailly 2010; Guyon, Philippe 2012.). Ovaj materijal ima svojstvo očuvanja ambijentalne vlage te kada se upotrebljava za ispunu u međuprostoru, ne dolazi do njegova skupljanja.

S druge strane, prisutnost morske trave je problematična. Tijekom istraživanja primijećeno je da je cvjetnica *Cymodocea nodosa* značajno zastupljena u sloju te da je prisutna u svakom procjepu unutar drvene brodske konstrukcije. Iako bi prisutnost različitih dijelova biljaka mogla ukazivati na to da je morska trava uspješno korištena kao sustav vodonepropusnosti, u ovoj fazi istraživanja nije moguće tvrditi da su brodograditelji namjerno koristili ovaj materijal.

U budućnosti bi bilo zanimljivo datirati neke od dijelova morske trave, možda uzetih iz drugih uzoraka. Ako se potvrdi upotreba vrste *Cymodocea nodosa*, morske trave koja je široko rasprostranjena u Sredozemlju, a posebice u Jadranskom moru, to će biti jako zanimljivo otkriće. Bilo bi to prvo arheološko svjedočanstvo o upotrebi ove vrste materijala za osiguranje vodonepropusnosti drevnog plovila. Strabon (IV, 4, 1) spominje da su Veneti, keltsko pleme koje je živjelo u današnjoj Bretanji, u Francuskoj, koristili morsku travu za brtvljenje svojih brodova. Strabon objašnjava da su se u venetskim plovilima, koja su se strukturno razlikovala od broda Zambratija, morske trave koristile za popunjavanje praznina namjerno ostavljenih između platica. Njihova sposobnost očuvanja vlage sprječavala je isušivanje drva prilikom izvlačenja plovila na kopno.

from the Gallo-Roman period up to modern times (Argant *et al.* 2000; Pomey, Rieth 2005, 197; Bailly 2010; Guyon, Philippe 2012). This material has the capacity to conserve the ambient humidity and, when used to fill large interstices, does not shrink.

On the other hand, the presence of sea-grasses is more problematic. During the excavation, it was observed that the roots of *Cymodocea nodosa* were extensively present within the sediments, and that they developed through every interstice between the wooden structures of the wreck. Although the presence of different parts of the plant seems to prove that sea-grasses were effectively used in the waterproofing system, in the current state of the research it is not possible to state that the shipbuilders deliberately used this material.

In future, it would be interesting to date some of these sea-grass parts, maybe taken from other samples. If the use of *Cymodocea nodosa*, a sea-grass plant widely spread in the Mediterranean and, in particular, in the Adriatic Sea, is to be confirmed, this information would be very interesting. It would represent the first archaeological evidence of the use of this kind of material for waterproofing an ancient vessel. Strabo (IV, 4, 1) mentions the Veneti, a Celtic tribe living in what is now Brittany, France, used sea-grass plants to waterproof their vessels. Strabo explains that in the Venetic vessels, which were structurally different from the Zambratija boat, the sea-grasses were used to fill gaps purposefully left between the planks. Their capacity to conserve humidity prevented the wood from drying out when the vessels were hauled up on the beaches.

Molekularno istraživanje vodonepropusnih tvari

Molecular study of waterproofing agents

Armelle Charrié-Duhaut

U svrhu identifikacije prirode makroostataka vodonepropusnog premaza trupa broda Zamratija, provedene su kemijske analize kombinacijom uobičajenih tehnika za takvu vrstu organskog materijala, točnije infracrvenom spektroskopijom i plinskom kromatografijom s masenom spektrometrijom. Studija je provedena na dvama ovdje opisanim uzorcima (T.III.1).

To identify the nature of macro-residues of the protective coating used to waterproof the hull of the Zamratija boat, chemical analyses were undertaken. These analyses combine the techniques conventionally used for this type of organic material, namely infrared spectroscopy and gas chromatography coupled with mass spectrometry (GC-MS). This study was carried out on two samples described herein (T.III.1).

Br. Uzorka	Napomena	Opis	Zapažanja
Z1/8	Zamratija brod PRL 1/8	Unutrašnja strana oplate P5	Svijetlosmeđi prah, gotovo u potpunosti topiv u diklormetanu
Z2	Zamratija brod PRL 2	Unutrašnja strana kobličnog elementa P2 (sjever)	

N° sample	Reference	Description	Observations
Z1/8	Zamratija wreck PRL 1/8	Inner face of the planking P5	Light brown powder, almost completely soluble in dichloromethane
Z2	Zamratija wreck PRL 2	Inner face of the keel-like timber P2 (north)	

T.III.1.

Metodologija

Objašnjenje osnovnih načela postupka koji se upotrebljava u istraživanju takvog arheološkog materijala izneseno je u nekoliko publikacija (Charrié-Duhaut *et al.* 2009a; 2009b). Molekularni pristup zasniva se na identifikaciji dijagnostičkih pokazatelja (biomarkera) dobivenih iz prirodnih organskih tvari. Biomarkeri su spojevi koji su zadržali dovoljno specifičan ugljikov kostur da ih se može povezati s njihovom biološkom pretečom, čime je omogućena identifikacija upotrijebljenih prirodnih tvari. U slučaju promjene moguće je osloniti se na specifične nusproizvode razgradnje (Burger *et al.* 2009).

Uzorci su primarno analizirani metodom prigušene totalne refleksije - infracrvenom spektroskopijom s Fourierovom transformacijom (ATR – FTIR). Uzorak praha nanosi se izravno na kristal. Pritom se upotrebljava spektrometar Golden Gate (Bruker), u načinu rada mono-ATR (64 snimka).

Zatim su uzorci ultrazvučno rastvoreni mješavinom diklormetanametanol (1:1 v/v). Dobivena otopina potom je silicirana primjenom BSTFA + TMSC (99:1). Analize plinskim kromatografom s masenim spektrometrom (GC-MS) obavljene su uz pomoć plinskog kromatografa Focus (ThermoScientific), povezanog s detektorom mase ISQ (početna temperatura ubrizgavača: 35°C, kolona HP-5 MS, 30 m x 0.25 mm i.d., debljina filma 0.1 mm, program temperature: 40°C (1 min.), 40-100°C (10°C/min.), 100-300°C (4°C/min.), izotermalni 300°C). Kao plin nositelj upotrijebljen je helij. Maseni spektri proizvedeni su na 70eV, izvor 180°C, u punom načinu otkrivanja na 50-700 amu.

Rezultati i rasprava

FTIR-spektri dvaju istraživanih uzoraka su slični. Vibracije istezanja -CH₂i -CH₃ skupina (2956-2922-2869 cm⁻¹), kao i njihovih vrpca istezanja (1458-1384 cm⁻¹), predstavljaju ugljikovodikov kostur ostatka. Međutim, značajno je istaknuti nedostatak karbonilnih skupina koje se obično iskazuju vibracijama izduženja na 1717 i 1701 cm⁻¹ i aromatičnih prstenova na 1600 cm⁻¹. Profili apsorbancije razlikuju se od onog koji se obično promatra kod produkta četinjača, preciznije porodice borovki (Colombini *et al.* 2003; Izzo *et al.* 2013).

GC-MS profili obaju uzoraka također su vrlo slični. Njima uglavnom dominiraju diterpenski spojevi derivirani iz abijetinske i pimarinske kiseline (Sl. III.25). Ovi derivati karakteristični su za crnogorična ulja, smolu i katran (Bailly *et al.* 2013; Bailly 2015).

Prisutnost aromatskih spojeva (reten, tetrahidroreten, 19-norabietatrien, 18-norabietatrien) upućuje na proizvod koji je podvrgnut zagrijavanju, što rezultira

Methodology

An account of the basic principles of the procedure used to study this type of archaeological material is reported in several publications (Charrié-Duhaut *et al.* 2009a; 2009b). The molecular approach is based on the identification of diagnostic biomarkers derived from naturally occurring organic substances. Biomarkers are compounds that have retained a carbon skeleton specific enough to be related to their biological precursor, thus enabling identification of the natural substances used. In case of alteration, it is possible to rely on specific degradation by-products (Burger *et al.* 2009).

At first, the samples were analysed by attenuated total reflection – Fourier-transform infrared spectroscopy (ATR – FTIR). The powder sample is directly deposited on the crystal. The device used was a Golden Gate spectrometer (Bruker) operating in mono-ATR mode (64 scans recorded).

Then the samples were solubilized ultrasonically with a mixture of dichloromethane/methanol (1:1 v/v). The solution obtained is then silylated using BSTFA + TMSC (99:1). GC-MS analyses were carried out using a Focus Gas chromatograph interfaced with a ISQ mass detector (injector initial temperature: 35°C, HP-5MS column, 30 m x 0.25 mm i.d., 0.1 mm film thickness, temperature program: 40°C (1 min), 40-100°C (10°C/min), 100-300°C (4°C/min), isothermal 300°C). Helium was used as carrier gas. Mass spectra were produced at 70eV, source 180°C, in full detection mode over 50-700 amu.

Results and discussion

The FTIR spectra of the two samples are similar. The stretching vibrations of the -CH₂ and -CH₃ groups (2956-2922-2869 cm⁻¹), as well as their bending bands (1458-1384 cm⁻¹), account for the hydrocarbon skeleton of the residue. However, the absence of carbonyl groups that are usually expressed by the vibrations of elongations at 1717 and 1701 cm⁻¹ and of aromatic rings at 1600 cm⁻¹ is noteworthy. The absorbance profiles seem different from that usually observed for a product derived from conifers, more specifically from the family of Pinaceae (Colombini *et al.* 2003; Izzo *et al.* 2013).

The GC-MS profiles of the two samples are again very similar. They are predominantly dominated by diterpenic compounds all derived from abietic and pimaric acid (Fig. III.25). These derivatives are diagnostic of coniferous oils, resins, and tars (Bailly *et al.* 2013; Bailly 2015).

The presence of aromatic compounds (retene, tetrahydroretene, 19-norabietatriene, 18-norabietatriene)

pojavnošću pakline, katrana dobivenog grijanjem crnogoričnog drva (Sl. III.26). Zagrijavanje je, međutim, bilo umjereno, s obzirom na to da udio poliaromatskih ugljikovodika ostaje nizak u usporedbi s kiselinama. Prevladavanje dehidroabietične kiseline te značajna prisutnost abietične, pimarinske i izopimarinske kiseline upućuju na niski stupanj promjena.

Bailly *et al.* (2016) opisali su niz alkil-gvajacil-dehidroabietata kao nove pokazatelje pakline. Takvi miješani esteri dehidro abietične kiseline i alkil-metoksi-fenola identificirani su u dva uzorka. Karakteriziraju ih fragmenti m/z 173 i 255 (značajka “dehidroabietičnog” dijela) i molekularna masa od 436 u.m.a.

indicates a product having undergone heating, and therefore probably pitch, tar obtained by heating coniferous wood (Fig. III.26). Heating, however, remained moderate since the proportion of polyaromatic hydrocarbons remains low compared to acids. The predominance of dehydroabietic acid, the presence in significant amounts of abietic, pimaric, isopimaric acid indicates a low degree of alteration.

Bailly *et al.* (2016) described a series of alkyl guaiacyldehydroabietates as novel markers of pitch. Such mixed esters between dehydroabietic acid and alkylmethoxyphenols were identified in the two samples. They are characterized by the fragments m/z 173 and 255 (characteristic of the “dehydroabietate” part) and a molecular mass of 436 u.m.a.

Zaključak

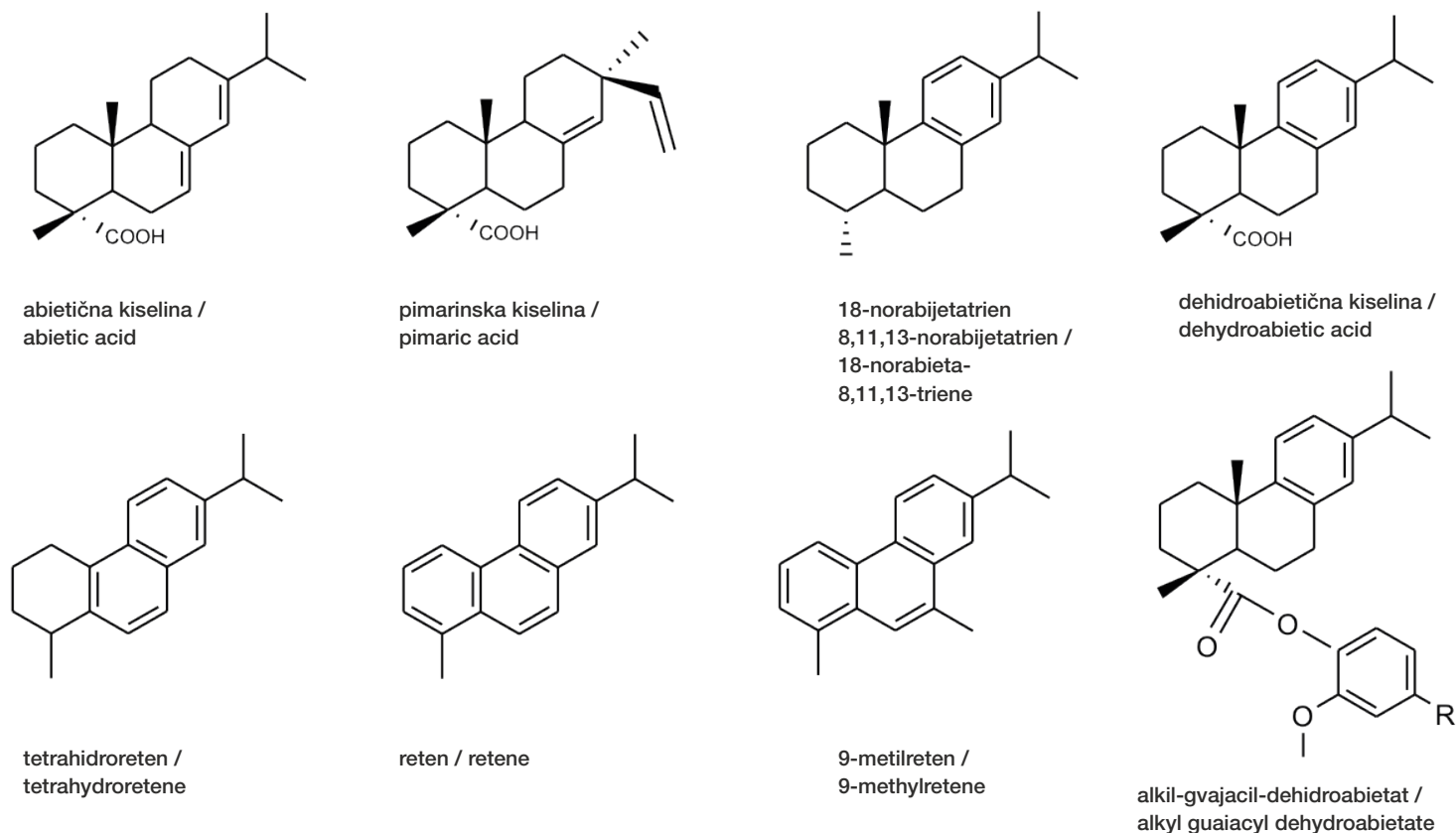
Molekularni podaci jasno pokazuju da dva istraživana uzorka odgovaraju paklini koju karakterizira prisutnost diterpenskih struktura povezanih s abietičnom/pimarinskom kiselinom i alkil-gvajacil-dehidroabietatima¹.

Conclusion

The molecular data clearly show that the two samples correspond to pitch, characterized by the identification of diterpenic structures related to abietic/pimaric acid and alkyl guaiacyl dehydroabietates.¹

¹ Zahvaljujemo dr.sc. Sandi Ravlić na pregledu stručnih termina u tekstu.

¹ We wish to thank Dr Sanda Ravlić for the review of the Croatian terms of the text.

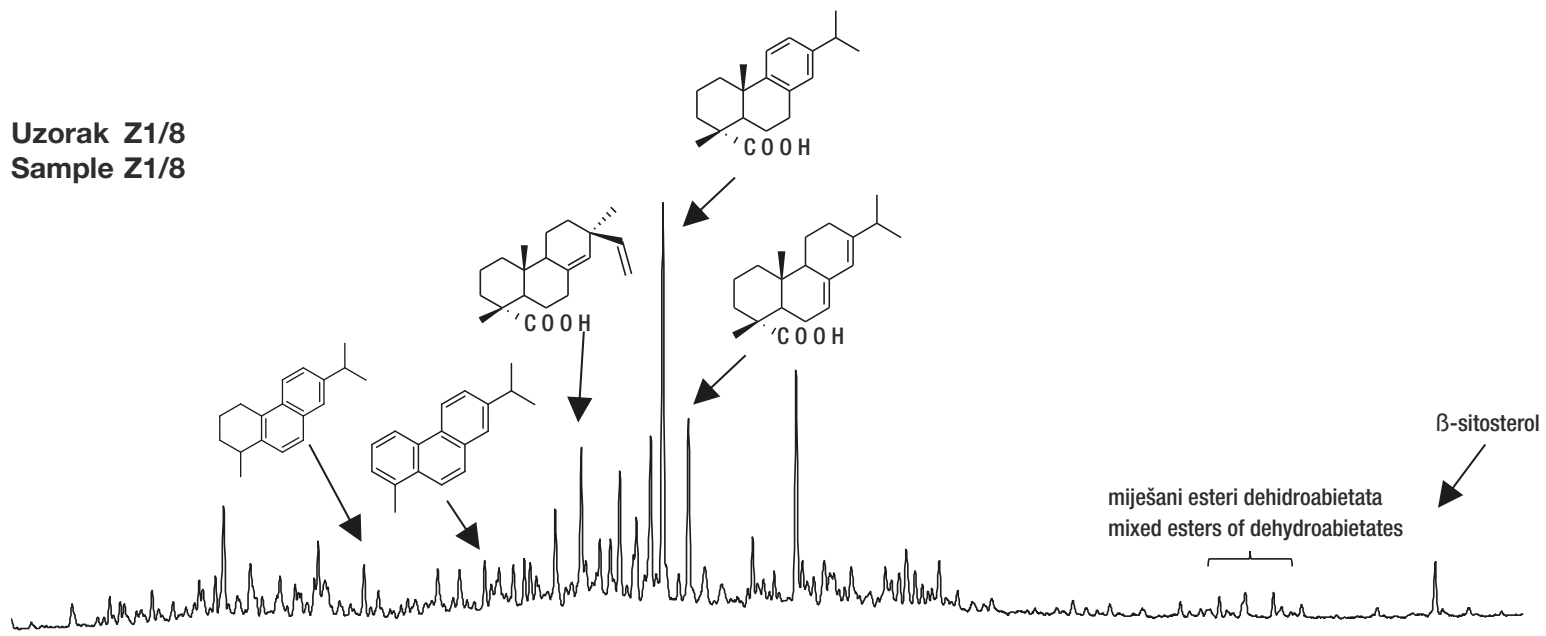


III.25.

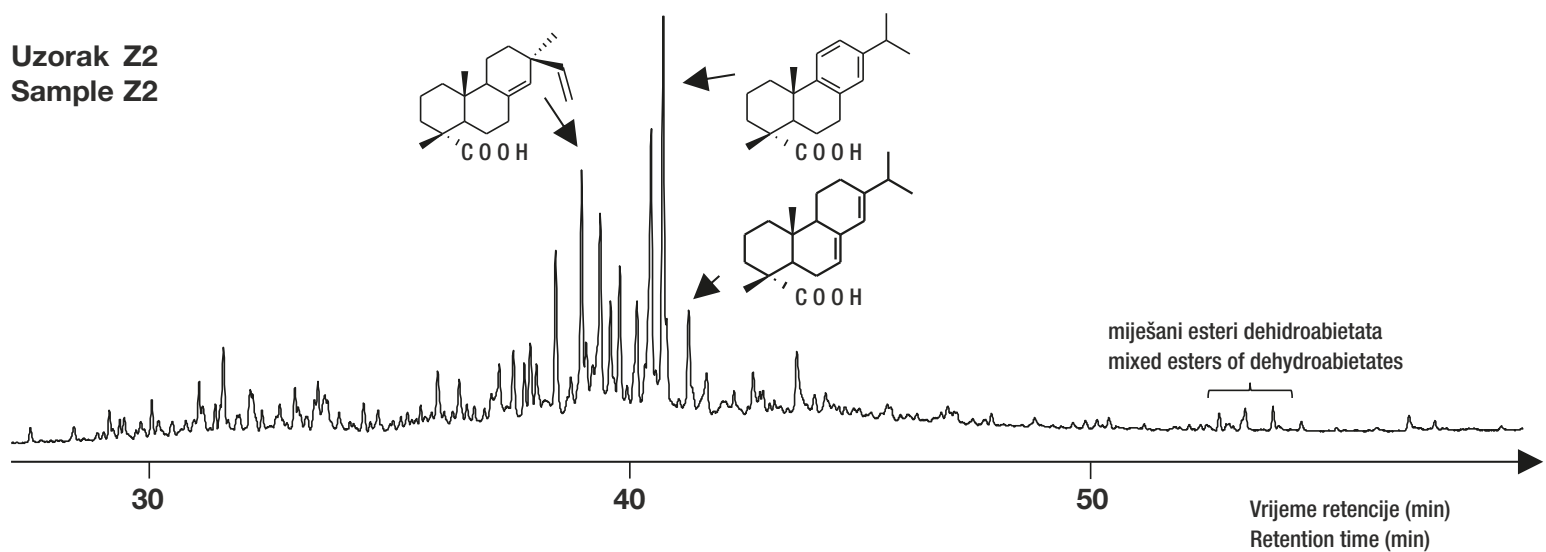
Primjeri dijagnostičkih spojeva pakline

Examples of diagnostic compounds of pitch

Uzorak Z1/8
Sample Z1/8



Uzorak Z2
Sample Z2

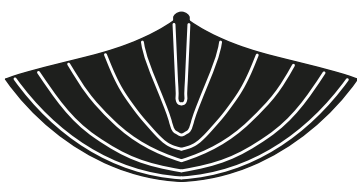


III.26.
GC-MS profili uzoraka Z1/8 i Z2
GC-MS profiles of samples Z1/8 and Z2

IV.

**Paleobotaničke
analize**

**Paleobotanical
Analyses**



Analiza peludi u zaštitnom premazu

Pollen analysis of protection pitch

Valérie Andrieu-Ponel

Zrnca peludi, zarobljena u zaštitnom premazu oplata antičkih brodova, dobro su sredstvo za utvrđivanje okoliša i ekosustava u kojima je taj materijal proizveden te mogu ukazati na to je li razvijen u blizini ili dalje od brodogradilišta (Argant 2010, Andrieu-Ponel 2010, 2011, 2012, 2018, Andrieu-Ponel *et al.* 2014, 2016).

Na šivanom brodu Zambratija uočeni su tragovi premaza na unutarnjoj strani oplata. Tijekom prve istraživačke kampanje u 2011. prikupljena su tri uzorka za analizu peludi (Sl. IV.1). Na dva (Z1 i Z2) od ta tri uzorka učinjena je molekularna analiza kojom je utvrđeno da je taj materijal, odnosno paklina, dobivena grijanjem četinjača.

Ciljevi analize peludi u uzorcima pakline bili su: 1.) utvrditi u kojem je okolišu proizvedena paklina: u primorju, u nižim predjelima na određenoj udaljenosti od mora ili u višim predjelima; 2.) utvrditi koji su se ekosustavi nalazili u blizini brodogradilišta ili mjesta proizvodnje pakline, odnosno jesu li to bili halofitski ekosustavi u nizinskim predjelima, otvoreni ekosustavi prekriveni šumom u višim predjelima ili ekosustavi na koje utječe djelovanje čovjeka (agrosustavi).

Rezultati su uspoređeni s onima s nalazišta u luci u Caski (otok Pag, Dalmacija). Ti su uzorci prikupljeni sa zaštitnog premaza rimskog šivanog broda (Caska 1) (Andrieu-Ponel 2010). Navedena je usporedba zanimljiva

Pollen grains trapped in the protective pitch of hulls of ancient ships are a good tool for identifying the environment and ecosystems in which this material was made and for indicating whether it was prepared near or away from the shipyard (Argant 2010; Andrieu-Ponel 2010, 2011, 2012, 2018; Andrieu-Ponel *et al.* 2014, 2016).

On the Zambratija sewn boat, traces of pitch were observed on the inner face of the planking. During the first excavation campaign in 2011, three samples were taken for pollen analysis (Fig. IV.1). Of these three samples, two (Z1 and Z2) were subjected to molecular analyses, which established that this material, specifically tar, was obtained by heating coniferous wood.

The objective of the pollen analysis of the pitch samples was twofold: 1) to identify in which environment the pitch was made - on the littoral, at low altitude but at some distance from the sea, or at higher altitude - 2) to define which ecosystems were present in the vicinity of the shipyard or to the manufacturing location of the pitch: halophytic ecosystems in low-lying areas, open or forested ecosystems in higher elevation areas, or ecosystems impacted by human activities (agrosystems).

The results were compared with those from the Caska harbour site (Pag Island, Dalmatia). These are samples taken from the protective pitch of a Roman sewn boat (Caska 1) (Andrieu-Ponel 2010). This comparison is

jer prema najnovijim tezama brodovi iz Zambratije i Caske pripadaju tradiciji šivanih brodova koji su specifični za sjeveroistočni Jadran, a potječu od prapovijesti, kao što je to pokazalo datiranje broda Zambratija (Pomey, Boetto 2019).

interesting because, according to the most recent hypotheses, the boats of Zambratija and Casca belong to a tradition of sewn boats specific to the North-East Adriatic, whose origin is very old as indicated by the dating of the Zambratija boat (Pomey, Boetto 2019).

Tehnike izoliranja peludi

Tehnike korištene za izoliranje peludi iz zaštitne pakline detaljno je opisala Valerie Andrieu-Ponel (2010). Za otapanje premaza koristili su se aceton i trikloretilen. Organski materijali (celuloza, humusne tvari) uništeni su lužinama (potašom, na primjer) i oksidirajućom mješavinom (acetolizom). Minerali su odstranjeni kiselinama (fluorovodičnom i klorovodičnom).

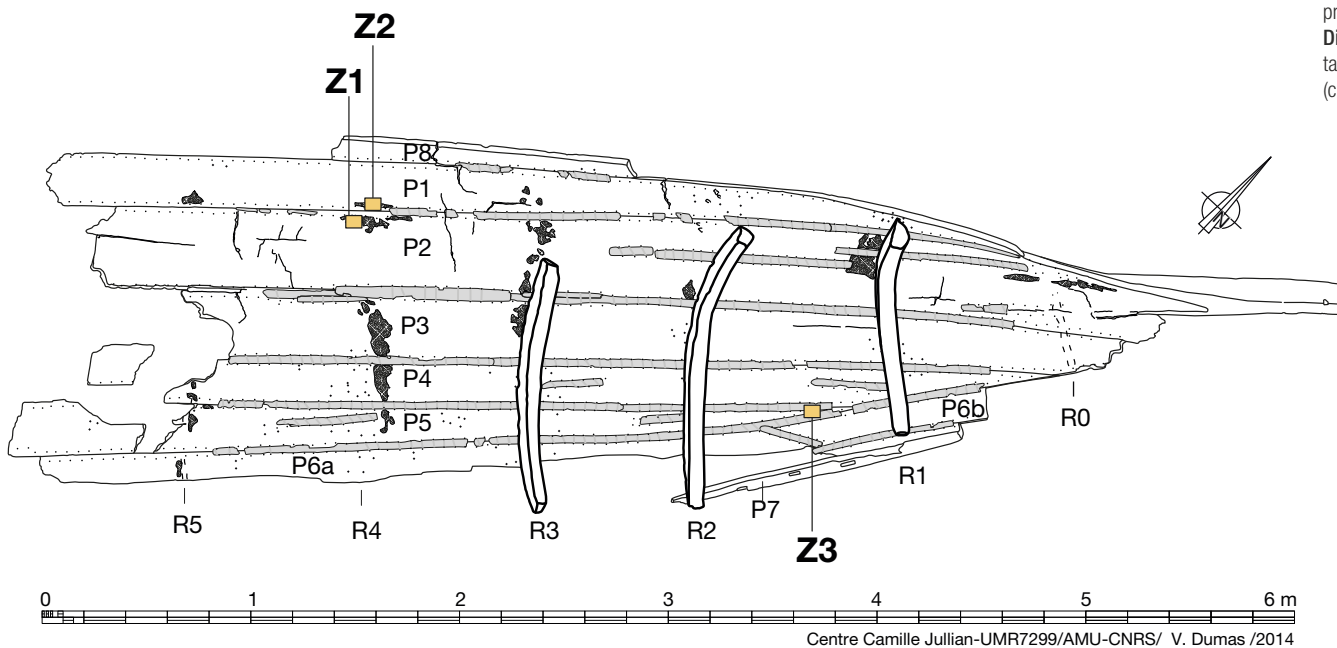
Na kraju tog postupka zrnca su prosijana kroz sito od 160 mikrona pa kroz filtar od 10 mikrona. Zatim su stavljena između predmetnog i pokrovnog stakalca. Predmetno stakalce očitano je uz pomoć mikroskopa te su upotrebom referentne zbirke peluda s Mediterranean

Pollen extraction techniques

The techniques used to extract pollen from sealing pitch are described in detail by Valerie Andrieu-Ponel (2010). Solvents (acetone and trichlorethylene) were used to dissolve the resin. Organic materials (cellulose, humic substances) have been destroyed with bases (potash for example) and an oxidizing mixture (acetolysis). Minerals were removed with acids (hydrofluoric acid and hydrochloric acid).

At the end of this treatment, the pellet was sieved on a sieve of 160 microns and then on a filter of 10 microns. It was then mounted between slide and coverslip. The slide was read using a photonic microscope

IV.1
Raspored uzoraka pakline prikupljene na olupini Zambratija
Distribution of pitch samples taken from the Zambratija wreck
(crtež / drawing by: V. Dumas)



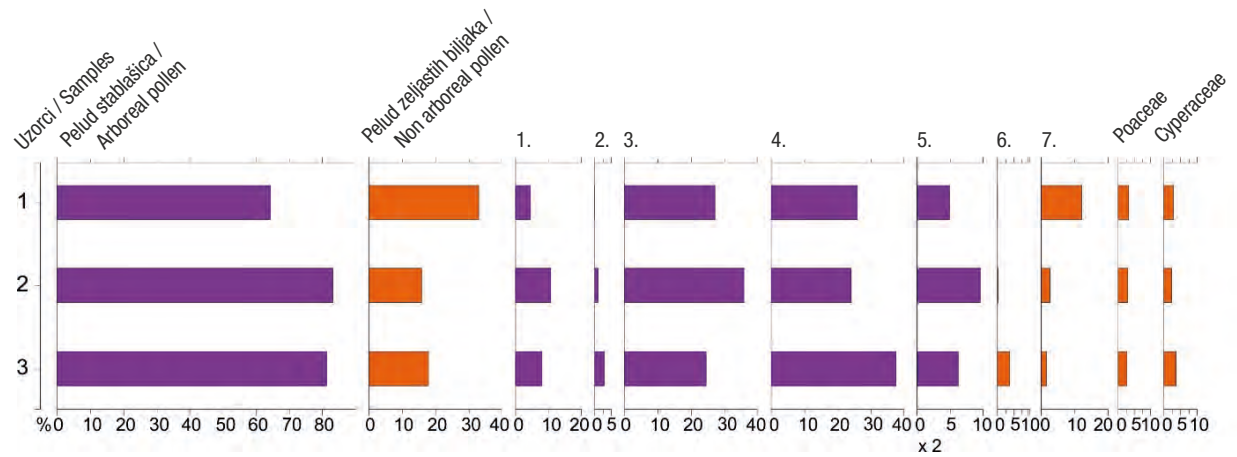
uzorak sample	mjesto prikupljanja provenance
Z1	P2
Z2	P1
Z3	P5

Institute of Marine and Continental Biodiversity and Ecology (IMBE) i znanstvene literature utvrđene svojte peludi te alge, gljivice i životinjski mikroostaci (Reille, 1992, 1995, 1998; Van Geel, 1978).

Postoci utvrđenih svojti izračunati su na temelju zbroja peludi (PS) koji uključuje sve svojte, jer je udio onih

and the pollen and non-pollen taxa (algae, fungi, animal microrestes) were identified using the pollen reference collection of the Mediterranean Institute of Marine and Continental Biodiversity and Ecology (IMBE) and scientific literature (Reille 1992, 1995, 1998; Van Geel 1978).

The percentages of the identified taxa were calculated



IV.2

Pojednostavljeni dijagrami peludi s olupina Zambratija (gore) i Caska (dolje), u postocima

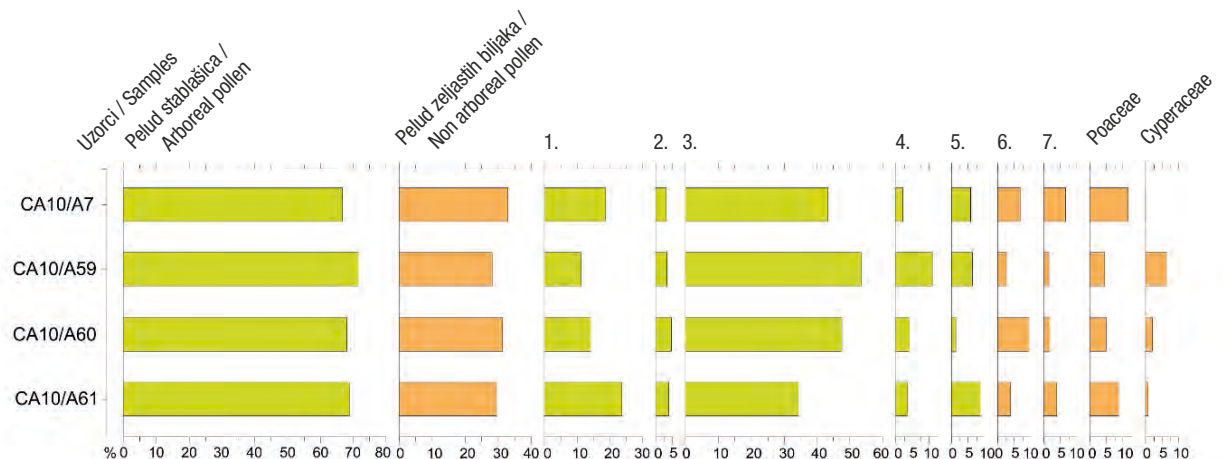
Simplified pollen diagrams, in percentages, of Zambratija (above) and Caska wrecks (bottom)

Zambratija

1. Planinsko drveće / Mountain trees: *Abies*, *Carpinus betulus*, *Fagus*, *Picea*, *Pinus sylvestris*.
2. Borova šuma / Pinus forest: *Pinus sylvestris*, mediteranski *Pinus*.
3. Mješovite mediteranske hrastove šume / Mixed mediterranean oak forest: *Buxus*, bjelogorice / deciduous *Quercus*, *Erica arborea*, *Hedera helix*, *Ostrya-Carpinus orientalis*, *Quercus ilex*, *Rhamnus*, *Sambucus*, *Ulmus*, *Viscum*.
4. Riječna šuma / Riverine forest: *Alnus*, *Corylus*, *Fraxinus*, *Salix*.
5. Arborikultura / Arboriculture: *Juglans*, *Olea*, *Prunus*, *Vitis*.
6. Žitarice / Cereals
7. Nitrofilne biljke / Nitrophilous: *Artemisia*, *Aster*, *Atriplex*, *Chenopodiaceae*, *Cichorioideae*, *Galium*, *Rumex*, *Urtica*.

Caska

1. Planinsko drveće / Mountain trees: *Abies*, *Carpinus betulus*, *Fagus*, *Picea*, *Pinus sylvestris*.
2. Borova šuma / Pinus forest: *Pinus sylvestris*, Mediterranean *Pinus*.
3. Mješovite mediteranske hrastove šume / Mixed mediterranean oak forest: *Corylus avellana*, bjelogorice / deciduous *Quercus*, *Erica arborea*, *Hedera helix*, *Olea*, *Ostrya-Carpinus orientalis*, *Quercus ilex*, *Phillyrea*, *Pistacia*, *Rhamnus*, *Ulmus*.
4. Riječna šuma / Riverine forest: *Alnus*, *Corylus*.
5. Arborikultura / Arboriculture: *Juglans*, *Olea*, *Prunus*.
6. Žitarice / Cereals
7. Nitrofilne biljke / Nitrophilous: *Artemisia*, *Aster*, *Atriplex*, *Chenopodiaceae*, *Cichorioideae*.



koje nisu vaskularne biljke bio malen. Rezultati su iskazani u pojednostavljenom dijagramu peludi (Sl. IV.2) na kojem su prikazani najveći ekosustavi i značajne svojite biljaka. Na ovoj je slici prikazan dijagram peludi s ostataka šivanog broda iz Caske (Andrieu-Ponel, 2010) radi usporedbe rezultata dobivenih s obje olupine. Detaljni rezultati izračuna peludi iz Zambratije i Caske prikazani su u tablicama IV.1 i IV.2.

Rezultati

Raznolikost sastava peludi koja je pronađena u trima uzorcima pakline velika je i uključuje stablašice (26 svojiti), zeljaste biljke (31 svojitu) i gljivice (vrsta 200) te svojitu formanifere (Tablica IV.1). Zanimljivo je naglasiti da među sporama peludi nije bilo mahovine, ali je ona pronađena među vlaknima ispod tankih letvica od jelovine, od kojih je bio izrađen vodonepropusni trup.

Udio peludi stablašica varira od 64,5% MS (Z1) do 83,29% MS (Z2). Prevladavajuće vrste stablašica su hrastovi, uključujući listopadni hrast, brijest (*Ulmus*) i lijesku (*Corylus*), zatim drvo iz obalne šume, johu (*Anus*) te kultiviranu biljku - vinovu lozu (*Vitis*) koja, međutim, proizvodi malo peludi i ne širi je nadaleko (Tablica IV.1). Planinske svojite: jela (*Abies*), obični grab (*Carpinus betulus*), bukva (*Fagus*), smreka (*Picea*) slabo su zastupljene (vrijednosti < 10% PS-a), jednako kao i one iz borove šume: mediteranski bor i obični bor (*Pinus sylvestris*), koje se javljaju u manje od 4% PS-a. Vrijednost zastupljenosti kultiviranih stablašica je <10% PS-a, što ukazuje na aktivnosti arborikulture. Kultivirane stablašice koje su utvrđene u Zambratiji karakteristične su u mediteranskoj poljoprivredi: orah (*Juglans*), vinova loza (*Vitis*), maslina (*Olea*) i *Prunus*, rod koji uključuje nekoliko voćki poput badema, šljive, trešnje i jabuke (*Malus*).

Udio peludi zeljastih biljaka varira od 16,14% (Z2) do 33,43% (Z1). Među utvrđenim svojitama prevladavaju nitrofilne biljke: lobodovka (*Chenopodiaceae*), glavočika (*Cichorioideae*), kiselica (*Rumex*), kopriva (*Urtica*), vrtna pepeljuga (*Atriplex*), zvjezdan (*Aster*), pelin (*Artemisia*), broćika (*Galium*) kao i trave (*Poaceae*). U uzorku Z3, žitarice postižu udio od 3,95%. Budući da one šire svoju pelud na kratke udaljenosti, vjerojatno su se na mjestu proizvodnje ili korištenja premaza iz uzorka Z3 uzgajale žitarice.

U uzorcima je pronađeno vrlo malo spora gljivica i nisu pronađene spore koprofilnih gljiva. Samo su u uzorku Z1 pronađene spore vrste 200. To znači da paklina nije bila onečišćena izmetom biljojeda koje su uzgajali stočari u vrijeme proizvodnje premaza ili izgradnje broda. Također se čini da izmet nije bio pomiješan sa zaštitnim

on a Pollen Sum (PS) that includes all taxa as the proportion of taxa that were not vascular plants was small. The results are presented in a synthetic pollen diagram (Fig. IV.2) where major ecosystems and significant plant taxa were represented. In this figure, the pollen diagram of Caska's sewn boat (Andrieu-Ponel 2010) was shown in order to compare the results obtained in the two wrecks. The detailed results of pollen counts of Zambratija and Caska are shown in Tables IV.1 and IV.2 respectively.

Results

The pollen diversity of the assemblages delivered by the three pitch samples is high and includes trees (26 taxa), herbaceous plants (31 taxa), fungi (Type 200) and a foraminifera taxon (Table IV.1). It is interesting to note the absence of bryophytes in the sporo-pollinic counts whereas mosses have been identified among the fibres present under the thin fir laths that made up the waterproofing system of the boat.

The rate of tree pollen varies from 64.5% of MS (Z1) to 83.29% of MS (Z2). Dominant trees are the elements of oak wood including deciduous oak, elm (*Ulmus*) and hazel (*Corylus*), a tree from the riparian forest - alder (*Alnus*), and a cultivated plant - wine (*Vitis*), which, however, produces little pollen and does not disperse it over long distances (Table IV.1). Montane taxa: fir (*Abies*), hornbeam (*Carpinus betulus*), beech (*Fagus*) and spruce (*Picea*), are poorly represented (values < 10% of PS) as are those of the pine forest: Mediterranean pine and Scots pine (*Pinus sylvestris*) whose percentages are less than 4% of PS. The cultivated trees are represented by values <10% of the PS, which shows the practice of arboriculture. The cultivated trees identified in Zambratija are characteristic of Mediterranean agriculture: walnut (*Juglans*), vine (*Vitis*), olive (*Olea*) and *Prunus*, a genus which includes several fruit trees including almond, the plum tree, the cherry tree and the apple tree.

The rate of herbaceous pollen ranges from 16.14% (Z2) to 33.43% (Z1). Among the identified taxa, the nitrophilous plants: *Chenopodiaceae*, *Cichorioideae*, *Rumex*, nettle (*Urtica*), saltbush (*Atriplex*), aster (*Aster*), mugwort (*Artemisia*), bedstraw (*Galium*) are dominant, as are the *Poaceae*. In the Z3 sample, cereals reach a rate of 3.95%. Since cereals disperse their pollen over short distances, it is likely that cereal cultivation was practiced at the place of manufacture or use of the pitch of the Z3 sample.

There were very few fungal spores and no spores of coprophilous fungi in the samples. Only Type 200 spores were found in the Z1 sample. This means that the pitch was not polluted by the excrement of herds of herbivores

Tablica IV.1 Popis svih svojiti utvrđenih u paklini broda Zambratija. Crvenom bojom označene su svojite čiji je postotak >10% izbroja peludi. Asteriskom (*) su označene svojite koje su bile korištene za izgradnju broda

Table IV.1 List of all taxa identified in Zambratija pitch samples. In red are indicated the taxa whose percentages are > 10% of the pollen sum. The asterisk (*) indicates the taxa used for the construction of the boat

Svojite peludi / Pollen taxa	Uzorci / Samples		
	Z1	Z2	Z3
Stablašice / Trees			
<i>Abies</i> sp. *	0.89	2.59	2.74
<i>Alnus glutinosa</i> t. *	15.68	18.44	31.61
<i>Betula</i> sp.	0.30	0.29	0.30
<i>Buxus</i> sp.	0.30	0.00	0.00
<i>Carpinus betulus</i>	1.18	3.75	0.61
<i>Corylus avellana</i>	5.33	3.17	3.95
<i>Erica arborea</i>	0.30	0.00	0.30
<i>Fagus</i> sp.	2.07	2.31	4.26
<i>Fraxinus</i> sp.	0.59	0.86	0.61
<i>Hedera helix</i>	0.00	2.02	0.00
<i>Juglans regia</i>	0.00	0.00	0.61
<i>Juniperus</i> sp.	0.30	0.00	0.00
<i>Olea</i> sp.	0.00	0.00	0.30
<i>Ostrya-Carpinus orientalis</i>	0.00	0.00	2.13
<i>Picea</i> sp.	0.59	2.31	0.61
<i>Pinus sylvestris</i> t.	0.00	0.00	1.22
<i>Pinus (mediterranean)</i>	0.30	1.44	1.82
<i>Prunus</i> t. *	2.37	1.15	0.30
<i>Deciduous Quercus</i>	15.68	17.29	15.50
<i>Quercus ilex</i> t.	0.00	0.58	0.61
<i>Rhamnus</i> sp.	0.00	0.00	0.61
<i>Salix</i> sp.	4.73	2.02	1.82
<i>Sambucus</i> sp.	0.00	0.00	0.61
<i>Ulmus</i> sp. *	11.24	16.14	5.78
<i>Viscum</i> sp.	0.00	0.29	0.00
<i>Vitis</i> sp.	2.66	8.65	5.17
Zeljaste biljke / Herbaceous plants			
<i>Agrimonia</i> sp.	0.00	0.00	0.30
<i>Allium</i> sp.	0.30	0.00	0.00
<i>Anemone</i> t.	0.30	0.00	0.00
Apiaceae	0.00	0.00	0.30
<i>Armeria</i> sp.	0.89	0.00	0.00
<i>Artemisia</i> sp.	6.80	0.00	0.30
<i>Aster</i> t.	2.37	0.86	0.30
<i>Atriplex</i> t.	0.00	0.29	0.30
<i>Cannabis</i> t.	0.00	0.00	3.95
<i>Centaurea nigra</i> t.	4.14	1.44	0.00
Cerealialia	0.30	0.58	3.95
Chenopodiaceae	0.30	0.29	0.30
Cichorioideae	2.37	1.15	0.00
Cyperaceae	3.25	2.59	3.95
<i>Euphorbia</i> sp.	0.89	3.17	0.30
<i>Galium</i> sp.	0.30	0.00	0.00
<i>Geranium</i> sp.	0.30	0.00	0.00
<i>Lotus</i> t.	0.00	0.29	0.00
<i>Lythrum</i> sp.	1.78	0.58	0.00
<i>Malva</i> sp.	0.30	0.00	0.00
<i>Mentha</i> t.	0.30	0.29	0.00
Poaceae	3.55	3.17	3.04
<i>Potentilla</i> t.	0.89	0.00	0.00
<i>Ranunculus</i> sp.	0.00	0.00	0.61
<i>Rosmarinus</i> t.	0.59	0.86	0.00
<i>Rumex</i> sp.	0.00	0.29	0.61
<i>Sanguisorba minor</i>	2.37	0.00	0.00
<i>Sinapis</i> t.	0.00	0.29	0.00
<i>Urtica</i> sp.	0.30	0.00	0.00
Foraminifers	0.30	0.00	0.00
<i>Sparganium-Typha</i>	0.00	0.58	0.00
<i>Trifolium</i> t.	0.30	0.00	0.30
Type 200	1.48	0.00	0.00

Tablica / Table IV.1

Svojte peludi / Pollen taxa	Uzorci / Samples			
	C1	C2	C3	C4
Stablašice / Trees				
<i>Abies alba</i> *	8.27	2.83	0.61	8.05
<i>Acer</i> sp.	0.00	0.00	0.00	0.62
<i>Alnus glutinosa</i> t.	1.50	4.72	3.05	2.48
<i>Carpinus betulus</i>	0.00	1.89	3.35	4.33
<i>Carpinus orientalis-Ostrya</i>	1.13	0.00	3.35	0.93
<i>Corylus avellana</i>	0.75	6.60	1.22	1.24
<i>Fagus sylvatica</i> *	5.64	0.94	4.57	8.36
<i>Hedera helix</i>	3.38	0.00	0.91	2.79
<i>Juglans regia</i>	0.38	0.00	0.61	0.62
<i>Juniperus</i> sp.	1.50	1.89	1.83	5.26
<i>Olea</i> sp.*	5.64	6.60	0.91	6.81
<i>Phillyrea</i> sp.	0.00	2.83	0.91	0.00
<i>Picea</i> sp.	2.63	1.89	1.22	0.31
<i>Pinus sylvestris</i> t.	2.26	3.77	4.57	2.79
<i>Pinus</i> (mediterranean) t. *	1.13	0.00	0.30	1.55
<i>Pistacia</i> sp.	0.00	0.94	1.22	0.00
<i>Prunus</i> t.	0.00	0.00	0.00	1.55
Deciduous <i>Quercus</i> *	22.56	11.32	18.29	12.38
<i>Quercus ilex</i> t. *	8.65	16.98	14.94	7.43
<i>Taxus baccata</i>	0.00	0.00	0.30	0.00
<i>Ulmus</i> sp.	0.00	1.89	1.22	0.62
Zeljaste biljke / Herbaceous plants				
<i>Allium</i> sp.	0.00	0.00	0.91	0.00
<i>Ammi</i> t	0.00	0.00	0.00	0.31
Apiaceae	0.00	1.89	0.30	0.31
<i>Artemisia</i> sp.	3.38	0.94	0.30	2.17
<i>Asphodelus</i> sp.	0.00	3.77	0.30	0.31
<i>Aster</i> t.	0.75	0.00	0.00	0.00
<i>Atriplex</i> t.	0.00	0.00	1.22	0.00
<i>Blackstonia</i> t.	0.00	0.00	0.30	0.00
<i>Cannabis</i> t.	0.00	0.00	0.30	0.00
<i>Carlina</i> t.	0.00	0.00	0.00	0.31
<i>Centaurea collina</i>	0.00	0.00	0.00	0.31
<i>Centaurea nigra</i> t.	1.50	0.00	0.30	1.86
Cerealialia	7.14	2.83	9.76	4.33
Chenopodiaceae	1.88	0.00	0.30	0.93
Cichorioideae	0.75	0.94	0.30	1.24
<i>Convolvulus</i> sp.	0.00	0.00	0.00	0.31
Cyperaceae	0.38	6.60	2.44	0.93
<i>Daphne</i> sp.	0.00	0.00	0.61	0.00
Dinoflagelates	0.00	0.00	0.00	1.24
<i>Dipsacus</i> sp.	0.00	0.00	0.30	0.00
<i>Echinops ritro</i>	0.00	0.00	0.00	0.31
<i>Erica arborea</i>	1.13	6.60	4.27	0.93
<i>Euphorbia</i> sp.	0.00	0.94	0.30	0.00
<i>Helianthemum</i> sp.	0.38	0.00	0.00	0.31
<i>Lotus</i> t.	0.00	0.00	1.22	0.00
<i>Malva</i> sp.	0.38	0.00	0.00	0.31
Monolete spores	0.75	0.00	0.00	0.00
<i>Odontites</i> sp.	0.00	0.94	1.52	0.00
<i>Ononis</i> t.	0.38	0.00	0.00	0.62
<i>Plantago coronopus</i>	1.13	1.89	4.57	1.55
Poaceae	12.03	4.72	5.18	8.98
<i>Polygonum aviculare</i>	0.00	0.94	0.61	0.62
<i>Pteridium aquilinum</i>	0.38	0.00	0.00	0.00
<i>Ranunculus</i>	0.38	0.00	0.00	0.00
<i>Rhamnus</i> sp.	0.38	0.00	0.61	0.00
<i>Rosmarinus</i> t.	0.00	0.00	0.30	0.93
<i>Sanguisorba minor</i>	0.00	0.94	0.30	0.93
<i>Secale</i>	0.75	0.00	0.00	0.93
<i>Sinapis</i> t.	0.00	0.00	0.00	0.31
<i>Sparganium-Typha</i>	0.00	0.00	0.00	0.31
<i>Thalictrum</i> sp.	0.00	0.00	0.00	0.31
<i>Trifolium</i> t.	0.75	0.00	0.00	0.00
Trilete spores	0.00	0.94	0.00	0.00

Tablica IV.2 Popis svih svojti utvrđenih u paklini broda Caska 1 i u sedimentima. Crvenom bojom označene su svojte čiji je postotak >10% izbroja peludi. Asteriskom (*) su označene svojte koje su bile korištene za izgradnju broda

Table IV.2 List of all taxa identified in the pitch of the Caska 1 wreck and in sediments. In red are indicated the taxa whose percentages are > 10% of the pollen sum. The asterisk (*) indicates the taxa used for the construction of the boat

premazom, što se ponekad radilo kako bi se povećao njegov volumen.

Halofilne biljke (*Chenopodiaceae*, *Atriplex*) vrlo su malo zastupljene (vrijednosti <1% PS-a). Ta okolnost upućuje na to da premaz nije proizveden u blizini vegetacije koja graniči s obalom.

Rasprava i zaključak

Podaci o peludi ukazuju na to da je paklina s broda Zambratija proizvedena ili se koristila u niskim predjelima, prekrivenima šumom u kojoj je prevladavao listopadni hrast. Stanovništvo je mijenjalo okoliš, kao što to pokazuju nitrofilne biljke, koje svjedoče o uzgoju životinja, drveća i žitarica. Stanovništvo su činili stočari koji su se bavili uzgojem domaćih životinja i arborikulturom, uključujući uzgoj vinove loze i žitarica.

Zanimljivo je napomenuti da je većina svojti korištenih za izgradnju brodske konstrukcije pronađena u sastavima peludi (Ferreira Dominuez *et al.* 2017). Riječ je o jeli (*Abies*), johi (*Alnus glutinosa*), brijestu (*Ulmus*) i vrsti *Prunus* koja uključuje rod *Pyrus* (Beug 2004). Visoki postotak joha i brijesta može se povezati s prisutnošću tih stablašica na mjestu proizvodnje pakline ili, vjerojatnije, izgradnje broda. Također je moguće da pelud jele dolazi s posječenog stabla koje se prevozilo u brodogradilište za potrebe izrade letvica korištenih za vodonepropusni sustav trupa.

Udjeli *Pinusa* i *Abiesa* niski su, niži od 3% PS-a u oba slučaja. Isti je slučaj i sa sastavima iz Caske (Tablica IV.2). Mala količina peludi bora i jele objašnjava se činjenicom da je materijal s kojim su premazane dvije olupine dobiven zagrijavanjem drva (paklina), a ne prikupljanjem smole sa stabala kao što to pokazuju biomolekularni podaci. Nadalje, ti podaci pokazuju i da je zagrijavano drvo pripadalo porodici *Pinaceae* te vrstama *Abies* i *Pinus*.

Sličnost sastava peludi iz Zambratije i Caske zapažajuća je (Sl. IV.2, Tablice IV.1 i IV.2). U oba slučaja prevladava hrast, što ukazuje na to da su paklina ili brodovi izgrađeni u šumovitom okolišu u kojem je prevladavao listopadni hrast, ali i koji je ljudskom intervencijom obrađivan. Za razliku od Caske, posebnost Zambratije očituje se u prisutnosti visokih udjela joha (15,68% <x <31,61%), vrste koja se nalazi u obalnim šumama, a koja se također koristila za izradu brodskih rebara.

Iz suvremenih regionalnih podataka o peludi iz druge polovice holocena proizlazi da je čovjek počeo utjecati na ekosustave čak u razdoblju eneolitika (Kanievski *et al.* 2018). Bez obzira na kulturološke prakse i požare, ekosustavi su u kasnom brončanom dobu u Istri još uvijek bili prekriveni šumom (Kanievski *et al.* 2018) isto kao i područje jugoistočno (otok Cres, Schmidt *et al.*

that were raised by the farmers at the time of making the pitch or building the boat. It also seems that excrement has not been mixed with the protective pitch as is sometimes practised to increase the volume.

Halophile plants (*Chenopodiaceae*, *Atriplex*) are underrepresented (values <1% of PS). This indicates that the pitch was not made near the salty vegetation bordering the seashore.

Discussion and conclusion

Pollen data show that the protective pitch of the Zambratija boat was manufactured or used in a low-altitude, wooded environment in which deciduous oak was dominant. Human populations had modified the environment as indicated by nitrophilous plants, testifying to the practice of breeding, and the presence of cultivated trees and cereals. These populations were farmers who practised animal husbandry, arboriculture including vine growing and cereal growing.

It is interesting to note that most taxa used for the construction of the hull (Ferreira Dominguez *et al.* 2017) were found in the pollen assemblages. They are fir (*Abies*), alder (*Alnus glutinosa*), elm (*Ulmus*) and *Prunus* type which includes the genera *Pyrus* (Beug 2004). The high percentages of *Alnus* and *Ulmus* may be related to the presence of these trees where the pitch was fabricated or, more probably, where the boat was built. It is also possible that the fir pollen comes from trees that were cut and transported to the shipyard to make the laths used in the waterproofing system.

The pollen rates of *Pinus* and *Abies* are low, less than 3% of PS in both cases. This is also the case in the Caska assemblages (Table IV.2). The scarcity of pine and fir pollen is explained by the fact that the material used to seal the two wrecks is pitch derived from the heating of wood and not from resins collected by gemming as indicated by the biomolecular data. These data also show that these heated woods are *Pinaceae*, and *Abies* and *Pinus* both belong to this plant family.

The similarity of the Zambratija and Caska pollen assemblages is striking (Fig. IV.2, Tables IV.1 and IV.2). They are both dominated by oak taxa and show that pitch or the boat were made in a forested environment, dominated by deciduous oak but also disturbed by man and cultivated. The peculiarity of Zambratija, unlike Caska, is the presence of high rates of alder (15.68% <x <31.61%), a species of riparian forest that was also used for the manufacture of the frames of the boat.

Contemporary regional pollen data of the upper half of the Holocene show that the human impact on ecosystems began as early as the Eneolithic (Kanievski *et al.* 2018). Despite cultural practices and fires, ecosystems are still forested in the late Bronze Age in Istria (Kanievski *et al.* 2018), in the southeast of this peninsula

2000) ili čak južnije, u Albaniji/Crnoj Gori (Skadarsko jezero, Sadori *et al.*, 2015), kao što potvrđuje paklina iz Zambratije, krajem brončanog i početkom željeznog doba.

Sličnost zapisa o peludi iz sedimentnih jezgri (Kaniewski *et al.* 2018; Sadori *et al.* 2015; Schmidt *et al.* 2000) te iz pakline s broda Zambratija naglašava interes za proučavanje peludi u zaštitnim materijalima brodskih konstrukcija radi rekonstrukcije drevnih biljnih krajolika.

(Cres Island, Schmidt *et al.* 2000) or more to the south in Albania/Montenegro (Lake Shkodra, Sadori *et al.* 2015) as is the case in the Zambratija pitch, at the end of the Bronze Age and the beginning of the Iron age.

The similarity of pollen recordings of sedimentary cores (Kaniewski *et al.* 2018; Sadori *et al.* 2015; Schmidt *et al.* 2000) and of Zambratija's pitch highlights the interest of the pollen study of protective materials of ship hulls for the reconstruction of ancient vegetal landscapes.

Arheobotanička analiza

Archaeobotanical analysis

Renata Šoštarić, Ida Koncani Uhač

Analiza je napravljena na tri uzorka koji su prikupljeni u stratigrafskim jedinicama (SJ) 3, 5 i 7, a u kojima je prisutnost organskog materijala primijećena prostim okom. Uzorci su opisani ovdje (Tab. IV.3).

Uzorci	Stratigrafska jedinica	Kvadrant	Datum uzorkovanja	Količina sedimenta
Uzorak-1	SJ 3	F2	21/09/2011	0,5 litra
Uzorak-2	SJ 5	F1	22/09/2011	1 litra
Uzorak-4	SJ 7	A4	24/09/2011	0,3 litra

T.IV.3

Metodologija

Uzorci su najprije ispirani preko sita veličine oka 2,5, 1 i 0,315 milimetara, a zatim su tri dobivene frakcije svakog uzorka pregledane uz pomoć binokularne lupe.

Rezultati i rasprava

Uzorci su sadržavali veće količine ljuštura školjaka, puževih kućica, bodlji, zubića i komadića čahura morskih ježinaca te fragmenata drva i recentnih korijena biljaka, ali vrlo malo, svega 10 karpoloških biljnih ostataka (Tab. IV.4). Dio nalaza je karboniziran (K) kao posljedica gorenja uz ograničeni pristup zraka, a dio nalaza je nekarboniziran i ostao je sačuvan zahvaljujući kombiniranom djelovanju slanosti mora te sedimenta koji ograničava pristup zraka i aktivnost mikroorganizama. Identifikacija biljnih nalaza je bila otežana, djelomično zbog oštećenosti i fragmentiranosti, a dijelom jer nađeni ostaci pripadaju skupinama biljaka bez jasnih razlikovnih

The study was carried out on three samples (collected in 2011) from the three stratigraphic units SU3, SU5 and SU7 that showed the presence of organic remains, some of them visible to the naked eye.

The samples are described herein (Tab. IV.3).

	Stratigraphic Unit	Quadrant	Date of sampling	Quantity of sediments
Sample-1	SU3	F2	21/09/2011	0.5 litres
Sample-2	SU5	F1	22/09/2011	1 litres
Sample-4	SU7	A4	24/09/2011	0.3 litres

T.IV.3

Methodology

The samples were first wet sieved using 2.5 mm, 1 mm and 0.315 mm sieves and then, three fractions of each sample were observed using a binocular microscope.

Results and discussion

The samples contained larger amounts of shells, sea snail shells, spines, small teeth and pieces of sea urchin tests as well as fragments of wood and recent plant roots, but just a few, that is, only 10 carpological plant remains were found (Table IV.4). A part of the finds was carbonised (C) as a consequence of burning with a limited air access and another part was non-carbonised and has remained preserved thanks to the high sea salinity and the sediment avoiding the air access and the activity of micro-organisms.

The identification of the plant finds was difficult, partly due to damage and fragmentation, and partly because

osobina. S obzirom na vrlo mali broj nalaza i poteškoće oko njihove identifikacije, nije moguće pretpostaviti radi li se o biljkama koje su bile dio brodskog tereta ili pak o ostacima okolne vegetacije. S obzirom da unutar trupa osim dva nedijagnostička sitna ulomka keramike koja su se nalazila u sloju direktno iznad korita nisu pronađeni pokretni arheološki nalazi, pretpostavka da se radi o okolnoj vegetaciji čini se više izglednom.

Najpreciznije su identificirane dvije karbonizirane sjemenke najvjerojatnije crne gorušice (*Brassica cf. nigra*). Sjemenke gorušice imaju karakterističnu površinsku strukturu pa je moguće razlikovati različite vrste (Cappers, Neef 2012, Cappers *et al.* 2012), međutim, u ovom slučaju nisu dovoljno dobro sačuvane da bi determinacija bila sasvim pouzdana.

Prema dosadašnjim saznanjima, crna gorušica se od antičkih vremena uzgajala za dobivanje senfa i kao ljekovita biljka. Pretpostavlja se da potječe iz jugoistočnog Sredozemlja, ali se, zahvaljujući uzgoju, kao podivljala raširila srednjom i južnom Europom, sjevernom Afrikom te Sjevernom i Južnom Amerikom. Danas se rijetko uzgaja i uglavnom je sastavni dio vegetacije visokih zelenih trajnica, smetlišta, korovne vegetacije polja na vlažnim glinastim i aluvijalnim podlogama bogatim vapnencem i hranjivim tvarima te poplavnim područjima (Oberdorfer 2001, Hanf 1999).

Ovaj nalaz potencijalno bi mogao ukazivati na njeno ranije korištenje u povijesti, međutim, samo dvije nedovoljno dobro očuvane sjemenke nisu dovoljne za takvu pretpostavku. Iako je predmetni sloj u kojem su pronađene sjemenke bio u direktnom kontaktu s brodskom konstrukcijom, ne može se sa sigurnošću tvrditi da je istovjetne datacije, osobito jer botanički materijal nije radiokarbonski datiran.

the remains found belong to plant groups that could not be clearly differentiated. Given a very small number of finds and the difficulties in their identification, it is not possible to propose whether those plants were part of the boat cargo or remains of surrounding vegetation. Considering that in the layer immediately above the hull no archaeological small finds were found, except for two unidentifiable tiny pottery fragments, the assumption that the plants pertained to the surrounding vegetation seems more plausible.

Most definitively identified were two carbonised, most probably black mustard (*Brassica cf. nigra*), seeds. The surface structure of black mustard seeds is characteristic, so different species may be distinguished (Cappers, Neef 2012; Cappers *et al.* 2012). However, in Zambratija, they have not been so well preserved to allow a fully accurate identification.

According to present knowledge, black mustard has been grown since ancient times for mustard production and as a medicinal herb. It is assumed that it originates from the southeast Mediterranean, but due to cultivation, it spread spontaneously across Central and South Europe, North Africa and North and South America. Nowadays, it is rarely cultivated and grows among perennial greens, on waste dumps, among weed vegetation in the fields, as well as on dump clay, alluvial soils rich in limestone and nutrients, and floodplains (Hanf 1999; Oberdorfer 2011).

The mustard seeds found within the Zambratija shipwreck could potentially indicate that this plant was used at least from the early Iron Age in the Adriatic area. However, two insufficiently preserved seeds are not enough to make such an assumption. Moreover, although the layer in which the seeds have been found was in direct contact with the preserved boat's structure, it cannot be stated with absolute certainty that it is of the same date, especially since the botanical material has not been dated through radiocarbon analysis.

POPIS SVOJTI / LIST OF TAXA	TIP NALAZA / FIND TYPE	SJ 3 Uzorak 1 / Sample 1	SJ 5 Uzorak 2 / Sample 2	SJ 7 Uzorak 4 / Sample 4	UKUPNO TOTAL
<i>Brassica cf. nigra</i> (L.) Koch (gorušica crna / Black mustard)	sjemenka K / seed C	1		1	2
<i>Fabaceae</i> (mahunarke / legumes)	sjemenka K / seed C	2			2
<i>cf. Rosa/Rubus</i>	vrh trna NK / thorn NC		1		1
<i>cf. Rosa/Rubus</i>	fragm. sjemenke NK / seed fragment NC			3	3
INDET.	fragm. sjemenke NK / seed fragment NC		2		2
UKUPNO / TOTAL:		3	3	4	10

Tumač kratica: K – karbonizirani biljni ostaci, NK – nekarbonizirani biljni ostaci, cf. – vjerojatno, INDET. – nije bilo moguće identificirati

Abbreviations: C – carbonised plant remains, NC – non-carbonised plant remains, cf. – *lat. confer compare* - probably, INDET. - could not be identified

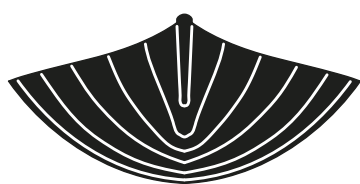
Tablica IV.4. Zambratija 2011., pregled biljnih nalaza

Table IV.4. Botanical remains from the Zambratija boat, campaign 2011.

V.

**Kulturno-povijesni
kontekst**

**Cultural &
Historical Context**



Brod u kontekstu kasnog brončanog/željeznog doba Istre (arheološko-povijesna slika istarskog prostora)

The boat in the context of the Late Bronze/Iron Age of Istria (an archaeological and historical survey of the Istrian region)

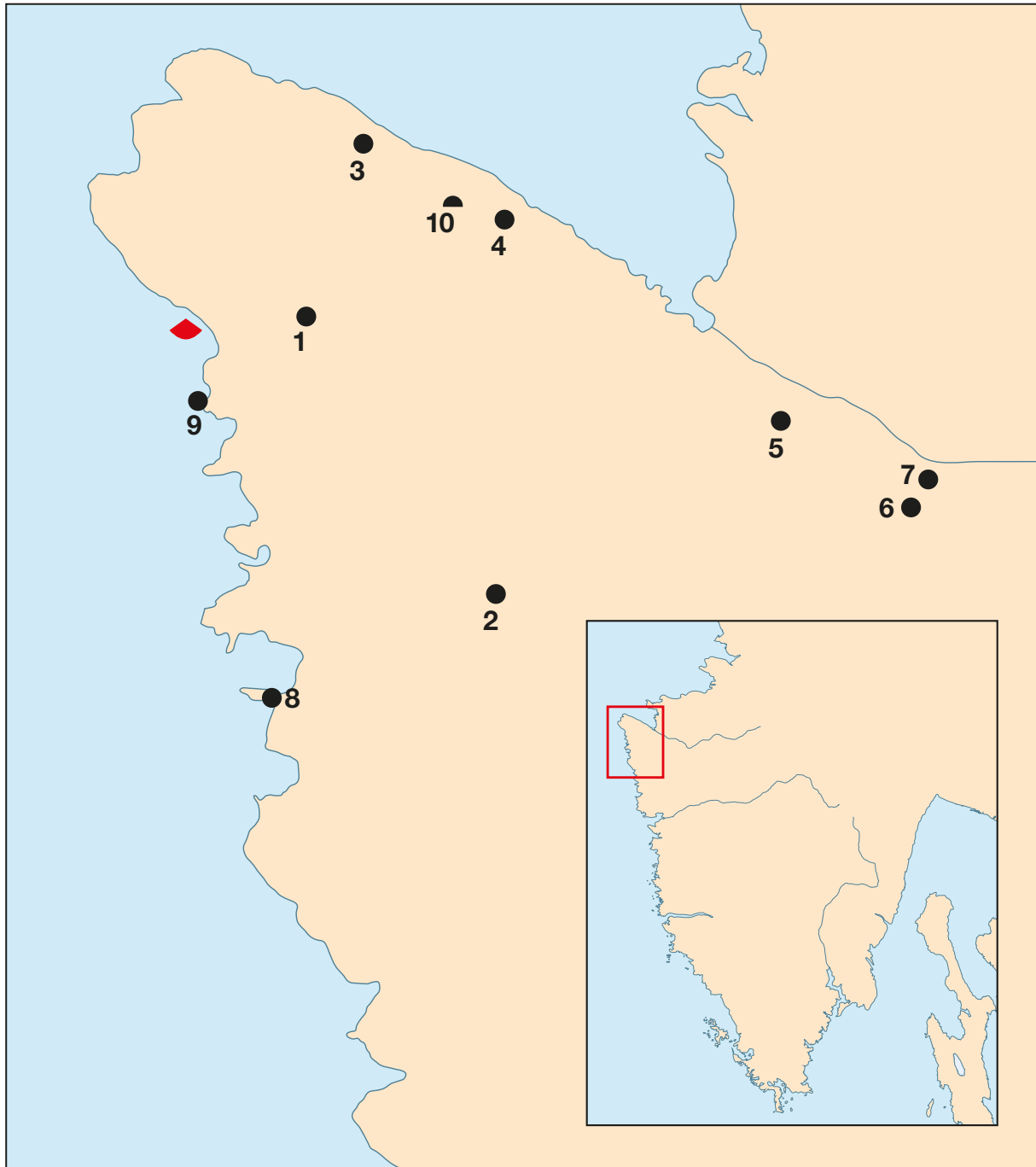
Kristina Mihovilić

Brojni arheološki nalazi ukazuju na važnost položaja istarskog poluotoka na raskrižju raznih putova, posebno na kraju jednog od kopnenih ili pomorskog puta razmjena znanja i roba kroz sva razdoblja - pa tako i kroz brončano i željezno doba - između Sredozemlja i središnje Europe. Brončano i željezno doba na području Istre, kvarnerskih otoka i Krasa označavaju brojna gradinska naselja ili kastele (prema C. Marchesettiju čak 455) (Marchesetti 1903; Buršić-Matijašić 2007; Mihovilić 2013a).

Način gradnje obrambenih zidina gradina, pojedini oblici keramičkih posuda i brončanih predmeta, tzv. krušni idoli, jantar i sl., govore o kontaktima stanovnika Istre sa susjednim, ali i vrlo udaljenim krajevima već od ranog brončanog doba, početkom 2. tisućljeća. Sustavna istraživanja gradine Monkodonja dala su podatke o ozbiljnom stradanju tog naselja već tijekom 15. st. pr. Kr., nakon čega je ono samo djelomično obnovljeno (Hänsel *et al.* 2015). S obzirom na stanje istraženosti, ne znamo je li se nešto slično istovremeno dogodilo i drugim gradinama, ali svakako se novi procvat gradinskih naselja na području Istre dogodio tijekom 12. st. pr. Kr., prodorom i prevlašću nositelja kulture polja sa žarama (Mihovilić 2013a, 2013b.).

Numerous archaeological finds indicate the importance of the position of the Istrian peninsula as the crossroad of several routes, particularly as the end point of some of the overland or maritime routes involved in the exchange of knowledge and goods, throughout the ages, and hence also in the Bronze and Iron Ages, between the Mediterranean and Central Europe. The Bronze Age and Iron Age in the region of Istria, the Kvarner Bay islands, and Kras (the Karst region) is marked by hillfort settlements, called *castellieri*, which numbered, according to C. Marchesetti (1903), as many as 455 (Buršić-Matijašić 2007; Mihovilić 2013a).

The manner of constructing the defensive walls of the hillforts, particular types of pottery vessels, and bronze objects such as idols, amber, and so forth, indicate the contact the inhabitants of Istria had with both neighbouring and very distant areas from as early as the Early Bronze Age, at the beginning of the 2nd millennium BCE. The systematic excavation of the hillfort of Monkodonja resulted in data about severe damage that occurred at this settlement as early as the 15th century BCE, after which it was only partially rebuilt (Hänsel *et al.* 2015). Given the state of investigations, it is not yet known



V.1

Karta s nalazištima gradina i tumula u zaleđu Zambratije: 1. Romanija (k. 50), 2. Kaštelir-Ungarija (k. 56), 3. Barafito (k. 46), 4. Sv. Petar (k. 78), 5. Kolumbanija (k. 134), 6. Markovac 1=Chia (k. 162), 7. Markovac 2=Mira (k. 156), a vjerojatno također 8. Umag i 9. Sipar; 10. Crveni vrh-Glavica (po Čučković 2007; 2008; 2012; Milošević, Petrović Markežić 2012; Buršić-Matijašić 2007)

Map of hillforts and tumuli in the hinterland of Zambratija: 1. Romanija (m. 50), 2. Kaštelir-Ungarija (m. 56), 3. Barafito (m. 46), 4. Sv. Petar (m. 78), 5. Kolumbanija (m. 134), 6. Markovac 1=Chia (m. 162), 7. Markovac 2=Mira (m. 156), and probably also 8. Umag and 9. Sipar; 10. Crveni vrh-Glavica (from Čučković 2007, 2008, 2012; Milošević, Petrović Markežić 2012; Buršić-Matijašić 2007)

U zaleđu uvale Zambratija i šireg prostora Savudrije dokumentiran je niz utvrđenih gradina, na kojima nisu obavljena posebna istraživanja. Uz brončanodobne gradine vežu se kameni tumuli - grobne gomile s kosturnim ukopima, kakve su dokumentirane i istraživane istočno od Crvenog vrha (Sl. V.1).

Vrijeme između 1120. i 930. g. pr. Kr., kako je datirano plovilo Zambratija, prema srednjoeuropskoj kronologiji predstavlja razdoblje od Ha A1 do B1. Na području sjeverne Hrvatske to je razdoblje od kraja II.

whether something similar occurred at the same time at other elevated fortified settlements, but certainly a new revival of the hillforts in Istria took place during the 12th century BCE, with the arrival and domination of the bearers of the Urnfield Culture (Mihovilić 2013a, 2013b).

A series of fortified hilltop settlements have been documented in the hinterland of Zambratija Cove and the broader region of Savudrija, where systematic excavations have unfortunately not yet been performed. Related to these Bronze Age hillforts are stone tumuli – grave mounds with inhumation burials, such as have



V.2
 Limska gradina, nalazi iz groba 57
 Limska gradina hillfort, findings
 from the grave 57
 (fotografija / photo by: A. Klarić)

faze kulture polja sa žarama do gotovo kraja IV. faze (Vinski-Gasparini 1973), a na području sjeverne Italije *Bronzo finale* (Bietti Sestieri 2001).

Vrijeme je to širenja kulture polja sa žarama s područja Karpatske kotline po cijeloj Europi, i njenog najvećeg uspona, nakon rušenja civilizacija mikenskih palača u Grčkoj, propasti Hetitskog kraljevstva u Maloj Aziji, vrijeme kad su „narodi s mora“ doprli do Egipta. Na području sjeverne Italije to je vrijeme krize sustava naselja sojenica i terramara, kao i centra metalurgije u Peschieri del Garda. Sve se to događa uz kretanje velikih masa ljudi i nastajanje novih političkih i ekonomskih odnosa.

O važnosti prostora sjevernog Jadrana i pomorskim putovima svjedoči nastanak novog vodećeg centra u Frattesini di Fratta Polesine kod Roviga, na području delte rijeke Po. Centar je to s organiziranom proizvodnjom - obradom, distribucijom i razmjenom jantara,

been documented and excavated to the east of Crveni vrh (Fig. V.1).

The period between 1120 and 930 BCE, which corresponds to the date of construction of the Zambratija boat, represents the period from Ha A1 to B1 in the central European chronology. In northern Croatia this is the period from the end of phase II of the Urnfield Culture to almost the end of phase IV (Vinski-Gasparini 1973), and in northern Italy this is called the *Bronzo finale* (Bietti Sestieri 2003).

This period marked the spread of the Urnfield Culture from the Carpathian Basin throughout Europe and also its high point, coming after the destruction of the civilization of the Mycenaean palaces in Greece, the fall of the Hittite Kingdom in Asia Minor, and the attacks of the “Sea Peoples” on Egypt. In the northern Italian



slonovače, staklene paste i bronce (Bietti Sestieri 2001).

Istovremeno duž istočne obale Jadrana traje kasno brončano doba, kada se već počinju oblikovati posebne kulturne skupine, među kojima je i ona istarska (Batović 1983; Mihovilić 2013b).

Vrijeme datacije plovila Zambratija odgovara razdoblju razvoja I. faze kulture Histra (od kraja 12. do kraja 10. st. pr. Kr.). Najstariji nalazi koji označavaju ovo razdoblje potječu prije svega iz žarnih nekropola Limske gradine, Nezakcija, Picuga, Pule, Sv. Martina nad Limom, a zatim je važno i nekoliko pojedinačnih nalaza, kao i nekoliko ostava brončanih predmeta (Mihovilić 2013b; Teržan 1995-1996) (Sl.V.2).

U ovom razdoblju karakteristične grobne žare imaju oblik šalice i ukrašene su plastičnim bradavicama s

region, this was the period of the lake dwellings and Terramare settlements, as well as the metallurgical centre at Peschiera del Garda. This all occurred along with the mass migrations and the creation of new political and economic relations.

The importance of the northern Adriatic and the maritime routes in this area are indicated by the creation of a new dominant regional centre at Frattesina di Fratta Polesine near Rovigo, in the Po River delta. This was a centre for the organized production, processing, distribution, and exchange of amber, ivory, glass paste, and bronze (Bietti Sestieri 2003).

At the same time, along the eastern coast of the Adriatic Sea in the Late Bronze Age specific cultural groups began to form, including the Istrian group (Batović 1983; Mihovilić 2013b).

V.3a
Brončana situla s prikazom pomorske bitke iz grobnice na Nezakciju, istražene 1981.: a) detalj broda
Bronze situla with the depiction of a maritime battle from the grave vault from Nesactium, explored in 1981: a) detail of the ship (fotografija / photo by: A. Klarić)

koncentričnim kružnicama, a zatim su tu i one ukrašene širokim kosim kanelurama. Nastale su kao rezultat miješanja prethodnih brončanodobnih oblika i novih ukrasnih detalja vezanih za nositelje kulture polja sa žarama.

Tipičan brončani nakit, kao što su narukvice C i V presjeka, široke horizontalno narebrenе manžete, spiralno naočalasti privjesci i sl., pojavljuje se istovremeno duž cijele istočne obale Jadrana.

U najstarijim grobovima Limske gradine uz ostatke spaljenih pokojnika bile su priložene perle od staklene paste, bačvastog oblika, izrađivane u radionicama Frattesine, koje su mogle stići brodom uz obalu, ali i preko Jadrana.

Istra se nalazi na jednom od jantarnih putova pa je tako jantar baltičkog porijekla bio uobičajen prilog već uz brončanodobne kosturne ukope pod kamenim gomilama, kao i u grobovima uz ulaze u brončanodobne gradine (Buršić-Matijašić 1989-1990; Mihovilić *et al.* 2011), a zatim kroz željezno doba gotovo nestaje, možda rastopljen na lomači uz pokojnika.

Povezanost Istre sa središnjim i južnim prostorom Apeninskog poluotoka već u 10. st. pr. Kr. pokazuju npr. grobna žara oblika kolibe (*a capanna*) iz groba VI/28 iz Nezakcija, s paralelama u nekropolama Rima i

The date of the Zambratija boat corresponds to the period of development of phase I of the culture of the Histri (from the end of the 12th to the end of the 10th centuries BCE). The earliest finds marking this period come primarily from the cremation cemeteries of Limska gradina hillfort, Nezakcij/Nesactium, Picugi, Pula, Sv. Martin nad Limom/St Martin above Lim Fjord, along with several individual finds and several hoards of bronze objects (Mihovilić 2013b; Teržan 1995-1996) (Fig.V.2)

In this period, the characteristic burial urns have a cup shape, and are decorated with relief lugs with concentric circles, while some are decorated with broad slanted channelling. They were created as a result of the mixing of the previous Bronze Age forms and new decorative details related to the bearers of the Urnfield Culture.

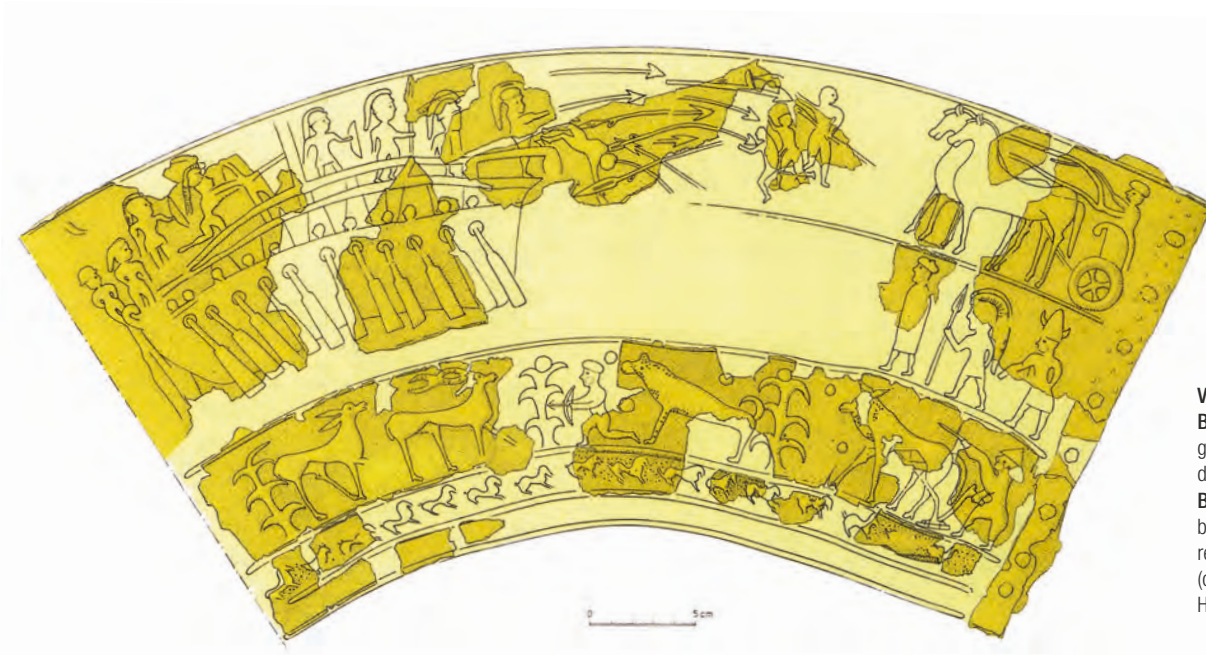
The typical bronze jewellery, such as bracelets of C and V cross section, broad horizontally ribbed cuffs, spirally coiled spectacle pendants, and so forth, appears at the same time along the entire eastern coast of the Adriatic Sea.

The earliest graves at the Limska gradina hillfort contained, in addition to the cremated remains of the deceased, barrel-shaped glass paste beads manufactured in the Frattesina workshops, which could have

V.3b

Brončana situla s prikazom pomorske bitke iz grobnice na Nezakciju, istražene 1981.:b) situla **Bronze situla** with the depiction of a maritime battle from the grave vault from Nesactium, explored in 1981.: b) situla (fotografija / photo by: A. Klarić)



**V.3c**

Brončana situla s prikazom pomorske bitke iz grobnice na Nezakciju, istražene 1981.: c) prikazi detalja na situli

Bronze situla with the depiction of a maritime battle from the grave vault from Nesactium, explored in 1981: c) view of the details on the situla (crtež / drawing by: Kristina Mihovilić, Bernhard Hänsel)

Alumiereea, i brončana fibula tipa „*serpegiante*“ sa spiralnom nogom, iz gradine Gradac-Turan iznad Koromačna. Rasprostranjenost ovog tipa fibula determinirana je jednim od pomorskih putova između dvije obale Jadrana, koji je u sljedećim stoljećima bio posebno intenzivno korišten u razmjenama.

O važnosti Histra na moru slikovito kazuje prikaz na situli iz Nezakcija (Sl.V.3a-c) (oko 500. g. pr. Kr.), a nešto kasnije o tome svjedoče pisani antički izvori koji spominju njihove brodove, zvane *serilije* (Verije Flak u Festu, *De Verborum significatu*, 508, 33 i Pavao Dijakon), kao i gusarsku aktivnost na Jadranu, zajedno s Liburnima (Tit Livije, 10, 2, 4)¹.

Konačno, nalaz plovila iz Zambratije možda potvrđuje dugu tradiciju načina gradnje i pomorstva stanovnika istarskog poluotoka.

been transported by sailing along the coast, but also straight across the Adriatic.

Istria is located on one of the amber routes, and hence amber of Baltic origin was a common grave good as early as the Bronze Age. It has been found with skeletons buried under stone mounds, as well as in graves located by the entrances to Bronze Age hillforts (Buršić-Matijašić 1989-1990; Mihovilić *et al.* 2011. During the Iron Age it almost entirely disappears, although perhaps it was burnt on the pyre along with the deceased.

The connections between Istria and the central and southern areas of the Apennine peninsula as early as the 10th century BCE are shown, for example, by a hut-shaped burial urn (*a capanna*) from grave VI/28 at Nesactium with parallels in cemeteries at Rome and Allumiere, and a bronze fibula of the *serpeggiante* type with a spiral foot from the Gradac-Turan hillfort above Koromačno. The distribution of this type of fibula marks one of the maritime routes between the two coasts of the Adriatic, which was particularly intensively utilized in the following centuries.

The importance of the Histri at sea is vividly illustrated by the depiction on the situla from Nesactium (Fig. V.3a-c) (c. 500 BCE) (Mihovilić 2004, 2013b, 245-247, fig. 165), and somewhat later written Roman sources also mention their ships, called *serilia* (Verrius Flaccus in Festus, *De Verborum significatu*, 508, 33 and in Paul the Deacon) as well as their pirate activities in the Adriatic, together with the Liburni (Livy, 10, 2, 4)¹.

In conclusion, the boat discovered in Zambratija Cove might confirm a long tradition of shipbuilding and voyaging among the inhabitants of the Istrian peninsula.

1 Prijevodi izvora u Križman, 1979.

1 Translations of the sources in Križman 1979.

Brod Zambratija u kontekstu drevnih tradicija šivanih brodova na Mediteranu

The Zambratija boat in the context of ancient Mediterranean sewn-boat traditions

Giulia Boetto, Patrice Pomey

Postojanje drevnih šivanih brodova na Mediteranu odavno je prepoznato zahvaljujući brojnim dobro dokumentiranim tekstualnim dokazima koji se izravno odnose na tehniku gradnje šivanjem (Casson 1963; 1971; Pomey 1981; 1985). Uz tekstualne izvore postoje i ikonografski podaci koji izgledno potvrđuju korištenje ove tehnike na Mediteranu od prapovijesti, tj. od brončanog doba (Bonino 1985; Basch 1987). S druge strane, u Egiptu je ova tehnika dobro posvjedočena na nekim brodovima još od faraonskog doba, uključujući poznati Keopsov brod (Landström 1970; Lipke 1984; Ward 2000; Pomey 2012b). Iako je ova brodograditeljska tradicija temeljena na poprečnom povezivanju, ona je jedinstvena i pojavljuje se isključivo u starom Egiptu te nema paralela na Mediteranu (Marlier 2005; 2007, 17, Sl. 9; Pomey 1997, 200; 2011a).

Od kraja šezdesetih do sredine osamdesetih godina, pronalaskom brodova građenih tehnikom šivanja kao i

The existence of ancient Mediterranean sewn boats has long been recognized thanks to numerous well-attested examples of textual evidence referring directly to sewn assembly techniques (Casson 1963, 1971; Pomey 1981, 1985). Supporting this literary evidence, iconographical data seems to confirm the use of this technique in the Mediterranean in very ancient times, dating back to the Bronze Age (Bonino 1985; Basch 1987). This technique was also used in the shipbuilding of the Pharaonic era in Egypt (Landström 1970; Lipke 1984; Ward 2000; Pomey 2012b), but the Egyptian tradition, based on transversal lashings or punctual ligatures, is quite specific and has no Mediterranean parallels (Pomey 1997, 200, 2011a; Marlier 2005, 2007, 17, fig. 9).

Since the end of the sixties until the mid eighties, the discovery of ancient wrecks of sewn-plank boats, or the reinterpretation of known remains, revealed the extent of the use of sewing and lashing techniques

njihovom reinterpetacijom, postupno je uočena važnost fenomena korištenja šivanja i vezivanja u mediteranskoj brodogradnji (Pomey 1985)¹. Ova otkrića navela su istraživače da na prvom kongresu „Sewn Plank Boats“, koji je održan u Greenwichu 1984. godine, ponovno razmotre problematiku šivanih brodova (McGrail, Kentley 1985). Slijedom toga došlo je do reinterpetacije nekih važnih antičkih tekstova, npr. o konstrukciji Odisejeva broda (Homer, *Odiseja*, 5, 244-257), koji je vjerojatno također bio šivan (Mark 1991, 1996, 2005; Tchernia 2001), suprotno interpretaciji L. Cassona (Casson 1964, 1971, 217-219, 1992) koji je predlagao teoriju po kojoj je brod bio izrađen tehnikom utora i jezičaca.

Godine 1993., otkrićem arhajskih grčkih brodova na trgu Jules-Verne (Marseille, Francuska, datiranih na kraj 6. st. pr. Kr.), nazvanih Jules-Verne 7 i 9, potvrđeno je postojanje izvorno mediteranske tehnike gradnje brodova šivanjem, koja je otad potvrđena i na nekoliko drugih lokaliteta, omogućavajući razumijevanje evolucije ove tehnike u kontekstu grčke tradicije šivanih brodova (Pomey 1995, 1997, 2010). U drugoj polovici devedesetih godina, C. Beltrame započeo je dugotrajan projekt katalogizacije novih, ali i starih dotad neobjavljenih podataka o šivanim brodovima na sjeverozapadnom Jadranu, obrađujući razvoj, dugotrajnost i rasprostranjenost tehnike šivanja brodova na ovom području (Beltrame 1996, 2000, 2001, 2002a, 2002b; Beltrame, Gaddi 2013).

U isto je vrijeme I. Negueruela istraživao brodove Mazarrón 1 i 2 (Murcia, Španjolska). Prva razmatranja, koja su ukazala da se radi o feničkim brodovima (Negueruela *et al.* 1995; Negueruela, Ortiz 2004; Negueruela 2000, 2005), pružila su dokaz o još jednoj tehnici gradnje šivanjem, prisutnoj na iberskoj obali (Pomey 2012a; De Juan 2014). Ovi brodovi su tada datirani u drugu polovicu 7. st. pr. Kr., dok se u novije vrijeme datiraju na početak 6. st. pr. Kr. (De Juan 2014, 30).

Upotreba tehnike šivanja i vezivanja pri izgradnji brodova postala je široko prepoznata u mediteranskoj brodogradnji (McGrail 2001, 134-138; Marlier 2005; Pomey 1997, 2010; Polzer 2010, 2011, 364-368).

Sve veći broj pronađenih brodova svjedoči o korištenju tehnika šivanja i vezivanja u različitim povijesnim i kulturološkim kontekstima. Recentno je objavljena sinteza koja ukazuje na postojanje nekoliko različitih mediteranskih tradicija gradnje šivanjem te rasprostranjenost i važnost ove tehnike. Ovaj prilog predstavlja smanjenu verziju tog članka, kako bi se brod Zambratija mogao smjestiti u kontekst mediteranske tradicije šivanih brodova (Pomey, Boetto 2019) (Sl. V.4, V.5).

in Mediterranean shipbuilding (Pomey 1985)¹. These discoveries encouraged scholars to reconsider this topic at the seminal conference *Sewn Plank Boats* held in Greenwich in 1984 (McGrail, Kentley 1985). Consequently, some important ancient texts were re-interpreted, such as the narrative of the construction of Odysseus' boat (Homer, *Odyssey*, 5, 244-257), which might have been a sewn boat (Mark 1991, 1996, 2005; Tchernia 2001), contrary to the interpretation previously proposed by L. Casson (Casson 1964, 1971, 217-219, 1992) who considered that the boat was built with mortise-and-tenon joints.

In 1993 the discovery of two Archaic Greek wrecks in Place Jules-Verne, Jules-Verne 7 and 9 (Marseilles, France, end of the 6th century BCE), has confirmed the existence of a genuine Mediterranean sewn-plank-boat tradition, well attested by several other wrecks, and has allowed us to comprehend its evolution in the context of the Greek tradition of sewing ships (Pomey 1995, 1997, 2010). In the second half of the nineties, C. Beltrame started a long-term project to collate new and known but unpublished data on the sewn wrecks of the Northwestern Adriatic, revealing the early development, the persistence, and the widespread use of the sewing technique in this area (Beltrame 1996, 2000, 2001, 2002a, 2002b; Beltrame, Gaddi 2013).

At the same time, I. Negueruela excavated the Mazarrón 1 and 2 wrecks (Murcia, Spain). First considerations, which indicated that these were Phoenician ships (Negueruela *et al.* 1995; Negueruela, Ortiz 2004; Negueruela 2000, 2005), provided evidence of another sewing tradition on the Iberic coast (Pomey 2012a; De Juan 2014). These wrecks were initially dated to the second half of the 7th century BCE, but, recently, a new very early 6th century BCE date has been suggested (De Juan 2014, 30).

The widespread use of sewing and lashing technique in Mediterranean shipbuilding is now generally recognized (McGrail 2001, 134-138; Marlier 2005; Pomey 1997, 2010; Polzer 2010, 2011, 364-368).

Finally, an increasing number of wrecks are being discovered that provide evidence of sewing and lashing techniques in a variety of historical and cultural contexts. Recently, we published a synthesis (Pomey, Boetto 2019) showing the existence of various original Mediterranean traditions and the widespread use of this technique. This chapter repropose a reduced version of this article to situate the Zambratija sewn boat within the Mediterranean sewn-boat traditions (Figs V.4, V.5).

¹ Brodolomi su: Cervia (Ravenna, Italija, 7. st., Bonino 1968, 1971) i Pomposa (Ferrara, Italija, vjerojatno 11. st., Bonino 1968, 1971); Zaton 1 i 2 (Nin, Hrvatska, 1. st., Brusić 1968; Brusić, Domjan 1985); Lipe (Slovenija, otkriven 1890, Müllner 1892, ponovno istražen od Salemke 1973); Bon-Porté 1 (Francuska, druga polovica 6. st., otkriven 1976, Joncheray 1976, reinterpetiran od Pomey 1981); Comacchio (Ferrara, Italija, 1. st. pr. Kr., Boccaccini *et al.* 1983; Bonino 1985); Giglio (Giglio Island, toskanski arhipelag, Italija, 580 god. pr. Kr., Bound 1985).

¹ The wrecks are: Cervia (Ravenna, Italy, 7th c. CE, Bonino 1968, 1971) and Pomposa (Ferrara, Italy, possibly 11th c. CE, Bonino 1968, 1971); Zaton 1 and 2 (Nin, Croatia, 1st c. CE, Brusić 1968; Brusić, Domjan 1985); Lipe (Slovenija, discovered in 1890, Müllner 1892, reconsidered by Salemke 1973); Bon-Porté 1 (France, second half of the 6th c. BCE, discovered in 1976, Joncheray 1976, and interpreted by Pomey 1981); Comacchio (Ferrara, Italy, 1st c. BCE, Boccaccini *et al.* 1983; Bonino 1985), Giglio (Giglio Island, Tuscan archipelago, Italy, 580 BCE, Bound 1985).



Jadranska tradicija

Brod Zambratija je izuzetno važan arheološki nalaz koji osvjetljava brodograditeljsku tehnologiju na prijelazu iz kasnog brončanog u željezno doba na prostoru sjevernog Jadrana. Zahvaljujući njegovim posebnim arhitektonskim karakteristikama i ranoj dataciji, ovaj šivani brod nema analogija ne samo na Mediteranu, nego i na Jadranu, koji predstavlja geografsko područje na kojem je tehnika šivanja i vezivanja preživjela i u rimskom te post-rimskom razdoblju.

Brod Zambratija je tehnološki derivat izveden iz monoksila, primitivnog oblika plovila, što dokazuje kobilični element oblikovan od brijestovog trupca. Iako još nije sigurno je li brijestov trupac bio prvo proširen, činjenica da su vojevi spojeni sistemom uzdužnog šivanja, kao i

The Adriatic traditions

The Zambratija boat is an extremely important archaeological find that sheds light on the shipbuilding technology of the Late Bronze Age/Early Iron Age in the northern Adriatic Sea. Due to its specific architectural features and its early date, this sewn boat is without parallels, not only in the Mediterranean but also in the Adriatic, which is one of the geographic areas where sewing and lashing techniques survived in the Roman and post Roman periods.

The Zambratija boat is a technological derivation of a logboat, a primitive vessel type, as evidenced by the keel-like timber that is shaped from an elm trunk. Although it is not yet certain if the elm trunk was first expanded, the strakes assembled with a system of



V.4

Brodolomi na Mediteranu koji se spominju u tekstu.

Šivani brodovi: 1-27, šivani brodovi sa sjevernog Jadrana; 28, Lipe; 29, Vrhnika 2; 30, Mazarrón 1; 31, Mazarrón 2; 32, Golo; 33, Binisafüller; 34, Bon Porté; 35, Giglio; 36, Jules-Verne 9; 37, Pabuç Burnu; 38, Cala Sant Vicenç; 39, Jules-Verne 7; 40, Villeneuve-Bargemon 1/César 1; 41, Grand-Ribaud F; 42, Gela 1; 43, Gela 2; 44, Ma'agan Mikhael; 45, Kyrenia; 46, Ereğli E; 47, Cap Béar; 48, La Tour Fondue; 49, Cavalière; 50, La Roche-Fouras; 51, Mèdes 6; 52, Dramont C; 53, Palamos; 54, Plane 1; 55, Barthélémy B; 56, Jeaume-Garde B; 57, Perduto 1; 58, Cap del Vol; 59, Saintes-Maries 2; 60, Saintes-Maries 24; 61, Baie de l'Amitié; 62, Cala Cativa 1; 63, Port-Vendres 3; 64, Port La Nautique.

Ostali brodolomi: A, Pisa C; B, Vrhnika 1; C, Sinja Gorica; D, Kamensko; E, Sisak; F, Kušjak; G, Uluburun; H, Cape Gelidonya.

The ancient Mediterranean shipwrecks cited in the text.

The ancient sewn boats: 1-27, sewn boats from the Northern Adriatic zone; 28, Lipe; 29, Vrhnika 2; 30, Mazarrón 1; 31, Mazarrón 2; 32, Golo; 33, Binisafüller; 34, Bon Porté; 35, Giglio; 36, Jules-Verne 9; 37, Pabuç Burnu; 38, Cala Sant Vicenç; 39, Jules-Verne 7; 40, Villeneuve-Bargemon 1/César 1; 41, Grand-Ribaud F; 42, Gela 1; 43, Gela 2; 44, Ma'agan Mikhael; 45, Kyrenia; 46, Ereğli E; 47, Cap Béar; 48, La Tour Fondue; 49, Cavalière; 50, La Roche-Fouras; 51, Mèdes 6; 52, Dramont C; 53, Palamos; 54, Plane 1; 55, Barthélémy B; 56, Jeaume-Garde B; 57, Perduto 1; 58, Cap del Vol; 59, Saintes-Maries 2; 60, Saintes-Maries 24; 61, Baie de l'Amitié; 62, Cala Cativa 1; 63, Port-Vendres 3; 64, Port La Nautique.

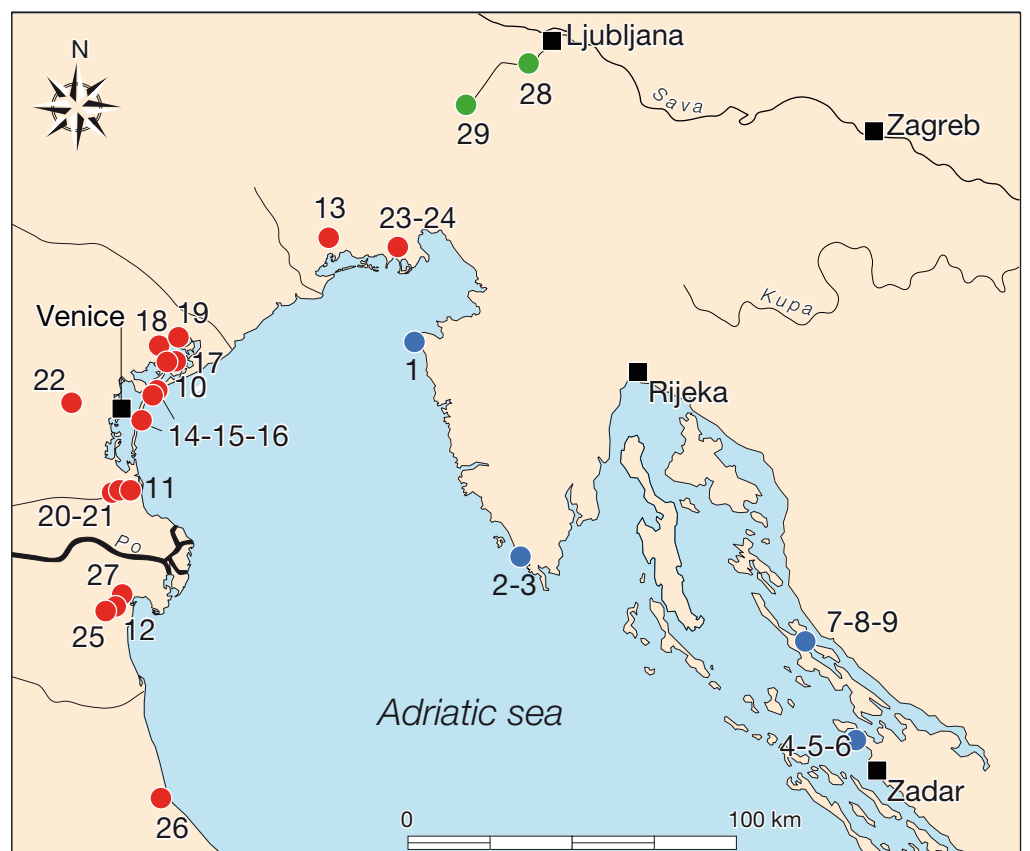
The other shipwrecks: A, Pisa C; B, Vrhnika 1; C, Sinja Gorica; D, Kamensko; E, Sisak; F, Kušjak; G, Uluburun; H, Cape Gelidonya. (crtež / drawing by V. Dumas, G. Boetto, P. Pomey)

V.5

Šivani brodovi s područja sjevernog Jadrana (u plavoj i crvenoj boji) te s područja dunavskog sliva (u zelenoj boji). U plavoj boji, sjeveroistočna jadranska tradicija ili Histro-liburnska tradicija: 1, Zambratija; 2, Pula 1; 3, Pula 2; 4, Zaton 1; 5, Zaton 2; 6, Zaton 3; 7, Caska 1; 8, Caska 3; 9, Caska 4. U crvenoj boji, sjeverno jadranska i sjeverozapadna jadranska tradicija: 10, Barena del Vigno; 11, Cavanella d'Adige; 12, Comacchio; 13, Stella 1; 14, Lido di Venezia 1; 15, Lido di Venezia 2; 16, Lido di Venezia 3; 17, S. Francesco del Deserto; 18, Marcon; 19, Meolo 1; 20, Corte Cavanella 1; 21, Corte Cavanella 2; 22, Padua; 23, Aquileia 1; 24, Aquileia 2; 25, Santa Maria in Padovetere; 26, Cervia; 27, Pomposa. U zelenoj boji, kontinentalna tradicija dunavskog sliva: 28, Lipe; 29, Vrhnika 2

Ancient Sewn Boats from the Northern Adriatic zone (blue and red) and from the Danube river basin (green). In blue, the north-eastern Adriatic tradition or Istro-Liburnian tradition: 1, Zambratija; 2, Pula 1; 3, Pula 2; 4, Zaton 1; 5, Zaton 2; 6, Zaton 3; 7, Caska 1; 8, Caska 3; 9, Caska 4. In red, the northern and north-western Adriatic tradition: 10, Barena del Vigno; 11, Cavanella d'Adige; 12, Comacchio; 13, Stella 1; 14, Lido di Venezia 1; 15, Lido di Venezia 2; 16, Lido di Venezia 3; 17, S. Francesco del Deserto; 18, Marcon; 19, Meolo 1; 20, Corte Cavanella 1; 21, Corte Cavanella 2; 22, Padua; 23, Aquileia 1; 24, Aquileia 2; 25, Santa Maria in Padovetere; 26, Cervia; 27, Pomposa. In green, the continental tradition of the Danube River basin: 28, Lipe; 29, Vrhnika 2.

(crtež / drawing by V. Dumas, G. Boetto, P. Pomey).



vodonepropusni sustav te oblikovane rebrenice vezane za oplatu pružaju detaljan uvid u dobro razvijenu tehnologiju obrade drva koja je u to vrijeme bila u upotrebi.

Štoviše, brod Zambratija predstavlja jedini dokaz o postojanju šivanih plovila u Istri u tom ranom periodu i može se koristiti kao odrednica za brodograditeljsku tradiciju koju bismo uvjetno mogli nazvati proto-histarskom. Također, treba istaknuti da latinski izvori potvrđuju dugovječnost i snagu histarske i liburnske tradicije šivanih brodova² te da je arheologija pružila dokaze o opstanaku tehnike šivanja brodova na sjevernom Jadranu kroz rimsko vrijeme i vjerojatno sve do ranog srednjeg vijeka.

Tehnika šivanja potvrđena je i u kontinentalnom dijelu (rijeka Ljubljanica, Slovenija), a s obzirom da nije u izravnoj vezi s Jadranskim morem, predstavlja dokaz o značajnom prenošenju brodograditeljskih tehnika.

Zbog navedenih razlika u uzorku šivanja i vrsti plovila, G. Boetto (Boetto, Rousse 2011, 2012) predložila je nazive za dvije izrazite tradicije šivanih brodova na Jadranu. Prva tradicija, koja je definirana kao „rimsko-ilirska“³, obuhvaća grupu brodova iz Istre i Dalmacije, dok drugoj tradiciji, definiranoj kao „rimsko-padanskoj“, pripadaju brodovi otkriveni u Raveni, na području delte rijeke Po pa do zaljeva kod Akvileje, tj. na području obalnih, lagunarnih i unutarnjih voda današnjih regija Emilia-Romagna, Veneto i Friuli Venezia Giulia.

Ipak, zbog problema koji su se pojavili u upotrebi termina „rimsko-ilirski“ i „rimsko-padanski“, šira geografska odrednica se čini prikladnijom, budući da je u ovoj fazi istraživanja određenu tradiciju šivanja teško pripisati pojedinoj geografskoj, sociokulturnoj i etničkoj skupini (Sl. V.4, V.5).

Sjeveroistočna jadranska tradicija

Ova tradicija datira u rimsko razdoblje, a Z. Brusić nazvao ju je liburnskom na osnovi otkrića dvaju šivanih brodova u uvali Zaton, nekadašnjoj luci antičke Aenone, današnjeg Nina (1. st., Brusić 1986, 1995; Brusić, Domjan 1985). Posljednjih godina još je šest šivanih brodova pronađeno na području sjeverne Dalmacije, u Zatonu⁴ i u Caski na otoku Pagu⁵ te u Istri u Puli (Sl. V.4-V.8)⁶.

2 Posebno u tekstovima, kod Varona (kojeg citira *Aulus Gellius*, XVII, 3, 4) i Verija Flaka (u Festu, 508, 33), koji se izravno odnose na termin *serilia naves* naroda Histra i Liburna.

3 Ovaj naziv nije fokusiran na etničko značenje Ilira već ima naglasak na zemljopisne granice Ilirika kako ga je definirao Strabon (*Geografija*, VII, 5). Time je obuhvaćen teritorij od rijeke Dunav do granice provincije Makedonije s cijelom istočnom obalom Jadranskog mora, od sjeveroistočnog dijela Istre i Dalmacije do južne Albanije.

4 Zaton 3 brod, 1. st., Gluščević 2004.

5 Caska 1, 3 i 4 brodovi, 1. st., Čelhar 2008; Radić Rossi, Boetto 2010, 2011, 2013; Boetto 2016; Boetto, Rousse 2011, 2012; Boetto, Radić Rossi 2014, 2017; Ruff 2017.

6 Pula 1 i 2 brodovi, kraj 2. st. - početak 3. st., Uhač, 2014, 351-353; Boetto *et al.* 2014, 2017.

longitudinal sewing, the waterproofing method, and the shaped floor-timbers lashed to the planking give us a detailed picture of a well-developed woodworking technology already in use for boatbuilding at that time. Nevertheless, the Zambratija boat stands alone as proof of the existence of sewn-plank vessels in Istria at this early period. The boat can be used to define a native shipbuilding tradition that we could tentatively term Proto-Histrian. It is also interesting to note that Latin texts attest the longevity and the strength of the Istrian and Liburnian traditions of sewn boats² and that archaeology has provided proof of the survival of the sewing technique in the northern Adriatic in Roman times and possibly up to the Early Middle Ages.

The sewn-plank technique is also found in a continental area (Ljubljanica River, Slovenia) that is not in direct contact with the Adriatic Sea, which is evidence of significant transfers of shipbuilding techniques.

Due to evident differences in the sewing patterns and types of vessels, G. Boetto (Boetto, Rousse 2011, 2012) has tentatively proposed the definition of two distinct sewn-boat traditions in the Adriatic Sea. The first, defined as “Romano-Illyrian”³, includes the wrecks discovered in Istria and Dalmatia; the second, defined as “Roman-Paduan”, includes the wrecks discovered from Ravenna, through the Po River delta, to the gulf of Aquilea in the coastal, lagoon and inland waters of the present Emilia-Romagna, Veneto, and Friuli Venezia Giulia regions of Italy. Nevertheless, due to issues raised by the use of the terms “Romano-Illyrians” and “Romano-Paduan”, a more general geographical definition seems appropriate as, at this stage of research, it is difficult to ascribe each sewn-boat tradition to a specific geographic, socio-cultural, and ethnic group (Figs V.4, V.5).

The north-eastern Adriatic tradition

This tradition is dated to the Roman period and has been defined as Liburnian by Z. Brusić following the discovery of two sewn-boats in Zaton, the harbour of *Aenona*, today known as Nin (1st century CE, Brusić 1986, 1995; Brusić, Domjan 1985). In recent years, six other sewn-boat wrecks have been discovered in Northern Dalmatia, at Zaton⁴ and Caska on the island of Pag⁵, and in Istria in Pula (Figs V.4 - V.8)⁶.

2 In particular, Varro (quoted by *Aulus Gellius*, XVII, 3, 4) and Verrius Flaccus (in Festus, 508, 33) explicitly refer to the sewn-boats, *serilia*, of the Istrians and Liburnians.

3 This appellation was not focusing on the ethnic notion of Illyrians, but on the geographic dimension of Illyria as defined by Strabo (*Geography*, VII, 5). That means a territory going from the Danube to the border of the province of Macedonia and comprehensive of the whole eastern coast of the Adriatic, from the north-eastern part of Istria, Dalmatia to southern Albania.

4 Zaton 3 wreck, 1st c. CE: Gluščević 2004.

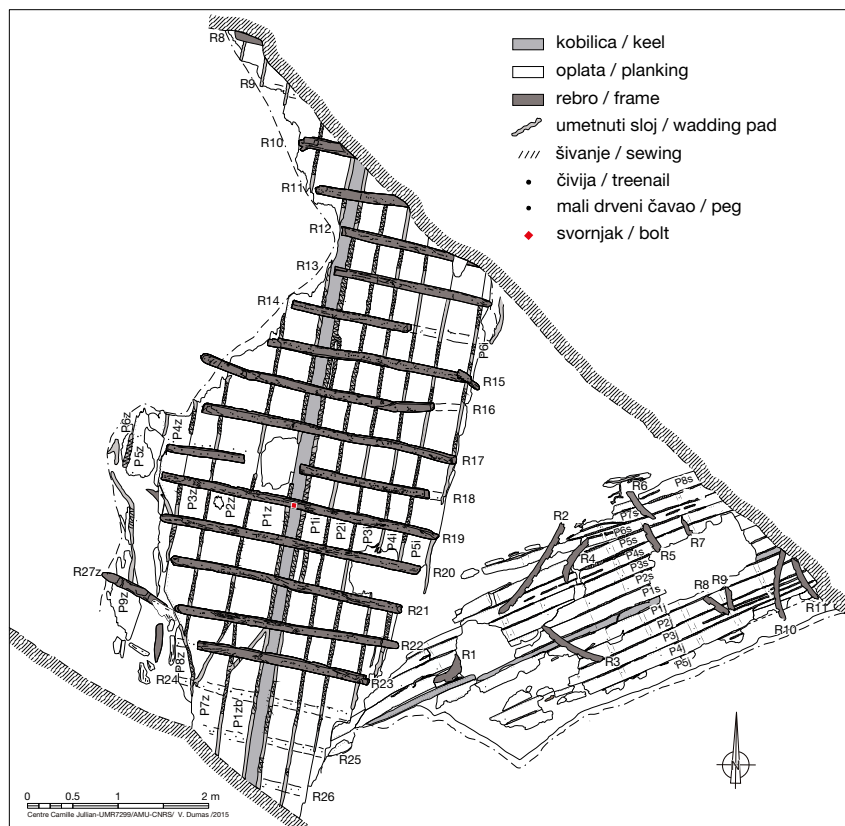
5 Caska 1, 3 and 4 wrecks, 1st c. CE: Čelhar 2008; Radić Rossi, Boetto 2010, 2011, 2013; Boetto 2016; Boetto, Rousse 2011, 2012; Boetto, Radić Rossi 2014, 2017; Ruff 2017.

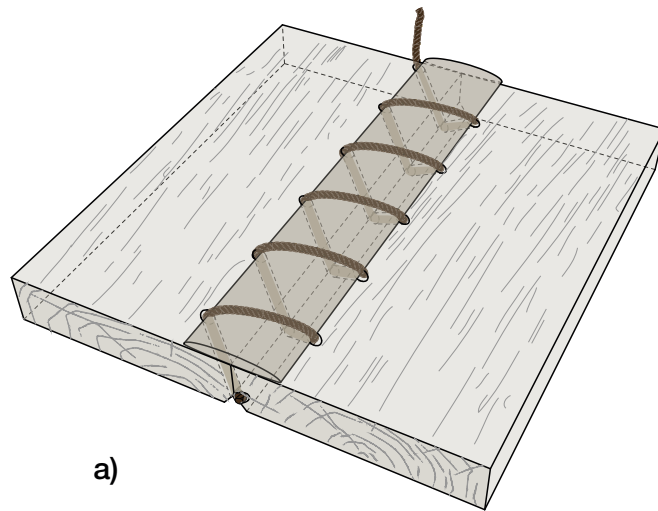
6 Pula 1 and 2 wrecks, end of the 2nd-beginning of the 3rd c. CE: Uhač 2014, 351-333; Boetto *et al.* 2014, 2017.



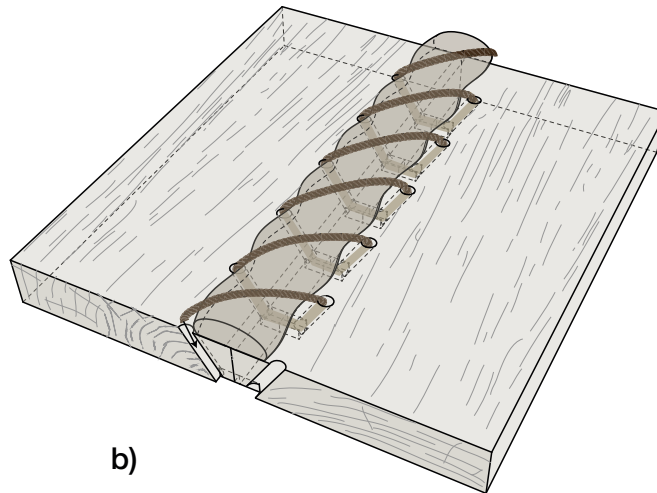
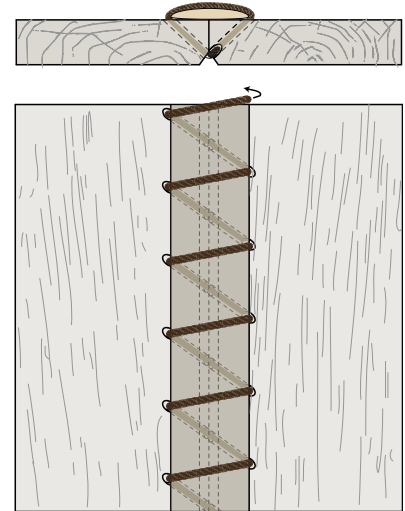
V.6
Brodovi Pula 1 i Pula 2. Pogled na nalazište s brodskim konstrukcijama tijekom istraživanja 2013.
Pula 1 and Pula 2 wrecks. View of the remains during the 2013 excavation
 (fotografija / photo by: T. Brajković)

V.7
Brodovi Pula 1 i Pula 2
Pula wrecks Pula 1 i Pula 2
 (crtež / drawing by: V. Dumas)

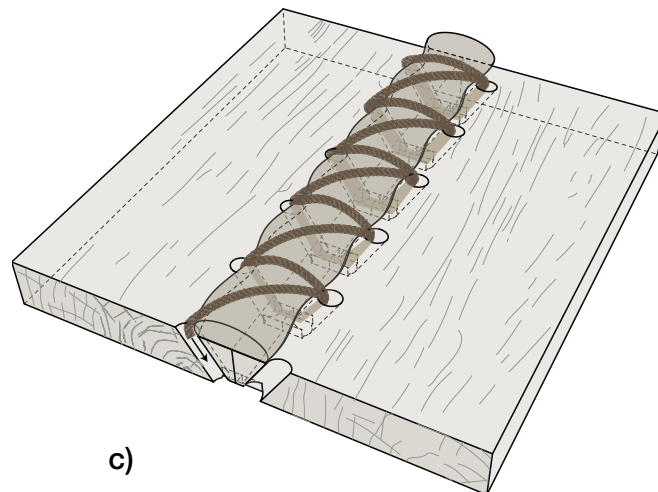
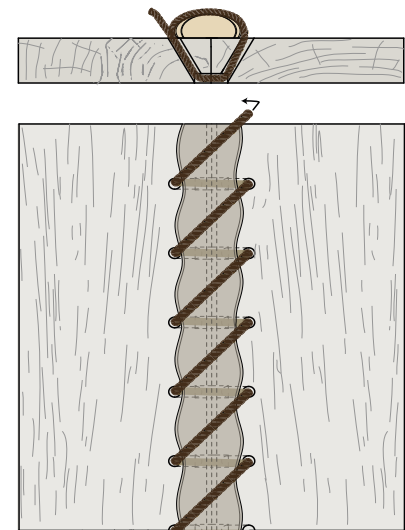




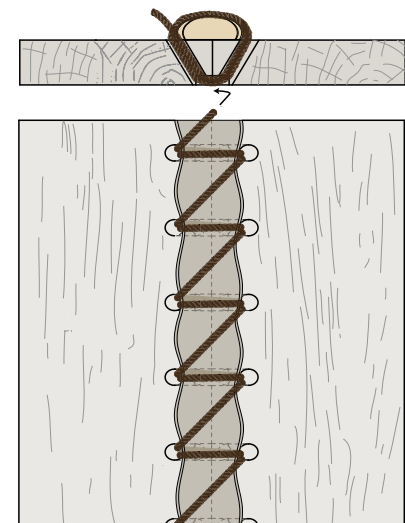
a)



b)



c)



V.8
Aksonometrijski prikaz šivanja: a) Zambratija; b) Pula 2; c) Pula 1
Axonometric illustrations of the sewing systems: a) the Zambratija wreck; b) Pula 2; and c) Pula 1
(crtež / drawing by: P. Poveda)

V.9

Pula 2, detalj šivanja na vanjskoj strani trupa

Pula 2, detail view of the sewing system on the outer face of the hull (fotografija / photo by: T. Brajković)



V.9



V.10

V.10

Pula 2, detalj spajanja šivanjem

Pula 2, detail view of the sewing system (fotografija / photo by: T. Brajković)

V.11

Pula 1, detalj spajanja šivanjem

Pula 1, detail view of the sewing system (fotografija / photo by: T. Brajković)



V.11

V.12

Pula 1, detalj spajanja šivanjem

Pula 1, detail view of the sewing system (fotografija / photo by: T. Brajković)



V.12

Svi ovi brodovi imaju kobilicu, a oplata im je sastavljena od stično položenih vojeva. Metoda i proces izgradnje trupa temelje se na načelu „prvo ljuska“ te na uzdužnom, vojevno orijentiranom konceptu za forme broda. Svi su ovi brodovi strukturalno i tehnički vrlo slični, ali ipak pokazuju značajne razlike u dimenzijama i obliku, u sustavu propulzije te u vrsti drva, dok se sve te razlike mogu pripisati različitim tipovima brodova. Međutim, većina plovila koja pripadaju ovoj skupini su manja (9-10 metara dužine), vjerojatno s kombiniranim pogonom, a karakterizira ih vrlo jednostavan sustav šivanja oplata, koji se sastoji od rubnih šavova (uzorak ///) koji prolaze kroz rupe izbušene okomito na rubove platica (Sl. V.9, V.10). Mali drveni čavli zaptivaju rupe i šavove, a umetnuti sloj vlakana osigurava da su sljubnice vodonepropusne. Brod Pula 1, koji tipologijom pripada većem brodu na jedra, dužine barem 15-17 m, ima složeniji uzorak šivanja, s rubnim šavovima i preklopnim okretom (uzorak ////) (Sl. V.11, V.12). Rebra pravokutnog presjeka većinom su za oplatu učvršćena čivijama, a njihova je baza istesana iznad sljubnica tj. šavova (Sl. V.13). S druge strane, brod Caska 4 ima rebrenice koje su povezane s rebrenim nastavkom, a rebra su vezana za oplatu bez upotrebe čivija.

All these boats are keeled, and the planking is flush-laid. The construction principle used is based on a shell concept for the hull structure, and a longitudinal strake-oriented concept for their shape. The building process is shell first. They are structurally and technically very similar but they also have significant differences in terms of their dimensions and shape, propulsion systems, and the selection of wood used; differences that might be ascribed to diverse ship types. Nevertheless, the majority of the vessels belonging to this group are small (9-10 m in length), probably with mixed propulsion, and are characterized by a very simple sewing pattern for the planking seams made of over-edge stitches (//) through oblique stitch holes perpendicular to the edges of the planks (Figs V.9, V.10). Pegs lock the ligatures in place and a wadding pad assures the seam is watertight. Only Pula 1, which is a bigger sailing vessel, at least 15-17 m long, presents a more elaborate sewing pattern made of over-edge stitches with a clamping turn (///) (Figs V.11, V.12). The frames, rectangular in section, are predominantly treenailed to the planking, and their base is crenellated to pass over the stitching (Fig. V.13). Otherwise, Caska 4 has floor-timbers connected to in-line futtocks, and the frames are lashed to the planking without the use of treenails.



V.13
Pula 1, pogled na rebra obrađena iznad šivanja
Pula 1, view of the frame crenellated to pass over the sewing
 (fotografija / photo by: T. Brajković)

Sjeverozapadna i sjeverna jadranska tradicija

Na sjevernoj i sjeverozapadnoj obali Jadrana zastupljena je jaka tradicija šivanih brodova, i to od Ravene i delte rijeke Po do zaljeva Akvileje, tj. na području obalnih, lagunarnih i unutrašnjih voda današnjih regija Emilia-Romagna, Veneto i Friuli Venezia Giulia u Italiji (Sl. V.4, V.5). Najstariji dokazi o toj tradiciji potječu iz 6. st. pr. Kr.⁷, i iz republikanskog razdoblja (2. – 1. st. pr. Kr.)⁸, dok su mlađi primjerci brodovi Cervia (Ravenna, 7. st.)⁹ i Pomposa (Ferrara, 7. ili 11. st.)¹⁰.

Veći broj brodskih dijelova, datiranih između 1. i 3. stoljeća, otkriven je nakon što je bio izbačen na plažu ili nakon što je sekundarno upotrijebljen u nasipima

The north-western and northern Adriatic tradition

In the northern and north-western part of the Adriatic, there is another strong sewn-boat tradition in use from Ravenna, through the Po River delta, to the gulf of Aquilea in the coastal, lagoon and inland waters of the present Emilia-Romagna, Veneto, and Friuli Venezia Giulia regions of Italy (Figs V.4, V.5). The earliest remains date to the 6th century BCE,⁷ and then to the Republican period (2nd - 1st century BCE),⁸ while the most recent examples are the Cervia (Ravenna, 7th century CE)⁹ and Pomposa wrecks (Ferrara, 7th or 11th century CE)¹⁰.

A large number of boat timbers, dated between the 1st and the 3rd centuries CE, have been discovered washed up on the beach or reused in embankments in the Venice

7 Ulomak platice broda Barena del Vigno iz venecijanske lagune, Beltrame 2002a, 365.

8 Brod Cavanella d'Adige, Tiboni 2009, 2017.

9 Beltrame 2002a, 559, Sl. 10-11, 2009, 415.

10 Bonino 1968. O kasnosrednjovjekovnom datumu broda Pomposa raspravljao je C. Beltrame (2009, 415, Sl. 11) jer na brodolomu nisu pronađeni databilni nalazi, a obalna linija iz 11. stoljeća bila je postavljena daleko od mjesta nalazišta. Moguće je da su, zbog sličnih karakteristika između brodova Cervia i Pomposa, oba datirana u 7. stoljeće.

7 Plank fragment of Barena del Vigno, Venice lagoon: Beltrame 2002a, 365.

8 Cavanella d'Adige wreck: Tiboni 2009, 2017.

9 Beltrame 2002a, 559, fig. 10-11, 2009, 415.

10 Bonino 1968. The Early Medieval date for the Pomposa ship has been discussed by C. Beltrame (2009, 415, fig. 11) because no datable finds were associated to the wreck and the 11th century coastline has been situated far away from the site. It is possible that, due to the similar characteristics between the Cervia and Pomposa wrecks, they were both dated to the 7th century.



V.14

V.14

Brod Comacchio. Opći prikaz trupa nakon demontaže rebara (po Berti 1990, 25)

Comacchio shipwreck. General view of the hull after dismantling the frame for recovery (from Berti 1990, 25)



V.15

V.15

Brod Comacchio. Detalj šivanja (po Berti 1990, 30, fig. 4)

Comacchio shipwreck. Detail view of the sewing system (from Berti 1990: 30, fig. 4)

venecijanske lagune i okolice¹¹, u gradu Padovi¹² te u kanalu Anfora u Akvileji¹³.

Naposljetku, samo tri olupine su dobro očuvane i dopuštaju razumijevanje njihove arhitekture i funkcionalnosti. Brod Comacchio, koji datira na početak augustovskog razdoblja (kraj 1. st. pr. Kr.)¹⁴, ima kobiličnu platicu i odgovara 20-metarskom riječno-morskom plovilu (Sl. V.14, V.15). Brodovi Stella (rijeka Stella, početak 1. st.; Sl. V.16)¹⁵, Corte Cavanella 2 (Rovigo, kraj 1. st. ili početak 2. st.; Sl. V.17)¹⁶ i Santa Maria in Padovetere (Ferrara, 5. st.)¹⁷ su brodovi s ravnim dnom bez obrađenih uzvojnih

lagoon and its surroundings¹¹, in the city of Padua,¹² and in the Canale Anfora in Aquileia¹³.

Finally, only three wrecks are sufficiently well preserved to permit a reasonable understanding of their architectural and functional types. The wreck of Comacchio, dated to the beginning of the Augustan era (end of the 1st century BCE)¹⁴ has a plank-keel and corresponds to a 20 m-long fluvio-maritime vessel (Figs V.14, V.15). The Stella wreck (Stella River, beginning of the 1st century CE; Fig. V.16)¹⁵, the Corte Cavanella 2 wreck (Rovigo, end of the 1st or the beginning of the 2nd century CE; Fig. V.17)¹⁶, and the Santa Maria in Padovetere wreck (Ferrara, 5th century CE)¹⁷ are flat-bottom based

11 Brodovi Lido di Venezia 1, 2 i 3: 1. – 2. st., Beltrame 1996, 2000, 2001, 2002a, 2002b; Beltrame, Gaddi 2013, 302; Willis, Capulli, 2014, 2017, 2018; brod S. Francesco del Deserto: Capulli, Pellegrini 2010; Marcon brod: Beltrame, Gaddi 2013, 302; brod Meolo 1: Beltrame 2002a, 370-371.

12 2. st., Beltrame 2002, 366.

13 Brodovi Aquileia 1 iz 1. st. pr. Kr. i Aquileia 2 s kraja 2. st. na početak 3. st.: Beltrame 2002a, 358-359; Beltrame, Gaddi 2013.

14 Berti 1986; 1990.

15 Vitri *et al.* 2003; Castro, Capulli 2016.

16 Sličan takav brod je pronađen unutar rimskog naselja u Corte Cavanella u Loreo, ali nije izvađen; Beltrame 2000, 2002a.

17 Beltrame, Costa 2016.

11 Lido di Venezia 1, 2 and 3 wrecks: 1st-2nd c. CE, Beltrame 1996, 2000, 2001, 2002a, 2002b; Beltrame, Gaddi 2013, 302; Willis, Capulli, 2014, 2017, 2018; S. Francesco del Deserto wreck: Capulli, Pellegrini 2010; Marcon wreck: Beltrame, Gaddi 2013, 302; Meolo 1 wreck: Beltrame 2002a, 370-371.

12 2nd c. CE, Beltrame 2002, 366.

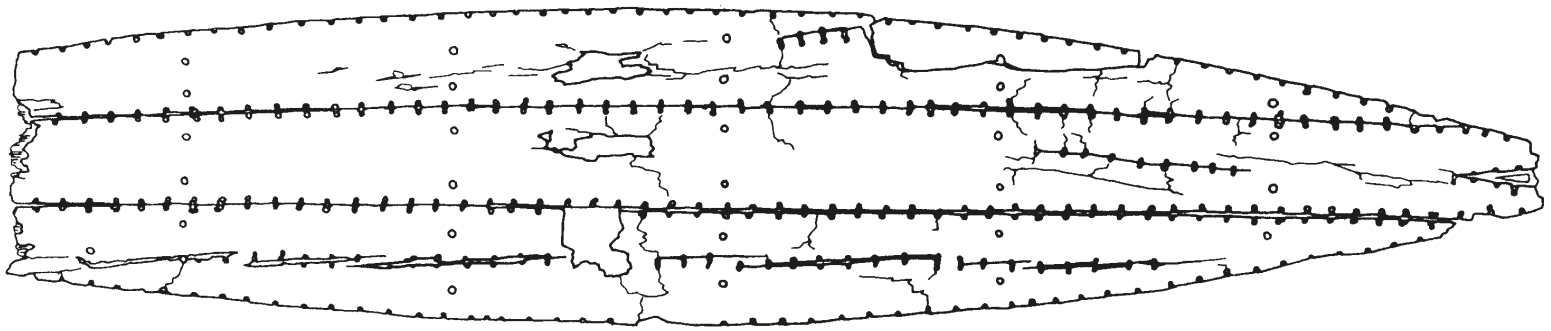
13 Aquileia 1, 1st c. CE, and Aquileia 2, end of the 2nd and the beginning of the 3rd c. CE: Beltrame 2002a, 358-359; Beltrame, Gaddi 2013.

14 Berti 1986, 1990.

15 Vitri *et al.* 2003; Castro, Capulli 2016.

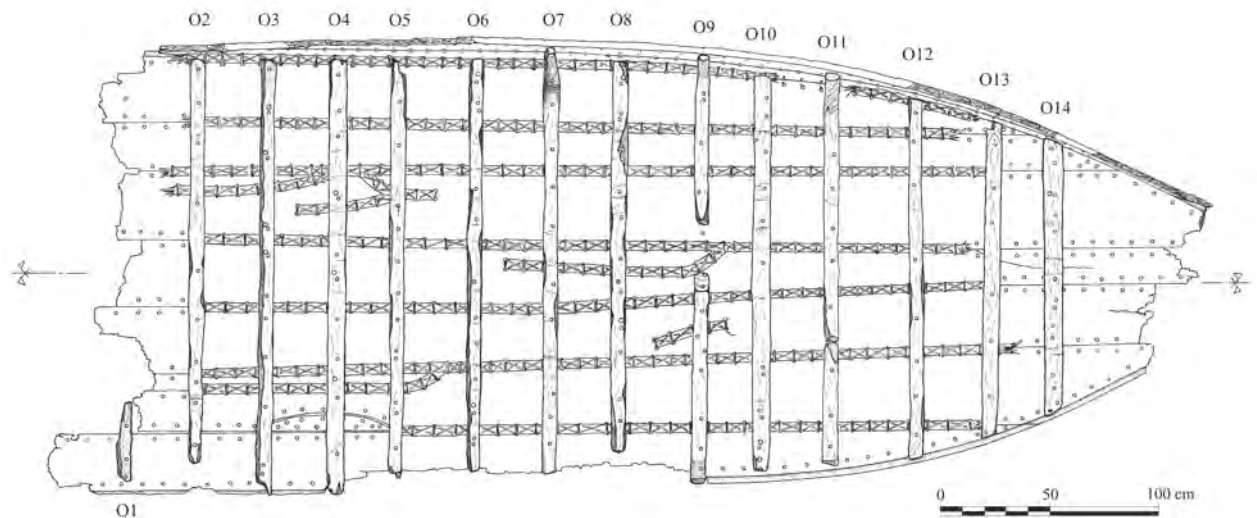
16 Another very similar wreck was also found in the Roman settlement at Corte Cavanella di Loreo but not recovered: Beltrame 2000, 2002a.

17 Beltrame, Costa 2016.



V.16
Brod Corte Cavanella 2. Plan vanjske oplata broda (crtež: G. Boetto, prema Beltrame 2002a, fig. 13)
Corte Cavanella 2 shipwreck. Plan of the outer face of the planking (drawing by: G. Boetto, after Beltrame 2002a, fig. 13)

V.17
Brod Stella 1 (crtež: K. Yamafune, iz Castro, Capulli 2016, 35, fig. 7)
Stella 1 shipwreck (drawing by: K. Yamafune, from Castro, Capulli 2016, 35, fig. 7)



platica¹⁸.

Nalazi ovih 18 brodova te ostaci šivanih dijelova brodova svjedoče o tradiciji brodogradnje šivanjem koju karakterizira uzorak križnog šivanja (tipa IXIXIX) oplata te prevladavanje trapezoidnih utora na kraju rupe pojednog šava.

Brod Comacchio poseban je po tome što je oplata sašivena do prve bokoštitnice, dok mu je gornji dio oplata izgrađen spojem utor i ježičac. Na brodu Aquileia 1 se čini da je uzorak šivanja bio rubni s preklapnim okretom (/I/I/I). Konačno, sva ova plovila su dobro prilagođena plovidbi u unutarnjim vodama ili riječno-morskoj i priobalnoj plovidbi.

vessels without carved bilge strakes¹⁸.

All of these eighteen wrecks and remains of sewn boats prove the extent of this shipbuilding tradition, which is characterized by a pattern of crossing stitches (IXIXIX type) for the plank seams and by the predominant presence of trapezoidal recesses at the end of each stitch hole.

The Comacchio ship has the particularity of a sewn bottom up to the first wale with the upper part of the planking fastened with mortise-and-tenon joints. In Aquileia 1, it seems that the sewing pattern used was the over-edge type with a clamping turn (/I/I/I). Finally, all of these crafts are well adapted to inland waters, or fluvio-maritime and coastal sailing.

18 Suprotno brodovima s kobličnom platicom koji su građeni na principu uzdužno orijentiranih vojeva po načelu „prvo ljuska“, brodovi s ravnim dnom su izgrađeni sukladno principu ravnog dna i procesu izgradnje u kojem su forma i struktura napravljene i organizirane oko prvo izgrađenog ravnog dna, koje može i ne mora imati izdubljeni uzvojni voj. Na ovim brodovima oplata je položena stično, osim na kasnoantičkom brodu Santa Maria in Padovetere, gdje su zadnji vojevi bokova građeni preklapno. Za različite koncepte, načela, metode konstrukcije i arhitektonske tipove vidi Pomey 2004a; Pomey, Rieth 2005, 29-33; Pomey *et al.* 2012, 2013.

18 On the contrary of the boats with a plank-keel, which are longitudinal strake-oriented and shell-first, the flat-bottomed boats are built according to a flat-bottom principle and process of construction in which the shape and the structure are given and organized around the flat-bottom laid down first with or without carved bilge plank (or carved transition strake). On these boats the planking is flush-laid with just one exception on the Late Roman Santa Maria in Padovetere wreck where the last strakes of the side are clinker built. About the different concepts of principle and method of construction and architectural types, see Pomey 2004a; Pomey, Rieth 2005, 29-33; Pomey *et al.* 2012, 2013.

Kontinentalna tradicija dunavskog porječja

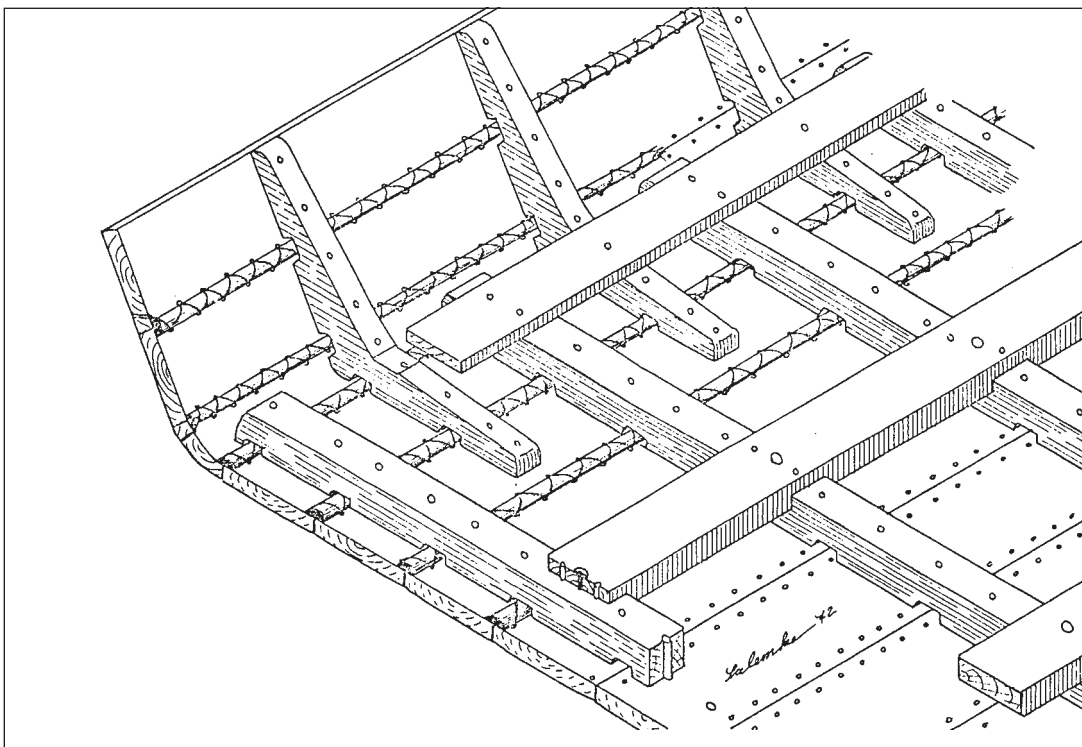
Teglenica Lipe, pronađena 1890. godine blizu današnjeg toka rijeke Ljubljanice u Sloveniji (Müllner 1892), pruža dokaze o još jednoj tradiciji šivanih brodova (Sl. V.5, V.18). Brod je nedavno reinterpreteran (Gaspari 2009) te je datiran u razdoblje između sredine 2. i sredine 1. st. pr. Kr. (Gaspari 2017, 141). Smješta se u okvir rimsko-keltske brodograditeljske tradicije koja pripada tradiciji s područja unutrašnjih voda jugoistočne Europe (Boetto, Rousse 2011, 2012). Brod Lipe pripada tipu velikih teretnih brodova ravnog dna, dug je 30 metara, a širok 4,8 metra. Nema kobilicu, ali ima izdubljenu uzvojniju platicu. Oplata je spojena šivanjem jednostavnim šavovima od biljnih vlakana koji prolaze kroz vertikalne rupe i čini se da tvore cik-cak uzorak (/1/1/).

Zbog sustava spajanja ravnog dna šivanjem, ovaj se brod prvotno nastojalo povezati s jadranskom tradicijom šivanih brodova budući da se u načinu šivanja oplata očituje jak utjecaj pomorskih tradicija brodogradnje jadranske regije (Gaspari 1998a, 1998b, 2009). Ovaj se utjecaj veže uz geografska obilježja tog prostora Slovenije, a koja je povijesno povezana s Tršćanskim zaljevom i Istrom te preko prijelaza u Julijske Alpe (Boetto, Rousse 2011, 2012; Gaspari 2017). Nadalje, područje plovidbe teglenice Lipe rijekom Ljubljanicom otvoreno je

The continental tradition of the Danube River basin

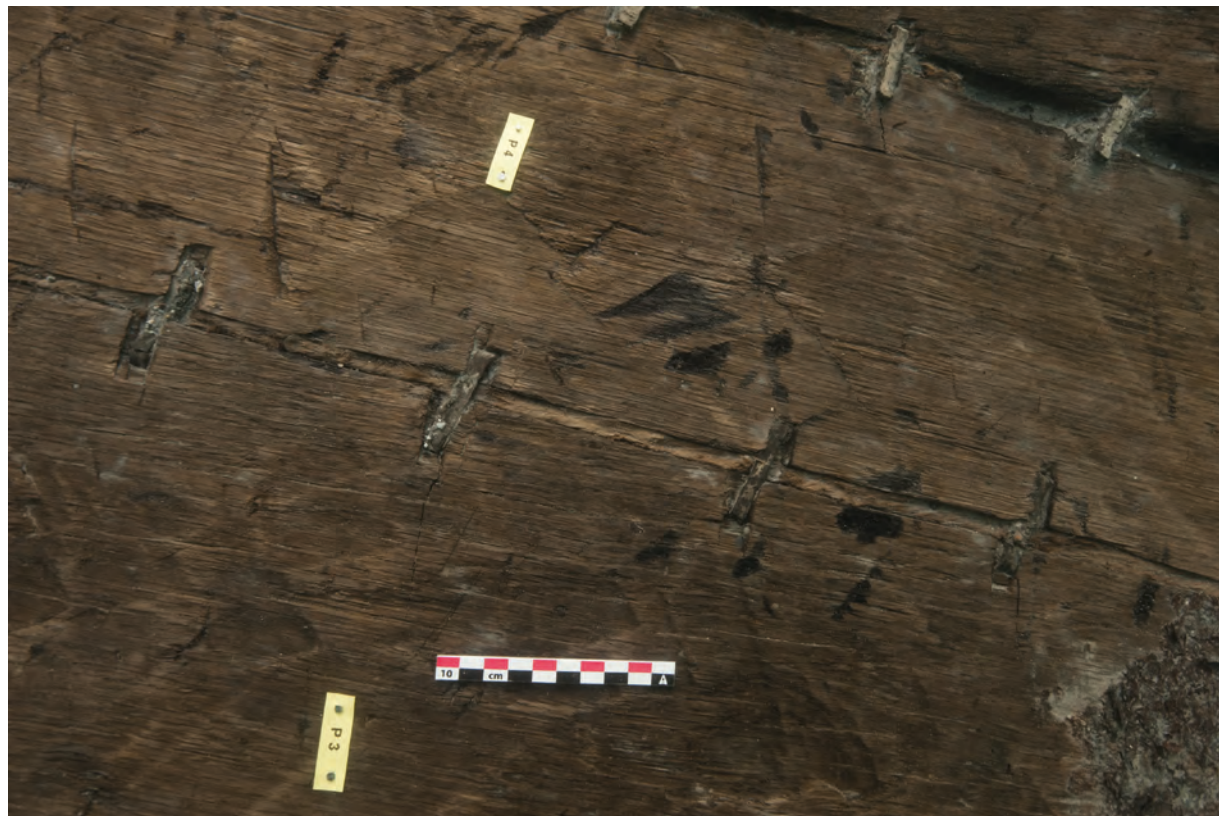
The Lipe barge, found in 1890 near the present-day Ljubljanica riverbed in Slovenia (Müllner 1892), offers evidence of another sewn-boat tradition (Figs V.5, V.18). The boat has been recently reinterpreted (Gaspari 2009), and dated between the mid 2nd and the mid 1st centuries BCE (Gaspari 2017, 141). It is now placed within the frame of the Romano-Celtic tradition of shipbuilding, belonging to a regional inland-waters tradition of South-Eastern Europe (Boetto, Rousse 2011, 2012). The Lipe wreck corresponds to a large flat-bottom river barge, 30 m long and 4.80 m wide, without a keel but with a carved bilge plank. The planking is sewn with simple vegetal stitches going through vertical holes and appears to be in a zigzag pattern (/1/1/).

As the flat bottom was sewn, the boat was first linked to the Adriatic sewn ship traditions: the sewn assemblage of the planking was interpreted as revealing the strong influence of maritime shipbuilding traditions of the Adriatic Sea (Gaspari 1998a, 1998b, 2009, 2017). This influence is linked to the particular geography of this part of Slovenia, which historically opened towards the Gulf of Trieste and Istria through the accessible passes of the Julian Alps (Boetto, Rousse 2011, 2012; Gaspari 2017). Moreover, the area in which the Lipe barge navigated on



V.18
Brod Lipe. Aksonometrijski prikaz trupa
Lipe wreck. Axonometry of the hull
(prema / from: Salemke 1973, 23)

V.19
 Brod Kamensko, detalj oplate s
 klanfama
 Kamensko wreck, detail view of
 the clamps
 (fotografija / photo by: L. Damelet)



prema rijeci Savi i hidrogeografskom porječju Dunava te jasno pripada dijelu jugoistočne Europe. Godine 2015. na Vrhniki je pronađen još jedan šivani brod (Vrhnika 2). Datiran je u 2. st. pr. Kr., čime je potvrđena tehnika šivanja na području rijeke Ljubljanice vjerojatno i prije vremena teglenice Lipe¹⁹. Sva ova otkrića šivanih brodova u Sloveniji nalaze se na spoju tri regionalne tradicije: kontinentalne tradicije Dunava te pomorske tradicije sjeveroistočnog i sjeverozapadnog Jadrana.

Također je važno naglasiti da dosad poznati šivani brodovi u gornjem slivu rijeke Ljubljanice tvore podgrupu brodova na području dunavske brodograditeljske tradicije. Brodovi s metalnim klanfama koje učvršćuju biljni materijal između platica, pripadaju drugoj regionalnoj podskupini brodova (Boetto, Rousse 2011, 188-190; 2012), što je potvrđeno otkrićima teglenice u Kušnjaku na Dunavu (2. st., Srbija, Bockius 2003), u Sinjoj Gorici na rijeci Ljubljanici (*terminus post quem*, godina 3. Slovenija, Erič *et al.* 2014; Čufar *et al.* 2014), u Sisku (2. i 3. st., Gaspari *et al.* 2006) i u Kamenskom kod Karlovca na

the Ljubljanica River opens towards the Sava River and the Danube hydrographical basin, and clearly belongs to the south-eastern region of Europe. In 2015, another sewn boat was discovered in Vrhnika (Vrhnika 2 wreck). Dated to the 2nd century BCE, this ship find confirms the use of the sewing technique in the Ljubljanica River, possibly at an earlier date than the Lipe barge¹⁹. All of these discoveries of sewn boats in Slovenia occur at the intersection of three regional traditions: the continental Danube, the maritime north-eastern Adriatic, and the north-western Adriatic.

It is important also to underline that the sewn boats now known only in the upper part of the Ljubljanica River form a sub group within the Danubian shipbuilding tradition. The vessels with metal clamps holding the vegetal luting in place between planks constitute another sub group (Boetto, Rousse 2011, 188-190, 2012), attested by the discoveries of the river barges of Kušnjak on the Danube (2nd century CE, Serbia, Bockius 2003), Sinja Gorica on the Ljubljanica River (*terminus post quem* the year 3 AD

19 Gornji dio vojeva na kojem su se nalazile rupe za šivanje i koji je vjerojatno izrađen od mekog drva, bio je vidljiv u dužini od oko 2 m na boku riječnog korita. Također je identificiran debeli odvojeni dio umetnutog sloja napravljenog od biljnog materijala te gornji dio od tri rebra, smještena u razmaku od 60 cm i povezani hrastovim čavliom za oplatu. Jedno od rebara je imalo pravokutni urez iznad umetnutog sloja. Radiokarbonske analize jednog malog čavla od drva tise (*Taxus baccata*), koji je služio za učvršćenje šavova, te jednog uzorka s oplata, datirale su ih u 2. st. pr. Kr., iako se ne može isključiti upotreba starog drva (Gaspari 2017, 87, Sl. 85-87). A. Gaspari je također istaknuo da je u 19. st. A. Müllner izvijestio o kronološki neutvrđenom monoksilu koji je pronađen u močvari Ljubljanice kod Zelenog Hriba. Iz njegovog izvješća čini se da je monoksil imao dio vezan za trup (Gaspari 2017, 117-118).

19 The upper part of a strake with stitch-holes, probably made from a soft wood, was visible on the side of the riverbed in the length of about 2 m. A detached part of a thick wadding pad made of plant material and the upper part of three ribs, placed at an interval of 60 cm and connected by oak nail to the planking, were also identified. One of the ribs presented a rectangular notch over the wadding pad. Radiocarbon analyses of one peg in yew (*Taxus baccata*) fixing the stitches and of one sample from the planking date this sewn boat to the 2nd c. BCE even if the use of old wood cannot be excluded (Gaspari 2017, 87, fig. 85-87). A. Gaspari has also pointed out that in the 19th c. A. Müllner reported a chronologically undetermined logboat found in the Ljubljanica Marshes near Zeleni Hrib. From his report it seems that the logboat presented a piece lashed to the hull (Gaspari 2017, 117-118).

rijeci Kupi (1. i 2. st., Hrvatska, Boetto, 2016; Boetto *et al.*, u tisku, Sl. V.19)²⁰.

S današnjeg gledišta teško je utvrditi da je korištenje klanfi omogućavalo bržu izgradnju i jednostavnije rukovanje te da se vezivalo uz rimsku okupaciju Ilirika i Panonije, kao i da je proizašlo iz tehnologije šivanja (Gaspari 2017, 184).

Monoksil Vrhnika 1, datiran na kraj 2. st. pr. Kr., koji je pronađen na Vrhniku u rijeci Ljubljanici i nedavno je objavljen (Gaspari 2017, u tisku), kao i drugi nalazi koje je reinterpreterao Gaspari (Gaspari 2017, 184), a gdje su u velikom broju pronađene metalne klanfe i metalne trake koje su korištene uglavnom kod popravaka, potvrđuju upotrebu klanfi kao tehničkog rješenja iz vjerojatno predrimskog razdoblja²¹.

Ostale mediteranske tradicije šivanih brodova

Iberska tradicija s punskim utjecajima

Iberska tradicija s punskim utjecajem je tradicija šivanih brodova potvrđena u Iberiji, današnjoj Španjolskoj (Pomey 2012a, 24-28; De Juan 2014), (Sl. V.4). Najraniji dokazi su lokaliteti Mazarrón 1 i 2 s brodovima skromnih dimenzija koje karakterizira zaobljeno dno trupa s kobilicom, oplata izgrađena spojem utor - jezičac te mala cilindrična rebra koja su privezana za oplatu (Sl. V.20, V.21). Ovakav princip izgradnje pronađen je i na kasnijem brodolomu kod Binisafüllera (4. st. pr. Kr., Minorca, Baleari) te vrlo vjerojatno i u brodolomu Golo (arhajsko razdoblje, Korzika).

Brodovi iz Mazarróna su lokalnog porijekla; i po korištenju i po konstrukciji namijenjeni su obalnoj plovidbi. Vezivanje rebara i opstanak ove tehnike stoljećima nakon toga, vrlo vjerojatno upućuju na stariju lokalnu tradiciju iberskog porijekla. S druge strane, u korištenju tehnike spajanja oplate spojem utor i jezičac još u arhajskom razdoblju očit je utjecaj punske brodograditeljske tradicije iz naselja u južnoj Iberiji.

Tehnika izgradnje spojem utor i jezičac, posvjedočena u brončanom dobu na istočnom Mediteranu u brodolomu Uluburun (Turska) s kraja 14. st. pr. Kr. (Bass 1989; Pulak 1998; 1999) te u brodolomu Cape Gelidonya s kraja 13. st. pr. Kr. (Bass 1967; 1999), vrlo se vjerojatno razvila na obali Levanta, u kanajskim i protofeničkim kontekstima (Wachsmann 1998; Polzer 2011). Tijekom razdoblja Rimske Republike, Katon Stariji (*De agr.*, XXI, 18, 9) tehniku sastavljanja oplate sustavom utora i jezičaca naziva

Slovenia, Erič *et al.* 2014; Čufar *et al.* 2014), Sisak (2nd-3rd century CE, Gaspari *et al.* 2006) and Kamensko, near Karlovac, on the Kupa River (1st-2nd century CE, Croatia, Boetto 2016; Boetto *et al.* forthcoming; Fig. V.19)²⁰.

At present, it is hard to see the clamps as a derivative of sewing technology that allowed faster construction and easier maintenance, related to the Roman conquest of Illyricum and Pannonia (Gaspari 2017, 184).

The logboat Vrhnika 1, dated to the end of the 2nd century BCE found in Vrhnika, Ljubljanica River, and recently published (Gaspari 2017, forthcoming), and the other findings reinterpreted by A. Gaspari (2017, 184), in which large iron clamps and nailed iron strips are used mostly for repairs, confirm the use of clamps as a technical solution possibly of Pre-Roman origin²¹.

Other Mediterranean sewn-boat traditions

The Iberian tradition with Punic influence

The Iberian tradition with Punic influence is an ancient sewn-boat tradition attested in Iberia, modern Spain (Pomey 2012a, 24-28; De Juan 2014) (Fig. V.4). The earliest evidence is provided by the Mazarrón 1 and 2 wrecks of boats of modest size characterized by a round-bottom hull with keel, planking assembled by mortise-and-tenon joints, and small cylindrical frames lashed to the planking (Figs V.20, V.21). This combination was also found in the later Binisafüller shipwreck (4th century BCE, Minorca, Balearic Islands) and very likely in the Golo shipwreck (Archaic period, Corsica).

The Mazarrón boats are coastal crafts of both local use and construction. The lashing of the frames and its survival several centuries later is very likely evidence of an ancient local tradition of Iberian origin. On the other hand, the use as early as the archaic period of the mortise-and-tenon joint for the planking is an obvious influence of the Punic tradition of shipbuilding due to the presence of Phoenician settlements in southern Iberia.

The mortise-and-tenon joint, evidenced from the Bronze Age in the Eastern Mediterranean by the Uluburun wrecks (Turkey) dated to the end of the 14th century BCE (Bass 1989; Pulak 1998, 1999) and the Cape Gelidonya wreck of the end of the 13th century BCE (Bass 1967, 1999), very likely originated on the Levantine coast, in a Cananean or proto-Phoenician context (Wachsmann 1998; Polzer 2011). Then, during the Roman Republican period, Cato the Elder (*De agr.*,

20 Ovaj lokalitet se istražuje od 2015. u sklopu bilateralne suradnje između Hrvatskog restauratorskog zavoda (HRZ) i Centra Camille Jullian.

21 Prisutnost proizvedenih materijala za popravak monoksila Vrhnika moglo bi se također povezati s pomorskom praksom u brodogradnji (Gaspari 2017, 180), čime se potvrđuje upliv mediteranskih utjecaja prema rijeci Ljubljanici. Pregled se donosi u Gasparijevom radu, koji je u tisku.

20 This site is excavated from 2015 in the frame of bilateral collaboration between the Croatian Conservation Institute (HRZ) and the Centre Camille Jullian.

21 The presence of fabric material in the repairs of the Vrhnika logboat could also be connected to maritime shipbuilding practises (Gaspari 2017, 180) confirming the opening of the Ljubljanica river area to the Mediterranean influences. An overview in Gaspari forthcoming.

V.20

Brod Mazarrón 2. Pogled na brodsku konstrukciju tijekom istraživanja 2008

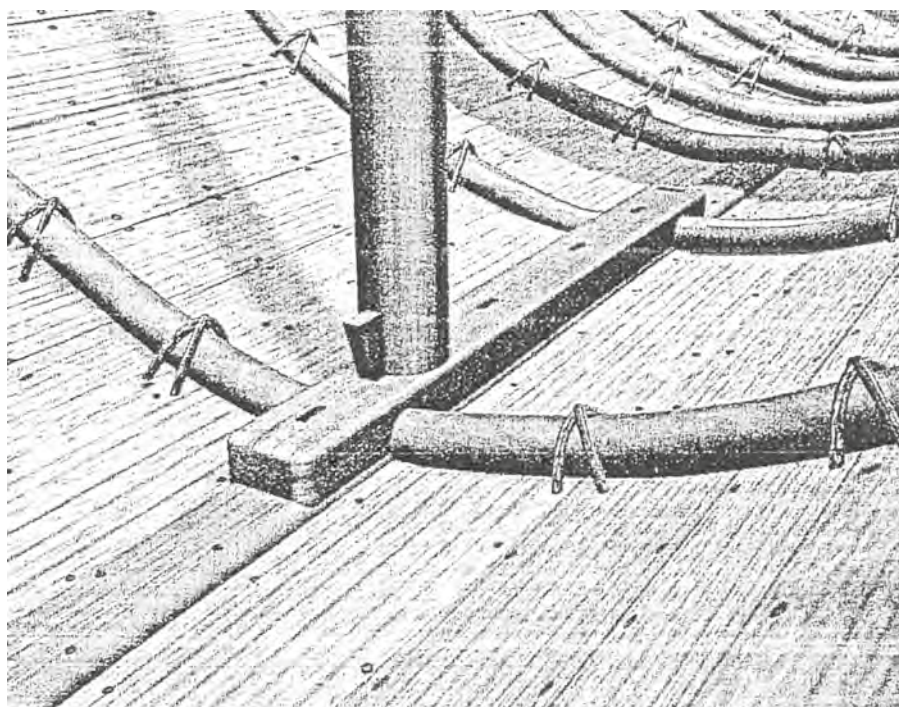
Mazarrón 2 shipwreck. General view of the hull during the 2008 excavation
(fotografija / photo by: J. A. Moya)



V.21

Brod Mazarrón 2. Crtež dna trupa s vezanim rebrima i usadnikom jarbola

Mazarrón 2 shipwreck. Drawing of the hull bottom with the lashing of the frames and the mast step timber
(prema / from: Negueruela 2005)



„*coagmenta punicana*“, potvrđujući njezino punsko-feničko porijeklo.

Grčka tradicija

Grčka tradicija šivanih brodova dobro je potvrđena na Mediteranu nalazima jedanaest olupina koje su pronađene u istočnom i zapadnom kontekstu (Sl. V.4). Zbog brojnosti brodoloma na kojima je utvrđena, ova tradicija je vjerojatno najbolje poznata od svih mediteranskih tradicija šivanih brodova. Ustanovljene su četiri faze njene evolucije od arhajskog razdoblja do početka helenističkog doba (Pomey 1997; Kahanov, Pomey 2004; Pomey 2008, 2010, 2012a, 25).

Ranija ili „izvorna skupina“ (Pomey 2010) se odnosi na pet olupina iz grčkih ili masalijskih konteksta, datiranih u 6. st. pr. Kr., pronađenih na istočnom i zapadnom Mediteranu. Ovi brodovi pripadaju istoj tradiciji grčkih šivanih brodova. Riječ je o brodovima sa šivanim platicama i vezanim rebrima, od kojih su veći bili dužine između 15 i 25 m (Giglio, Pabuç Burnu i Cala Sant Vicenç), a manji dužine oko 10 m (Bon-Porté 1 i Jules-Verne 9) (Sl. V.22-V.24).

U usporedbi s ostalim mediteranskim sustavima šivanja, grčki djeluje vrlo sofisticirano. Tako se u sljubnice

XXI, 18, 9) called mortise-and-tenon joints ‘*coagmenta punicana*’, confirming their Punic-Phoenician origin.

The Greek tradition

The Greek sewn-boat tradition is well attested in the Mediterranean by 11 wrecks found in both Eastern and Western contexts (Fig. V.4). Due to numerous shipwrecks belonging to this tradition, it is the best known of the Mediterranean sewn-boat traditions and four phases of evolution have been identified from the archaic period up to the beginning of the Hellenistic era (Pomey 1997; Kahanov, Pomey 2004; Pomey 2008, 2010, 2012a, 25).

The first or “original” group concerns five wrecks attesting to an Aegean or Massalian context dated to the 6th century BCE, found in both the Eastern and Western Mediterranean. They belong to the same Greek archaic sewn-boat tradition, and they correspond to large sailing vessels between 15 and 25 m long (Giglio, Pabuç Burnu, and Cala Sant Vicenç), or small boats around 10 m long (Bon-Porté 1 and Jules-Verne 9), each with sewn planks and lashed frames (Figs V.22-V.24).

In particular, the sewing system used for the planking appears more sophisticated than in the other known



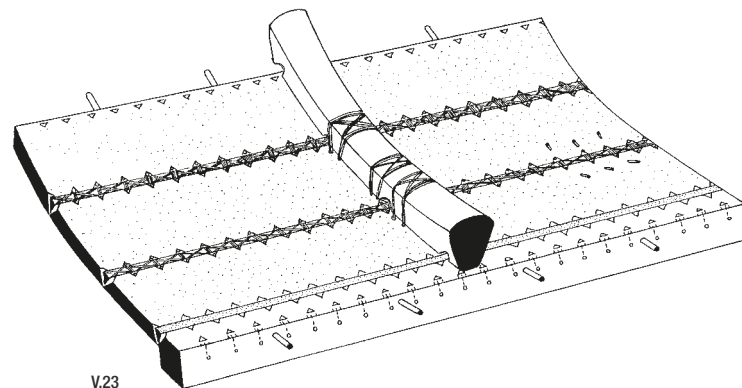
V.22

V.22
Brodovi Jules-Verne 7 i 9. Pogled tijekom istraživanja

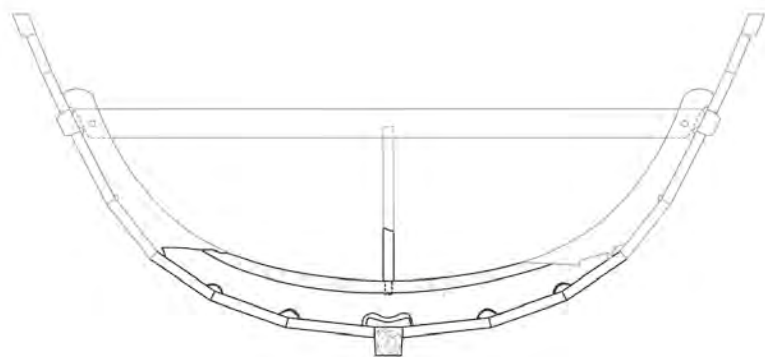
Jules-Verne 7 and 9 wrecks. View of the wrecks in excavation
(fotografija / photo by: M. Derain)

V.23
Brod Jules-Verne 9. Aksonometrijski prikaz sustava spajanja, šivanjem i vezanjem Jules-Verne 9 wreck. Axonometry of the sewing and lashing assembly system
(crtež / drawing by: M. Rival)

V.24
Brod Jules-Verne 9. Crtež rekonstruiranog glavnog poprečnog presjeka Jules-Verne 9 wreck. Reconstruction drawing of the transversal main section
(crtež / drawing by: P. Poveda)



V.23



0 1 2m
© P. Poveda, 2018. Aix Marseille Univ., CNRS, CCJ

V.24



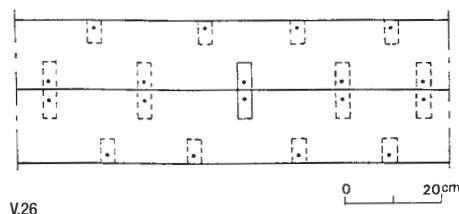
V.25

V.25
Brod Jules-Verne 7. Detalj popravka platice šivanjem Jules-Verne 7 wreck. Detailed view of the sewing on a plank repair (fotografija / photo by: M. Derain)

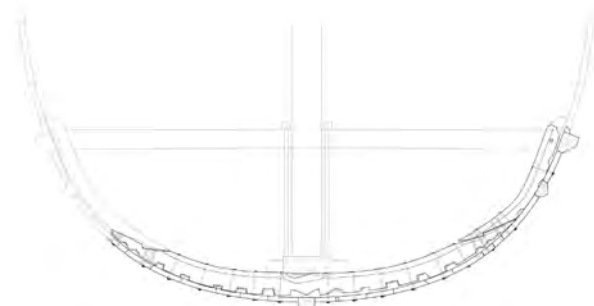
V.26
Brod Jules-Verne 7. Shematski prikaz spoja utor i jezičac Jules-Verne 7 wreck. Schema of the mortise-and-tenon joint (crtež / drawing by: M. Rival)

V.27
Brod Jules-Verne 7. Rekonstrukcija glavnog poprečnog presjeka Jules-Verne 7 wreck. Reconstruction of the transversal main section (crtež / drawing by: P. Poveda)

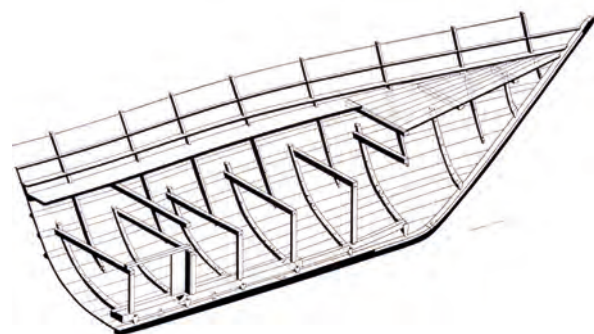
V.28
Brod Jules-Verne 7. Aksonometrijski prikaz strukture trupa Jules-Verne 7 wreck. Axonometric view of the hull structure (crtež / drawing by: M. Rival)



V.26



V.27



V.28

platica umeću tiple kako bi se spoj učvrstio i spriječilo smicanje. Zatim se izrađuju dijagonalne rupe s unutrašnje strane platice do nižeg ugla sljubnica, kako šavovi ne bi bili ispupčeni izvan korita tj. da se umanjí mogućnost njihova oštećenja trenjem. Tetraedalni urezi se zatim izrađuju pravilno uz unutrašnji rub platice, na ulazu na svakoj rupi za šivanje. Ove tetraedalne rupe su rađene kako bi se postiglo pravilno šivanje te izbjegli oštri kutovi na ulazu pojedine rupe.

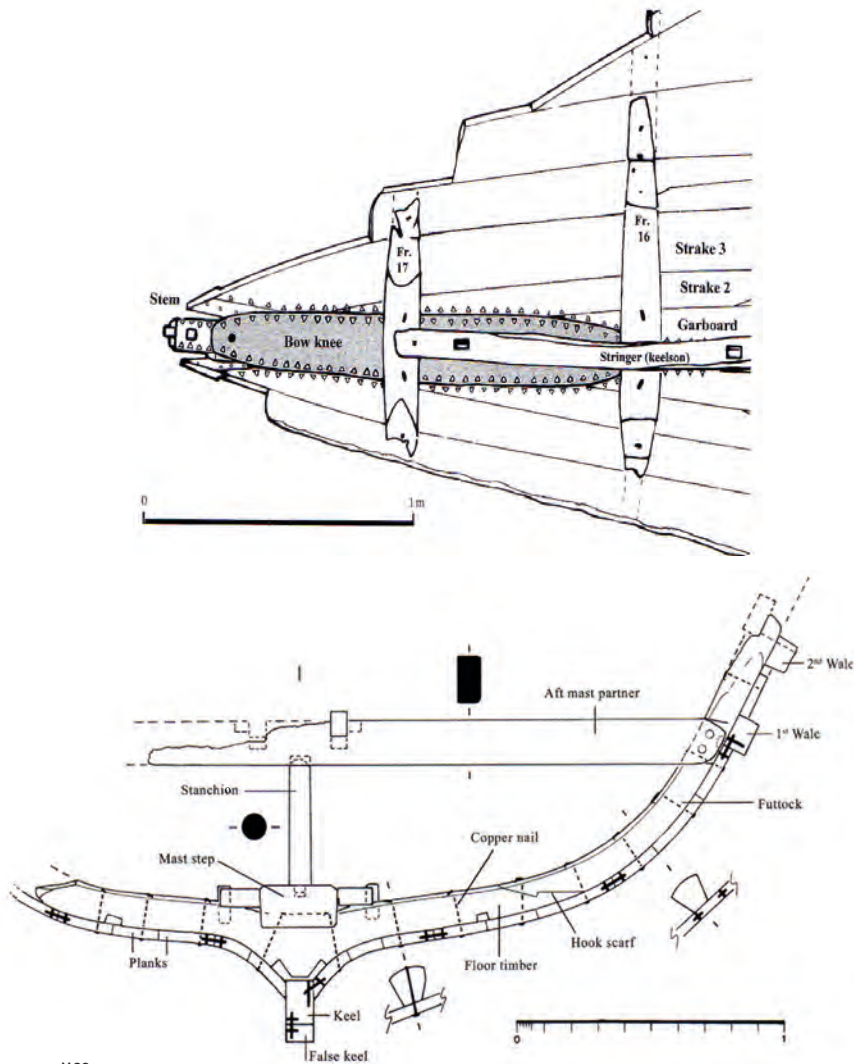
Sljubnice platice su prije šivanja prekrivene smotuljkom lanene tkanine koja osigurava vodonepropusnost. Nakon toga se obavlja šivanje trostrukom lanenom niti prema shemi IXIXIX, koja je istovjetna duplom preklopnom šavu s dijagonalnim prolazom cijelom dužinom sljubnice i nazad. Naposljetku se u rupe umeću mali drveni čavli kako bi se šavovi fiksirali, a rupe začepile.

Položaje svih elemenata za sastavljanje (čivije, tetraedalni utori, dijagonalne rupe) brodograditelji su precizno označili na oplati. Rebra su oblikovana tako da se mogu vezati na najbolji mogući način.

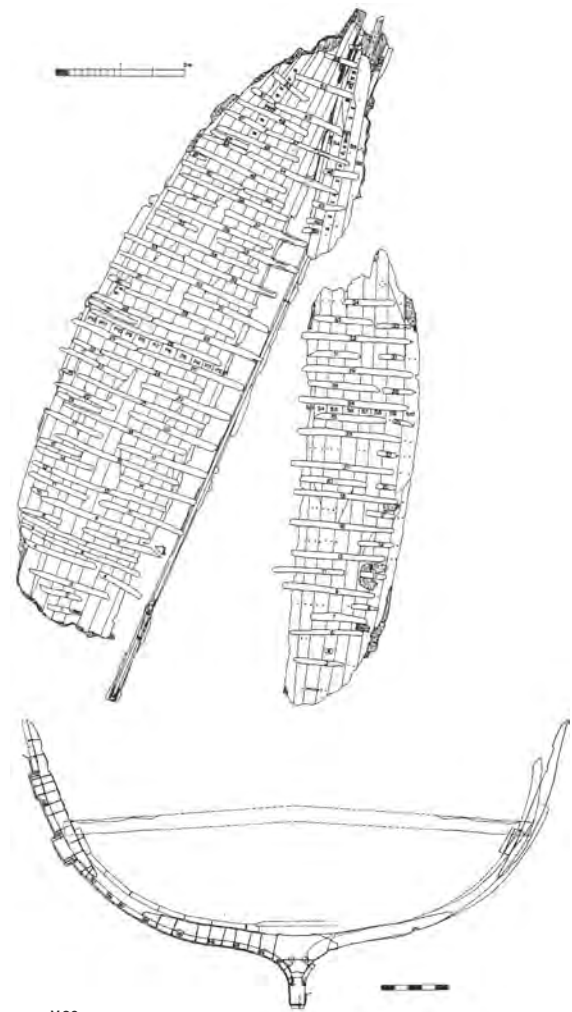
Drugu, tzv. „prijelaznu skupinu“ čine četiri broda; ova

traditions. First, pre-assembly dowels (coaks) are placed in holes drilled in the thickness of the planks to keep the planks in place and to prevent the phenomena of shear. Then diagonal stitch holes start from the inner edge of the plank and finish just on the lower corner of the seams to avoid the stitches protruding and so prevent chafing. Tetrahedral recesses are cut regularly along the inner edge of the planks around the entry of each stitch hole. These tetrahedral recesses are made to ensure the sewing is very even and to avoid sharp angles at the entrance of the stitch channels.

A roll of linen fabric assures the seams are watertight and the sewing is made of a triple linen thread following an IXIXIX pattern corresponding to a double clamping turn with a diagonal passage, the whole length of the seam and back. Lastly, little pegs were driven into the channels to lock the stitches and plug the holes. The positions of all the assembly elements (treenails, tetrahedral recesses, and diagonal channels) were precisely marked by the carpenter on the planking. The frames are shaped to be lashed in the most efficient manner



V.29



V.30

grupa ujedno predstavlja prvu fazu evolucije – vjerojatno u različitim stadijima – od tehnike šivanja do upotrebe spoja na utor i jezičac.

Šivanje se, slično kao u izvornoj grupi, još koristi za sastavljanje krajeva broda i popravke. Rebra su i dalje oblikovana za potrebe vezivanja, ali su rebrenice pričvršćene metalnim čavlima čiji je kraj s gornje strane savijen u obliku kuke. Ova skupina uključuje velike brodove (Grand-Ribaud F, Gela 1), srednje (Jules-Verne 7), (Sl. V.25-V.28) i brodice (Villeneuve-Bargemon 1).

Treća, tzv. „evolucijska skupina“ predstavlja drugu fazu u evoluciji ove grčke tradicije i posvjedočena je sredinom i u drugoj polovici 5. st. pr. Kr., na dvije olupine: Gela 2 i Ma’agan Mikhael (Sl. V.29).

Nekoliko karakteristika, poput ključa kobilice na zub, korištenja više tehnika za sastavljanje oplata, opće karakteristike slaganja rebara spojenih kukastim čavlima te korištenje tehnike šivanja s tetraedalnim rupama (ali bez prethodno umetanih drvenih tipli), povezuju ova dva brodoloma s prethodnom skupinom, ali ipak, oni imaju i bitne promjene u formi trupa (poprečni presjek u obliku

possible.

The second or “transition” group is composed of four wrecks and constitutes the first phase of evolution – possibly in a series of steps – from the sewing technique to the use of mortise-and-tenon joints for planking.

The sewing, similar to that attested in the “original group” type, was still used for the extremities and for repairs. The frames were still shaped for lashing, but the floor-timbers were fixed with clenched nails. This group concerns large ships (Grand-Ribaud F, Gela 1), medium (Jules-Verne 7) (Figs V.25-V.28), and small vessels (Villeneuve-Bargemon 1).

The third or “evolution” group is the second phase of evolution of this Greek tradition and is attested in the mid and the second half of the 5th century BCE by two wrecks: Gela 2 and Ma’agan Mikhael (Fig. V.29).

Several features, such as the keel hook scarf and a mixed coating, the general characteristics of the framing pattern fixed with clenched nails, and the use of the sewing technic with tetrahedral recesses (but without pre-assembly dowels) link these two wrecks to the former

V.29

Brod Ma’agan Mikhael. Tlocrt sašivenog pramčanog koljena; glavni poprečni presjek trupa **Ma’agan Mikhael shipwreck.** Top view of the sewing on the bow knee; transversal main section of the hull (Linder, Kahanov 2003).

V.30

Brod Kyrenia. Opći plan i glavni poprečni presjek trupa **Kyrenia shipwreck.** General plan and main cross section of the hull (Wylde Swiny, Katzev 1973).

„čaše za vino“), a u morfološkom smislu, rebra postaju više kvadratnog presjeka.

Na sami kraj 4. i početak 3. st. pr. Kr. datira se brod Kyrenia (sjeverna obala Cipra, Wylde Swiny, Katsev 1973; Steffy 1985) (Sl. V.30); iako na njemu nije ustanovljeno šivanje, spada u jedini dovoljno istražen brodolom važan za razumijevanje finalne faze evolucije grčkih šivanih brodova. Pripadnost broda iz Kyrenije obitelji grčkih šivanih brodova nije jasno vidljiva već se može uočiti jedino kroz usporedbe s prethodnom „evolucijskom skupinom“, a osobito s brodolomom Ma’agan Mikhael, s kojim dijeli nekoliko karakteristika. Štoviše, reupotreba platice s tetraedalnim utorima sa šivanog broda kao podnice za brod Kyrenia dokaz je za određenu bliskost i povezanost između broda Kyrenia i grčke tradicije šivanih brodova. Brodolom Ereĝli E, recentno otkriven u Crnom moru (Brennan *et al.* 2013; Davis *et al.* 2018), koji se datira na početak 3. st. pr. Kr., dokazuje da se grčka tradicija šivanih brodova nije ugasila sa zadnjim stupnjem evolucije, tj. s brodom Kyrenia.

Prema svim ovim karakteristikama, Kyrenia pripada novom tipu broda helenističkog i republikanskog razdoblja (Pomey 2004b). Ipak, ovaj brod predstavlja kulminaciju duge evolucije grčke tradicije šivanih brodova do prijelaza prema korištenju spoja utor i jezičac. Sustavno korištenje spojeva utor i jezičac ne implicira samo usvajanje novog sustava spajanja već i novi sustav gradnje broda. Ova tehnika je ostala u upotrebi u brodogradnjama diljem Mediterana, u grčkom, punskom i rimskom kontekstu od kraja klasičnog razdoblja do kraja antike, tj. do prijelaza prema izgradnji brodova tehnikom „prvo kostur“ (Steffy 1994; Pomey *et al.* 2012). Prednosti ovog novog sustava izgradnje dobro su poznate u literaturi (Pomey 2011b).

Jezičci, izrađeni uglavnom od tvrdog drva, mnogo su jači i izdržljiviji od ligatura biljnog porijekla čime je omogućen razvoj novih tipova brodova te povećanje dimenzija i nosivosti brodova u skladu s razvojem pomorske trgovine, kao i gradnja efikasnijih, dugotrajnijih i sigurnijih plovila.

Može se pretpostaviti da je upravo utjecaj korištenja spoja utor i jezičac u punsko-feničkoj tradiciji bio odlučujući impuls za usvajanje takve tehnike od grčkih brodograditelja, osobito u kontekstu zapadno-grčke kolonizacije te izravnog kontakta i sukoba Grka i Kartažana.

group, but they present major changes in the hull shape (a “wine-glass” transversal section) and in the morphology of the frames, which are evolving towards a square section.

In the last years of the 4th and beginning of the 3rd century BCE, the Kyrenia wreck (northern coast of Cyprus, Wylde Swiny, Katsev 1973; Steffy 1985) (Fig. V.30), although devoid of sewing, is the only wreck sufficiently excavated to allow an understanding of the final phase of the evolution of the Greek sewn-boat tradition. The Kyrenia ship’s affiliation to the Greek sewn-boat tradition is not evident and can be established only through comparison with the former “evolution group” and especially with the Ma’agan Mikhael ship, which shares several features with Kyrenia. Moreover, the reuse in the ceiling of the Kyrenia ship of a plank with tetrahedral recesses from a sewn boat (Steffy 1985, 95) is a clue that proves a certain proximity and familiarity between the Kyrenia vessel and the Greek sewn-boat tradition. Moreover, at the start of the 3rd century BCE, the Ereĝli E wreck-site, recently discovered in the Black Sea (Brennan *et al.* 2013; Davis *et al.* 2018), shows that the Greek tradition of sewn boats did not suddenly vanish with the ultimate step of evolution evidenced by the Kyrenia wreck.

By all its traits, Kyrenia belongs to a new ship type characteristic of the Hellenistic and Republican period (Pomey 2004b). However, if this ship represents the culmination of the long evolution of the Greek sewn-boat tradition, up to the adoption of the mortise-and-tenon joint, the systematic use of mortise-and-tenon joints implies not only the adoption of a new system of assembly but also a new system of construction. This system was used in all Mediterranean shipbuilding, in Greek, Punic and Roman contexts, from the end of the Classical period to the end of Antiquity and the transition towards skeleton construction (Steffy 1994; Pomey *et al.* 2012). The benefits of the new system of construction are well known (Pomey 2011b).

Tenons, made generally of hard wood, are much stronger and much more durable than vegetal ligatures. It became possible to develop new ship types and to increase the size and tonnage of the ship in line with the development of maritime trade and to build more efficient, safer ships of greater longevity.

It is possible that the influence of the use of mortise-and-tenon joints in the Punic-Phoenician tradition gave the decisive impulse for the adoption of mortise-and-tenon joints by Greek shipbuilders, especially in the particular context of Western Greek colonization and the direct contact and confrontation between Greeks and Carthaginians.

Sjeverozapadna mediteranska tradicija

Unatoč prevladavajućoj tehnici korištenja spoja utor i jezičac u mediteranskoj brodogradnji od kraja 4. st. pr. Kr., praksa šivanja preživjela je u drugim zemljopisnim i kulturnim područjima. Ovo je slučaj rimske tradicije na Jadranu, međutim postoje i dokazi preživljavanja tehnike šivanja u brodogradnji gdje je tradicionalno korištena tehnika izgradnje spojem utor i jezičac. Primjer za to je brod pogonjen jedrima i veslima Pisa C (Pisa, Italija, 1. stoljeće) (Sl. V.4), koji je na jednom malom dijelu oplata popravljen šivanjem (Camilli 2002, Sl. 7).

Značajnija je tradicija sastavljanja rebara unutarnjim vezivanjem, a koja je utvrđena na šesnaest olupina koje su pronađene na sjevernom dijelu zapadnog Mediterana, od Katalonije do južne Francuske i Korzike (Sl. V.4). Ova specifična tehnika vezivanja koja se koristi samo za rebara, i koja dolazi u kombinaciji s oplatom građenom spojem utor i jezičac, tvori zasebnu tehnološku tradiciju koju možemo nazvati „sjeverozapadnom mediteranskom tradicijom“. Rebra su spojena za oplatu pojedinačnim čivijama te naizmjenično unutarnjim vezivanjem. Povezi se sastoje od omče napravljene od isprepletenih biljnih vlakana koja prolaze kroz dvije vertikalne rupe u rebrima. Šavovi su nakon toga fiksirani u rupama uz pomoć dugih drvenih čavala. Žljebovi povezuju rupe na unutarnjoj gornjoj strani rebara i na vanjskoj strani oplata, ne bi li spriječili izvirivanje šavova i zaštitili ih od trenja.

Ovakav sustav pričvršćivanja rebara utvrđen je na brodovima koji se datiraju između sredine 3. st. pr. Kr. i kraja 1. stoljeća (Pomey 2002; Marlier 2005; Wicha 2005), a tvore je dvije skupine brodova.

Prva skupina obuhvaća male priobalne brodove s kobilicom i više-manje oštrim poprečnim presjekom dna, a druga uključuje brodove za riječno-morsku plovidbu koji imaju ravnu kobilicu i ravno dno. Brodovi iz druge skupine plovili su na području koje karakterizira mreža riječnih i morskih lokaliteta, između današnjih regija Katalonije i Languedoca, od rijeke Ebro do rijeke Rhone.

Zaključak

U korpusu od preko 64 šivana broda koji su do danas poznati na Mediteranu moguće je razlučiti nekoliko različitih tradicija, koje su dobro okarakterizirane i identificirane te se mogu vezati uz precizno određene geografske regije i kulturološka područja. Važnost ovih tradicija, široko rasprostranjenih diljem Mediterana, svjedoči o značaju tehnika šivanja i vezivanja te o vrlo visokom stupnju njihove sofisticiranosti, što dokazuje da su bile dobro prilagođene potrebama brodogradnje

The north-western Mediterranean tradition

In spite of the dominant use of the mortise-and-tenon joint in Mediterranean shipbuilding from the end of the 4th century BCE, the practice of sewing survives in other geographic and cultural areas. This is the case of the Roman traditions of the Adriatic Sea, but we also have evidence of the survival of sewing practices in fully mortise-and-joint fastened shipbuilding. An example is the Pisa C wreck, a sailed and rowed boat (Pisa, Italy, 1st century CE) (Fig. V.4), where a little sewn repair has been observed on the planking (Camilli 2002, fig. 7).

More significant is the tradition using frames assembled by internal lashings, which has been observed on 16 wrecks found in the northern part of the Western Mediterranean, from Catalonia to Southern France and Corsica (Fig. V.4). This specific lashing technique, used only for the frames and associated with mortise-and-tenon joints for the planking, constitutes a particular technical group that can be called the “north-western Mediterranean tradition”. The frames are attached to the planking by individual treenails alternating with internal lashings. The lashings are made of a loop of vegetal braid that passes through two vertical channels in the frames. The ligature is then locked in the channels with long wooden pegs. Grooves connect the exits of the vertical holes on the inside face of the frames, and on the outer surface of the planking, to prevent the ligatures protruding, and so protect them from friction.

This technical tradition has been observed on wrecks dated from the middle of the 3rd to the end of the 1st centuries CE (Pomey 2002; Marlier 2005; Wicha 2005), belonging to two architectural families.

The first concerns small, keeled coastal vessels with a more-or-less sharp bottom, while the second group concerns fluvio-maritime vessels, characterized by a flat keel and a flat bottom. The boats of this second group sailed in the geographic zone characterized by the network of rivers and coastal lagoons situated between the modern regions of Catalonia and Languedoc, from the Ebro River to the Rhône River.

Conclusion

In conclusion, in the corpus of more than 64 sewn boats known in the Mediterranean region, several different traditions have been distinguished, that have been characterized, identified, and attributed to precise geographic and cultural areas. The importance of these traditions, spread widely throughout the Mediterranean, testifies to the pertinence of sewing and lashing techniques, which achieved a very high degree of sophistication, and proves they were well adapted to shipbuilding needs

u antici. Iako su uglavnom posvjedočene nalazima iz arhajskog razdoblja, čini se da su njihovi korijeni vrlo stari i da ih treba datirati barem u kasno brončano doba, ako ne i u ranija razdoblja.

Prema dostupnim podacima, tradicije šivanih brodova koje smo ovdje predstavili uglavnom se odnose na sjeverne obale Mediterana, s osobito jakim korijenima u Grčkoj, od jonske obale do zapadnih fokejskih naselja oko Marseillea, potom na sjevernom Jadranu, na Iberskom poluotoku te na sjevernom kraju zapadnog Mediterana.

Također, bilo je moguće razlučiti nekoliko sustava šivanja koji su se razvijali na različite načine. Primjerice, iako egejska grčka i tzv. protohistarska tradicija koriste isti princip šivanja oplata s vezanim rebrima, njihova evolucija je sasvim različita. U grčkoj tradiciji evolucija je vidljiva kroz postupno usvajanje spajanja oplata spojem utor i jezičac te kroz brzo napuštanje vezivanja rebara, koje je zamijenjeno učvršćivanjem čivijama i metalnim čavlima. U jadranskoj se pak tradiciji šivanje oplata očuvalo i tijekom rimskog razdoblja.

S druge strane, iberska tradicija s punskim utjecajima vrlo je brzo usvojila građenje oplata spojem utor i jezičac, vjerojatno radi punskog utjecaja i kao dio prethodne tradicije, dok vezivanje rebara ostaje prisutno još dugo. To je tehničko rješenje slično onom koje se pronalazi u sjeverozapadnoj mediteranskoj tradiciji, u kojoj je oplata spojena na na utor i jezičac, u kombinaciji s rebrima koja su djelomično spojena unutarnjim vezanjem.

Paralelno s time, u tom se razdoblju sustav spajanja oplata spojem utor i jezičac, koji je dobro posvjedočen na kraju brončanog doba u brodogradnji na Levantu, širio cijelim Mediteranom tijekom arhajskog i klasičnog razdoblja, da bi krajem 4. st. pr. Kr. postao dominantnom tehnikom gradnje brodova. Ipak, čak i kada je sustav spajanja oplata utorima i jezičcima dominantan, tradicije šivanja ne nestaju. Neke od njih preživjele su do kraja antike, a u određenim regijama čak i do ranog srednjeg vijeka, primjerice na Jadranu, gdje je tradicija bila izuzetno jaka i dobro prilagođena specifičnom okolišu i plovnom području.

Veliki broj brodova jadranske tradicije čini se izuzetnim u usporedbi s drugim tradicijama šivanja, otvarajući pitanje opstanka te tradicije (Carre 1997; Marlier 2002). Vjerojatno je prema P. Pomeyu (Pomey 1985, 41) i S. Marlier (Marlier 2002) da se opstanak te tradicije može objasniti upotrebom u zatvorenom području plovidbe (poput arhipelaga liburnske obale ili mreže delte rijeke Po, kao i drugih rijeka i laguna sjeverne Italije) koji je utjecao na efekt očuvanja ove tradicije.

in Antiquity. Although these techniques are mainly attested during the archaic period, their origin appears to be very old, dating back to at least the Late Bronze Age, if not before.

According to our data, the sewn-boat shipbuilding tradition mainly concerns the northern coasts of the Mediterranean with particularly active roots in Greece, from the Ionian coast to the western Phocaeen settlements around Marseilles, in the northern Adriatic, in the Iberian Peninsula, and in the northern arc of the Western Mediterranean.

We can also distinguish different sewing systems that evolved in different ways. For example, the Aegean Greek and the so-called Proto-Histrian traditions originally both used sewn planking with lashed frames, but their evolution differed. In the Greek tradition, the evolution saw the progressive adoption of the mortise-end-tenon joint and the rapid abandonment of lashed frames in favour of nailing or treenailing, while in the Adriatic traditions sewn planking was maintained during the Roman period.

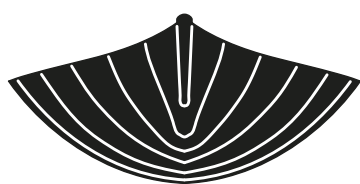
On the other hand, in the "Iberian with Punic influence tradition" mortise-and-tenon joints were rapidly adopted to assemble planking, probably under Punic influence and as part of an earlier tradition, while lashed frames survived for a long time. A similar technical solution is found in the north-western Mediterranean tradition in which the planking is fastened with mortise-and-tenons associated with frames in part connected using internal lashings.

During that time, in parallel, the mortise-and-tenon joint system, well attested at the end of the Bronze Age in Levantine shipbuilding, spread progressively throughout the Mediterranean during the Archaic and Classical periods, becoming the dominant technique of assembly in ancient Mediterranean shipbuilding by the end of the 4th century BCE. But, even when the mortise-and-tenon joint was predominant, sewing traditions did not disappear. Some of them survived until the end of Antiquity and even the Early Medieval Period in some precise areas, such as in the Adriatic region, where the tradition was particularly strong and well adapted to a specific environment and sailing area.

The large numbers of vessels discovered within the Adriatic traditions appear exceptional in comparison to the other sewn traditions, raising the question of survival (Carre 1997; Marlier 2002). It is probable, according to P. Pomey (Pomey 1985, 41) and S. Marlier (Marlier 2002), that their survival can be explained as they operated in closed sailing areas (such as the archipelagic Liburnian coasts or the fluvio-maritime network of the Po delta area and the other rivers and lagoons of northern Italy), which had the effect of conserving these traditions.

**Zaključna
razmatranja**

**Concluding
Remarks**



Zaključna razmatranja

Concluding remarks

Na kraju ove monografije radova možemo iznijeti sljedeće zaključke.

Podmorsko arheološko istraživanje, analize i studija olupine broda iz Zambratije predstavljali su iznimnu pustolovinu, kako sa znanstvene, tako i s ljudske točke gledišta. U prvom se redu radilo o znanstvenoj pustolovini, jer su nam ostaci ovog jedinstvenog plovila omogućili proučavanje jednog izvanrednog postignuća iz daleke prošlosti, materijalne baštine stanovništva koje je živjelo u skladu s prirodom, dobro ga poznavalo te posjedovalo napredne tehničke vještine za izradu broda, kao i potrebno iskustvo plovidbe sjevernim Jadranom.

Zahvaljujući poznavanju drvene sirovine, obradi različitih vrsta drva sukladno njihovim fizičkim karakteristikama i oblicima, oblikovanju elemenata broda odgovarajućim alatima, sastavljanju brodskih dijelova biljnim ligaturama te istraživanju učinkovitog sustava za brtvljenje, ovaj je brod, izgrađen od pažljivo spojenih platica, plutao i plovio. Ovo plovilo je moglo zadovoljiti elementarne, a moguće i vojne te trgovačke potrebe zajednice koja ga je izgradila zbog svih navedenih razloga.

Budući da prema trenutačnim saznanjima ova pomorska zajednica još nije dovoljno istražena, otežano je i datiranje izgradnje broda iz Zambratije. Vremenski raspon, iako poprilično širok (kraj 12. - kraj 10. st. pr. Kr.), upućuje na početnu fazu razvoja kulture Histra. Arheološki predmeti, uglavnom otkriveni u nekropolama, ukazuju da su stanovnici ovoga područja već u ranoj fazi bili izrazito orijentirani na plovidbu Jadranom. Pronađeni predmeti svjedoče o trgovinskim vezama s mjestima u

Altogether, the excavation, analyses and study of the Zambratija shipwreck have proven to be a remarkable scientific and human adventure. First and foremost scientific, since this exceptional wreck has allowed us to closely observe a waterborne craft from the most distant past, a tangible witness to a community that had clearly mastered its environment and was endowed with a high level of technical know-how.

This boat of carefully assembled planking was able to float and navigate as a result of a series of successful actions: the selection of raw materials in the forest, the adaptation of different wood species to specific uses according to their physical characteristics and form, the shaping of boat's timbers with the appropriate tools, the assembly of said timbers with vegetal ligatures, and the choice of an efficient sealing system. The vessel was a response to the contemporary requirements, perhaps military and certainly trade, of the community that built it.

A precise date for the Zambratija wreck has yet to be fixed and thus the maritime community to which it belonged cannot be clearly identified. The timescale is very wide (end of the 12th – end of the 10th century BC), placing it within the initial phases of Histri culture. Archaeological material of this era, primarily discovered in necropoli has shown that this first phase featured strong connections with navigation in the Adriatic. The material testifies to trade links with the Po Delta, and especially with the then prominent centre of the region, Frattesina di Fratta Polesine, but also with central and

dolini rijeke Po, osobito s naprednim središtem te regije Frattesinom di Fratta Polesine, ali i sa srednjom i južnom Italijom. Možemo pretpostaviti da su stanovnici gradinskih naselja iz bliže okolice trgovali s ovakvim brodovima, koji su pristizali morskim putem.

Ne smijemo zaboraviti ni povijesne izvore koji spominju da su Histri, uz Liburne i Ilire, bili i opasni gusari, a o čemu svjedoči Tit Livije u svojoj Povijesti Rima (10, 2, 4). Možemo pretpostaviti da su se Histri već na samom početku razvoja svoje kulture bavili gusarstvom, možda upravo ploveći brodovima poput onoga otkrivenog u uvali Zambratija.

Kako god bilo, brod iz Zambratije izravni je materijalni dokaz poznavanja brodograđevnih tehnika na Jadranu u davnoj prošlosti. Nalaz upućuje i na to da su podrijetlo, razvoj i primjena tih tehnika gradnje ukorijenjeni u lokalnu tradiciju, dok latinski tekstovi otkrivaju da je njihovo najznačajnije obilježje bio sustav gradnje broda šivanjem i vezivanjem ligaturama. Svojim jednostavnim karakteristikama, koje su bile povezane s reduktivnim tehnikama oblikovanja kobilice, zatim visoko usavršenom tehnikom za sastavljanje oplata i rebara te formom trupa velikog obujma i dobrih plovnih svojstava, *serilla* iz Zambratije omogućila nam je putovanje kroz prošla stoljeća i udarila temelje za poznavanje brodograditeljskih tradicija na Jadranu.

S današnjeg gledišta mogli bismo reći da ova znanstvena pustolovina za istraživače još nije završena, s obzirom da su mnoga pitanja ostala otvorena. Jedno od pitanja na koje nismo uspjeli pronaći odgovor odnosi se na procese zbog kojih je brod iz Zambratije postao olupina te kako je olupina očuvana do današnjih dana. Premda su u ovoj monografiji prikazane sažete studije i analize, ujedno se otvaraju perspektive za daljnja istraživanja i prezentaciju. Entuzijazam, ljudi i naravno tehnička sredstva potiču na daljnje proučavanje ovog u povijesnom smislu izvanrednog nalaza, koji se možda može adekvatno valorizirati i iznova oživjeti uz pomoć današnjih stanovnika toga područja.

Naposljetku, ovu monografiju ne možemo zaključiti bez prisjećanja na pustolovinu tima koji se okupio oko istraživanja. Deseci ljudi, svaki na svojoj razini i unutar svoje nadležnosti, omogućili su dovršenje ove prve znanstvene etape i izradu monografije. Rad na istraživanju, analizama i studiji olupine broda iz Zambratije ostat će nam u sjećanju cijeli život. Željeli bismo se ovdje prisjetiti i dvojice protagonista kojima život nije dao priliku da s nama proslave završetak ove važne etape. Ova publikacija ne bi ugledala svjetlo dana niti bi ovako izgledala bez sudjelovanja i rada naših prijatelja Nikija Fachina, koji je neizmjerljivo volio i poznao Istru, i Philippea Groscauxa, kojemu smo zahvalni na većini lijepih fotografija u knjizi. Sretni smo što smo ih poznavali i što smo surađivali s dvjema tako sjajnim osobama. Šivani brod iz Zambratije u nama će zauvijek buditi sjećanje na njih.

southern Italy, as is finely demonstrated by Kristina Mihovilić in this volume. A craft such as we have found at Zambratija was perfectly capable of participating in trade networks involving the hillforts (*castellieri*) that are known in the region of Zambratija, but which have yet to be systematically studied.

It should not be forgotten that the Histri, along with the Liburnians and the Illyrians, were considered to be formidable pirates, as is recorded by Livy in his *History of Rome (Ab Urbe Condita 10, 2 4)*. We are tempted to suggest that from the very beginnings of their cultural development, the Histri engaged in piracy, possibly using boats similar to the Zambratija find.

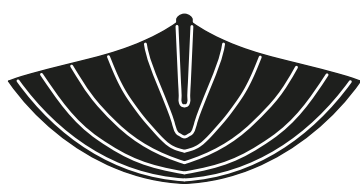
In any event, the Zambratija boat is proof of the mastery of nautical construction techniques at a very early period. It also demonstrates that the origins, development and usage of these construction techniques are rooted in a local tradition, whose most central feature, as noted in Latin texts, is an assembly system employing stitches and lashings. With its primitive craft characteristics associated with reductive keel design techniques, the highly refined planking and frame assembly system, the large-scale hull shape and nautical properties, the *serilla* from Zambratija has allowed us to travel through past centuries, laying the foundations for our understanding of shipbuilding traditions in the Adriatic.

This scientific adventure is, however, not yet over, since several questions remain unanswered, including those concerning the processes that transformed the boat into a wreck and then allowed for its preservation until today. While this volume is designed to summarise the studies and analyses that have so far been conducted, it also opens up avenues of future research and encourages us to gather together the human and technical resources and go further in our examinations. Perhaps we might one day be able to return this remarkable and historically significant find to the present-day residents of the area.

And finally, we cannot close the book without recalling the human adventure. Dozens of people, each with their own distinctive role and expertise, made it possible to reach this first scientific milestone and produce this volume, and we will all treasure our memories of the collaborative experience. But here we wish to remember two of our colleagues who are sadly no longer with us to celebrate the completion of this important work. This volume would not have seen the light of day nor been what it is without the participation and effort of our friends Niki Fachin, who loved the antiquities of Zambratija Bay, and Philippe Groscaux, to whom we are grateful for the many beautiful photographs adorning this book. We had the chance to know and work side by side with these two beautiful people and for us the boat of Zambratija will forever be linked to their memory.

Rječnik

Glossary



Rječnik osnovnih pojmova arheologije broda korištenih u radu

Termin

Objašnjenje

B

Bok (*Side*)

Dio korita iznad uzvoja (strana broda)

Bokoštitnica, žuljnica (*Wale*)

Deblji voj na boku plovila koji služi da se opaše i ojača vanjski dio trupa

Č

Čavao (*Nail*)

Metalni element koji služi za povezivanje drvenih brodskih dijelova

Čivija, drveni čavao (*Treenail*)

Izduženi, konusni i zašiljeni drveni dio koji služi za spajanje drvenih dijelova broda

D

Drveni brodski dio/element (*Timber*)

Općenito, svi drveni građevni dijelovi broda

G

Glavno rebro (*Midship frame*)

Rebro na najširem dijelu trupa

J

Jezičac (*Tenon*)

Drvena pločica ili izdanak na drvenom elementu koji se umetao u utor. U grčko-rimskoj brodogradnji, daščica od tvrdog drva umetnuta u utor i učvršćena malim drvenim čavlom, primjenjivano u tehnici spajanja utor i jezičac

K

Ključ na zub (*Hook scarf*)

Spoj dviju platica ili drvenih elemenata s dodatnim središnjim zubom radi ukrućenja spoja. Služi za spajanje kobilice i statve i ponekad je osiguran drvenim čepom ili ključem

Kobilica (*Keel*)

Osnovni uzdužni drveni dio konstrukcije broskog trupa

Kosi ključ (*Oblique scarf*)

Uzdužni spoj dviju platica u cilju formiranja voja

Konstrukcija „prvo kostur“ (*Skeleton-first construction*)

Termin koji opisuje proces gradnje trupa kojim se prvo postavljaju kobilica i rebra, a potom za njih povezuju platice

Konstrukcija „prvo ljuska“ (*Shell-first construction*)

Termin koji opisuje proces gradnje kojim se prvo izrađuje kobilica te dio ili cjelokupnost elemenata oplate, prije ugradnje rebara

Konstrukcija zasnovana na ravnom dnu (*Flat bottom-based construction*)

Termin koji opisuje proces gradnje kojim je forma i struktura broda određena i organizirana oko prvo izrađenog ravnog dna, sa ili bez izdubljenih uzvojnih vojeva

L

Letvica (*Lath*)

Tanka drvena traka postavljena iznad sljubnica oplate u cilju učvršćenja vlaknastog materijala i osiguranja vodonepropusnosti sljubnica

Ligatura (*Ligature*)

Špaga, uzica koja se koristi za šivanje ili vezanje

LJ

Ljuska (*Shell*)

Vanjska oplata broda

M

Mali drveni čavao (*Peg*)

Mali konusni i zašiljeni drveni dio koji služi za zaptivanje prethodno izrađenih rupa za šavove ili za spajanje jezičaca u spoju utor i jezičac

Monoksil, ladva (*Logboat*)

Plovilo izrađeno iz izdubljenog trupca

Monoksil dograđen vojevima (*Extended logboat*)

Plovilo s izdubljenim trupcem kao osnovnim elementom, koji je dograđen vojevima (jednim ili više)

Mrtvi voj (*Stealer / drop strake*)

Voj kojem se jedan ili oba kraja ne pružaju cjelokupnom dužinom oplate već jednostavno završava između dva voja koja ga zatvaraju

O

Oplata (*Planking*)

Vanjska obloga ili ljuska trupa

P

Paklina (*Pitch*)

Viskozna materijal za zaštitu drva i osiguravanje vodonepropusnosti trupa, biljnog ili mineralnog porijekla

Platica (*Plank*)

Osnovni drveni element oplate trupa

Preklopna gradnja (*Clinker-built*)

Tehnika gradnje u kojoj se platice vanjske oplate spajaju, preklapajući nižu platicu

Prošireni monoksil (*Expanded logboat*)

Plovilo koje kao osnovu ima izdubljeni trupac, koji je grijanjem i omekšavanjem vatom proširen u novu formu trupa

R

Rebrenica (*Floor-timber*)

Drveni dio položen poprijeko kobilice

Rebreni nastavak, priklad (*Futtock*)

Drveni dio u sredini elemenata rebra. U antičkoj brodogradnji jedan dio rebra u produžetku rebrenice

Rebro (*Frame*)

Poprečni drveni element sačinjen iz jednog ili više dijelova, sastavni dio trupa

Rubni šav (*Over-edge stitch*)

Vrsta jednostrukog šava, bez preklopnog okreta

S

Slivnica, kaljužni otvor (*Limber hole*)

Otvor usječen na najnižem dijelu broskog rebra, za protok vode

Sljubnica (*Seam*)

Uzdužni spoj između dviju platica

Spoj utor i jezičac (*Mortise-and-tenon joint*)

U grčko-rimskoj brodogradnji sistem sastavljanja oplate na način da se drvena pločica (jezičac) umeće u utor na boku platice te pričvršćuje malim drvenim čavlom

Statva (*Post*)

Okomiti ili zakrivljeni drveni element ili više njih, koji je uzdužno spojen s kobilicom na pramcu (pramčana statva) ili na krmu (krmna statva)

Stična (glatka) gradnja (*Flush laid (carvel-built)*)

Tehnika gradnje oplate kojom se sljubljuju bočne strane platica

Š

Šav (*Stitch*)

Cjelovit prolaz ligaturom ili udjevenom iglom kroz rupu na platicama

Šivani brod (*Sewn-boat*)

Izraz za bilo koji brod koji koristi potpuno ili djelomično različite tehnike sastavljanja uz pomoć ligatura (šivanje, vezanje...)

Šivanje (*Sewing*)

Tehnika kontinuiranog uzdužnog spajanja ligaturama, sa šavovima sašivenim kroz drvene dijelove

T

Tipla (*Dowel*)

Cilindrični drveni dio (jednog presjeka) koji prilikom gradnje služi poravnanju dva drvena elementa, osobito platica

Trup, korito (*Hull*)

Vodonepropusno tijelo broda

U

Umetnuti sloj (*Wadding pad*)

Snop vlakana ili smotuljak tkanine postavljen preko sljubnica oplate prije šivanja

Utor (*Mortise*)

Utor koji je izrađen na drvenom dijelu broda. U grčko-rimskoj brodogradnji to je utor izrađen u bočnom dijelu platice radi omogućavanja umetanja jezičca

Uzvoj (*Turn of the bilge*)

Dio trupa između dna i boka

Uzvojna platica/voj (*Bilge plank/strake*)

Platica/voj postavljena na uzvoju

V

Vezanje (*Lashing*)

Tehnika spajanja ligaturama jednim samostalnim šavom (vezom)

Voj (*Strake*)

Uzdužni red platica koji se pruža od pramca do krmu

Z

Završni voj (*Sheerstrake*)

Najgornji kontinuirani voj bočne oplate koji opisuje liniju palubnog uzvoja

Glossary of the principal nautical terms used in the volume

Term

Definition

B

Bilge plank/strake (*Uzvojna platica/voj*)

A plank/strake placed at the turn of the bilge

C

Clinker-built (*Preklopna gradnja*)

A vessel constructed so that its outer planking overlaps, and is fastened to the plank immediately below it

D

Dowel (*Tipla*)

A cylindrical piece of wood (of constant diameter) used to align two members during building, especially planks

E

Expanded logboat (*Prošireni monoksil*)

A boat that has a hollowed-out log as its basic component, which is heated and softened over fire and then expanded out into a new hull form

Extended logboat

(*Monoksil dograđen vojevima*)

A boat that has a hollowed-out log as its basic component, which is enlarged by attaching one or more strakes

F

Flat bottom-based construction

(*Konstrukcija zasnovana na ravnom dnu*)

A term used to describe the construction process in which the shape and the structure are determined and organized around the first-made flat bottom, with or without carved bilge strakes

Floor-timber (*Rebrenica*)

A timber laid across the keel

Flush laid (carvel-built)

(*Stična (glatka) gradnja*)

Technique of building the planking by fastening the planks edge to edge

Frame (*Rebro*)

A transverse timber, or line or assembly of timbers as a part of the hull

Futtock (*Rebreni nastavak, priklad*)

A frame timber in the middle of a frame. In ancient shipbuilding, one of the frame timbers extending the floor-timber

H

Hook scarf (*Ključ na zub*)

The union of two planks or timbers whose angular ends are offset to lock the joint. Hook scarfs join the keel with the end posts, and are sometimes locked with wedges, or keys

Hull (*Trup, korito*)

The watertight body of a vessel

K

Keel (*Kobilica*)

The main longitudinal timber of the ship hull

L

Lashing (*Vežanje*)

Technique of assembly using ligatures with single, independent stitches

Lath (*Letvica*)

A thin, narrow strip of wood placed above the seams of the planking in order to secure fibrous material and assure the seams are watertight

Ligature (*Ligatura*)

A cord that serves for sewing or fastening

Limber hole (*Šlivenica, kaljužni otvor*)

Opening cut in the bottom of a frame to allow water to drain

Logboat (*Monoksil, ladva*)

A boat made from a hollowed tree trunk

M

Midship frame (*Glavno rebro*)

The frame at the greatest breadth of the hull

Mortise (*Utor*)

A cavity cut into a timber. In Greco-Roman shipbuilding, a hole cut in the thickness of a plank to fit a tenon

Mortise-and-tenon joint

(*Spoj utor i jezičac*)

In Greco-Roman shipbuilding, a system of assembly of the planking in which a tongue of hardwood (tenon) is inserted in a hole (mortise) opened in the thickness of the plank, and fastened by a peg

N

Nail (*Čavao*)

Metallic element used to assemble timbers

O

Oblique scarf (*Kosi ključ*)

A joint used to longitudinally connect two planks thus forming a strake of the vessel

Over-edge stitch (*Rubni šav*)

A stitch forming a single loop, without clamping turn

P

Peg (*Mali drveni čavao*)

A small tapered and faceted wooden pin driven into a pre-drilled hole to fix the stitches or to lock tenons in mortise-and-tenon joints

Pitch (*Paklina*)

A viscous substance for protecting wood and ensuring the watertightness of the hull, of vegetal or mineral origin

Plank (*Platica*)

A timber belonging to the planking of the hull

Planking (*Oplata*)

The outer shell of the hull

Post (*Statva*)

A vertical or upward curving timber or assembly of timbers, joined longitudinally to the keel on the bow (stem or the stern (stempost))

S

Seam (*Sjubnica*)

A longitudinal joint between two planks

Sewing (*Šivanje*)

Technique of continuous longitudinal assembly using ligatures with stitches sewn through the wood

Sheerstrake (*Završni voj*)

Uppermost continuous strake of side planking describing the sheer line of a vessel

Sewn-boat (*Šivani brod*)

Expression for any boat that uses – entirely or partially – different assembly techniques using ligatures (sewing, lashing ...)

Shell (*Ljuska*)

The external planking of a vessel

Shell-first construction

(*Konstrukcija „prvo ljuska“*)

A term used to describe the construction process in which the hull is constructed by first erecting the keel, and then all or part of the planking before frames are attached to it

Side (*Bok*)

The part of the hull above the turn of the bilge

Skeleton-first construction

(*Konstrukcija „prvo kostur“*)

A term used to describe the construction process in which the hull is constructed by first erecting the keel and the frames, and then attaching the planking to them

Stealer / drop strake (*Mrtvi voj*)

A strake in which one or both extremities do not extend from bow to stern but simply end between two strakes which enclose it

Stitch (*Šav*)

One complete movement of a ligature or a threaded needle to join two elements (planks)

Strake (*Voj*)

A continuous line of planks, running from bow to stern

T

Tenon (*Jezičac*)

A rectangular tongue, inserted into corresponding mortises. In Greco-Roman shipbuilding, a tongue of hardwood inserted in a mortise, and fastened by a peg, used in mortise-and-tenon joint

Timber (*Drveni brodski dio/element*)

In general context, all wooden hull members

Treenail (*Čivija, drveni čavao*)

Tapered rounded and faceted piece of wood used to assemble timbers

Turn of the bilge (*Uzvoj*)

Part of the hull between the bottom and the side

W

Wadding pad (*Umetnuti sloj*)

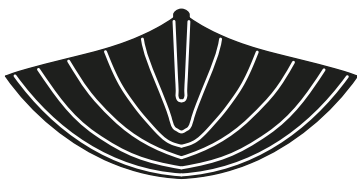
A bundle of fibres or a roll of fabric placed over the seams of the planking prior to sewing

Wale (*Bokoštitnica, žuljnica*)

A thick strake of planking located along the side of a vessel for the purpose of girding and stiffening the outer hull

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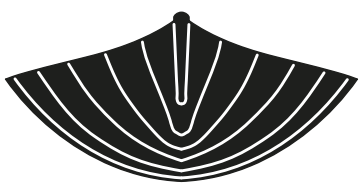
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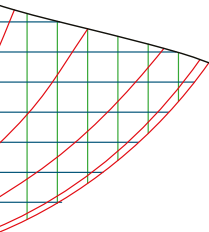
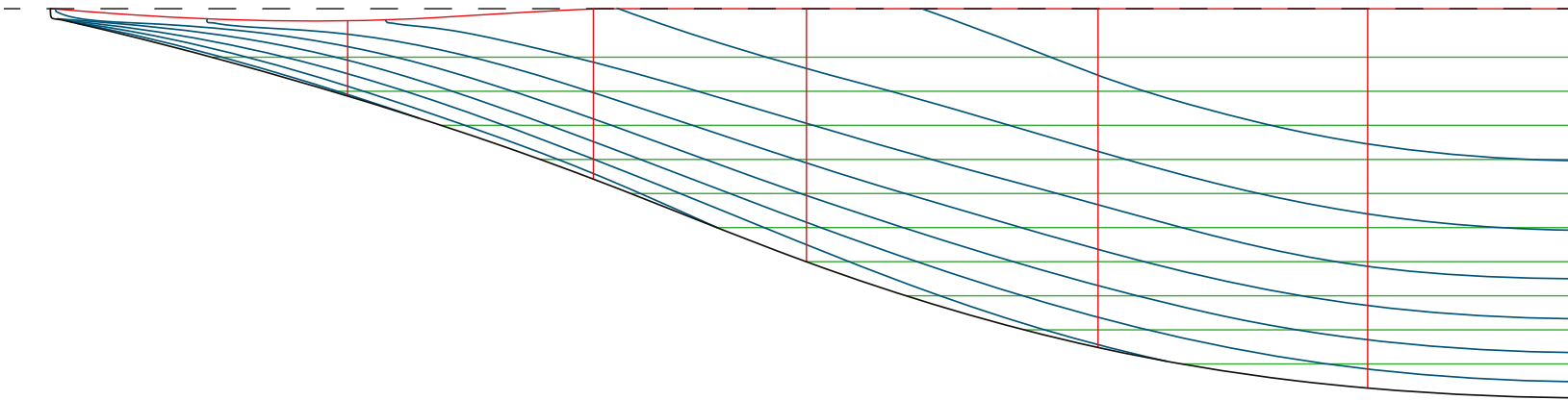
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