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Uredile / Edited by
Irena Radić Rossi – Giulia Boetto

PAKOŠTANE VELI ŠKOLJ

Kasnoantički brodolom u geološko-geografskom
i kulturno-povijesnom kontekstu

The Late Roman shipwreck in its geological-geographic
and cultural-historical context



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Nenad Cambi
Marie-Brigitte Carre
Damir Magaš

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PODMORSKO ISTRAŽIVANJE I ANALIZA BRODSKE KONSTRUKCIJE

UNDERWATER RESEARCH AND ANALYSIS OF THE HULL STRUCTURE

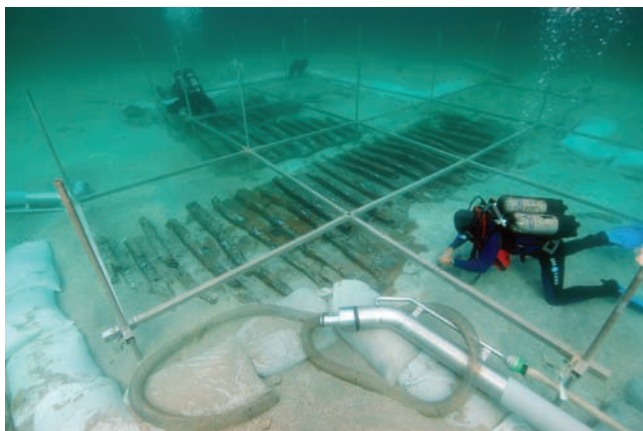
Nakon detaljnog planiranja podmorskog zahvata i potpisivanja sporazuma o suradnji među suradničkim institucijama⁴, prva istraživačka kampanja na nalazištu brodoloma kod otočića Velog Školja (Sl. 11) realizirana je tijekom druge polovine lipnja i početkom srpnja 2007. godine, u trajanju od 20 radnih dana. Njezini osnovni ciljevi bili su istražiti i dokumentirati nalazište po metodološkim načelima arheologije broda, ispitati mogućnosti primjene fotogrametrijskog snimanja za detaljno dokumentiranje brodske konstrukcije, uvježbati međunarodni tim stručnjaka za rad na istraživanju brodskih olupina te zaštititi ugroženo podmorsko arheološko nalazište.

The first excavation campaign at the shipwreck site at the islet of Veli Školj (Fig. 11) was carried out during the second half of June and early July 2007, for a duration of 20 days, following the detailed planning of the underwater project, and the signing of a cooperation agreement between the participating institutions⁴. Its primary objectives were to excavate and document the site in line with the methodological principles of nautical archaeology, examine the possibility of applying photogrammetric recording for detailed documentation of the hull structure, train an international team of experts for work on excavating a wreck, and protect the threatened underwater archaeological site.



Sl. 11 Pogled na nalazište i otočić Veli Školj tijekom istraživanja 2008. (foto: Ph. Groscaux).

Fig. 11 View of the site and the islet of Veli Školj during the 2008 excavation campaign (photo: Ph. Groscaux).



Sl. 12 Pogled na nalazište početkom istraživanja 2007. (foto: Ph. Groscaux).

Fig. 12 View of the site at the beginning of the 2007 excavation campaign (photo: Ph. Groscaux).

METODOLOGIJA I TIJEK ISTRAŽIVANJA

Ostatci broda počivaju na morskom dnu, na dubini od 2,5 do 2,75 m, pokriveni razmjerno tankim slojem čistog rastresitog pijeska, u neposrednoj blizini velikog polja posidonije. Sloj pijeska koji štiti olupinu podložan je utjecaju morskih mijena, strujanja i ostalih morskih gibanja. Uzimajući u obzir opisanu situaciju i povećanu frekvenciju turista u ljetnim mjesecima, ostatci brodoloma bili su višestruko ugroženi, pa se sustavno istraživanje pokazalo kao najprimjerenija opcija zaštite nalazišta. Osim toga, već spomenuta mala dubina, dobra vidljivost, relativno dobra očuvanost i podrška lokalne zajednice utjecali su na odluku da se upravo na tome mjestu započne s projektom hrvatsko-francuske suradnje u području arheologije broda⁵.

Blizina pakoštanske luke i korištenje razmjerno jeftine i lako dostupne opreme za istraživanje koja je uključivala drveni brodić za prijevoz ronilaca i malu vodenu pumpu za pokretanje podvodnih sisaljki također su doprinijeli uspješnoj realizaciji projektne ideje. Vremenski uvjeti tijekom obje istraživačke kampanje, uz manje probleme izazvane jakim jugoistočnim vjetrom, uglavnom su pogodovali istraživanju, a samo u nekoliko kratkotrajnih situacija uzrokovali su prekidanje podmorskog iskopavanja.

Istraživanje je započelo identificiranjem zone u kojoj se radilo tri godine ranije. Nakon utvrđivanja točne pozicije nalazišta i pripreme sidrene pozicije, postavljeno je pomoćno metalno mrežište sastavljeno od kvadrata dimenzija 2 x 2 m (Sl. 12). Nad najbolje očuvanim dijelom broda mrežištem je zahvaćena površina od 40 m² (od južnog kraja olupine do rebra F118E u njegovom istočnom dijelu), (Sl. 16/2007), a potom su ostatci broda temeljito očišćeni od pijeska (Sl. 13, 14). Rastresiti fini pijesak s okolnog morskog dna, koji se bez prestanka urušavao u sondu, uzrokovao je odluku da se profili sonde učvrste vrećama s pijeskom, složenima u dva do tri sloja. Nakon blokiranja erozije pješčanog sedimenta bilo je



Sl. 13 Čišćenje drvenih ostataka broskog trupa (foto: Ph. Groscaux).

Fig. 13 Cleaning of the wooden hull remains (photo: Ph. Groscaux).

METHODOLOGY AND COURSE OF THE RESEARCH

The remains of the ship rest on the seabed, at depths of 2.5 to 2.75 m, covered with a relatively thin layer of pure, loose sand, in the immediate vicinity of a large Posidonia meadow. The layer of sand protecting the wreck is subject to tidal motion, currents and other marine movements. Taking into account the described situation and the increased frequency of tourists in the summer months, the remains of the shipwreck were threatened on multiple occasions, so that systematic research has emerged as the most appropriate option for protecting the site. Additionally, the already noted shallow depth, good visibility, its relatively good condition and the support of the local community have influenced the decision to launch the Franco-Croatian nautical archaeology cooperation project precisely at this site.⁵

The proximity of the Pakoštane harbour and the use of relatively inexpensive and readily available gear for excavation work, including a small wooden boat to convey the divers and a small pump to run the water dredges, also contributed to the successful implementation of the project. Besides some minor problems caused by a strong south-east wind, the weather was generally conducive to the work, and only a few brief incidents led to interruptions in the underwater excavation.

The excavation campaign began with the identification of the zone in which work had been done three years before. After ascertaining the exact position of the site and preparation of the anchoring spot, a metal grid frame consisting of 2 x 2 m squares was installed (Fig. 12). The grid covered a surface of 40 m² (from the end of the hull to frame F118E in its eastern section), (Fig. 16/2007). It was positioned above the best-preserved part of the hull, and the wooden remains were thoroughly cleaned of sand (Fig. 13, 14). The loose fine sand

moguće detaljno očistiti od pijeska čitavu površinu sonde, a na mjestima bez nalaza otkriti matičnu stijenu na kojoj olupina izravno počiva (Sl. 14, 15).

S obzirom na ograničeno vrijeme istraživanja, tijekom istraživačke kampanje 2007. nije bilo moguće u cijelosti istražiti brodolom, pa je zapadni dio ostao neistražen (prostor između rebara F117W i F123W). Na već ranije istraživanom dijelu broda nisu uočeni nikakvi keramički predmeti, uz iznimku grla amfore (Sl. 17), slučajno pronađenog u jugoistočnom dijelu sonde prilikom pokrivanja nalazišta. Tijekom iskopa, međutim, uočene su među rebrima manje nakupine granja (Sl. 18)⁶ i komadić konopa (Sl. 86)⁷ koji je vjerojatno pripadao brodskoj snasti⁸.

Godine 2008. odlučeno je nastaviti započeti posao i definirati granice nalazišta u smjeru sjevera. S obzirom na raspoloživo vrijeme, dio istražen u prethodnoj istraživačkoj kampanji ostao je zaštićen geotekstilom i slojem pijeska, a za potrebe preciznog objedinjavanja dokumentacije otvoren je tek dio između rebrenica F117W i F123W. Na isti način, u smjeru istoka, dio broda istražen tijekom 2007. otvoren je samo od rebrenice F117E.

Istraživanje se odvijalo u dvije faze. U prvoj fazi otvorena je površina od 24 m² (kvadrati C3 – H3, od F117E/F117W do F124E/F124W), a potom su u smjeru sjevera dodani kvadrati



Sl. 15 Pogled na očišćeni dio brodske konstrukcije, matičnu stijenu i vreće s pijeskom (foto: Ph. Groscaux).

Fig. 15 View of the cleaned part of the hull, bedrock and sandbags (photo: Ph. Groscaux).



Sl. 14 Fino čišćenje matične stijene na kojoj počiva brodolom; u pozadini vreće s pijeskom za sprječavanje urušavanja profila sonde (foto: V. Frka).

Fig. 14 Fine cleaning of the rocky substratum; sandbags preventing the erosion of the trench profile in the background (photo: V. Frka).

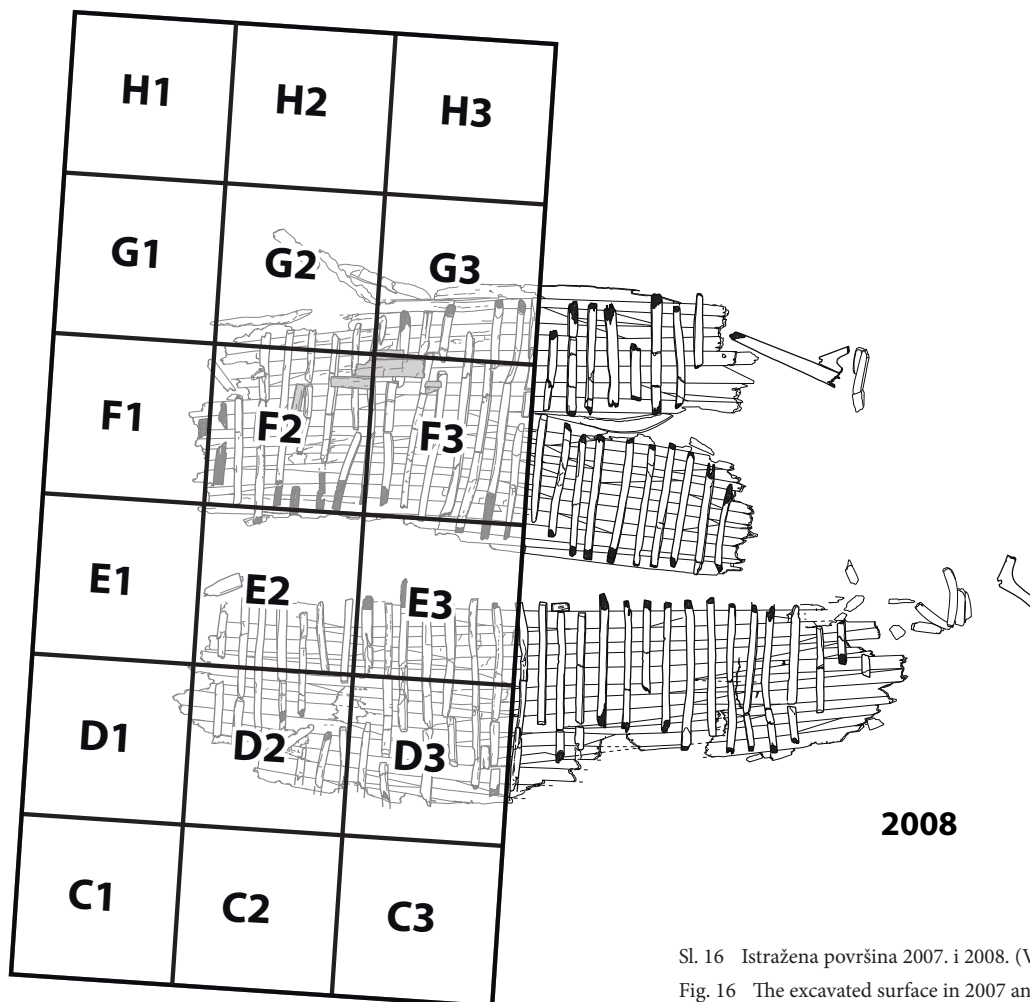
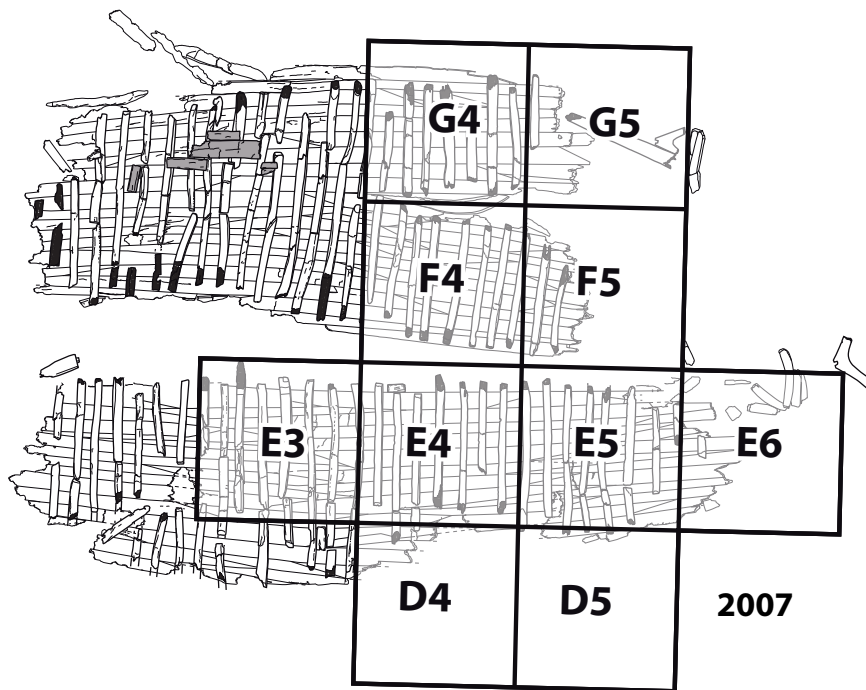
from the surrounding seafloor, which constantly poured into the trench, prompted the decision to reinforce the contours of the trench with sandbags, placed in two to three layers. After blocking the erosion of the sandy sediment, it was possible to thoroughly clear the sand from the entire surface of the trench, and, at places without finds, uncover the bedrock on which the hull directly rests (Fig. 14, 15).

Given the time constraints on the research, during the excavations in 2007 it was not possible to entirely explore the shipwreck, so the western part remained unexcavated (the space between frames F117W and F123W). No ceramics were discovered in the part of the ship already excavated earlier, with the exception of an amphora neck (Fig. 17), found by chance in the south-east section of the test trench when covering the site. During the dig, however, smaller clusters of dunnage (Fig. 18),⁶ and a piece of rope (Fig. 86)⁷ probably belonging to the ship's rigging, were observed.⁸

The 2008 excavation campaign lasted 20 days and was carried out in May. The decision was made to begin the work and define the boundaries of the site in the northerly direction. Given the available time, the part examined in the previous campaign remained under protection by geotextile and a layer of sand, while for the needs of precise consolidation of the documentation, only a portion between floor timbers F117W and F123W was uncovered. The part of the ship examined in 2007 was similarly uncovered in an easterly direction only from floor timber F117E.

The work proceeded in two phases. In the first phase, a surface of 24 m² (squares C3-H3, from F117E/F117W to F124E/F124W) was uncovered, and then squares C2-H2 and C1-H1 were added in the northerly direction, in order to encompass the entire preserved section of the ship (Fig. 16/2008). The overall surface encompassed by the research work thereby reached 72 m².

In the zone encompassed by excavations in 2007, the opening of the site proceeded rather rapidly, and it consisted



Sl. 16 Istražena površina 2007. i 2008. (V. Dumas).

Fig. 16 The excavated surface in 2007 and 2008 (V. Dumas).



Sl. 17 Grlo velike afričke amfore za skladištenje namirnica (foto: L. Damelet).

Fig. 17 Neck of a large storage African amphora (photo: L. Damelet).



Sl. 18 Granje za zaštitu brodskog tereta (foto: Ph. Groscaux).

Fig. 18 Wooden branches interpreted as dunnage (photo: Ph. Groscaux).

C2 – H2 i C1 – H1, kako bi se obuhvatio čitav očuvani dio broda (Sl. 16/2008). Time je sveukupna površina zahvaćena istraživanjem dosegla 72 m².

U zoni zahvaćenoj istraživanjem 2007. otvaranje nalazišta teklo je razmjerno brzo, a sastojalo se od uklanjanja vreća s pijeskom i geotekstila, postavljenih s ciljem privremene zaštite drvene građe. Nakon toga, čišćenje preostalog dijela broda nastavilo se uz pomoć vodenih sisaljki.

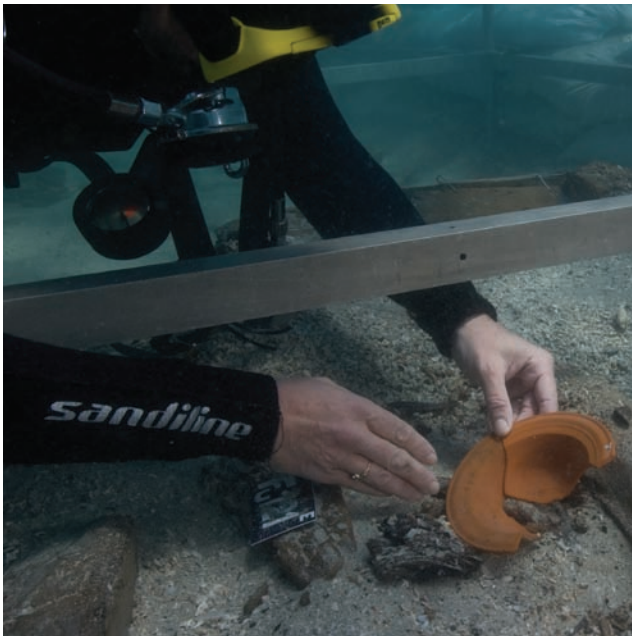
of removing the sandbags and geotextile installed with the aim of temporarily protecting the wooden materials. The cleaning of the remaining portion of the ship then continued with the use of water dredges.

A cultural layer was discovered in the eastern section of the shipwreck, particularly in the area of squares F2 and F3, which had not been previously excavated (Fig. 16/2008). It contained a number of ceramic fragments (Fig. 19), belonging



Sl. 19 Područje s keramičkim ulomcima i ostalim sitnim nalazima (foto: Ph. Groscaux).

Fig. 19 Area with pottery shards and other small finds (photo: Ph. Groscaux).



Sl. 20 Zdjelica (afrička keramika s crvenim premazom) u području pretpostavljene kuhinje (foto: V. Frka).

Fig. 20 Bowl (African red slip ware) in the presumed galley area (photo: V. Frka).



Sl. 21 Poklopac za kuhanje s bademastim obodom (foto: L. Damelet).

Fig. 21 Cooking lid with almond-shaped rim (photo: L. Damelet).



Sl. 22 Opeka iz broskog ognjišta (foto: L. Damelet).

Fig. 22 Brick from the ship's hearth (photo L. Damelet).

U istočnom dijelu brodoloma, a posebno na području kvadrata F2 i F3 koji prije nisu bili istraženi (Sl. 16/2008), otkriven je kulturni sloj s brojnim fragmentiranim keramičkim nalazima (Sl. 19). Riječ je o ulomcima posuđa (Sl. 20, 21), ambalaže (amfore) i građevinskog materijala (Sl. 22)⁹. Osim toga, pronađeni su i drugi predmeti (Sl. 23, 24, 28, 29)¹⁰ te brojni komadići granja među kojima i primjerci sa spaljenim krajem¹¹. Sveukupni materijal otkriven u tome prostoru zasigurno pripada samome brodu jer je pronađen među brodskim rebrima i u izravnom kontaktu s brodskom oplatom. Neki su ulomci skliznuli i pod platice unutrašnje oplote koje su se još uvijek nalazile *in situ* (poput npr. platice C4E).



Sl. 23 Žeton izrađen od ulomka *terra sigillata* posude (foto: Ph. Groscaux, mjerna traka u cm).

Fig. 23 Token made of a fragment of terra sigillata vessel (photo: Ph. Groscaux, scale in cm).

to pottery (Fig. 20, 21), transport containers (amphorae) and building materials (Fig. 22).⁹ Besides this, other items were found (Fig. 23, 24, 28, 29),¹⁰ as well as many pieces of branches, among which some had charred ends.¹¹ The overall materials discovered in this area certainly belonged to the ship itself, because they were found among the frames and in direct contact with the planking. Some fragments had also slipped below the ceiling planks, which were still located *in situ* (such as, e.g., planks C4E).

Even though the ceramic shards were not firmly embedded in the layer, due to its already described composition, it was noted that these were rather homogenous materials, and during analysis many pieces of the same items were assembled into a single whole.¹² The remains of animals,¹³ charcoal¹⁴ and seeds¹⁵ were relatively rare, which may be ascribed to the composition of the sediment that was not conducive to their preservation. At the moment of the appearance of a higher quantity of tiny movable finds, the search strategy was adapted to this situation, and all more significant items were documented in their original position. The selected items, designated with numbers from 1 through 51, mainly consist



Sl. 24 Ulomak keramičke uljanice (foto: L. Damelet).

Fig. 24 Fragment of ceramic lamp (photo: L. Damelet).



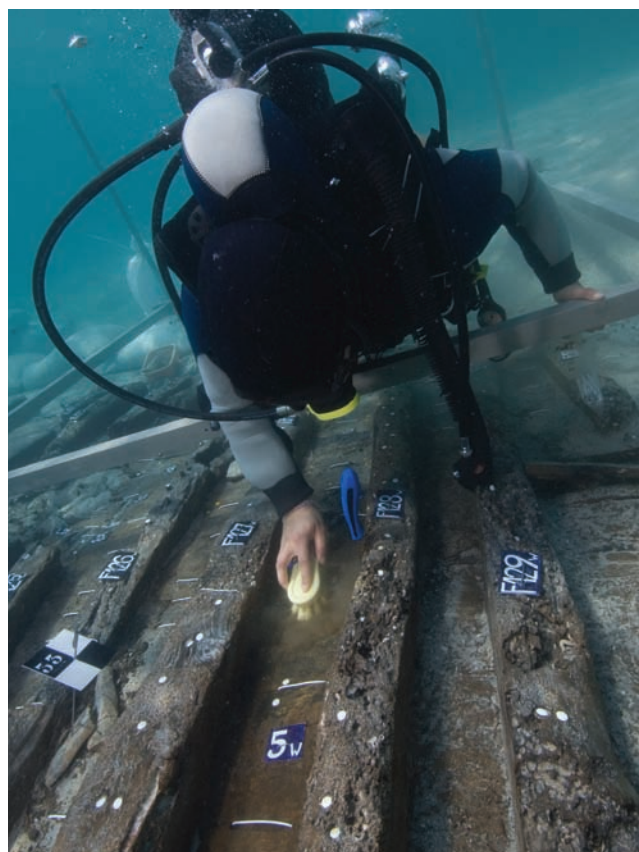
Sl. 25 Označavanje rebara (desno) i uklanjanje sedimenta između rebara (lijevo), (foto: R. Mosković).

Fig. 25 Labelling the frames (on the right) and fine cleaning between the frames (on the left), (photo R. Mosković).



Sl. 26 Označavanje rebara (foto: Ph. Groscaux).

Fig. 26 Labelling the frames (photo Ph. Groscaux).



Sl. 27 Uklanjanje zaštitnog sloja smole u potrazi za drvenim čavlicima koji učvršćuju jezičce (foto: V. Frka).

Fig. 27 Removing the protective layer of pitch in search of the wooden pegs for fixing the tenons (photo: V. Frka).



Sl. 28-29 Kasnoantički (?) novac PK08/65 i PK08/135 (foto: Ph. Groscaux).

Fig. 28-29 Late Roman (?) coins PK08/65 and PK08/135 (photo: Ph. Groscaux).

Iako keramika nije bila čvrsto blokirana u sloju, zbog njegovog već opisanog sastava, primijećeno je kako je riječ o prilično homogenom materijalu, a mnogi ulomci istih predmeta spojeni su prilikom obrade u jednu cjelinu¹². Ostaci faune¹³, ugljena¹⁴ i sjemenki¹⁵ bili su razmjerno rijetki, što bi se moglo pripisati sastavu sedimenta koji nije pogodovao njihovom očuvanju. U trenutku pojave veće količine sitnih pokretnih nalaza istraživačka je strategija prilagođena situaciji, a svi značajniji predmeti dokumentirani su u svome izvornom položaju. Među odabranim predmetima, označenim brojevima od 1 do 51, našli su se uglavnom rubovi ili dna posuda, ili skupine ulomaka iste posude. Osnovna funkcija brojeva bila je pozicioniranje ulomka ili skupine ulomaka u odnosu na ostale sitne nalaze i drvene dijelove broda. Prije vađenja nalaza situacija je nacrtano i fotografski dokumentirana.

Inventarni broj pripisan nalazima nakon uklanjanja s nalazišta, osim brojčane oznake, sadržavao je kraticu PK i oznaku godine istraživačke kampanje (07 ili 08). Ulomci koji su očigledno pripadali istoj posudi ili su sastavom bili vrlo slični označeni su jednim inventarnim brojem i podbrojevima za svaki pojedini ulomak.

Po završetku detaljnog čišćenja uz pomoć fleksibilnih usisnih cijevi pričvršćenih na vodenu sisaljku, tijekom obje istraživačke sezone pristupilo se označavanju brodske konstrukcije (Sl. 25, 26). Za potrebe sustavnog označavanja stičnih spojeva među platicama bilo je potrebno, nakon dokumentiranja, mjestimično ukloniti zaštitni sloj smole (Sl. 27). Pojedini nedovoljno stabilni elementi kojima je prijetilo odvajanje od ostatka konstrukcije učvršćeni su uz pomoć žice i vrećica ispunjenih pijeskom (Sl. 30).

Prije negoli je započelo proučavanje drvenih ostataka broda, svi su sastavni elementi brodske konstrukcije obilježeni četvrtastim oznakama, bijelim i žutim zakovicama i bijelom žicom. Takav pristup neophodan je pri pregledu, mjerenju, izradi fotogrametrijske i tradicionalne dokumentacije, dokumentiranju detalja, uzimanju dendrokronoloških uzoraka i svih ostalih uzoraka namijenjenih arheometrijskim, botaničkim i/ili zoološko-paleontološkim analizama (Pomey, Rieth, 2005).



Sl. 30 Učvršćivanje elemenata brodske konstrukcije uz pomoć malih plastičnih vrećica ispunjenih pijeskom (foto: V. Frka).

Fig. 30 Fixing the structure with small plastic bags, filled with sand (photo: V. Frka).



Sl. 31 Oznake s alfanumeričkim kodom pripremljene prije ronjenja (foto: Ph. Groscaux).

Fig. 31 The labels with the alphanumeric codes prepared before the diving (photo: Ph. Groscaux).

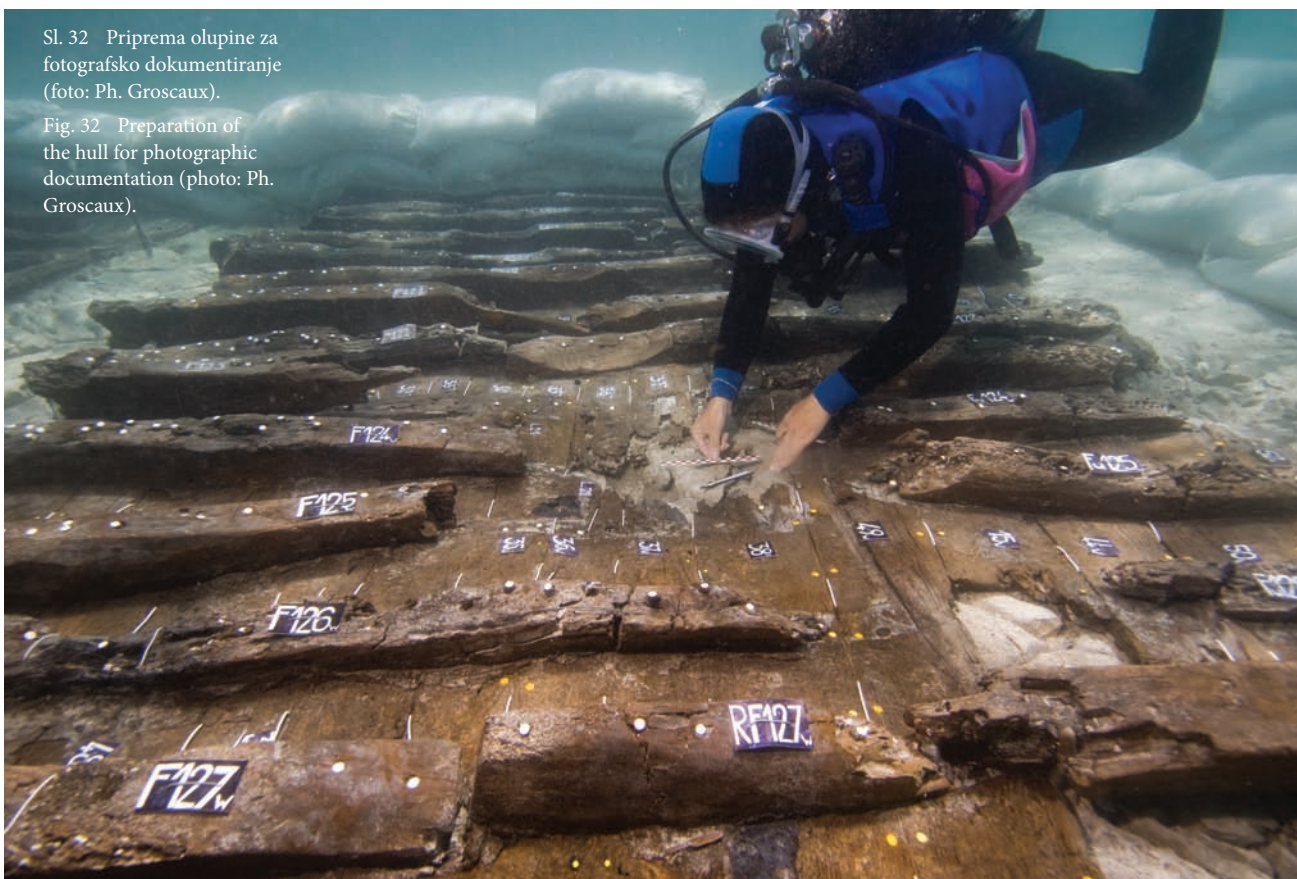
of edges or bases of vessels, or sets of fragments of the same vessel. The basic function of the numbers was to position the fragments or sets thereof in relation to the remaining tiny finds, and wooden components of the ship. Prior to extraction of the finds, the situation was sketched and documented by photographic recording.

The inventory numbers assigned to the finds after removal from the site contained, besides a numerical designation, the abbreviation PK and an indication of the year of the excavation campaign (07 or 08). Fragments that obviously belonged to the same vessel or were very similar in composition were designated with a single inventory number and subordinate numbers for each individual fragment.

Upon the completion of thorough cleaning with the help of flexible suction tubes attached to the water dredges, during both excavation seasons the marking of the structural elements of the hull was done (Fig. 25, 26). For the needs of systematic designation of the joints among the planks, after documentation it was necessary to partially remove the

Sl. 32 Priprema olupine za fotografsko dokumentiranje (foto: Ph. Groscaux).

Fig. 32 Preparation of the hull for photographic documentation (photo: Ph. Groscaux).



Prije svega, označeni su oplata i elementi poprečne čvrstoće broda (rebra). Oznake su izrađene od pravokutno izrezanog bijelog linoleuma čija je bijela površina vodootpornim flomasterom obojena u crno (Sl. 31). Na taj su način oznake istaknute bijelo (u negativu), čime se izbjegla refrakcija svjetlosti prilikom fotografiranja, koja često kvari sliku u slučaju bijele podloge¹⁶.

Alfanumerički kod korišten za označavanje elemenata brodske konstrukcije sastojao se od slova (kratica za element o kojem je riječ), broja dodijeljenog progresivno i oznake za položaj elementa u odnosu na uzdužnu os – E (engl. *East* = istok) i W (engl. *West* = zapad) – tj. os kojom bi prolazila kobilica da je očuvana (Sl. 32). Prilikom označavanja zanemaren je manji otklon od zamišljene osi istok – zapad, radi jasnoće i jednostavnosti u komunikaciji.

S obzirom na izostanak kobilice i statvi, označavanju pomoću strana svijeta pribjeglo se zbog nemogućnosti utvrđivanja položaja pramca i krme broda. U slučaju jasnog položaja broda, položaj elemenata u odnosu na uzdužnu os (kobilicu) bio bi označen kao lijevi (P = engl. *Portside*) ili desni (S = engl. *Starboard*) bok broda.

Kao što je razvidno iz prethodnog teksta, oznake za elemente brodske konstrukcije preuzete su iz engleskog jezika zbog nekoliko razloga. Odlučujući faktor bio je svakako međunarodni sastav istraživačkog tima koji je obuhvaćao stručnjake i studente iz Hrvatske, Francuske, Italije i Grčke.

protective layer of resin (Fig. 27). Individual insufficiently stable elements that were in danger of separating from the remaining structure were reinforced with the help of wire and small bags filled with sand (Fig. 30).

Before the study of the ship's wooden remains began, all of the constituent elements of the hull were designated with rectangular tags, white and yellow pins and white wire. Such an approach was essential in the inspection, measurement, compilation of photogrammetric and traditional documentation, documentation of the details, and the taking of dendrochronological samples and all other samples intended for archaeometric, botanical and/or zoological/paleontological analyses (Pomey, Rieth, 2005).

The ship's planking and transversal elements (frames) were marked first and foremost. The labels were made of rectangularly cut white linoleum, of which the surface was coloured black with a waterproof marker (Fig. 31). In this manner, the markers were distinguished in white (in negative), thereby avoiding light refraction during photographing, which often ruins photographs in cases of white backgrounds.¹⁶

The alphanumeric code used to designate the structural elements of the hull consisted of letters (abbreviation for the relevant element), progressively assigned numbers and designations for the position of the elements in relation to the longitudinal axis: E (east) and W (west), i.e., the axis along

Osim toga, terminologija arheologije broda na hrvatskom jeziku bila je u to vrijeme krajnje ograničena, pa za mnoge elemente nije bilo moguće u kratkom vremenskom roku pronaći odgovarajući prijevod. Iako se do danas situacija promijenila, a rad na standardiziranju terminologije arheologije broda uzeo maha (Radić Rossi, 2012; 2017), engleski se termini i dalje koriste da bi se osiguralo razumijevanje i izbjegli nesporazumi unutar istraživačkog tima.

Osnovna terminologija na engleskom jeziku dobro je razrađena i jasna, pa se i zbog toga pribjegavanje takvom rješenju pokazalo najučinkovitijim. Osim toga, baza podataka u tom je slučaju dostupna svim stručnjacima, a za potrebe publiciranja na drugim jezicima ne pojavljuje se problem jasnoće pri prevođenju.

S obzirom na navedene argumente, oznakom P (engl. *plank*) označene su platice koje čine oplatu broda, oznakom F (engl. *frame*) rebra, oznakom Fu (engl. *futtock*) rebreni nastavci, oznakom RF (engl. *repair of frame*) popravci izvedeni na brodskim rebri, oznakom C (engl. *ceiling*) platice unutrašnje oplate i proveze¹⁷ i oznakom St (engl. *stanchion*) upore. Brojne pločice olovnog lima korištene za popravak broskog trupa obilježene su oznakom L (engl. *lead*) u značenju olova, uz dodatak progresivno rastućeg broja i oznake strane svijeta s obzirom na uzdužnu os nalaza.

Ulomci oplate, orebrenja i neidentificiranih drvenih elemenata pronađeni u sloju, nevezani za glavnu konstrukciju, dobili su umjesto alfanumeričkog koda samo brojčanu oznaku, poput ostalih pokretnih nalaza pronađenih nad olupinom. Za potrebe uvođenja u inventar nalaza svim je izvađenim elementima pridijeljen inventarni broj koji se sastojao od kratice PK07 ili PK08 (ovisno o godini istraživanja) i odgovarajućeg progresivno rastućeg broja.

Druga skupina oznaka koristila se za obilježavanje raznih značajki brodske konstrukcije ili zanimljivih pojedinosti te spojnih elemenata. Stični, tj. sljubni spojevi među platicama označeni su komadima galvanizirane željezne žice obloženima bijelom plastičnom izolacijom, utisnutima na određenim razmacima u same spojeve (Sl. 33).

Nešto tanja žica istog sastava kao i prethodna poslužila je za označavanje metalnih čavala korištenih za međusobno spajanje elemenata brodske konstrukcije. Bijele zakovice korištene su za označavanje drvenih čavala (čivija) uz pomoć kojih su rebra bila spojena za oplatu, a žute za označavanje čavlića koji su jezičice utisnute u utore fiksirali za platice (Sl. 33).

Nakon toga pristupilo se promatranju, bilježenju i proučavanju svih zanimljivih pojedinosti. Prije svega, promatranje i mjerenje provedeno je na središnjim dijelovima brodskih rebara kako bi se utvrdilo je li riječ o rebrenicama, polurebrenicama ili rebrenicama nejednakih krakova te kako bi se zabilježio njihov oblik (pravokutni ili kvadratni presjek, presjek u obliku četvrtine kruga i dr.). U slučaju svakog rebra uzete su osnovne mjere (očuvana duljina, širina i visina), a

which the keel would have ran had it been preserved (Fig. 32). During this designation process, a minor deviation from the ideal east-west axis was neglected for the sake of clarity and simplicity in communication.

Given the absence of a keel and posts, marking with the help of compass directions was used because of the impossibility of ascertaining the position of the ship's stem and stern. Insofar as the ship's position had been clear, the position of the elements in relation to the longitudinal axis (keel) would have been designated as the ship's portside (P) or starboard (S).

As apparent from the preceding text, the designations for the elements of the hull were taken from the English language for several reasons. The decisive factor was certainly the international structure of the research team, which included experts and students from Croatia, France, Italy and Greece. Besides that, the terminology of nautical archaeology in the Croatian language was extremely limited at the time, so it was not possible to find adequate translations for many elements in such a brief period. Even though today the situation has changed, and work on a standardized terminology for nautical archaeology has progressed significantly (Radić Rossi, 2012; 2017), the English terms are still used in order to ensure clarity and avoid misunderstandings within the research team.

The basic terminology in English is well-developed and clear, so adopting such a solution has proven the most effective solution. Additionally, the database in this case is accessible to all experts, and the problems of clarity in translation do not then emerge for publication in other languages.

Given these points, the designation P was used for the planks forming the ship's planking, F for frame, Fu for futtocks, RF for frame repairs, C for ceiling (inner hull planks and stringers)¹⁷ and St for stanchion. The numerous lead patches used to repair the ship's hull were designated as L (for lead), with the addition of progressive numbers and designations of the compass directions given the longitudinal axis of the find.

Pieces of the planking, skeleton and unidentified wooden elements found in the layer and not linked to the primary construction were given only numerical designations instead of alphanumeric codes, like the remaining movable finds discovered above the wreckage. For the needs of recording in the inventory of finds, all extracted elements were assigned an inventory number that consisted of the abbreviations PK07 or PK08 (depending on the excavation year) and the corresponding progressively higher number.

The second set of markers was used to designate various features of the hull structure or intriguing details, as well as connective elements. The edges of the strakes were marked with pieces of galvanized iron wire covered by white plastic insulation, inserted at specific intervals in the joints themselves (Fig. 33).



Sl. 33 Označeni detalj brodske konstrukcije; vide se alfanumeričke oznake za rebra, platice i olovne zakrpe, bijela žica za sljubove, bijele zakovice za drvene čavle i žute zakovice za drvene čavlice (foto: Ph. Groscaux).

Fig. 33 Marked detail of the hull: visible alphanumerical codes for frames, planks and lead patches, white wire for seams, white pins for treenails and yellow pins for pegs (photo: Ph. Groscaux).

potom je izmjeren i njihov međusobni razmak. Osim toga, zabilježen je broj svih drvenih i metalnih čavala te njihovi promjeri; položaj, oblik i dimenzije slivnica tj. otvora za protok vode kroz kaljužnicu izvedenima na donjem dijelu rebara te položaj i vrsta tragova brodograđevnog alata na elementima brodske konstrukcije (pila, bradva, tesla i dr.).

U slučaju oplata posebna je pozornost posvećena dokumentiranju širine utora i njihovih međusobnih razmaka, što je bilo moguće izmjeriti samo na rubnim dijelovima brodske konstrukcije, duž vidljivih uzdužnih strana platica. Na mjestima na kojima se mogao razaznati položaj drvenih čavlića za fiksiranje jezičaca tj. na onim mjestima na kojima čavlići nisu bili prekrivni debelim slojem smole koja je s unutrašnje strane štitila brodsko korito izmjereni su njihovi promjeri i međusobne udaljenosti. Posebne tablice mjera napravljene su za potrebe detaljnog dokumentiranja zakrpnih olovnih pločica iskorištenih za brojne reparacije broskog trupa.

Neki elementi potpuno odvojeni od ostatka brodske konstrukcije, a time i u opasnosti od nestanka, izvađeni su, upisani u katalog i izmjereni, a prema potrebi i dokumentirani u mjerilu 1:1 (Sl. 34, 35, 36). Izdvojena su i detaljno dokumentirana i tri manja komada oplata na kojima su se

Somewhat thinner wire of the same composition as that above served to designate the metal nails used to fasten elements of the hull. White pegs were used to designate the wooden nails (or treenails) that helped fasten the frames to the planking, while yellow and white were used to designate the pegs that blocked the tenons into the mortises carved in the thickness of the planks (Fig. 33).

After this, the observation, registration and study of all interesting details began. Above all, observation and measurements were conducted on the central sections of the frames in order to ascertain whether these were floor-timbers, half-frames or asymmetrical floor-timbers, and record their shape (rectangular or square cross-section, quarter circle cross-section, etc.). The basic measurements for each (preserved length, width and height) were taken for each frame, and then the distance between them was also measured. Besides this, the number of all pegs, treenails and nails and their diameters were recorded, as were the position, shape and dimensions of the limber holes, i.e., the openings for the flow of water through the bilge, made on the lower part of the frames, and the position and types of shipwright's tool marks on the elements of the hull (saw, hatchet, shipwright's adze).



Sl. 34 Chiara Zazzaro crta dislocirane ulomke oplate u mjerilu 1:1 (foto: Ph. Groscaux).

Fig. 34 Chiara Zazzaro draws a displaced fragments of planking in scale 1:1 (photo: Ph. Groscaux).

nalazile zakrpnne olovne pločice L24, L25 i L29, kako bi se proučio način reparacije brodskog korita.

Za potrebe mjerenja i nacrtnog dokumentiranja preko nalazišta je postavljena uzdužna os sastavljena od dvije široke aluminijske šipke sveukupne duljine 7 m (Sl. 37) i rastegnute mjerne trake. Šipke su postavljene uzduž zapadnog dokobiličnog voja (P1W), na mjestu na kojem se nekada nalazila kobilica, a poslužile su kao osnovica za sva mjerenja. Uz pomoć vodoravno postavljenih šipki oslonjenih na pomoćno metalno mrežište napravljena su i 24 poprečna presjeka koji prikazuju dijelove rebara i njihove spojeve na oplatu (Sl. 37, 38).

Za potrebe radnog prostora na kopnu odlično je poslužila dvorana za sastanke općinskog vijeća koju je Općina Pakoštane stavila na raspolaganje tijekom obje istraživačke kampanje. U njoj se svakodnevno radilo na prenošenju dokumentacije na papir (Sl. 40, 41) i u digitalni oblik (Sl. 42) te na izradi inventara elemenata brodske konstrukcije i ostalih nalaza.

In the case of the planking, particular attention was dedicated to documentation of the width of the mortises and the distance between them, which was only possible to measure on the peripheral sections of the hull, along the visible longitudinal sides of the planks. At places where the position of the wooden pegs used to block the tenons could be discerned, i.e., at those places where the pegs were not covered with a thick layer of pitch that protected the inner side of the hull, their diameters and distance from one another were measured. Special tables of measurements were compiled for the needs of detailed documentation of the lead patches used to make many repairs to the ship's hull.

Some elements entirely separated from the remainder of the hull, and thus in danger of perishing, were extracted, recorded in a catalogue and measured, and in some cases also documented at a 1:1 scale (Fig. 34, 35, 36). Three small parts of planking, which had lead patches, L24, L25 and L29, attached to them, were also sampled and thoroughly documented in order to study the hull repairs.

A longitudinal axis, consisting of two wide aluminium bars with a total length of 7 m (Fig. 37) and extended measuring tapes were installed over the site for the needs of measurement and sketch documentation. The bars were installed along the western garboard strake (P1W), at the place where the keel once was, and they served as the basis for all measurements. With the help of the horizontally placed bars, leaning on the grid, 24 perpendicular cross-sections were also made, showing the parts of the frames and their connections to the planking (Fig. 37, 38).

The municipal council's conference hall, which the Pakoštane Municipality made available during both excavation campaigns, superbly served the needs of a work space on land. It served to elaborate the traditional (Fig. 40) and digital (Fig. 42) documentation, and the inventory of hull elements, and other finds.



Sl. 35 Pierre Poveda crta uporu St1 u mjerilu 1:1 (foto: Ph. Groscaux).

Fig. 35 Pierre Poveda draws the stanchion St1 in scale 1:1 (photo: Ph. Groscaux).



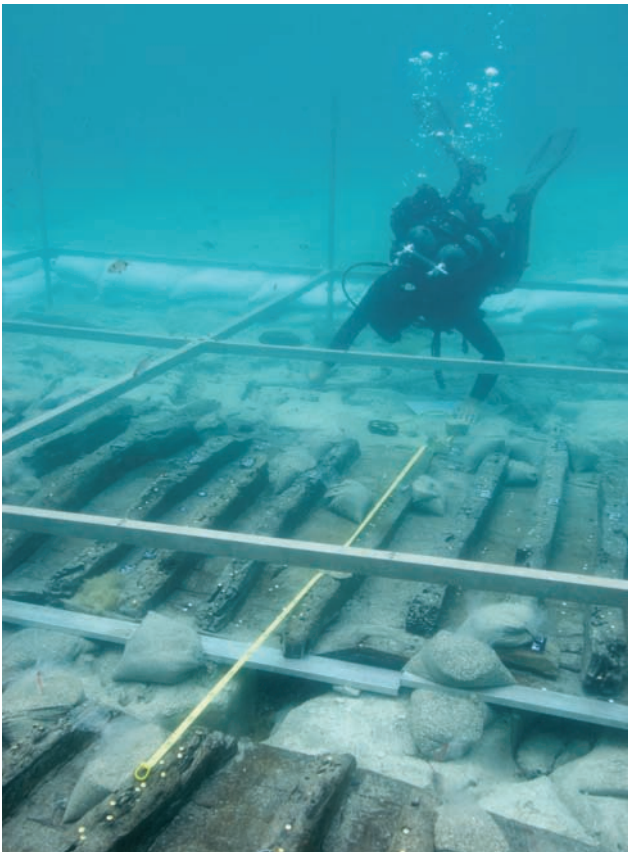
Sl. 36 Kalliopi Baika crta reparaciju rebra u mjerilu 1:1 (foto: V. Frka).

Fig. 36 Kalliopi Baika draws the frame repair in scale 1:1 (photo: V. Frka).

DRAFTING THE SITE MAP

Numeric photogrammetry, already used earlier in underwater archaeological projects, was still not in wide use at the time of the excavations conducted in Pakoštane in 2007 and 2008. Great strides have been made in the past several years, as photogrammetric documentation became available to everyone, and thereby became a part of the standard methodology for underwater archaeological excavations. What follows is a brief description of the procedure applied to the shipwreck near the islet of Veli Školj, in order to preserve a record of the experiences of the time in applying photogrammetry to document ship hulls (Dumas, 2012).

One of the current and relatively easily accessible programmes for photogrammetric documentation of underwater finds at the time was *PhotoModeler* (Eos Systems



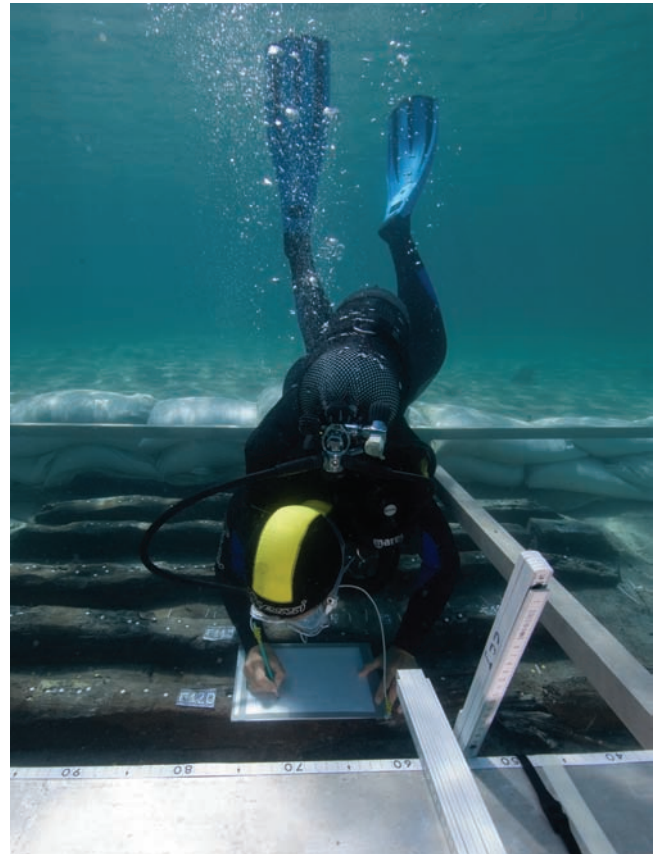
Sl. 37 Uzdužna aluminijska os postavljena za potrebe dokumentiranja duž zapadne dokobilične platice P1W (foto: Ph. Groscaux).

Fig. 37 Longitudinal aluminium axis, placed for documentation purposes along the western garboard P1W (photo: Ph. Groscaux).

IZRADA PLANA NALAZIŠTA

Numerička fotogrametrija, korištena već ranije u podvodnim arheološkim projektima, u vrijeme istraživanja u Pakoštanima 2007. i 2008. godine još uvijek nije bila u širokoj primjeni. Veliki pomaci dogodili su se tijekom posljednjih godina, kad je fotogrametrijsko dokumentiranje postalo dostupno svima, a time i dijelom standardne metodologije podmorskih arheoloških istraživanja. U nastavku teksta ukratko je opisan postupak primijenjen na brodolomu kod otočića Velog Školja kako bi se očuvao zapis o tadašnjim iskustvima primjene fotogrametrije za dokumentiranje brodskih konstrukcija (Dumas, 2012).

Jedan od aktualnih i razmjerno lako dostupnih programa za fotogrametrijsko dokumentiranje podmorskih nalazišta bio je u to vrijeme *PhotoModeler* (Eos Systems Inc.). Dodašnjim radom postignuto je oblikovanje mreže sigurnih referentnih točaka unutar kojih je bilo moguće pozicionirati arheološke nalaze tijekom istraživanja¹⁸ ili modelirati brodske terete (Green, 1991: 8-13; Green *et al.*, 2002; Drap, Long, 2005). Malobrojni radovi rezultirali su i stvaranjem korisne dokumentacije u domeni arheologije broda prilikom otkrića brodoloma u nekadašnjim lučkim bazenima ili u kopnenim kontekstima (Kocabaş, 2008)¹⁹.



Sl. 38 Crtanje poprečnih presjeka (foto: V. Frka).

Fig. 38 Drawing the cross-sections (photo: V. Frka).

Inc.). A network of specific reference points was obtained in previous work, within which it was possible to assign positions to archaeological finds during excavations¹⁸ or model the ship's cargo (Green, 1991: 8-13; Green *et al.*, 2002; Drap, Long, 2005). A modest amount of work resulted in the creation of useful documentation in the field of nautical archaeology during the discovery of shipwrecks in former harbour basins or in dry land contexts (Kocabaş, 2008).¹⁹



Sl. 39 Crtanje poprečnih presjeka, detalj (foto: V. Frka).

Fig. 39 Drawing of the cross-sections, detail (photo: V. Frka).



Sl. 40 Rad na grafičkoj dokumentaciji u terenskoj bazi u Općini Pakoštane: u prvom planu Michel Rival (desno) i Marko Meštrovi i Mate Parica (lijevo); u pozadini Zdenko Brusić, Irena Radić Rossi i Chiara Zazzaro (foto: Ph. Groscaux).

Fig. 40 Working on the graphic documentation in the fieldwork base in the Municipality of Pakoštane: in the first plan Michel Rival (right) and Marko Meštrovi and Mate Parica (left); in the background Zdenko Brusić, Irena Radić Rossi and Chiara Zazzaro (photo Ph. Groscaux).

U slučaju brodoloma kod Pakoštana, cilj projekta nije bio izrada fotorealističnog trodimenzionalnog modela, već definiranje korisnog i lako primjenljivog operativnog protokola zasnovanog na korištenju numeričke fotogrametrije za izradu preciznog plana nalazišta.

Probna su snimanja obavljena u laboratorijskim uvjetima u Centru Camille Jullian. Na osnovi obavljenih eksperimenata uspostavljen je preliminarni radni protokol te su provjereni učinkovitost i ograničenja primijenjene metode. Druga eksperimentalna faza realizirana je na terenu tijekom istraživačke kampanje 2008. godine.

Uzimajući u obzir malu dubinu nalazišta (2–3 m) te razliku od 0,5 m između morskih mijena, za fotogrametrijsko je snimanje u pravilu odabirano vrijeme plime. Osim toga, bilo je potrebno voditi računa o vremenskim uvjetima jer blizina površine u slučaju jačeg vjetera utječe na gibanje



Sl. 42 Robert Mosković i Zdenko Brusić tijekom rada na digitalizaciji dokumentacije (foto: Ph. Groscaux).

Fig. 42 Robert Mosković and Zdenko Brusić engaged in the digitalization of the documentation (photo Ph. Groscaux).



Sl. 41 Radni dogovor u terenskoj bazi u Općini Pakoštane, s lijeva na desno: Irena Radić Rossi, Martina Čelhar, Marko Meštrovi, Mate Parica (foto: V. Frka).

Fig. 41 Briefing in the fieldwork base in the Municipality of Pakoštane, from left to right: Irena Radić Rossi, Martina Čelhar, Marko Meštrovi, Mate Parica (photo: V. Frka).

In the case of the shipwreck at Pakoštane, the project's objective was not to make a photo-realistic three-dimensional model, but rather to define a useful and easily applicable operating protocol based on the use of numerical photogrammetry to create a precise site map.

Test shooting was carried out under laboratory conditions in the Centre Camille Jullian. Based on the completed experiments, a preliminary working protocol was established and the effectiveness and limits of the applied method were verified. The second experimental phase was carried out in the field during the 2008 field season.

Taking into consideration the shallow depth of the site (2-3 m), and the difference of 0.5 m between high and low tide, high tide was as a rule chosen for photogrammetric recording. Additionally, it was necessary to take into account the weather, because in cases of stronger winds the nearness to the surface affects the photographer's, and thus the camera's, movement, while greater movement of the mass of water significantly reduces visibility. The small distance between the photographer and the find also created the additional problem of a high quantity of photographs that must be processed in order to achieve satisfactory overlap, so that the development of the model becomes considerably more complex.

The markers placed for the needs of documentation and study of the hull remains (Fig. 30, 31) were used as the foundation for photogrammetric mapping. This operation consists of the materialization of the position of different elements through a series of reference points, such as the pins designating the wooden pegs, the thin wire designating the plank joints, etc.²⁰ The reference points were sufficiently numerous, easily recognizable and regularly distributed across the entire surface of the wreck. Moreover, they simultaneously directly indicated the salient features of the hull structure.

fotografija, a time i kamere, a jača pomicanja vodene mase znatno smanjuju vidljivost. Mala udaljenost između fotografija i nalaza uzrokuje i dodatni problem velike količine fotografija koju je potrebno izraditi kako bi se ostvarilo zadovoljavajuće preklapanje, čime i izrada modela postaje znatno složenija.

Kao osnovica za fotogrametrijsko snimanje korištene su oznake postavljene za potrebe dokumentiranja i proučavanja brodske konstrukcije (Sl. 30, 31). Ta se operacija sastoji u materijaliziranju položaja raznih elemenata putem niza referentnih točaka kao što su zakovice kojima su označeni drveni čavli, tanja žica kojom su označeni željezni čavli, deblja žica kojom su označeni sljubovi platica i dr.)²⁰. Referentne točke bile su dovoljno brojne i lako prepoznatljive te pravilno raspoređene po čitavoj površini broda. Osim toga, one su istovremeno izravno upućivale na značajna obilježja brodske konstrukcije.

Kako bi se upotpunila mreža referentnih točaka i osigurala geometrijska koherentnost plana, oko brodoloma je postavljena mreža kalibrirajućih točaka (Sl. 43). Precizna orijentacija nalaza i umještanje u odgovarajuće mjerilo ostvareni su uz pomoć zidarskog kutnika postavljenog usred brodoloma. Zidarski je kutnik bio orijentiran prema sjeveru kako bi se njime definirale osi X i Y. Horizontalni plan u obliku osi Z postignut je uz pomoć libele. Zidarski kutnik poslužio je kasnije i za uspostavu odgovarajućeg mjerila u 3D modelu.

Nakon što je dovršeno obilježavanje elemenata brodske konstrukcije, s nalazišta je uklonjeno metalno mrežište, a čitava površina još je jednom očišćena od sitnih čestica sedimenta. Potom je fotograf sustavno snimio ostatke broda (Sl. 44)²¹.

Struktura svake brodske konstrukcije, usprkos činjenici da je ponekad potpuno stiješnena i spljoštena poput olupine kod Velog Školja, izrazito je složena. U pakoštanskom slučaju posebno je problematična bila mala udaljenost između brodskih rebara koja je ograničavala pogled na strukturu brodske oplata. Pozitivan čimbenik bila je svakako dobra očuvanost drvene građe, zahvaljujući kojoj su bridovi platica i rebara bili dobro vidljivi i jasno raspoznatljivi na fotografijama.

Kako bi se količina skrivenih površina smanjila na minimum, odlučeno je da se poveća broj fotografija i ostvari preklapanje od oko 60%. Površina olupine snimljena je u četiri smjera, dva uzdužna i dva poprečna, pod kutem od 45°. Eventualne zone u sjeni pokrivene su nizom fotografija snimljenih po dijagonalnim pravcima. Tome su pridodana i četiri seta ortogonalno snimljenih fotografija s ciljem kompletiranja prethodnog seta snimaka, ali i realizacije ortogonalnog plana nalazišta. Sveukupan broj snimljenih fotografija iznosio je oko 680.

Izrada trodimenzionalnog modela obavljena je uz pomoć računalnog programa *PhotoModeler 5*. Za potrebe korelacije 4600 točaka koje su obilježavale drvene čavle i čavlice, metalne čavle i sljubove platica korištene su devedeset i četiri fotografije. Perimetar brodoloma definiran je na osnovi dobro vidljivih karakterističnih točaka brodske konstrukcije. S

In order to fill in the network of reference points and ensure the geometric coherence of the map, a grid of calibrating points (Fig. 43) was installed around the shipwreck. The precise orientation of the finds and placement into the proper scale were achieved with the help of a mason try square placed in the middle of the shipwreck. The try square had a northerly direction in order to define the X and Y axes. The horizontal plane in the shape of the Z axis was obtained with the help of a levelling instrument. The try square was also used later to establish the proper scale in the 3D model.

After the designation of elements of the hull was completed, the metal grid was removed from the site, and the entire surface was once more cleared of tiny sediment particles. Then the photographer systematically photographed the hull remains (Fig. 44).²¹

The layout of any hull, despite the fact that it is sometimes entirely compressed and flattened like the wreck at Veli Školj, is quite complex. In the Pakoštane case, the small space between the ship's frames, which limited the view of the structure of the ship's planking, was particularly problematic. A positive factor was certainly the good state of preservation of the timber, thanks to which the edges of the planks and frames were clearly visible and discernible in the photographs.

In order to reduce the amount of concealed surfaces to a minimum, the decision was made to increase the number of photographs, and create an overlap of approximately 60%. The surface of the wreck was shot from four different directions, two longitudinal and two perpendicular, at 45° angles. Any possible zones in shadow were covered by a series of photographs shot diagonally. To these were added four sets of orthogonally shot photographs with the aim of completing the preceding set of photographs, as well as achievement of the orthogonal site map. The total number of photographs taken was approximately 680.

The three-dimensional model was made with the help of *PhotoModeler 5* software. Ninety-four photographs were used for the needs of correlation of 4,600 points that designated the wooden pegs, metal nails and plank butt joints. The perimeter of the shipwreck was defined on the basis of the clearly visible characteristic points of the hull. Given the results of modelling in relation to the situation in the field, it was concluded that a minimum distance of 0.5 m between the edge of the ship and the edge of the excavation, i.e., the profile of the archaeological test trench, was necessary for proper and effective photogrammetric documentation.

A precisely oriented scale model was exported to *Autodesk AutoCAD* in order to create the orthogonal site map. In this sense, use was made of 68 orthogonal photographs corrected with the help of the reference points created in *PhotoModeler*, and with the help of the *Autodesk AutoCAD* application *Vector RealView*.²² Given the aforementioned small depth of the site, the use of a lens that ensures minimum deformation



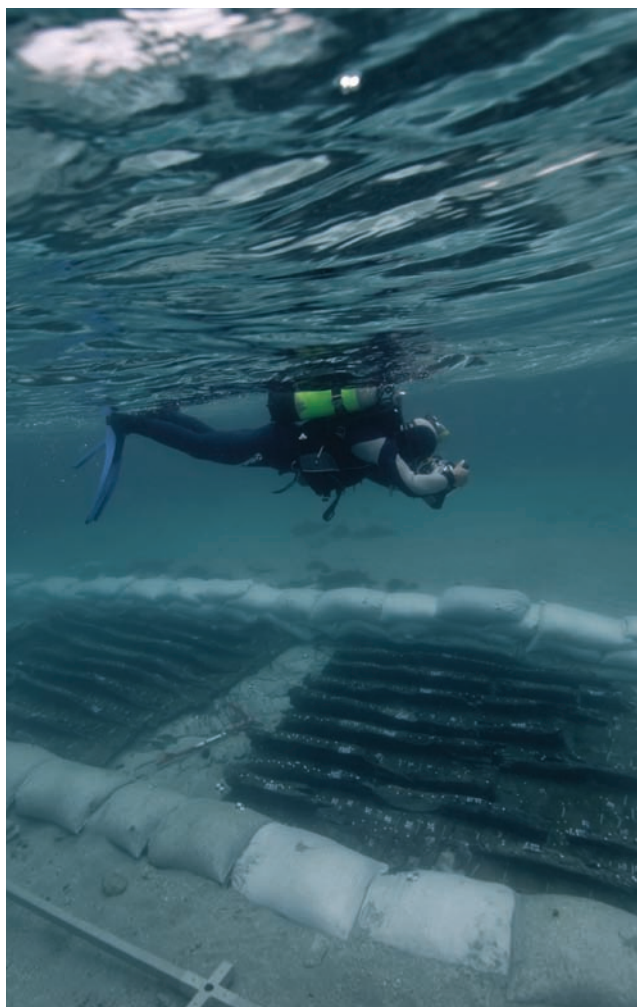
Sl. 43 Postavljanje fiksnih točaka na matičnu stijenu, za potrebe fotogrametrijskog dokumentiranja (foto: V. Frka).

Fig. 43 Placing the reference points on the rocky seabed, for photogrammetric recording (photo: V. Frka).

obzirom na rezultate modeliranja u odnosu na stanje na terenu zaključeno je da je za pravilno i učinkovito fotogrametrijsko dokumentiranje bilo potrebno najmanje 0,5 m udaljenosti između ruba broda i ruba iskopa, tj. profila arheološke sonde.

Precizno usmjeren model u mjerilu eksportiran je u program AutoCAD (ed. Autodesk) kako bi se realizirao ortogonalni plan nalazišta. U tome smislu iskorišteno je 68 ortogonalnih fotografija ispravljenih uz pomoć referentnih točaka kreiranih u programu *PhotoModeler*, uz pomoć AutoCAD aplikacije RealView (ed. Vector)²². S obzirom na prije spomenutu malu dubinu nalazišta, uporabu objektiva koji minimalno deformira sliku i korištenje samo centralnog dijela fotografija, jednom je fotografijom bila pokrivena površina od manje od 1 m². Dobra strana takvog ograničenja bila je velika količina detalja koji su se pokazali korisnima prilikom vektorizacije plana.

Na opisani su način izrađena dva ortogonalna plana nalazišta: plan oplata i plan orebrenja. Plan oplata realiziran je na osnovi točaka koje označuju metalne čavlice za učvršćenje



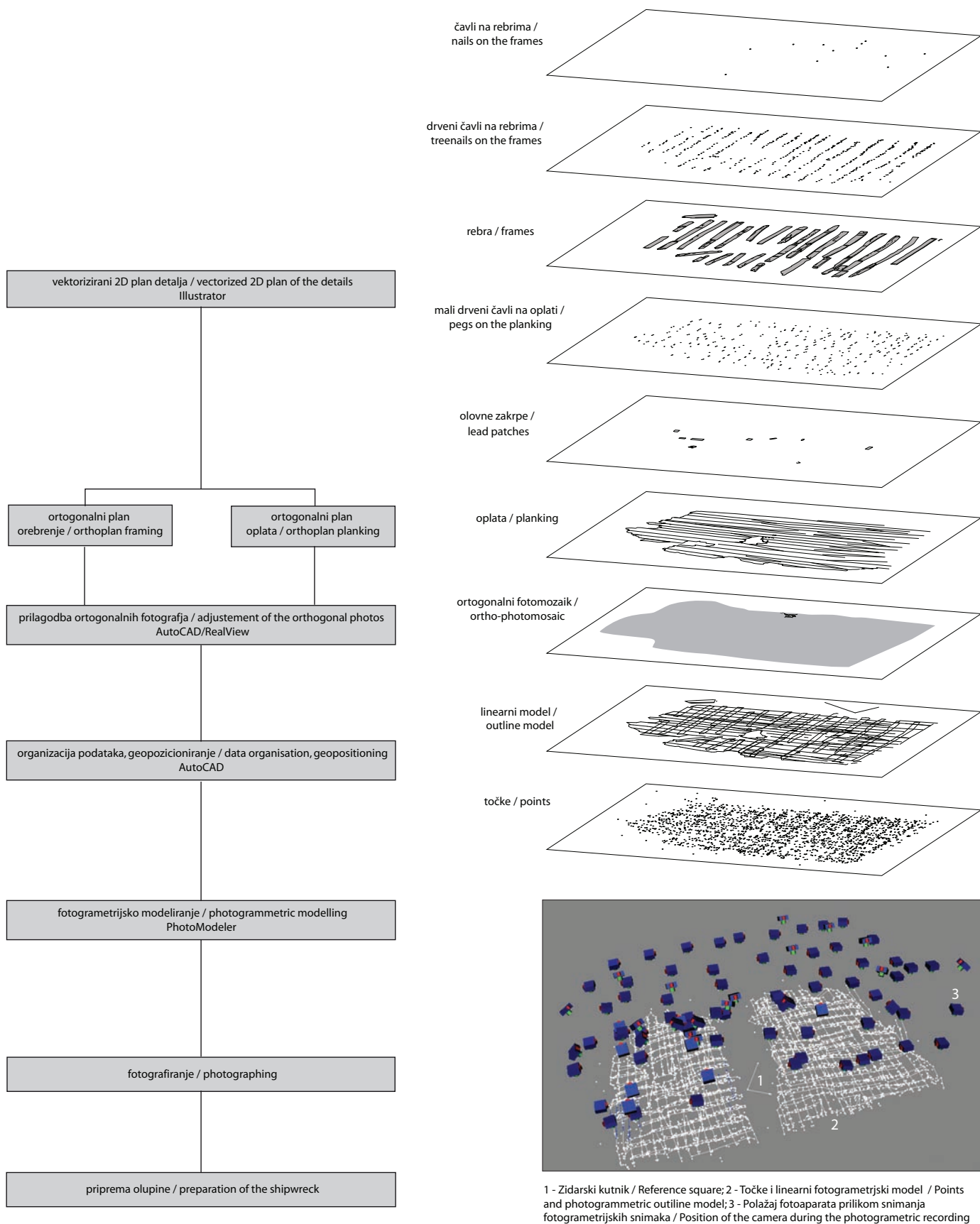
Sl. 44 Fotogrametrijsko dokumentiranje ostataka broda (foto: V. Frka).

Fig. 44 Photogrammetric recording of the hull remains (photo: V. Frka).

of the image, as well as use of only the central portion of the photographs, meant that each photograph covered a surface of less than 1 m². The positive side of such a limitation was the high amount of detail, which proved useful in map vectorization.

Two orthogonal site maps were made by the described method: the representation of the planking and representation of the skeleton. The planking was represented on the basis of the points denoting the pegs blocking the tenons, clamps made of white wire, used to mark the seams, and reference points set around the shipwreck (Fig. 45). The skeleton was represented on the basis of the points denoting the treenails and metal nails marked on the upper sections of the frames. The representations were then vectored in *Adobe Illustrator*, after which they were combined in order to obtain the final site map (Fig. 46).

The most sensitive phase was the merging of the maps from the excavation campaigns 2007 and 2008. The first map, based on the preliminary documentation compiled in 2004,



Sl. 45 Tijek rada i organizacija podataka od fotogrametrijskog dokumentiranja do 2D plana nalazišta (shema: V. Dumas).

Fig. 45 Operational sequence and organisation of information from the photogrammetric survey to the 2D siteplan (scheme: V. Dumas).

jezičaca i sljubove platica te referentnih točaka postavljenih oko brodoloma (Sl. 45). Plan orebrenja realiziran je na osnovi točaka koje označuju drvene i metalne čavle obilježene na gornjim površinama rebara. Planovi su potom vektorizirani u programu Illustrator (ed. Adobe), nakon čega su objedinjeni kako bi se dobio konačan plan nalazišta (Sl. 46).

Najosjetljivija faza rada bila je spajanje planova iz istraživačkih kampanja 2007. i 2008. godine. Prvi plan, zasnovan na preliminarnoj dokumentaciji izrađenoj 2004. godine, bio je izrađen na tradicionalan način, dok je drugi bio izrađen tehnikom fotogrametrije (Sl. 16). Prilikom spajanja dvaju planova izrađenih primjenom dviju različitih metoda pojavilo se nekoliko problema. Svaka metoda dovodi do različitih rezultata glede količine zabilježenih detalja i neminovnih nepreciznosti koje su dobrim dijelom uzrokovane radom ljudi uključenih u proces podmorskog dokumentiranja, obrade dokumentacije i dr. Kao što je već prije spomenuto, tijekom istraživanja 2008. otkriven je i manji dio olupine istražen prethodne godine kako bi se dokumentacija iz dviju istraživačkih kampanja lakše povezala u jednu cjelinu, što je s uspjehom i ostvareno.

Po dovršetku posla zaključeno je da je numerička fotogrametrija za potrebe arheologije broda metoda koja mnogo obećava, stoga ju je potrebno koristiti i u drugim projektima, a s vremenom razviti u sustavnu metodologiju rada. Razina detalja i visoka preciznost planova zadovoljila je potrebe istraživača, a vrijeme prikupljanja podataka fotografiranjem (u konkretnom slučaju oko 2 sata) bilo je izrazito kratko u odnosu na dugotrajno prikupljanje podataka na tradicionalan način. Iako kasnija obrada fotografija i izrada planova odnosi mnogo vremena, činjenica da se posao pod morem skraćuje, a preciznost povećava nesumnjivo je značajan faktor u planiranju podmorskih istraživanja.

U svakom slučaju, korisnost opisane metode neupitna je pri modeliranju i proučavanju nalaza *in situ* koji u dogledno vrijeme neće izaći na površinu i postati dostupni za proučavanje na kopnu. Veća gustoća točaka rezultira većom preciznošću modela, a konačan proizvod sažima u sebi vektorske informacije koje se sastoje od elemenata modeliranih na osnovi referentnih točaka, provjerenih i dopunjenih na osnovi promatranja detalja, preciznih mjerenja i skica izrađenih tijekom istraživanja. Sve nabrojeno značajan je sastavni dio dokumentiranja brodskih konstrukcija i ne može se ispustiti niti zaobići ako se želi dobro razumjeti brod odabran za istraživanje.

Zaključci izvedeni na osnovi fotogrametrijskog dokumentiranja olupine kod otočića Velog Školja tijekom sljedećih godina pokazali su se u potpunosti opravdanima, pa je fotogrametrija danas postala uobičajenim sastavnim dijelom metodologije dokumentiranja podmorskih arheoloških nalazišta. Dostupnost suvremenih računalnih programa, angažiranje mladih stručnjaka i sve veće iskustvo praktičnoga rada doveli su do ostvarenja mnogih 3D modela i ortogonalnih

was drafted in the traditional way by drawing underwater and adding details from the photomosaic, while the other was made by photogrammetry (Fig. 16). Several problems emerged when consolidating the two maps made by the application of two different methods. Each method yields different results with regard to the quantity of recorded details and the unavoidable imprecisions largely caused by the work of people involved in the process of underwater documentation, processing of documentation, etc. As already noted, during the excavation in 2008, a smaller part of the wreck examined in the preceding year was uncovered, so that the documentation from the two campaigns could be more easily merged into a single whole, which was successfully accomplished.

Upon the completion of the work, it was concluded that numerical photogrammetry for the needs of nautical archaeology was quite promising, and that it must be used in other projects and, with time, grow into a systematic work methodology. The level of detail and high precision of the maps satisfied all of the criteria of the researchers, and the time required to gather data by photography (in this specific case about 2 hours) was exceptionally short in comparison to the long-lasting data gathering in the traditional manner. Although the subsequent processing of the photographs and the compilation of the maps consume considerable time, the facts that the underwater workload is reduced while the precision is increased are certainly vital factors in the planning of underwater excavations.

In any case, the usefulness of this method is evident in the modelling and study of *in situ* finds that will not come to the surface any time soon and become available for study on dry land. The higher density of points has resulted in the higher precision of the models, and the final product summarizes the vectorial information that consists of elements modelled on the basis of reference points, verified and supplemented on the basis of observed details, precise measurements and sketches made during the excavations. All of these aspects form a significant component of the documentation of the ship's hull, and they cannot be neglected nor bypassed if a sound understanding of the ship chosen for research is to be obtained.

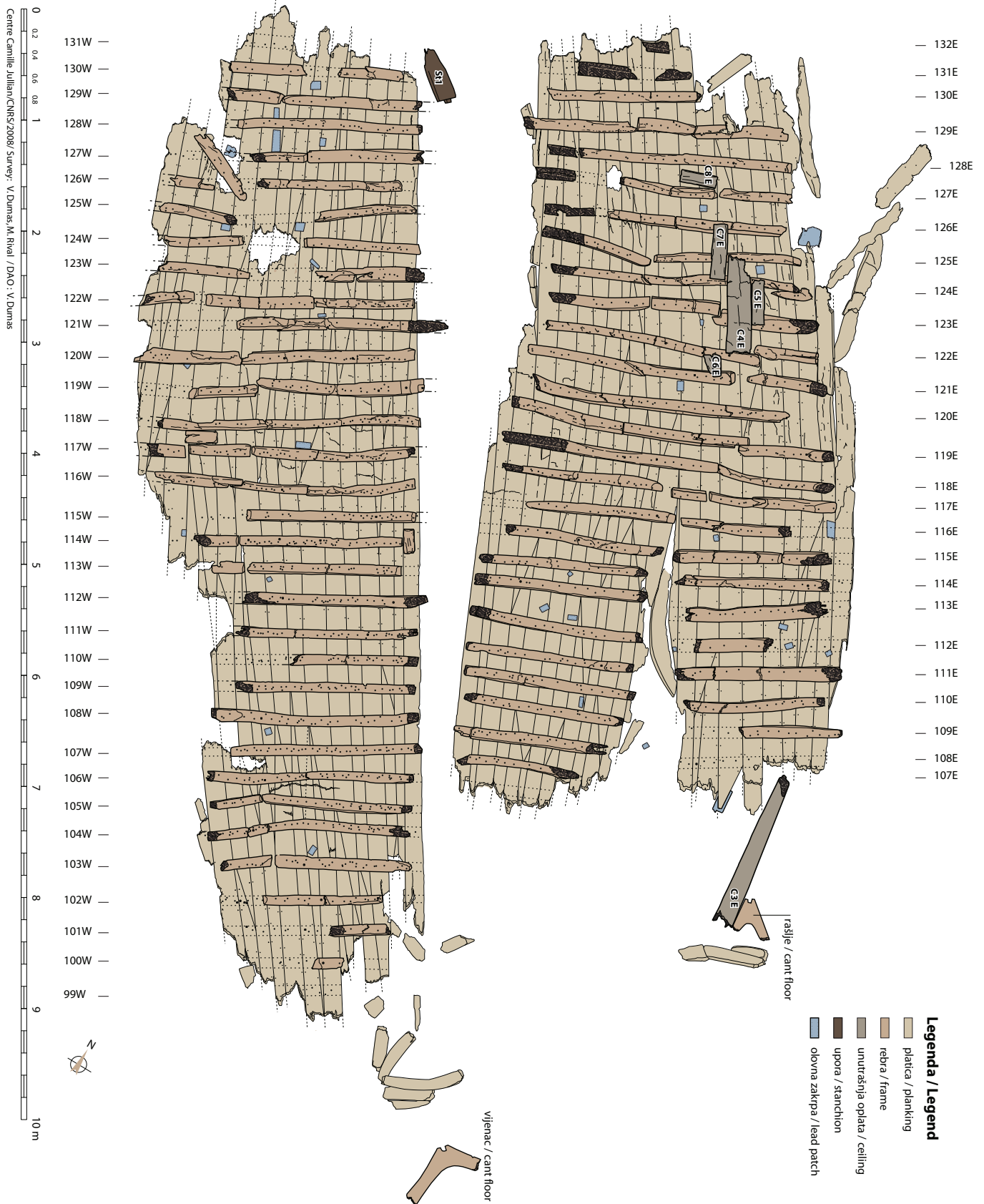
The conclusions derived on the basis of photogrammetric documentation of the wreck near the islet of Veli Školj during the subsequent years have been proven entirely justified, so today photogrammetry has become a standard component of the documentation methodology for underwater archaeological sites. The availability of contemporary computer programmes, the engagement of young experts and the increased experience of practical work have led to the creation of many 3D models and orthogonal maps of sites, saving researchers time spent on the seafloor for manual drawing and simultaneously increasing the precision of documentation and

planova nalazišta, uštedjevši istraživačima vrijeme boravka na morskome dnu, ujedno povećavajući preciznost dokumentacije.

Georeferenciranje i umještanje brodoloma u katastarski plan općine Pakoštane obavljeno je uz pomoć totalne stanice i prizme postavljene na nekoliko fiksnih točaka uokolo brodoloma. Šest fiksnih točaka (A – F) postavljeno je oko nalazišta 2007. godine pomoću željeznih šipki i brzovezujućeg cementa, a dvije oznake postavljene su na sjevernom i južnom kraju uzdužne osi brodoloma.²³ Geodetski snimak upotpunjen je 2008. godine točkama koje su pratile perimetar olupine. Kako bi se osigurala čim veća preciznost mjerenja, operater na gumenjaku bio je opremljen radio uređajem (engl. *walkie-talkie*) za komunikaciju s geodetom na obali, a tri člana podmorskog tima bila su zadužena za pozicioniranje prizme, održavanje njezinog vertikalnog položaja i bilježenje snimljenih točaka.

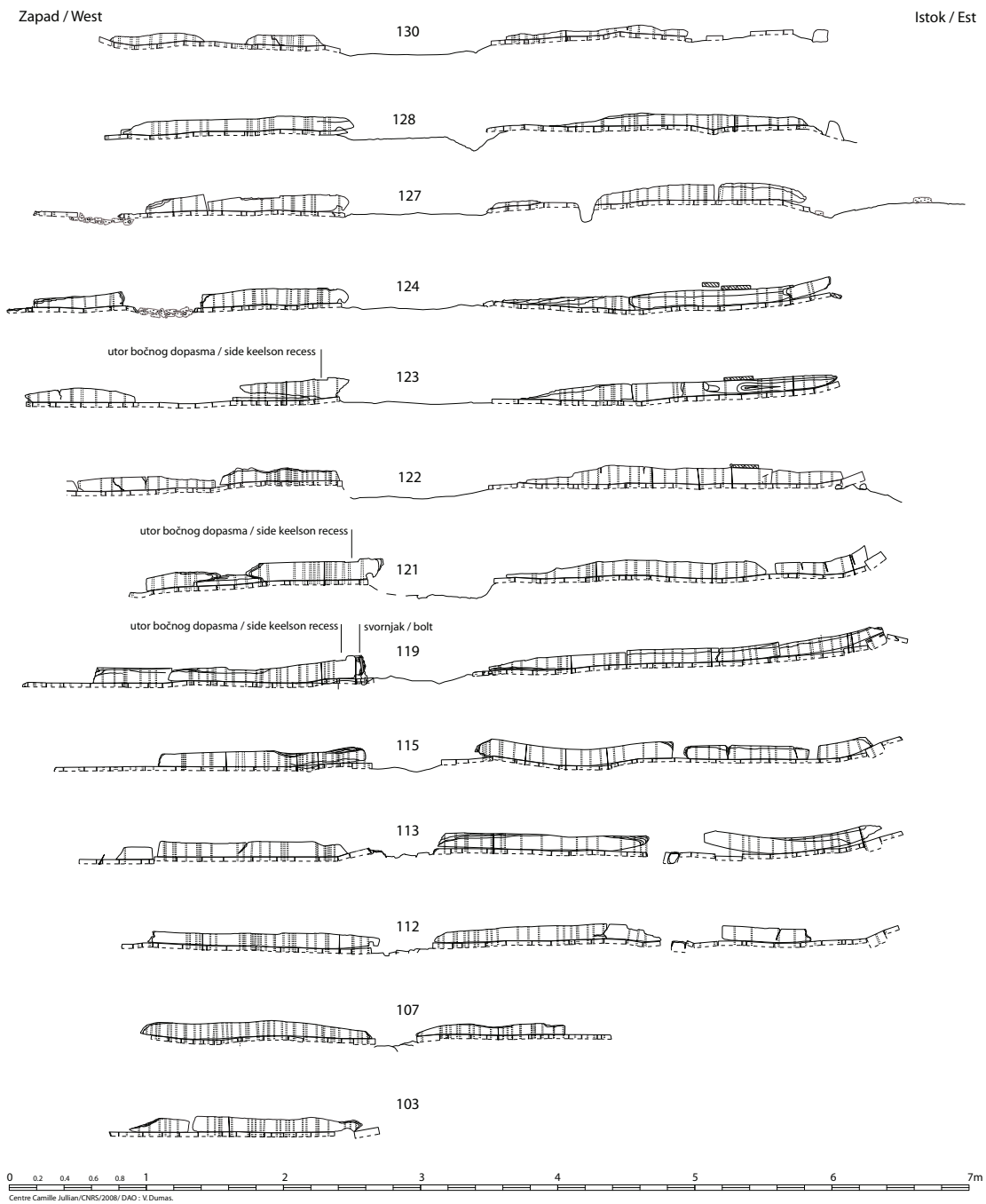
increasing the time for careful observation and measurement *in situ* of the construction details by the archaeologists.

Georeferencing and insertion of the shipwreck into the cadastral map of the Pakoštane Municipality was done with the help of a total station and the prisms set at several fixed points around the shipwreck. Six fixed points (A-F) were set around the site in 2007 with the help of iron bars and quick-setting cement, while two markers were placed on the northern and southern ends of the shipwreck's axis.²³ The geodetic survey was supplemented in 2008 with points that adhered to the wreck's perimeter. In order to ensure the greatest possible precision of measurement, the operator on a dingy was equipped with a walkie-talkie to communicate with a surveyor on shore, while the three members of the underwater team were tasked with positioning the prism, maintaining its vertical position and registering the recorded points.



Sl. 46 Generalni plan očuvanih ostataka broda (plan: M. Rival, V. Dumas).

Fig. 46 General scheme of the conserved remains of the hull (scheme: M. Rival, V. Dumas).



Sl. 47 Poprečni presjeci na brodskim rebrima (zajedničko dokumentiranje, plan: V. Dumas).

Fig. 47 Cross sections in the position of the frames (collective survey, scheme: V. Dumas).

- ¹ *Cf. supra* (M. Parica). Istraživanje u organizaciji Odjela za arheologiju Sveučilišta u Zadru provedeno je pod vodstvom Zdenka Brusića, uz sudjelovanje Mate Ilkića iz istog Odjela te tadašnjih studenata arheologije Mate Parice i Marka Meštrova.
- ² Istraživačkoj ekipi, s ciljem logističke podrške i izrade nacrtne, fotografske i videodokumentacije nalazišta, pridružili su se Irena Radić Rossi i Krunoslav Zubčić iz Odjela za podvodnu arheologiju Hrvatskog restauratorskog zavoda te podvodni snimatelj Marino Brzac.
- ³ Analiza je provedena u Laboratoriju za mjerenje niskih aktivnosti Zavoda za eksperimentalnu fiziku Instituta Ruđer Bošković u Zagrebu.
- ⁴ Godine 2007. sporazum o suradnji potpisali su Hrvatski restauratorski zavod, Centre Camille Jullian (Aix-en-Provence, Francuska) i udruga Arkaeos (Marseille, Francuska), a 2008. godine u ime hrvatskog partnera u sporazumu je nastupio Odjel za arheologiju Sveučilišta u Zadru. Na temelju sklopljenog ugovora međunarodna suradnja u području arheologije broda i arheologije pomorstva nastavila se do danas.
- ⁵ Projekt su financijski i organizacijski podržali Ministarstvo kulture RH, Centre Camille Jullian (Aix-en-Provence, Francuska) i Općina Pakoštane. Prethodna izvješća o tijeku i rezultatima podmorskog istraživanja objavljena su u više navrata: Radić Rossi, 2008a; 2008b; 2009; Boetto, Marlier, Radić Rossi, 2008; 2012; 2015; Boetto *et al.*, 2012.
- ⁶ *Cf. infra* (C. Huguet).
- ⁷ *Cf. infra* (F. Guibal *et al.*).
- ⁸ *Cf. infra* (C. Zazzaro).
- ⁹ *Cf. infra* (C. Huguet).
- ¹⁰ Keramički žeton (PK08/119: promjer 1,7 cm; debljina 0,4 cm, Sl. 23) i dva komada nečitkog novca (PK08/65 i PK08/135) u kvadratu F2 (Sl. 28, 29); ulomak staklene posude neidentificiranog oblika (PK08/105) u kvadratu E2 i ulomak drva s utorima (PK08/2) u kvadratu F3.
- ¹¹ *Cf. infra* (F. Guibal *et al.*).
- ¹² *Cf. infra* (C. Huguet).
- ¹³ Faunalne ostatke proučila je Audrey Renaud, tada doktorandica na Sveučilištu Paul-Valery, Montpellier (UMR 5140, Lattes), kojoj zahvaljujemo na suradnji i trudu. Riječ je o ulomku dijafize metakarpalne kosti odrasle jedinke iz roda *Ovis* ili *Capra* (ovca ili koza) i jednom ulomku kralješka malog biljojeda (*Ovis*, *Capra*, *Capreolus*).
- ¹⁴ PK08/79, pronađen u kvadratu G2.
- ¹⁵ PK08/74 i PK08/160.
- ¹⁶ Druga slična rješenja mogu se ostvariti uz pomoć drugih tipova linoleuma ili plastičnih materijala crne ili sive boje, na koje se oznake nanose vodootpornim flomasterima bijele ili žute boje.
- ¹⁷ Navedene elemente nije u svim slučajevima bilo moguće razlikovati, pa se zbog toga u trenutku istraživanja odlučilo primijeniti zajedničku oznaku, a konačne zaključke o vrsti konstruktivnog elementa donijeti tek nakon naknadne analize brodske konstrukcije.
- ¹⁸ Usp. npr. brodolom broda tipa *navis lapidaria* na nalazištu Kizilburun (Turska, 1. st. po Kr.): Carlson, 2006 i Higgins, 2007.
- ¹⁹ Na francuskim nalazištima stereo fotogrametrija počela se primjenjivati sedamdesetih godina prošloga stoljeća (usp. npr. brodolome *Planier 3*, Liou, 1973, i *Madrague de Giens*, Tchernia *et al.*, 1978). Fotogrametrija je poslije primijenjena i na nalazištu *Grand-Ribaud D* kako bi se skratilo vrijeme podmorskog dokumentiranja (Blaustein, Hesnard, 1988).
- ²⁰ *Cf. supra*.

- ¹ *Cf. supra* (M. Parica). Research organized by the Archaeology Department of the University of Zadar was conducted under the direction of Zdenko Brusić, with the participation of Mate Ilkić from the same department and Mate Parica and Marko Meštrov, both archaeology students at the time.
- ² In order to provide logistical support and to draft sketches and compile photographic and video documentation of the site, the research team was complemented by Irena Radić Rossi and Krunoslav Zubčić from the Underwater Archaeology Department of the Croatian Conservation Institute, and underwater cameraman Marino Brzac.
- ³ The analysis was conducted in the Laboratory for Low-level Radioactivities of the Experimental Physics Division at the Ruđer Bošković Institute in Zagreb.
- ⁴ In 2007, the cooperation agreement was signed by the Croatian Conservation Institute, the Centre Camille Jullian (Aix-en-Provence, France) and the association Arkaeos (Marseille, France), while in 2008, the agreement was joined on behalf of the Croatian partner by the Archaeology Department of the University of Zadar. Based on the concluded agreement, international cooperation in the field of nautical archaeology and maritime archaeology continues to the present.
- ⁵ The project has received financial and organizational support from the Croatian Ministry of Culture, the Centre Camille Jullian (Aix-en-Provence, France), the Pakoštane Municipality and the region Provence-Alpes-Côte d'Azur. Prior reports on the course and results of the underwater research have been published in: Radić Rossi, 2008a; 2008b; 2009; Boetto, Marlier, Radić Rossi, 2008; 2012; 2015; Boetto *et al.*, 2012.
- ⁶ *Cf. infra* (C. Huguet).
- ⁷ *Cf. infra* (F. Guibal *et al.*).
- ⁸ *Cf. infra* (C. Zazzaro, S. Wicha).
- ⁹ *Cf. infra* (C. Huguet).
- ¹⁰ A ceramic token (PK08/119: diameter 1.7 cm; thickness 0.4 cm, Fig. 23) and two illegible coins (PK08/65 and PK08/135) in square F2 (Fig. 28, 29); shard of a glass vessel of unidentifiable shape (PK08/105) in square E2 and fragment of wood with grooves (PK08/2) in square F3.
- ¹¹ *Cf. infra* (F. Guibal *et al.*).
- ¹² *Cf. infra* (C. Huguet).
- ¹³ The faunal remains were studied by Audrey Renaud, then a doctoral student at Paul-Valery University, Montpellier (UMR 5140, Lattes), whom we thank for her cooperation and efforts. This is a piece of the diaphysis of the metacarpal bone of an adult individual from genus *Ovis* or *Capra* (sheep or goat) and one vertebral fragment from a small ruminant (*Ovis*, *Capra*, *Capreolus*).
- ¹⁴ PK08/79, found in grid square G2.
- ¹⁵ PK08/74 and PK08/160.
- ¹⁶ Another, similar solution may be implemented with the help of other types of linoleum or black or grey plastic materials, to which marks are applied with water-resistant white- or yellow-ink markers.
- ¹⁷ These elements could not be distinguished in all cases, so the decision was made to use a common designation during excavations, while the final conclusion on the type of constructive element will be made only after subsequent analysis of the ship's construction.
- ¹⁸ See for example, the wreck of a *navis lapidaria* type ship at the Kizilburun site (Turkey, 1st cent. AD). Carlson, 2006 and Higgins, 2007.

- ²¹ Fotograf Centra Camille Jullian, Philippe Groscaux, snimio je ostatke broda fotoaparatom Nikon D70s, s objektivom od 20 mm.
- ²² U trenutku pisanja ovog teksta navedeni program više nije bio dostupan.
- ²³ Geodetsko snimanje brodoloma obavio je geodet Marijan Radović.
- ²⁴ Bokoštinci pripadaju tri ulomka P37E, P46E i P53E.
- ²⁵ Položaj ostalih rebrenica utvrđen je na osnovi tragova veznih elemenata na oplati.
- ²⁶ Srećom, godine 2004. napravljen je crtež u mjerilu 1:1 (Sl. 57.2). Riječ je o značajnom dokumentu koji je očuvao ne samo oblik elementa, već i važne mjere poput širine gornje površine kobilice koja se nije očuvala.
- ²⁷ *Cfr. infra.*
- ²⁸ Udaljenost među drvenim čavlicima za učvršćenje jezičaca bila je izmjerena na mjestima koja nisu bila prekrivena debelim zaštitnim slojem smole. Zbog takve situacije, na planu oplata (Sl. 51) spojevi uz pomoć jezičaca pričvršćenih drvenim čavlicima nisu prikazani na svim mjestima, što je posljedica nemogućnosti dokumentiranja, a ne nepostojanja takvih spojeva.
- ²⁹ Izračun za raspored utora na dokobiličnim platicama izveden je na osnovi iznosa 6,8 cm (udaljenost među utorima) podijeljenog s 8,26 cm (širina utora). Izračun za raspored utora na ostalim platicama dobiven je dijeljenjem iznosa 8,7 cm (razmak među utorima) s 5,9 cm (širina utora).
- ³⁰ Rezultati pokazuju da su na dokobiličnim platicama utori za spoj na kobilicu izvedeni tako da u slobodan prostor koji ostaje među njima nije moguće ubaciti još jedan utor (preciznije, ostaje prostora za 0,821 dio utora), dok je u slučaju ostalih platica u slobodan prostor među utorima moguće ubaciti još gotovo jedan i pol utor (preciznije, ostaje prostora za 1,47 utora).
- ³¹ Za objašnjenje stožastog oblika čavlića vidi Rival, 1991: 202.
- ³² Na brodolomima na kojima su sustavno izmjereni unutrašnji i vanjski promjeri svih drvenih čavlića, nakon što su s oplata uklonjeni elementi uzdužne čvrstoće, pokazalo se kako su oni uglavnom ubačeni s unutrašnje strane broda, uključivo i mjesta koja su poslije pokrivena rebri. Riječ je o jednom od jasnih pokazatelja da je brod bio izgrađen tehnikom „prvo ljuska“. Suprotan smjer ubacivanja drvenih čavlića može se interpretirati kao pokazatelj prijelaza na tehniku „prvo kostur“ samo u slučaju kad su čavlići ubačeni na mjestima na kojima se s unutrašnje strane nalaze rebrenice. U slučaju brodoloma na lokalitetu *Bourse (Burza)* u Marseilleu (Francuska, 190. – 200. g. po Kr.), ubacivanje drvenih čavlića s vanjske strane broda primijećeno je tek ispod nekoliko rebrenica i u gornjem dijelu broda (Gassend, Cuomo, 1982a; 1982b; 1985). Taj detalj naveo je autore na pretpostavku da je riječ o kombinaciji dviju tehnika, što je poslije doveo u pitanje P. Pomey (1988; 2004). Vidi također Pomey, Rieth, 2005: 169-171.
- ³³ Usp. čavlice s brodoloma *Madrague de Giens* (Rival, 1991: 195, tav. 54 e 95) i *Dramont E* (Santamaria, 1995: 145, tav. XVI); za objašnjenje malog utora na mjestu dodira s jezičcem vidi Rival, 1991: 195.
- ³⁴ Rebro F99W nije se očuvalo, ali je moguće rekonstruirati njegov položaj na osnovi drvenih čavala uz pomoć kojih je bilo pričvršćeno na oplatu. Na isti način, nizovi drvenih čavala omogućuju rekonstrukciju položaja još nekih neočuvanih dijelova rebara.
- ³⁵ F115W, F117W, F119W, F121W, F123W, F125W, F127W i F129W.
- ³⁶ F112W, F118W, F120W, F122W, F124W, F126W i F128W.
- ³⁷ Analize vrsta drvene građe ukazale su na veliku heterogenost vrsta iskorištenih za gradnju broda, ne upućujući na neke posebne vrste kojima se davala prednost prilikom popravaka; *cfr. infra.*
- ³⁸ Slivnice su primijećene i na ulomku rebrenice pronađenom izvan
- ¹⁹ At French sites, stereo photogrammetry began to be used in the 1970s (cf., for example, shipwrecks such as the Planier 3, Liou, 1973, and Madrague de Giens, Tchernia *et al.*, 1978). Photogrammetry was later also applied to the Grand-Ribaud D site, in order to reduce the time needed for underwater documentation (Blaustein, Hesnard, 1988).
- ²⁰ *Cf. supra.*
- ²¹ A photographer from the Centre Camille Jullian, Philippe Groscaux, shot the remains of the ship with a Nikon D70s camera with a 20 mm lens.
- ²² At the time when this text was written, this programme was no longer available.
- ²³ The geodetic survey of the shipwreck was done by surveyor Marijan Radović.
- ²⁴ Three pieces, P37E, P46E and P53E, belong to the wale.
- ²⁵ The position of the remaining floor timbers was ascertained on the basis of traces of connective elements on the planking.
- ²⁶ Fortunately, in 2004 a sketch at 1:1 scale was drawn (Fig. 57.2). This is a vital document, which preserved not only the shape of the elements, but also important measures such as the width of the upper surface of the keel, which had not been preserved.
- ²⁷ *Cfr. infra.*
- ²⁸ The distance between the wooden pegs to fasten the tenons was measured at places that were not covered with a thick protective layer of resin. Because of this, the map of the planking (Fig. 51) does not show the joints with the tenons fastened by wooden pegs at all places, which was a result of the impossibility of documentation rather than the absence of such joints.
- ²⁹ The calculation for the distribution of mortises on the garboard planks was done on the basis of the value of 6.8 cm (the average distance between the mortises) divided by 8.26 cm (average width of mortises). The calculation of the distribution of mortises on the remaining plans was obtained by dividing 8.7 cm (the average interval between mortises) by 5.9 cm (average width of mortises).
- ³⁰ The results show that on the garboard planks, the mortises to connect to the keel were rendered so that one more mortise could not be inserted into the free space that remained between them (to be precise, space for a 0.821 share of a mortise remained), while in the case of the remaining planks, almost one and a half mortise can be inserted in the free spaces among the mortises (to be exact, space for 1.47 mortises remained).
- ³¹ For an explanation of the conical shape of the pegs, see Rival, 1991: 202.
- ³² At shipwrecks where the internal and external diameters of all wooden pegs were systematically measured, after the frames were removed from the planking, it was found that they were generally inserted from the inside of the ship, including those places that were subsequently covered by frames. This is one of the clear indicators that the ship was constructed by the shell-first technique. The opposite direction of inserting wooden pegs may be interpreted as an indicator of the transition to the frame-first technique only in cases in which the pegs were inserted at places at which there are frames from the inside. In the case of the shipwreck at the Bourse site in Marseille (France, 190-200 AD), the insertion of wooden pegs from the outside of the ship was observed only under some frames and in the upper section of the ship (Gassend, Cuomo, 1982a; 1982b; 1985). This detail led the authors to assume that this entailed a combination of the two techniques (shell first and skeleton first), which was later challenged by P. Pomey (1988; 2004). See also Pomey, Rieth, 2005: 169-171. See recently Pomey, Kahanov, Rieth 2012.
- ³³ Cf. the pegs from the Madrague de Giens shipwreck (Rival, 1991: 195, tab. 54 and 95) and Dramont E (Santamaria, 1995: 145, tab. XVI); for an

- izvornog položaja (PK07/F2) i na rebrima u zapadnom dijelu broda (rebrnice F115W, F117W, F119W, F121W, F123W, F125W, F127W i F129W; polurebrnice F112W, F118W, F124W, F126W i F128W).
- ³⁹ F119W, F125W i F19W.
- ⁴⁰ Iako metalni čavli nisu analizirani, dvije vrste metala sugerirane su na osnovi boje (crna za željezo i zelenkasto-plava za bakar).
- ⁴¹ Velik broj čavala, visine od 8,6 do 11 cm i promjera glavice od 1,5 do 2 cm, pronađen je u sloju oko brodoloma.
- ⁴² F119W, F121W, F122W i F123W.
- ⁴³ Po pitanju datiranja vidi Bonifay *et al.*, 1998: 101.
- ⁴⁴ Po pitanju datiranja vidi Bonifay, 2004: 105.
- ⁴⁵ Zbog vremenskih ograničenja uzrokovanih, prije svega, raspoloživim financijskim sredstvima, nije bilo moguće sustavno dokumentirati sve spomenute indikatore prisutnosti unutrašnje oplate.
- ⁴⁶ Ulomci platica PK07/P9 i PK07/P10; zakrpnj jezičac PK08/P80.
- ⁴⁷ Prema informaciji dobivenoj od Marka Meštrova i danas se u Hrvatskoj neki vlasnici drvenih brodova koriste smjesom od smokava, osušenom na suncu, za zatvaranje pukotina na drvenoj građi, jer ju šećer koji sadrži čini učinkovitim ljepilom.
- ⁴⁸ Više o elementima koji ukazuju na primjenu tehnike „prvo ljska” na tehniku „prvo kostur” vidi u Pomey, Kahanov, Rieth, 2012 i 2013, gdje je navedena ostala relevantna literatura.
- ⁴⁹ Tehnika dokumentiranja konopa preuzeta je iz Wendrich, 1994.
- ⁵⁰ Analize je provela Stéphanie Wicha u Mediteranskom institutu za morsku i kontinentalnu bioraznolikost i ekologiju (Institut Méditerranéen de Biodiversité et d'Ecologie marine et continentale – IMBE) 2013. godine, zahvaljujući sredstvima francuskog Ministarstva vanjskih poslova i međunarodnog razvoja ((Ministere de l'Europe et des affaires étrangères - MEAE). Autorica zahvaljuje Régine Verlaque za pomoć pri određivanju vrste vlakana.
- ⁵¹ Mala dubina i sastav sedimenta na nalazištu (rastresiti pijesak s ulomcima školjaka) upućuju na mogućnost kontaminacije skupine nalaza predmetima koji ne pripadaju cjelini brodoloma. U tom smislu mogu se interpretirati tri velika ulomka amfore kampanskoga podrijetla. Preostala skupina keramičkih ulomaka homogena je po pitanju podrijetla i datiranja.
- ⁵² Zahvaljujem Michelu Bonifayu, istraživaču u institutu Camille Jullian (Aix Marseille Univ, CNRS, Minist Culture) na dragocjenim savjetima prilikom obrade keramičkih nalaza.
- ⁵³ O razlikovanju brodskog tereta i opreme broda vidi Beltrame, 2002: 6-8 i 42.
- ⁵⁴ Kao što je to slučaj na mnogim brodolomima u Sredozemlju. Vidi npr. *Madrague de Giens* (Francuska, 75. – 60. g. pr. Kr.); Tchernia *et al.*, 1978: 20-21.
- ⁵⁵ Na ulomku uljanice ne vide se tragovi gorenja, što je siguran pokazatelj korištenja uljanice na brodu (Beltrame, 2002). Moguće je, međutim, pretpostaviti kako su tragovi gorenja nestali zbog dugotrajnog djelovanja morske vode.
- ⁵⁶ O predmetima koji potvrđuju prisutnost igara na brodu vidi Beltrame, 2002.
- ⁵⁷ Oko 1 cm³ drvene građe bio je uzet na mjestima na kojima je drvo bilo najkompaktnije i najbolje očuvano. Posebna pozornost posvećena je izbjegavanju mjesta na kojima su bili prisutni kanali nastali djelovanjem crvotočca ili brodskog crva (*Teredo navalis*).
- ⁵⁸ Danas Institut Méditerranéen de Biodiversité et d'Ecologie marine et continentale.
- explanation of the small narrowing at the point of contact with the tenon, see Rival, 1991: 195.
- ³⁴ Frame F99W was not preserved, but it is possible to reconstruct its position on the basis of the treenails that helped fasten it to the planking. In the same way, rows of treenails allow for the reconstruction of the position of certain other unpreserved parts of the frames.
- ³⁵ F115W, F117W, F119W, F121W, F123W, F125W, F127W, and F129W.
- ³⁶ F112W, F118W, F120W, F122W, F124W, F126W, and F128W.
- ³⁷ Analyses of the wood have underscored the great heterogeneity of the types used to build the ship, without giving an indication of any specific type that was preferred during repairs; cf. *infra*.
- ³⁸ Limber holes were also observed on the floor timber piece found away from its original position (PK07/F2) and on the frames in the ship's western section (futtocks F115W, F117W, F119W, F121W, F123W, F125W, F127W, and F129W; half-frames F112W, F118W, F124W, F126W, and F128W).
- ³⁹ F119W, F125W and F19W.
- ⁴⁰ Even though the metal nails have not undergone analysis, the two types of metal are indicated on the basis of colour (black for iron and greenish-blue for copper).
- ⁴¹ A high number of nails, 8.6 to 11 cm high and head diameters from 1.5 to 2 cm, were found in the layer around the shipwreck.
- ⁴² F119W, F121W, F122W, and F123W.
- ⁴³ On the question of dating, see Bonifay *et al.*, 1998: 101.
- ⁴⁴ On the question of dating, see Bonifay, 2004: 105.
- ⁴⁵ Due to the time constraints caused by, above all, available funding, it was not possible to systematically document all of these indicators of the presence of internal planking.
- ⁴⁶ Plank fragments PK07/P9 and PK07/P10; patched tenon PK08/P80.
- ⁴⁷ According to information obtained from Marko Meštrović, even today some owners of wooden boats in Croatia use a mixture of figs dried in the sun to fill cracks on wood, because the sugar they contain is an effective glue.
- ⁴⁸ For more on the elements that indicate application of the shell-first technique and frame-first technique, see Pomey, Kahanov, Rieth, 2012 and 2013, in which the remaining relevant sources are cited.
- ⁴⁹ The technique for documenting rope was taken from Wendrich, 1994.
- ⁵⁰ The analysis was conducted by Stéphanie Wicha in the Mediterranean Institute of Marine and Terrestrial Biodiversity and Ecology (Institut Méditerranéen de Biodiversité et d'Ecologie marine et continentale – IMBE) in Aix-en-Provence in 2013, thanks to funding provided by the French Ministry of Foreign Affairs and International Development (Ministère des affaires étrangères et du développement international – MAEDI). The author would like to thank Régine Verlaque for her assistance in determining the type of fibre.
- ⁵¹ The modest all depth and composition of the sediment at the site (loose sand with pieces of seashells) point to the possibility of contamination of the set of finds with items that do not belong to the wreckage site. In this sense, they may be interpreted as three large fragments of Campanian amphorae. The remaining group of ceramic fragments is homogenous in terms of origin and dating.
- ⁵² The author is grateful to Michel Bonifay, director of Research at the Camille Jullian Institute (Aix Marseille Univ, CNRS, Minist Culture) for his valuable advice during the analysis of ceramic finds.
- ⁵³ On the distinction between a ship's cargo and accessories, see Beltrame, 2002: 6-8 and 42.

- ⁵⁹ Valja napomenuti kako je samo šest elemenata poprečne čvrstoće broda ostalo neanalizirano.
- ⁶⁰ Podatci dobiveni iz polena izdvojenog iz smole iskorištene za zaštitu riječnog galo-rimskog broda *Arles-Rhône 3* upućuju na njezino lokalno podrijetlo: vidi Andrieu-Ponel, 2011 i Marlier, 2014.
- ⁶¹ Mali brod za lokalnu plovidbu (Caska, otok Pag, Hrvatska) i riječni brodovi (Lion i Arles, Francuska).
- ⁶² Korištenje ove vrste dokazano je također na nekim dijelovima rebara brodoloma *Pisa C* (Italija, poč. 1. st. po Kr.): Giachi *et al.*, 2003.
- ⁶³ Kao primjer može nam poslužiti podatak da je prilikom istraživanja brodoloma YK 11 (MRY 5) iz 7. st. po Kr., otkrivenog na nalazištu Yenikapı, gdje se nalazila bizantska i srednjovjekovna luka Carigrada, istraživački tim Sveučilišta Texas A&M primijetio kako je hrptenica u pramčanom dijelu broda bila izrađena sekundarnom uporabom dijela kobilice drugog broda (osobno priopćenje C. Pulak, prosinac 2010.).
- ⁵⁴ As was the case of many shipwrecks in the Mediterranean. See, e.g., *Madrague de Giens* (France, 75-60 BC); Tchernia *et al.*, 1978: 20-21.
- ⁵⁵ No traces of burning can be seen on the oil-lamp, which is a certain indicator of its use on the ship (Beltrame, 2002). It is possible, however, to assume that the traces of burning disappeared due to the long-term effects of seawater.
- ⁵⁶ On the items that confirm the presence of games played on board, see Beltrame, 2002.
- ⁵⁷ Approximately 1 cm³ of wooden material was taken at places where the wood was the most compact and best preserved. Particular attention was accorded to the avoidance of places where there are holes made by the boring of shipworms (*Teredo navalis*).
- ⁵⁸ Now called the Institut Méditerranéen de Biodiversité et d'Ecologie marine et continentale.
- ⁵⁹ It should be noted that only six elements of the ship's transversal carpentry remain unanalysed.
- ⁶⁰ The data from the pollen extracted from the pitch used for the Gallo-Roman river ship, Arles-Rhône 3, indicate a local origin: see Andrieu-Ponel 2011 and Marlier 2014.
- ⁶¹ Small boat for local traffic (Caska, island of Pag, Croatia), river boats (Lyon and Arles, France).
- ⁶² The use of this wood type has also been proven on some parts of the frames at the Pisa C shipwreck (Italy, beg. 1st cent. AD): Giachi *et al.*, 2003.
- ⁶³ A useful example here may be the fact that during exploration of the YK11 (MRY 5) shipwreck from the 7th cent. AD discovered at the Yenikapı site, the location of the Byzantine and medieval harbour of Constantinople, a research team from Texas A&M University noticed that the sternson of the ship had been made from the keel of another ship in secondary use (Pulak, Ingram, Jones, 2015).

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