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KASNOANTIČKA BRODSKA KONSTRUKCIJA U UVALI DEBELJAK NA RTU KAMENJAK (PREMANTURA, ISTRA) THE LATE ANTIQUE WRECK OF DEBELJAK COVE (CAPE KAMENJAK, PREMANTURA, ISTRIA)

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Rad se bavi analizom brodske konstrukcije iz uvale Debeljak kod Premanture koja je bila predmetom podmorskih arheoloških istraživanja u razdoblju od 2017. do 2019. godine. Brod je pronađen na maloj dubini, u ravnini s morskim dnom, ali u poprilično fragmentiranom stanju. Proučavanje ostataka broda dovelo je do novih spoznaja o konceptu i procesu gradnje, iako su zasad još uvijek nepoznati podaci o njegovu podrijetlu i mjestu izgradnje. Međutim, može se pretpostaviti da je riječ o trgovačkom jedrenjaku, dužine 15 do 17 m, koji je najvjerojatnije služio za plovidbu lokalnim akvatorijem.

This article focuses on the study of a wreck found in Debeljak Cove, Premantura Promontory in the region of Istria and which was the object of research from 2017 to 2019. The wreck is located in shallow water, lying flat and highly fragmented on the seabed. The study of the remains has led to hypotheses about its construction concept and processes, though it has not been possible to locate its origin and construction site. It was a sailing ship, 15 to 17 m long, used for trade, probably on a regional level.

KLJUČNE RIJEČI: brodogradnja; Istra; Jadran; kasna antika; olupina; rt Kamenjak; spoj na jezičac i utor

KEY WORDS: shipbuilding; Istria; Adriatic Sea; late antiquity; wreck; Cape Kamenjak; mortise-and-tenon

1. UVOD

Uvala Debeljak jedna je od uvala koje se nalaze na istočnoj obali poluotoka Kamenjak kod Premanture, unutar zaštićenog područja parka prirode Kamenjak (Općina Medulin) (sl. 1-3). Proteže se u smjeru istok-zapad i dobro je zaštićena od vjetrova iz zapadnog kvadranta. Uz Debeljak, na Donjem Kamenjaku se nalaze još dva dobra sidrišta, uvale Portić i Polje.

Uvalu tvori vapnenačko stijenje (Plejić 2018). Plići dio uvale naseljen je infralitoralnim algalnim biocenozama, a zatim obalnim detritalnim biocenozama s grmovima morske trave *Posidonia oceanica* koji prekrivaju pješčano dno. Na dubini od 4 m na središnjem dijelu uvale nalaze se biocenoze obalnih muljevutih pijesaka zaštićenih obala u kojima rastu livade cvjetnice *Cymodocea nodosa*. Na dubini od 5 m na pješčanom dnu raste gusta i dobro očuvana livada posidonije (Šugar 2017, 30-31).

Pronalazak brodske konstrukcije prijavili su 2015. godine Arheološkom muzeju Istre članovi udruge Eko More i Ronilačkog kluba Centar iz Medulina, koji su na morskom dnu u pijesku uočili nekoliko brodskih rebara (sl. 4). Brod leži na dubini od 3 - 3,5 m, otprilike na sredini uvale, oko 80 m od zapadne obale (Koncani Uhač 2017, 417-419; sl. 5 i 6).

Iste su godine Arheološki muzej Istre i Konzervatorski odjel u Puli proveli prvo istraživanje te je ustanovljeno da se u podmorju nalaze ostaci brodske konstrukcije s



Sl. 1 Uvala Debeljak (crveno), Istra, Hrvatska (crtež: V. Dumas).

Fig. 1 Location of Debeljak Cove (in red), Istria, Croatia (drawing by: V. Dumas).

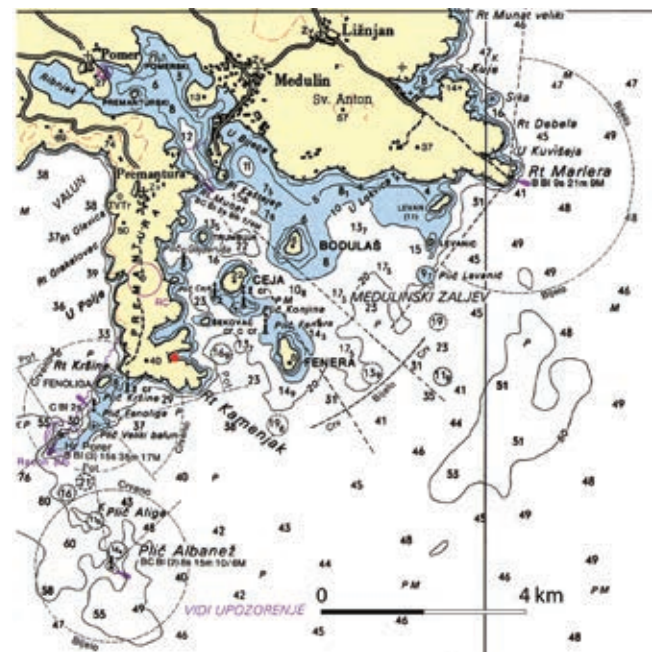
1. INTRODUCTION

Debeljak Cove is one of the bays on the east coast of the peninsula Kamenjak near Premantura in the protected Kamenjak Natural Park (Municipality of Medulin) (Figs. 1-3). Oriented east/west and well protected from the western quadrant winds, Debeljak Cove is one of the main mooring bays of the Lower Kamenjak, along with Portić and Polje.

Debeljak Cove is formed by limestone formations (Plejić 2018). The shallows are colonised by infralittoral algal biocenoses, followed by coastal detrital biocenoses with *Posidonia oceanica* growths on the sandy bottom. At a depth of 4 m there are biocenoses of coastal muddy sands of protected coasts, in which *Cymodocea nodosa* meadows are found in the central part of the bay. Below 5 m, the sandy bottom features a dense and well-preserved *Posidonia* meadow (Šugar 2017, 30-31).

The presence of the wreck was reported to the Archaeological Museum of Istria in 2015 by members of the Eko More Association and Diving Club Centre from Medulin, who noticed a few visible frames appearing in some places through the sandy bottom (Fig. 4). The remains were located approximately in the centre of the inner part of Debeljak Cove, about 80 m from its western shore, and at a depth of 3-3.5 m (Figs. 5 and 6).

In the same year, the Archaeological Museum of Istria and Conservation Department in Pula conducted a first



Sl. 2 Položaj lokaliteta brodske konstrukcije (detalj nautičke karte Kvarner MK-4, Državni hidrogrfski institut).

Fig. 2 Location of the wreck in Debeljak Cove (detail from nautical map Kvarner MK-4, Državni Hidrogrfski Institut).



Sl. 3 Pogled s jugoistoka na Kamenjak i uvalu Debeljak (fotografija: L. Damelet).
Fig. 3 View from the south-east of Debeljak Cove and Premantura Promontory (photo by: L. Damelet).



Sl. 4 Brodska rebra prilikom uviđaja 2015. (fotografija: I. Koncani Uhač).
Fig. 4 Frames appearing from the sea bottom in 2015 (photo by I. Koncani Uhač).



Sl. 5 Istraživanje brodske konstrukcije tijekom arheološke kampanje 2017. (fotografija: L. Damelet).
Fig. 5 Excavation of the wreck during the 2017 campaign (photo by: L. Damelet).

oplatom građenom tehnikom utora i jezičca. Tom je prilikom na lokalitetu prikupljeno i nekoliko ulomaka kasnoantičkih amfora koje su ponudile preliminarnu kronološku dataciju. Datacija je naknadno potvrđena rezultatom AMS analize (od 335. do 425. godine, 95% vjerojatnosti)¹.

examination of the ship's remains. It was observed that the hull planks were fastened by mortise-and-tenon joints. The few fragments of late antique amphorae collected on the wreck site provided an initial chronological indication, which was later confirmed by AMS calibrated radiocarbon dating of a plank (from 335 to 425 AD, 95% probability)¹.

¹ Radiokarbonska analiza provedena je 2016. godine u laboratoriju Beta Analytic Inc., Miami, SAD (uzorak Beta-442368).

¹ Radiocarbon analysis was conducted in 2016 by Beta Analytic Inc. laboratory, Miami, USA (sample Beta-442368).



Sl. 6 Različite faze rada na brodskoj konstrukciji: a) fino čišćenje; b) označavanje; c) bilježenje i mjerenja; d) podizanje elementa W54 (fotografija: L. Damelet).
 Fig. 6 Different working phases on the wreck: a) fine cleaning; b) marking; c) observation and measurements; d) recovering the timber W54 (photos by: L. Damelet).

Budući da su brodske ostatke bili vidljivi na morskom dnu te su bili u opasnosti od devastacije, u srpnju 2016. odlučeno je da se lokacija zaštiti postavljanjem metalnih mreža usidrenih na 14 betonskih blokova. Betonski blokovi su opremljeni metalnim ušicama koje su omogućile djelomično ili potpuno pomicanje mreže po potrebama istraživanja. Ovakav način zaštite dosad se pokazao učinkovitim za zaštitu podvodnih arheoloških nalazišta, posebno u podmorju Istre (Koncani Uhač, Uhač 2019, 44, 47).

Sustavno istraživanje započelo je 2017. te se nastavilo kroz tri arheološke kampanje do 2019. (sl. 8), u sklopu znanstvene suradnje između Arheološkog muzeja Istre, Konzervatorskog odjela u Puli (Ministarstvo kulture i medija) i Centra Camille Jullian (CNRS, Sveučilište Aix Marseille).

Metodologija istraživanja broda u Debeljaku već je ranije primijenjena pri istraživanju različitih brodoloma

As the wooden remains were exposed on the surface of the seabed and at risk of being destroyed, it was decided in July 2016 to protect the site by placing some metal nets anchored to 14 concrete blocks. The concrete blocks were provided with metallic eyelets allowing for the partial or total removal of the nets according to the needs of research. This system has proven to be effective for the protection of underwater archaeological sites and it is commonly used in Istria (Koncani Uhač, Uhač, 2019, 44, 47)

Systematic excavation began in 2017 and continued into 2019 (Fig. 8) as part of a scientific collaboration between the Archaeological Museum of Istria, the Conservation Department in Pula (Ministry of Culture and Media) and the Centre Camille Jullian (CNRS, Aix Marseille University).

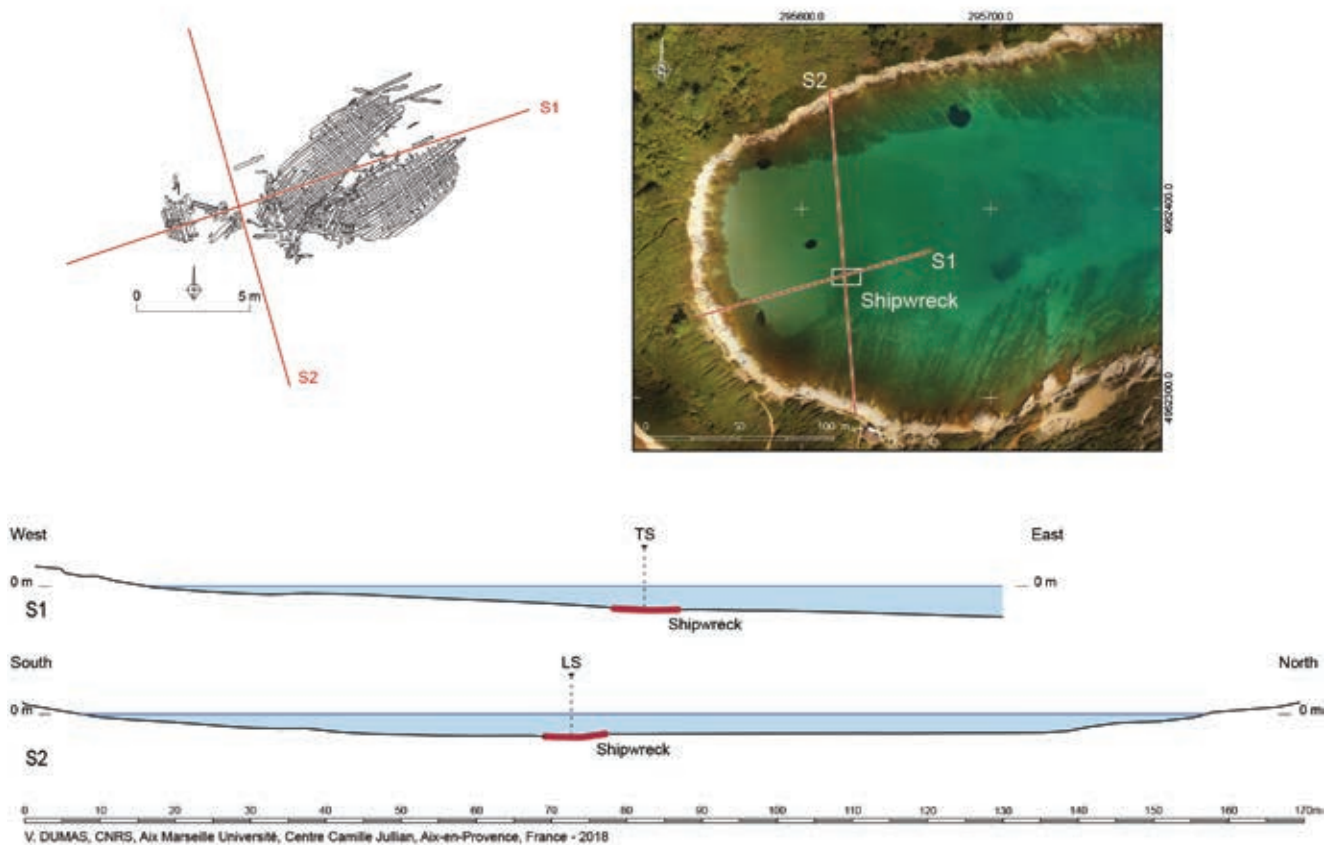
The study procedures were those implemented in the excavation of shipwreck sites in the Mediterranean Sea (Pomey, Rieth 2005, 89-154) and of the prehistoric



Sl. 7 Pogled na uvalu Debeljak s jugozapada: tri crne mrlje su livade posidonije; olupina se nalazi na sredini zaljeva (fotografija: L. Damelet).
 Fig. 7 View from the south-west of Debeljak Cove: the three black spots are *Posidonia oceanica* meadows; the wreck lies in the middle of the bay (photo by: L. Damelet).

u podmorju Sredozemlja (Pomey, Rieth 2005, 89-154), između ostalog i pri istraživanju prapovijesnog broda Zambratija u Istri (Koncani Uhač et al. 2019). Istraživanje je obuhvatilo cjelovito otvaranje i čišćenje brodske konstrukcije, označavanje elemenata alfanumeričkim oznakama i označavanje spojeva pribadačama u boji, georeferenciranje i izmjeru, fotogrametrijsko snimanje i izradu fotografija, prikupljanje nalaza i drvene građe za daljnje analize na kopnu, kao i sustavno uzimanje uzoraka za analize (drvo, paklina i dr., sl. 7 i 8). Po završetku arheološke kampanje istraženi dio brodske konstrukcije prekriven je geotekstilom i slojem pijeska te su iznad nalazišta postavljene vreće s pijeskom i sve je dodatno prekriveno metalnim mrežama.

wreck of Zambratija in Istria (Koncani Uhač et al. 2019). They included extensive exposure and cleaning of the hull remains, marking the structures with alphanumeric labels and the assemblages with coloured pins, georeferencing and measurements, photogrammetric survey and photographic documentation, recovery of artefacts and timbers for study on land, and systematic sampling (wood, pitch, etc.) for analyses (Figs. 7 and 8). At the end of each campaign, the wreck was covered with geotextiles, a layer of sand, sandbags and the metallic nets.



Sl. 8 Lokalizacija brodske konstrukcije i presjek morskog dna (fotografija: L. Damelet; topografija i crtež: V. Dumas).
 Fig. 8 Location of the wreck and sea bottom sections (photo by: L. Damelet; topography and drawing: V. Dumas).

2. OPIS BRODSKE KONSTRUKCIJE

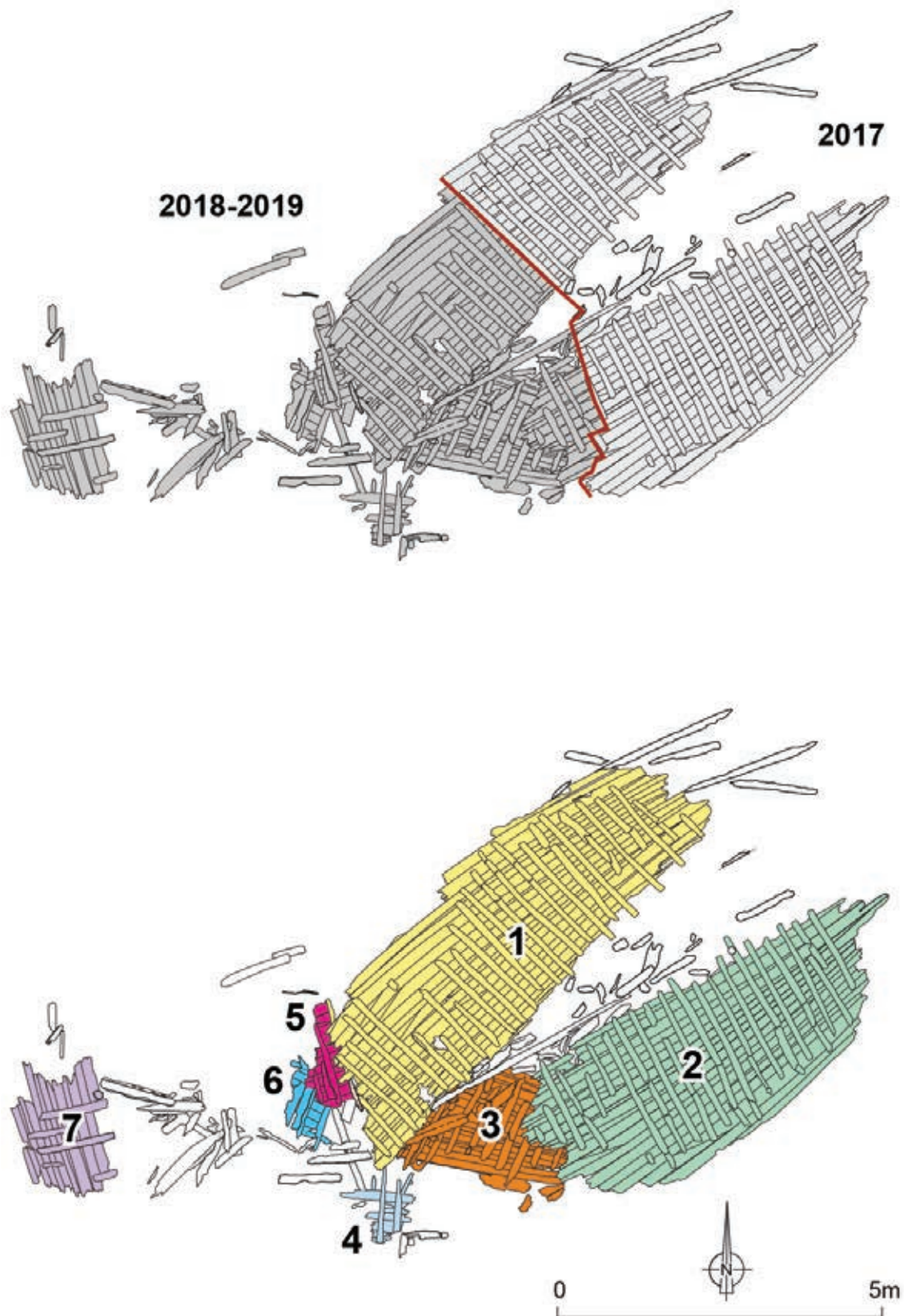
Ostaci broda prostiru se na površini od oko 90 m², a sastoje se od sedam odvojenih cjelina te većeg broja elemenata dislociranih uslijed raspada brodskog trupa (sl. 9–11). Segmenti brodske konstrukcije br. 1 i br. 2 čine glavni dio konstrukcije; njihova dužina iznosi 9 m, a širina 6,2 m. Ovi segmenti odgovaraju sjevernoj i južnoj strani broda. Orijentirani su u smjeru sjeveroistok/jugozapad, dodiruju se na svom jugozapadnom kraju, a međusobno su udaljeni 1,8 m na sjeveroistočnom kraju. Djelomično ispod i između ove dvije cjeline nalazi se treći segment trupa (br. 3; dimenzije 2,5 x 1,8 m) koji je vjerojatno pripadao južnoj strani (br. 2) (sl. 12).

Tri ostala manja segmenta brodskog trupa leže na jugozapadnom kraju. Segment br. 4 nalazi se južno od segmenta br. 3, segment br. 5 djelomično je preklapljen sjevernom stranom broda (br. 1), a segment br. 6 djelomično pokriva segment br. 5. Naposljetku, na udaljenosti od oko 6 m prema zapadu pronađen je još jedan dio brodskog trupa (br. 7; dimenzije 2,3 x 1,5 m) (sl. 9).

2. DESCRIPTION OF THE PRESERVED HULL STRUCTURE

The remains of the ship are scattered over an area of approximately 90 m², and consist of seven separate assemblages and a large number of individual pieces resulting from the disintegration of the hull (Figs. 9–11). Assemblages no. 1 and no. 2 form the main part of the deposit, measuring 9 m in length and 6.2 m in width. They correspond, respectively, to the north and south sides of the ship. These are oriented north-east/south-west, converging at their south-west end and separated by 1.8 m to the north-east end. Partially below and between these two sides is a third segment of the hull (Assemblage no. 3, 2.5 x 1.8 m), possibly belonging to the southern side (Assemblage no. 2) (Fig. 12).

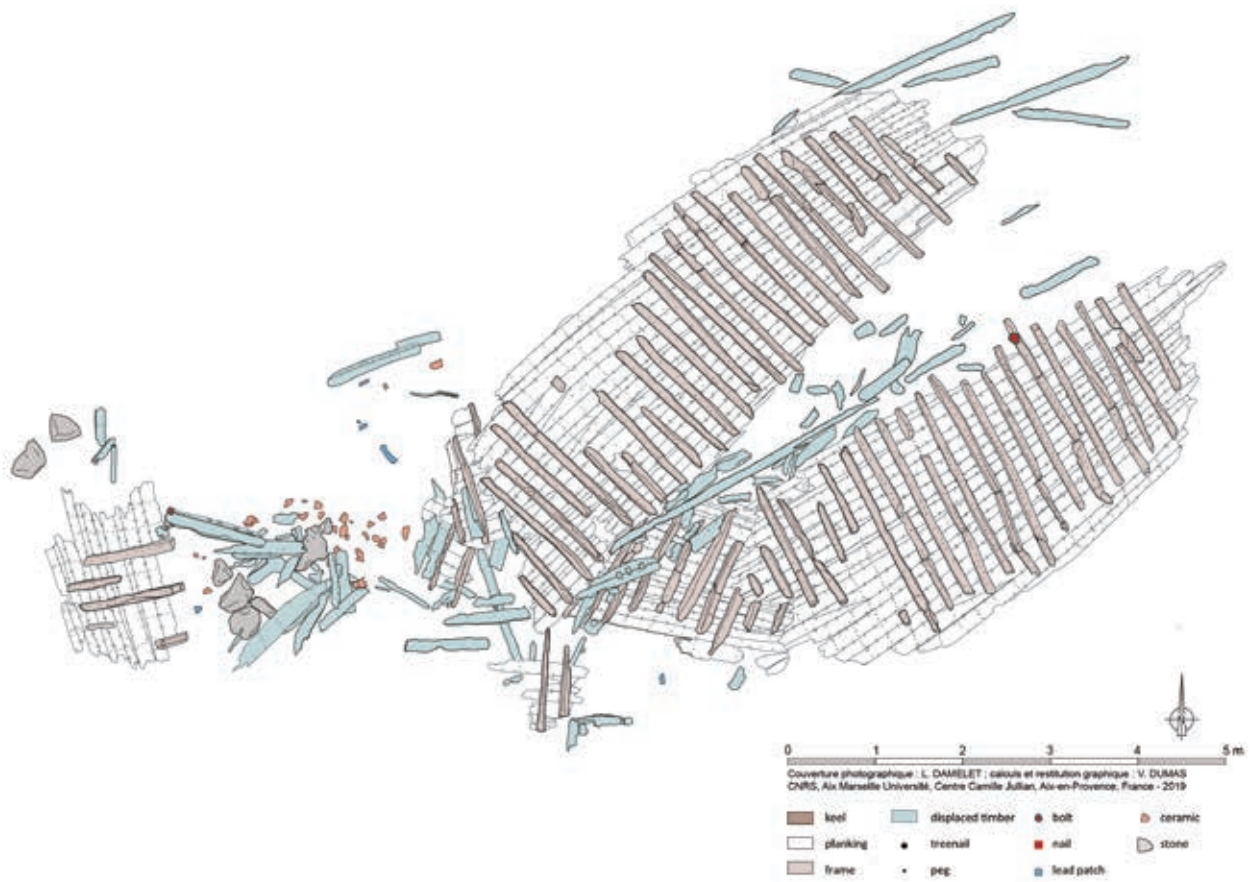
Three other small hull fragments lie at the south-western end of the main deposit: Assemblage no. 4 to the south of Assemblage no. 3; Assemblage no. 5, partially overlapped by the northern side of the ship (Assemblage no. 1); and Assemblage no. 6, partially covered by Assemblage no. 5.



Sl. 9 Istraženi dijelovi brodske konstrukcije kroz tri kampanje te sedam segmenata broskog trupa (crtež: V. Dumas).
Fig. 9 The excavated parts of the wreck during the three campaigns, and the seven hull assemblages (drawing by: V. Dumas).



Sl. 10 Ortofotografija brodske konstrukcije (fotografija: L. Damelet; fotogrametrija: V. Dumas).
Fig. 10 Ortho-image of the wreck (photo by: L. Damelet; photogrammetry: V. Dumas).



Sl. 11 Plan lokaliteta (crtež: V. Dumas).
Fig. 11 General plan of the wreck (drawing by: V. Dumas).



Sl. 12 Pogled s jugozapada na brodsku konstrukciju, istraživanje u 2019.: u prvom planu se nalazi djelomično vidljiv treći segment brodskog trupa (fotografija: L. Damelet; fotogrametrija: V. Dumas).

Fig. 12 View from the south-west of the wreck during the 2019 campaign: in the foreground is the partially covered third section of the hull bottom (photo by: L. Damelet; photogrammetry: V. Dumas).

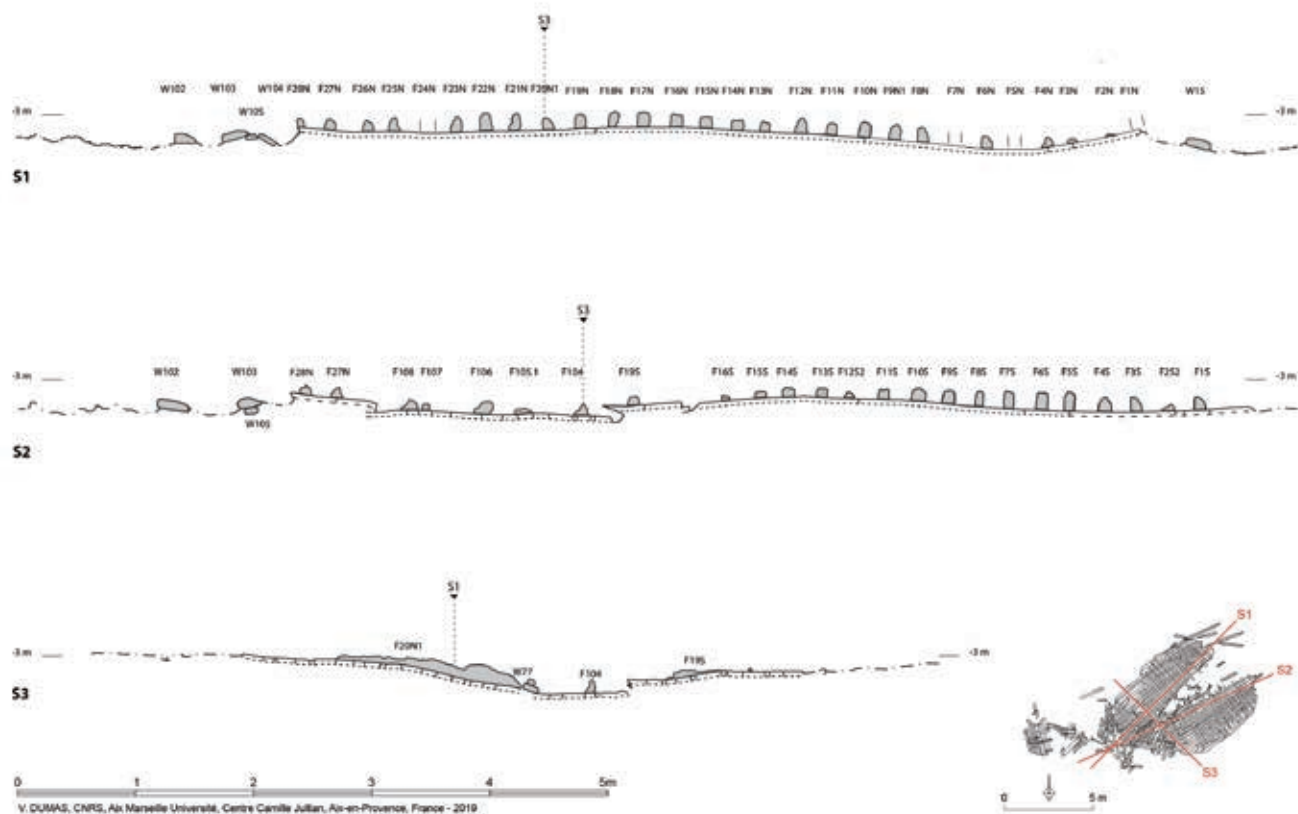
Većina pojedinih elemenata (u lošem stanju sačuvanosti) nalazi se blizu sjeveroistočnog kraja sjeverne strane segmenta br. 1 te u praznini između segmenta br. 1 i br. 2 (sl. 11). Ukupno je 46 elemenata identificirano kao

Finally, another part of the hull (Assemblage no. 7, 2.3 x 1.5 m) was found at a distance of about 6 m to the west (Fig. 9).

Most of the individual timbers are unidentified due to their poor state. These are located near the north-eastern end of the north side Assemblage no. 1, and in the gap between Assemblages nos. 1 and 2 (Fig. 11): 46 were identified as fragments of planks, 19 of frames, eight of ceilings, and two as belonging to the axial carpentry. A few fragments of dislocated planking fastened by mortise-and-tenon joints were also found upside down on the hull (W72, W75, W136, W137).

The wreck is heavily distorted and lies flat on the seafloor under a layer of sand (Fig. 13). Some larger rocks are also visible in the vicinity of Assemblage no. 7 (Figs. 10 and 11). The excavation reached a layer of pebbles and small stones only in the area opened during the 2019 campaign (Fig. 14), which corresponds to the ancient seafloor, underneath the wreck.

The shallow water and the compact seabed, which prevented the ship from sinking into the loose substrate, are factors that certainly accelerated the destruction of the ship's structures, which were quickly colonised by



Sl. 13 Poprečni presjek broda (crtež: V. Dumas).

Fig. 13 Cross section of the wreck (drawing by: V. Dumas).

dijelovi oplata, 19 kao dijelovi rebara, 8 je dijelova podnice te dva dijela uzdužnih elemenata. Nekoliko dislociranih ulomaka platica, pričvršćenih spojevima na utor i jezičac, pronađeno je na samom trupu broda, u obrnutom položaju (W72, W75, W136, W137).

Brodaska konstrukcija je jako deformirana i leži ravno na morskom dnu ispod sloja pijeska (sl. 13). U blizini segmenta br. 7 vidljiva je nakupina većih stijena (sl. 10 i 11). Iskopavanjem tijekom kampanje 2019. (sl. 14) istraženo je dno do sloja šljunka i sitnog kamenja, što bi moglo odgovarati antičkom morskom dnu koje se proteže ispod brodske konstrukcije.

Mala dubina te kompaktno morsko dno, koji su spriječili propadanje broda u rahlu podlogu, s druge strane najvjerojatnije ubrzali proces uništenja brodske konstrukcije razvojem bakterija i morskih crva (*Teredo navalis*), čiji su tragovi posebno vidljivi na gornjem dijelu brodskih rebara (sl. 15).

Kasniji izrast morske trave također je vjerojatno pridonio očuvanju brodske olupine budući da su ostaci trupa i svi dislocirani drveni elementi bili prekriveni vlaknastim materijalom (sl. 15). Ovaj organski sloj, debljine do 10 mm, uočen je ispod rebara i između spojeva platica. Analizom je utvrđeno da je riječ o korijenju i lišću morske trave *C. nodosa*² koja je prekrivši konstrukciju stvorila određenu vrstu zamke za pijesak.

Uzdužni profil kobilice i središnji poprečni presjek broda Debeljak nepoznati su, zbog lošeg stanja sačuvanosti konstrukcije. Međutim, nekoliko brodskih rebara na

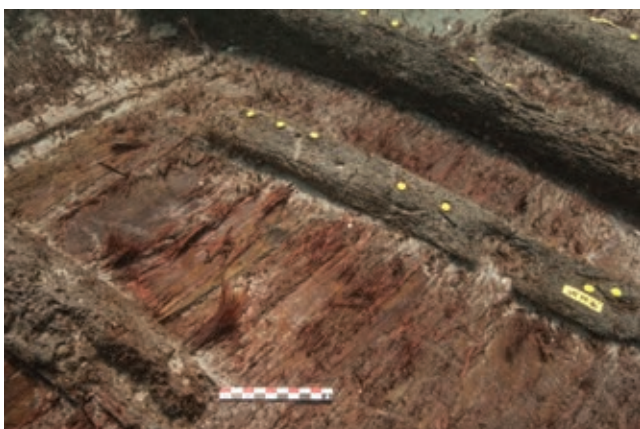


Sl. 14 Pogled s juga na najzapadniji segment konstrukcije (br. 7) koji leži na šljunku i kamenčićima odnosno antičkom morskom dnu (fotografija: L. Damelet).

Fig. 14 View from the south of the westernmost section of the wreck (No. 7) resting on pebbles and small stones corresponding to the ancient seafloor (photo by: L. Damelet).

bacteria and shipworm (*Teredo navalis*), whose channels are particularly visible on the upper surface of the frames (Fig. 15).

Later, marine plants probably contributed to the preservation of the wreck. In fact, the remains of the ship and the dislocated timbers were covered with a fibrous material (Fig. 15). This organic layer, up to 10 mm thick, was also observed under the frames and between the seams of the planks. Analysis revealed that it is composed of roots and leaves of *Cymodocea nodosa*², a species of seagrass. Thus, a *C. nodosa* meadow grew over the wreck creating a trap for the sand.



Sl. 15 Ostaci *Cymodocea nodosa* na brodsjoj konstrukciji. Gornji dio rebara je bio jako oštećen djelovanjem morskog crva (fotografija: L. Damelet).
Fig. 15 Remains of *Cymodocea nodosa* on the ship structures. The upper sides of the frames have been heavily attacked by shipworm (photo by: L. Damelet).



Sl. 16 Poprečni presjek V oblikovanog rebara F1116 i F6S (fotografija: L. Damelet).

Fig. 16 Cross sections of the shallow V-shaped frames F1116 and F6S (photo by: L. Damelet).

² Identifikaciju je obavio prof. Charles-François Boudouresque s Mediteranskog instituta za oceanografiju Sveučilišta Aix Marseille.

² The identification was carried out by Prof Charles-François Boudouresque of the Mediterranean Institute of Oceanography, Aix Marseille University.

krajevima broda pokazuje blagi presjek tzv. vinske čaše (sl. 16). Slijedom navedenog, moguće je da je brod imao umjereni središnji presjek tzv. vinske čaše, kao i brod Dramont E iz Francuske, datiran između 425.–455. godine (Santamaria 1995; Poveda 2017). Ipak, brodske krajeve (pramac – krma) nije moguće utvrditi zbog nepostojanja indikativnih struktura kao što je temeljnica jarbola.

2.1. Uzdužni elementi brodske konstrukcije

2.1.1. Ulomak statve K

Na udaljenosti od 6 metara od brodske konstrukcije, prema zapadu, u blizini segmenta br. 7, godine 2018. otkriven je ulomak statve (K) (sl. 17). Element je prilikom istraživanja izvađen i analiziran na kopnu.

Ulomak statve izrađen je od brijesta (*Ulmus* sp.), blago zakrivljen, širok 14 cm i visok 18 cm (sl. 18). Iako je donja strana jako oštećena, izvorna visina se može procijeniti na oko 20–25 cm. Utori za platice su trokutastog oblika (6,6–7,7 cm visoki i 3,0–3,3 mm duboki). Dva ulomka platica pričvršćena su za statvu jezičcima učvršćenim drvenim čavlima te dodatno s pet željeznih čavlića (prosječno promjera 2,2 cm, međusobno razmaknutih 16,2 cm). Čavli su zabijeni u bočnu stranu platica (sljubnu stranu) i učvršćivali su oštri kraj platice u utor statve. Gornji rub platica ima niz spojeva u formi utor i jezičac. Utori su široki 6,3 cm, visoki 8 mm, duboki 3,0–3,5 cm i razmaknuti 8,5 cm (jedan od drugog).

Zapadni kraj statve K je ključ na zub koji je služio za spoj s kobilicom (nije sačuvana). Ključ je zabrtvljen metalnom



Sl. 17 Detalj statve K, pogled sa zapadne strane. U prvom planu spoj na ključ s ulomkom rebrenice spojene s gornje strane. Konkrecija odgovara svornjaku i metalnom limu koji je služio za brtvljenje spoja (fotografija: L. Damelet).
Fig. 17 Detail of view from the west of transitional timber K. In the foreground, the hook scarf with a fragment of floor timber attached on the top. The concretions correspond to the bolt and the sheet of metal waterproofing the scarf (photo by: L. Damelet).

The longitudinal profile along the keel and the midship cross section of the Debeljak ship are unknown due to the poor state of preservation of the remains. However, a few frames located at the ends of the wreck show a gentle wine-glass cross section (Fig. 16). Thus, it is possible that the ship had a moderate wine-glass midships cross section, perhaps similar to that of Dramont E (France, AD 425–455, Santamaria 1995; Poveda 2017). Finally, the sailing direction cannot be established due to the absence of indicative structures, such as the mast step.

2.1 The axial carpentry

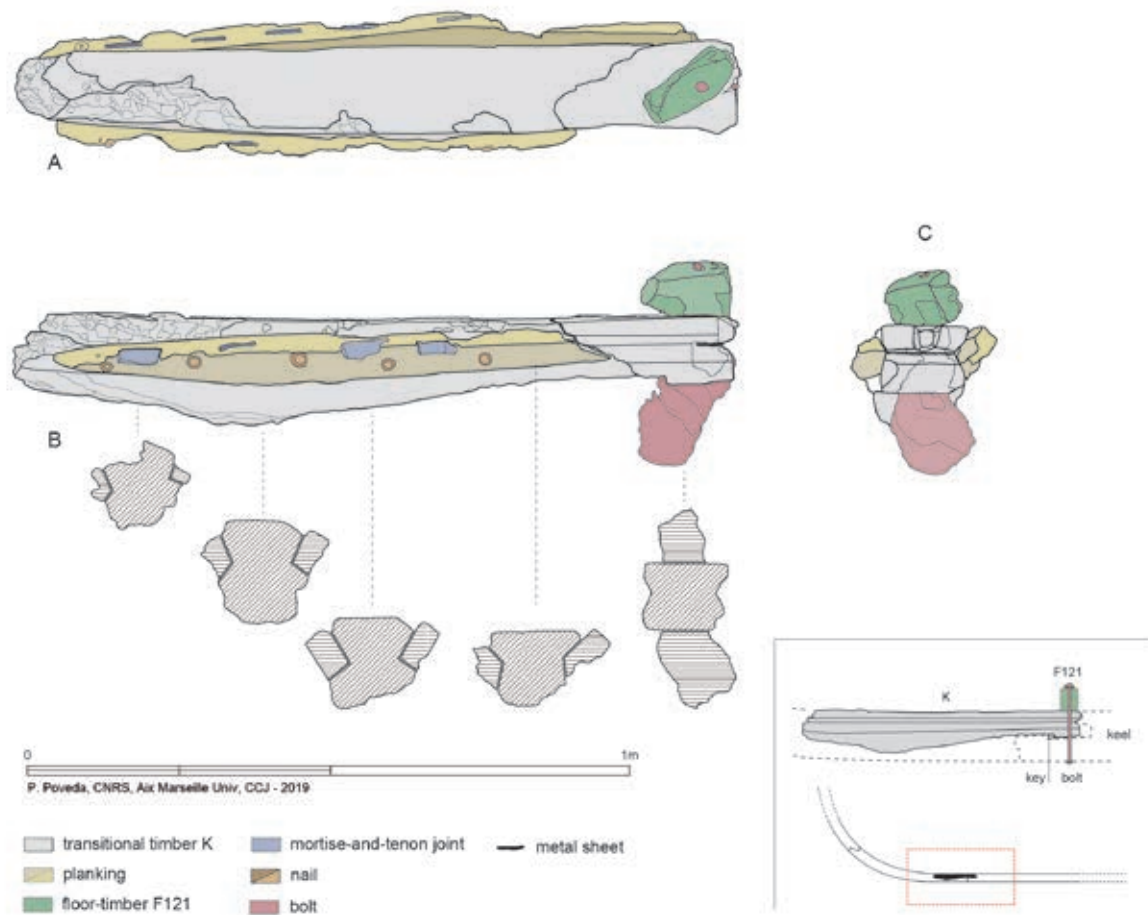
2.1.1 Transitional timber K

In 2018, a rabbeted piece (K) was discovered near Assemblage no. 7, at a distance of 6 m to the west of the wreck (Fig. 17). In 2019, this transitional timber was recovered and examined on land.

The piece, made of elm (*Ulmus* sp.), is slightly curved, 14 cm sided and 18 cm moulded (Fig. 18). Although the underside is badly deteriorated, the original mould could be evaluated at about 20–25 cm. The rabbet is triangular in shape (6.6–7.7 cm high and 3–3.3 cm deep). Two fragments of planks are attached to the piece by pegged tenons, each plank being secured by five nails (average diameter 2.2 cm, spaced 16.2 cm apart). Nails driven into the thickness of the planks lock their ends into the rabbets. The top edge of the planks has a row of mortise-and-tenon joints. The mortises are 6.3 cm wide, 8 mm thick, 3–3.5 cm deep and spaced 8.5 cm apart (side-to-side).

On the western end of transitional timber K is a hook scarf which ensured connection to the keel (not preserved). The scarf was sealed by a metal sheet. This is a well-attested sealing system for keel scarfs on ships of the Roman Empire and late antiquity. Comparable examples are the wrecks of Antibes (2nd century AD, Boetto 2019, 247–248), Toulon 3–4 and 6 (3rd century AD, Boetto 2022, 345 and 356), Pointe de la Luque B and Port-Vendres I (4th century AD and circa AD 400, Dubois 1976, 174) and Dramont E (Santamaria 1995, 138, Fig. 134).

The hook scarf was locked with a horizontal key (not preserved). A bolt, which has turned into a shapeless concretion (shaft diameter 2.5 cm), secured the scarf and connected a floor timber (F121), a small fragment of which is preserved on the upper surface of K. Thus, the total height of the transitional timber K and the floor timber F121 is 32 cm.



Sl. 18 Statva K: A) pogled odozgo; B) sjeverna strana; C) zapadna strana sa spojem na ključ (crtež: P. Poveda).
 Fig. 18 Transitional timber K: A) top view; B) north side; C) west side with hook scarf (drawing by: P. Poveda).

pločicom. Ovaj sustav brtvljenja ključa kobilice poznat je na brodovima iz carskog i kasnoantičkog vremena. Analogije se mogu pronaći na brodovima Antibes (2. st., Boetto 2019, 247–248), Toulon 3–4 i 6 (3. st., Boetto 2022, 345, 356), Pointe de la Luque B i Port - Vendres I (4. st. i 5. st., Dubois 1976, 174) i Dramont E (Santamaria 1995, 138, sl. 134).

Spoj s ključem na zub bio je osiguran vodoravnim čepom (nije sačuvan). Svornjak koji se pretvorio u bezličnu konkreciju (promjera 2,5 cm), učvršćivao je spoj i povezivao rebrenicu (F121), čiji je mali ulomak sačuvan na gornjoj plohi statve K. Time je ukupna visina prijelaznog elementa K i rebrenice F121 iznosila 32 cm.

2.1.2. Dislocirani element W54

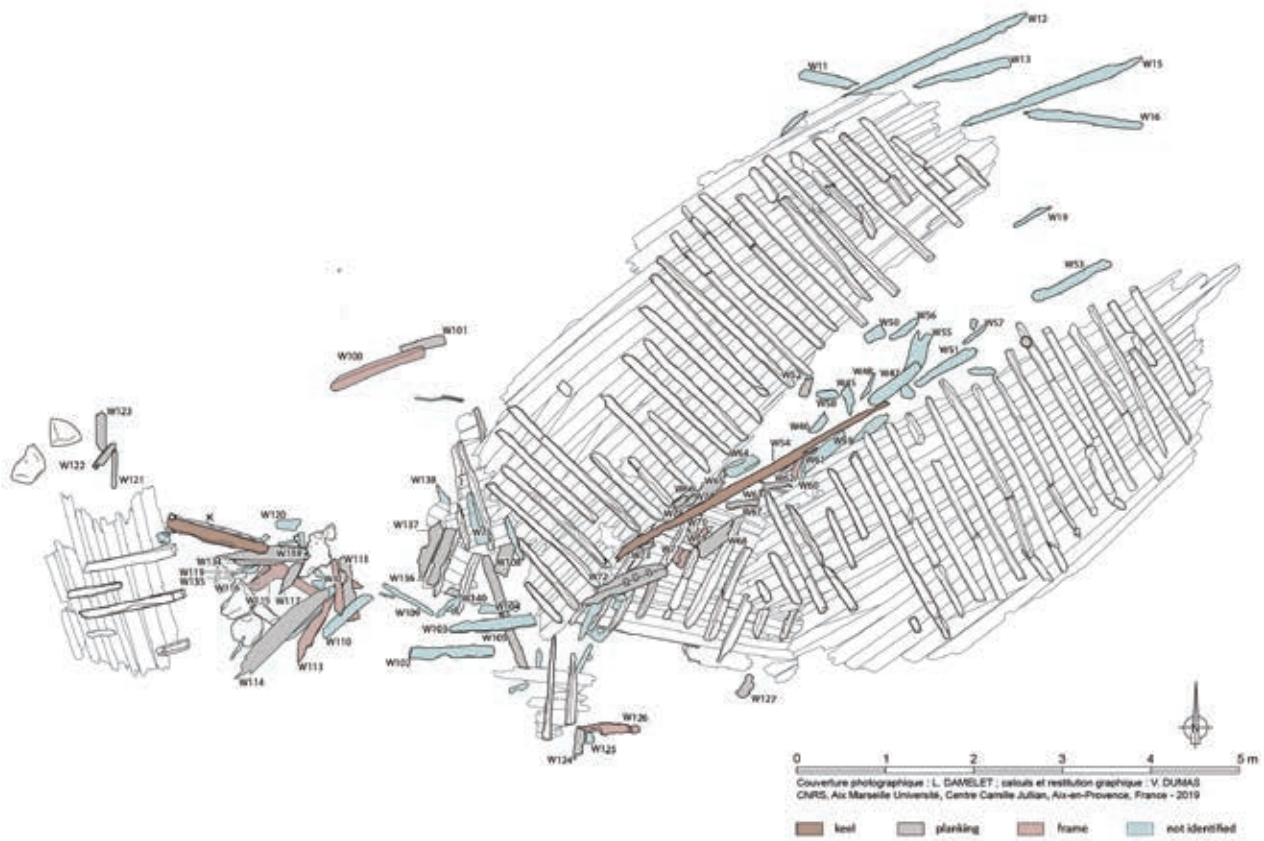
Drveni element W54 pronađen je između dviju strana brodske konstrukcije, u jako lošem stanju, a dužina mu je 3,5 m (sl. 19).

2.1.2 The dislocated timber W54

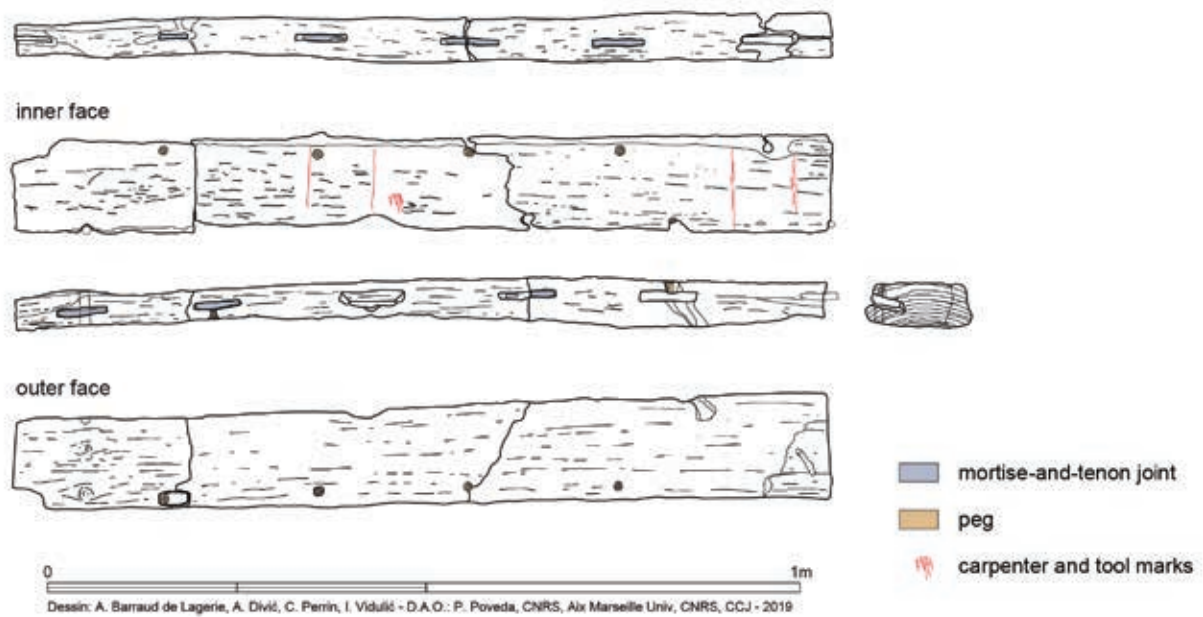
A timber designated as W54 was found between the two sides of the wreck. Although heavily damaged by shipworm, it is preserved over a length of 3.5 m (Fig. 19).

A segment of W54, 1.8 m long, was recovered in 2019 and examined on land (Fig. 6d). The timber, of elm (*Ulmus* sp.), is 12.7 cm sided and 5.5 cm moulded (Fig. 20). The edges are cut by mortise-and-tenon joints. The mortises are, on average, 6.5 cm wide, 4–5 mm thick and spaced 12 cm. Tenons are 5.8 cm wide. Small pegs secure the tenons; they are on average 12 mm inner diameter, 9–10 mm outer diameter, and spaced 18 cm centre-to-centre. No treenails or nails for joining the frames were observed, but a few parallel lines, inscribed with a sharp point and spaced 47 cm apart (side-to-side), mark the position of the frames. These marks were also observed in other areas of the hull (see infra).

Although extremely damaged, it seems that this timber W54 was wider than it was thick. Two identification



Sl. 19 Lokacija dislociranog drvenog elementa (crtež: V. Dumas).
 Fig. 19 Location of the displaced timbers (drawing by: V. Dumas).



Sl. 20 Element W54 identificiran kao kobilica (crtež: P. Poveda).
 Fig. 20 Timber W54 identified as the keel (drawing by: P. Poveda).

Dio elementa W54, dužine 1,8 m, izvađen je 2019. te je analiziran na kopnu (sl. 6d). Izrađen je od brijesta (*Ulmus* sp.), širine 12,7 cm i visine 5,5 cm (sl. 20). Na bočnim stranama elementa nalaze se utori prosječne širine 6,5 cm, visine 4–5 mm i razmaka 12 cm, kao i jezičci širine 5,8 cm. Mali drveni čavli učvršćuju jezičce. Dimenzije čavala su u prosjeku unutarnjeg promjera 1,2 cm, vanjskog promjera 10–9 mm, razmak od središta do središta 18 cm. Na elementima nisu uočene čivije ili metalni čavli za spajanje rebara, ali nekoliko paralelnih linija, iscrtanih ostrim šiljkom (međusobno udaljenih 47 cm), označavalo je položaj rebara. Ovi su tragovi uočeni i na drugim dijelovima broskog trupa (vidi dolje).

Iako izuzetno oštećen, čini se da je drveni element W54 izvorno bio širi nego viši. Kao njegova identifikacija predlažu se dvije pretpostavke: dio kobilice ili dio dokobilicnog voja. Budući da je pronađen u procjepu između dviju strana broda te je izrađen od istog drva (brijest) od kojeg je izrađena statva K, za razliku od oplata koja je bila homogeno izgrađena od vrsta četinjača (vidi dolje), hipoteza da je element W54 zapravo kobilica broda čini se ispravnom. Ukoliko je navedena pretpostavka točna, brod je na pojedinim dijelovima imao plosnatu kobilicu.

Smanjena visina kobilice mogla bi se objasniti činjenicom da je brod bio izvučen na navoz ili izravno na obalu, čime se ona mogla oštetiti. To je slično objašnjenju koje se nudi kako bi se objasnila izuzetno mala visina kobilice broda Napoli A, koji je napušten u napuljskoj luci krajem 1. stoljeća (Boetto, Poveda 2018, 27).

2.2. Oplata

Očuvana brodska oplata sastoji se od 31 platice na sjevernoj i 30 platica na južnoj strani (sl. 21). Treći segment trupa ima 19 platica, dok se ostali segmenti sastoje od manjeg broja platica³.

Bile su spojene kosim spojem u cilju formiranja vojeva te međusobno uz pomoć utora i jezičaca koji su bili izvedeni na njihovim bočnim stranicama. Krajevi platice bili su spojeni čavlima, zabijenim u bok sa susjednom platicom (sl. 22). Utvrđeno je postojanje velikog broja mrtvih vojeva.

U prosjeku, platice su širine 13 cm i debljine 3,3 cm. Platica P117 je žuljnica, kao i četiri dislocirana fragmenta otkrivena 2019. godine (W105, W117, W130 i W136). Njihova debljina je između 9 i 12 cm, a prosječna širina je 12 cm.

hypotheses can be put forward: it is part of the keel, or part of a garboard strake. As it was found in the gap between the two sides of the ship and is made from a wood species similar to that employed for transitional timber K (elm), whereas the planking was homogeneously made from coniferous species (see infra), the hypothesis that W54 is the keel of the ship seems convincing. If this is the case, the ship had a flat keel, at least along some sections of its length.

The reduced thickness of the keel could be explained by the fact that the ship was hauled on a slipway or directly on the shore. This activity would have damaged the keel. Such an explanation has also been proposed to explain the extremely reduced mould of the keel of the Napoli A ship, which was abandoned in the port of Naples at the end of the 1st century AD (Boetto, Poveda 2018, 27).

2.2 The planking

The planking consists of 31 planks on the north side and 30 planks on the south side (Fig. 21). The third segment of the hull has 19 planks, while the other assemblages consist of a smaller number of planks³.

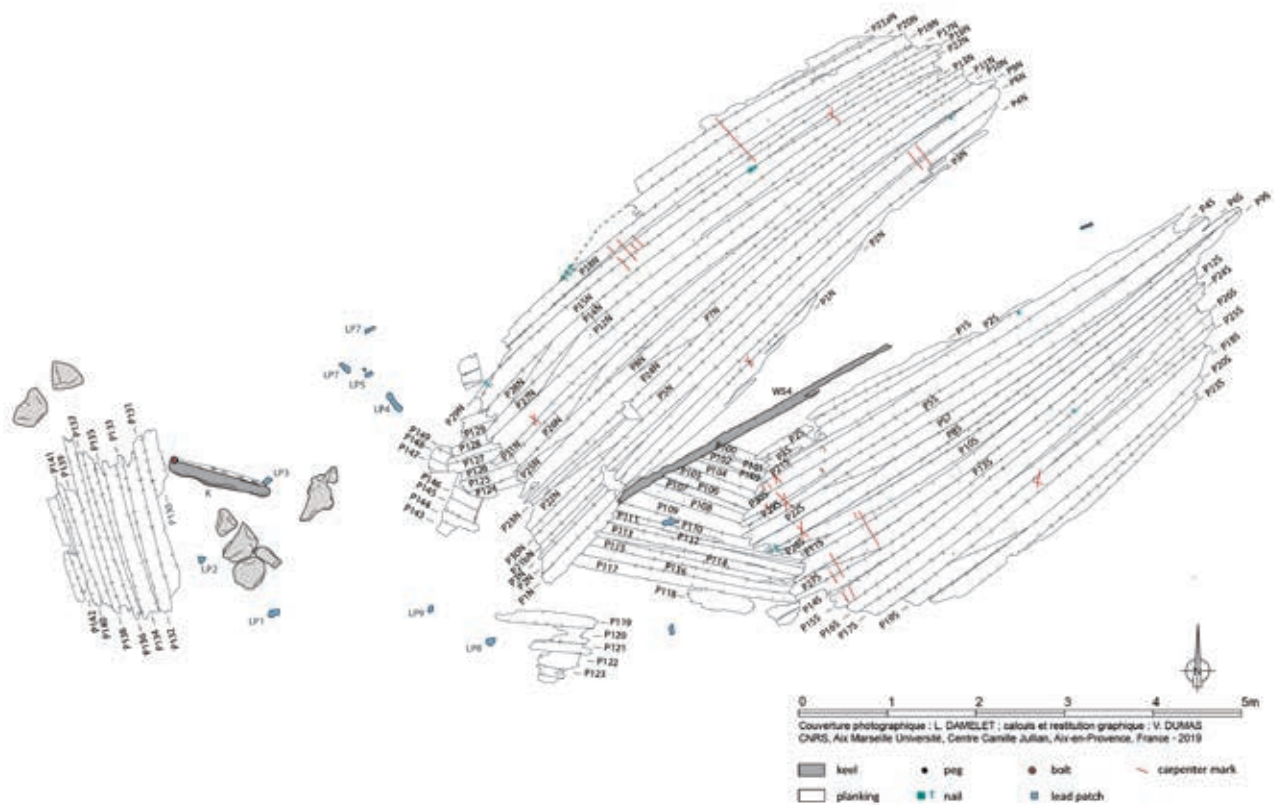
Planks are joined by diagonal scarfs to form strakes and are fastened by mortise-and-tenon joints. Horizontal nails driven into the thickness of the planks secure their ends to the edges of adjacent planks (Fig. 22). A large number of stealers are also documented.

On average, the planks are 13 cm wide and 3.3 cm thick. Plank P117 is a wale, as are four other dislocated fragments discovered in 2019 (W105, W117, W130 and W136). Their thickness is between 9 cm to 12 cm, the average width is 12 cm.

Measurements of the fasteners were taken on some of the individual pieces and, where possible, on the hull (Figs. 23–25). The mortises are larger than the tenons. They are, on average, 6.2 cm wide, 8 mm thick, 4.5 cm deep, and spaced 12 cm apart (side-to-side). The pegs are tapered (inner diameter 11 mm, outer diameter 9.2 mm) and spaced 10 cm apart (centre-to-centre). The tenons are 8.2 cm long, 4.7 cm wide, 6 mm thick. One tenon (DE18/N10), found detached, is longer than the others (13 cm) and was secured by three pegs. It was used to join three planks at an oblique scarf or a stealer (Fig. 25).

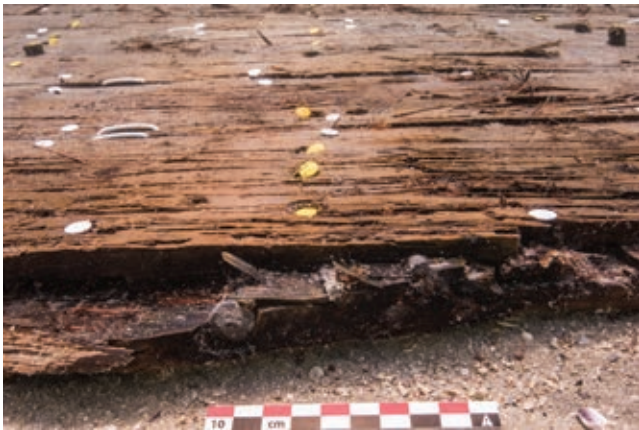
³ Segmenti. br. 4, 6 platica; br. 5, 11 platica; br. 6, 7 platica i br. 7, 14 platica.

³ Assemblages no. 4, 6 planks; no. 5, 11 planks; no. 6, 7 planks; and no. 7, 14 planks.



Sl. 21 Brodska oplata (crtež: V. Dumas).

Fig. 21 The planking (drawing by: V. Dumas).



Sl. 22 Tri čavla koja učvršćuju kraj platice P19N za susjednu platicu P18N (fotografija: L. Damelet).

Fig. 22 Detail view of three horizontal nails fixing the tip of plank P19N to the adjacent plank P18N (photo by: L. Damelet).



Sl. 23 Ulomak platice sa spojem jezičac i utor: utor je blago trapezast i veći od jezičca (fotografija: L. Damelet).

Fig. 23 A fragment of plank with mortise-and-tenon joints: the mortise is slightly trapezoidal and larger than the tenon (photo by: L. Damelet).

Mjerenja spojnih elemenata izvedena su na pojedinim dijelovima trupa, gdje je to bilo moguće (sl. 23–25). Utori su veći od jezičaca – prosječno su široki 6,2 cm, visoki 8 mm, duboki 4,5 cm i razmaknuti jedan od drugog 12 cm. Mali drveni čavli su zašiljeni (unutarnji promjer 11 mm,

2.3 The frames

Twenty-seven and 21 frames survived in place on the north and south sides (Assemblages nos. 1 and 2 respectively). The traces of additional four frames were identified on the south side, and of one on the north side.



Sl. 24 Jezičci i mali drveni čavli dislocirane platice W39 (fotografija: L. Damelet).

Fig. 24 Tenons and pegs from displaced plank W39 (photo by: L. Damelet).

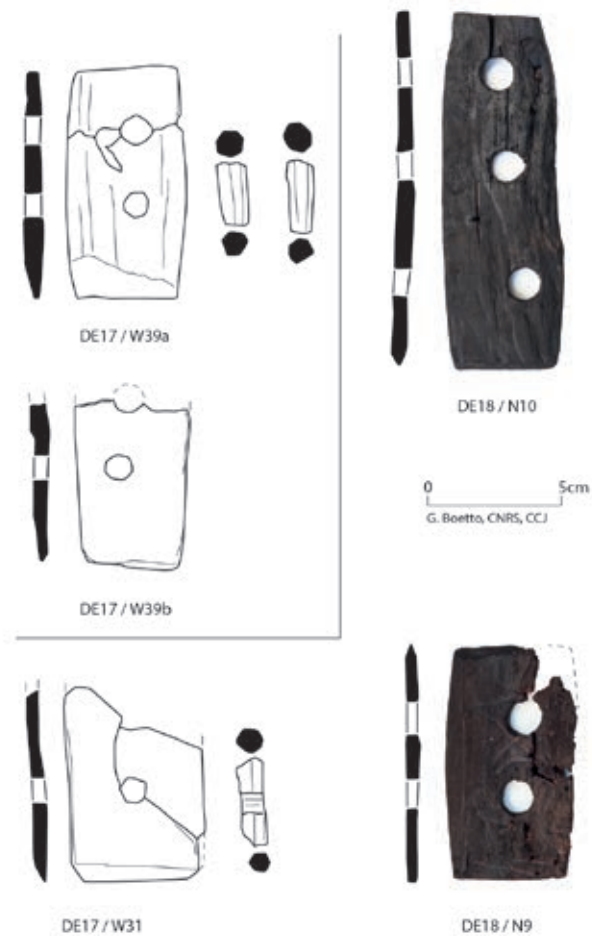
vanjski promjer 9,2 mm) i međusobno udaljeni 10 cm (od centra do centra). Jezičci su dugi 8,2 cm, široki 4,7 cm, debeli 6 mm. Jezičac (DE18/N10) koji je pronađen odvojeno, duži je od ostalih (13 cm) i bio je pričvršćen s tri klina. Služio je za spajanje triju platica ili mrtvog voja kosim spojem (sl. 25).

2.3 Poprečni elementi brodske konstrukcije

Brodská konstrukcija se sastoji od 27 rebara na sjevernom segmentu broda (br. 1) te 21 rebra na južnom segmentu (br. 2). Na južnom su uočeni tragovi još četiri rebra, a na sjevernom jednog. Na trećem segmentu trupa sačuvano je deset rebara, a na ostala četiri segmenta ukupno 12 rebara (br. 4-7). Devetnaest dislociranih drvenih elemenata također je identificirano kao rebra. Jedno brodsko rebro bilo je pričvršćeno na prijelazni element K (sl. 26).

Pravokutnog presjeka (9,4 cm širina i 12,2 cm visina), rebra su razmaknuta 16,8 cm jedan od drugoga. Na južnom segmentu se prepoznaje opća shema orebrenja s tipičnom izmjenom rebrenice produljene rebrenim nastavkom s polurebrenicom. Izmjenu je teško prepoznati drugdje jer je većina rebara slomljena na krajevima. Pojedina rebra čine dva ili tri elementa koji nisu međusobno spojeni, već su jednostavno sljubljeni (sl. 27).

Rebrenica F6S, polurebrenice F5S i F7S na istočnom kraju južnog segmenta (br. 2) i polurebrenica F116 (br. 7) blago su oblikovane u obliku slova V u donjem dijelu (sl. 13, 28 i 29). Dislocirana rebrenica u obliku slova V (W115) također je pronađena u blizini statve K. Zbog nepravilnog oblika sirovine iz koje je oblikovana, bilo je potrebno umetnuti komad drva (W116) da se popuni

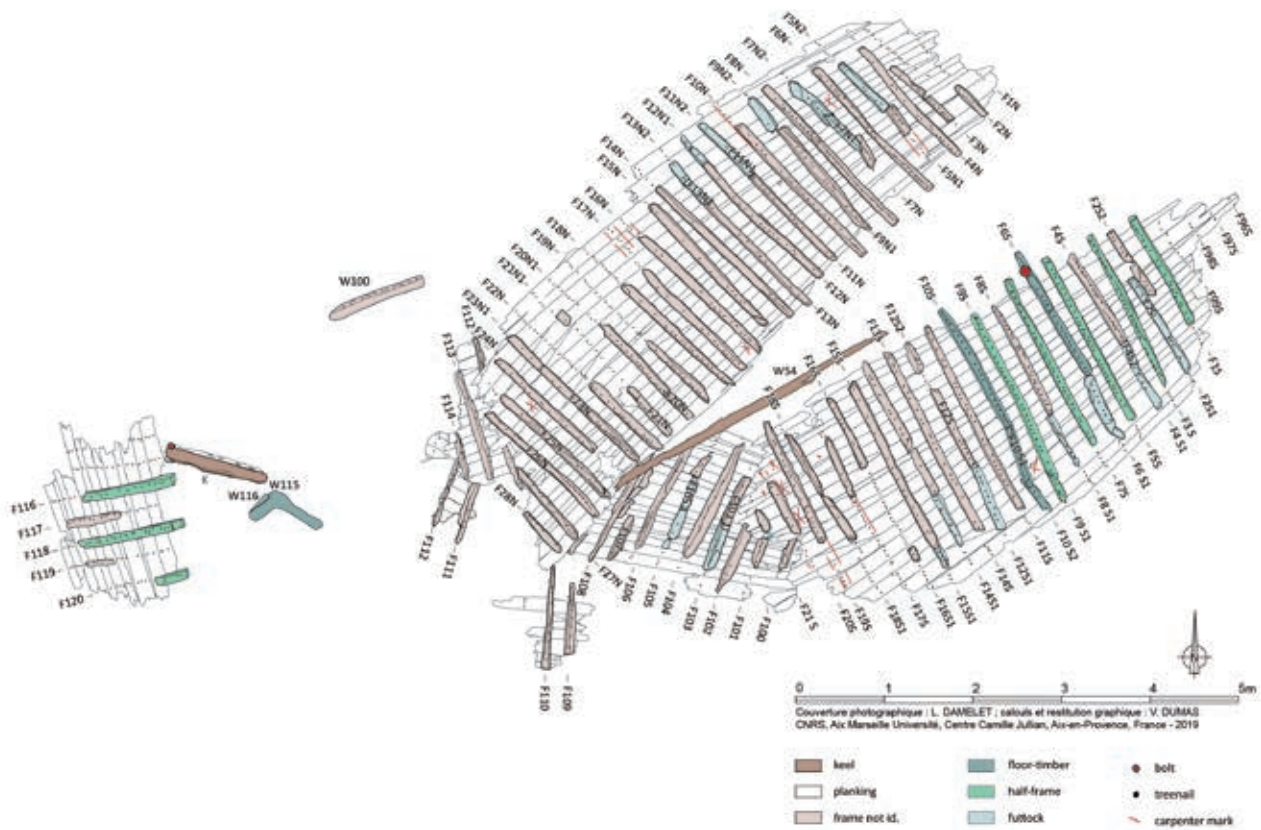


Sl. 25 Jezičci iz spojeva oplata (fotografije: L. Damelet; crteži: G. Boetto).
Fig. 25 Tenons from the assemblies (photos by: L. Damelet; drawings by: G. Boetto).

Ten frames survived on the third assemblage of the hull, and 12 in total on the other four assemblages (nos. 4-7). Nineteen displaced timbers were also identified as frames. One was attached to transitional timber K (Fig. 26).

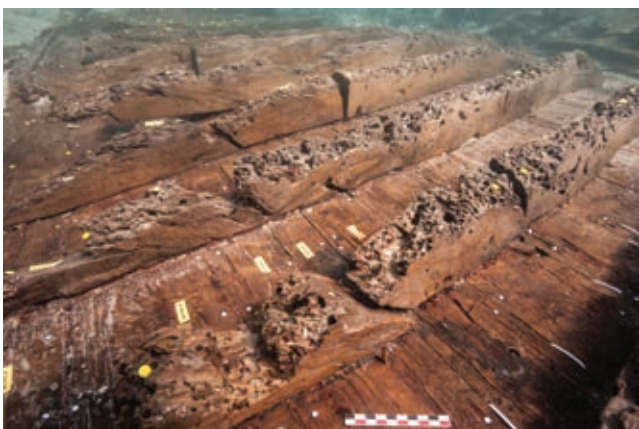
The frames are rectangular in section (9.4 cm sided and 12.2 cm moulded) and spaced 16.8 cm apart (side-to-side). The general framing pattern with a typical alternation between floor timber prolonged by futtocks and half-frame is recognisable on the south side. The alternation is difficult to recognise elsewhere as most of the frames are broken at their ends. Some of the frames are made up of two or three pieces which are not joined together but are simply butt-jointed (Fig. 27).

Floor timber F6S, half-frames F5S and F7S at the east end of the south side (Assemblage no. 2) and half-frame F116 of Assemblage no. 7 are gently V-shaped at their base (Figs. 13, 28 and 29). A dislocated V-shaped floor timber (W115) was also found near transitional timber K. Due



Sl. 26 Brodska rebra (crtež: V. Dumas).

Fig. 26 The frames (drawing by: V. Dumas).

Sl. 27 Pogled sa sjeverozapada na rebro sa sljubljenim elementima. U prvom planu, tri emelenta rebra F13 na sjevernoj strani (fotografija: L. Damelet).
Fig. 27 View from the north-west of a frame with butt-jointed components. In the foreground, the three components of frame F13, north side (photo by: L. Damelet).Sl. 28 Pogled sa sjeverozapada na rebro F6S: gornja površina je obrađena s utorima za smještaj dohrptenice i proveze (nisu sačuvane); kongrecija je gornji dio svornjaka (fotografija: L. Damelet).
Fig. 28 View from the north-west of floor timber F6S: the upper surface is carved with recesses to house a sister keelson and a stringer (not preserved); the concretion is the upper part of the bolt (photo by: L. Damelet).



Sl. 29 Polurebrenica F116 s trokutastom rupom za slivnicu i udubljenjem za smještaj kobilice, pogled sa sjevera (fotografija: L. Damelet).
Fig. 29 View from the north of half-frame F116 with a triangular limber hole and a recess to house a keelson (photo by: L. Damelet).



Sl. 30 Komad drva W115 iskorišten za učvršćenje rebra F116 (fotografija: L. Damelet).
Fig. 30 Floor timber W115 and its filling piece F116 (photo by: L. Damelet).

praznina između rebra i oplata (sl. 30). Sva ova rebra imaju trokutaste rupe tj. slivnice na dnu, kako bi se omogućio protok u brodskoj kaljuži.

Tri mala drvena umetka s rupom u sredini (prosječne dužine 8 cm, širine 3,7 cm, debljine 8 mm) (sl. 31) vjerojatno su korištena za učvršćenje rebara.

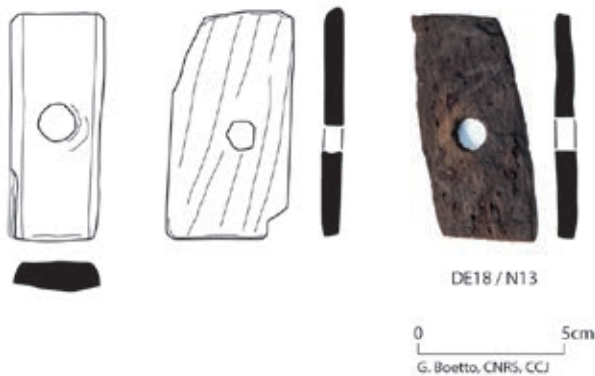
Najmanje dvije rebrenice bile su pričvršćene svornjacima, F121 za statvu K (sl. 17 i 18) i F6S za kobilicu (nije sačuvana) (sl. 13 i 28).

Rebra su bila pričvršćena za oplatu zašiljenim čivijama (prosječni promjer 1,4 cm, sl. 32) i metalnim čavlima, od

to the irregular shape of the branch used to form it, it was necessary to add a piece of wood (W116) to fill the gap between the frame and the planking (Fig. 30). All these frames are carved with triangular limber holes at their base to allow bilge water to circulate.

Three small rectangular pieces of wood with a hole in the middle (average 8 cm long, 3.7 cm wide, 8 mm thick) were found during the excavation (Fig. 31). These are probably wedges that have been inserted under some frames.

At least two floor timbers were attached to the axial carpentry by bolts: F121 to transitional timber K (Figs.



Sl. 31 Tri drvena umetka (fotografija: L. Damelet; crtež: G. Boetto).
Fig. 31 Three wedges (photo by: L. Damelet; drawing by: G. Boetto).

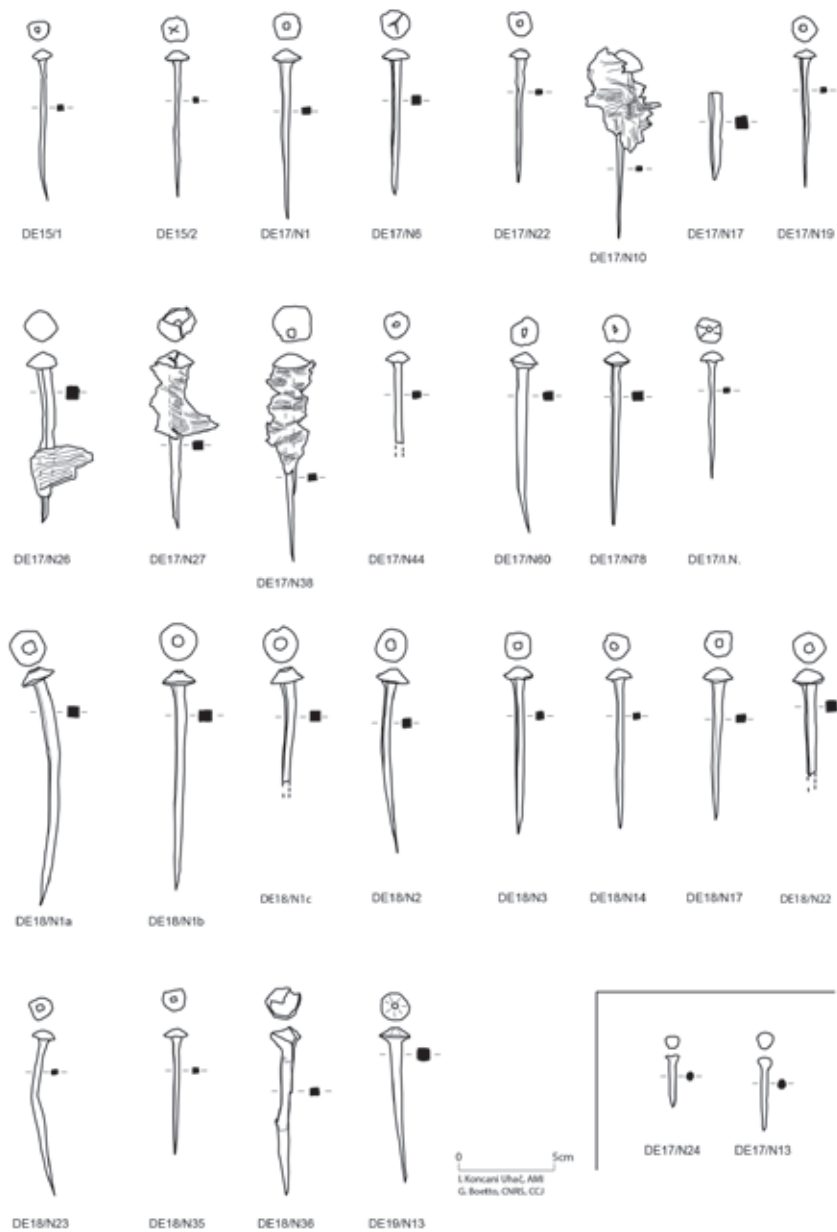


Sl. 32 Čivija na dislociranom brodskom rebru W20 (fotografija: L. Damelet).
Fig. 32 Treenail driven into the displaced frame W20 (photo by: L. Damelet).



Sl. 33 Čavli koji spajaju rebra s oplatom i detalj glave čavla (fotografije: L. Damelet).

Fig. 33 Nails joining the frames to the planking and detail of a head (photos by: L. Damelet).



Sl. 34 Čavli za rebra i dva mala čavla za pričvršćivanje olovnih zakrpa (crteži: I. Koncani Uhač).

Fig. 34 Nails for the frames and two small nails to fix the lead patches (drawings by: I. Koncani Uhač).

kojih je 27 pronađeno dislocirano na morskom dnu (sl. 33 i 34). Dužina metalnih čavala iznosi u prosjeku 8,7 cm (od 6,6 cm do 12,4 cm) s prosječnim promjerom glave 1,4 cm, kvadratnog presjeka. Na čavlu DE18/N1 provedena je SEM-EDS mikroanaliza sastava uz pomoć skenirajućeg elektronskog mikroskopa. Mikroanalizom je utvrđeno da je čavao izrađen od legure bakra i kositra, odnosno vrste bronce s dodatkom olova⁴. Visok udio ugljika otkriven na površini ukazuje na prisutnost zaštitnog sredstva organske prirode (tj. pakline).

2.4 Unutarnji elementi

Na samim rebrima nisu sačuvane podnice, već se samo devet vrlo dotrajalih pojedinačnih elemenata moglo prepoznati kao dijelovi podnica (W4-W6, W8, W26, W35, W57, W101 i W111). Njihova debljina iznosi oko 3,5-4,5 cm.

Dva rebra su na gornjoj površini imala urezane otore, što ukazuje na postojanje unutarnjih elemenata. Polurebrenica F116 ima utor urezan na gornjoj površini prema kobilici, gdje je vjerojatno bila pričvršćena hrptenica (sl. 13 i 29). Rebrenica F6S ima dva utora južno od svornjaka, razmaknuta 37 cm. Vjerojatno je ovaj drugi utor služio za umetanje proveze dok je prvi urezan za ugradnju dohrptenice, u cilju podupiranja hrptenice / temeljnice jarbola (sl. 13 i 28). I kod rimskih carskih brodova zapadnog tipa uzdužni elementi se sastoje od dvije središnje dohrptenice, koje su u većini slučajeva spojene poprečnim sponama (Pomey et al. 2012, 300) oslonjenim na rebrenice, podupirući dugu i jaku hrptenicu / temeljnicu jarbola. Ovakva unutarnja uzdužna konstrukcija predložena je i za kasnoantički brod Pakoštane (Boetto et al. 2018, 57-58, sl. 68-69).

2.5 Alati i brodograditeljske oznake

Tragovi alata i brodograditeljskih oznaka sačuvani su s unutarnje strane broskog trupa (Sl. 35a i d).

Utvrdeno je postojanje tri tipa brodograditeljskih oznaka. Paralelne linije urezane oštrim šiljkom označavale su položaj rebara (sl. 35b), sukladno vrlo čestoj praksi zabilježenoj na nekoliko rimskih brodova, poput Saint-Gervais 3 (sredina 2. stoljeća, Liou, Gassend 1990, sl. 98) i Toulon 3-4, 6 i 7 (3. - 4. stoljeće, Boetto 2022, 351, 361, 367). Crne okomite linije napravljene ugljenim štapićem (sl. 35c) sačuvane su na bočnim stranama pet

17 and 18), and F6S to the keel (not preserved) (Figs. 13 and 28).

The frames are attached to the planking with tapered treenails (average diameter 1.4 cm, Fig. 32) and nails: 27 individuals were found scattered on the seabed (Figs. 33 and 34). They are, on average, 8.7 cm long (from 6.6 cm to 12.4 cm) with an average head diameter of 1.4 cm and a square shank. A SEM-EDS microanalysis was carried out on the nail DE18/N1. It revealed that it is made of a copper-tin alloy, or a type of bronze with the addition of lead⁴. A high proportion of carbon detected on the surface indicates the presence of a protective agent of an organic nature (e.g. pitch).

2.4 The internal carpentry

The internal carpentry was not preserved on the frames, and only nine highly deteriorated individual timbers could be recognised as part of the ceiling (W4-W6, W8, W26, W35, W57, W101 and W111). Their thickness is about 3.5-4.5 cm.

Two frames have recesses carved into their upper surfaces indicating the presence of an internal carpentry. The half-frame F116 has a recess cut into its upper surface towards the keel. It is possible that a keelson was attached in this recess (Figs. 13 and 29). Floor timber F6S also has a step south of the bolt, and another 37 cm apart. It is likely that this second step was cut to accommodate a stringer, while the first was cut to install a sister keelson to support the keelson/mast step (Figs. 13 and 28). In the western Roman Imperial type, the longitudinal components were made of two central sister keelsons connected by transverse braces and fitted on the floor timbers supporting a long and large keelson/mast step timber, and, in most cases, prolonged at each end by a central longitudinal timber (Pomey et al. 2012, 300). This is the longitudinal internal structure that has been proposed for the late antique Pakoštane ship (Boetto et al. 2018, 57-58, Figs. 68-69).

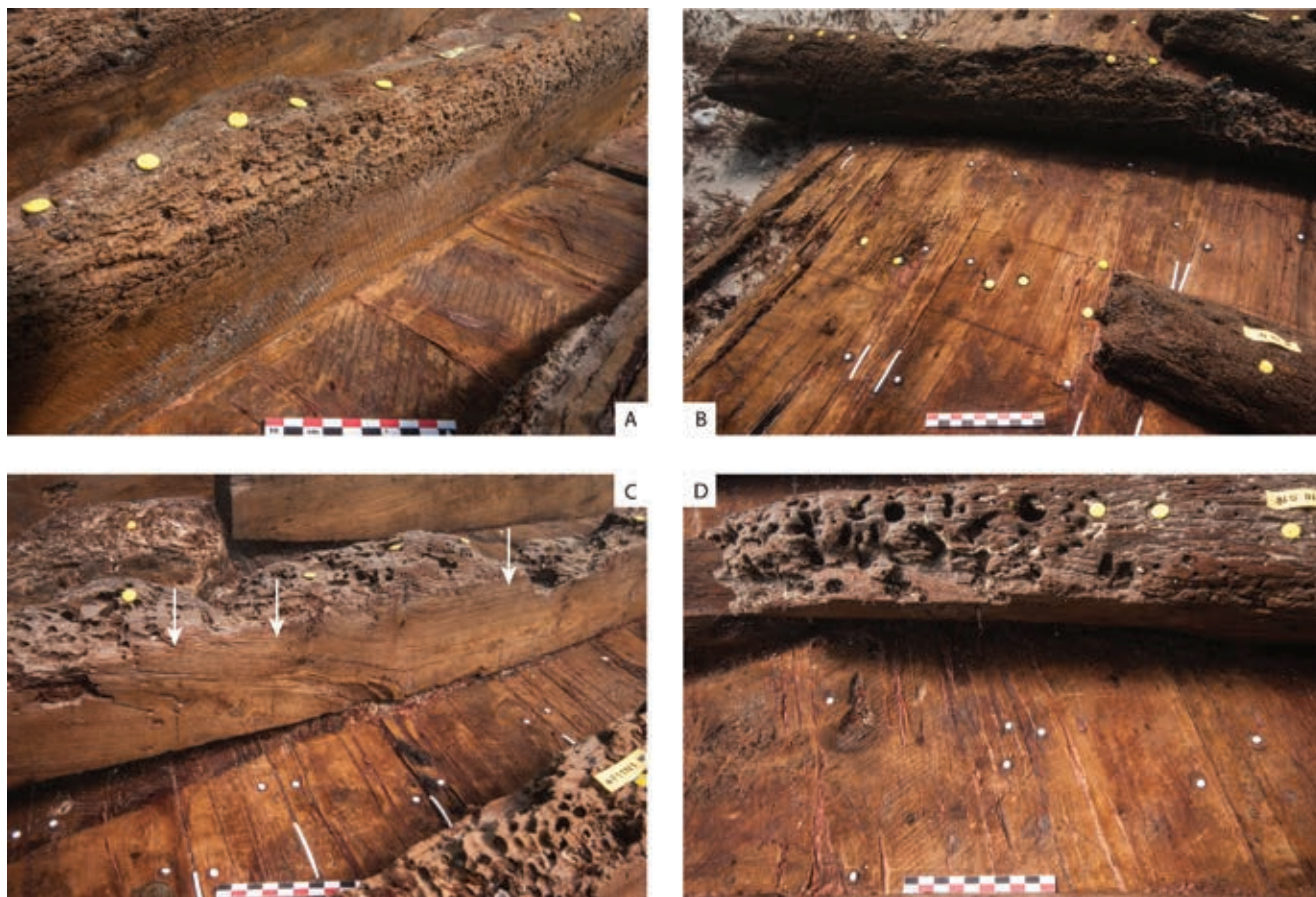
2.5 Tool and carpenter marks

Tool and carpenter marks are preserved on the inner surface of the hull. Saw marks are clearly visible on the mould of the frames and on the planking (Figs. 35a and d).

There are three types of carpenter marks. Parallel lines inscribed with a sharp point indicate the position of the frames on the planking (Fig. 35b) according to a fairly common practice documented on a number of Roman

⁴ Mikroanalizu dva metalna čavla je 2020. godine obavila dr. sc. Tea Zubin Ferri iz firme ArcheoLab iz Pule, u suradnji s Geološkim zavodom Slovenije.

⁴ Analyses were performed in 2020 by Dr Tea Zubin Ferri, ArcheoLab, Pula, in collaboration with the Slovenian Geological Institute.



Sl. 35 a) Tragovi pile vidljivi na oplati i brodskom rebru; b) dvije paralelne linije urezane oštrim predmetom koje označavaju položaj brodskog rebra F05N; c) X oznaka između F10S1 i F09S1; d) Okomite linije ispisane ugljenom na zapadnoj strani rebra F10N: linije se nalaze na spojevima vojeva (fotografija: L. Damelet).

Fig. 35 a) Saw marks on planking and frame; b) Two parallel lines inscribed with a sharp point marking the location of frame F05N; c) X-shaped mark in the room-and-space between F10S1 and F09S1; d) Vertical lines inscribed with a charred stick on the western surface of frame F10N: they are located along the seams of the planking (photos by: L. Damelet).

rebara (F5N2, F6N, F10N, F12N1, F7S). Ove oznake nalaze se na sljubnicama vojeva, a bile su važne tijekom gradnje broda, posebno zbog pozicioniranja i obrade rebara nakon izgradnje oplata. Slične linije su utvrđene na brodu Jules-Verne 4 (1. - 2. stoljeće, Pomey 1999, 322). Sve ove brodograditeljske oznake značajni su pokazatelji da je brod građen metodom „prvo ljuska“. Naposljetku, velike X grafitne oznake pojavljuju se u međuprostoru pojedinih rebara (sl. 35d), kao što je slučaj i na brodu Grado (2. stoljeće, Beltrame, Gaddi 2007, 144, fig. 13). Na južnom segmentu, u prostoru između rebara F19S i F20S, brodograditelji su urezali tri X oznake, sve u istom smjeru (sl. 26).

Moglo bi se pretpostaviti da su te tri oznake bile posebno važne polazne točke u gradnji, možda čak i oznake za pozicioniranje glavnog rebra. Nažalost, stanje brodske konstrukcije, koja se nalazi u segmentima i u ravnom položaju, onemogućava daljnja saznanja.

ships, such as Saint-Gervais 3 (mid-2nd century AD, Liou, Gassend 1990, fig. 98), and Toulon 3-4, 6 and 7 (3rd-4th century AD, Boetto 2022, 351, 361 et 367).

Black vertical lines made with a charred stick (Fig. 35c) are preserved on the mould of five frames (F5N2, F6N, F10N, F12N1, F7S). These marks are located at the joints between the strakes and were important indications during the construction of the ship, especially for positioning and adjusting the shape of the frames after the planking was joined. Similar lines were found on the wreck Jules-Verne 4 (1st-2nd century AD, Pomey 1999, 322). All these carpenter marks are significant indications that the ship was built using the shell-first construction method.

Finally, large X-shaped graffiti appear in the room-and-space between some of the frames (Fig. 35d), as in the Grado wreck (2nd century AD, Beltrame, Gaddi 2007, 144, fig. 13). On the southern side, in the space between frames

2.6 Olovne zakrpe i brtvljenje trupa

Samo je jedna olovna zakrpa pronađena *in situ*, pričvršćena na unutarnju površinu oplata (segment br. 3). Jednast drugih olovnih zakrpa, cjelovitih ili fragmentiranih, bilo je razasuto po morskom dnu, uglavnom sa zapadne strane broda (sl. 21, sl. 36), i vjerojatno su bile pričvršćene na vanjsku površinu trupa. Većina njih su limovi, s prosječnom širinom od 5 cm i maksimalnom dužinom od 29 cm (sl. 37). Samo jedna zakrpa je blago četvrtastog oblika (DE19/LP3, 6x5,3 cm).

Budući da je vodonepropusnost trupa bila osigurana unutarnjim i vanjskim slojem pakline, olovne zakrpe su također imale jedan njezin sloj. Unutarnja površina DE19/LP1 urezana je šrafranom uzorkom, vjerojatno radi poboljšanja prijanjanja pakline.

Olovne zakrpe bile su pričvršćene za trup malim čavlicima, o čemu svjedoče perforacije vidljive na njihovom rubu (sl. 37). Pronađena su samo dva mala čavla korištena u tu svrhu, DE17/N24 i DE18/N1 (sl. 34). Dužina ovih čavala je 3,8 cm, odnosno 2,7 cm, s promjerom glave od 7-8 mm i tijelom kružnog presjeka. SEM-EDS mikroanaliza pojedinačnog čavla DE17/N24 otkrila je da je njegov sastav sličan jednom od čavala, tj. da je bio izrađen od legure kositra i bakra s dodatkom olova, a ima i tragove organskog zaštitnog sredstva (pakline, vidi *gore*).

Moguće je da su olovne zakrpe dokaz intenzivnog popravljivanja, ali nije isključeno da su neke od njih bile ugrađene na brodsku oplatu već prilikom izgradnje, kako bi se postigla bolja vodonepropusnost na osjetljivim mjestima. Ista namjena je također utvrđena analizom olovnih zakrpa s brodske konstrukcije Pakoštane (Boetto et al. 2018, 61-67, sl. 78-85).

Naposljetku, pronađena su dva presavijena olovna lima bez tragova rupica za čavlice, što upućuje da nisu bili korišteni (DE19/N2 i DE18/N39) i da su se mogli po potrebi držati među alatima i priborom za popravak broskog korita (sl. 37 i 38). Analogije navedenom pronalazimo također na brodu Pakoštane (Boetto et al. 2018, 62, sl. 80).

F19S and F20S, the shipbuilders engraved three X-shaped marks, all on the same line (Fig. 26). One might suppose that these three marks were a particularly important reference in the construction, perhaps even an indication of the position of the main section. Unfortunately, the fragmentary and flattened state of the structures prevents us from going further.

2.6 Lead patches and hull sealing

Only one lead patch was found in place, attached to the inner surface of the planking (Assemblage no. 3). Eleven other patches, complete or fragmentary, were scattered on the seabed, mostly toward the west (Figs. 21 and 36), and were probably attached to the outer hull. Most of them are strips with an average width of 5 cm and a maximum length of 29 cm (Fig. 37). Only one has a roughly square shape (DE19/LP3, 6x5.3 cm).

As the hull was made watertight by an internal and external coat of pitch, the patches preserve a layer of pitch. The inner surface of DE19/LP1 is incised with a cross-hatched pattern presumably to improve pitch adherence.

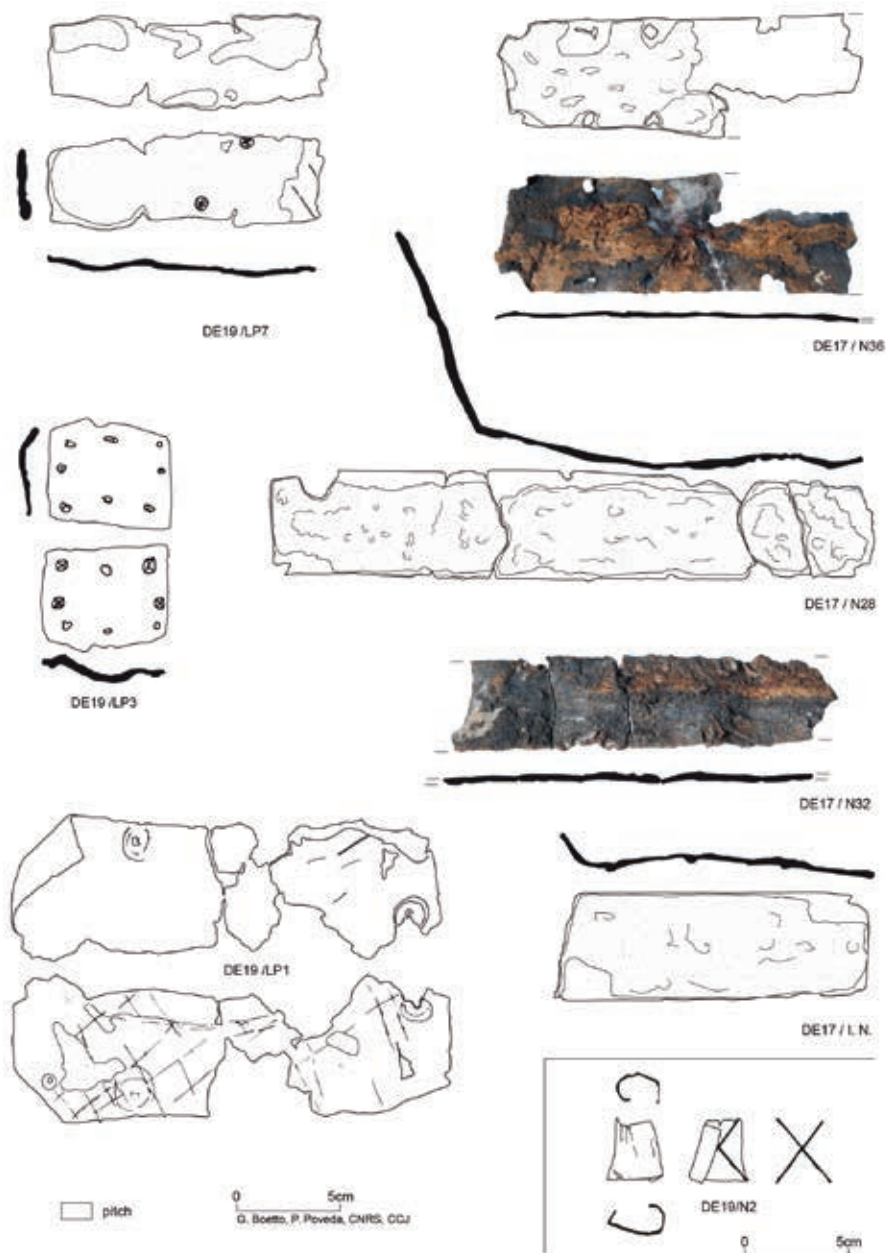
The patches were attached to the hull with tacks, as evidenced by the perforations visible on their perimeter (Fig. 37). Only two tacks used for this purpose were found, DE17/N24 and DE18/N1 (Fig. 34). They are respectively 3.8 and 2.7 cm long, with a head diameter of 7-8 mm and a circular shaft. SEM-EDS microanalysis of the tack DE17/N24 revealed that its composition was similar to that of nail DE18/N1: a tin-copper alloy with the addition of lead. It also has traces of an organic protective agent, such as pitch (see *supra*).

It is possible that the lead patches are evidence of intense repairing activity, but it is not excluded that some of them were nailed to the planking during construction to prevent water leakage at sensitive points, as has been argued after the study of the lead patches of the Pakoštane wreck (Boetto et al. 2018, 61-67, Figs. 78-85).

Finally, two folded pieces of lead with no traces of nail holes (DE19/N2 and DE18/N39) were kept among the tools and accessories to repair the hull in case of need (Figs. 37 and 38). They can be compared with a similar piece found on the Pakoštane wreck (Boetto et al. 2018, 62, Fig. 80).



Sl. 36 Detalj olovne zakrpe pričvršćene za platicu P110 (fotografija: L. Damelet).
 Fig. 36 Detail view of the lead patch attached to plank P110 (photo by: L. Damelet).



Sl. 37 Olovne zakrpe (crteži: G. Boetto, I. Koncani Uhač).
 Fig. 37 Lead patches (drawings by: G. Boetto, I. Koncani Uhač).



Sl. 38 Presavijeni komad olovne trake bez tragova rupa za čavle (DE18/N39) (fotografija: L. Damelet).

Fig. 38 Folded piece of lead with no traces of nail holes (DE18/N39) (photo by: L. Damelet).

2.7 Identifikacija drva

Na brodskoj konstrukciji iz Debeljaka identificirano je 11 različitih vrsta drva, od čega su tri od četinjača i osam vrsta od listača (sl. 39 i 40).

Elementi statve K i kobilice W54 izrađeni su od brijesta (*Ulmus* sp.). Oplata je uglavnom izrađena od mediteranskog čempresa (*Cupressus sempervirens* L.) te u manjoj mjeri od pinije (*Pinus pinea* sp., 5 platica) ili alepskog bora (*Pinus halepensis* Mill. / *Pinus pinea* L., 4 platice). Zanimljivo je da je većina drva za oplatu mediteranski čempres. Riječ je o biljci koja je naširoko uzgajana od davnina i koja je bila vrlo cijenjena i korištena zbog svoje trajnosti. Homogena oplata mediteranskog čempresa pronađena je i na nekim olupinama u Italiji, Fiumicino 4 i 5 (Portus, 2. – 3. st., Boetto 2006), Napoli B (Napulj, 2. – 3. st., Allevato et al. 2010) i Pisa D (druga polovica 6. – početak 7. st., Giachi et al. 2017.). Od mediteranskog čempresa sporadično je napravljena i oplata kasnoantičkog broda Pakoštane (Guibal et al. 2018, 84, slika 98).

Analiza rebrenih elemenata utvrdila je korištenje 9 različitih vrsta drva, najviše brijesta (48), zatim pinije i alepskog bora (24), jasena (*Fraxinus* sp., 13), oraha (*Juglans* sp., 6), johe (*Alnus* sp., 2), bukve (*Fagus sylvatica* L., 1), čempresa (1) i rosaceous vrste (*Sorbus* sp. / *Crataegus* sp.).

Za spojne elemente brodograditelji su koristili listače. Jezičci su izrađeni od hrasta crnike/oštrike (*Quercus ilex* L. / *Quercus Coccifera* L.), mali čavli od jasena (samo jedan je od čempresa), dok su čivije izrađene od maslinovog drveta (*Olea europaea* L.).

S obzirom da je sredozemna obalna vegetacija u antici po sastavu i izgledu uvelike odgovarala današnjoj, vrste korištene u gradnji broda iz Debeljaka mogle su rasti bilo gdje u Sredozemlju. Bukva, koja raste u umjerenj klimi, korištena je kod jedne rebrenice i mogla je biti

2.7 Wood identification

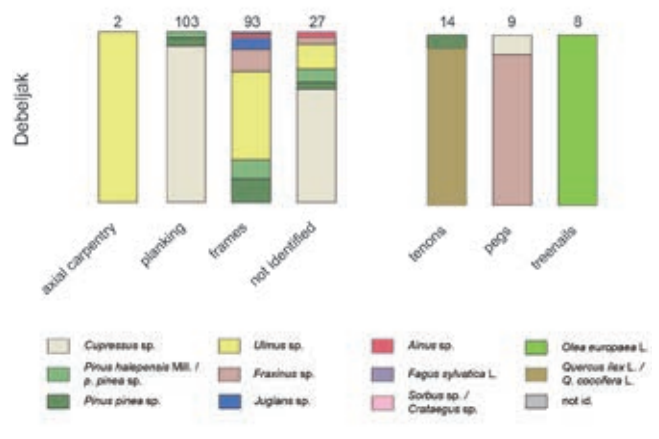
Eleven different wood species were identified on the Debeljak wreck: three coniferous and eight deciduous species (Figs. 39 and 40).

Transitional timber K and the keel W54 are made of elm (*Ulmus* sp.). The planking is mainly of Mediterranean cypress (*Cupressus sempervirens* L.) and to a lesser extent of stone pine (*Pinus pinea* sp., five planks) or Aleppo pine/ stone pine (*Pinus halepensis* Mill. / *Pinus pinea* L., four planks). The preferential use of Mediterranean cypress for planking is interesting. It was widely cultivated from ancient times and was also highly valued and employed for its durability. Homogenous Mediterranean cypress planking has been found in some wrecks in Italy: Fiumicino 4 and 5 (Portus, 2nd-3rd century AD, Boetto 2006), Napoli B (Naples, 2nd-3rd century AD, Allevato et al. 2010), and Pisa D (second half 6th-beginning 7th century AD, Giachi et al. 2017). Mediterranean cypress was also used sporadically in the planking of the late antique Pakoštane ship (Guibal et al. 2018, 84, Fig. 98).

The analysis of frames revealed nine different types of wood, elm being the most used (48), followed by stone pine and Aleppo/stone pine (24), ash (*Fraxinus* sp., 13), walnut (*Juglans* sp., 6), alder (*Alnus* sp., 2), beech (*Fagus sylvatica* L., 1), cypress (1) and a rosaceous species (*Sorbus* sp. / *Crataegus* sp.).

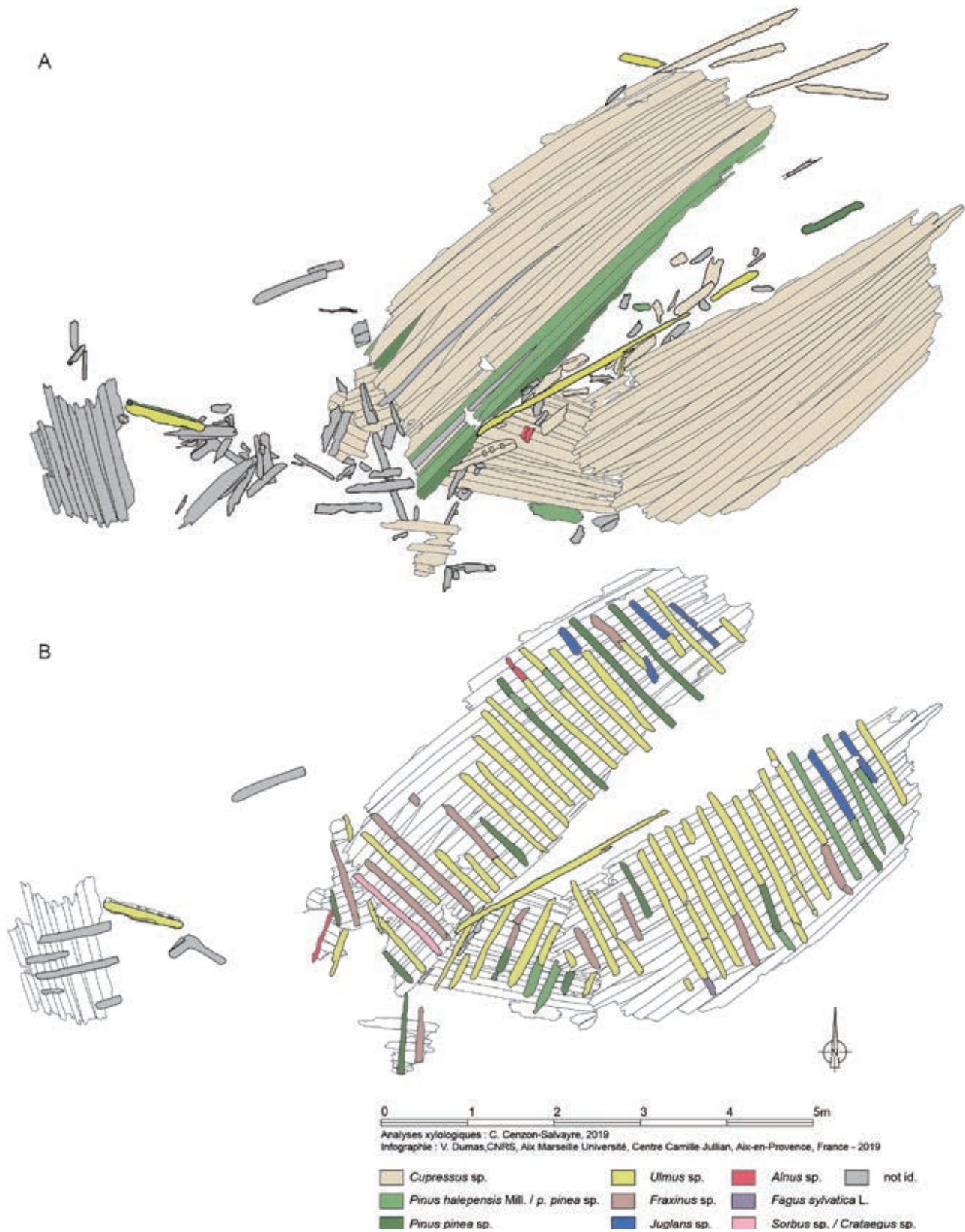
For assemblies, the shipbuilders chose hardwoods. Thus, tenons are made of holm oak/kermes oak (*Quercus ilex* L. / *Quercus Coccifera* L.), pegs are mainly made of ash with only one occurrence of cypress, and treenails of olive wood (*Olea europaea* L.).

Considering that the Mediterranean coastal vegetation in antiquity largely corresponded to that of present day in



Sl. 39 Grafikon koji prikazuje različite vrste drva.

Fig. 39 Graph showing the number of pieces per different type of wood.



Sl. 40 Raspodjela različitih vrsta drva na brodskoj konstrukciji (crtež: V. Dumas).

Fig. 40 Distribution of the different species of wood in the wreck (drawing: by V. Dumas).

uvezena. Drvo nam stoga ne pomaže u prepoznavanju mjesta gradnje i podrijetla broda, iako se ne može isključiti podrijetlo i gradnja na Jadranu.

2.8 Brodograđevni principi i metode

Glavnu ulogu u strukturi brodskog trupa u Debeljaku imaju spojevi platica sistemom utora i jezičca. Prosječna udaljenost između dva utora je 1,7 cm x širina utora, što svjedoči o visokoj gustoći uzorka jezičca i utora⁵. Svi jezičci su bili učvršćeni malim drvenim čavlima, a njihova funkcija nije bila ograničena samo na praktičnu ulogu predmontaže i poravnavanja oplata, kao u slučaju visoko razmaknutih jezičaca bez drvenih čavala koji su se počeli češće upotrebljavati od kraja 4. st. do početka 7. st. (Pomey et al. 2012). Također, žuljnica je bila dio oplata, a spojena utorima i jezičcima činila je snažno uzdužno ojačanje.

Oplata je bila homogeno izrađena od mekog čempresa, dok su rebra s druge strane bila izrađena od više vrsta listača. Ova raspodjela vrsta također je dobar pokazatelj da se izboru drva pridavala pažnja pri konstrukciji oplata u odnosu na strukturu rebara.

Nedostatak spojeva između elemenata rebara (rebrenica ili rebrenih nastavaka), koji su jednostavno stično sljubljeni, i nedostatak cjelovitosti sustava rebara još je jedna bitna značajka konstrukcije broda Debeljak, koja se temelji na konceptu konstrukcije ljuske, umanjujući značaj orebrenja s konceptualnog i strukturalnog gledišta. Štoviše, prosječna udaljenost između rebara (međuprostor) je 1,8 x širina rebara, što ukazuje na umjerenu gustoću sustava⁶.

Oznake brodograditelja na oplati i rebrima upućuju na to da je oplata u cijelosti ili djelomično izgrađena prije nego što su rebra ugrađena u trup, vodeći se principom gradnje „prvo ljuska“. S druge strane, još je otvoreno pitanje jesu li svornjacima spojena rebra mogla igrati aktivnu ulogu u oblikovanju trupa tijekom gradnje. Zbog izostanka demontaže rebrenice F6S i općenito lošeg stanja ostataka nije bilo moguće evidentirati zašiljene drvene čavle zabijene izvana, što ukazuje na prethodnu gradnju kostura i mješoviti proces gradnje.

Zaključno, slijedeći pojam arhitektonskih tipova te koncept principa i metoda gradnje (Pomey 2004; Pomey, Rieth 2005, 29–33; Pomey et al. 2012), princip gradnje broda Debeljak temelji se na konceptu ljuske za strukturu trupa te na konceptu uzdužno položenih vojeva za njegov oblik, dok je proces gradnje „prvo ljuska“.

terms of composition and appearance, the species used in the construction of the Debeljak ship could have grown anywhere in the Mediterranean. Beech, which grows in temperate climates, is documented for only one frame and could have been imported. The wood therefore does not help us to identify the place of construction and origin of the ship, although an origin and construction in the Adriatic cannot be excluded.

2.8 Shipbuilding principles and processes

Mortise-and-tenon joints play the main role in the hull structure of the Debeljak ship. The average distance between two mortises is 1.7 x mortise width, testifying to a high density mortise-and-tenon pattern⁵. All the tenons are pegged and their function is not restricted to the practical role of pre-assembly and planking alignment, as in the case of widely spaced unpegged tenons that became more frequent from the end of the 4th century to the beginning of the 7th century (Pomey et al. 2012). Moreover, the wale is part of the planking, connected by mortise-and-tenon joints, constituting a strong longitudinal reinforcement.

In addition, the planking is fairly homogeneous as it is constructed from softwoods and, in particular, cypress. The frames, on the other hand, are more heterogeneous, although hardwoods were chosen. This distribution of species is also a good indication of the attention paid to the construction of the planking in relation to the structure of the frame.

The absence of connection between the framing components, which are simply butt-jointed, and the lack of integrity of the framing system is another essential feature of the construction of the Debeljak ship, which is based on a shell structural concept, expressing the lesser importance given to the framing system from a conceptual and a structural point of view. Moreover, the average distance between frames (room-and-space) is 1.8 x frame sided dimension, indicating a moderate density of the framing system⁶.

The carpenter marks inscribed on the planking and frames imply that the planking was erected either totally or partially before the frames were introduced into the hull, thus following a shell-first process of ship construction. On the other hand, the question of whether the bolted floor timbers could have played an active role in helping

5 1,7 je omjer razmaka između dva susjedna utora i širine utora.

6 1,8 je omjer prosječnog međuprostora između rebara (bok - bok) i prosječne širine rebara.

5 1.7 is the ratio of the space between two adjacent mortises to the width of the mortises.

6 1.8 is the ratio of the average room-and-space between frames (side-to-side) to the average sided dimension of frames.

3. KERAMIČKI I DRUGI NALAZI

Tijekom tri arheološke istraživačke kampanje pronađeno je više od 160 keramičkih ulomaka (posuđe, amfore i građevinski materijal). Iako je mali broj ulomaka dijagnostičan, uglavnom se mogu odrediti kao kasnoantički, a što je i u skladu dobivenom radiokarbonskom datacijom drva (vidi *gore*).

Nekoliko ulomaka stolnog i kuhinjskog posuda pripada posuđu korištenom na brodu, a ulomci tri krovne opeke ili crijepa vjerojatno pripadaju brodskom ognjištu. Poznati su ostaci brodskog ognjišta izgrađenog na palubi u pramčanom dijelu brodice Caska 2 iz 1. st. (Rossi Radić, Boetto 2020, 280, sl. 29), dok su na kasnoantičkom brodu Pakoštane, kao i na Debeljaku, opeke i crjepovi pronađeni u ulomcima te koncentrirani na malom prostoru (Huguet 2018, 76-78, sl. 22). Nekoliko karboniziranih grana također može biti povezano s kuhinjskim aktivnostima (sl. 41). Dvije su grane pripadale drvu hrasta (*Quercus ilex L.* / *Quercus Coccifera L.*) dok je jedna pripadala maslinovu drvu (*Olea europaea L.*)

Brod je prevezio teret amfora, iako ulomci koji uglavnom pripadaju tijelima amfora upućuju na manji broj takvih nalaza. U svakom slučaju, moguće je da je većina tereta izvađena još u antičko doba jer je brod potonuo u plitkom moru, a valja uzeti u obzir i moguće pljačkanje lokaliteta tijekom vremena. Također je moguće da se u amforama nalazila hrana za mornare, što objašnjava njihov mali broj na brodu. Međutim, pretpostavku o teretu podupiru nalazi grana koje su vjerojatno stavljane između amfora za zaštitu tijekom plovidbe. Tri grane pripadaju listopadnom hrastu lišćaru (*Quercus sp.*), dvije hrastu crniki/oštriki (*Quercus ilex L.* / *Quercus Coccifera L.*), jedna je od alepskog bora/

the hull shape during construction is still open. Since floor timber F6S was not dismantled, and because of the generally poor condition of the remains, it was not possible to record tapered pegs driven from the outside that would indicate skeleton solutions and a mixed building process.

In conclusion, following the notion of architectural types and the concept of principles and methods of construction (Pomey 2004; Pomey, Rieth 2005, 29-33; Pomey et al. 2012), the construction principle of the Debeljak ship is based on a shell concept for the hull structure, and on a longitudinal strake-oriented concept for its shape, while the building process was shell-first.

3. CERAMICS AND OTHER FINDS

More than 160 fragments of ceramics (pottery, amphorae and building materials) were found during the three excavation campaigns. Although a small number is intrusive, most of the sherds are in line with the late antique dating obtained by radiocarbon analysis of the wood (see *supra*).

A few fragments of common and kitchen ware are from vessels used on board, and fragments of three bricks or tiles are probably from the hearth. A well-preserved hearth was constructed in the hold near the bow of the 1st century AD ship, Caska 2 (Rossi Radić, Boetto 2020, 280, Fig. 29), while on the late antique Pakoštane wreck, as at Debeljak, the bricks and tiles constituting the hearth were found in scattered fragments, although concentrated in a small area (Huguet 2018, 76-78, Fig. 22). A few charred sticks may also be related to cooking activities (Fig. 41). Two of them are from holm oak/



Sl. 41 Karbonizirane grančice (fotografija: L. Damelet).
Fig. 41 Carbonised sticks (photo: by L. Damelet).



Sl. 42 Ulomci amfora s okomitim linijama (fotografija: L. Damelet).
Fig. 42 Fragments of amphorae with horizontal striations (photo by: L. Damelet).

bora (*Pinus halepensis* Mlin. / *Pinus pinea* L.) i jedna od borovice (*Juniperus* sp.).

Jedan brončani novčić (DE18/N11), nažalost zbog lošeg stanja neprepoznatljiv, mogao je biti predmet vezan uz trgovinu.

Na osnovu analize samo ulomaka trbuha amfora, bez petrografske analize presjeka keramike, teško je odrediti tipologiju amfora i njihovu provenijenciju. Primjerice, neki ulomci imaju vodoravne kanelure s vanjske strane stijenke, slične onima na kasnijim rimskim amforama (sl. 42), ali presjek keramike ne ukazuje na podrijetlo iz istočnog Mediterana, već na moguću regionalnu proizvodnju. Tako je gornji dio amfore s vratom i ručkama određen kao amfora tipa "Empoli" (sl. 43), koja je služila za prijevoz vina iz sjeverne Toskane (Valdarno i obalna područja Pise i Volterre), a čija se proizvodnja nastavila u kasnoj antici. Ovakav tip amfore rijedak je na jadranskom području i samo je jedan primjerak utvrđen u Jesolu (Negrelli 2018, 47-48).

U suštini, ove amfore predstavljaju trgovačke mreže Tirenskog mora i zapadnog Mediterana, uključujući Toskanu, Lazio, Kampaniju, Korziku i Sardiniju, uz Sjevernu Afriku i Španjolsku.

Naposljedku, dva manja drvena predmeta pronađena su 2017. Prvi je ručka svrdla, dužine 15,7 cm, debljine 3 cm, a koja je vjerojatno bila dio alata ili pribora za popravak broskog trupa, kao i komadi olova (vidi gore) (sl. 44, A). Drugi predmet je polukonični nalaz s urezanim utorom na središnjem dijelu, maksimalne širine 2,5 cm i

kermes oak (*Quercus ilex* L. / *Quercus Coccifera* L.) and one from olive wood (*Olea europaea* L.).

The ship carried a cargo of amphorae, although the fragments, mostly from bodies, correspond to a small number of containers. In any case, it is possible that most of the cargo was recovered in antiquity because the ship sank in shallow water; looting over time must also be considered. It is also possible that the amphorae contained food for the sailors, hence their small number. However, the hypothesis of a cargo is reinforced by the discovery of some twigs, which are probably remains of dunnage used to protect the cargo during navigation. Three are from deciduous oak (*Quercus* sp.), two from holm oak/kermes oak (*Quercus ilex* L. / *Q. coccifera* L.), one from Aleppo pine/stone pine (*Pinus halepensis* Mill. / *P. pinea* L.), and one from juniper (*Juniperus* sp.). The single bronze coin (DE18/N11), unfortunately not recognisable due its poor condition, may be a trade-related object.

The identification of amphora types and their provenance is very difficult from body fragments, especially without petrographic thin-section analysis of the inclusions in the clay. For example, some of the body fragments have horizontal striations similar to those of Late Roman amphorae (Fig. 42), however the clay clearly does not indicate an eastern Mediterranean, but possibly a regional production. Indeed, a neck with handles has been identified as an Empoli amphora (Fig. 43), a wine vessel from northern Tuscany (Valdarno and the coastal areas of Pisa and Volterra), whose production continued into late antiquity. This type of vessel is rare in the Adriatic region and only one example is attested in Jesolo (Negrelli 2018, 47-48). In fact, these vessels represent the commercial networks of the Tyrrhenian and the western Mediterranean Seas, including Tuscany, Lazio, Campania, Corsica and Sardinia, in addition to North Africa and Spain.

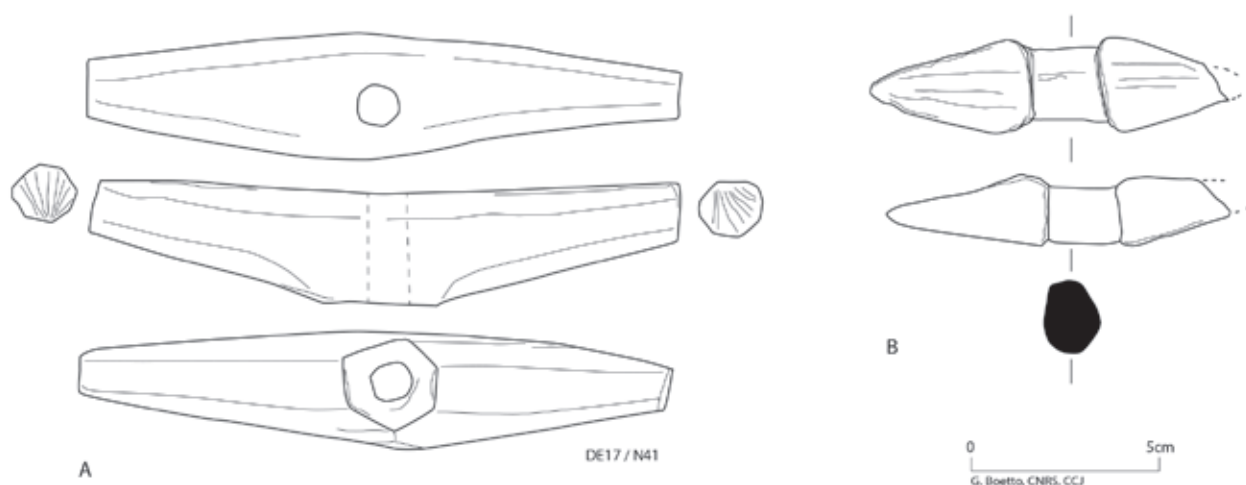
Finally, two small wooden objects were found in 2017. The first is an auger handle, 15.7 cm long, 3 cm high, that was probably part of the tools and accessories for hull repairs, as were some of the pieces of lead (see *supra*) (Fig. 44, A). The second find is a toggle, a bi-conical piece with a carved groove around its centre, maximum 2.5 cm wide and with a reconstructed length of 10 cm. From its small dimensions, this toggle was probably part of the rigging of the ship (Fig. 44, B).

4. CONCLUSION: SHIP TYPE, FUNCTION AND ORIGIN

Although the limited preservation of the ship structure invites caution, the Debeljak ship appears to have some



Sl. 43 Vrat Empoli amfore (fotografija: L. Damelet).
Fig. 43 Neck of an Empoli amphora (photo by: L. Damelet).



Sl. 44 Drveni predmeti: A) drška svrdla; B) zatezač (crteži: G. Boetto).
 Fig. 44 Wooden finds: A) auger handle; B) toggle (drawings by: G. Boetto).

rekonstruirane dužine od 10 cm. Zbog malih dimenzija ovaj je predmet vjerojatno služio kao zatezač brodske opute (sl. 44, B).

4. ZAKLJUČAK: TIP BRODA, FUNKCIJA I PODRIJETLO

Iako djelomična očuvanost brodske konstrukcije upućuje na oprez kod određivanja tipologije, čini se da brod Debeljak ima određene sličnosti s tipom broda Dramont E iz 5. stoljeća. Osim što su bili u potpunosti izrađeni po principu „prvo ljuska“, obje konstrukcije su na glavnom rebru imale blagi presjek tzv. vinske čaše sa zaobljenim uzvojem, u kojem su se izmjenjivale rebrenice s polurebrenicama, te su imale složenu uzdužnu strukturu koja se sastojala od hrptenice / temeljnice jarbola ojačane dvjema dohrptenicama.

Na osnovu rada Pomey et al. 2012, brod Dramont E je kombinacija ranijeg helenističkog tipa broda (geometrija trupa, orebrenje) i zapadnorimskog carskog tipa (uzdužni elementi brodogradnje). Ovaj tip broda, zajedno s brodom Saint-Gervais 2 iz 7. stoljeća, potvrđuje jedan od „korijena“ u razvoju brodogradnje, od „prvo ljuske“ prema kostur gradnji na području antičkog Mediterana. Ukoliko se prihvati pretpostavka o povezanosti broda Debeljak i Dramont E, to bi mogao biti novi dokaz ranijeg postojanja ovog korijena u brodograđevnoj tranziciji.

similarities to the 5th-century Dramont E ship type. Besides being entirely shell-built, both had a gentle wine-glass master frame with a round turn of the bilge, alternating floor timbers and half-frames, and an elaborate axial longitudinal structure consisting in a keelson/mast step supported by two sister keelsons.

Following Pomey et al. 2012, the Dramont E ship is a combination of the earlier Hellenistic type (hull geometry, framing system) and the western Roman Imperial type (longitudinal components). This ship type, together with the 7th-century Saint-Gervais 2, identifies one of the “roots” in the transition from shell to skeleton in the ancient Mediterranean. If the hypothesis of the connection between Debeljak and Dramont E is accepted, the former could be new evidence of the earlier existence of this evolution in transition.

In term of its function, the Debeljak ship was a medium-sized sailing transport vessel, about 15 to 17 m long. It was engaged, at least for its last voyage, in regional trade, although the analysis of amphorae and pottery is very preliminary and deserves further research. Unfortunately, it seems quite impossible to locate the ship’s precise place of construction and origin as the tree species identified grow all over the Mediterranean. However, given the size and cargo of the Debeljak ship, it is possible to hypothesize that it was built in the western or central Mediterranean.

Brod Debeljak je po svojoj funkciji bio jedrenjak srednje veličine, dužine oko 15 do 17 m. Njegova je uloga, barem na posljednjoj plovidbi, bila lokalna trgovačka aktivnost, iako je analiza amfora i keramičkog posuda vrlo preliminarna i zaslužuje daljnja istraživanja. Nažalost, čini se prilično nemogućim locirati točno mjesto njegove izgradnje i podrijetlo, budući da identificirane vrste drva rastu diljem Sredozemlja. Međutim, s obzirom na veličinu i teret, moguće je iznijeti hipotezu da je izgrađen na području zapadnog ili srednjeg Sredozemlja.

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