Preliminary results of the wood analyses of the Roman vessels of Caska, island of Pag, Croatia

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Abstract
Two assemblages compose the scuttled Roman vessels discovered in Caska inlet (Pag Island, Croatia): three sewn boats (Caska 1, 3 and 4) and one mortise-and-tenon constructed ship (Caska 2). While the wood species used for the construction of the sewn boats are quite similar (beech trunks split radially for planking), the construction of Caska 2 shows greater heterogeneity and more common use of conifer species for planking. The systematic identification of the wood species, the analysis of the morphological characteristics and the tree-ring dating of a large number of ship's components provide new insight into ancient Adriatic shipbuilding traditions.

Keywords
Caska, dendrochronology, Pag Island, wood species, wood technology

Résumé
Deux méthodes d'assemblages ont été observées sur les embarcations, coulées volontairement, découvertes à Caska (île de Pag, Croatie) : trois bateaux sont cousus (*Caska 1*, *3* et *4*) et un quatrième est assemblé à tenons et mortaises (*Caska 2*). Si les essences de bois utilisées pour la construction des bateaux cousus sont assez similaires (troncs de hêtre fendus radialement pour le bordage), la construction de *Caska 2* se révèle plus hétérogène et l'on observe une utilisation plus commune d'essences résineuses pour le bordé. L'identification systématique des essences de bois, l'analyse de leurs caractéristiques morphologiques et la datation des cernes d'un grand nombre des éléments des embarcations offrent un nouvel aperçu des traditions de la construction navale antique en Adriatique.

Mots clés
Caska, dendrochronologie, île de Pag, essences de bois, technologie du bois

As part of the international project entitled CissAntiqua developed in 2009 by the University of Zadar (Croatia) and the University of Aix-Marseille, CNRS, Centre Camille Jullian (France), recent archaeological research in the Roman settlement of Caska, Pag Island, Croatia, has provided evidence of intense building activities, which occurred from the 1st century BC and lasted until the 4th century AD. The project, mainly focused on the submerged coastal structures, has led to the discovery of a remarkable group of vessels that were deliberately sunk after being filled with stones as part of the harbour construction. The group of scuttled vessels is composed of three sewn boats (Caska 1, 3 and 4) and one mortise-and-tenon constructed ship (Caska 2) (Boetto, Radić Rossi 2015, p. 279; Radić Rossi, Boetto 2020) (fig. 1).

During the underwater archaeological campaigns, the preserved ship elements were systematically sampled in order to study their morphology, to reconstruct the parent trunks and the way they were fashioned, and to identify the tree species. As the shipwrecks were devoid of cargo and the rare ceramic shards found in association with them belonged to the reuse phase of the vessels and offered a too wide chronological range, it was decided to carry out dendrochronological and accelerator mass spectrometry (AMS) dating in an attempt to date the felling of the trees used in the ship construction. Currently, the identification of the wood species has been completed, while dendromorphological, dendrochronological and AMS dating analyses are still in progress.

1. THE SEWN BOATS

Only the bottom of the hull of Caska 1 and 4 survived to a length of 8 m and 7 m respectively. Some parts of the former's sides were found nearby, broken and detached from the main structure, while the latter was particularly damaged. A large piece, 3.25 m long, and some detached fragments of a third sewn boat, Caska 3, were identified among the wooden elements of various origin thrown into the hold of a mortise-and-tenon constructed ship, Caska 2, before the fill of rocks. Caska 3, although poorly preserved, was similar to Caska 1.

Caska 1 and 4 are characterised by similar structural features (keels without chamfers, keyed-hook scarfs locked by vertical dowels, flush-laid strakes with simple overedge vegetal stiches (/// pattern), a wadding pad of vegetal fibres, crenelated frames, sequences of floor timbers without alternation with half-frames) and cross section (flat bottom with round turn of the bilge). The main differences concerned the arrangement of the frames (loose futtocks in Caska 1, futtocks scarfed and locked to the floor timbers in Caska 4), the system of assembly between frame and planking (treenails in Caska 1 and 3, external lashings in Caska 4), the larger room and space of the frame, and the addition of textile wadding pads in Caska 4.

Although it is difficult to reconstruct the original shape of the sewn boats from Caska due to the lack of information about their longitudinal form at the extremities, the original length of Caska 1, which was the best preserved of the group, could be estimated to 9-10 m. The boat could probably have been

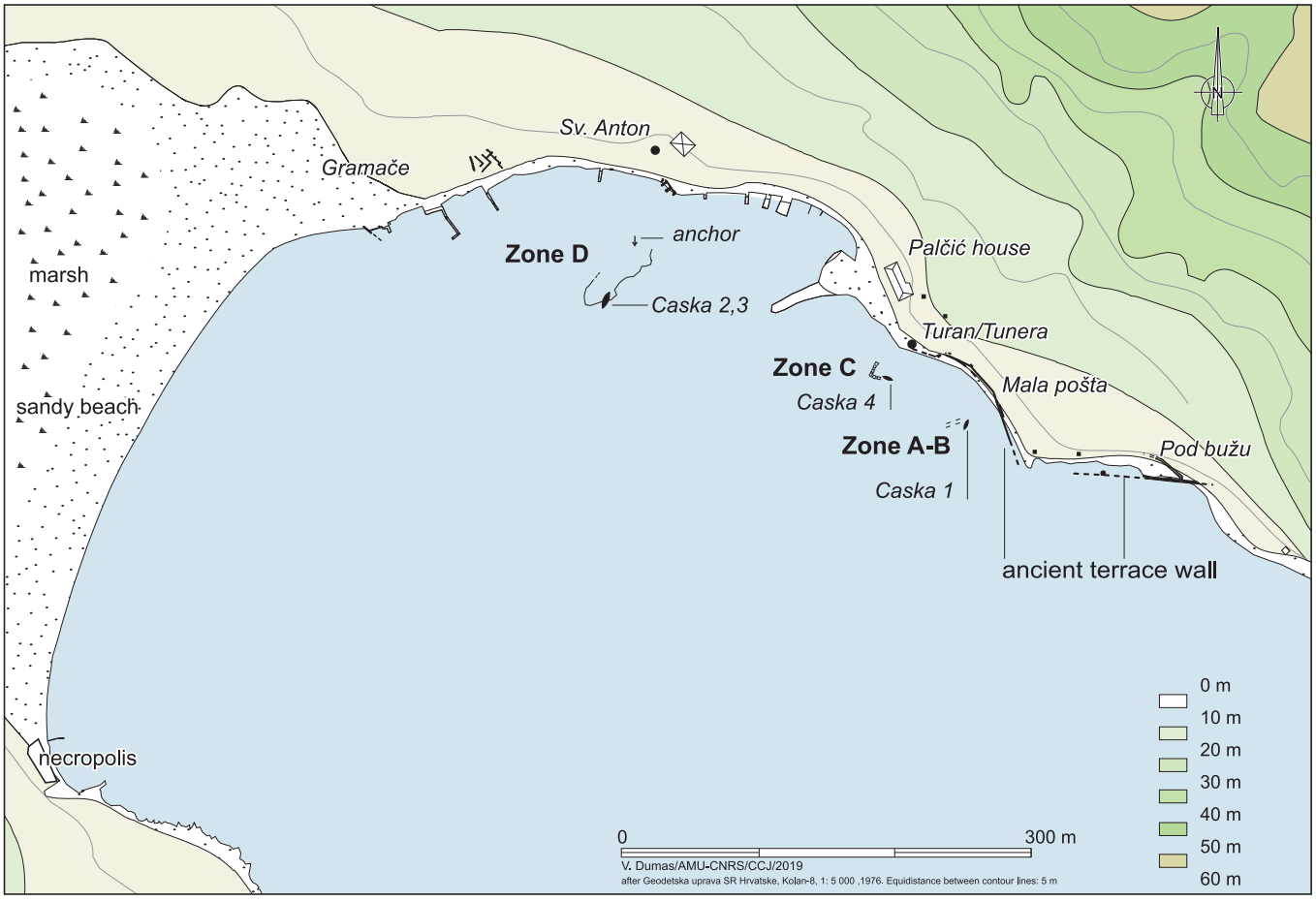


Fig. 1: *Site plan of the archaeological evidence in Caska inlet (V. Dumas, AMU, CNRS, CCJ).*

propelled either by sail or oars, although no trace of the propulsion system or steering devices was discovered on the shipwreck. It was a multipurpose boat, used in regional navigation for the transport of goods, animals and people, and for fishing.

The three sewn boats from Caska, according to their dimensions and architectural characteristics, were built and used locally or in the nearby region and belong to a local indigenous sewn-boat tradition. According to Pomey and Boetto (2019, p. 11-19), this northeastern Adriatic tradition of sewn boatbuilding dates back to the Late Bronze Age (Zambratija shipwreck) and survives into Roman times in connection with a well-defined sailing space, characterised by a multitude of islands and an indented coastline.

1.1. WOOD SPECIES

Twelve different wood species were identified, six belonging to broadleaved hardwood and six to softwoods trees (fig. 2). The correlation of wood species with different structural pieces is quite similar in the three boats.

Holm oak (*Quercus ilex* L.) was used for the keels of Caska 1 and 4. The transitional timber of Caska 1 was also made of holm oak, while the two transitional timbers of Caska 4 were made of deciduous oak (*Quercus* sp.)[1] and maple (*Acer* sp.). The horizontal keys of the keel scarfs of Caska 1 and 4 were made, respectively, of holm oak and of beech. The three vertical dowels locking the keel scarfs of Caska 4 were made of dogwood (*Cornus* sp.).

The planking was homogeneously made of beech (*Fagus sylvatica* L.) (fig. 3). The sole fragment of wale preserved in the group belonging to Caska 1 was made of holm oak. Fir (*Abies* sp.) was systematically used for the small pegs locking the stitching of the planking, and other conifers were also used, in particular in Caska 4.

In Caska 1, the frames were mostly made of deciduous oak with one exception for the detached V-shaped floor timber of beech. In the frame of Caska 4, holm oak was dominant with a few pieces made of deciduous oak. Olive wood (*Olea europaea* L.), beech and holm oak/kermes oak (*Quercus ilex* L./*Q. coccifera* L.)[2] were used for the treenails of Caska 1 and 3. The external lashing of Caska 4 employed different wood species for the pegs locking the stiches (dogwood, beech, fir).

1. The wood of deciduous Quercus species cannot be differentiated on the basis of their wood anatomy (Schweingruber 1978, p. 144).

2. The anatomy of holm oak and kermes oak cannot be differentiated (Akkemik, Yaman, 2012, p. 176). The assignment to one or another species of oak is possible on the basis the type and the size of the ship element. For example, due to the shape and dimensions of the kermes oak, it is impossible that this wood would be used for the keels or the frames. On the other hand, for the small assembly elements, such as treenails, tenons or pegs, its use cannot be excluded.

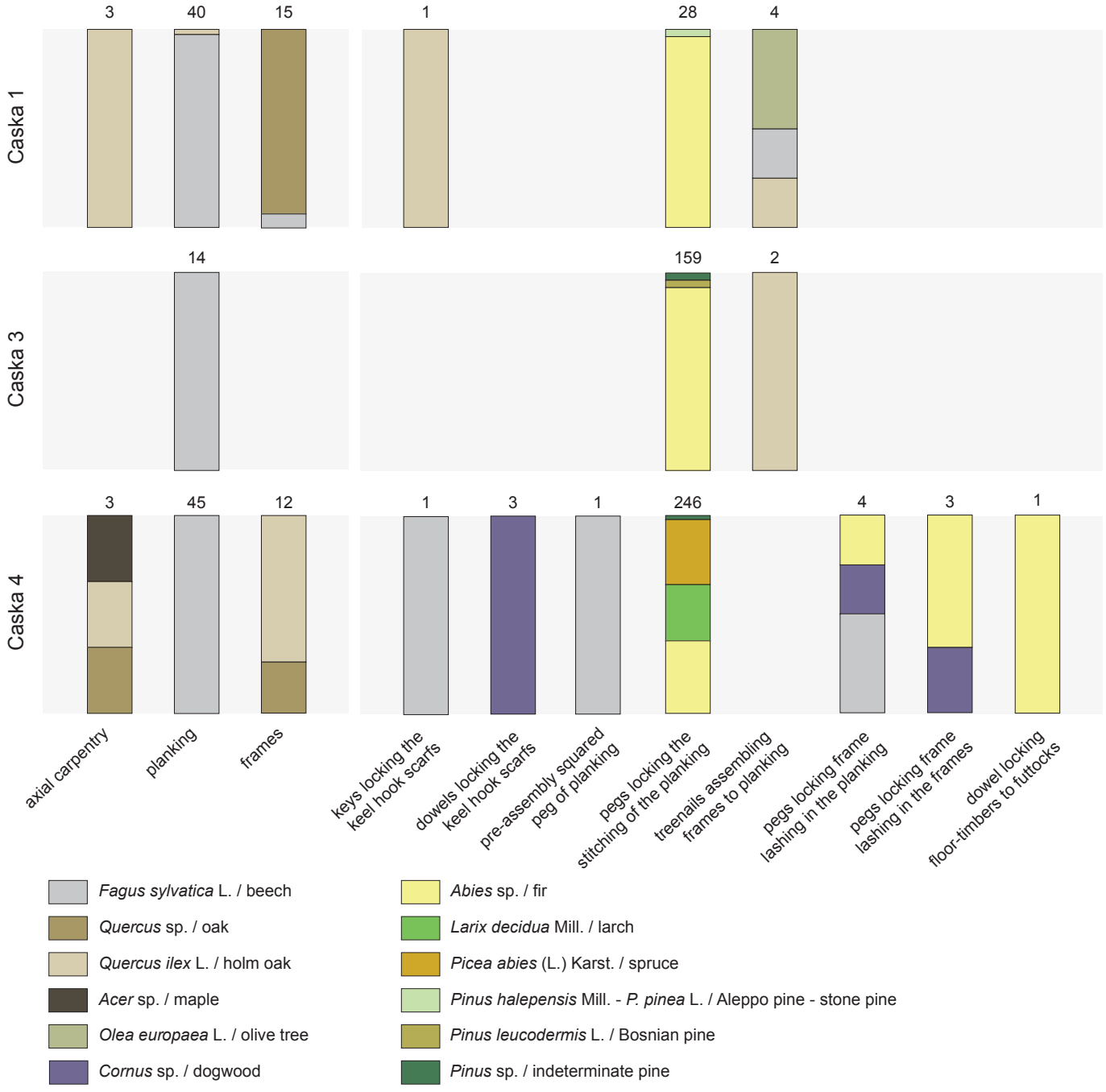


Fig. 2: *Distribution of the different wood species of the sewn boats from Caska (A. Ferreira Domínguez, AMU, CNRS, CCJ).*

1.2. WOOD TECHNOLOGY

An examination of the morphology of the architectural pieces of the three sewn boats and measurements of the ring-widths allow us to point out interesting similarities in the construction and in the selection of trees.

The keels and transitional timbers were made from squared trunks, using trees of around 11-14 cm in diameter, and about 60 years old. The planks were produced from beech trunks split radially, pith and bark being systematically removed. Marks of squaring axes confirm the radial splitting, probably by using wedges and maces. Parent logs were about 10-44 cm in diameter, and length would exceed 8 m, which is the minimum length of some of the preserved planks. The trees were older than 183 (Caska 1), 172 (Caska 3) and 142 years (Caska 4).

The presence of pith, sapwood, and sometimes bark in these frames allow us to calculate their initial diameter and thus the age of the parent log. Young branches or coppiced tree trunks of deciduous or holm oaks were hewn into halves or quarters for the frames. These branches or coppiced tree trunks were between 20 and 50 years old with an average diameter of 10 cm.

2. THE MORTISE-AND-TENON CONSTRUCTED SHIP, CASKA 2, AND ITS WOODEN FILL ELEMENTS

The remains of Caska 2 were 13 m long and consisted of a keel, nine strakes on each side (the ninth strake was the lower

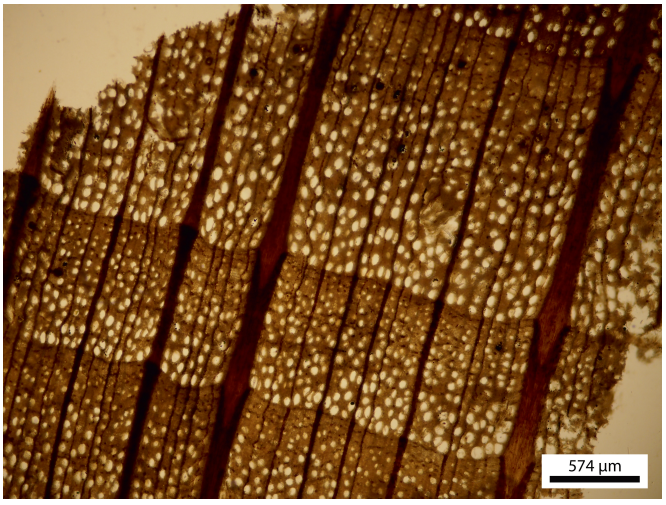


Fig. 3: *Transversal section of beech wood (*Fagus sylvatica *L.) from Caska 3 (plank P7-1) (A. Ferreira Domínguez, AMU, CNRS, CCJ).*

wale) connected to each other by mortise-and-tenon joints, 24 frames, a keelson/mast step and some stringers. Two of these stringers were planks with mortise-and-tenon joints reused from a scuttled ship. A hearth of mortar, tiles and bricks used for cooking was situated in the bow and settled on planks above the keelson and the frame. During its life, the hull underwent several refits as testified by patch tenons, graving pieces in the planking, and other internal reinforcements and frame repairs.

When scuttled, the bottom of Caska 2 was reinforced with wooden elements of various origins thrown into the hold before the filling of rocks. As previously mentioned, the sewn boat Caska 3 was found in this assemblage of wooden elements.

Caska 2 was a small sailing ship of around 15 m in length. It could have been used for the transport of different kinds of goods and could undertake longer voyages as demonstrated also by the presence of a hearth for cooking onboard. It is not possible to establish with any certainty the location of the place where the ship was built.

2.1. WOOD SPECIES

Eleven species were identified in the mortise-and-tenon constructed Caska 2: five hardwood and six softwood (fig. 4).

The keel and the stern transitional timber of Caska 2 were made of holm oak, and the stem transitional timber was made of Aleppo/stone pine (*Pinus halepensis* Mill./*P. pinea* L.)[3]. The planking was built mainly from Scots pine type (*Pinus* t. *sylvestris*)[4] and Aleppo pine/stone pine. Due to the presence of patch tenons in six of the planks of Aleppo pine/stone pine, it is possible that all the planks built with this wood species were repairs. Other planks in Bosnian pine (*Pinus leucodermis* L.) and an undetermined pine (*Pinus* sp.) could also be repairs. Three of the five identified graving pieces were made of Aleppo pine/stone pine and elm (*Ulmus* sp.). Frames were mostly made from holm oak, with a few of them from deciduous oak, Aleppo pine/stone pine and Scots pine type. The frame repairs were made from holm oak, spruce (*Picea abies* (L.) Karst.) and from an indeterminate gymnosperm, while the internal reinforcements were from holm oak, elm and Aleppo pine/stone pine. The ceiling was built in Scots pine type, spruce, elm, poplar (*Populus* sp.) and fir. Holm oak/kermes oak was employed for tenons and treenails, and ash (*Fraxinus* sp.) for the small pegs locking the tenons. Finally, the planks used as a foundation for the hearth were made of Aleppo pine/stone pine, Scots pine type and fir.

Several softwood and hardwood species were also identified in the large number of discarded pieces thrown into the hold of the ship before scuttling. However, most of the planks (complete or fragmentary) without assemblages were homogeneously made of fir, only a few were made of spruce, holm oak and indeterminate pine. Other various pieces, such as stanchions, beams or bulkheads, small and big logs, and a pole were made of different types of woods spieces already attested in the other fill elements or in the ship structure.

The five fragments of planks with tenon-and-mortise joints discovered in the fill and not identified as ceiling were made of Scots pine type, elm, fir and indeterminate pine.

2.2. WOOD TECHNOLOGY

Dendromorphological analyses were carried out only on four frames of Caska 2 due to the lack of sampling and the difficulties of *in situ* analysis. As for the sewn boats, the presence of pith and sapwood rings allows a reliable reconstruction of the initial diameter and age of the parent logs. Branches or coppiced tree trunks were hewn into halves or quarters, offering between 26 and 55 rings for a diameter of about 8-12 cm.

The majority of samples were collected from the fir planks without assemblages belonging to the filling of Caska 2. Radial cuts were generally identified with a few exceptions involving tangential splitting. Trees used were up to 166 years old and at least 44 cm in diameter.

3. DATING

Only Caska 1 has been dated, to between 42 and 102 AD on the basis of the synchronisation on the ^{14}C calibration curve using a wiggle-matching method (Pearson 1986, p. 295-296) of six AMS dates on six samples taken on the same beech plank (P3)[5]. In the current state of the research, the dates of construction of the three other vessels found in Caska are still not precisely established.

In the sewn boats, planks were the most convenient for dendrochronology because they provided long tree-ring series. In addition, the radial splitting made it possible to measure the almost complete ring series formed by the trees. So, we were able to build four mean chronologies for beech: a 197 year-long

3. As pointed out by Akkemik, Yaman (2012, p. 46), Aleppo pine and stone pine are difficult to differentiate due to their great anatomical similarity, thus we prefer to use a double classification.

4. The Scots pine (*Pinus sylvestris* L.), mountain pine (*Pinus uncinata* Ramond) and black pine (*Pinus nigra* Arnold) cannot be distinguished on the basis of their wood anatomy (Schweingruber 1978, p. 62, 1990, p. 129, 131).

5. Laboratory codes Lyon-9267 (SacA29517), Lyon-9272 (SacA29522). We thank Christine Oberlin, Centre de Datation par le Radiocarbone (Lyon), who prepared the samples for the AMS dates through the ARTEMIS programme of the CNRS.

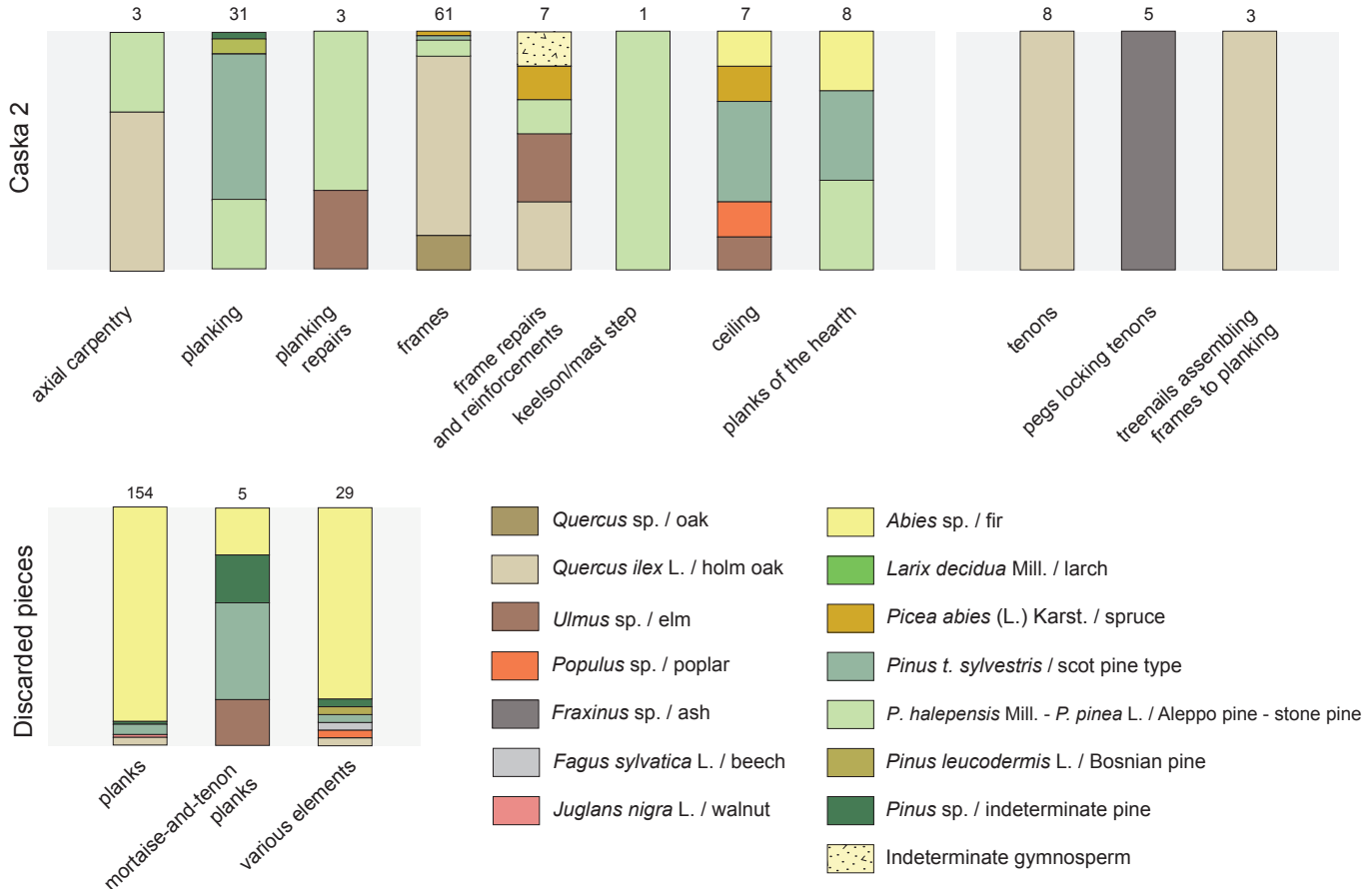


Fig. 4: *Distribution of the different wood species of Caska 2 and of the discarded pieces (A. Ferreira Domínguez, AMU, CNRS, CCJ).*

chronology for Caska 1, a 165 and a 200 year-long chronologies for Caska 3, and a 163 year-long chronology for Caska 4.

In addition to that, the analysis of the radial-cut planks belonging to the internal fill of Caska 2 allowed us to build up a fir mean chronology 197 years long.

Statistical tests aimed at cross-dating ring-width of the Caska series are in progress. Given the absence of a Croatian dendrochronological database for Antiquity, we will try to cross-correlate our series with datasets developed in Slovenia, northern Italy, and Austria. If our attemps are unsuccessfull, we will try to date our mean chronologies by combining AMS ^{14}C dates with the wiggle-matching method.

4. CONCLUSION

In the current stage of the research, the most interesting results come from the analysis of the types and morphologies of wood species used in the construction, coupled with the study of their occurrence and distribution within the ship construction.

All the species identified in the tenon-and-mortise ship Caska 2 are commonly attested in Greek-Roman Mediterranean shipbuilding. Their distribution within the ship structure is in accordance with specific choices that prefer conifer species for planking due to their elasticity, which makes them flexible enough to be shaped according to shell-first processes (Guibal, Pomey 1998, p. 435-436, 2003, p. 36), and hardwood species (such as deciduous or holm oaks) for keels, frames and assemblages due to their high resistance qualities (Rival 1991, p. 54; Guibal, Pomey 1998, p. 432-435, 2003, p. 36 and 38).

Besides the common use of hardwoods for keel and frame, the sewn boats of Caska show the particularity of planking entirely built from beech wood, despite its bad resistance to humid conditions (Teissier du Cros *et al.* 1981, p. 384-385; Bary-Lenger *et al.* 1988, p. 160). Consequently, it is probable that a number of different reasons other than wood quality played a role in the selection of beech for the sewn boats. Since beech is particularly suitable for radial splitting, shipbuilders precisely selected this type of wood because they could obtain long and straight planks with mechanical properties (Rival 1991, p. 125) well adapted to the characteristics sought for the sewn boats they were building. In addition, it is probable that beech forests of northern Dalmatia were then larger than today and located closer to the coast, therefore the availability of the wood resource surely had an impact on the choice of ancient shipbuilders: they could easily supply their shipyards. Another particularity of the sewn boats consists in the specific use of fir or, to a lesser extent, other conifer species for the small pegs locking the planking stitching assemblies.

Lastly, it is worth noting that the same type and distribution of wood species have also been recorded in the Pula 2 sewn boat found in the Roman harbour of Pula (Istria, Croatia), which is quite similar from an architectural point of view to the Caska 1 (Boetto *et al.* 2017, p. 196; Pomey, Boetto 2019, p. 10).

As previously underlined, the sewn boats of Caska belong to a strong local shipbuilding tradition. Thus, the existence of

local shipyards building sewn boats in Dalmatia is certain. From the wood analysis it is possible to advance the hypothesis that these local shipyards imported timber from mountainous areas located near the Dalmatian coast, such as the Velebit, Učka or Čičarija mountains, where forests of beech, fir and spruce are still nowadays particularly abundant (Nikolić *et al*. 2010, p. 426, 445; Nikolić 2015).

Dendromorphological and dendrochronological analyses show the variety of timbers used and how they were worked. On the one hand, for frames and axial carpentry, young logs, branches or coppiced trees were very slightly squared, keeping the original diameters. On the other hand, century-old beech or fir trees were radially split to obtain straight planks. Before shaping, the trunks used could easily reach 200 years of age and 50 cm in diameter.

In conclusion, it is expected that our study will make it possible to better understand the development of the northeastern Adriatic sewn-boat tradition and, perhaps, its relationships with other different shipbuilding traditions, such as that attested on the Caska 2 shipwreck. Our research also underlines the necessity of setting up a dendrochronological database in Croatia. This country, with its exceptional wealth of well-preserved ancient shipwrecks and other wooden structures, will certainly supply new data through the systematic combination of underwater research, nautical and maritime studies, and wood analyses.

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