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RADIOKARBONSKA DATACIJA TRIJU ŠIVANIH BRODOVA IZ ANTIČKE LUKE U ZATONU KOD NINA – REVIZIJA NAPRAVLJENIH ANALIZA

Metoda određivanja starosti pomoću radioaktivnog izotopa ugljika ^{14}C jedna je od najčešće korištenih metoda određivanja apsolutne starosti arheoloških artefakata biološkog podrijetla. Uvidom u bazu Instituta Ruđer Bošković utvrđeno je da su analizirana ukupno četiri uzorka iz antičkog doba iz Zatona, dva uzorka broda Zaton 1 te po jedan uzorak brodova Zaton 2 i Zaton 3. Datirani su u rasponu od sredine 3. st. pr. Kr. do sredine 2. st. po. Kr. U radu se donosi revizija napravljenih radiokarbonskih analiza triju šivanih brodova iz antičke luke u Zatonu kod Nina i rezultati nakon dendrokronološke kalibracije konvencionalne ^{14}C starosti.

Ključne riječi: Zaton, šivani brodovi, određivanje starosti, ^{14}C, dendrokronološka kalibracija

RADIOCARBON DATING OF THREE SEWN BOATS FROM THE ANCIENT PORT IN ZATON NEAR NIN – A REVISION OF THE EXISTING ANALYSES

The method of determining the age using the radioactive isotope of carbon ^{14}C is one of the most commonly used methods of determining the absolute age of archaeological artefacts of biological origin. An inspection of the Ruđer Bošković Institute database revealed that a total of four samples from the ancient period from Zaton were analysed, two samples from the boat Zaton 1 and one sample each from the boats Zaton 2 and Zaton 3. They were dated in the range from the middle of the 3rd century BC to the middle of the 2nd century AD. The paper presents a revision of the radiocarbon analyses of three sewn boats from the ancient port in Zaton near Nin, and the results after the dendrochronological calibration of the conventional ^{14}C age.

Key words: Zaton, sewn boats, age determination, ^{14}C, dendrochronological calibration

UVOD

Tri šivana broda iz antičke luke u Zatonu kod Nina predstavljaju jedan od izuzetno vrijednih nalaza ne samo u ovoj luci nego i na cijelom Jadranu (Sl. 1–2).[1] Luka je funkcionirala puna tri stoljeća. Nastala je sredinom 1., intenzivno se koristila do kraja 3., a najvjerojatnije je prestala egzistirati početkom ili polovinom 4. stoljeća.[2] Otkrivena je sredinom šezdesetih godina 20. st., a istraživanja su se vršila od njezina otkrića s manjim i većim prekidima u više kampanja. Nakon prvog rekognosciranja terena 1966. g. kada su otkriveni manji dijelovi prvog šivanog broda Zaton 1,[3] istraživanja su nastavljena 1979. g.[4] kada je brod dokumentiran i izvađen. Ostatci drugog šivanog broda Zaton 2 otkriveni su 1982. godine. Istraživanja su nastavljena 1983. i 1986., a 1987. g. brod je dokumentiran, izvađen i pohranjen u Arheološkom muzeju Zadar.[5] Voditelji podvodnih istraživanja od 1966. do 1987. g. bili su Zdenko Brusić i Miljenko Domijan. Sustavna arheološka istraživanja luke nastavljena su 2002. g. kada je pronađen i treći šivani brod Zaton 3.[6] Od tada istraživanja s manjim prekidima traju sve do danas, a zadnja kampanja provedena je 2019. g. kada je brod Zaton 3 detaljno dokumentiran. Voditelj podvodnih istraživanja od 2002. do 2013. g. bio je Smiljan Gluščević, dok je voditeljica kampanje 2019. g. bila Dušanka Romanović. Od tri zatonska broda prva dva su izvađena iz mora, dok se treći još uvijek nalazi u moru. Brodovi su jedinstveni zbog načina međusobnog spajanja platica tehnikom šivanja.[7] Z. Brusić tu je tradiciju nazvao „liburnskom", ali s obzirom na ostale nalaze šivanih brodova koji su pronađeni i na sjevernom Jadranu možemo govoriti o sjeveroistočnoj jadranskoj tradiciji koju su prije rimskog razdoblja koristili Liburni i Histri.[8]

Slika 1. Karta s položajem luke
Figure 1. Map with the location of the port
izvor / source: **Arkod**; **priredila** / edited by: **D. Romanović**

INTRODUCTION

Three sewn boats from the ancient port in Zaton near Nin represent one of the extremely valuable findings, not only in this port, but also on the entire Adriatic (Figs. 1–2).[1] The port was used for three full centuries. It was established in the middle of the 1st century, and it was used extensively until the end of the 3rd century, and it most likely ceased to exist in the beginning or the middle of the 4th century.[2] It was discovered in the mid-sixties, and since its discovery, research has been carried out in several campaigns, with minor and major interruptions. After the first reconnaissance of the terrain in 1966, when smaller parts of the first sewn boat Zaton 1 were discovered,[3] research was continued in 1979,[4] when the boat was documented and raised. The remains of the second sewn boat Zaton 2 were discovered in 1982. Research continued in 1983 and 1986, and in 1987 the boat was documented, raised and stored in the Archaeological Museum Zadar.[5] The leaders of the underwater research team from 1966 to 1987 were Zdenko Brusić and Miljenko Domijan. The systematic archaeological research of the port

1 Na istočnoj jadranskoj obali, uz tri zatonska šivana broda (Zaton 1, 2 i 3), zasad je otkriveno još šest rimskih šivanih brodova koji datiraju u razdoblje između 1. i 2. st., tri u Caskoj (Caska 1, 3 i 4), dva u Puli (Pula 1 i 2) i jedan u Poreču. Također možemo izdvojiti nalaz šivanog broda iz Zambratije koji datira u razdoblje kasnog brončanog doba. Dakle, na istočnoj jadranskoj obali pronađeno je ukupno deset šivanih brodova.
2 Više o datiranju vremena nastanka i korištenja luke vidi Z. Brusić, M. Domijan 1985, 69; S. Gluščević 1986a, 131–132; 2005, 46–48; 2011, 14; Z. Brusić 2006, 42, 45; A. Pydyn, S. Gluščević 2011, 30–31; D. Romanović, S. Gluščević 2014, 143; D. Romanović 2017, 388; 2021, 7, 83–84.
3 Više o otkriću prvog šivanog broda vidi Z. Brusić 1968, 203–210.
4 Više o istraživanju prvog šivanog broda vidi Z. Brusić 1968, 203–210; 1969, 215–222; 1980, 112–113; 1995, 39–59; Z. Brusić, M. Domijan 1985, 67–85; I. Radić Rossi, Z. Brusić 2014, 21–33; D. Romanović 2021.
5 Više o istraživanju drugog šivanog broda vidi S. Gluščević 1984, 17–18; 1986, 46–47; 1986a, 131–132; 1987, 43–44; Z. Brusić, M. Domijan 1985, 67–85; Z. Brusić 1989, 121–122; 1995, 39–59; I. Radić Rossi, Z. Brusić 2014, 21–33; D. Romanović 2021.
6 Više o istraživanju trećeg šivanog broda vidi S. Gluščević 2002, 76–86; 2004, 104–111; 2005, 41–52; 2007, 358–360; 2008, 420–421; A. Pydyn, S. Gluščević 2011, 25–48; D. Romanović 2021.
7 Više o brodovima i njihovoj tehnici brodogradnje vidi Z. Brusić 1968, 203–210; 1995, 39–59; Z. Brusić, M. Domijan 1985, 67–85; S. Gluščević 2006, 180–181; A. Pydyn, S. Gluščević 2011, 25–48; I. Radić Rossi, Z. Brusić 2014, 21–33; D. Romanović 2021.
8 G. Boetto, P. Pomey 2019, 162–165; P. Pomey, G. Boetto 2019, 8–12.

1 In addition to three Zaton sewn boats (Zaton 1, 2 and 3), six more Roman sewn boats dating from the 1st and 2nd centuries have been discovered on the eastern Adriatic coast so far; three in Caska (Caska 1, 3 and 4), two in Pula (Pula 1 and 2) and one in Poreč. We can also single out the finding of a sewn boat from Zambratija that dates back to the Late Bronze Age. Thus, a total of ten sewn boats were found on the eastern Adriatic coast.
2 For more information about the period of establishment and the use of the port see Z. Brusić, M. Domijan 1985, 69; S. Gluščević 1986a, 131–132; 2005, 46–48; 2011, 14; Z. Brusić 2006, 42, 45; A. Pydyn, S. Gluščević 2011, 30–31; D. Romanović, S. Gluščević 2014, 143; D. Romanović 2017, 388; 2021, 7, 83–84.
3 More on the discovery of the first sewn boat see Z. Brusić 1968, 203–210.
4 More on the research of the first sewn boat see Z. Brusić 1968, 203–210; 1969, 215–222; 1980, 112–113; 1995, 39–59; Z. Brusić, M. Domijan 1985, 67–85; I. Radić Rossi, Z. Brusić 2014, 21–33; D. Romanović 2021.
5 More on the research of the second sewn boat see S. Gluščević 1984, 17–18; 1986, 46–47; 1986a, 131–132; 1987, 43–44; Z. Brusić, M. Domijan 1985, 67–85; Z. Brusić 1989, 121–122; 1995, 39–59; I. Radić Rossi, Z. Brusić 2014, 21–33; D. Romanović 2021.

Slika 2. Rt Kremenjača s prikazom lukobrana i mjestom pronalaska triju brodova
Figure 2. Cape Kremenjača with a view of the breakwater and the location where the three boats were found
foto / photo: **D. Grosman**; **priredila** / edited by: **D. Romanović**

DATIRANJE ZATONSKIH BRODOVA

Datiranje brodova u Zatonu oslanja se na tri metode: standardna arheološka metoda datacije prema stratigrafskom položaju nalaza, radiokarbonska metoda ^{14}C i dendrokronologija.[9] Radiokarbonskom metodom ^{14}C analizirana je drvena građa svih triju brodova iz Zatona, a sve analize napravljene su u Institutu Ruđer Bošković u Zagrebu.[10] Vrijeme korištenja zatonskih brodova was continued in 2002, when the third sewn boat Zaton 3 was discovered.[6] Since then, the research has been ongoing with minor interruptions, and the last campaign was carried out in 2019, when the boat Zaton 3 was documented in detail. The head of underwater research team from 2002 to 2013 was Smiljan Gluščević, while the head of the 2019 campaign was Dušanka Romanović. The first two of the three Zaton boats were raised, while the third is still in the sea. The boats are unique because of the way the hull-plates were connected using the sewing technique.[7] Z. Brusić called this the "Liburnian" tradition, but considering other findings of sewn boats that were also found in the northern Adriatic, we can talk about the north-eastern Adriatic tradition, which was used by the Liburnians and the Histri before the Roman period.[8]

9 Prema dostupnim informacijama u literaturi za brodove Zaton 1 i Zaton 2 nisu napravljene dendrokronološke analize, a za brod Zaton 3 tijekom kampanje 2019. g. uzeta su dva uzorka za dendrokronologiju.

10 Svi podatci o uzorcima datiranim u Laboratoriju za mjerenje niskih radioaktivnosti (LNA) Instituta Ruđer Bošković nalaze se u bazi podataka IRB. Uzorci su označeni šifrom Z i rednim brojem. U svakom trenutku mogu se izlistati podatci o nekom uzorku, seriji uzoraka, uzorcima po vrsti materijala ili datumu pripreme ili mjerenja, ili nekom drugom podatku koji je zapisan u bazi.

6 More on the research of the third sewn boat see S. Gluščević 2002, 76–86; 2004, 104–111; 2005, 41–52; 2007, 358–360; 2008, 420–421; A. Pydyn, S. Gluščević 2011, 25–48; D. Romanović 2021.

7 More on the boats and the ship-building technique see Z. Brusić 1968, 203–210; 1995, 39–59; Z. Brusić, M. Domijan 1985, 67–85; S. Gluščević 2006, 180–181; A. Pydyn, S. Gluščević 2011, 25–48; I. Radić Rossi, Z. Brusić 2014, 21–33; D. Romanović 2021.

8 G. Boetto, P. Pomey 2019, 162–165; P. Pomey, G. Boetto 2019, 8–12.

se prema stratigrafiji nalazišta datira u razdoblje 1. – 2. st.,[11] a pomoću metode ^{14}C datirani su u rasponu od sredine 3. st. pr. Kr. do sredine 2. st. po. Kr.

Pregledavajući do sada objavljenu stručnu literaturu[12] vezanu za šivane brodove iz Zatona, uočeno je da se ne navode rezultati analize, tj. konvencijska starost za prvi šivani brod, da se za drugi šivani brod navode različiti rezultati analize, tj. konvencijska starost, dok su za treći brod uzorci na analizu poslani tek 2020. g., nakon zadnje kampanje istraživanja. U ovom će se radu objediniti sve analize s dendrokronološki kalibriranim rezultatima.

Slika 3. Ostatci broda Zaton 1
Figure 3. Remains of the boat Zaton 1
izvor / source: **Fototeka AMZd** / Photographic archive of the AMZd

PRVI ŠIVANI BROD

Ostatci prvog šivanog broda otkriveni su 1966. g. s unutrašnje strane lukobrana, na kopnenom kraju nasipa, gdje je more sada dubine 1,5 do 2 m (Sl. 3). Nastavak istraživanja uslijedio je 1979. g. nakon što su osigurana sredstva za njegovo vađenje i konzervaciju.[13] Brod je izvađen u dijelovima i prenesen u Centar za konzervaciju Republičkog zavoda za zaštitu spomenika kulture SRH u Zadru. Nakon vađenja konzerviran je otopinom polietilen-glikola (PEG 4000).

11 Među rebrima broda Zaton 1 pronađen je dobro sačuvan primjerak novca cara Vespazijana (69. – 79. g.). Na temelju toga može se pretpostaviti da je brod potonuo na dno zatonske luke najranije tijekom druge polovine 1. stoljeća. Nakon vađenja broda Zaton 2 ispod broda pronađen je primjerak novca cara Nerve (96. – 98. g.). Značajan je jer predstavlja *terminus ante quem non* potonuća koji govori da je brod dospio na dno luke krajem 1. ili početkom 2. stoljeća.

12 Bibliografija Zdenka Brusića pregledana je prema popisu R. Oštarić 2015, 7–20.

13 Istraživanje je financirao Republički zavod za zaštitu spomenika kulture SRH, a samo istraživanje vodio je Zavod za zaštitu spomenika kulture u Zadru u suradnji s Arheološkim muzejem Zadar, vidi Z. Brusić 1980, 112.

DATING OF THE BOATS FROM ZATON

The dating of the boats in Zaton relies on three methods: the standard archaeological dating method according to the stratigraphic position of the findings, the ^{14}C radiocarbon dating method and dendrochronology.[9] The wooden structure of all three boats from Zaton was analysed using the ^{14}C radiocarbon dating method, and all analyses were done at the Ruđer Bošković Institute in Zagreb.[10] According to the stratigraphy of the site, the period of use of Zaton boats is dated to the period of the 1st –2nd century,[11] and according to the ^{14}C method they were dated in the range from the middle of the 3rd century BC to the middle of the 2nd century AD.

Reviewing the published scientific literature[12] related to sewn boats from Zaton, it was observed that the results of the analysis were not stated, i.e. the conventional age for the first sewn boat, that different results of the analysis, that is the conventional age, are given for the second sewn boat, while the samples of the third boat were sent for analysis only in 2020, after the last research campaign. This paper will incorporate all analyses with the dendrochronologically calibrated results.

THE FIRST SEWN BOAT

The remains of the first sewn boat were discovered in 1966 at the inner part of the breakwater, at the landward end of the embankment, where the sea is now 1.5 to 2 m deep (Fig. 3). The continuation of research followed in 1979 after funds were secured for its extraction and conservation.[13] The boat was removed in parts and transferred to the Conservation Centre of the Republic Institute for the Protection of Cultural Monuments of Socialist Republic of Croatia in Zadar. After extraction, it was preserved with a solution of polyethylene glycol (PEG 4000). Although the conserved parts of the boat were lost, they were found in

9 According to the information available in sources, no dendrochronological analyses were done for the boats Zaton 1 and Zaton 2, and two samples for dendrochronology were taken for the boat Zaton 3 during the 2019 campaign.

10 All data on samples dated in the Laboratory for Low-level Radioactivities (LNA) of the Ruđer Bošković Institute are in the IRB database. The samples are marked with code Z and serial number. The data on a sample, the series of samples, the samples by type of material, or date of preparation, or measurement, or any other data recorded in the database can be listed at any time.

11 Among the frames of the boat Zaton 1, a well-preserved coin of the emperor Vespasian (AD 69–79) was found. Based on this, it can be assumed that the boat sank to the bottom of the port of Zaton during the second half of the 1st century at the earliest. After raising the boat Zaton 2, a coin of the Emperor Nerva (AD 96–98) was found under the boat. It is significant because it represents a *terminus ante quem non* of the sinking, which indicates that the boat sank to the bottom of the port at the end of the 1st or the beginning of the 2nd century.

12 The bibliography of Zdenko Brusić was reviewed according to the list by R. Oštarić 2015, 7–20.

13 The research was financed by the Republic Institute for the Protection of Cultural Monuments of the Socialist Republic of Croatia, and the research itself was led by the Institute for the Protection of Cultural Monuments in Zadar in cooperation with the Archaeological Museum Zadar, see Z. Brusić 1980, 112.

Iako se konzerviranim dijelovima broda izgubio trag, pronađeni su 2021. godine i vidljivo je da njihova konzervacija nažalost nije bila završena.[14]

Podatci o prvom pronađenom šivanom brodu u antičkoj luci u Zatonu poznati su nam uglavnom iz sačuvane dokumentacije, koja i nije opsežna. Pregledom arhive Muzeja pronađeni su malobrojni izvještaji vezani za podvodna istraživanja prvog broda. Tijekom prve etape istraživanja 1966. g. iz mora je izvađen manji dio oplate broda Zaton 1 radi analize. Prema dostupnim informacijama u literaturi nigdje se ne spominje da je za brod Zaton 1 napravljena dendrokronološka analiza, ali se navodi da je napravljena analiza vrste drva.[15]

U literaturi se sporadično spominje da je napravljena analiza drvene građe prvog šivanog broda radiokarbonskom metodom ^{14}C. U većini slučajeva navodi se u množini da su brodovi datirani radiokarbonskom metodom, ali nigdje se ne navode datumi konvencijske starosti, posebno za brod Zaton 1.[16] Međutim, uvidom u arhivu Instituta Ruđer Bošković utvrđeno je da su analizirana čak dva uzorka drva koja su izvađena u Zatonu kod Nina (Tab. 1). Za analizu obaju uzoraka korištena je tehnika plinskog proporcionalnog brojača (GPC – *Gas Proportional Counting*).

Prvi je uzorak s oznakom Z-129 *Zaton near Nin* iz 1967. godine.[17] Mjerenjem uzorka koje je objavljeno u časopisu *Radiocarbon* 13 (1) iz 1971. g. (data list I) dobio se izračun konvencijske starosti od 2063 ± 67 BP, 113 BC.[18] Isti podatak nalazimo i u bazi podataka Instituta Ruđer Bošković.

14 Više o samoj konzervaciji brodova Zaton 1 i Zaton 2 vidi J. Lovrić 2021, 241–254; D. Romanović 2021.

15 Z. Brusić 1969, 207–208; Z. Brusić, M. Domijan 1985, 71.

16 Literatura gdje se spominje datacija brodova radiokarbonskom metodom: Z. Brusić, M. Domijan 1985, 67 – *These boats are dated by ^{14}C to the 3rd and 4th century BC, but stratigraphically they are assigned to the 1st century AD* (Ovi brodovi su datirani s ^{14}C u 3. i 4. st. pr. Kr., ali stratigrafski pripadaju 1. st. po. Kr.); S. Gluščević 1986, 131 – *Najvrijedniji nalazi su svakako ova dva broda, odnosno njihovi ostatci, koja su ^{14}C metodom datirana od 4. – 2. st. pr. n. e., iako okolnosti nalaza ukazuju da su potopljeni početkom 1. st. n. e.*; M. Kozličić, Z. Brusić 1994, 35 – *Činjenica da se brodovi na temelju radiokarbonske analize datiraju u 295. g. pr. n. e. (± 132 godine) upućuje na zaključak da je to tek jedan od vidova brodograđevnog umijeća Liburna*; Z. Brusić *et al.* 2002, 44 – *Starost barki određena je pomoću arheoloških kao i ^{14}C analiza. Sudeći po novcu i drugim arheološkim nalazima, barke su potonule negdje u drugoj polovici 1. stoljeća pr. Kr., a prema analizi drvene građe bile su sagrađene oko 200 godine prije potonuća*; Z. Brusić 2006, 36–37 – *Il radiocarbonio a cui i campioni della struttura in legno sono stati sottoposti ha indicato una datazione attorno al 2. secolo a.C., riferita al taglio del legno utilizzato per la costruzione delle navi, mentre queste ultime vennero abbandonate in epoca romana* (Radiokarbonsko mjerenje kojem su bili podvrgnuti uzorci drvene konstrukcije ukazuje na datiranje oko 2. st. pr. Kr., što se odnosi na sječu drva za gradnju brodova, dok su potonji u rimsko doba napušteni); I. Radić Rossi, Z. Brusić 2014, 26 – *Koristeći se metodom ^{14}C, voditelj istraživanja Zdenko Brusić datirao je u 3. st. pr. Kr. drvenu građu od koje su brodovi bili izgrađeni, ali je stratigrafija nalazišta sugerirala njihovo potonuće tek u 1. st. po. Kr.*

17 Vidi D. Srdoč, B. Breyer, A. Sliepčević 1971, 135–140. U opisu se navodi da je riječ o ulomku drvene grede, na dubini od 1,80 m, u 40 cm debelom pjeskovitom sloju, i da je uzorak prikupio 1967. g. Z. Brusić. Uzorak je datiran u 2063 ± 67 BP, 113 BC.

18 D. Srdoč, B. Breyer, A. Sliepčević 1971, 139.

2021 and it is evident that their conservation was unfortunately not completed.[14]

The information about the first sewn boat found in the ancient port in Zaton is available mainly from the preserved documentation, which is not extensive. A review of the Museum's archives revealed a small number of reports related to the underwater research of the first boat. During the first stage of the research in 1966, a small part of the hull plating of the boat Zaton 1 was raised from the sea for analysis. According to the information available in the sources, it is not mentioned anywhere that a dendrochronological analysis of the boat Zaton 1 was done, but it is stated that a wood type analysis was done.[15]

It is sporadically mentioned in the sources that an analysis of the wooden structure of the first sewn boat was done using the ^{14}C radiocarbon method. In most cases, it is stated in plural that the boats were dated using the radiocarbon method, but the conventional age dates were not given anywhere, especially for the Zaton 1 boat.[16] However, an insight in the Ruđer Bošković Institute archives showed that actually two wood samples, taken from Zaton near Nin, were analysed (Tab. 1). The Gas Proportional Counting (GPC) technique was used for the analysis of both samples.

The first sample marked Z-129 Zaton near Nin is from 1967.[17] The measurement of the sample published in the

14 More on the conservation of the boats Zaton 1 and Zaton 2 see J. Lovrić 2021, 241–254; D. Romanović 2021.

15 Z. Brusić 1969, 207–208; Z. Brusić, M. Domijan 1985, 71.

16 Sources which mention the radiocarbon dating of the boats: Z. Brusić, M. Domijan 1985, 67 – *These boats are dated by ^{14}C to the 3rd and 4th century BC, but stratigraphically they are assigned to the 1st century AD*; S. Gluščević 1986, 131 – *Najvrijedniji nalazi su svakako ova dva broda, odnosno njihovi ostatci, koja su ^{14}C metodom datirana od 4. – 2. st. pr. n. e., iako okolnosti nalaza ukazuju da su potopljeni početkom 1. st. n. e.* (The most valuable findings are certainly these two boats i.e. their remains, which were dated by the ^{14}C method to the 4th–2nd centuries BC, although the circumstances of the findings indicate that they sunk at the beginning of the 1st century AD); M. Kozličić, Z. Brusić 1994, 35 – *Činjenica da se brodovi na temelju radiokarbonske analize datiraju u 295. g. pr. n. e. (± 132 godine) upućuje na zaključak da je to tek jedan od vidova brodograđevnog umijeća Liburna* (The fact that the boats are dated to 295 BC [± 132 years] according to the radiocarbon analysis, leads to the conclusion that this is only one of the aspects of Liburnian shipbuilding skills); Z. Brusić *et al.* 2002, 44 – *Starost barki određena je pomoću arheoloških kao i ^{14}C analiza. Sudeći po novcu i drugim arheološkim nalazima, barke su potonule negdje u drugoj polovici 1. stoljeća pr. Kr., a prema analizi drvene građe bile su sagrađene oko 200 godine prije potonuća* (The age of the boats was determined through archaeological and ^{14}C analyses. According to coins and other archaeological findings, the boats sank sometime in the second half of the 1st century BC, and according to the analysis of wooden materials, they were built about 200 years before the sinking); Z. Brusić 2006, 36–37 – *Il radiocarbonio a cui i campioni della struttura in legno sono stati sottoposti ha indicato una datazione attorno al 2. secolo a.C., riferita al taglio del legno utilizzato per la costruzione delle navi, mentre queste ultime vennero abbandonate in epoca romana* (The radiocarbon measurement, to which the samples of the wooden structure were subjected, indicates a dating around the 2nd century BC which refers to the harvesting of timber used for ship-building, while the latter were abandoned in Roman times); I. Radić Rossi, Z. Brusić 2014, 26 – *Koristeći se metodom ^{14}C, voditelj istraživanja Zdenko Brusić datirao je u 3. st. pr. Kr. drvenu građu od koje su brodovi bili izgrađeni, ali je stratigrafija nalazišta sugerirala njihovo potonuće tek u 1. st. po. Kr.* (Using the ^{14}C method, research leader Zdenko Brusić dated the timber used for the building of boats to the 3rd century BC, but the stratigraphy of the site suggested they sunk in the 1st century AD).

17 See D. Srdoč, B. Breyer, A. Sliepčević 1971, 135–140. The description states that it is a fragment of a wooden beam, at a depth of 1.80 m, in a 40 cm thick sandy layer, and that the sample was collected in 1967 by Z. Brusić. The sample was dated to 2063 ± 67 BP, 113 BC.

Z-BROJ UZORKA Z-SAMPLE NUMBER	**NAZIV UZORKA** SAMPLE NAME	**OBJAVLJEN REZULTAT (RADIOCARBON) ^{14}C KONVENCIJSKA STAROST (BP)** PUBLISHED RESULT (RADIOCARBON) ^{14}C CONVENTIONAL AGE (BP)	**REZULTAT IZ IRB BAZE PODATAKA ^{14}C KONVENCIJSKA STAROST (BP)** RESULT FROM THE RBI DATABASE ^{14}C CONVENTIONAL AGE (BP)	**KALIBRACIJA PODATAKA IZ IRB BAZE PODATAKA ^{14}C KONVENCIJSKA STAROST (BP)** CALIBRATION OF DATA FROM THE RBI DATABASE ^{14}C CONVENTIONAL AGE (BP)
Z-129	Potopljeni brod, Zaton kod Nina, Z. Brusić, 1967.	2063 ± 67	2063 ± 67	166 cal BC – 16 cal AD (68,3%)
Z-571	Gradina, Zaton kod Nina, stara rimska luka, Z. Brusić, 1977.	2010 ± 95	1978 ± 92	53 cal BC – 166 cal AD (63,6%)
Z-1041	„Sunk gallion", Zaton kod Nina, M. Domijan, 1982.	2130 ± 120	2166 ± 94	235 – 99 cal BC (37,6%)
Z-7391	Drvo, šivani brod #3, antička luka Zaton kod Nina, D. Romanović, 2019.	-	1925 ± 15	74 – 127 cal AD (68,3 %)

Tablica 1. Rezultati radiokarbonske metode ^{14}C, konvencijska starost (BP) brodova Zaton 1, 2 i 3; Institut Ruđer Bošković
Table 1. Radiocarbon method ^{14}C results, conventional age (BP) of Zaton 1, 2 and 3 boats; Ruđer Bošković Institute
priredila / prepared by: **D. Romanović**

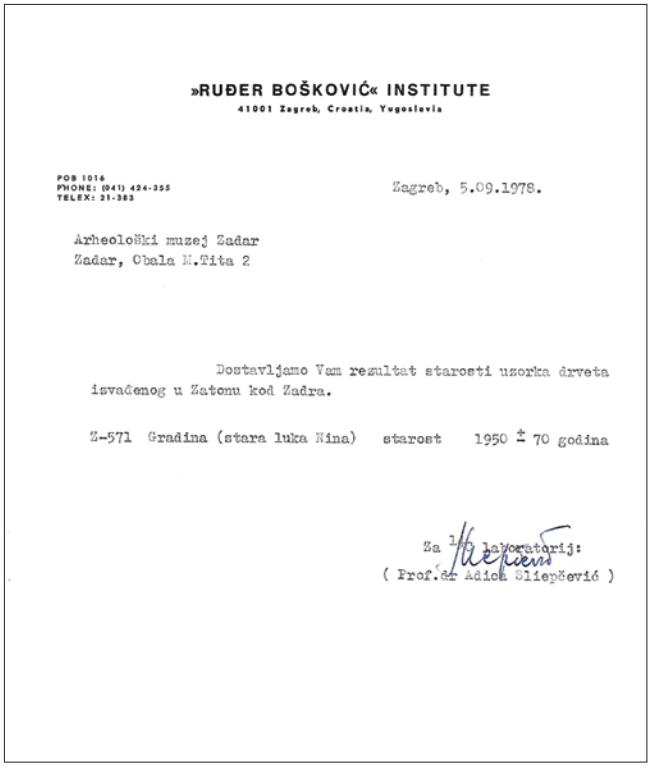
Drugi je uzorak s oznakom Z-571 Gradina[19] iz 1977. godine.[20] Mjerenjem uzorka koje je objavljeno u časopisu *Radiocarbon* 21 (1) iz 1979. g. (data list V) dobio se izračun konvencijske starosti od 2010 ± 95 BP, $\delta^{13}C$ = -24 ‰.[21] Za taj drugi uzorak (Z-571) pregledom arhive Muzeja pronađen je i dopis Instituta Ruđer Bošković iz 1978. g. u kojem se navodi da je analiziran uzorak drva izvađen u Zatonu kod Zadra, lokalitet Gradina (stara luka Nina) (Sl. 4). U navedenom dopisu navodi se izračun konvencijske starosti od 1950 ± 70 BP. Naime, vrijednosti objavljene u časopisu *Radiocarbon* su iz doba kad su mjerenja napravljena, a kasnije su se u Institutu ponavljala mjerenja ili radile korekcije u skladu s novim saznanjima. Prema dopisu A. Sliepčević riječ je o ponovljenom mjerenju istog uzorka 7. srpnja 1978. i 25. srpnja 1978., uzeta je srednja vrijednost svih triju mjerenja te se dobio izračun konvencijske starosti od 1950 ± 70 BP. Prema svemu sudeći, tu je $\delta^{13}C$ = -25 ‰, tj. uobičajena

journal *Radiocarbon* 13 (1) from 1971 (data sheet I) resulted in a calculation of the conventional age of 2063 ± 67 BP, 113 BC.[18] The same data can be found in the Ruđer Bošković Institute database.

The second sample marked as Z-571 Gradina[19] is from 1977.[20] The sample measurement published in the journal *Radiocarbon* 21 (1) from 1979 (data sheet V) resulted in the calculation of the conventional age of 2010 ± 95 BP, $\delta^{13}C$ = -24 ‰.[21] A research of the Museum's archives produced a 1978 report from the Ruđer Bošković Institute for the second sample (Z-571), which states that the analysed wood sample was extracted from Zaton near Zadar, from the Gradina site (the old port of Nin) (Fig. 4). The aforementioned report states the calculation of the conventional age of 1950 ± 70 BP. Namely, the values published in the Radiocarbon journal stem from the period when the measurements were first made, and afterwards the measurements

19 Cijelo je područje antičke luke kod lokalnog stanovništva poznato i pod nazivom Gradina, prema velikim gomilama ovalnog kamenja, odnosno balastnog kamena, koje se i danas vide u moru.
20 Vidi D. Srdoč *et al.* 1979, 131–137. U opisu se navodi da je riječ o ulomku drvene grede, 80 cm ispod pjeskovitog i muljevitog sloja, 200 cm ispod površine mora, iz Zatona kod Nina (44°14′ N, 15°20′ E), i da je uzorak prikupio 1977. g. Z. Brusić koji je rekao da je očekivana dob oko 2000 godina. Uzorak je datiran u 2010 ± 95 BP, $\delta^{13}C$ = -24 ‰.
21 D. Srdoč *et al.* 1979, 135.

18 D. Srdoč, B. Breyer, A. Sliepčević 1971, 139.
19 The entire area of the ancient port is also called Gradina by the local population, and it was named after the large piles of oval stones, i.e. the ballast stones, which are still visible in the sea today.
20 See D. Srdoč *et al.* 1979, 131–137. The description states that it is a fragment of a wooden beam, 80 cm below the sand and mud layer, 200 cm below the sea surface, located in Zaton near Nin (44°14′ N, 15°20′ E), and that the sample was collected in 1977 by Z. Brusić who said that the expected age was about 2000 years. The sample was dated to 2010 ± 95 BP, $\delta^{13}C$ = -24 ‰.
21 D. Srdoč *et al.* 1979, 135.



»RUĐER BOŠKOVIĆ« INSTITUTE
41001 Zagreb, Croatia, Yugoslavia

POB 1016
PHONE: (041) 424-355
TELEX: 21-383

Zagreb, 5.09.1978.

Arheološki muzej Zadar
Zadar, Obala M.Tita 2

Dostavljamo Vam rezultat starosti uzorka drveta izvađenog u Zatonu kod Zadra.

Z-571 Gradina (stara luka Nina) starost 1950 ± 70 godina

Za laboratorij:
(Prof.dr Adica Sliepčević)

Slika 4. Dopis Instituta Ruđer Bošković iz 1978. g.
Figure 4. A report from the Ruđer Bošković Institute from 1978.
izvor / source: **arhiva AMZd** / Archives of the AMZd

vrijednost za drvo.[22] Tijekom godina mijenjale su se konvencije izražavanja starosti, ali sami rezultati mjerenja aktivnosti izraženi kao relativna specifična aktivnost $a^{14}C$ (u „jedinicama" pMC – *percent Modern Carbon*) ostaju nepromijenjeni.[23] Kod prelaska u novu bazu ZAGRADA (*ZAGreb RADiocarbon DAtabase*) koristili su se podatci za $a^{14}C$ od sva tri mjerenja, te se dobio izračun konvencijske starosti prema važećim konvencijama od 1978 ± 92 BP koji nalazimo u bazi podataka Instituta Ruđer Bošković.

Podatci iz arhive obiju ustanova, godine uzorkovanja, opisi u popisu podataka i vrijeme datacije drvene građe, upućuju na to da se ovdje stvarno radi o uzorcima broda Zaton 1, jednom uzetom odmah nakon otkrića broda i drugom uzetom prije njegova vađenja. Razlika dendrokronološke kalibracije (Z-571 je nešto mlađi od Z-129) da se objasniti vjerojatno različitim rasponom godova u ta dva uzorka.

Predlažemo da se u budućim objavama za šivani brod Zaton 1 koristi podatak iz baze IRB uz kalibraciju konvencijske

22 Delta vrijednost za ^{13}C ($\delta^{13}C$) relativno je odstupanje omjera izotopa $^{13}C/^{12}C$ u uzorku od toga omjera u međunarodno prihvaćenom referentnom materijalu, izraženo u promilima (‰).
23 Relativna specifična aktivnost ^{14}C ($a^{14}C$) izmjerena je aktivnost ^{14}C u uzorku, izražena kao udio modernog ugljika u % (pMC).

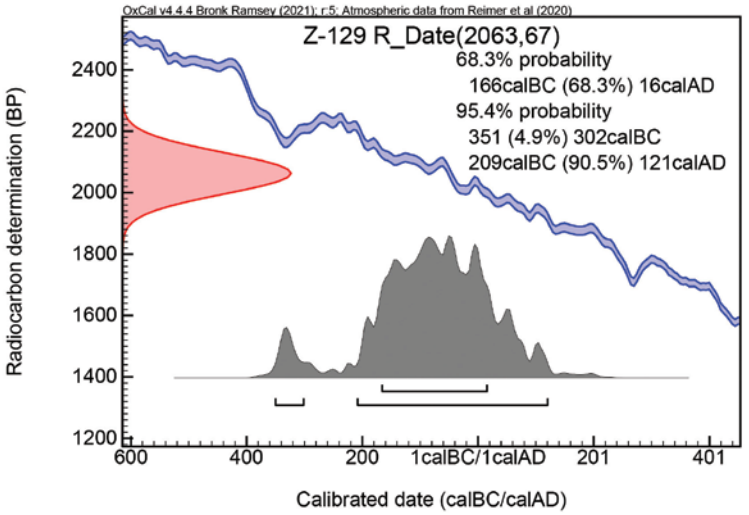
were repeated at the Institute or corrections were made in accordance with new insights. According to the report by A. Sliepčević, this is a repeated measurement of the same sample, done on July 7, 1978 and July 25, 1978 where the mean value of all three measurements was taken into account which resulted in the calculation of the conventional age of 1950 ± 70 BP. Apparently, the delta value here is $\delta^{13}C$ = -25 ‰, i.e. the usual value for wood.[22] Over the years, the conventions for expressing age have changed, but the activity measurement results, expressed as the relative specific activity of $a^{14}C$ (in pMC "units" – percent Modern Carbon), remain unchanged.[23] When transferring to the new ZAGRADA database (ZAGreb RADiocarbon DAtabase), the data for $a^{14}C$ from all three measurements were used, and the calculation of the conventional age was obtained according to the valid conventions of 1978 ± 92 BP found in the Ruđer Bošković Institute database. The data from the archives of both institutions, the years of sampling, the descriptions in the data sheets, and the dating time of the timber indicate that these are indeed the samples of the boat Zaton 1, one taken immediately after the discovery of the boat, and the other taken before its removal. The difference in dendrochronological calibration (Z-571 is slightly younger than Z-129) is likely explained by different growth rings in these two samples.

We suggest that in future publications regarding the sewn boat Zaton 1, data from the IRB database is used with the calibration of the conventional age at 166 cal BC – 16 cal AD (68.3 %) (middle of the 2nd century BC – beginning of the 1st century AD) for the first sample, and calibration of the conventional age to 53 cal BC – 166 cal AD (63.6 %) (middle of the 1st century BC – middle of the 2nd century AD) for the second sample (Figs. 5–6; Tab. 1).

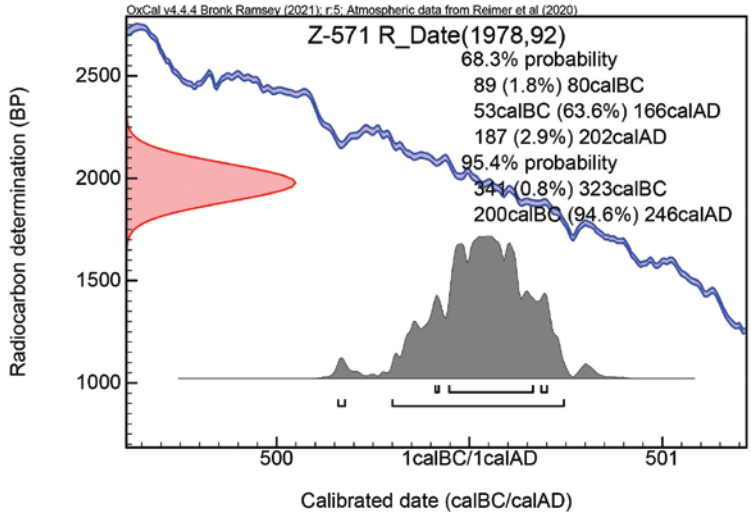
THE SECOND SEWN BOAT

The remains of the second sewn boat were discovered in the immediate vicinity of the boat Zaton 1, only a few meters to the south, at a depth of 1.5 to 2 m, during underwater research in 1982 (Fig. 7). The second boat was in much better condition and much better preserved than the first. The research continued in 1987, when the boat was raised in parts and transported to the Conservation Centre of the Archaeological Museum Zadar. The conservation of the second sewn boat began 29 years after its extraction, when it was preserved with a solution of polyethylene glycol in 2016.[24]

22 The delta value for ^{13}C ($\delta^{13}C$) is the relative deviation of the $^{13}C/^{12}C$ isotope ratio in the sample from that ratio in the internationally accepted reference material, expressed in per mil (‰).
23 The relative specific activity of ^{14}C ($a^{14}C$) is the measured activity of ^{14}C in a sample, expressed as the proportion of modern carbon in % (pMC).
24 The entire conservation process was led by the conservator and restorer of the Archaeological Museum Zadar, Josipa Lovrić. See J. Lovrić 2021, 241–254.



Slika 5. Kalibrirani datum uzorka Z-129 broda Zaton 1
Figure 5. Calibrated date of sample Z-129 of the boat Zaton 1
priredila / prepared by: **I. Krajcar Bronić**



Slika 6. Kalibrirani datum uzorka Z-571 broda Zaton 1
Figure 6. Calibrated date of sample Z-571 of the boat Zaton 1
priredila / prepared by: **I. Krajcar Bronić**

starosti na 166 cal BC – 16 cal AD (68,3 %) (sred. 2. st. pr. Kr. – poč. 1. st.) za prvi uzorak, te kalibraciju konvencijske starosti na 53 cal BC – 166 cal AD (63,6 %) (sred. 1. st. pr. Kr. – sred. 2. st.) za drugi uzorak (Sl. 5–6; Tab. 1).

DRUGI ŠIVANI BROD

Ostatci drugog šivanog broda otkriveni su u neposrednoj blizini broda Zaton 1, svega nekoliko metara južnije, na dubini 1,5 do 2 m, tijekom podvodnih istraživanja 1982. g. (Sl. 7). Drugi je brod bio u mnogo boljem stanju i znatno uščuvaniji od prvog. Istraživanja su nastavljena 1987. g. kada je brod izvađen u dijelovima i prevezen u Centar za konzervaciju Arheološkog muzeja Zadar. Konzervacija drugog šivanog broda započela je 29 godina nakon njegova vađenja kada je 2016. g. konzerviran otopinom polietilen-glikola.[24]

I njegova je dokumentacija oskudna; podatci su nam poznati uglavnom iz sačuvane dokumentacije i malobrojnih

The documentation about this boat is also scarce; the data is known to us mainly from the preserved documentation, and few reports related to the underwater research of the second boat. According to the available information, there is no mention in the sources that a dendrochronological analysis was done for the boat Zaton 2. During the cleaning and the structure processing of the Zaton 2 boat in 2014, 80 samples were taken for the wood type analysis, which determined the presence of a total of five different types of wood.[25]

For the boat Zaton 2, the sources state that after the boat was raised in 1982, the dating of the wooden structure was done using the radiocarbon method.[26] It has already been mentioned that certain sources often state in plural that the boats were dated using the radiocarbon method,

24 Cijeli postupak konzervacije vodila je konzervatorica restauratorica Arheološkog muzeja Zadar Josipa Lovrić. Vidi J. Lovrić 2021, 241–254.

25 The identification of the wood type was done by Nili Liphschitz from the Tel Aviv University in Israel. See N. Lipschitz, S. Gluščević 2015, 158–160.

26 S. Gluščević 1984, 18 – *Starost drva od kojega je sagrađen ovaj brod, a na osnovi rezultata radiokarbonske analize izvršene u Institutu "Ruđer Bošković" u Zagrebu, seže u 2. st. pr. n. e.* (The age of the wood from which this boat was built, and based on the results of radiocarbon analysis performed at the Ruđer Bošković Institute in Zagreb, dates back to the 2nd century BC).

izvještaja vezanih za podvodna istraživanja drugog broda. Prema dostupnim informacijama u literaturi nigdje se ne spominje da je za brod Zaton 2 napravljena dendrokronološka analiza. Tijekom čišćenja i obrade građe broda Zaton 2 2014. g. uzeto je 80 uzoraka za analizu vrste drva kojom je utvrđena prisutnost sveukupno pet različitih vrsta drva.[25]

Za brod Zaton 2 u literaturi se navodi da je, nakon što je brod izvađen 1982. g., napravljena datacija drvene građe radiokarbonskom metodom.[26] Već je spomenuto i da se u pojedinoj literaturi često navodi u množini da su brodovi datirani radiokarbonskom metodom, ali bez navođenja datuma konvencijske starosti.[27] Isto tako u literaturi nalazimo navedeno nekoliko različitih datuma konvencijske starosti za brod Zaton 2.[28] Za dendrokronološku korekciju objavljenu u radu iz 1995. g. od 2276 ± 142 BP nisu pronađeni podatci u Institutu Ruđer Bošković.[29]

Uvidom u arhivu Instituta Ruđer Bošković utvrđeno je da je radiokarbonskom metodom analiziran samo jedan uzorak drva koji je izvađen u Zatonu kod Nina, Z-1041 iz 1982. godine.[30] Za analizu je korištena tehnika plinskog proporcionalnog brojača (GPC – *Gas Proportional Counting*). Mjerenjem uzorka koje je objavljeno u časopisu *Radiocarbon* 26 (3) iz 1984. g. (data list VIII) dobio se izračun konvencijske starosti od 2130 ± 120 BP.[31] Podatak koji Z. Brusić navodi u radu iz 1985. g. od 2194 ± 128 BP jest starost računata s vremenom poluraspada od 5568 godina, ali ne znamo s kojim $\delta^{13}C$. Drugi podatak koji Z. Brusić na-

Slika 7. Ostatci broda Zaton 2
Figure 7. Remains of the boat Zaton 2
izvor / source: **Fototeka AMZd** / Photographic archive of the AMZd

but without specifying the date of the conventional age.[27] Likewise, the sources state several different conventional age dates for the boat Zaton 2.[28] No data were found at the Ruđer Bošković Institute for the dendrochronological correction of 2276 ± 142 BP which was published in a paper from 1995.[29]

An inspection of the Ruđer Bošković Institute archives revealed that only one wood sample, taken from Zaton near Nin, Z-1041 from 1982, was analysed using the radiocarbon method.[30] The Gas Proportional Counting (GPC)

25 Identifikaciju vrste drva napravila je Nili Liphschitz sa Sveučilišta Tel Aviv u Izraelu. Vidi N. Liphschitz, S. Gluščević 2015, 158–160.

26 S. Gluščević 1984, 18 – *Starost drva od kojega je sagrađen ovaj brod, a na osnovi rezultata radiokarbonske analize izvršene u Institutu "Ruđer Bošković" u Zagrebu, seže u 2. st. pr. n. e.*

27 Vidi bilj. 17.

28 Literatura gdje se spominje datacija broda Zaton 2 s konvencijskom starosti: Z. Brusić, M. Domijan 1985, 81 – *The radiocarbon analyses of two samples from the second boat determined the age of the wood, or the date of felling the trees from which the boat was made, as 295 ± 132 BC. The first analysis gave 2194 ± 128 BP, the second analysis, 2260 ± 132 BP* (Radiokarbonskim analizama dvaju uzoraka drugog broda utvrđena je starost drva, odnosno datum sječe stabala od kojih je brod napravljen, u 295 ± 132 g. pr. Kr. Prva analiza dala je 2194 ± 128 BP, druga analiza 2260 ± 132 BP); Z. Brusić 1989, 122 – *Drugom metodom datiranja drva, radiokarbonskom analizom ^{14}C koja je obavljena na Institutu Ruđer Bošković u Zagrebu dobili smo datum 2276 ± 142 godine, od vremena kada je drvo posječeno za gradnju. To bi naime značilo da je brod izgrađen u drugom ili trećem stoljeću stare ere a bio u upotrebi do konca prvog stoljeća nove ere*; Z. Brusić 1995, 43 – *Drugi podatak za vremensku determinaciju dobiven je ^{14}C analizom uzorka drva s drugog broda i dendrokronološkom korekcijom istog uzorka. Dobivene su sljedeće vrijednosti: 2194 ± 128 (vrijednost računata s vremenom poluraspada 5570 godina), 2260 ± 132 (vrijednost računata s točnijom vrijednosti poluraspada 5730 godina), 2276 ± 142 godine (dendrokronološka korekcija)*; N. Liphschitz, S. Gluščević 2015, 159 – *The radiocarbon analyses of two samples from Zaton 2 determined the age of the wood, or the date of felling of the trees from which the boat was made, as 295 ± 132 BC. The first analysis gave the result of 2194 ± 128 BP and the second analysis gave the result of 2260 ± 132 BP* (Radiokarbonskim analizama dvaju uzoraka iz Zatona 2 utvrđena je starost drva, odnosno datum sječe stabala od kojih je brod napravljen, u 295. ± 132. g. pr. Kr. Prva analiza dala je rezultat od 2194 ± 128 BP, a druga analiza je dala rezultat od 2260 ± 132 BP).

29 Z. Brusić 1995, 43.

30 Vidi D. Srdoč *et al.* 1984, 449–459. U opisu se navodi da je riječ o drvenoj gredi broda potonulog 1,8 m ispod površine mora, zakopanoj u mulj na dubini od 60 cm, iz Zatona kod Nina, u Dalmaciji (44°13'40" N, 15°09'50" E), da je uzorak predao 1982. g. M. Domijan te da je očekivana dob oko 2000 godina. Uzorak je datiran u 2130 ± 120 BP.

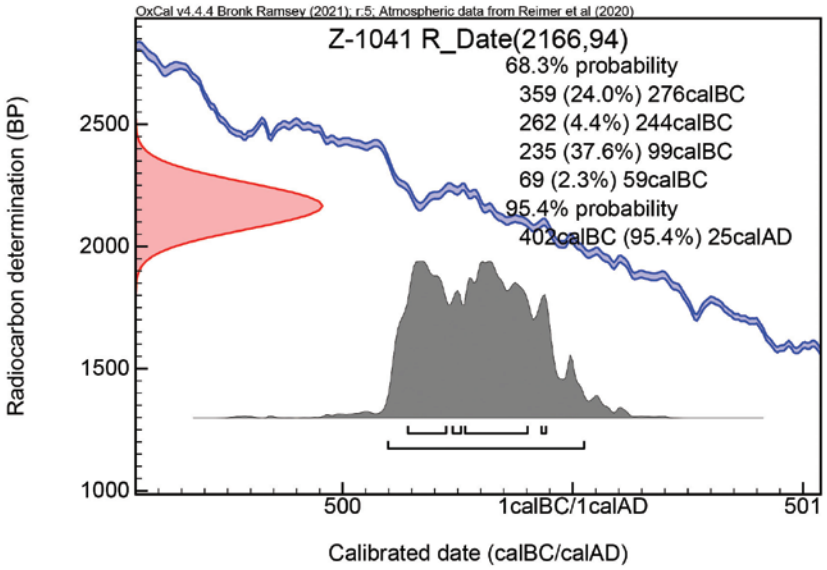
31 D. Srdoč *et al.* 1984, 451.

27 See n. 17.

28 Sources which mention the dating of the boat Zaton 2 with the conventional age: Z. Brusić, M. Domijan 1985, 81 – *The radiocarbon analyses of two samples from the second boat determined the age of the wood, or the date of felling the trees from which the boat was made, as 295 ± 132 BC. The first analysis gave 2194 ± 128 BP, the second analysis, 2260 ± 132 BP*; Z. Brusić 1989, 122 – *Drugom metodom datiranja drva, radiokarbonskom analizom ^{14}C koja je obavljena na Institutu Ruđer Bošković u Zagrebu dobili smo datum 2276 ± 142 godine, od vremena kada je drvo posječeno za gradnju. To bi naime značilo da je brod izgrađen u drugom ili trećem stoljeću stare ere a bio u upotrebi do konca prvog stoljeća nove ere* (By using another method of wood dating, the ^{14}C radiocarbon analysis, which was performed at the Ruđer Bošković Institute in Zagreb, we obtained a date of 2276 ± 142 years, from the period when the wood was cut down for the construction. This would mean that the boat was built in the second or third century BC and it was in use until the end of the first century AD); Z. Brusić 1995, 43 – *Drugi podatak za vremensku determinaciju dobiven je ^{14}C analizom uzorka drva s drugog broda i dendrokronološkom korekcijom istog uzorka. Dobivene su sljedeće vrijednosti: 2194 ± 128 (vrijednost računata s vremenom poluraspada 5570 godina), 2260 ± 132 (vrijednost računata s točnijom vrijednosti poluraspada 5730 godina), 2276 ± 142 godine (dendrokronološka korekcija)* (Another age determination data was obtained by ^{14}C analysis of a wood sample from the second boat, and by dendrochronological correction of the same sample. The following values were obtained: 2194 ± 128 [the value calculated with a half-life of 5570 years], 2260 ± 132 [the value calculated with a more accurate half-life value of 5730 years], 2276 ± 142 years [dendrochronological correction]); N. Liphschitz, S. Gluščević 2015, 159 – *The radiocarbon analyses of two samples from Zaton 2 determined the age of the wood, or the date of felling of the trees from which the boat was made, as 295 ± 132 BC. The first analysis gave the result of 2194 ± 128 BP and the second analysis gave the result of 2260 ± 132 BP.*

29 Z. Brusić 1995, 43.

30 See D. Srdoč *et al.* 1984, 449–459. The description states that it is a wooden beam of a sunken boat at a depth of 1.8 m below the surface, buried in mud at a depth of 60 cm, from Zaton near Nin, in Dalmatia (44°13'40" N, 15°09' 50" E), that the sample was submitted in 1982 by M. Domijan, and that the expected age is about 2000 years. The sample is dated to 2130 ± 120 BP.



Slika 8. Kalibrirani datum uzorka Z-1041 broda Zaton 2
Figure 8. Calibrated date of sample Z-1041 of the boat Zaton 2
priredila / prepared by: **I. Krajcar**

vodi od 2260 ± 132 BP zapravo je ista starost, samo računata s vremenom poluraspada od 5730 godina. Naime, u to doba, 1980-ih godina, preciznije je izmjereno vrijeme poluraspada ^{14}C (5730 godina), pa su ljudi počeli računati starost prema novom vremenu, ali su istovremeno koristili i „staro" Libbyjevo vrijeme (5568 godina) i rezultati su se često javljali s oba vremena poluraspada, što je korisnike moglo dovesti u zabludu da se radi o dva različita mjerenja ili čak dva različita uzorka.[32] Naime, u pojedinim se radovima u literaturi navodi da se radi o „dva uzorka" broda Zaton 2 koja su analizirana.[33] Brojke navedene u Brusićevu radu pronađene su u laboratorijskom dnevniku Instituta Ruđer Bošković iz tog doba i iz njega je jasno da se radi o istom (jednom) uzorku, samo različito izračunate starosti. Uvidom u bazu podataka Instituta Ruđer Bošković nalazimo još jedno mjerenje uzorka kojim se dobio izračun konvencijske starosti od 2166 ± 94 BP.

Predlažemo da se u budućim objavama za šivani brod Zaton 2 koristi podatak iz baze IRB uz kalibraciju konvencijske starosti na 235 – 99 cal BC (37,6 %) (sred. 3. – poč. 1. st. pr. Kr.) (Sl. 8; Tab. 1).

TREĆI ŠIVANI BROD

Ostatci trećeg šivanog broda pronađeni su na nekih 40-50 m udaljenosti od broda Zaton 2, na dubini od 2,5 do 3 m, u pravcu juga uz lukobran, tijekom podvodnih istraživanja 2002. g. (Sl. 9). Od sva tri pronađena broda, njegovi sačuvani ostatci u najboljem su stanju i još uvijek se nalaze na morskom dnu, zaštićeni geotekstilom i slojem pijeska.

Prema informacijama dostupnim u literaturi analiza ^{14}C broda Zaton 3 nije objavljena, iako se navodi da su

technique was used for the analysis. By measuring the sample, which was published in the journal *Radiocarbon* 26 (3) from 1984 (data sheet VIII), a conventional age calculation of 2130 ± 120 BP was obtained.[31] The data given by Z. Brusić in his paper from 1985 of 2194 ± 128 BP is an age calculated with a half-life of 5568 years, but we do not know which $\delta^{13}C$ was used. The second data that Z. Brusić cites, 2260 ± 132 BP, is actually the same age, only calculated with a half-life of 5730 years. Namely, at that time, during the 1980s, the half-life of ^{14}C (5730 years) was measured more precisely, so people began to calculate age according to the new time-frame, but at the same time they also used the "old" Libby time-frame (5568 years) and the results were often reported with both half-life periods, which could mislead the users into thinking these were two different measurements or even two different samples.[32] Namely, certain sources state that "two samples" of the boat Zaton 2 were analysed.[33] The figures mentioned in Brusić's paper were found in the laboratory diary of the Ruđer Bošković Institute from that period, and it is clear that this is the same (single) sample, only with a different calculated age. By inspecting the Ruđer Bošković Institute database, we found another measurement of the sample that resulted in the calculation of the conventional age of 2166 ± 94 BP.

We suggest that in future publications for the sewn boat Zaton 2, the information from the IRB database is used with the calibration of the conventional age at 235 – 99 cal BC (37.6 %) (middle of the 3rd – beginning of the 1st century BC) (Fig. 8; Tab. 1).

32 I. Krajcar Bronić 2009, 83.
33 Z. Brusić, M. Domijan 1985, 81; N. Liphschitz, S. Gluščević 2015, 159, vidi bilj. 28.

31 D. Srdoč *et al.* 1984, 451.
32 I. Krajcar Bronić 2009, 83.
33 Z. Brusić, M. Domijan 1985, 81; N. Liphschitz, S. Gluščević 2015, 159, see n. 28.

Slika 9. Ostatci broda Zaton 3
Figure 9. Remains of the boat Zaton 3
foto / photo: **I. Šelendić**

uzorci uzeti i da je analiza u tijeku.[34] Ni u dokumentaciji Muzeja nisu pronađeni nikakvi rezultati napravljenih analiza (^{14}C i vrsta drva) broda Zaton 3. Glavni razlog ponovnog otvaranja nalazišta i brodske konstrukcije broda Zaton 3 2019. g. upravo je izostanak dokumentacije. Izmjereni su i fotografirani svi elementi broda, a od svih elemenata brodske konstrukcije uzeti su uzorci za analizu vrste drva, ^{14}C analizu i dendrokronologiju. Ukupno su uzeta 74 uzorka za analizu vrste drva kojom je utvrđena prisutnost sveukupno pet različitih vrsta drva.[35] Za brod Zaton 3 tijekom kampanje 2019. g. uzeta su i dva uzorka za dendrokronologiju koji se u analizi, nažalost, nisu pokazali kvalitetnima jer nisu imali dovoljan broj godova i nije ih bilo moguće preciznije datirati.[36] Za analizu ^{14}C u Institut Ruđer Bošković 2020. g. poslan je

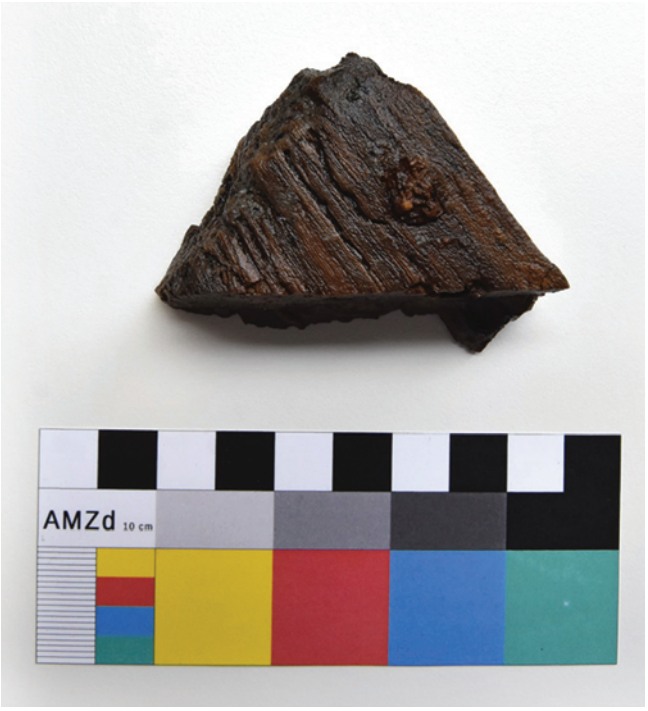
34 S. Gluščević 2002, 84; 2005, 52; A. Pydyn, S. Gluščević 2011, 42.
35 Identifikaciju vrste drva napravila je Jelena Trajković s Fakulteta šumarstva i drvne tehnologije Sveučilišta u Zagrebu.
36 Dendrokronološku analizu radio je Fakultet šumarstva i drvne tehnologije u suradnji sa Stjepanom Mikcem.

THE THIRD SEWN BOAT

The remains of the third sewn boat were found 40-50 m away from the boat Zaton 2, at a depth of 2.5 to 3 m, in the direction of the south near the breakwater, during underwater research in 2002 (Fig. 9). Of all the boats found, the preserved remains of this boat are in the best condition, and they are still located on the seabed, protected by geotextile and a layer of sand.

According to the information available in the sources, the ^{14}C analysis of the boat Zaton 3 has not been published, although it is stated that the samples have been taken and that the analysis is in progress.[34] No results of the analyses (^{14}C and wood type) of the boat Zaton 3 were found in the Museum's documentation either. The main reason for the 2019 reopening of the site, and the structure of the boat Zaton 3, is precisely the lack of the documentation. All elements of the boat were measured and photographed, and samples were taken from all elements of the boat's structure for the wood type analysis, the ^{14}C analysis, and dendrochronology. A total of 74 samples were taken for the wood type analysis, which determined the presence of a total of five different types of wood.[35] During the 2019 campaign,

34 S. Gluščević 2002, 84; 2005, 52; A. Pydyn, S. Gluščević 2011, 42.
35 The wood type identification was done by Jelena Trajković from the Faculty of Forestry and Wood Technology at the University of Zagreb.



Slika 10. Uzorak broda Zaton 3 poslan na analizu
Figure 10. Sample of the boat Zaton 3 sent for analysis
foto / photo: **D. Romanović**

uzorak dijela vanjske oplate uzet 2019. g. (Sl. 10). Uzorak je zaveden pod oznakom Z-7391 A2197 Drvo, šivani brod #3, antička luka Zaton kod Nina, dubina mora 2,5 do 3 m. Za analizu je korištena tehnika akceleratorske masene spektrometrije (AMS – *Accelerated mass spectrometer*). Mjerenjem uzorka (28. listopada 2020.) dobio se izračun konvencijske starosti od 1925 ± 15 BP, $\delta^{13}C$ = -25,6 ‰.

Predlažemo da se u budućim objavama za šivani brod Zaton 3 koristi podatak iz baze IRB uz kalibraciju konvencijske starosti na 74 – 127 cal AD (68,3 %) (kraj 1. – poč. 2. st.) (Sl. 11; Tab. 1).

ZAKLJUČAK

Metodom radioaktivnog izotopa ugljika (^{14}C) određuje se starost materijala, a ne predmeta koji je od tog materijala izrađen. Odnosno, određuje se vrijeme kad je drvo od kojeg je brod napravljen prestalo rasti, tj. kad je posječeno, a ne kad je određeni brod od njega napravljen.[37] U obzir se mora uzeti i činjenica da je drvo nakon sječe, a da bi se moglo obrađivati, moralo određeno vrijeme odležati i osušiti se prije upotrebe za gradnju

37 Više o datiranju arheoloških predmeta metodom ^{14}C vidi I. Krajcar Bronić 2009, 81–92.

two samples were taken from the boat Zaton 3 for dendrochronology, which as it was shown by the analysis, were unfortunately of poor quality because they did not have a sufficient number of growth rings, and it was not possible to date them more precisely.[36] For the ^{14}C analysis, a sample of a part of the external hull-plate taken in 2019 was sent to the Ruđer Bošković Institute in 2020 (Fig. 10). The sample is registered under the designation Z-7391 A2197 Wood, sewn boat #3, ancient port of Zaton near Nin, sea depth 2.5 to 3 m. The Accelerated mass spectrometer technique (AMS) was used for the analysis. By measuring the sample (October 28, 2020), a conventional age calculation of 1925 ± 15 BP, $\delta^{13}C$ = -25.6 ‰ was obtained.

We suggest that in future publications for the sewn boat Zaton 3, data from the IRB database is used with the calibration of the conventional age at 74 – 127 cal AD (68.3 %) (the end of the 1st – the beginning of the 2nd century) (Fig. 11; Tab. 1).

CONCLUSION

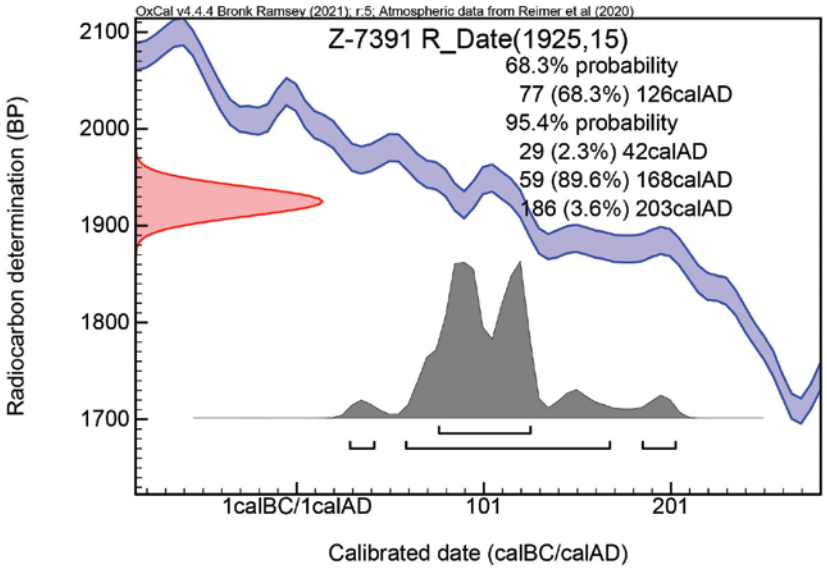
The radioactive carbon isotope (^{14}C) method determines the age of the material, and not the age of the object made of that material. That is, it determines the period when the tree, which was used for the construction of the boat, stopped growing, i.e. when it was cut down, and not when a particular boat was made from it. It must also be taken into account that the wood, after the harvesting, and in order to be processed, had to be aged and dried for a certain period of time before being used for the boat construction.[37] The timber was prepared carefully for a long time before being processed. Although there are many different types of wood, not all of them can be used in shipbuilding in the same way. The timber had to be stacked, exposed to the weather elements, and completely dry before being processed.[38]

The Zaton boats were dated using the ^{14}C method in the range from the middle of the 3rd century BC to the middle of the 2nd century AD which is visible on the graph which shows the parallel period of growth (Fig. 12). The wooden structure of the boat Zaton 1 is dated to the middle of the 2nd century BC – beginning 1st century AD for the first sample, i.e. to the middle of the 1st century BC – middle of the 2nd century for the second sample; Zaton 2 is dated to the middle of the 3rd – beginning of the 1st century BC; and the boat Zaton 3 is dated to the end

36 The dendrochronological analysis was done by the Faculty of Forestry and Wood Technology in cooperation with Stjepan Mikac.

37 More on the dating of archaeological objects using the ^{14}C method, see I. Krajcar Bronić 2009, 81–92.

38 The preparation of the wood for vessel construction was well planned because it was constantly exposed to water and sun. The building of a wooden boat requires the knowledge on the types and properties of wood, and long-term preparation until the wood can be used (wood harvesting, transport, sawing, drying), see M. Bego 2020, 2; D. Radić 2015, 173.



Slika 11. Kalibrirani datum uzorka Z-7391 broda Zaton 3
Figure 11. Calibrated date of sample Z-7391 of the boat Zaton 3
priredila / prepared by: **I. Krajcar Bronić**

broda. Drvena se građa dugo i pažljivo pripremala prije nego što bi se počela obrađivati. Iako postoji mnogo različitih vrsta drva, ne mogu se sve na isti način koristiti u brodogradnji. Drvena je građa morala biti složena na hrpe, izložena vremenu te posve suha prije nego što bi se obrađivala.[38]

Zatonski su brodovi pomoću metode ^{14}C datirani u rasponu od sredine 3. st. pr. Kr. do sredine 2. st. po. Kr., što vidimo na grafikonu gdje je prikazano usporedno vrijeme rasta (Sl. 12). Drvena građa broda Zaton 1 datira se za prvi uzorak u sred. 2. st. pr. Kr. – poč. 1. st., odnosno u sred. 1. st. pr. Kr. – sred. 2. st. za drugi uzorak; Zaton 2 datira se u sred. 3. – poč. 1. st. pr. Kr.; a brod Zaton 3 datira se u kraj 1. – poč. 2. st. Kronološki je najstariji brod Zaton 2, a najmlađi brod Zaton 3. Arheološka stratigrafija određuje vrijeme trajanja, tj. korištenja antičke luke i brodova od 1. do početka 4. stoljeća.

Datacija drvene građe brodova Zaton 1 i Zaton 2, koja je dobivena starom GPC metodom, mora se uzeti s dozom opreza. U Laboratoriju za mjerenje niskih radioaktivnosti (LNA) Instituta Ruđer Bošković za mjerenja ^{14}C od 1968. do 2003. g. korištena je tehnika plinskog proporcionalnog brojača (GPC – *Gas Proportional Counting*), nakon čega je ta metoda napuštena, a ona je u odnosu na suvremene tehnike mjerenja (LSC i AMS)[39] davala relativno veću pogrešku mjerenja (danas govorimo o mjernoj nesigurnosti). Sve tri metode su destruktivne i da bi se odredila starost organskog uzorka potrebno je

of the 1st – beginning of 2nd century. The chronologically oldest boat is Zaton 2, and the youngest is Zaton 3. The archaeological stratigraphy determines the duration, i.e. the use of the ancient harbour and boats from the 1st to the beginning of the 4th century.

The dating of the wooden structure of the boats Zaton 1 and Zaton 2, which was obtained by the old GPC method, must be taken with a degree of caution. The Laboratory for Low-level Radioactivities (LNA) at the Ruđer Bošković Institute used the Gas Proportional Counting (GPC) technique for ^{14}C measurements from 1968 to 2003, after which this method was abandoned, and compared to modern measurement techniques (LSC and AMS)[39] this technique resulted in a relatively higher measurement error (today this is called the measurement uncertainty). All three methods are destructive, and in order to determine the age of an organic sample, it is necessary to burn the sample and further prepare it for the measurement of the ^{14}C activity.

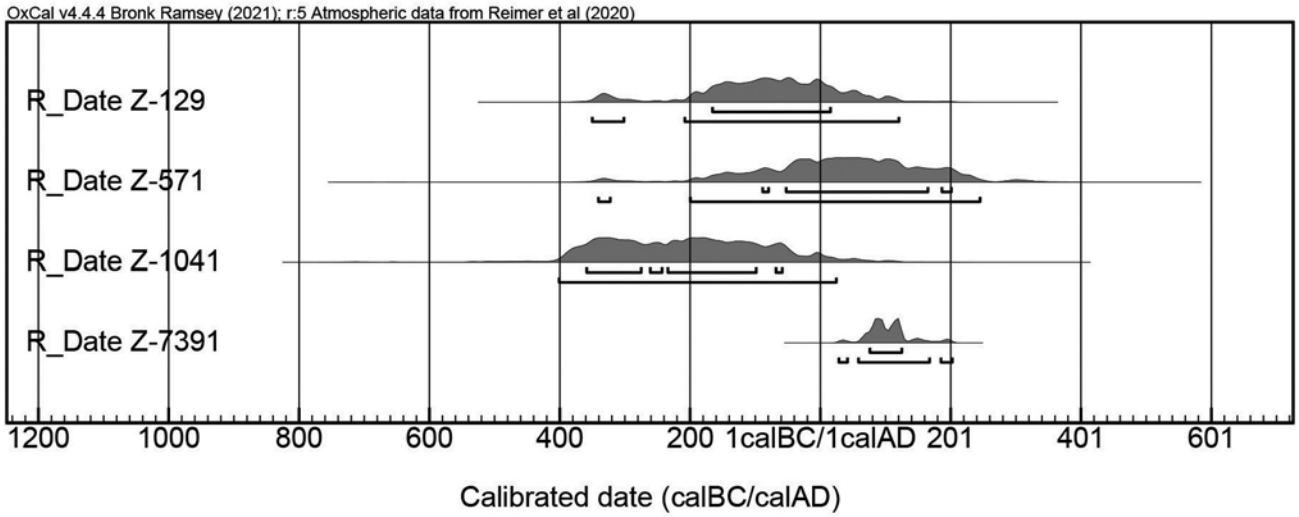
Another circumstance that affects the result of the ^{14}C method is the age of the tree itself, which is determined by the part of the trunk (with regard to growth rings) from which the tree sample was taken. It is important to note the part of the tree from which the wooden structure of the boat was carved, because the tree is the oldest in the very center of the trunk. The elements of the boat structure made from the central part of the trunk (the core) will show a slightly older result than elements made from the part of the trunk closer to the bark (sapwood), which can ultimately lead to an age difference of up to 200 years (Fig. 13).

This would mean that in the case of the oldest Zaton boat, the Zaton 2, about 300 years have passed between

38 Priprema drva za gradnju plovila bila je dobro planirana jer je stalno izloženo utjecaju vode i sunca. Gradnja drvenog broda zahtijeva poznavanje vrsta i svojstava drva te dugotrajnu pripremu do mogućnosti njegove upotrebe (obaranje stabla, transport, piljenje, sušenje), vidi M. Bego 2020, 2; D. Radić 2015, 173.

39 LSC – *Liquid scintillation counting*, brojenje u tekućinskom scintilacijskom brojaču, uz pripremu benzena i AMS – *Accelerated mass spectrometer*, akceleratorska masena spektrometrija, uz pripremu grafita.

39 LSC – Liquid scintillation counting, counting in a liquid scintillation counter, with the preparation of benzene and AMS – Accelerated mass spectrometer, with the preparation of graphite.



Slika 12. Usporedba ^{14}C svih četiriju uzoraka
Figure 12. Comparison of ^{14}C of all four samples
priredila / prepared by: **I. Krajcar Bronić**

uzorak spaliti i dalje pripremiti za mjerenje ^{14}C aktivnosti.

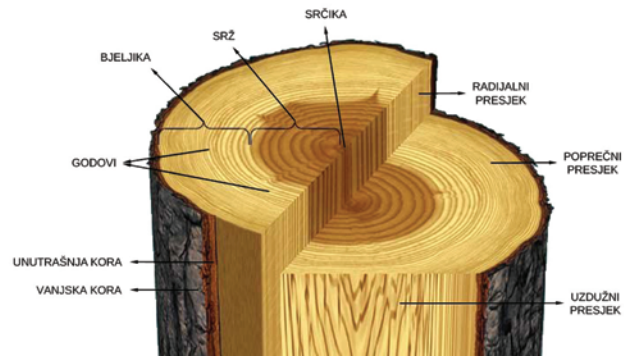
Još jedna okolnost koja utječe na rezultat metode ^{14}C starost je samog drveta, a što je određeno mjestom u samom deblu (s obzirom na godove) iz kojeg je drvo uzorka uzeto. Nije svejedno iz kojeg je dijela stabla bila istesana drvena građa broda, jer drvo je najstarije u samom središtu debla. Elementi brodske konstrukcije izrađeni od središnjeg dijela debla (srž) pokazat će nešto stariji rezultat od elemenata izrađenih od dijela debla koji je bliže kori (bjeljika), što može u konačnici u rezultat unijeti razliku u starosti i do 200 godina (Sl. 13).

Za najstariji zatonski brod Zaton 2 to bi značilo da je od sječe drvene građe za izgradnju broda u 2. ili 3. stoljeću stare ere do prestanka njegove upotrebe krajem 1. stoljeća nove ere proteklo oko 300 godina, što je teško zamislivo čak i sa suvremenog stajališta. S obzirom na mogućnost da uzeti uzorak nije bio kvalitetan, samo mjesto uzorkovanja i dataciju starom GPC metodom ne možemo sa sigurnošću reći da je to točan podatak. Brodovi Zaton 1 i Zaton 2 konzervirani su polietilen-glikolom što onemogućuje ponavljanje radiokarbonske metode za drvenu građu. Nadamo se da će buduća analiza ostataka brodova Zaton 1 i Zaton 2, naročito izdvajanje kvalitetnog uzorka za moguću dendrokronologiju, rasvijetliti dobivene rezultate.

Konačan rezultat ^{14}C datiranja sadrži konvencijsku starost (u godinama BP)[40] i dendrokronološki kalibriran

the cutting of timber used for the construction of the boat in the 2nd or 3rd century BC and the cessation of its use at the end of the 1st century AD, which is hard to imagine even from a modern perspective. Given the possibility that the taken sample was of poor quality, by taking into account only the sampling location, and the dating according to the old GPC method, it cannot be said with certainty that this is accurate information. The Zaton 1 and Zaton 2 boats were preserved with polyethylene glycol, which makes it impossible to repeat the radiocarbon method for wood. We hope that the future analysis of the remains of the Zaton 1 and Zaton 2 boats, especially the extraction of a quality sample for the possible dendrochronology, will shed light on the obtained results.

The final ^{14}C dating result contains a conventional age (in BP years)[40] and a dendrochronologically calibrated



Slika 13. Presjek drva
Figure 13. Cross-section of the wood
priredila / prepared by: **D. Romanović**

40 Apsolutna starost izražena u godinama „prije sadašnjosti" (BP – *before present*), gdje se kao početna godina uzima 1950. g., uz primijenjenu normalizaciju na vrijednost δ^{13}C od -25 ‰ i konvencijski usvojeno vrijeme poluraspada izotopa ^{14}C od 5570 g. (tzv. Libbyjevo vrijeme poluraspada).

40 The absolute age expressed in years "before present" (BP), where 1950 is taken as the starting year, with applied normalization to the δ^{13}C value of -25 ‰ and the conventionally adopted half-life of the ^{14}C isotope of 5570 years (the so-called Libby half-life).

raspon (ili raspone)[41] izražen u cal AD/cal BC.[42] Da ne bi došlo do različitih tumačenja i navođenja podataka kod objavljivanja, prema sadašnjim preporukama, treba uvijek navesti sljedeće podatke:

- ID broj uzorka u laboratoriju gdje je rađena analiza
- materijal koji se datira (drvo, kost, drveni ugljen itd.)
- jednoznačni naziv uzorka
- metoda kojom je izvršena datacija (GPC, LSC, AMS)
- konvencijska starost uzorka u BP
- ako je poznata $\delta^{13}C$ vrijednost, a ako nije, onda se treba reći da je korištena „default" vrijednost za tu vrstu materijala (za drvo se obično koristi $\delta^{13}C = -25$ ‰)
- kalibrirani raspon s vjerojatnošću te koji je program i koja kalibracijska krivulja korištena.

Pri navođenju podataka radiokarbonske analize u literaturi potrebno je navesti sve potrebne podatke o uzetom uzorku. Najbolje je koristiti podatke iz laboratorija u kojem su mjerenja napravljena, u ovom slučaju baza podataka Instituta Ruđer Bošković, i na temelju kojih su napravljene sve kalibracijske krivulje.

range (or ranges)[41] expressed in cal AD/cal BC.[42] In order to avoid different interpretations, and citing different information when publishing, according to current recommendations, the following information should always be provided:

- ID number of the sample from the laboratory where the analysis was done
- material that will be dated (wood, bone, charcoal, etc.)
- unique sample name
- the dating method (GPC, LSC, AMS)
- the conventional age of the sample expressed in BP
- the $\delta^{13}C$ value if known, and if not, then it should be said that the "default" value for that type of material was used ($\delta^{13}C = -25$ ‰ is usually used for wood)
- calibrated range with a probability, and which program and which calibration curve was used.

When citing radiocarbon analysis data in the sources, it is necessary to provide all necessary data about the taken sample. It is best to use the data from the laboratory where the measurements were done, in this case the database of the Ruđer Bošković Institute, and the basis on which all calibration curves were made.

41 Raspon povijesnih godina, izražen u kalibriranim godinama (cal BC, cal AD), određen na osnovi dendrokronološke kalibracijske krivulje IntCal20 programom OxCal najnovije verzije (dostupna na https://c14.arch.ox.ac.uk/).

42 I. Krajcar Bronić 2009, 85.

41 The range of historical years, expressed in calibrated years (cal BC, cal AD), determined on the basis of the dendrochronological calibration curve IntCal20 by the program OxCal latest version (available at https://c14.arch.ox.ac.uk/).

42 I. Krajcar Bronić 2009, 85.

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