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# Datiranje

# Dating

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

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

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

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

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

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

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

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

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

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

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

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

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

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

## Dendrokronologija

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

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

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

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

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

Nisu pronađena podudaranja s referentnom kronologijom, odnosno sa serijom čija je starost već određena, a razlog tomu može biti činjenica da u bazama podataka nema dostatnih zapisa o brijestu<sup>2</sup>.

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

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

## Dendrochronology

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

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

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

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

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

No match could be found with a reference chronology, that is, a series that is already dated, possibly because elm is not a very well recorded species in the available databases<sup>2</sup>.

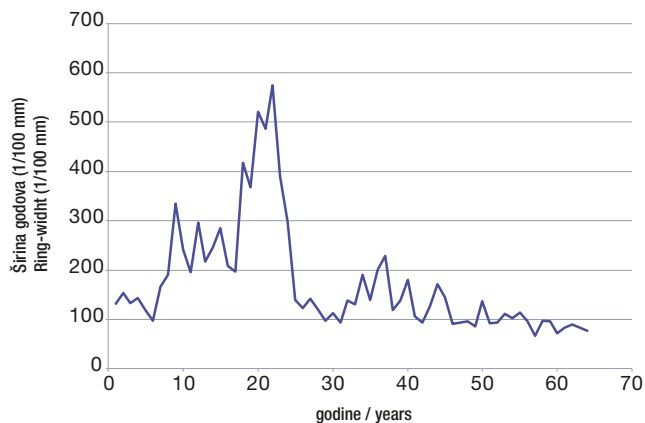
At present, the tree-ring series for the Zambratija wreck have not been dated. However, the study allowed these chronologies for elm to be added to the database for the Croatian coast.

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

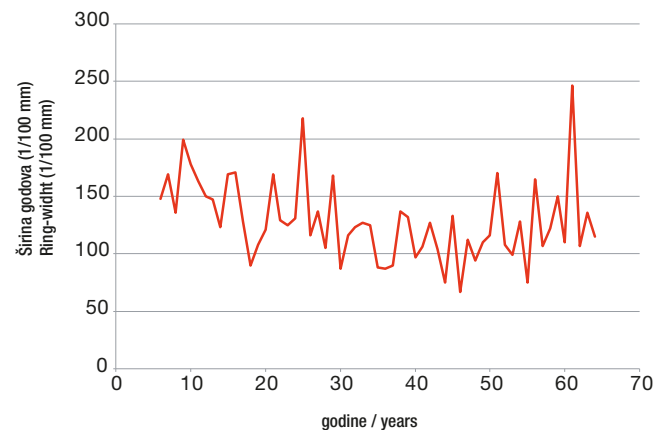
2 Najpotpunija serija brijestova nalazi se u Mediteranskom institutu za bioraznolikost i ekologiju mora i kopna (IMBE). Druge podudarnosti tražit će se u budućnosti u lokacijski bližim serijama, posebno u Sloveniji.

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

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



— odvojeni fragment platice PRL 11  
disjointed fragment of plank PRL11



— odvojeni fragment platice PRL 19  
disjointed fragment of plank PRL19

### III.1

**Neobrađena krivulja** promjena širine godova iz fragmenata oplata PRL11 i PRL19

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

(izrada / made by: A. Ferreira Dominguez)

### Radiokarbonsko datiranje

Osim radiokarbonskog datiranja koje su proveli Institut Ruđer Bošković iz Zagreba 2009. i 2013., te laboratorij Beta Analytics Inc. iz Miamija, mi smo za potrebe analize tehnikom AMS, uz pomoć programa Artemis CNRS-a, uzeli četiri jednako vremenski udaljena uzorka iz nizova godova jedne rebrenice (PRL11), odnosno konstantni broj zasebnih godova (Sl. III.2)<sup>3</sup>. Rezultati su pokazali starost između 1288. pr. Kr. i 1056. pr. Kr., za koje je utvrđeno podudaranje na kalibracijskoj krivulji <sup>14</sup>C primjenom metode wiggle matching<sup>4</sup>, ali oni nisu pružili precizan kronološki interval zbog ravnine na kalibracijskoj krivulji, koja se odnosi na razdoblje od 1210. do 1140. pr. Kr. (Sl. III.3). Naime, fluktuacije u proizvodnji ugljika u stratosferi dovele su u nekim razdobljima do ravnine u količini <sup>14</sup>C u materijalima koji sadržavaju ugljik. Zbog toga nije bilo moguće točnije odrediti starost (Evin, Oberlin 2005, 113).

Ipak, uzorak PR11 za radiokarbonsku analizu tehnikom AMS, koji je uzorkovan s mjesta najbližeg rubu debla<sup>5</sup> (radi približnog određivanja vremena sječe stabla od kojeg je izrađena oplata broda) datira iz razdoblja između 1268. i 1056. pr. Kr., što je slično vremenu koje je odredio Institut Ruđer Bošković iz Zagreba 2013. godine (Sl. III.2).

### Radiocarbon dating

In addition to radiocarbon dating carried out by the Institut Ruđer Bošković in Zagreb in 2009 and 2013, and by Beta Analytic Inc. in Miami, we took four temporally equidistant dating samples from the tree-ring sequences from a single timber (PRL11), that is, a constant number of rings apart, for AMS within the Artemis programme of the CNRS (Fig. III.2)<sup>3</sup>. The results gave dates between 1288 BCE and 1056 BCE that have been matched on the <sup>14</sup>C calibration curve by wiggle-matching<sup>4</sup>, but they did not provide a very precise chronological interval because of the plateau in the calibration curve that affects dates in the period 1210-1140 BCE (Fig. III.3). In fact, fluctuations in radiocarbon production in the stratosphere have led to plateaux in the quantity of <sup>14</sup>C in carbon-containing materials at some periods. For this reason, no tighter dating could be obtained (Evin, Oberlin 2005, 113).

Nonetheless, AMS radiocarbon sample PR11 taken closest to the edge of the trunk<sup>5</sup> so it could provide an approximate date for felling of the tree used for the boat's planking, gave a date between 1268-1056 CE, which is a similar date to that obtained by the Institut Ruđer Bošković of Zagreb in 2013 (Fig. III.2).

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

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

5 Code Lyon-12425 (SacA43735).

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

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

5 Code Lyon-12425 (SacA43735).

## Zaključak

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

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

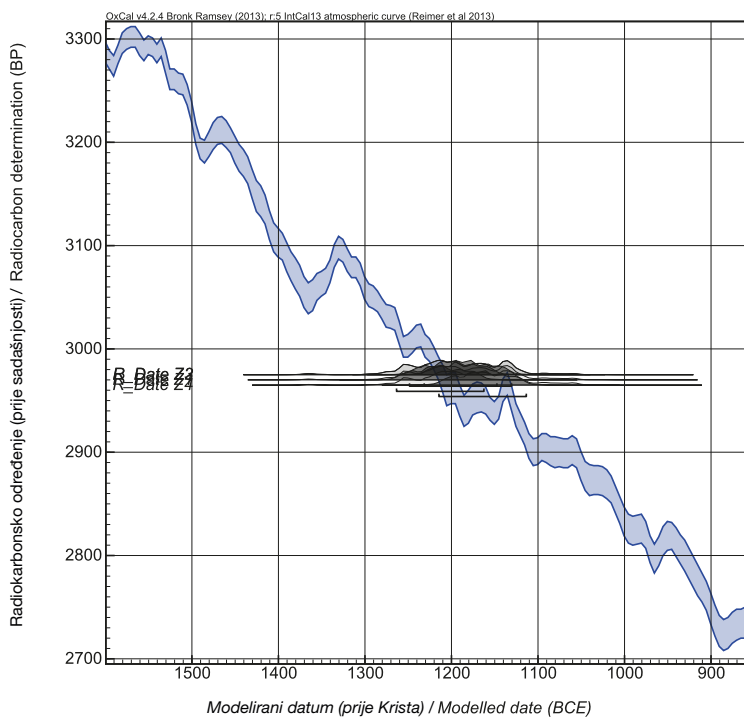
## Conclusion

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

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

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

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



## III.3

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

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

