Radiocarbon dating of cultural heritage objects – case studies of regional importance

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Dating – determination of the age of an object

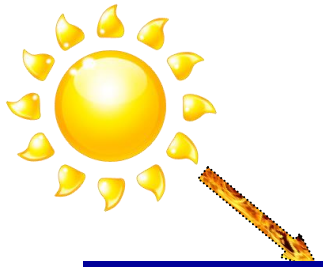
Absolute dating of object of cultural heritage and art is one of the most important issues in art history studies and in archaeology.

Accurate dating in art history is essential for valuation of original objects of arts, for differentiation between the original works and later imitations and/or frauds and for recognition of reparation and restauration works.

Radiocarbon (^{14}C) dating is a convenient and accurate method of absolute dating of organic materials.

Radiocarbon (^{14}C) dating

- one of the most well-known radiometric methods of absolute dating
- it can be applied for dating materials of biogenic origin, such as wood, charcoal, bones, grains, paper, parchment, textile, etc.
- the range of ^{14}C age determination spans from 19th century up to ~60,000 years in the past
- the anthropogenic influence on the natural ^{14}C distribution during 20th century can be used for recognition of frauds



$^{14}N + n \rightarrow {}^{14}C + p$

O_2

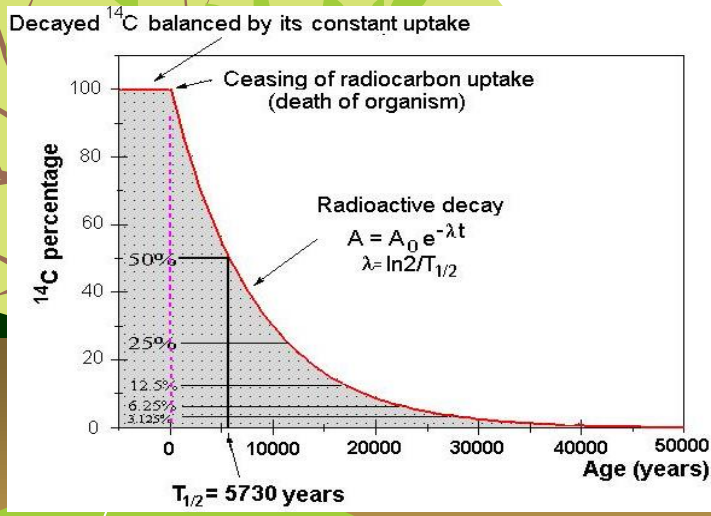
$^{14}CO_2$

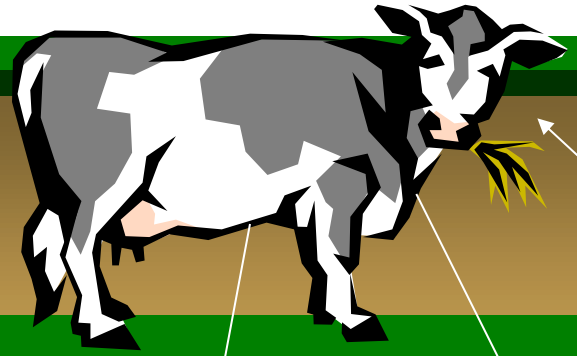
Carbon on Earth

^{12}C: 98.89 %

^{13}C: 1.1 %

^{14}C: 1.18 x 10^{-10} %





$^{14}C \rightarrow {}^{14}N + e + \bar{\nu}$

Measurement technique - AMS

Accelerator Mass Spectrometry (AMS)

number of ^{14}C atoms is counted, together with the number of ^{12}C and ^{13}C

Required mass: <2 mg C, <1 g sample

The AMS measurement technique enables precise analysis of very small amount of samples, e.g. micro-sized samples, containing a few milligrams of carbon, or less, and is therefore applicable to various objects of cultural heritage.

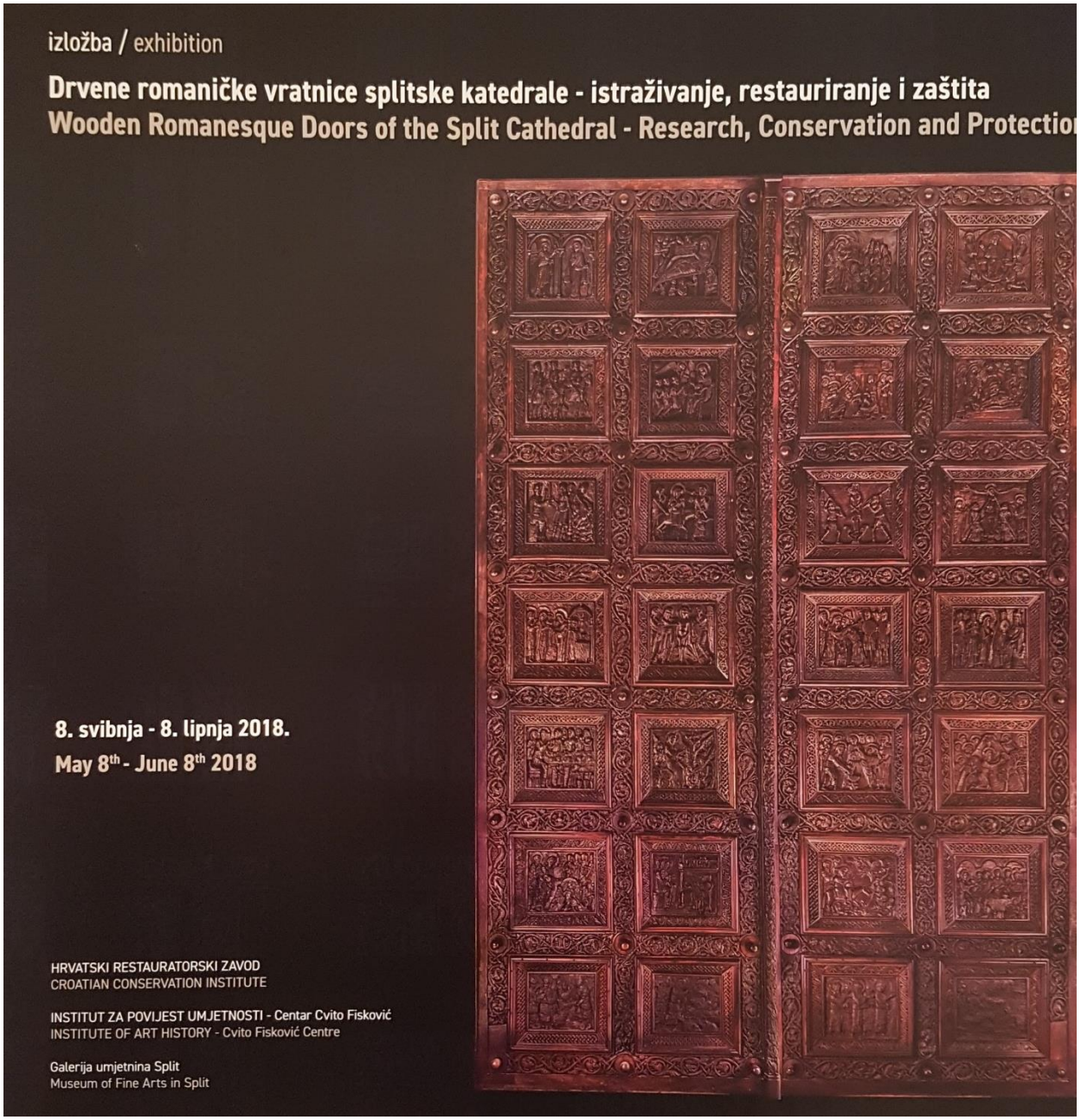
How to interprete radiocarbon dates and calibrated ages?

One has to keep in mind that radiocarbon dating gives the **age of material** (e.g., wood) and not the time of the creation of the art work, and that the creation of the art work cannot precede the formation of the material.

The Cathedral of St. Domnius in Split

received a massive gilded wooden door on the Feast of St. George in 1214.
The doors were made by the local craftsman Master Andrija Buvina.
530 cm high and the two wings 360 cm wide

exhibition

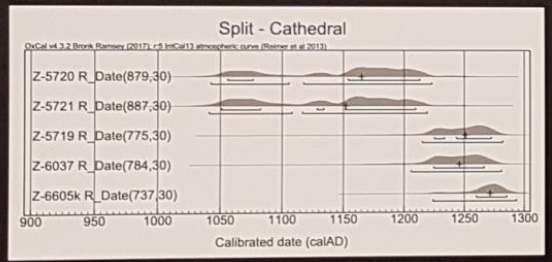

izložba / exhibition
Drvene romaničke vratnice splitske katedrale - istraživanje, restauriranje i zaštita
Wooden Romanesque Doors of the Split Cathedral - Research, Conservation and Protectio
8. svibnja - 8. lipnja 2018.
May 8th - June 8th 2018
HRVATSKI RESTAURATORSKI ZAVOD
CROATIAN CONSERVATION INSTITUTE
INSTITUT ZA POVIJEST UMJETNOSTI - Centar Cvito Fisković
INSTITUTE OF ART HISTORY - Cvito Fisković Centre
Galerija umjetnina Split
Museum of Fine Arts in Split

Određivanje starosti drvene građe Buvininih vratnica metodom ^{14}C
Carbon Dating of Buvina's Door from the Split Cathedral

Metodom radioaktivnog ugljika ^{14}C određena je starost pet drvenih fragmenata iz Buvininih vratnica katedrale u Splitu. Za dva uzorka pokazano je da potječu iz originalnih vratnica iz 1214. godine (rasponi kalibriranih godina cal AD 1155 – 1210 i cal AD 1054 – 1191). Dva uzorka su nešto mlađa i jedan znatno mlađi, što upućuje na podatak da taj fragment nije bio dio originalnih vratnica.

The age of five wooden pieces from Buvina's door from the Split cathedral was determined using carbon dating. The results of two samples indicate they belong to the original door from 1214 (calibrated years cal AD 1155 – 1210 and cal AD 1054 – 1191). Two other samples are somewhat younger, and the last one is considerably younger indicating that it could not have been built into the original door.

Ines Krajcar Bronić



Rezultati analize četiri uzorka drva Buvininih vratnica i jednog uzorka korskih klupa splitske katedrale
Results of the analysis of four wood samples from Buvina's door and one sample from choir benches of the Split Cathedral

Polikromija vratnica
Door Polychromy

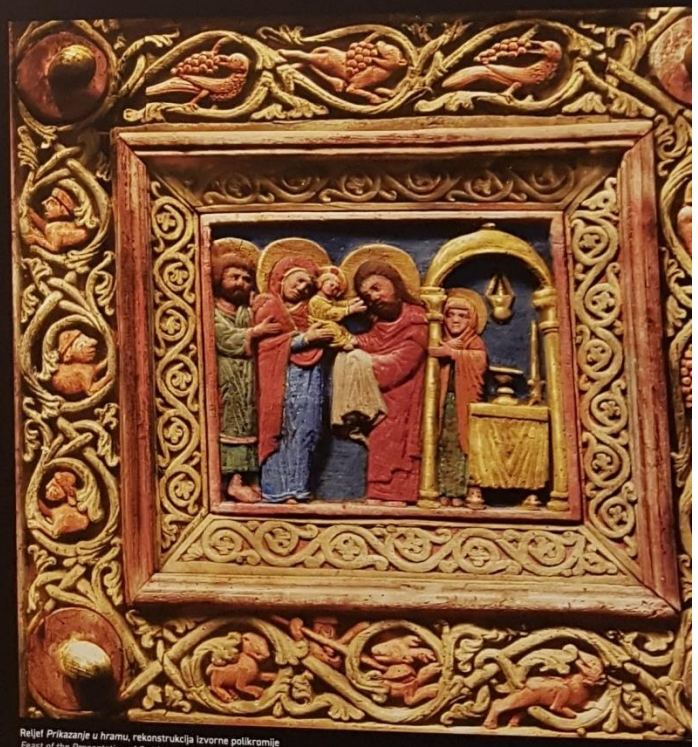
Fotografije vratnica snimljene prije restauriranja 1908. godine, premda crno-bijele, jasno govore o bogato nataloženim povijesnim slikanim slojevima. Odlukom o njihovu uklanjanju u restauratorskim radovima 1908. godine i upotrebom metalne nazubljene alatke za taj posao, do današnjega su vremena stigle tek čestice izvorne boje, koje su detektirane mikroskopima, a uzorci obrađeni u laboratoriju Hrvatskog restauratorskog zavoda i Tehničkog fakulteta u Münchenu. Virtualno su mogle biti rekonstruirane tek tri kasete, ali su istražene osobitosti slikarstva vratnica: punila i vezivo, paleta pigmenata te tehnike slikanja i pozlaćivanja.

Photographs of the door taken before the 1908 restoration, though black and white, clearly show centuries of rich painted layers. Because of the decision to remove the layers during the 1908 restoration using a metal notched tool, today we only have traces of the original color, detected by microscopes and analyzed at the laboratory of the Croatian Conservation Institute and the Technical University of Munich. Only three cassettes could be virtually reconstructed, but painting characteristics on the door were thoroughly researched – fillers and binder, pigment palette, and painting and gilding techniques.

Žana Matulić Bilač

Reljef *Raspeće*, oznake pronađenih čestica sekundarne polikromije
Crucifixion relief, markings of detected particles of secondary polychromy

Reljef *Prikazanje u hramu*
Feast of the Presentation of Our Lord Jesus relief

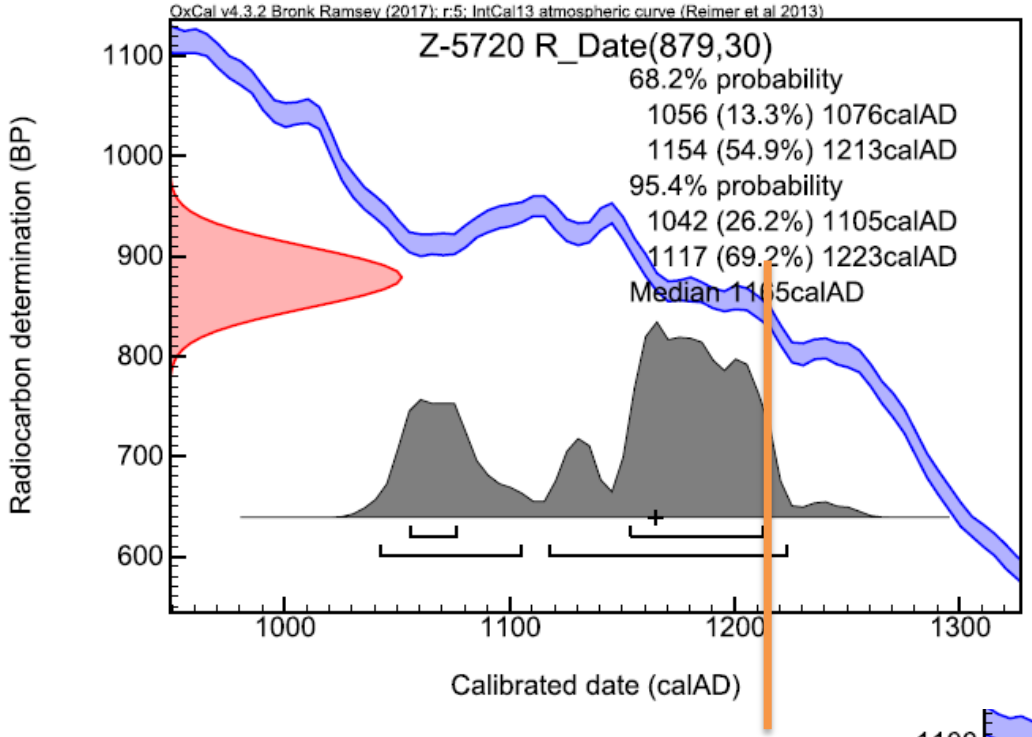


Reljef *Prikazanje u hramu*, rekonstrukcija izvorne polikromije
Feast of the Presentation of Our Lord Jesus relief, reconstruction of original polychromy

During the study of the Master Buvina's door of the Split cathedral ^{14}C method (AMS) was dated 5 wood samples from the door and 2 samples from the choir benches.

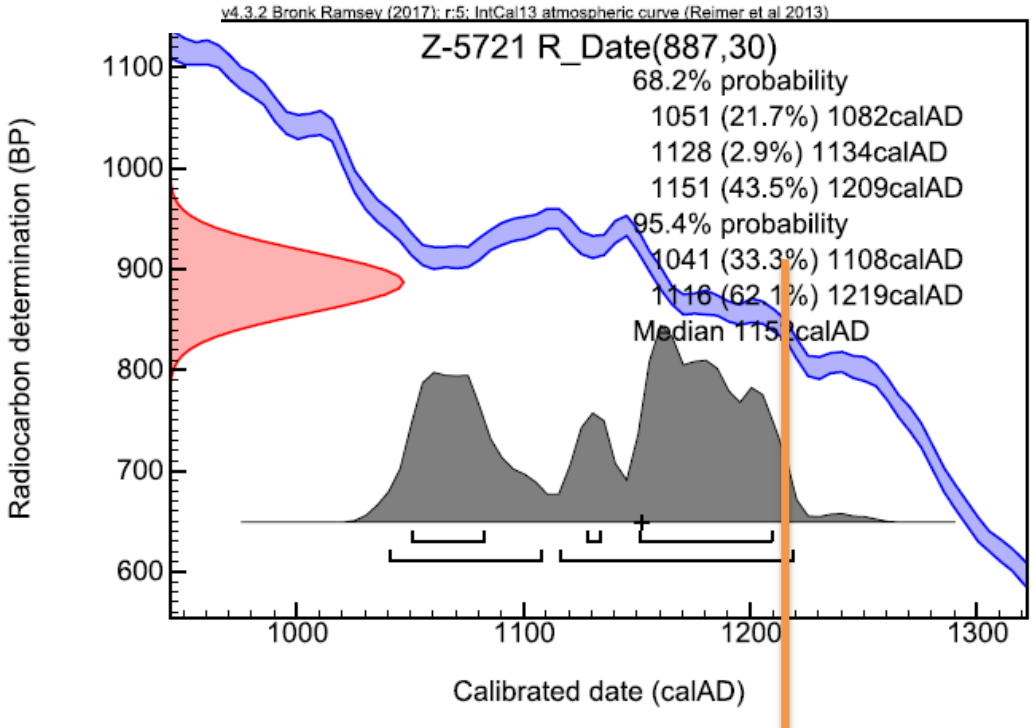
Split-Cathedral – conventional ^{14}C ages

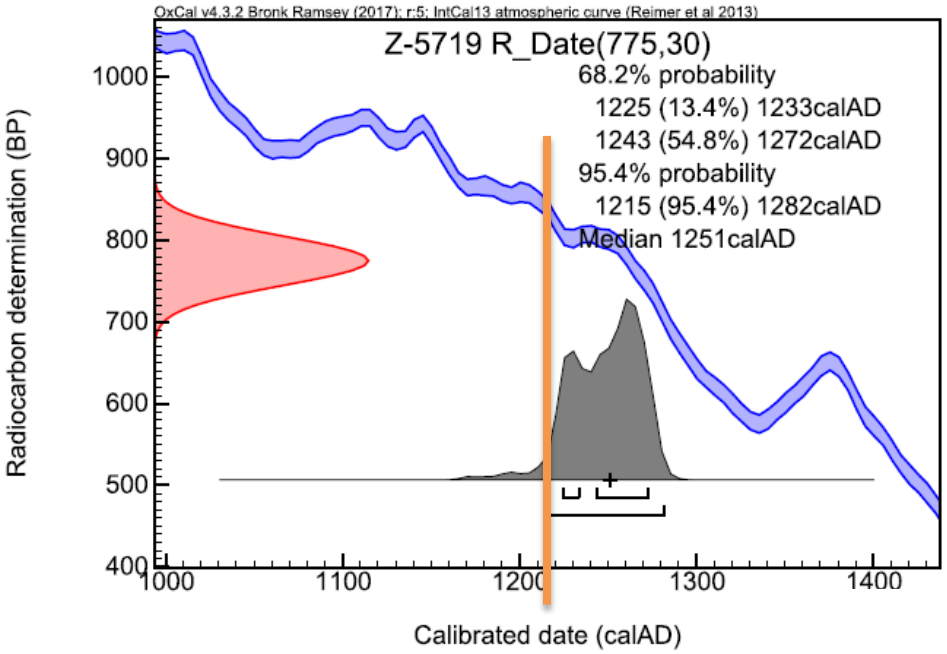
Z-	Sample desc.	δ^{13}C ‰	AMS Age	σ	comm
5469	Wood, Buvina's door, Split - Cathedral, br.inv. M6S 6671-1	*-25.0*	***313***	***80***	***LSC***
5719	Wood, Buvina's door, Split - Cathedral, cassette 24, (*Uzašće*) - wallnut, #1	-23.6	**775**	**22**	
5720	Wood, Buvina's door, Split - Cathedral, between cassetes 21-22, wallnut, #2	-24.3	**879**	**21**	
5721	Wood, Buvina's door, Split - Cathedral, middle part of the door - oak, #3	-27.1	**887**	**21**	
6037	Wood (Juglans L.), Buvina's door, Split - Cathedral, cassette 1, #1	-23.2	**784**	**22**	
6038	Wood, Split - Cathedral, Choir bench, #2	-27.1	**100.74**	**0.27**	pMC
6605	Wood, Split - Cathedral, Choir bench, south-west verticale 13th century, #3	-26.9	**737**	**21**	



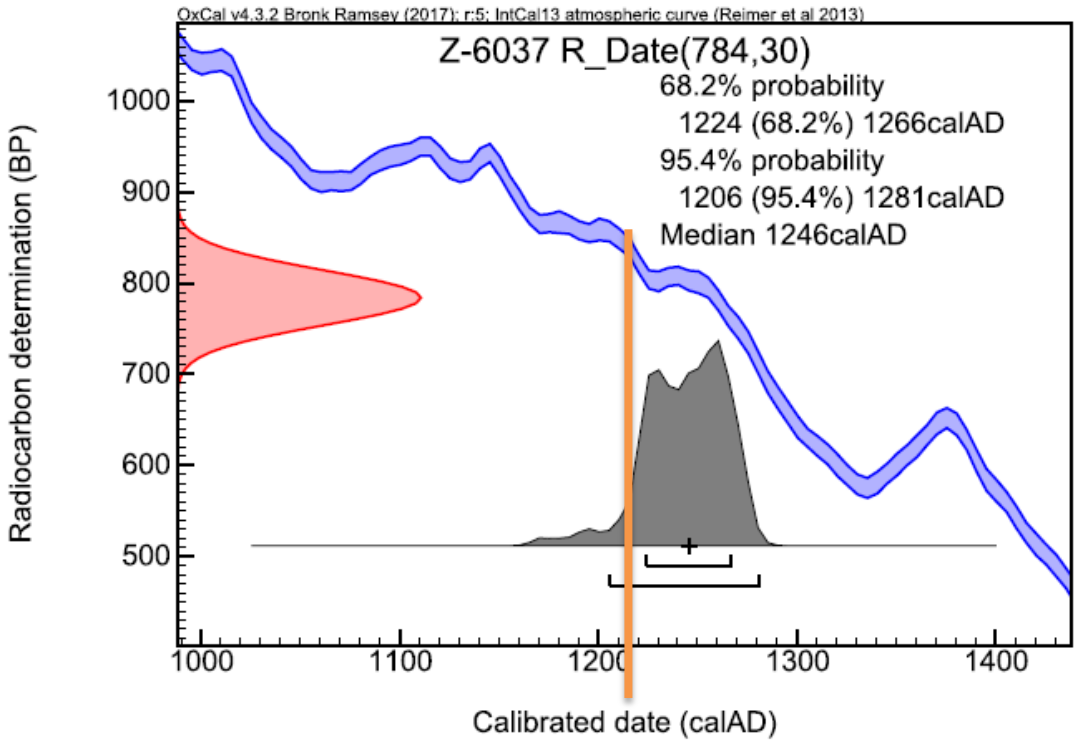
Samples **Z-5720** and **Z-5721** from the door give the calibrated age spans cal AD 1154 – 1213 (54.9 %) and cal AD 1151 – 1209 (43.5 %), respectively.

It may be concluded that these two wooden pieces belong to the original door from AD 1214.

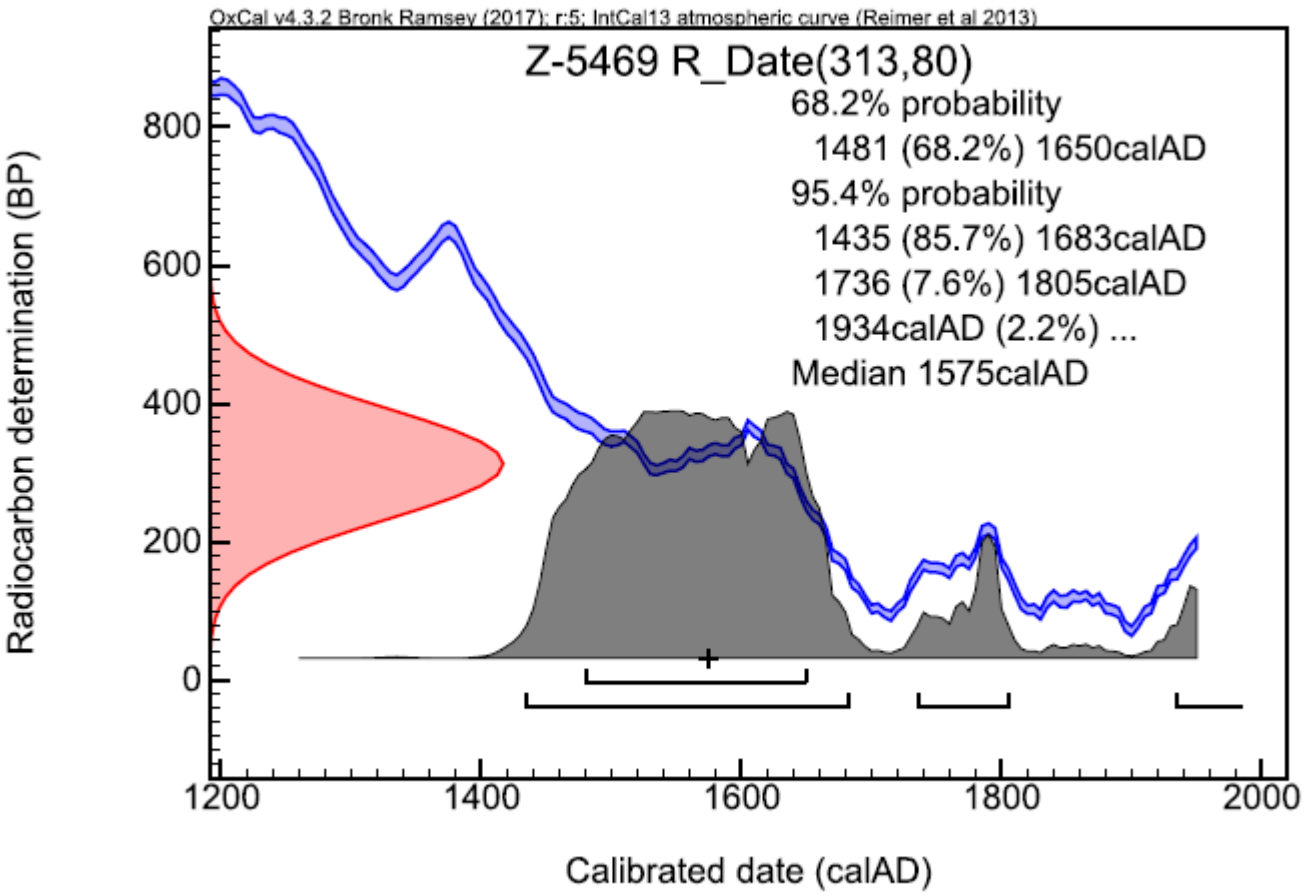




Samples **Z-5719** and **Z-6037** are somewhat younger, cal AD 1243 – 1272, 54.8 %) and cal AD 1224 – 1266 (68.2 %), respectively) indicating that these pieces could not have been built into the door in AD 1214., but they belong to 13th century.

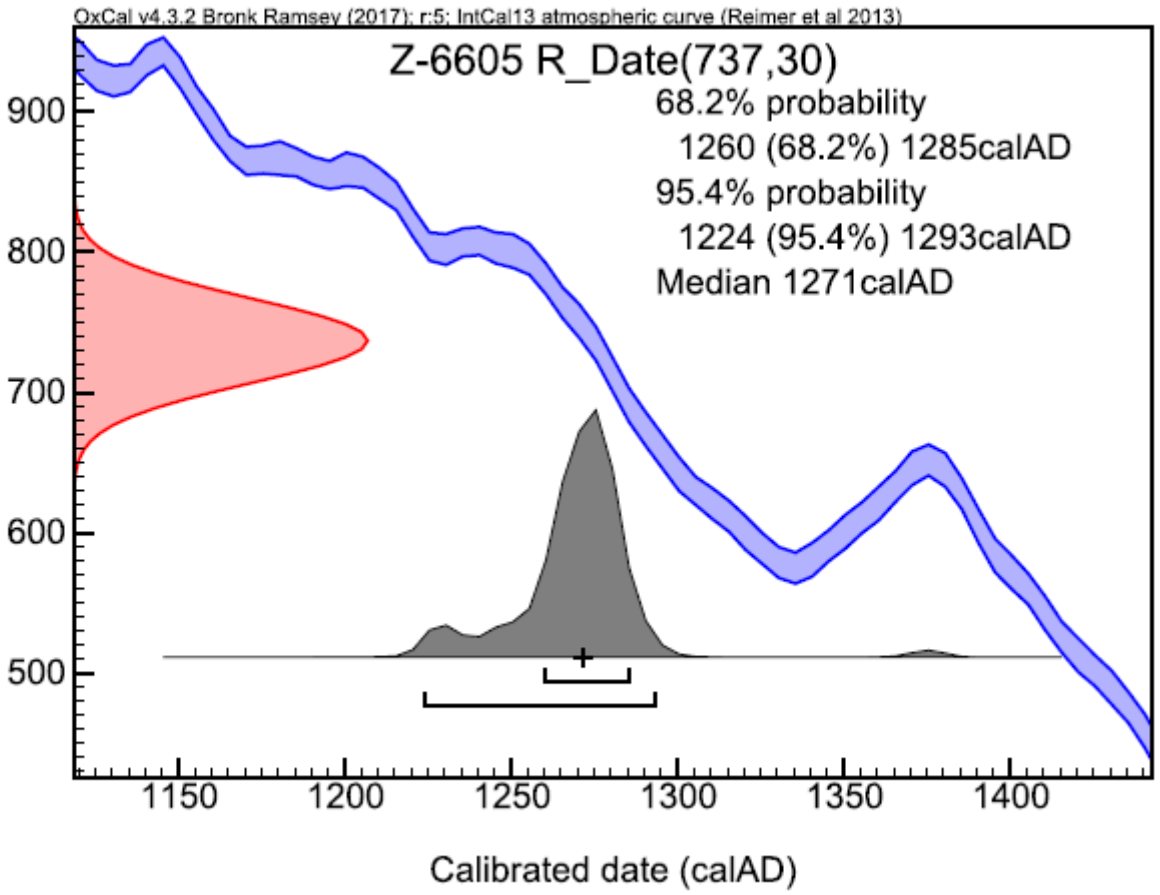


Sample **Z-5469** is considerably younger that the others, it is dated to cal AD 1481 - 1650 (probability 68.2 %), and therefore it was not a part of the original door.

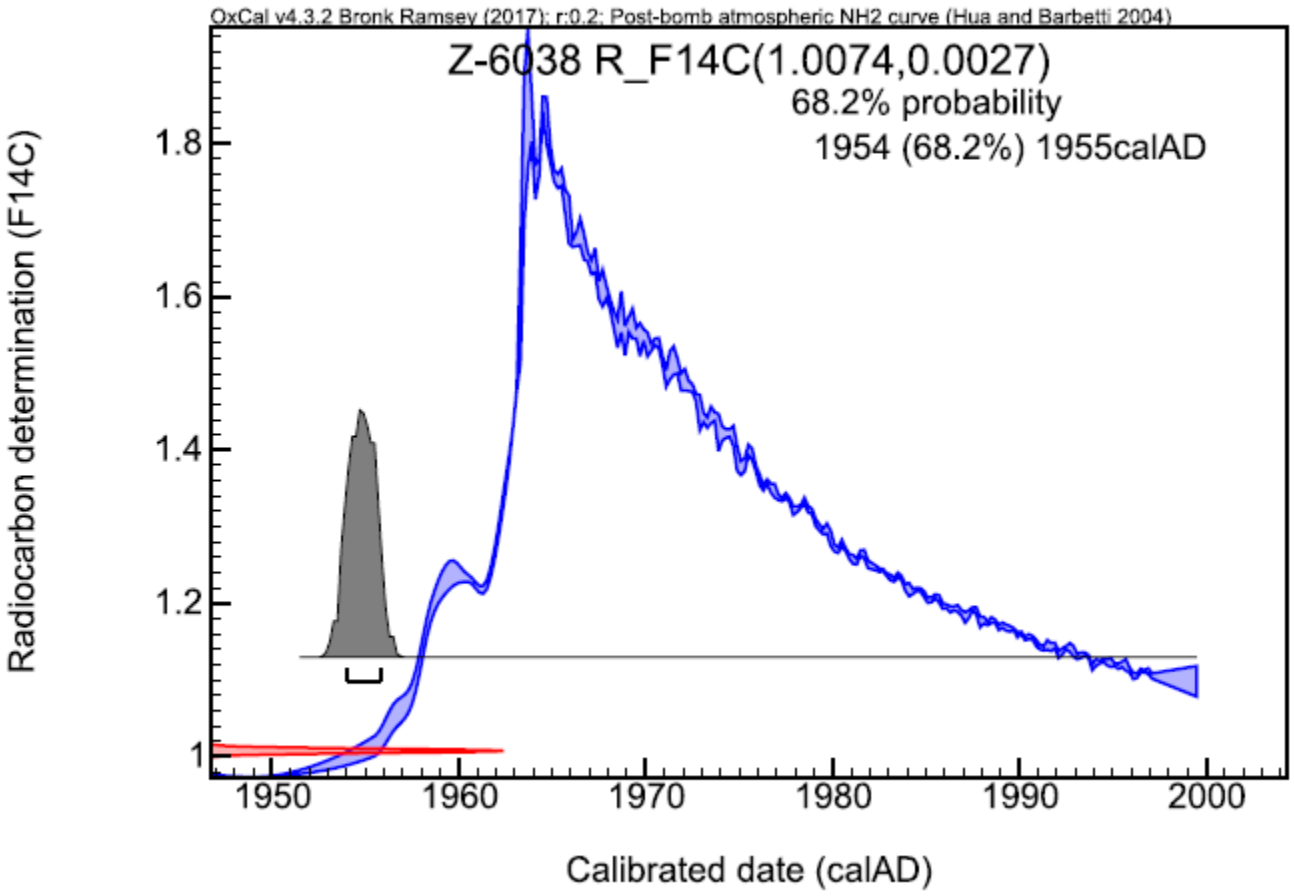


Two samples from the **choir benches**

Z-6605 was dated to the second half of the 13th century (cal AD 1260 – 1285).



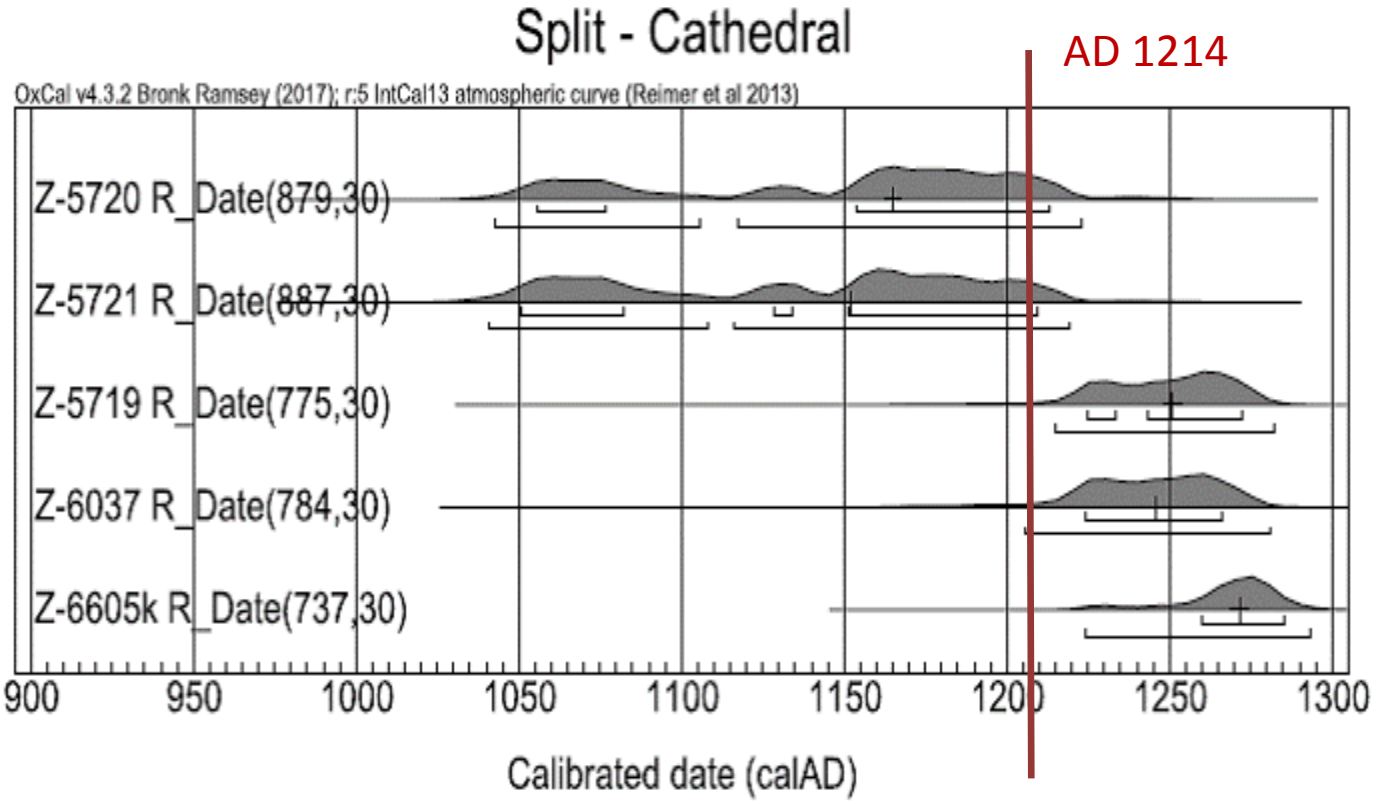
Z-6038 was dated to cal AD 1955, so it may be concluded that this piece of wood was added to the bench during reconstruction/repair in the second half of the 20th century.

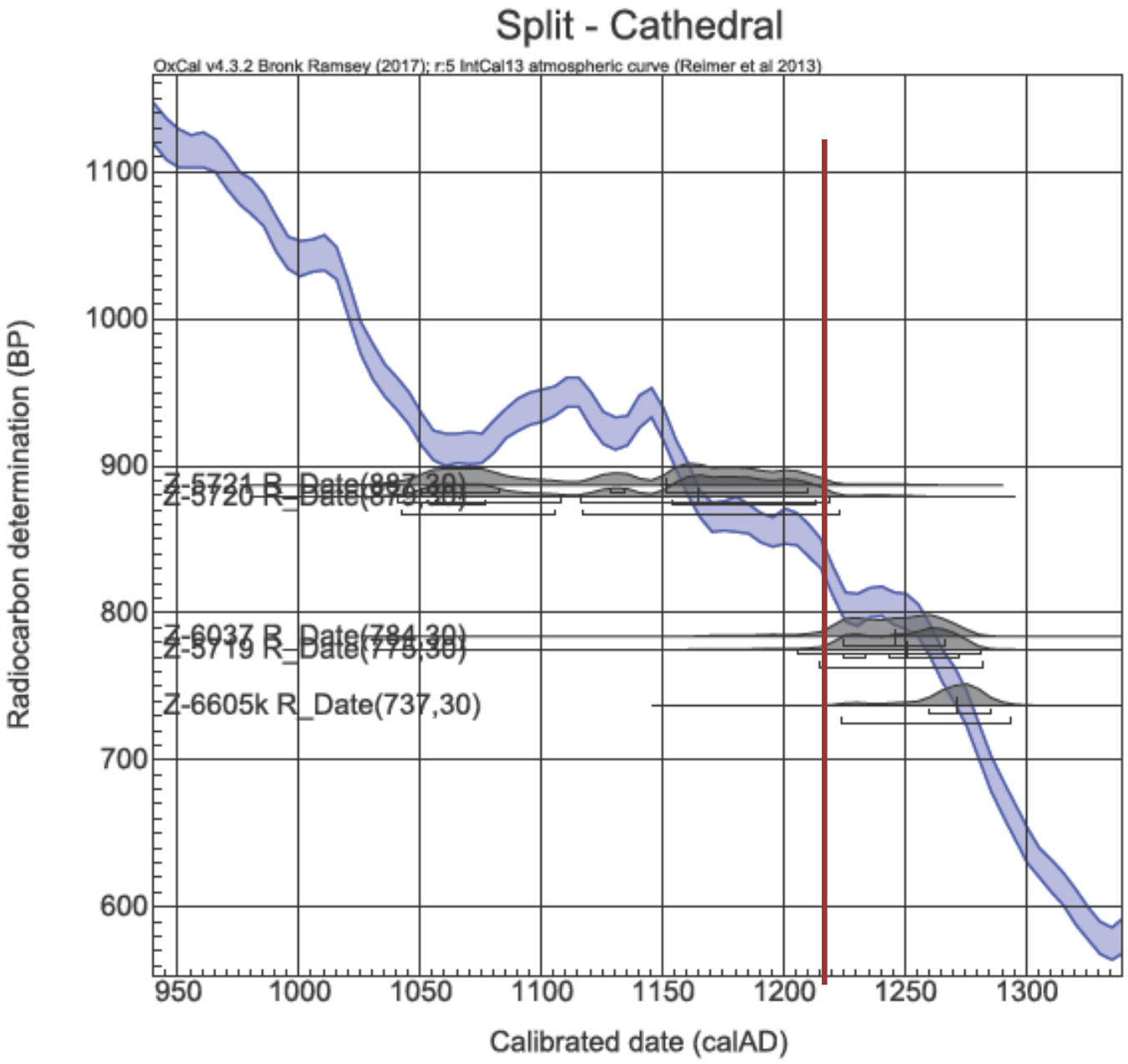


Summary

Samples Z-5720 and Z-5721 from the door give the calibrated age spans cal AD 1155 – 1210 and cal AD 1054 – 1191, respectively. It may be concluded that these two wooden pieces belong to the original door from AD 1214.

Samples Z-5719 and Z-6037 are somewhat younger (cal AD 1245 – 1272 and cal AD 1225 – 1266, respectively) indicating that these pieces could not have been built into the door in AD 1214.




Split - Cathedral
OxCal v4.3.2 Bronk Ramsey (2017); r:5 IntCal13 atmospheric curve (Reimer et al 2013)
Radiocarbon determination (BP)
1100
1000
900
800
700
600
Z-5721 R_Date(887,30)
Z-5720 R_Date(875,30)
Z-6037 R_Date(784,30)
Z-5719 R_Date(775,30)
Z-6605k R_Date(737,30)
950
1000
1050
1100
1150
1200
1250
1300
Calibrated date (calAD)

Old Olive tree, Brijuni Islands

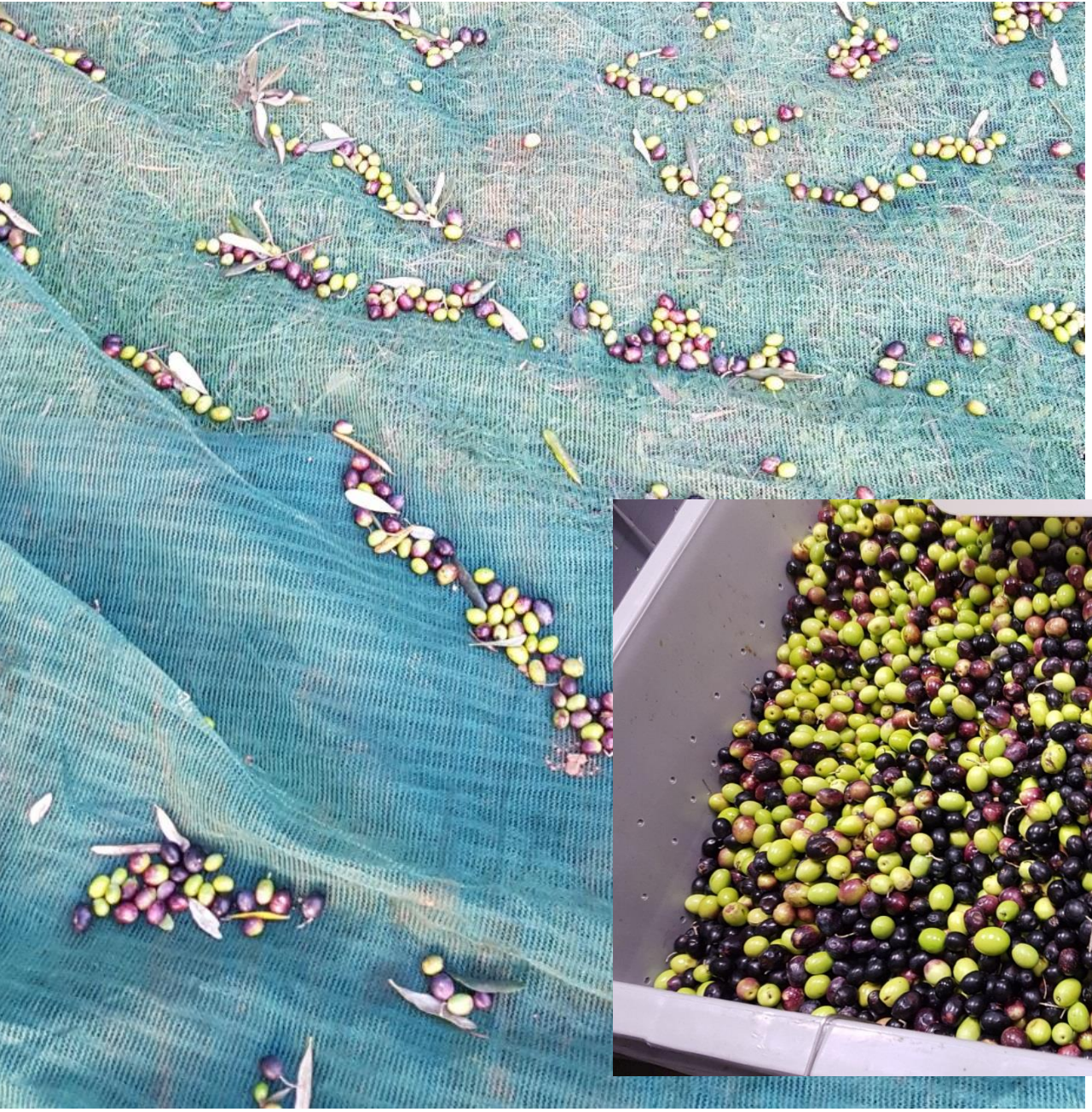
Olive trees do not form clear circular annual rings, and the most central wood is frequently rotted. Thus the direct dating of the tree based on ring counting in cores or radiocarbon dating of the pith cannot be carried out.

Olive oil production facility (oil mill) from the Roman times

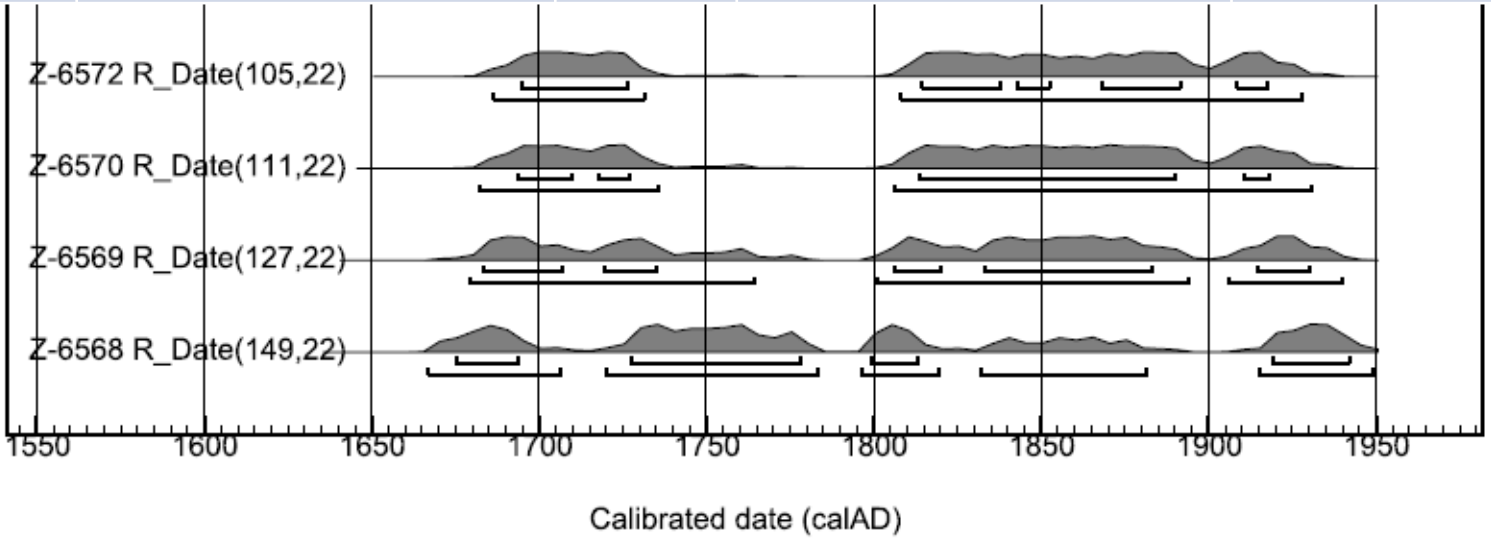

Samples 1, 2, 3
Samples 4, 5

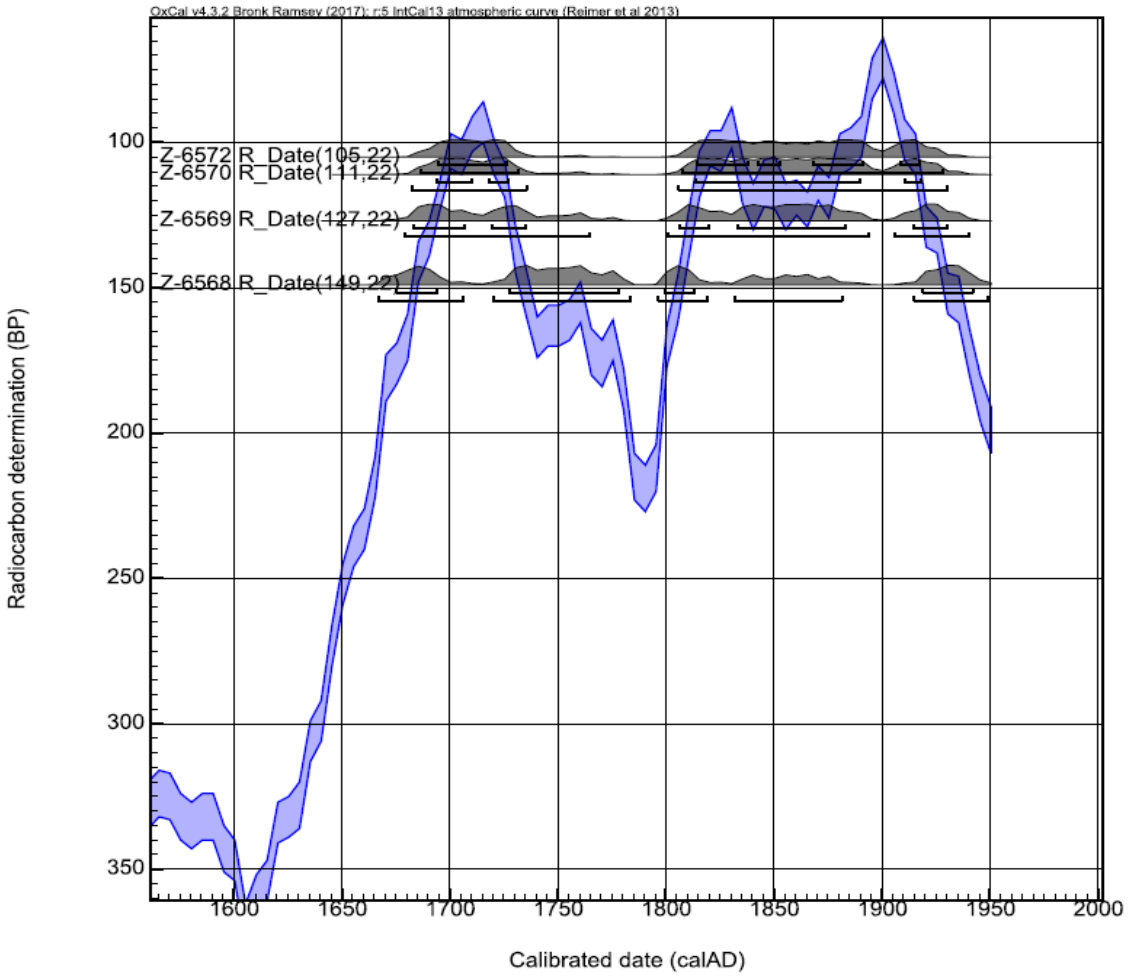

Sample 2


Sample 4

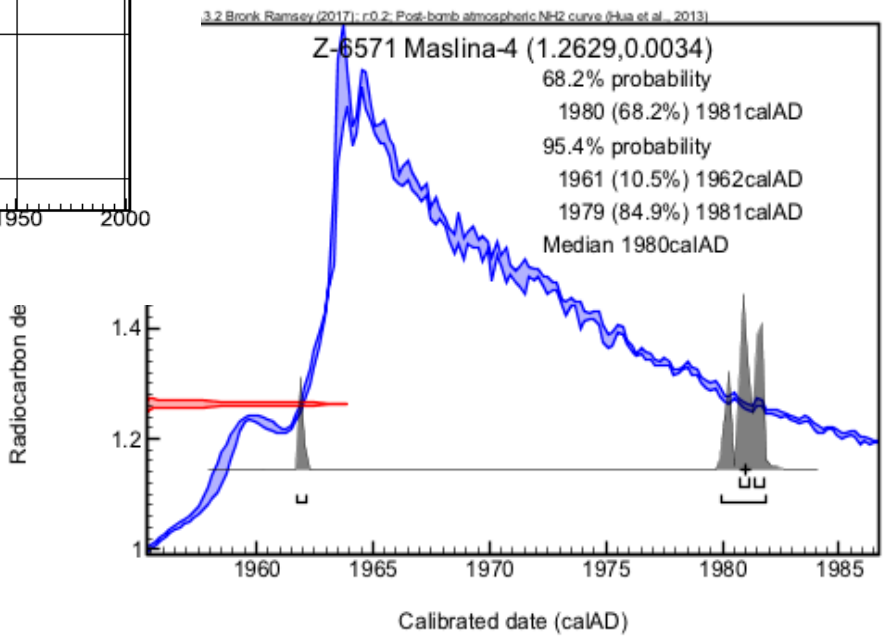


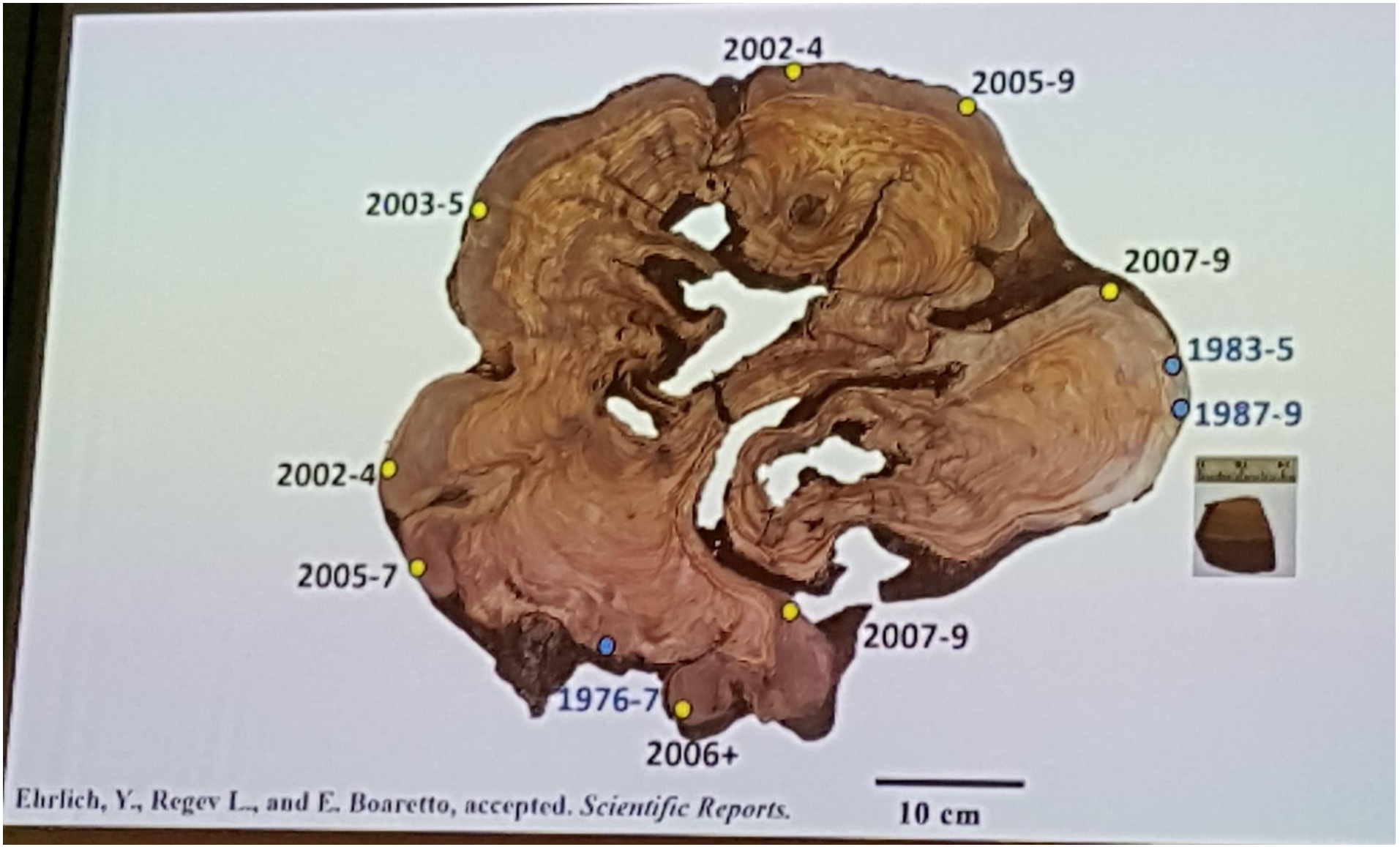
Sample code	Sample name	$\delta^{13}C$ (‰)	Conventional ^{14}C age (BP)	Calibrated age span (cal AD)
Z-6568 A1575	Brijuni, *Olea europeae*, sample 1		150±20	1675 – 1942
Z-6569 A1576	Sample 2	-23.6	130 ± 20	1683 – 1930
Z-6570 A1577	Sample 3	-25.5	110 ± 20	1694 – 1890
Z-6571 A1578	Sample 4	-24.2	126.3 ± 0.3 pMC Modern sample	1980 – 1981
Z-6572 A1579	Sample 5	-23.7	105 ± 20	1695 – 1917



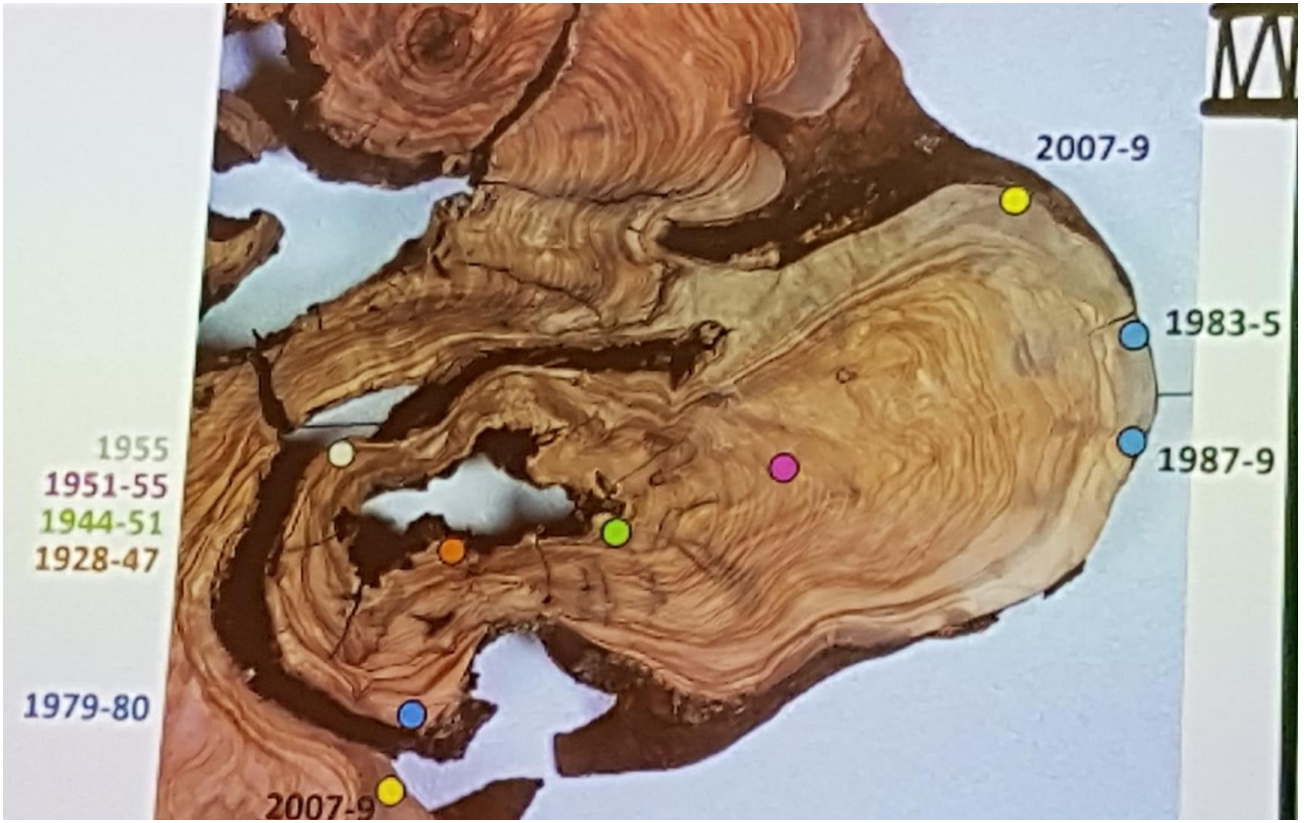


This is in agreement with most other existing inner wood within live olive trees which has not been dated to older than 200–300 years.





Ehrlich, Y., Regev L., and E. Boaretto, accepted. *Scientific Reports.*



frontiers in Plant Science

ORIGINAL RESEARCH
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Radiocarbon Dating of an Olive Tree Cross-Section: New Insights on Growth Patterns and Implications for Age Estimation of Olive Trees

*Yael Ehrlich[1], Lior Regev[1], Zohar Kerem[2] and Elisabetta Boaretto[1]**

Fojnica Franciscam Monastery, B&H

Fojnica is a town and municipality in central Bosnia and Herzegovina, located west of the capital Sarajevo.

The most important cultural site in Fojnica is the Holy Spirit Franciscan Monastery which houses an important part of the nation's cultural heritage, maintained by the Franciscan Province of Bosna Srebrena.

The Franciscan monastery in Fojnica has a large library of philosophical and theological works printed from the 16th to the 19th centuries, with some dating back to 1481.

Fojnica Armorial

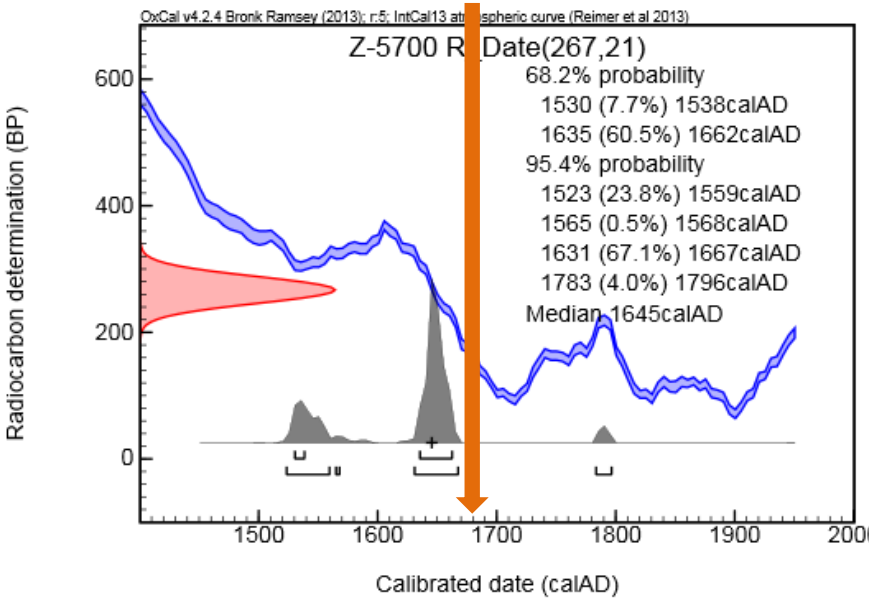
Fojnički grbovnik ***Fojnica Armorial***
an early modern roll of arms including heraldry of South Slavic history.
The manuscript is an important source of the classical heraldry of the Balkans peninsula.
The manuscript contains a total of 139 coats of arms.

Various estimates of its ages (from 1340 AD to 18th cent.)
Most probably dated to in between **1675 and 1688**, i.e. in the context of the revolts against Ottoman rule during the Great Turkish War.

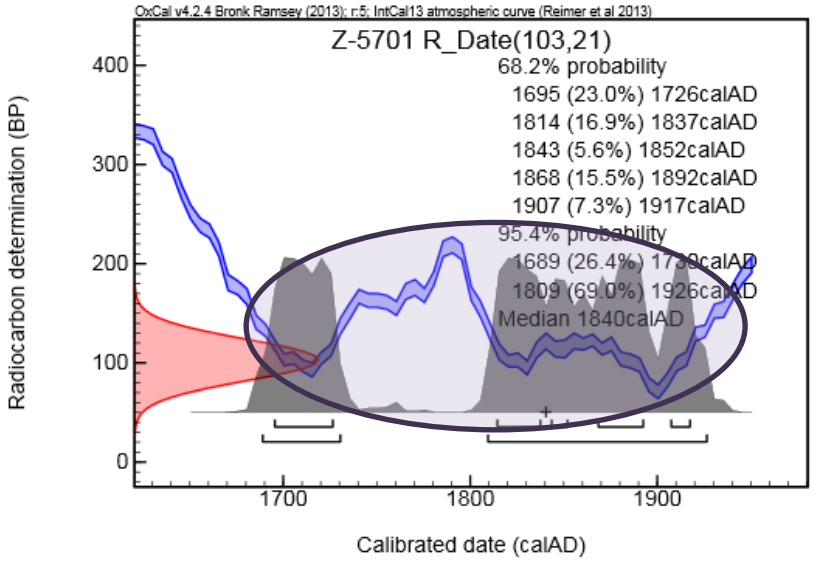
<1 cm^2 of original sample
13 mg – after pretreatment

^{14}C dating – 2 samples, paper, AMS

ID	Sample name	Conventional ^{14}C age (BP)	$\delta^{13}C$ (‰)	Calibrated age (cal AD)	median cal AD
Z-5700 A1079	Paper (thick), #1	270 ± 20	-25.6	1635 – 1662 (60,5%)	1645
Z-5701 A1080	Paper (thin), #2	105 ± 20	-24.9	1695 – 1917 (68,2%)	1840



Confirmed hypothesis for the time of origin (17th century, 1675-1688)



Most probably restauration/reparation

Fojnica Ahd-Namah

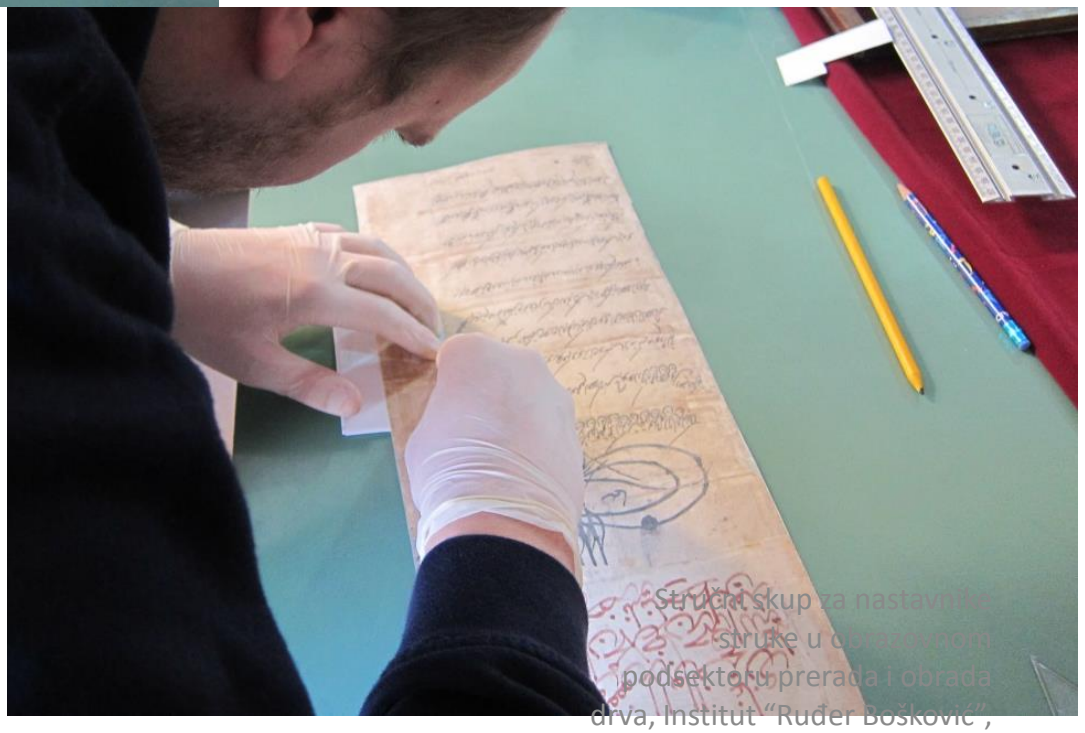
The monastery's museum collections hold the Ahd-Namah (the Order) of Sultan Mehmed II the Conqueror (**1463 AD**) guaranteeing security and freedom to the Franciscans. This document allowed the Franciscans of the day to preach freely among the Catholics in BiH, which in turn enabled the preservation of Bosnian Catholicism through the centuries.

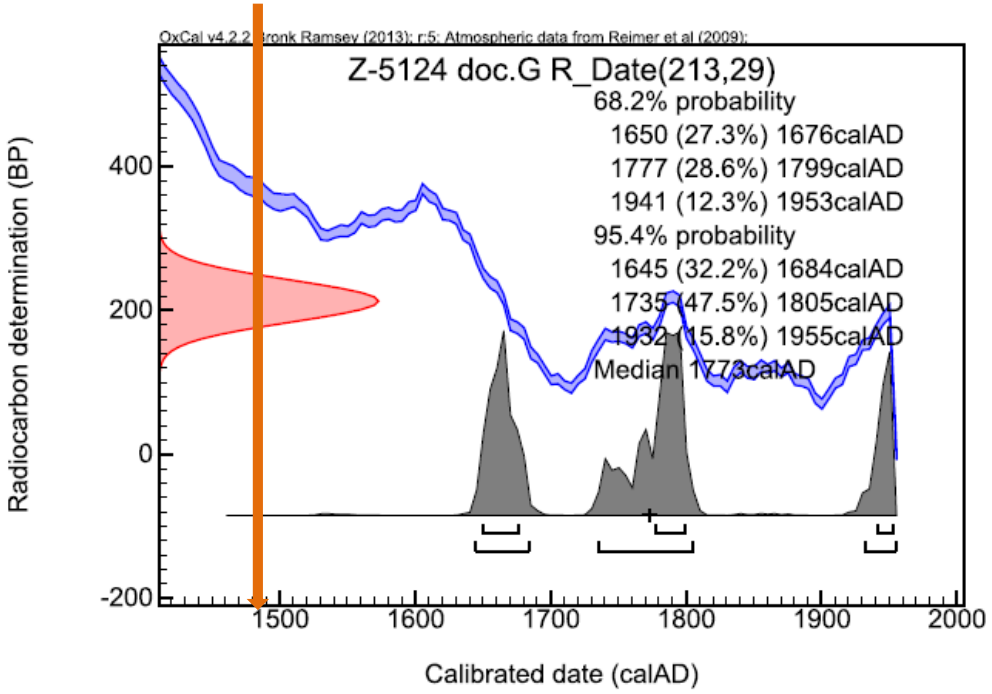
In 2013 celebration of the 550th anniversary of Ad-Namah

Expected origin: Ottoman Empire, Sultan Mehmed II, 1463 AD

Paper sample taken from upper part of Ahd-Namah (sample #1)

Paper sample taken from lower part of Ahd-Namah (#2)





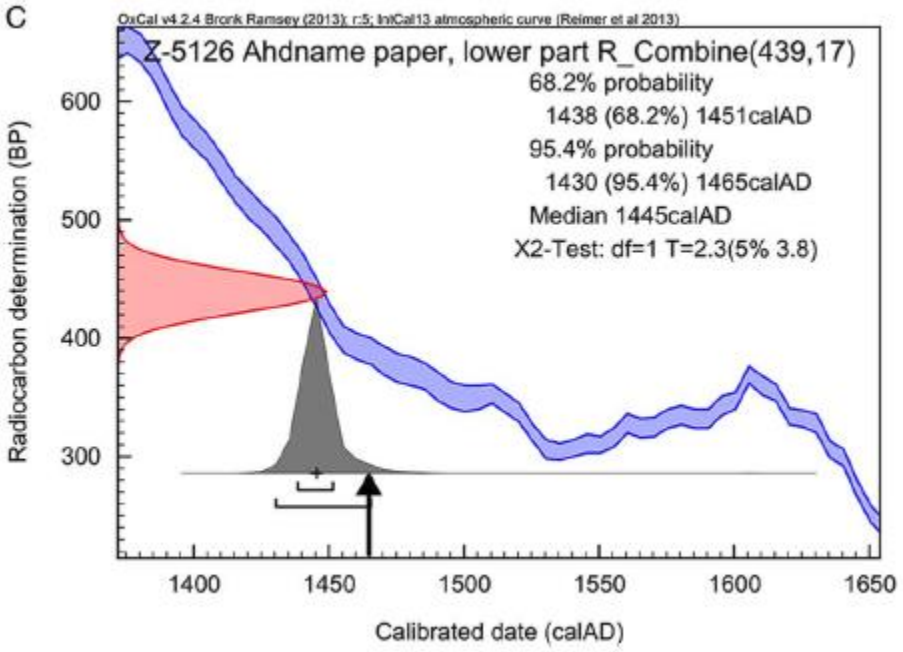
^{14}C age of Ahd-Namah

Upper part (#1) **Z-5124** A628

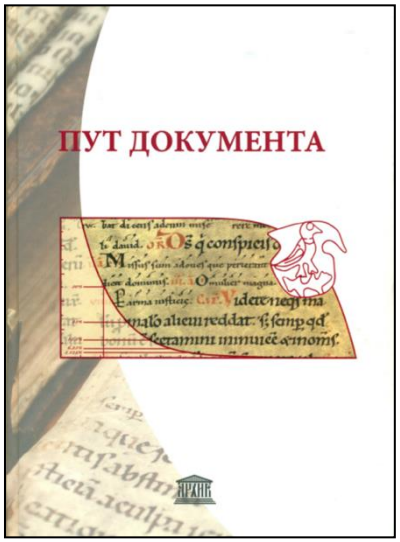
^{14}C conventional age (BP)	**215 ± 30**
Calibrated age (cal AD)	1650 – 1799 (55.9%)
Median cal AD	1773

Lower part (#2) **Z-5126** A630

^{14}C conventional age (yr BP)	**439 ± 17**
Calibrated age (cal AD)	1438 – 1451 (68.2%)
Median cal AD	1445



Archives of Vojvodina, Novi Sad, Serbia

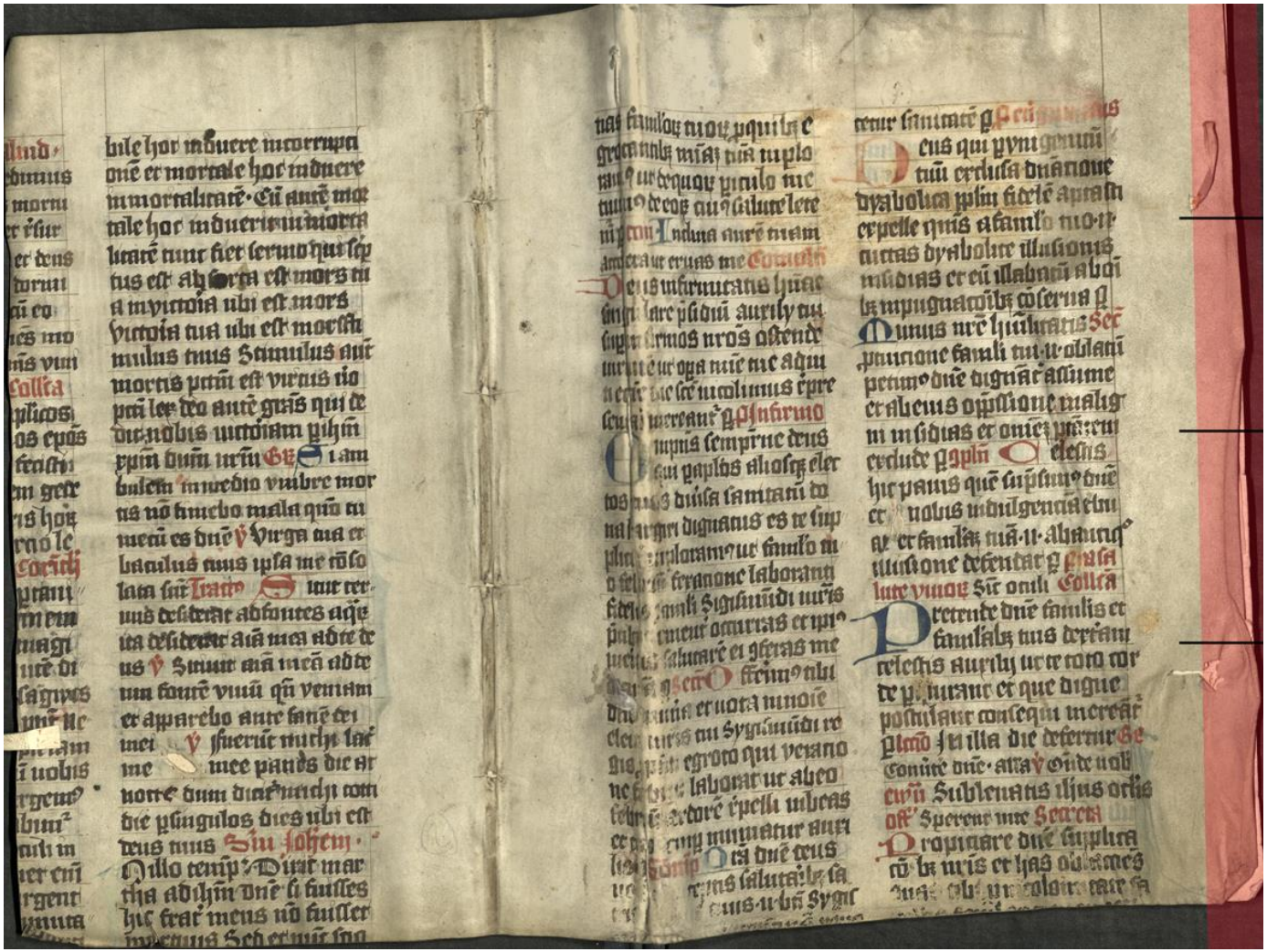


manuscripts with liturgical texts in Latin were used as binders for the notebooks from the end of 16th cent (1569-70 AD, 1590 AD)

Archives of Vojvodina, Novi Sad, Serbia
manuscripts on parchment

manuscripts K3 and K4 with liturgical texts in Latin

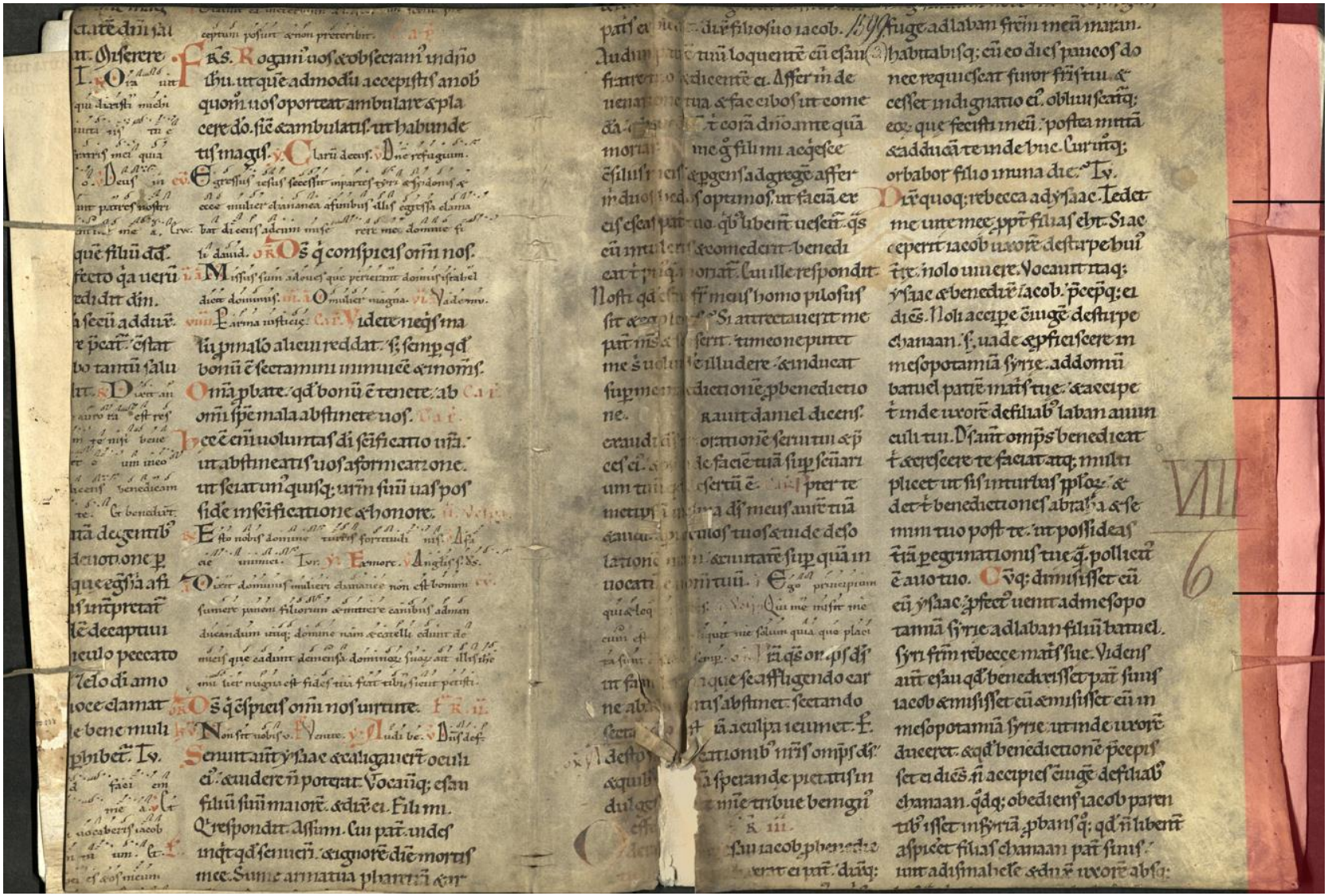
Used as binders for the notebooks from the end of 16th cent (1569-70 AD, 1590 AD)



K3

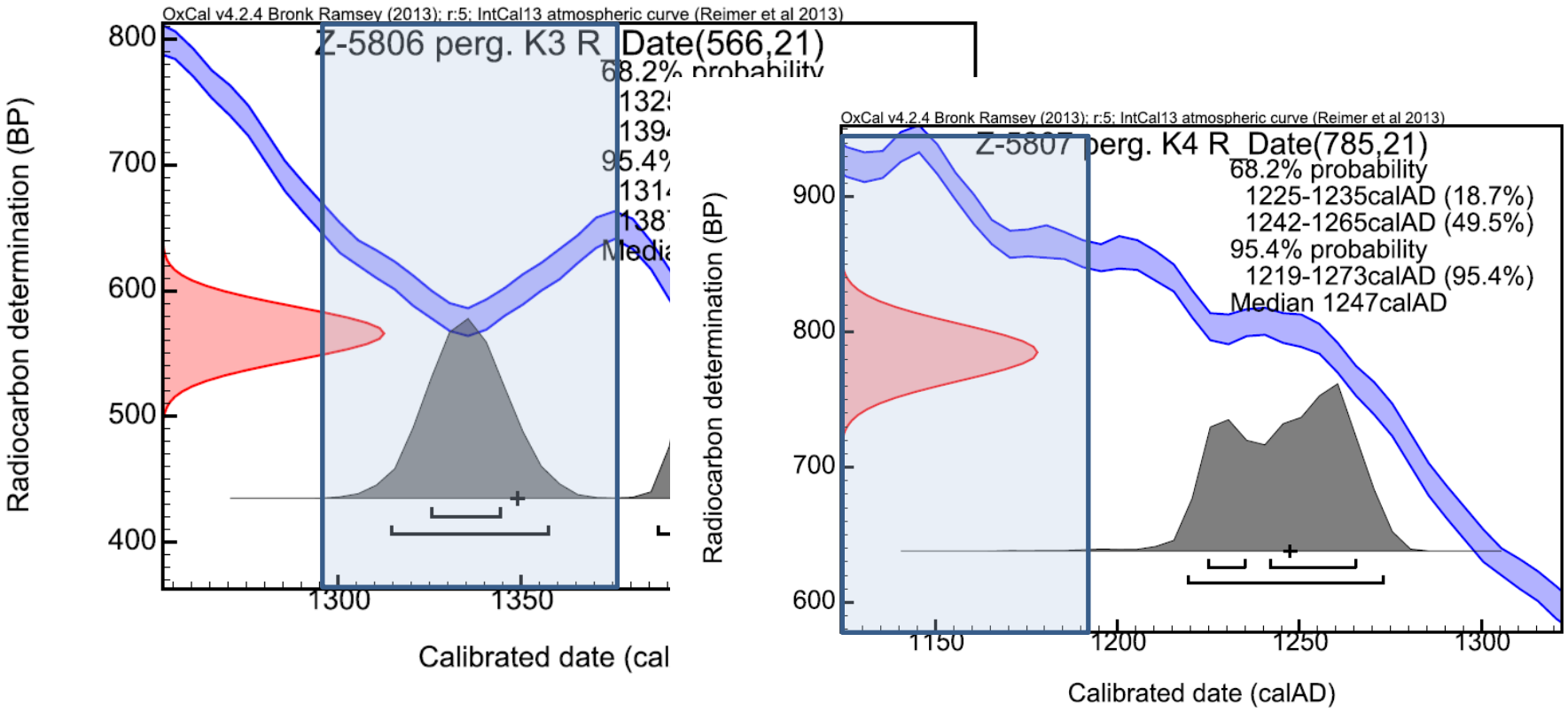
manuscripts with liturgical texts in Latin from the Archives of Vojvodina, Novi Sad

Used as binders for the notebooks from the end of 16th cent (1569-70 AD, 1590 AD)



K4

Lab. no	Sample name	Concentional ^{14}C age (BP)	$\delta^{13}C$ (‰)	Calibrated age span (cal AD)	median cal AD	Expected period
Z-5806 A1140	Parchment K3	565 ± 20	-21.0	1325 – 1410 (68.2%)	1349	14th c.
Z-5807 A1141	Parchment K4	785 ± 20	-21.4	1225 – 1265 (68.2%)	1247	12th c.



CONCLUSIONS

- Radiocarbon dating gives **the age of material** (e.g., wood) and not the time of the creation of the art work – however, the creation of the art work cannot precede the formation of the material
- Radiocarbon dating cannot give a single year – **a range of years** is obtained with a certain probability, the width of the range depends on the measurement uncertainty and on the shape of the calibration curve
- Interpretation of results should be performed in **close collaboration** of art historian and radiocarbon specialists