Radiocarbon dating of paper and parchment

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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

- 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 19$^{th}$ century up to $\sim$60,000 years in the past
- the anthropogenic influence on the natural $^{14}$C distribution during 20$^{th}$ century can be used for recognition of frauds
$^{14}N + n \rightarrow ^{14}C + p$

$^{14}CO_2$

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

Carbon on Earth

$^{12}C$: 98.89 %

$^{13}C$: 1.1 %

$^{14}C$: $1.18 \times 10^{-10}$ %

Decayed $^{14}C$ balanced by its constant uptake

Ceasing of radiocarbon uptake (death of organism)

Radioactive decay

$A = A_0 e^{-\lambda t}$

$\lambda = \ln(2) / T_{1/2}$

$T_{1/2} = 5730$ years
Due to very low natural $^{14}$C concentration the radiocarbon dating method requires special techniques for chemical preparation of samples and measurement of $^{14}$C.

Particular care has to be taken for sample collection and/or storage as well as during sample pretreatment and chemical preparation.

- Extract all carbon from a sample (fractionation)
- All carbon only from the sample (contamination)
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.
**14C sample preparation for AMS**

- **ABA pretreatment**
- **Collagen extraction**
- **Combustion to CO₂**
- **Reduction to C**
- **Preparation of targets**
- **AMS measurement**

**Organic carbon**

**Graphitization line**
• **conventional radiocarbon age of the sample**, expressed in years Before Present (BP), where 0 BP = 1950 AD
• conventional $^{14}$C years do not directly equate to calendar years because atmospheric $^{14}$C concentration varies through time due to changes in the production rate
• a **calibration is required** to convert the conventional radiocarbon age to the calendar age
• accurate and precise **calibration curves** should be based on absolutely dated record that has carbon incorporated directly from the atmosphere at the time of formation
Radiocarbon calibration curves

ARCHIVES:
- Tree-rings
- Speleothems
- Marine sediments
- Lake sediments
- Corals
Presentation of calibrated data

Conventional radiocarbon ages (ordinate) in years BP are represented as the Gaussian curve with mean and standard deviation (uncertainty) being 1420 ± 25. Calibrated values, in calendar years, are obtained by transferring the values on ordinate over calibration curve to the abscissa. Results can be presented by 1σ, 2σ or 3σ probabilities and by mean or median values.
Several cases of $^{14}$C dating of objects (paper, parchment) of arts will be presented here.

How to interpret 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.
**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.

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
Ahd-Namah and mantel from the museum collection in Fojnica Monastery (Ottoman Empire, Sultan Mehmed II, 1463 AD)
**14C age of Ahd-Namah**

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

<table>
<thead>
<tr>
<th>14C conventional age (yr BP)</th>
<th>215 ± 30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calibrated age (cal AD)</td>
<td>1650 – 1799 (55.9%)</td>
</tr>
<tr>
<td>Median cal AD</td>
<td>1773</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>14C conventional age (yr BP)</th>
<th>410 ± 25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calibrated age (cal AD)</td>
<td>1443 – 1484 (68.2%)</td>
</tr>
<tr>
<td>Median cal AD</td>
<td>1466</td>
</tr>
</tbody>
</table>
\[ {^{14}C \text{ age of linen of mantel}} \]

\[ \text{\textit{Note the flatness of the calibration curve!}} \]

\[ \text{\textit{OxCal v4.22 Brook Ramsey (2013); r5: Atmospheric data from Reimer et al (2009):}} \]

\[ Z-5125 \text{ mantle R\_Date(358,29)} \]

\[ 68.2\% \text{ probability} \]

\[ 1469 (38.2\%) \text{ 1522 calAD} \]

\[ 1575 (5.2\%) \text{ 1584 calAD} \]

\[ 1590 (24.8\%) \text{ 1625 calAD} \]

\[ 95.4\% \text{ probability} \]

\[ 1452 (46.7\%) \text{ 1530 calAD} \]

\[ 1540 (48.7\%) \text{ 1635 calAD} \]

\[ \text{Median 1542 calAD} \]

\[ \begin{array}{|c|c|}
\hline
{^{14}C \text{ conventional age (yr BP)}} & \text{360 \pm 30} \\
\hline
\text{Z-5125 A629} & \text{} \\
\hline
\text{Calibrated age (cal AD)} & \text{1469 – 1625 (68.2\%)} \\
\hline
\text{Median cal AD} & \text{1542} \\
\hline
\end{array} \]
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.
### 14C dating – 2 samples, paper, AMS

<table>
<thead>
<tr>
<th>ID</th>
<th>Sample name</th>
<th>Conventional 14C age (BP)</th>
<th>δ^{13}C (‰)</th>
<th>Calibrated age (cal AD)</th>
<th>median cal AD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z-5700</td>
<td>Paper (thick), #1</td>
<td>270 ± 20</td>
<td>-25.6</td>
<td>1635 – 1662 (60.5%)</td>
<td>1645</td>
</tr>
<tr>
<td>A1079</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Z-5701</td>
<td>Paper (thin), #2</td>
<td>105 ± 20</td>
<td>-24.9</td>
<td>1695 – 1917 (68.2%)</td>
<td>1840</td>
</tr>
<tr>
<td>A1080</td>
<td></td>
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</tr>
</tbody>
</table>

**Confirmed hypothesis for the time of origin (17th century)**

**Most probably restauration/reparation**
Case 3. manuscripts on parchment

manuscripts K3 and K4 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)
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Used as binders for the notebooks from the end of 16th cent (1569-70 AD, 1590 AD)
<table>
<thead>
<tr>
<th>Lab. no</th>
<th>Sample name</th>
<th>Conventional $^{14}$C age (BP)</th>
<th>$\delta^{13}$C (‰)</th>
<th>Calibrated age span (cal AD)</th>
<th>median cal AD</th>
<th>Expected period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z-5806</td>
<td>Parchment K3</td>
<td>565 ± 20</td>
<td>-21.0</td>
<td>1325 – 1410</td>
<td>1349</td>
<td>14th c.</td>
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<tr>
<td>A1140</td>
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<td></td>
</tr>
<tr>
<td>Z-5807</td>
<td>Parchment K4</td>
<td>785 ± 20</td>
<td>-21.4</td>
<td>1225 – 1265</td>
<td>1247</td>
<td>12th c.</td>
</tr>
<tr>
<td>A1141</td>
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</tbody>
</table>

OxCal v4.2.4; Bronk Ramsey (2013); r.5; IntCal13 atmospheric curve (Reimer et al. 2013)
Radiocarbon dating gives the age of material (e.g., wood, canvas, paper, parchment... - the material of biogenic origin) 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.