Radiocarbon dating method as a tool for cultural heritage protection

Nada Horvatinčić, Ines Krajcar Bronić, Jadranka Barešić

Ruđer Bošković Institute, Zagreb
Department of experimental physics
Laboratory for low-level radioactivity
Content

- Radiocarbon ($^{14}$C) dating method - application
- Radiocarbon Laboratory in Zagreb, Ruđer Bošković Institute
- Few examples for $^{14}$C dating
Application of radiocarbon (\(^{14}C\)) dating method:

- Archaeology
- Palaeontology
- Geology
- Hydrogeology
- Palaeoclimatology
- Environment/geochemical study
- Forensics
Type of samples for $^{14}\text{C}$ dating

**Organic samples:**
- wood
- leaves
- seed
- charcoal
- bones
- organic sediment, soil
- linen, paper
- dissolved organic carbon

**Carbonate:**
- speleothem
- carbonate sediment
- tufa
- shells
- algae
- corals
- water (diss. inorg. carbon DIC)
- atmospheric $\text{CO}_2$
Which periods can be dated by $^{14}$C?

- **Maximal age:** ~ 60,000 yr BP
  Determined by half-time decay of $^{14}$C ($\sim10 \times T_{1/2}$)

- **Minimal age:** till the end of XIX. century
  Determined by anthropogenic contamination:

  1) *Suess effect* $\Rightarrow$ influence of fossil fuel combustion at the end of XIX century

  2) *Nuclear and thermonuclear tests in the atmosphere* $\Rightarrow$ significant increase of $^{14}$C (increase up to 100%) after World War II
Accuracy of $^{14}$C dating method depends on:

1) type of sample, organic material is more suitable than inorganic (carbonate sample)

2) Sample must be representative, not contaminated with some other material (careful sampling is important)

3) $^{14}$C results (in year BP with $1\sigma$ uncertainty) are calibrated according to the radiocarbon calibration curves (in calendar year BC/AD) and the range of age depends on $^{14}$C result uncertainty and on the shape of calibration curve for this range
Ruđer Bošković Institute
Laboratory for low-level radioactivity (Radiocarbon Laboratory)

- Laboratory established in 1968. at RBI
- Dated more than 5000 samples for archaeology, paleontology, geology, paleoclimatology, ecology
- Development of new techniques for $^{14}\text{C}$ dating
- Successful cooperation with institutions in Croatia and international cooperation
Techniques for $^{14}$C dating at Ruđer Bošković Institute, Laboratory for low-level radioactivity

1) Radiometric method – Liquid Scintillation Counter (LSC), sample in form of benzene
   - required amount of sample 10-20 g of organic sample (wood, charcoal, textile, paper)

2) Accelarator method – Accelerator Mass Spectrometry (AMS), sample in form of graphite;
   - required amount of sample 10-100 mg of organic sample
Comparison of $^{14}$C AMS and LSC technique at Ruđer Bošković Institute

<table>
<thead>
<tr>
<th></th>
<th>$^{14}$C AMS</th>
<th>$^{14}$C LSC</th>
</tr>
</thead>
<tbody>
<tr>
<td>mass of C in sample/ g</td>
<td>$3.5 \cdot 10^{-3}$</td>
<td>4-5 (2.5)</td>
</tr>
<tr>
<td>form of prepared sample</td>
<td>graphite (+Fe)</td>
<td>benzen</td>
</tr>
<tr>
<td>Measurement accuracy/ pMC</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>Detection limit/ year BP</td>
<td>56 200</td>
<td>55 000</td>
</tr>
<tr>
<td>Time measurement</td>
<td>30 minutes</td>
<td>24 hours</td>
</tr>
<tr>
<td>No. of prepared samples per week</td>
<td>16</td>
<td>5</td>
</tr>
</tbody>
</table>
Vacuum line for benzene synthesis from the sample for $^{14}$C dating

Liquid scintillation counter for $^{14}$C measurement in benzene

LSC $^{14}$C method - applied for „big” sample, 10-20 g wood, textile, paper
Vacuum line for synthesis of graphite for AMS measurement

AMS $^{14}$C method – for small samples, 10 – 100 mg wood, textile, paper

AMS for $^{14}$C measurement in graphite targets in cooperation with Scottish University Environmental Research Centre (SUERC), Glasgow
Archaeology

Sv. Donat-Zadar, Convent st. Claire - Old Zagreb

Stobi-Pelagonia, Andautonia, Nin-ships

Kaptol-Požega, Zagreb Town Museum, Privlaka-Vinkovci

Cave Bezdanjača, Pupićina peć-Istra, Igrišće Kalnik

Vučedol-Vukovar, Grabrovac-Đakovo Vinkovci, Rudine-Koprivnica

Sopot-Vinkovci, Vela špilja-Korčula

Lepenski vir, Vela špilja-Korčula
### Egyptian Mummy in Archaeological Museum in Zagreb with wrappings of the Etruscan linen “book”, the *Liber linteus Zagabriensis*

#### Sample material

<table>
<thead>
<tr>
<th>Sample material</th>
<th>Lab. No.</th>
<th>$^{14}$C age (BP)</th>
<th>Calibrated range</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Liber linteus Zagabriensis</em></td>
<td>OxA-1680</td>
<td>2110 ± 60</td>
<td>360 cal BC-cal AD 5</td>
</tr>
<tr>
<td>MummyTissue</td>
<td>OxA-1388</td>
<td>2160 ± 80</td>
<td>385 - 210 cal BC</td>
</tr>
<tr>
<td>Linen wrappings</td>
<td>Z-1653</td>
<td>2220 ± 40</td>
<td>405 - 210 cal BC</td>
</tr>
<tr>
<td></td>
<td>GrN-13875</td>
<td>2210 ± 13</td>
<td>365-205 cal BC</td>
</tr>
<tr>
<td></td>
<td>GrN-14442</td>
<td>2335 ± 15</td>
<td>405-395 cal BC</td>
</tr>
<tr>
<td>Lišće</td>
<td>Z-1654</td>
<td>2760 ± 90</td>
<td>1015-800 cal BC</td>
</tr>
<tr>
<td></td>
<td>OxA-1387</td>
<td>2700 ± 90</td>
<td>1015-800 cal BC</td>
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<tr>
<td></td>
<td>OxA-1388</td>
<td>2700 ± 90</td>
<td>1015-800 cal BC</td>
</tr>
<tr>
<td></td>
<td>Z-1654</td>
<td>2580 ± 60</td>
<td>900-520 cal BC</td>
</tr>
<tr>
<td>Leaves</td>
<td>GrN-14467</td>
<td>2825 ± 15</td>
<td>1015-925 cal BC</td>
</tr>
<tr>
<td></td>
<td>OxA-1389</td>
<td>2920 ± 100</td>
<td>1400-905 cal BC</td>
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</tbody>
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Z - Ruđer Bošković Institute, Zagreb  
GrN - Center for Isotope Research, Groningen  
OxA - Radiocarbon Accelerator Unit, Research Laboratory for Archaeology and The History of Art, Oxford
Etruscan linen “book” known as the *Liber linteus Zagrabiensis*, from the collection of the Archaeological Museum in Zagreb. This liturgical calendar, with over 1200 words, represents the longest known Etruscan inscription.
Reconstruction of the Zagreb Town Museum (former Convent st. Claire); 14C dating of samples from the basement of building.

The bases of wooden walls of Old Grič from 12. century

1200 – 1900 cal AD

1000 cal BC – 500 cal AD

Calibrated results of 14C dating from periods Hallstatt and Mediaeval age.
Old bridge in Mostar; dating of different period of construction of the bridge

Calibrated $^{14}C$ results and comparison with dendrochronological dating results
Samples for $^{14}C$ dating of Old bridge in Mostar: 6 wood and 2 charcoal samples
Vučedol near Vukovar
Eneoliticka kultura:
Baden, Kostolac and Vučedol

<table>
<thead>
<tr>
<th>Kultura</th>
<th>uzorci</th>
<th>starost</th>
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<tbody>
<tr>
<td>Badenska</td>
<td>4 uglj, 1 kost</td>
<td>3500 - 2780 cal BC</td>
</tr>
<tr>
<td>Kostolačka</td>
<td>2 uglj</td>
<td>3300 - 2920 cal BC</td>
</tr>
<tr>
<td>Vučedolska</td>
<td>8 uglj, 2 kost</td>
<td>3040 - 2580 cal BC</td>
</tr>
<tr>
<td>Vinkovačka (kasni Vučedol)</td>
<td>2 uglj</td>
<td>2480 - 2040 cal BC</td>
</tr>
</tbody>
</table>
Conclusions:

- Radiocarbon ($^{14}\text{C}$) dating method is the most accurate method for determination of absolute age of different organic samples (wood, bone, charcoal, paper, seed) and some carbonate samples (spelothem, lake sediment, tufa) but with higher uncertainty.

- Development of new technique (AMS) enable $^{14}\text{C}$ dating of very small amount of material (~10 mg) and can be applied for dating of objects important for cultural heritage. Thus, radiocarbon dating method is a good tool for identification and/or protection of cultural heritage.