

Use of accelerators to preserve Cultural Heritage objects and detect forgeries

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Foss 8/2/84

NUCLEAR SCIENCE APPLICATIONS

SECTION B EDITED BY
ALEXANDER ZUCKER
OAK RIDGE NATIONAL LABORATORY

ION BEAM TECHNIQUES IN ARCHAEOLOGY AND THE ARTS

J.R. Bird, P. Duerden and D.J. Wilson

J. R. Bird, P. Duerden and D. J. Wilson, Ion beam techniques in archaeology and the arts, Nucl. Sci. Appl., 1 (1983)

Cyclotron

- Proton activation analysis (PAA)
- Neutron activation analysis (NAA)

Tandem

Accelerator mass spectrometry for radiocarbon (+other nuclides) dating

1977-78

Van de Graaff or Tandem

- Ion beam analysis (IBA)

Synchrotron

- Chemical mapping
- Tomography
- ...

Science

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ARTICLE

f t in r w e

Radioisotope Dating with a Cyclotron: The sensitivity of radioisotope dating is improved by counting atoms rather than decays.

RICHARD A. MÜLLER

REPORT

Radiocarbon Dating with Electrostatic Accelerators: Dating of Milligram Samples

BY C. L. BENNETT, R. P. BEUKENS, M. R. CLOVER, D. ELMORE, H. E. GOVE, L. KILIUS, A. E. LITHERLAND, K. H. PURSER • SCIENCE • VOL. 201, NO. 4353 • 28 JUL 1978 : 345-347

The recently developed direct counting technique for radiocarbon atoms has been used to measure the relative numbers of such atoms in various ge samples which had earlier been dated by the beta-ray counting method. Sample weights ranged ...

REPORT

Radiocarbon Dating Using Electrostatic Accelerators: Negative Ions Provide the Key

BY C. L. BENNETT, R. P. BEUKENS, M. R. CLOVER, H. E. GOVE, R. B. LIEBERT, A. E. LITHERLAND, K. H. PURSER, W. E. SONDEHEIM • SCIENCE • VOL. 198, NO. 4316 • 04 NOV 1977 : 508-510

Mass spectrometric methods have long been suggested as ways of measuring $^{14}\text{C}/^{12}\text{C}$ ratios for carbon dating. One problem has been to distinguish between ^{14}C and ^{14}N . With negative ions and a tandem electrostatic accelerator, the ^{14}N background is ...

Applications

J.R. Bird, P. Duerden and
D.J. Wilson, Ion beam
techniques in
archaeology and the arts,
Nucl. Sci. Appl., 1 (1983)
357.

1 INTRODUCTION

Materials analysis has played an important role in providing a scientific base for the gradual development of archaeology, authentication, conservation and related topics from a general interest in antiquities to the present sophisticated level. It is not surprising, therefore, that the revolution in analytical methods which accompanied the advance in knowledge in atomic and nuclear physics has been of vital importance for those topics. It is the purpose of this article to review applications of ion beam techniques to archaeology and the arts¹⁻⁸⁶ and to explore the question “When should ion beam techniques be used in such studies in preference to other methods?”.

There are numerous interlocking aspects of such studies and for convenience the following distinctions are made:

1) Provenance – details of the discovery of an object in recent times and its subsequent history;

– often also used to describe the historic or prehistoric origin of an object and/or the material from which it is made. It is therefore convenient to refer to this second use as “characterization” and to use the following additional distinctions;

2) Typological Properties – visual, stylistic and related features which are useful for classifying or grouping objects;

3) Physical Properties – parameters determined by physical, chemical, mineralogical and other such methods;

4) Technology – methods for materials processing and fabrication used in the preparation of an object;

5) Group – a selection of objects which have physical and/or typological properties that are distinguishable from those for other objects;

6) Source – the geographic location of the material(s) from which an object or group of objects was made;

7) Characterization – the use of physical or typological properties to allocate an object or group to a particular historic or prehistoric context;

8) Authenticity – the correctness or incorrectness of the claimed provenance or characterization of an object.

9) Alteration/preservation

- Non destructive analysis
- Trace elements
- Multiple information

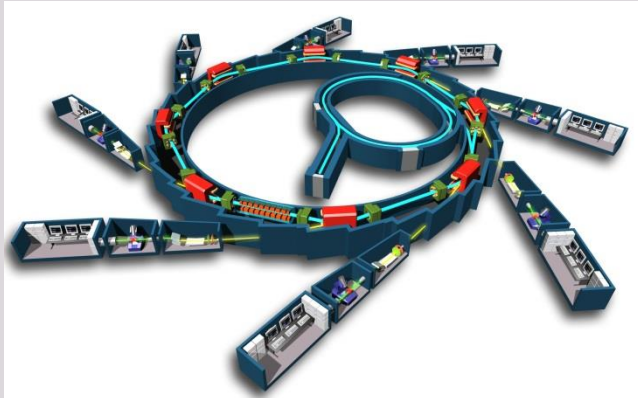
- composition and depth resolution
- mixed materials

- “Recipes”
- Technology
- Provenance
- History
- Art history

- Provenance
- History
- Art history
- Fight against the illicit art trade

Accelerators for cultural heritage studies

Synchrotron SOLEIL



The "IPANEMA" laboratory supports synchrotron projects on Cultural Heritage applications
stitut photonique d'analyse non destructive européen des matériaux anciens

Van de Graaff



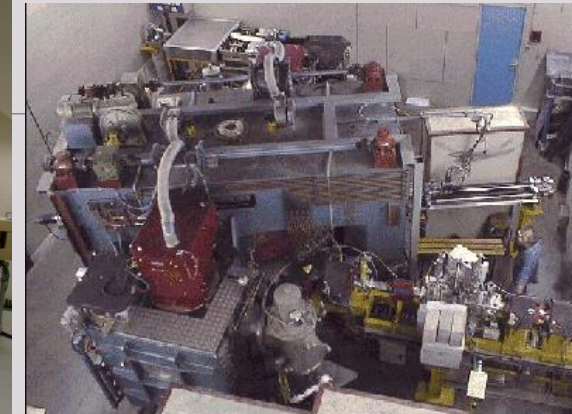
NewAGLAE: Accélérateur Grand Louvre d'Analyse élémentaire – Louvre -Paris

Tandem



ARTEMIS – Radiocarbon dating - Saclay

Cyclotron

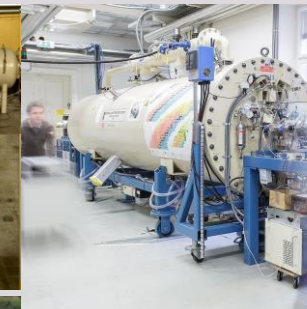


CEMHTI cyclotron – Orléans

CTN LISBOA



VERA, WIEN



ETH, ATOMKI, OXFORD



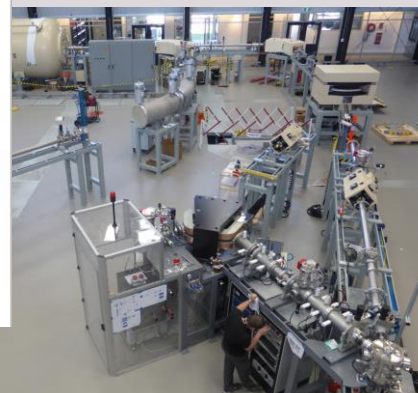
ESRF



CEDAD



ANSTO



ELETTRA



LABEC



Accelerators for analysis and dating



Preservation of Cultural Heritage objects

- Assistance for restoration
- Assistance for museography

Detection of forgeries

- Misattribution
- Fighting against the illicit trade in art

1-Restoration of a metal screen



Attributed to Yoshida

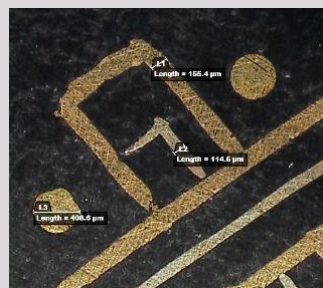


COLLECTION OF THE MUSÉE DES ARTS DÉCORATIFS (PARIS), FIRST DISPLAY AT THE PARIS INTERNATIONAL EXPOSITION IN 1878

Metal screen from Japan



© C2RMF – D. Robcis



COLLECTION OF THE MUSÉE DES ARTS DÉCORATIFS (PARIS), FIRST DISPLAY AT THE PARIS INTERNATIONAL EXPOSITION IN 1878

Metal screen from Japan



In Europe, colors are obtained by chemical and thermal treatments of homogeneous alloys (bronze or brass)

≠

In Japan, colors are obtained from different alloys with possibly chemical/thermal treatments

Shakudo : copper with gold (1 to 7%), black patina

Shibuichi : copper-silver alloy (Ag from 15 to 35%), gray patina

Sentoku : copper-zinc-tin alloy (Zn ~20%, Sn(15%), yellow to brown

Suaka : pure copper, red patina

Gin : almost pure silver, white to gray

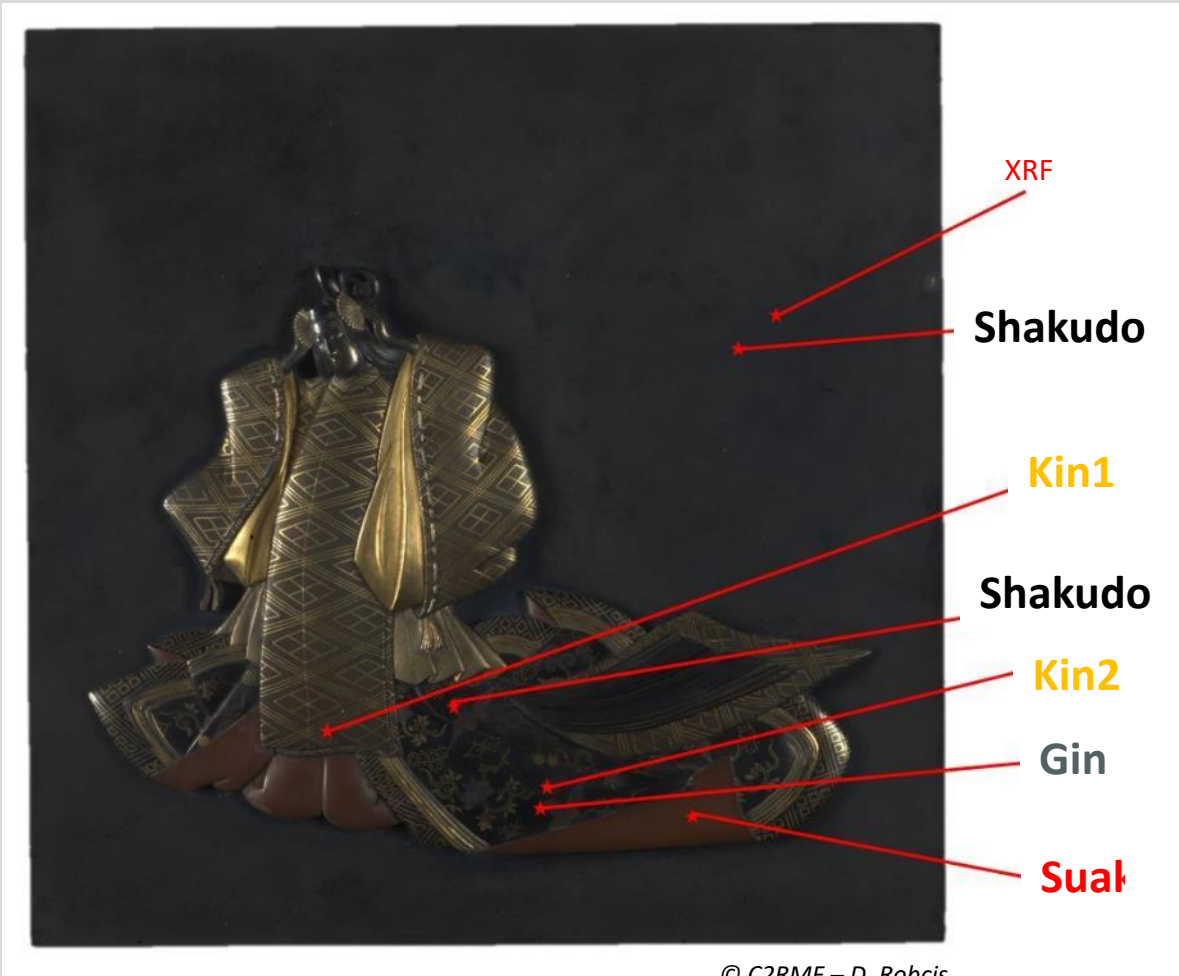
Kin : gold with silver or copper (a few %), yellowish

Tetsu : almost pure iron, black to brown patina

...



Non destructive analysis by PIXE

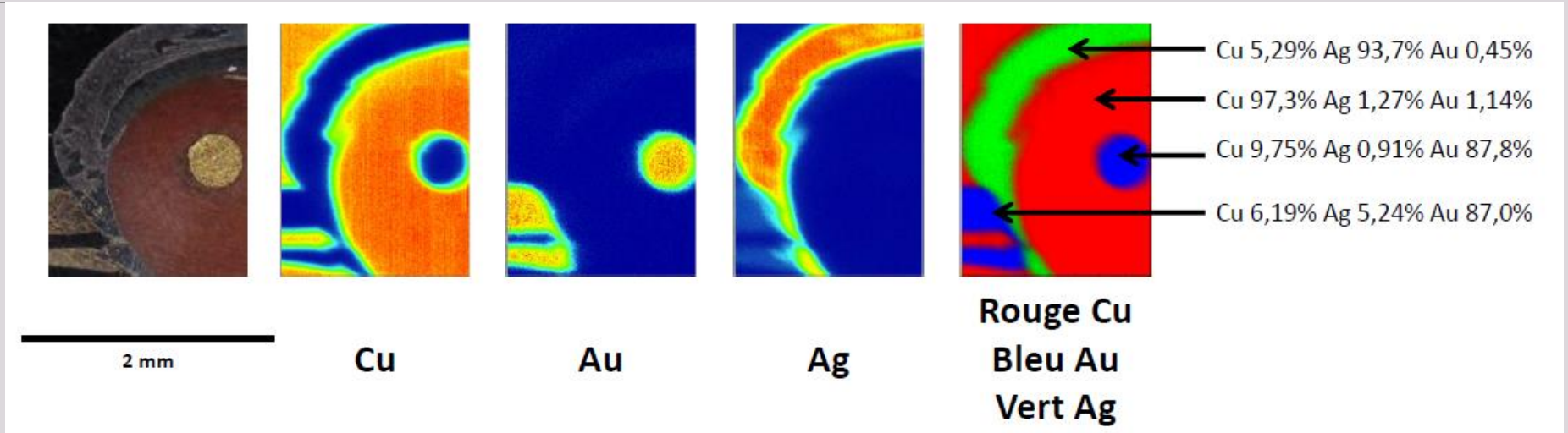


© C2RMF – D. Robcis

File N°	Sample info	Cu	Zn	Ag	Au # LA	Pb # LA	Hg # LA	Sb	As
20180712_0040_A 14.16_MAD_JBA	A14.16 fond patiné	957011	0	5826	28741	1150	0	592	3825
20180712_0041_A 14.16_MAD_JBA	A14.16 cuivre fauve	994900	0	388	102	1907	96	811	280
20180712_0042_A 14.16_MAD_JBA	A14.16 cuivre fauve	950262	0	15896	24255	961	0	956	4176
20180712_0043_A 14.16_MAD_JBA	A14.16 marron fond	320224	159	140572	525959	353	0	194	246
20180712_0044_A 14.16_MAD_JBA	A14.16 or pale	3281	368	335895	652855	273	0	461	101
20180712_0045_A 14.16_MAD_JBA	A14.16 or jaune	12221	1005	8348	966348	83	0	106	262
20180712_0046_A 14.16_MAD_JBA	A14.16 oiseau rouge	972126	0	20480	2993	1110	0	549	93
20180712_0047_A 14.16_MAD_JBA	A14.16 oiseau blanc	9790	49	978851	4426	4684	0	0	0

Courtesy C. Pacheco, Q. Lemasson, D. Robcis, L. Pichon

Non destructive PIXE mapping



Elemental composition as well as mapping provided crucial information for the restoration of the screen

- Compatible material
- No or few chemicals
- Precision
- Safe restoration

Courtesy: C. Pacheco, Q. Lemasson, D. Robcis, L. Pichon

2-Exhibition



Courtesy: Sibylle Emerit, Maison de l'Orient et de la Méditerranée, Hélène Guichard, Musée du Louvre, Anita Quiles, IFAO

Louvre-Lens du 13 septembre 2017 au 15 janvier 2018

These instruments entered the Louvre Museum collections in the 19th century and no information about possible conservation work is available.



N 1441 (purchased in 1826, Salt collection)

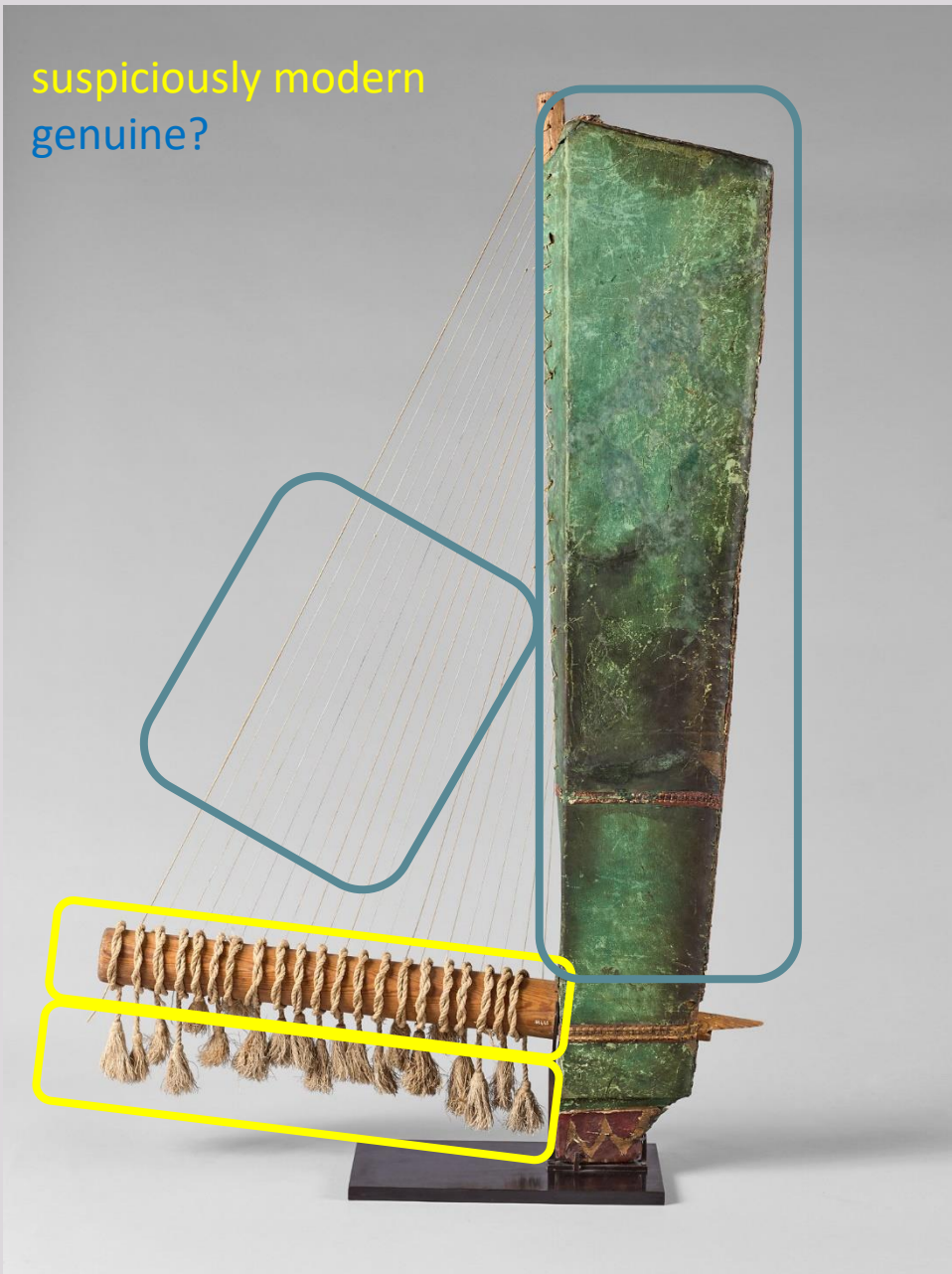


N 1442 (Salt collection)

The harp N 1441 was attributed from between the 19th and 30th Dynasties (1300 to 340 BCE)

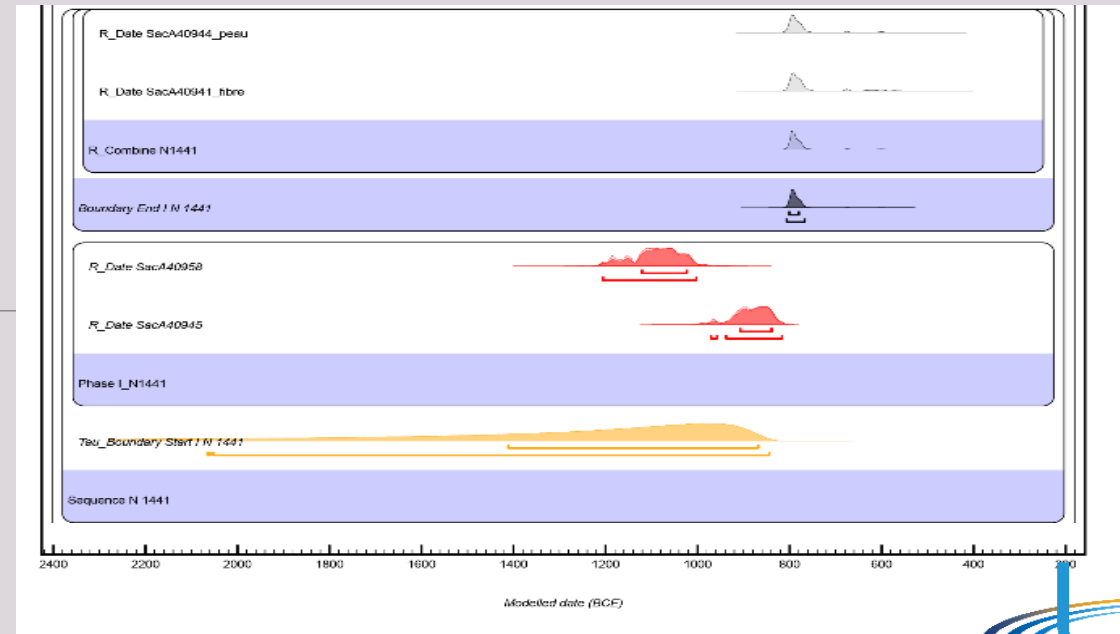
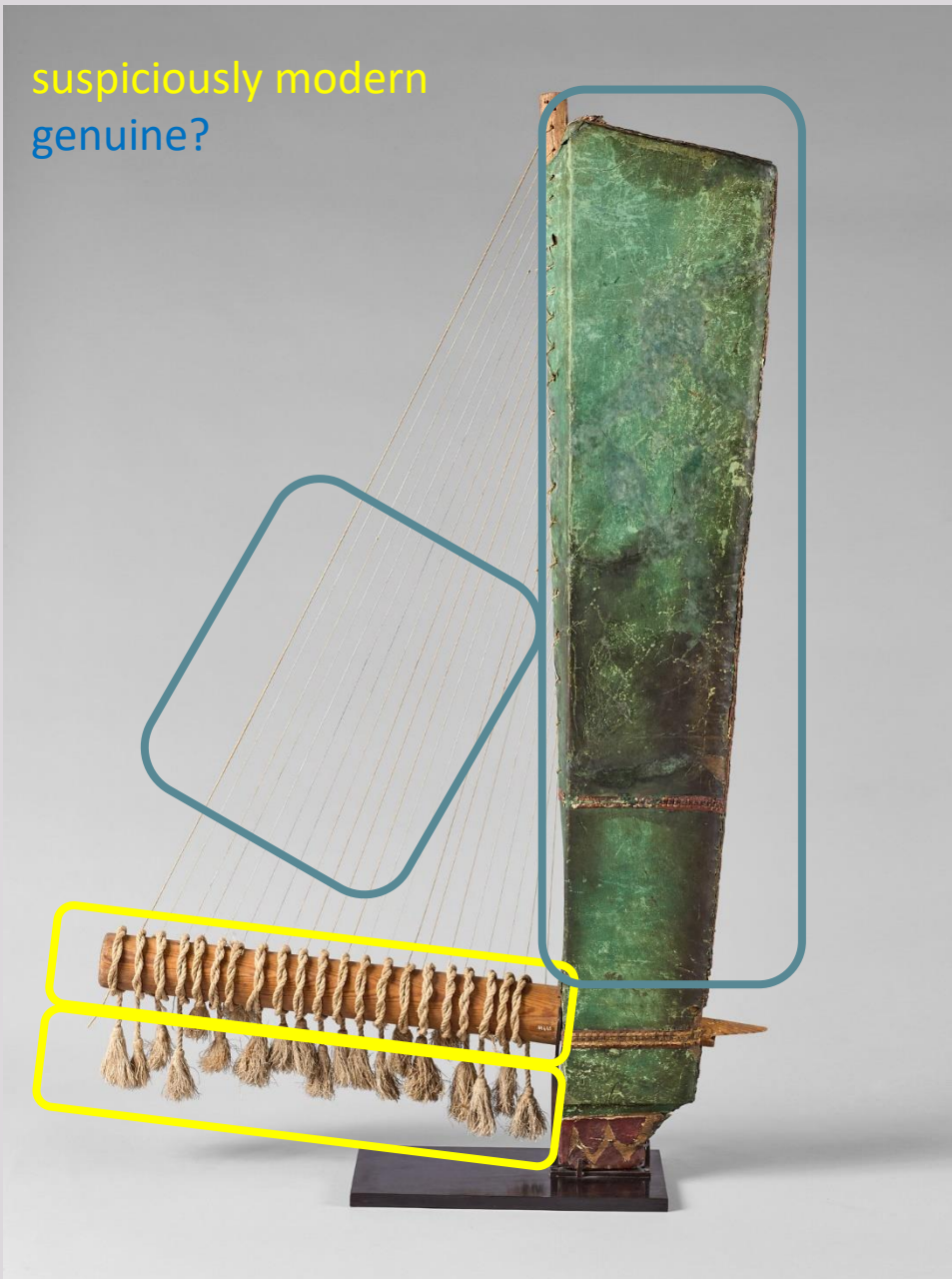
The drum N 1442 was attributed to the 4th c. BCE

suspiciously modern
genuine?



Harp N 1441 : six samples were collected from this almost complete harp.

suspiciously modern
genuine?



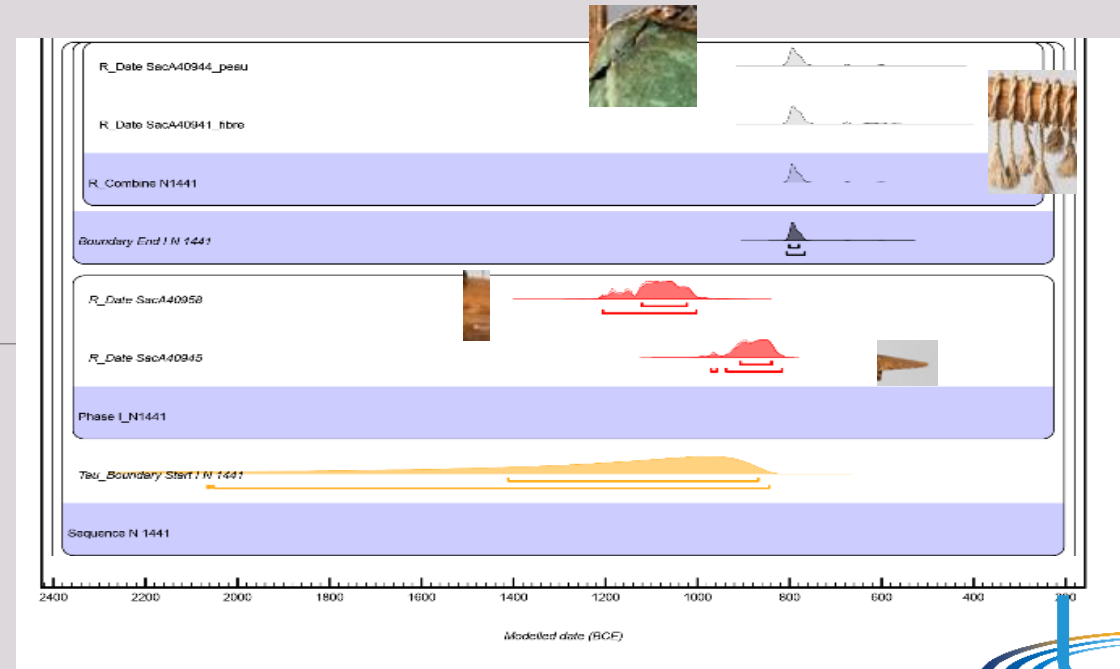
Short-lived
organisms

Wooden pieces

LMC¹⁴

Harp N 1441 : six samples were collected from this almost complete harp. The **two strings** analyzed are modern; therefore, the result of restoration works. **Wood samples** from the neck and the peg have been identified as respectively as Pinus type pinaster and Ziziphus cf. spina-christi (L.) Desf. and provided ages of respectively 2905 ± 30 BP and 2745 ± 30 BP, older than the short-lived samples. The sound-box made of Ficus sycomorus L. was dated by a **leather sample** to 2585 ± 30 BP, consistent with the **textile pompom** of 2580 ± 30 BP.

modern
genuine



Short-lived
organisms

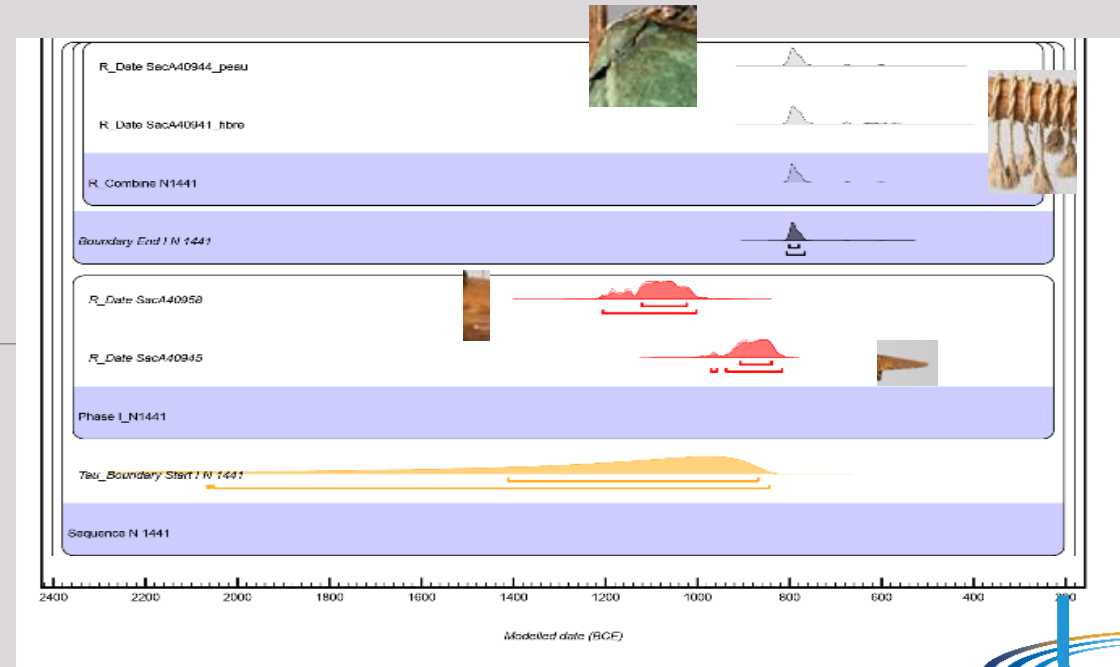
Wooden pieces

LMC¹⁴

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1 - New display for the exhibition and in the museum, new explanation.

modern
genuine



Short-lived
organisms

Wooden pieces

LMC¹⁴

Harp N 1441 : six samples were collected from this almost complete harp. The **two strings** analyzed are modern; therefore, the result of restoration works. **Wood samples** from the neck and the peg have been identified as respectively as Pinus type pinaster and Ziziphus cf. spina-christi (L.) Desf. and provided ages of respectively 2905 ± 30 BP and 2745 ± 30 BP, older than the short-lived samples. The sound-box made of Ficus sycomorus L. was dated by a **leather sample** to 2585 ± 30 BP, consistent with the **textile pompom** of 2580 ± 30 BP.

2- These two last samples provide a combined age for the manufacturing of this harp between 808 and 766 BCE (95.4%) → end of the Third Intermediate Period (more precise than the attribution between 1300 and 340 BC)



leather



Drum N 1443 : 3 samples were collected

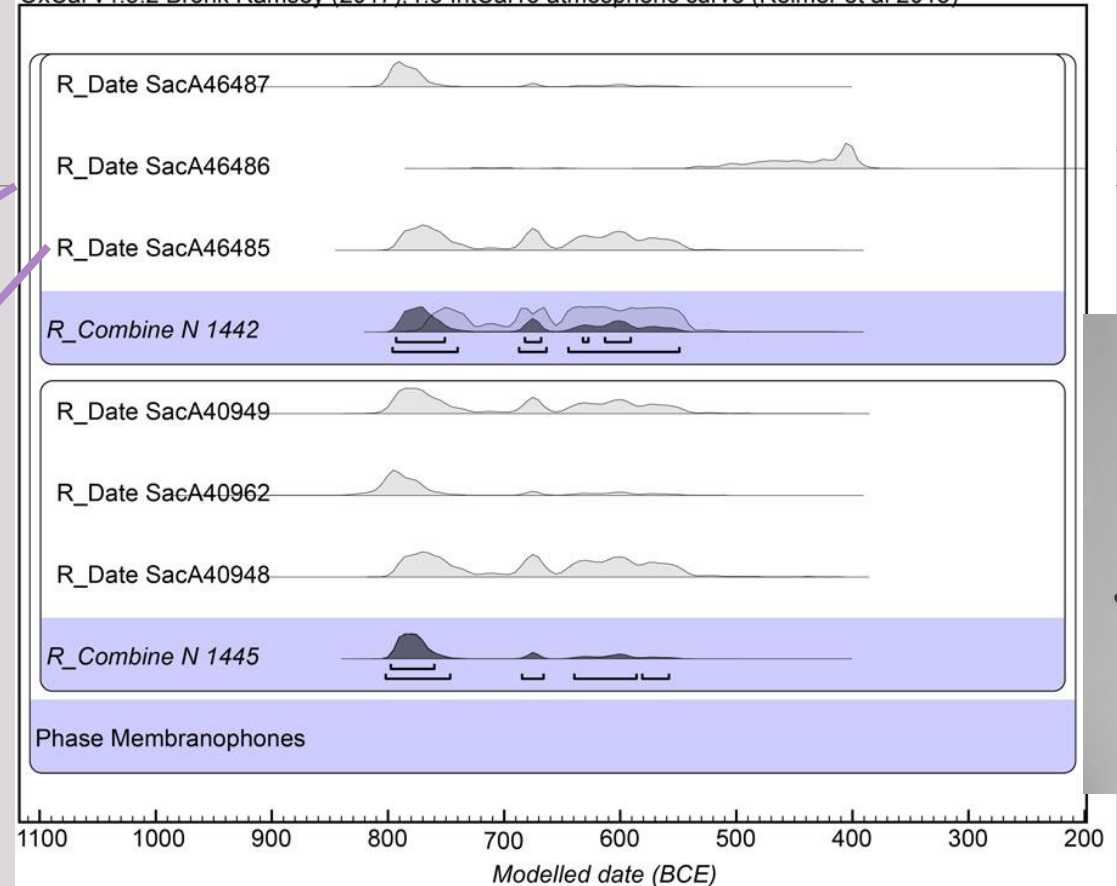


suspiciously modern twine (19th c. labelling?)

The drum N 1442 was attributed to the 4th c. BC



OxCal v4.3.2 Bronk Ramsey (2017); r:5 IntCal13 atmospheric curve (Reimer et al 2013)



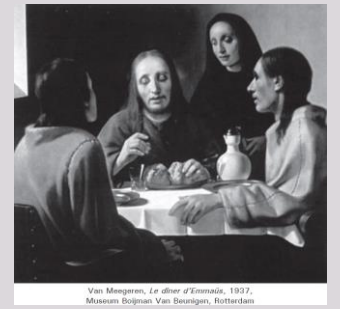
The tambourine N 1445 was attributed from between the 19th and 30th Dynasties (1300 to 340 BC)



Same period → end of the Third Intermediate Period

Quiles, A., Emerit, S., Asensi-Amorós, V., Beck, L., et al.. Radiocarbon 63, 2021

3-Art forgeries



Vermeer, Hals/Van Meegeren

“Millions of counterfeit art works are circulating in the online environment”



The exhibition in Genoa, Italy was shut down three days early on July 13th, 2017.

After careful examination, experts confirmed that 20 of the 21 paintings seized by the prosecutors were forgeries.



There are many forgeries of Alberto Giacometti's *Walking Man*.



Calligaro et al.



Tête “égyptienne” bleue du Louvre, Biron et al.



In der Art des Leonardo da Vinci Flora

Anchiano 1452-1519 Amboise

16. oder 19. Jahrhundert, Wachs

Die berühmte Wachs­büste der *Flora* hatte Wilhelm Bode 1909 in der festen Überzeugung erworben, dass es sich um ein Werk Leonardo da Vincis, oder aus dessen Umfeld handelt. Von anderen als Arbeit des 19. Jahrhunderts erkannt, geriet sie über 100 Jahre ins Kreuzfeuer. Bode ließ sogar eine Öffnung in die Rückseite schneiden, um die Echtheit zu beweisen. Fachleute streiten bis heute um die Zuschreibung der *Flora*. Wird das Geheimnis je gelüftet?

Erworben 1909

Acquired in 1909

SMB-SBM, Inv. Nr. 5951

Erforscht mit Unterstützung der Ernst von Siemens Kunststiftung.
Researched with the support of the Ernst von Siemens Kunststiftung.

In the Style of Leonardo da Vinci Flora

Anchiano 1452-1519 Amboise

16th or 19th century, wax

Wilhelm Bode acquired the famous wax bust of *Flora* in 1909 with the firm conviction that it was a work of Leonardo da Vinci or his circle. Recognised by others as a 19th-century work, it came under heavy criticism for over 100 years. Bode even had an opening cut into the back side to prove its authenticity. Experts argue to this day over the attribution of the *Flora*. Will the secret ever be revealed?



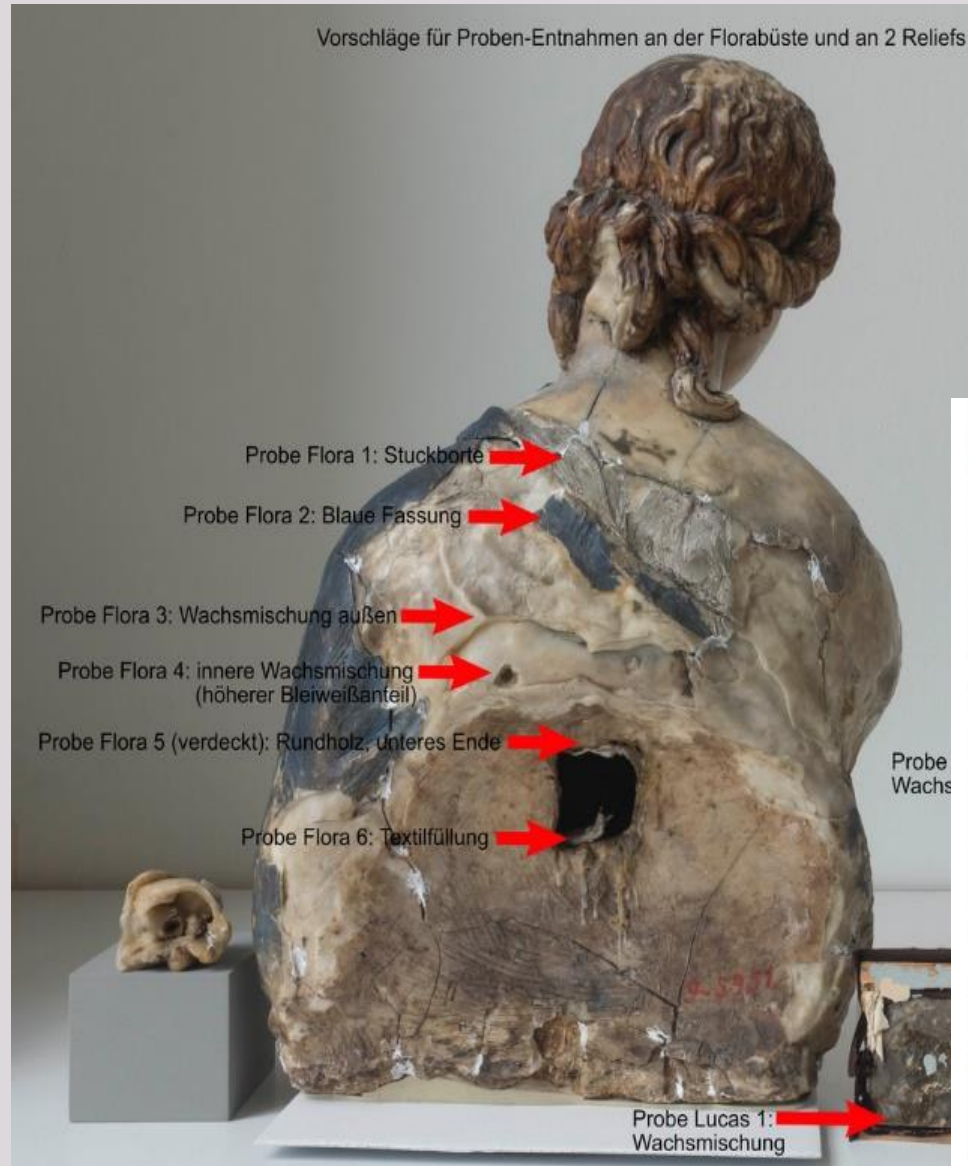
In der Art des
Leonardo da Vinci
Anchiano 1452-1519 Amboise
Flora

16. oder 19. Jahrhundert, Wachs

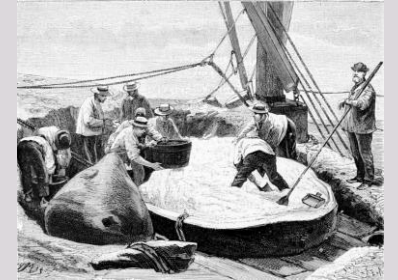
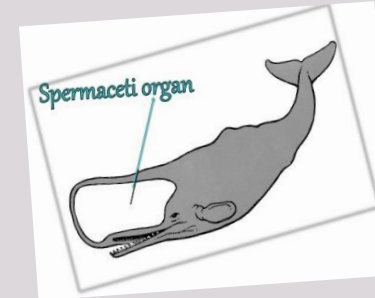
Die berühmte Wachs­büste der *Flora* hatte Wilhelm Bode 1909 in der festen Überzeugung erworben, dass es sich um ein Werk Leonardo da Vincis, oder aus dessen Umfeld handelt.

In the Style of
Leonardo da Vinci
Anchiano 1452-1519 Amboise
Flora

16th or 19th century, wax



- 7 wax samples (unusual material coming from the head of the sperm whales, called spermaceti)

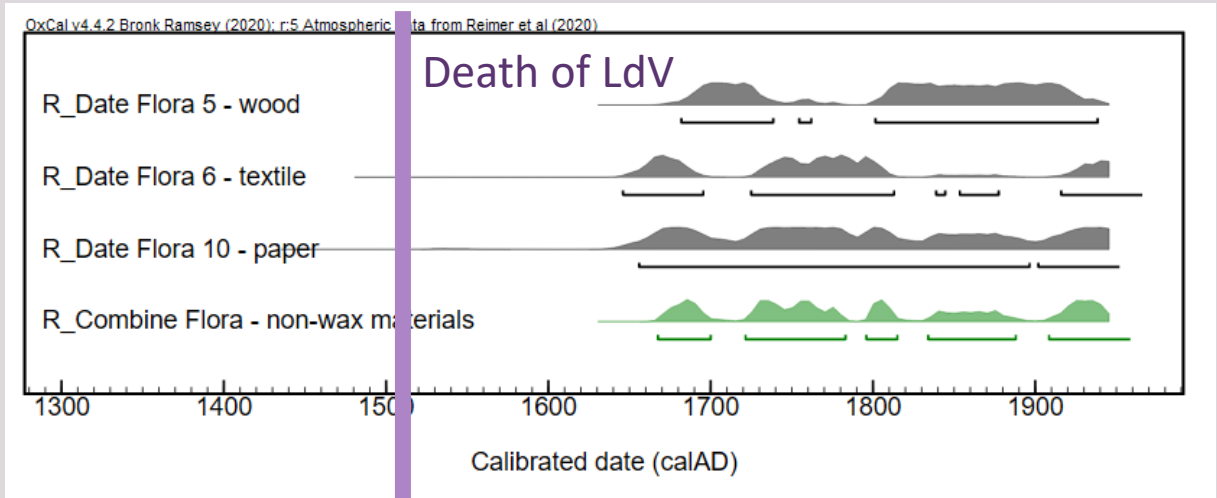


used for candles, cosmetics, pharmacy from 1750

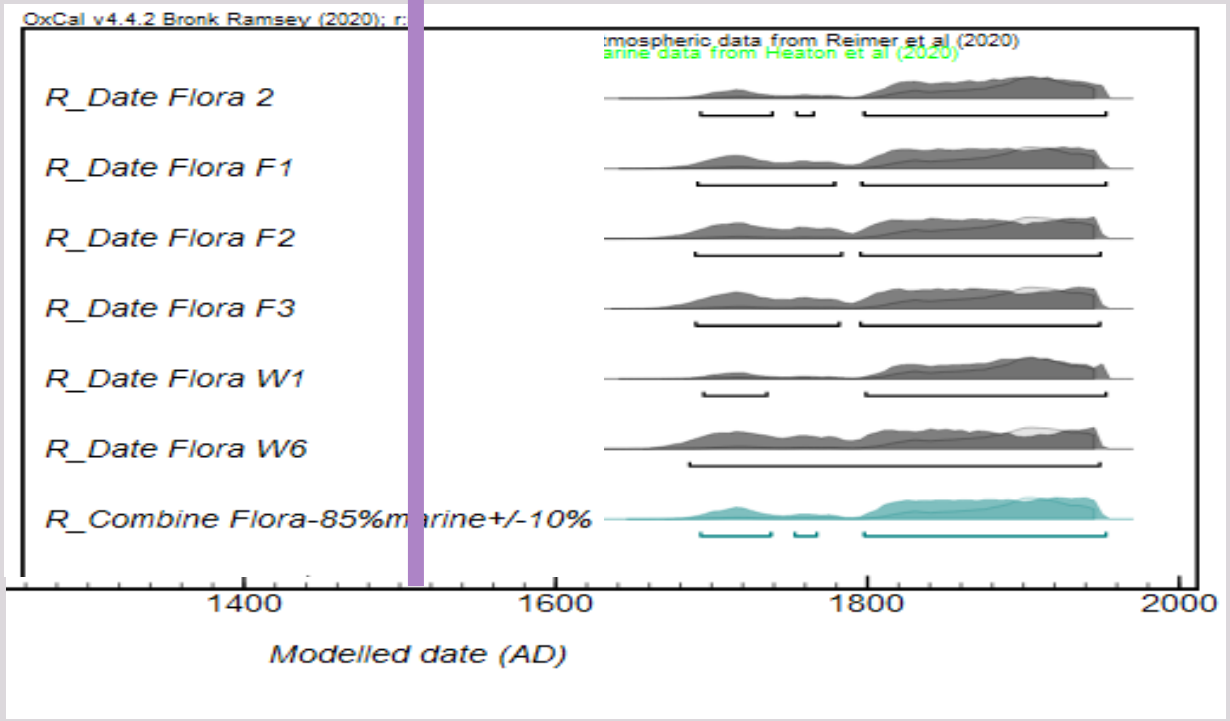


- 3 other samples: wood, paper and textile

Terrestrial samples
Wood, paper, textile
After 1670



Wax samples
(Spermaceti + beeswax)
After 1707



scientific reports

April 2021

OPEN

New results with regard to the Flora bust controversy: radiocarbon dating suggests nineteenth century origin

Ina Reiche^{1,2,3}, Lucile Beck³ & Ingrid Caffy³





From Fake Flora to a Gold Robbery: A Virtual Tour through the History of the Bode-Museum

13.04.2021

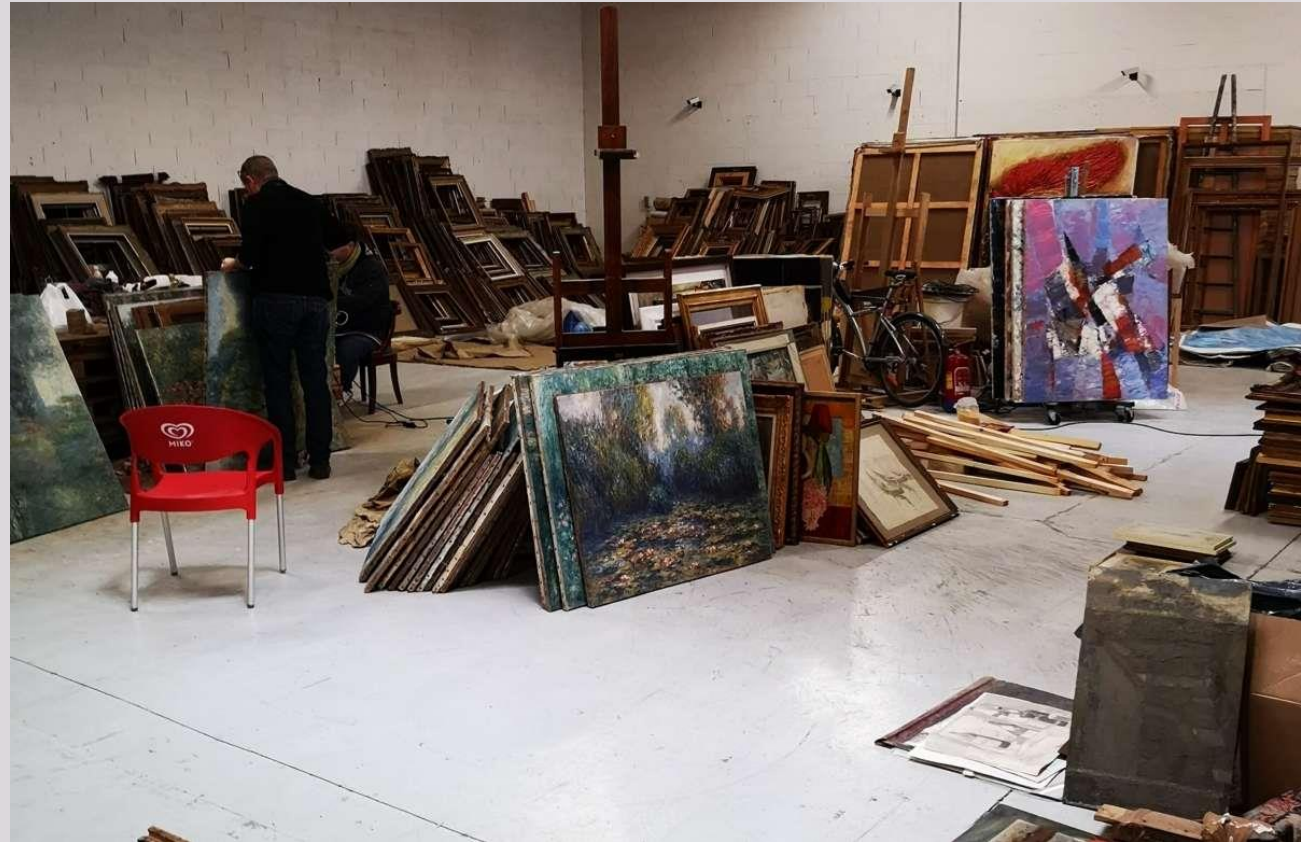
[Bode-Museum](#)

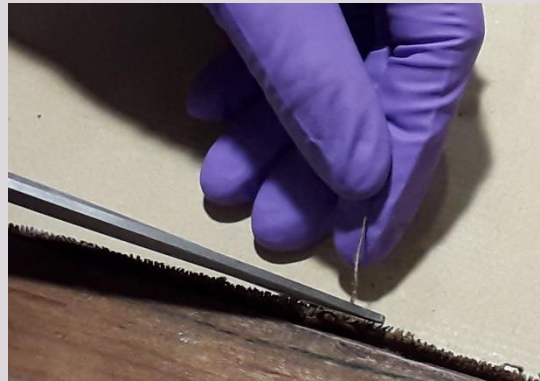


Radiocarbon dating of seized paintings

Hundreds of paintings were discovered in a restorer's workshop by the French *Central Office for the Fight against Illicit Trafficking in Cultural Property (OCBC)*

From Impressionist period to contemporary art





Bomb peak: “the nuclear option”



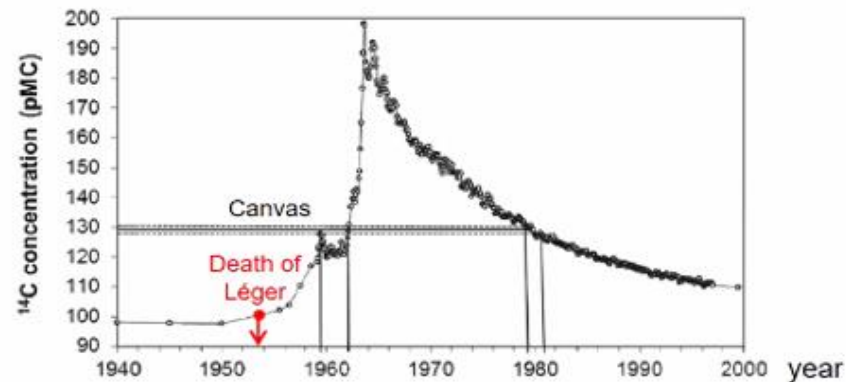
Contraste de formes, Fernand Léger (?)
Peggy Guggenheim Collection, Venice



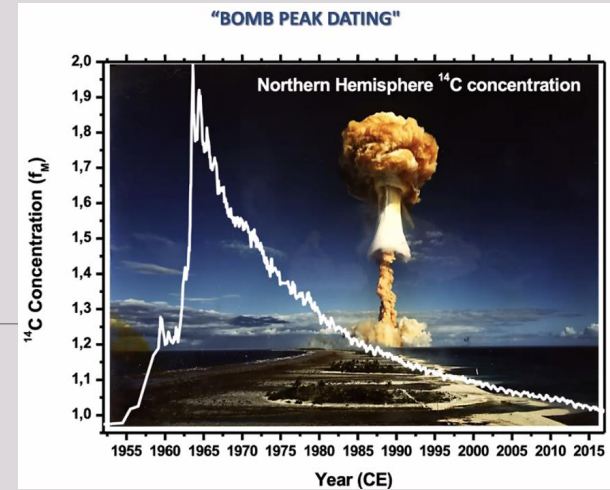
Contraste de formes, Fernand Léger (1881-1955), 1913,
Solomon G. Guggenheim Foundation, New York



Detail of the canvas sample



L. Caforio et al., Discovering forgeries of modern art by the ^{14}C bomb peak, *Eur. Phys. J. Plus* **129:6** (2014)

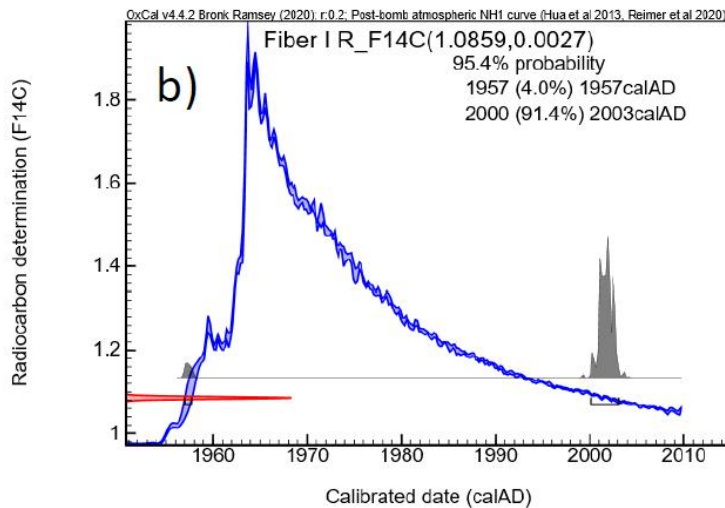
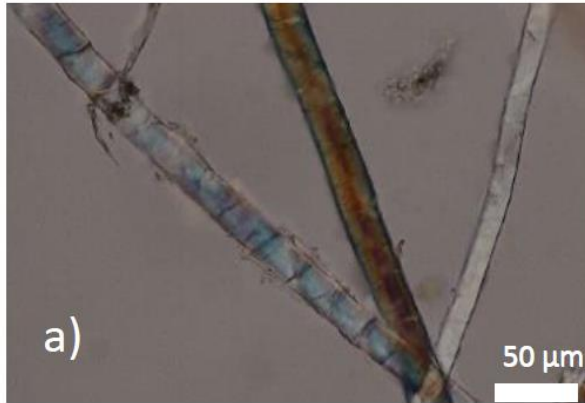


Atmospheric nuclear tests carried out in atmosphere after 1950 resulted in an increase of the ^{14}C concentration by almost a factor 2 in the mid 1960s

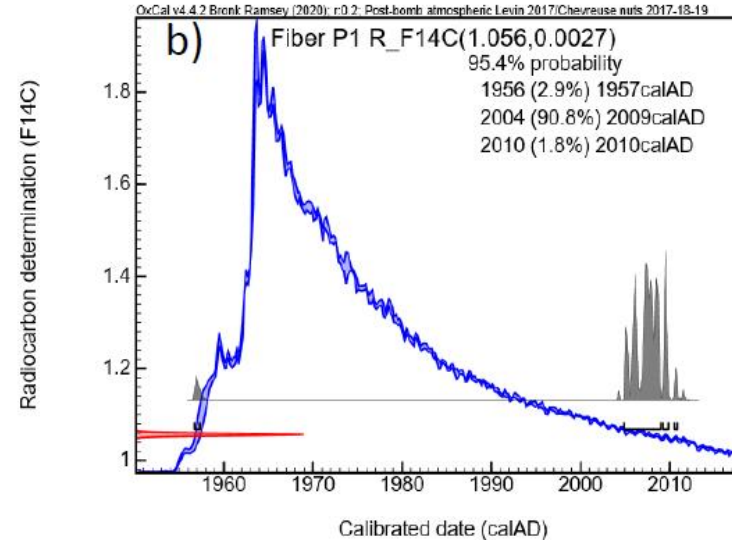
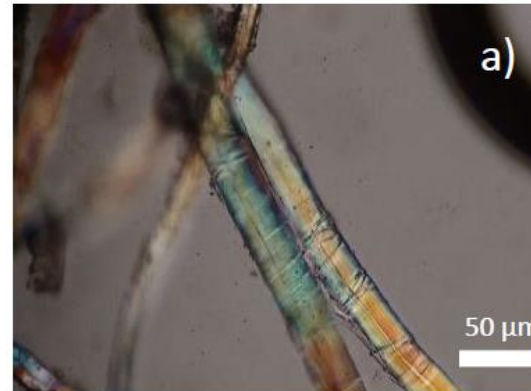
- 😊 High resolution
- 😊 Bomb peak curve well documented
- 😊 Calibration software freely available and easy to use
- 😞 Multiple intercepts

Dating canvas fibers

Impressionist



Post-impressionist



1) Identification of the fibers

Bast fibers → flax used for linen

2) Plants producing the fabric fibers were harvested

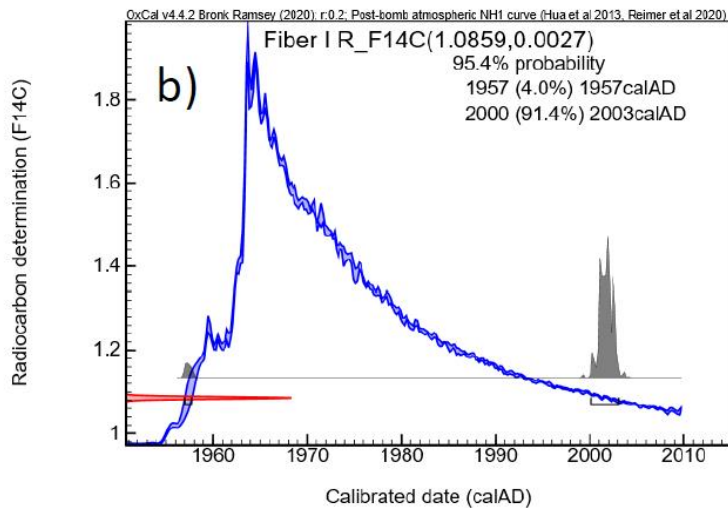
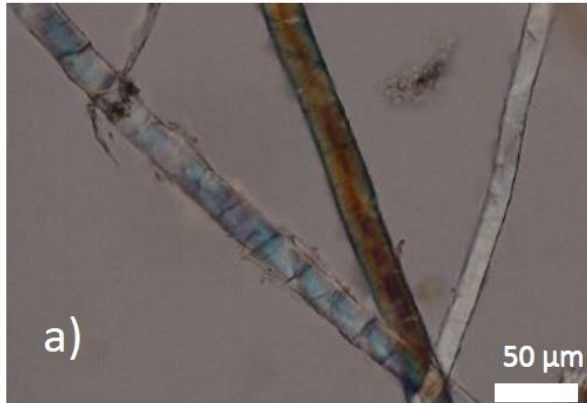
- in 1957 or between 2000 and 2003 for the Impressionist painting (alleged artist died in 1947)

- in 1956-1957 or between 2004 and 2010 for the Post-impressionist painting (alleged artist died in 1943)

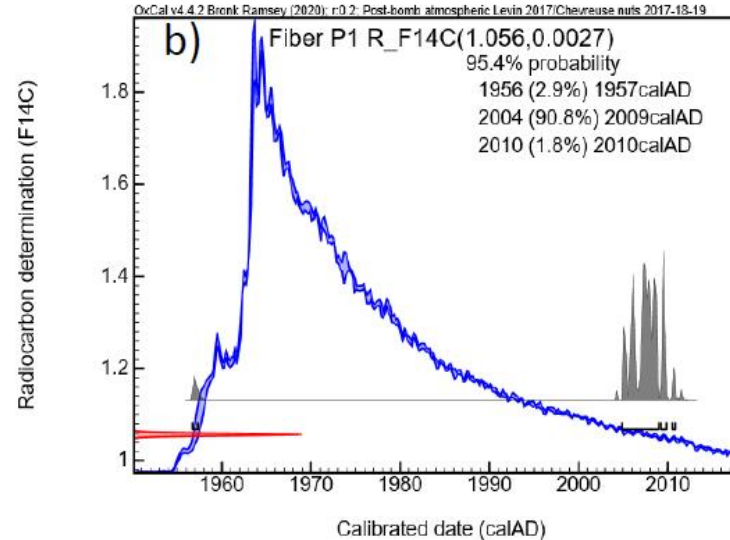
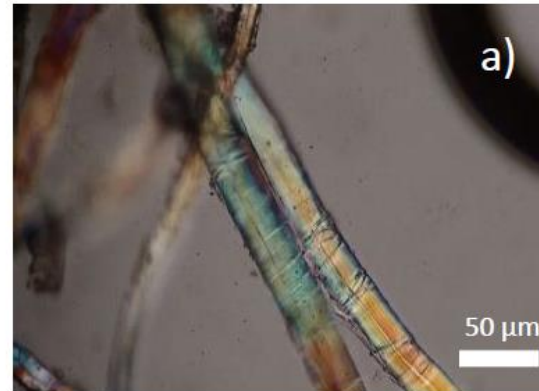


Dating canvas fibers

Impressionist



Post-impressionist



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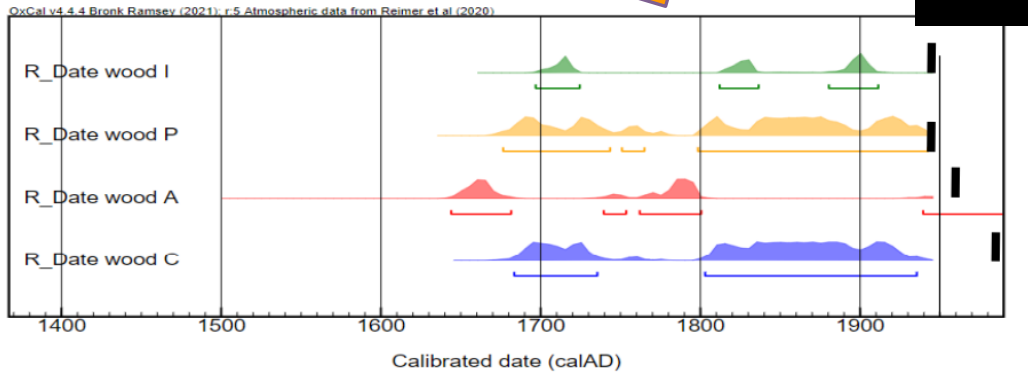
- in 1957 or between 2000 and 2003 for the Impressionist painting (alleged artist died in 1947)

- in 1956-1957 or between 2004 and 2010 for the Post-impressionist painting (alleged artist died in 1943)

Radiocarbon dates > death of the alleged artist → modern forgeries

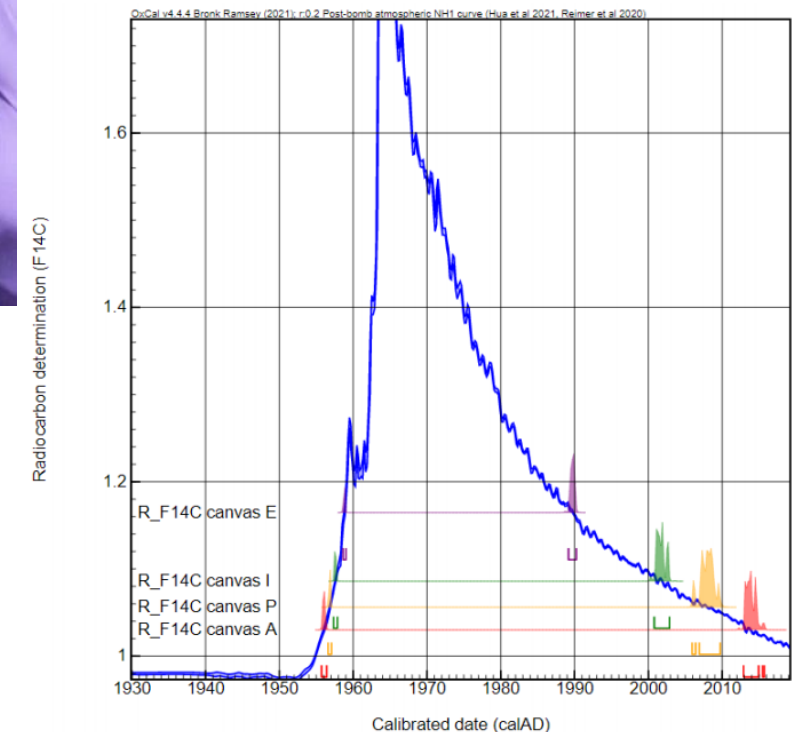
Beck, al. Forensic Science International 333 (2022) 111214 (Special Issue in Nuclear Technologies for Forensic-IAEA CRP)

Dating canvas fibers is the key!



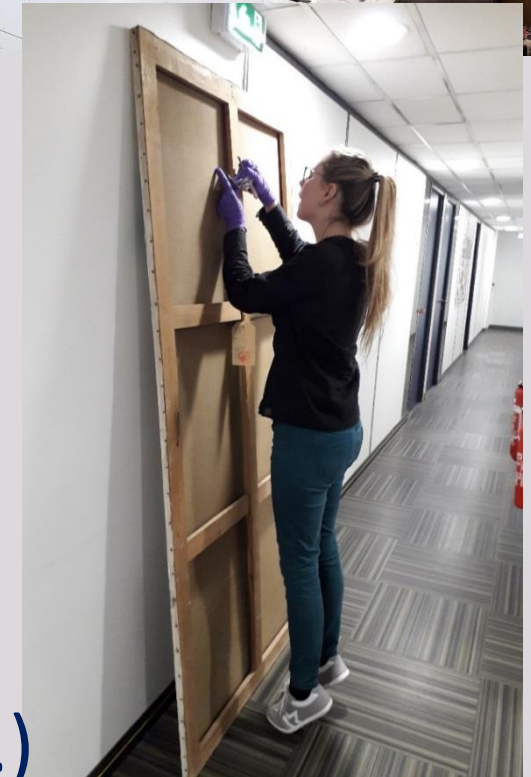
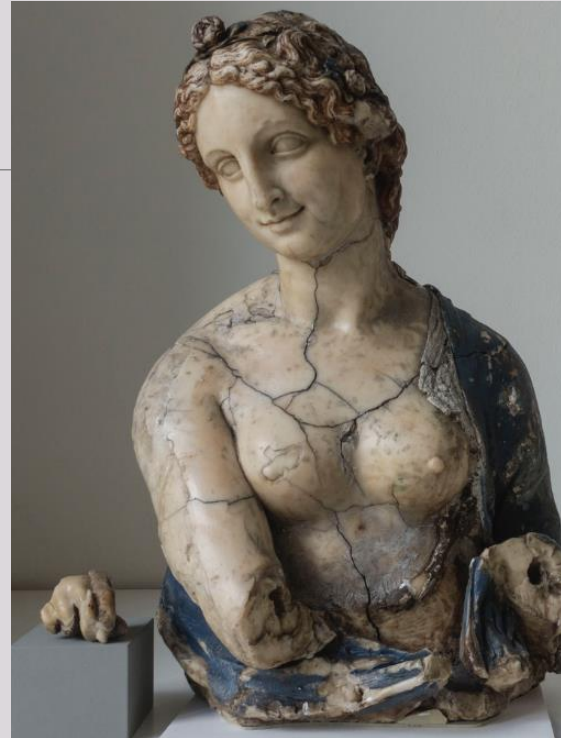
Dates before 1950 → Old wood or selection of ancient stretchers by the forgers

Beck, Physics 4, (2022) 462–472

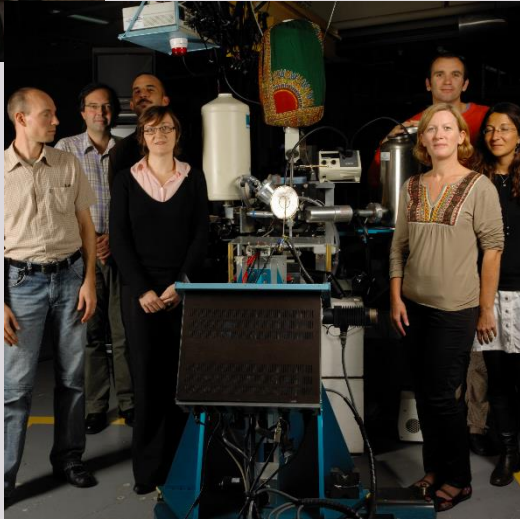


Dates after 1950 → Painted after 1955

Accelerators for CH



from fundamental and applied research to current issues (for museum, police,...)



AGLAE colleagues

lucile.beck@cea.fr





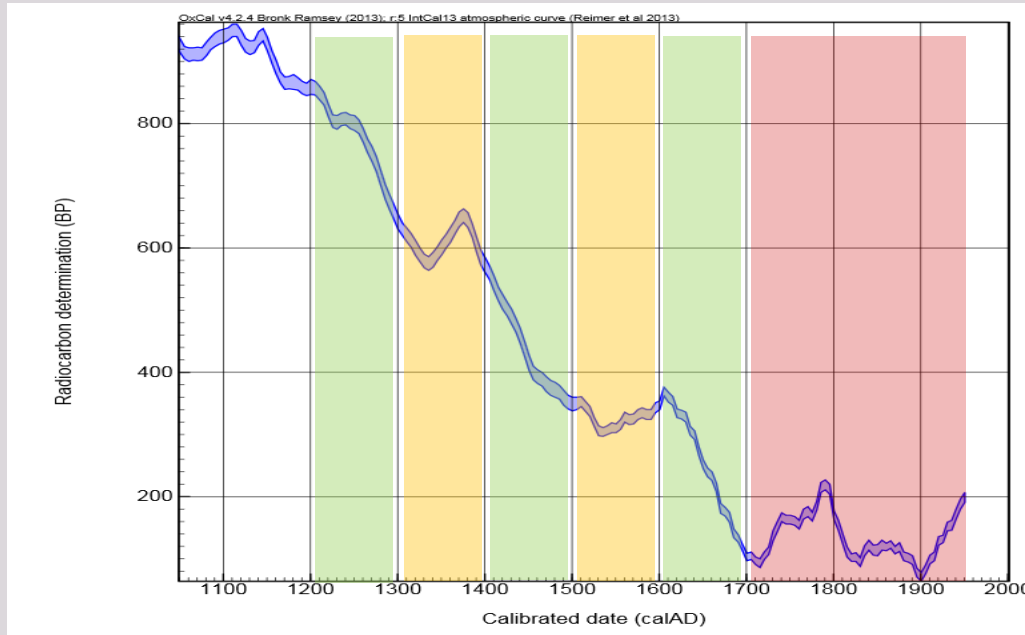
News

<http://lmc14.lsce.ipsl.fr/index.html>

Le Laboratoire de Mesure du Carbone 14 (LMC14) réalise les mesures de carbone 14 pour la communauté scientifique nationale. Créé en 2003 en tant qu'unité mixte de service, la Plateforme Nationale LMC14 est rattachée au LSCE depuis 2015.

Detecting forgeries using ^{14}C

Calibration curve up to 1800 based on natural ^{14}C fluctuations



^{14}C was long considered:

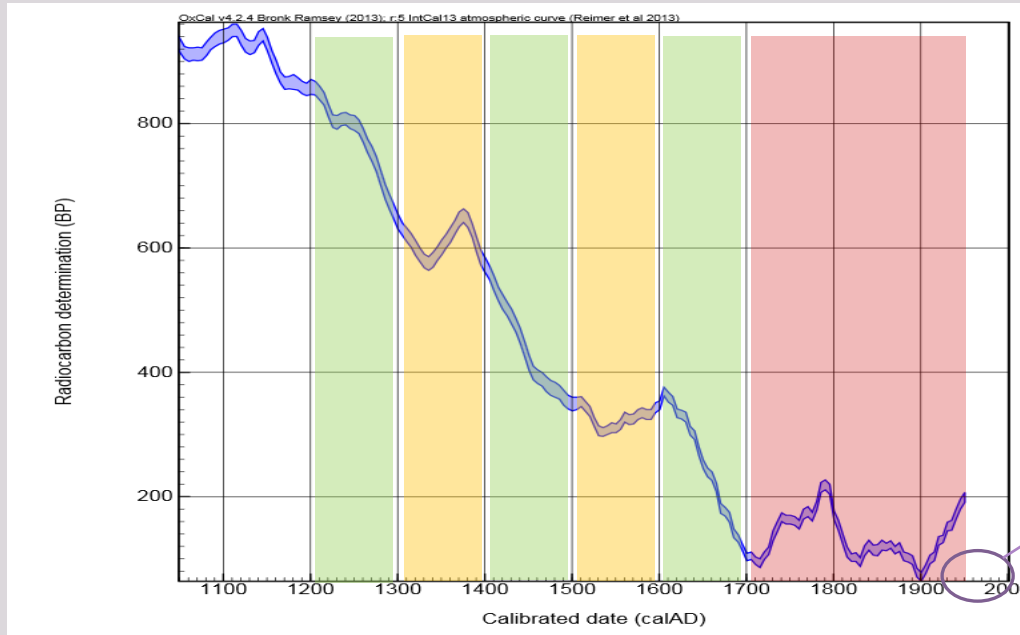
- Too invasive
→ AMS and μ sample procedures
- Too imprecise

Precise

Imprecise

Detecting forgeries using ^{14}C

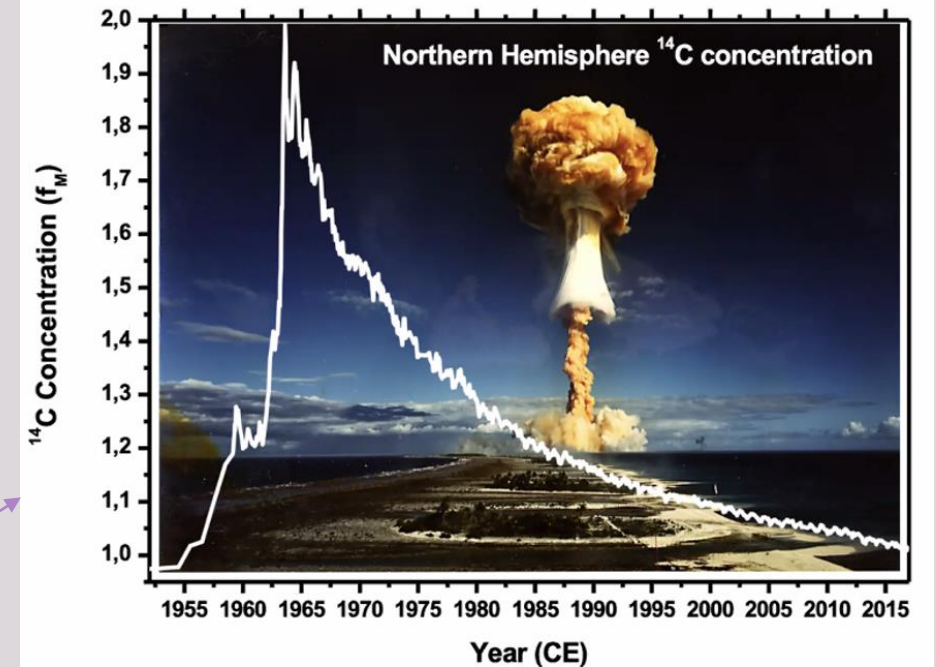
Calibration curve up to 1800 based on natural ^{14}C fluctuations



Precise

Imprecise

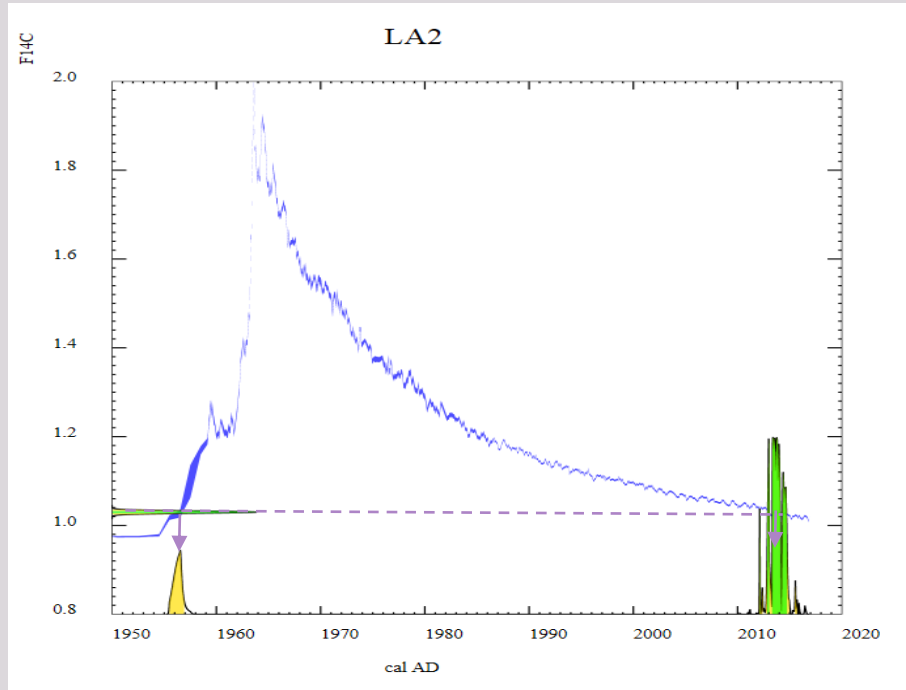
"BOMB PEAK DATING"



Atmospheric nuclear tests carried out in atmosphere after 1950 resulted in an increase of the ^{14}C concentration by almost a factor 2 in the mid 1960s

Bomb peak: “the nuclear option”

^{14}C value ($F^{14}\text{C}$) :
 1.0301 ± 0.0027



Two solutions:

1955 – 1956

2012 – 2014

- ☺ High resolution
- ☺ Bomb peak curve well documented
- ☺ Calibration software freely available and easy to use
- ☹ Multiple intercepts

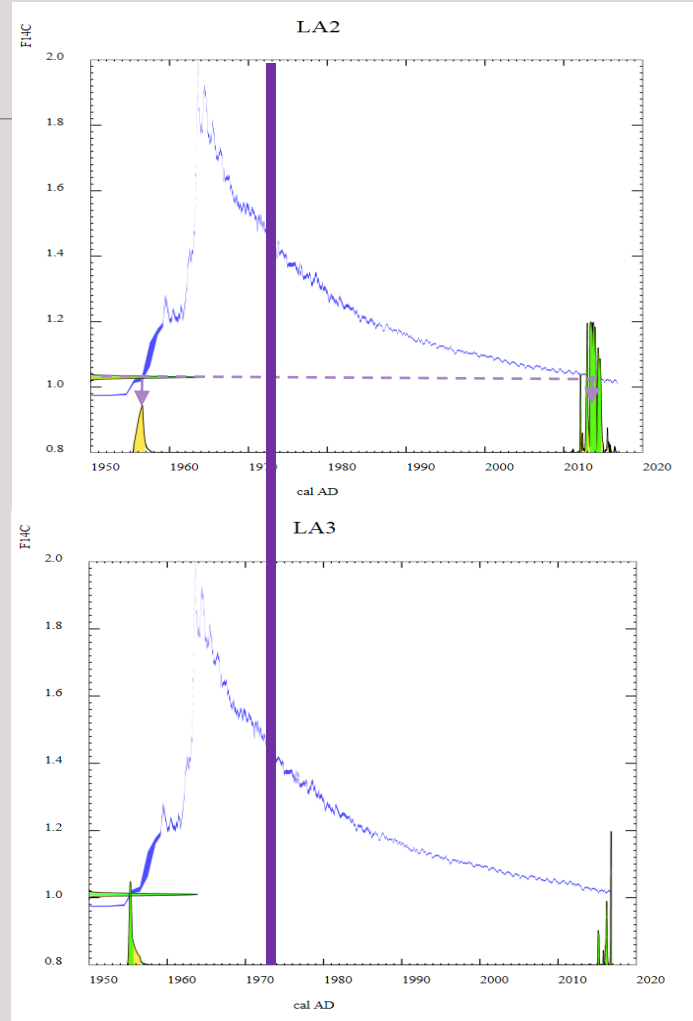


- 2800 samples to be dated per year
(→ \approx 4000 samples including calibration, normalisation, blanks)
- 11 permanent positions (mainly engineers and technicians)
- 80% service/20 % research



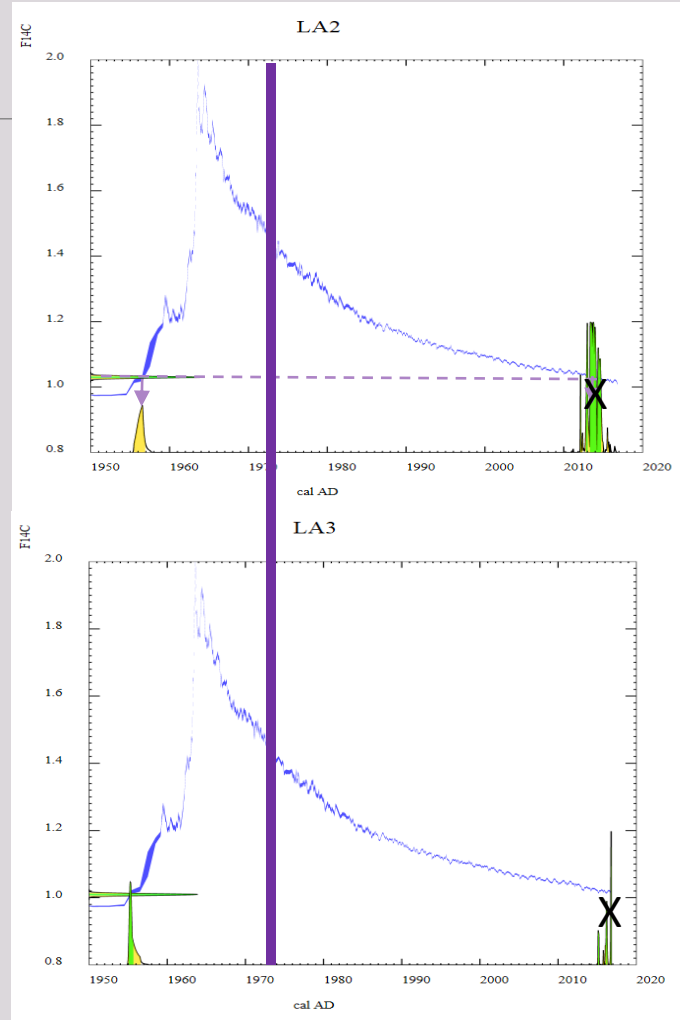
Dating canvas fiber and paint!

Abstract painting (1970s)



Dating canvas fiber and paint!

Abstract painting (1970s)



Good agreement with the active period of the artist who died in 1976, but 20 years before the date of the painting
→ Acceptable for the canvas, but less probable for the paint

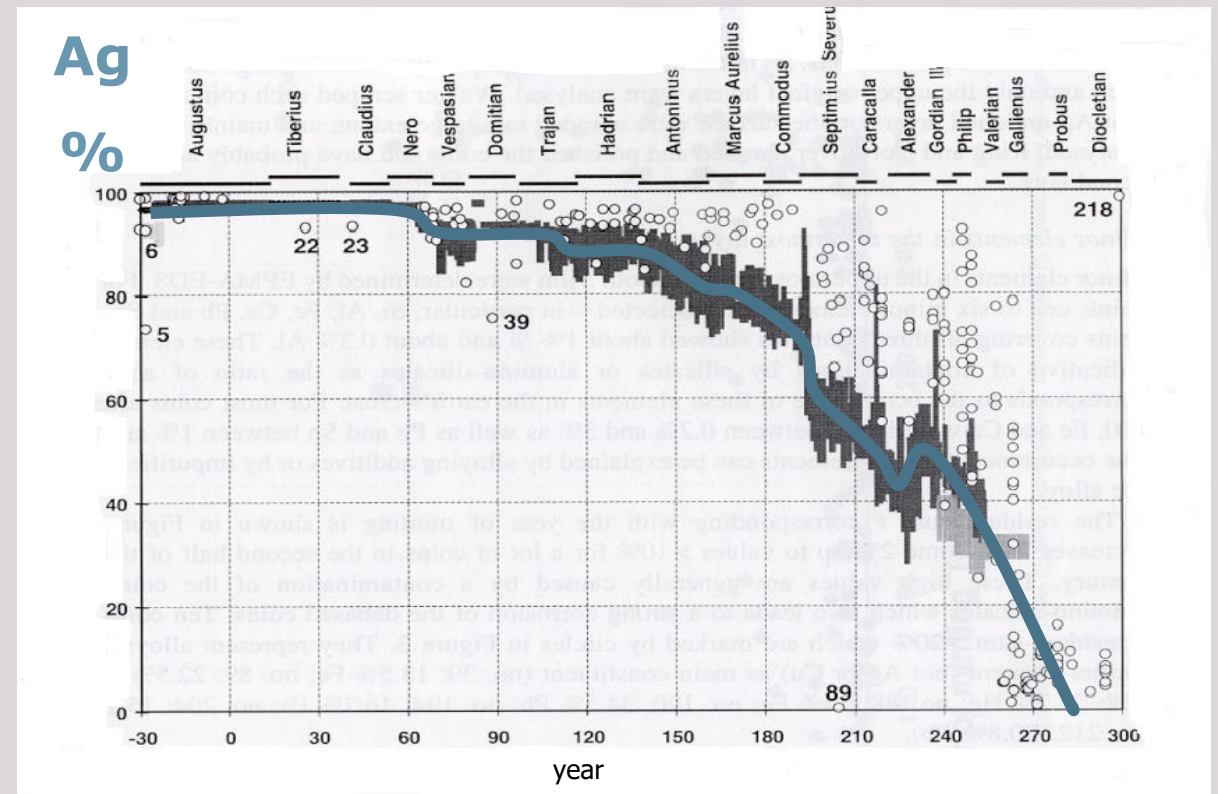
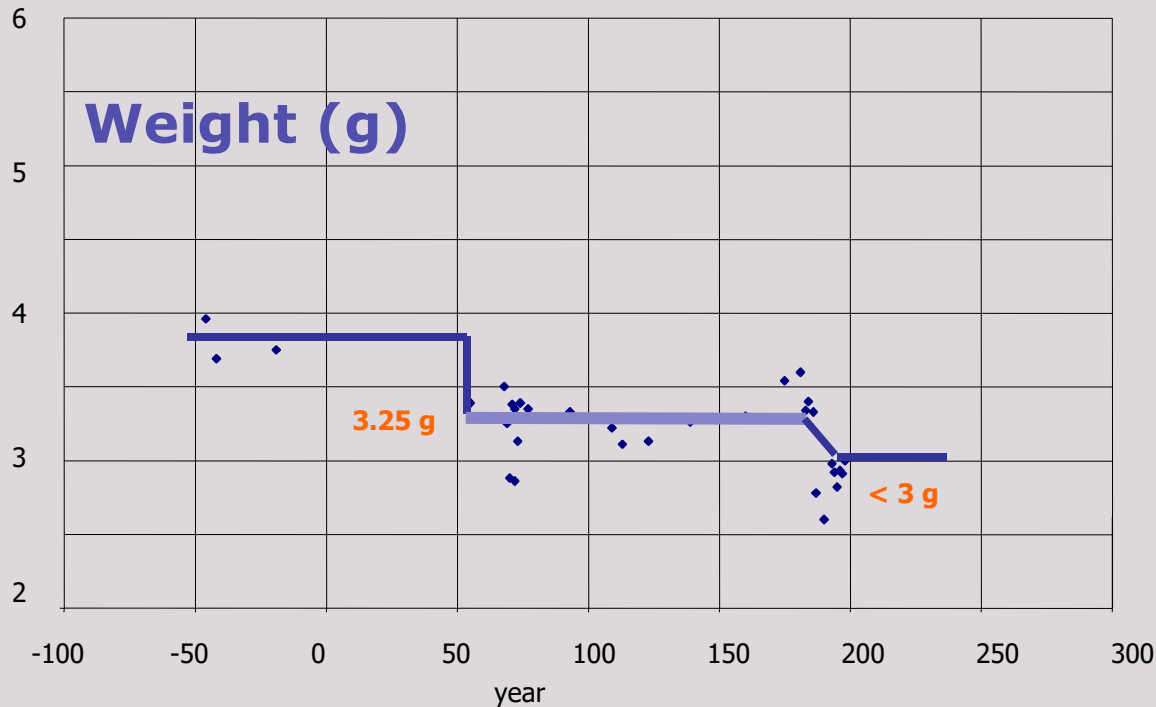
→ **Probably a fake**

Official coinage

Example: ROMAN DENARIUS (from 50 BC to 300 AD)

3.9 g ; %Ag > 98%

But inflation and debasement = decreasing the precious metal content (gold or silver)

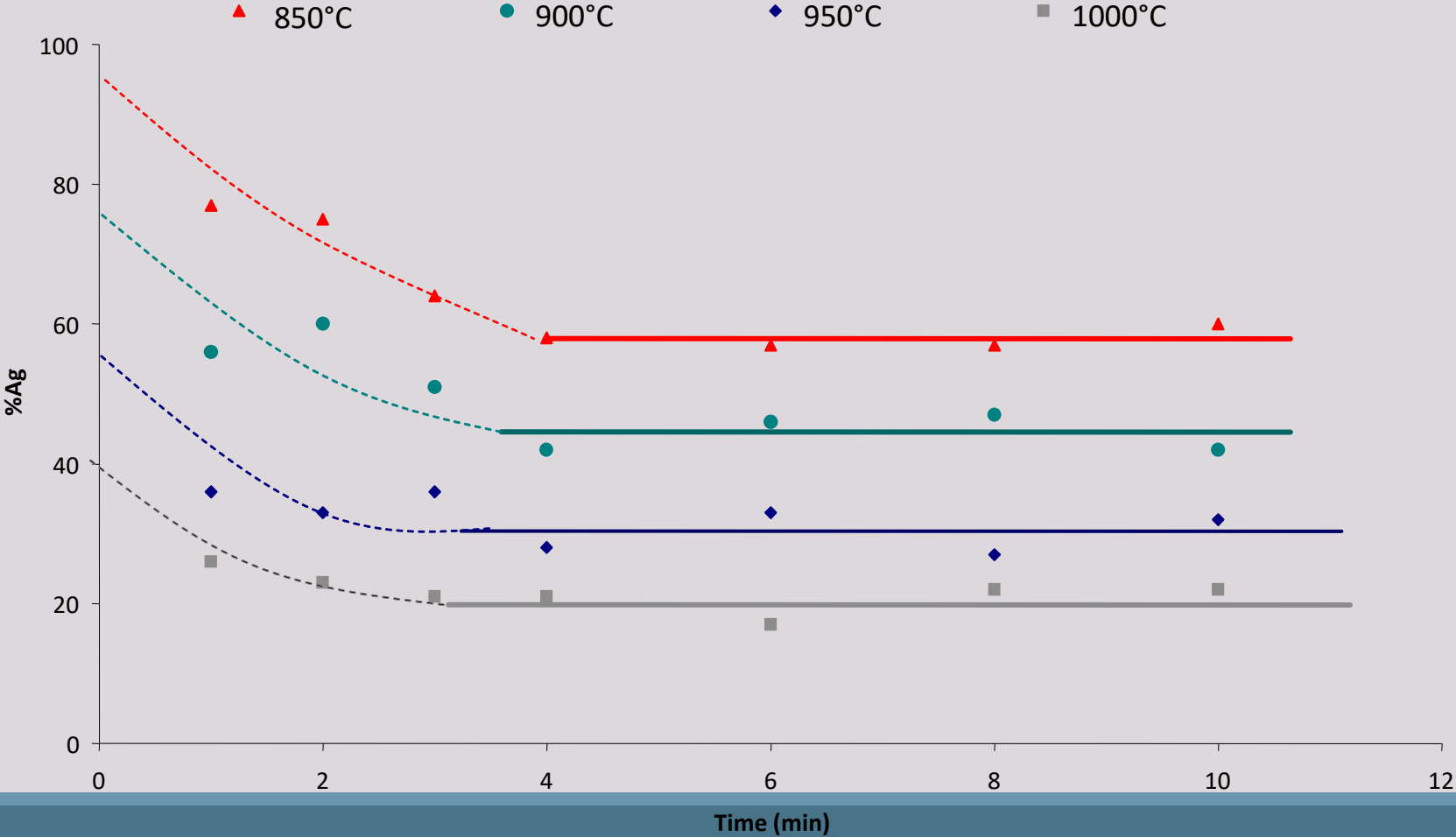


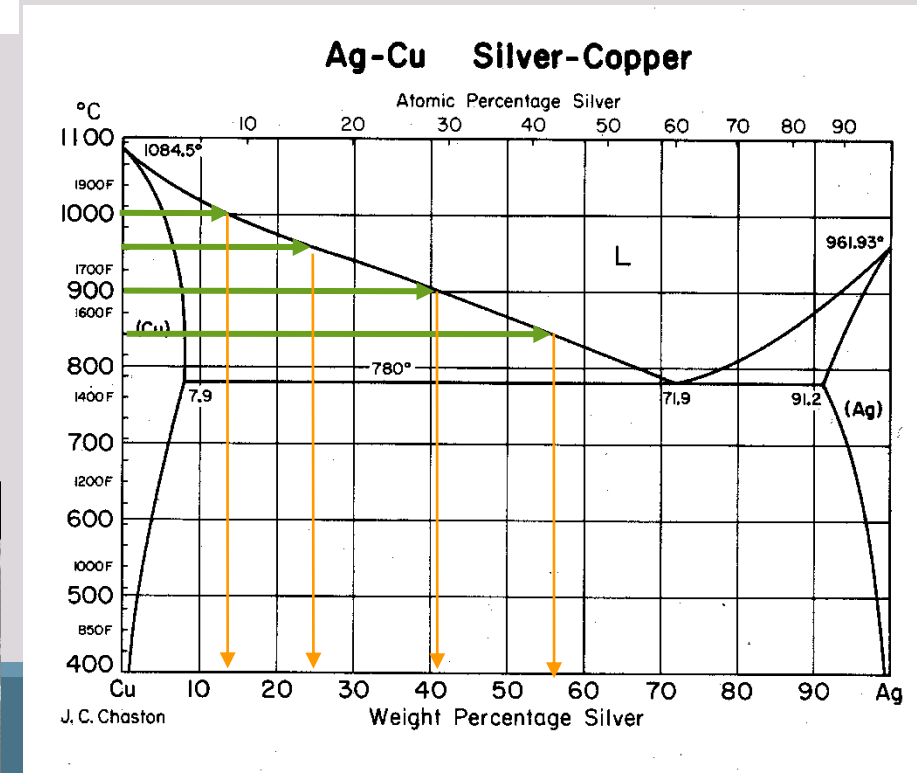
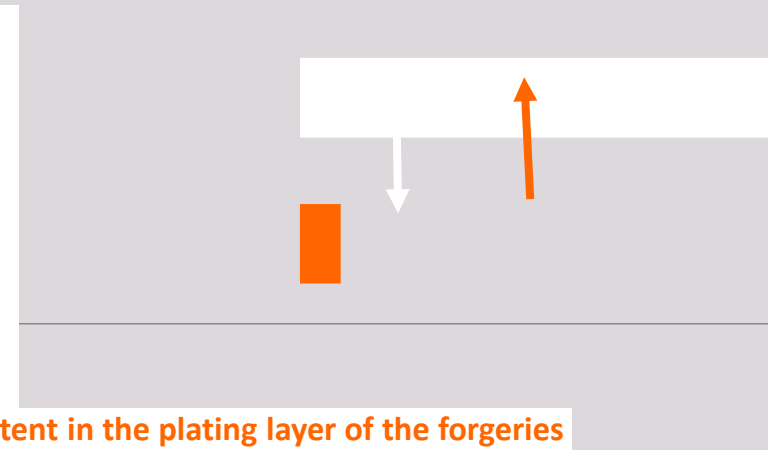
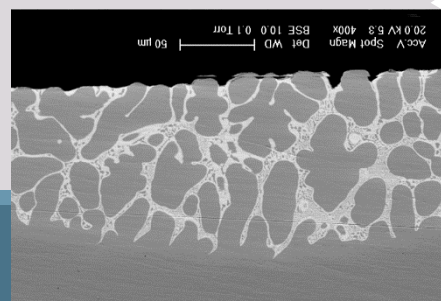
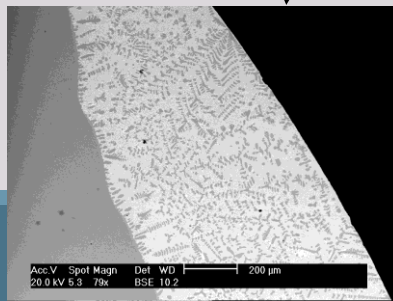
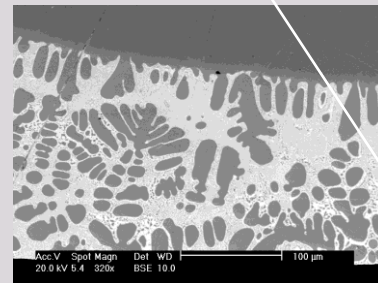
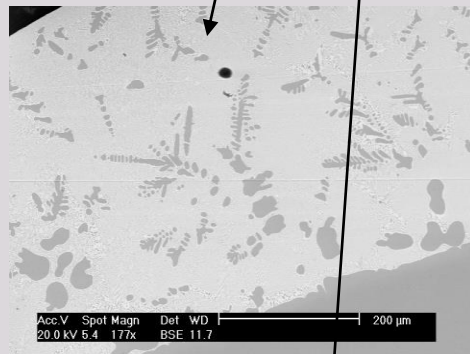
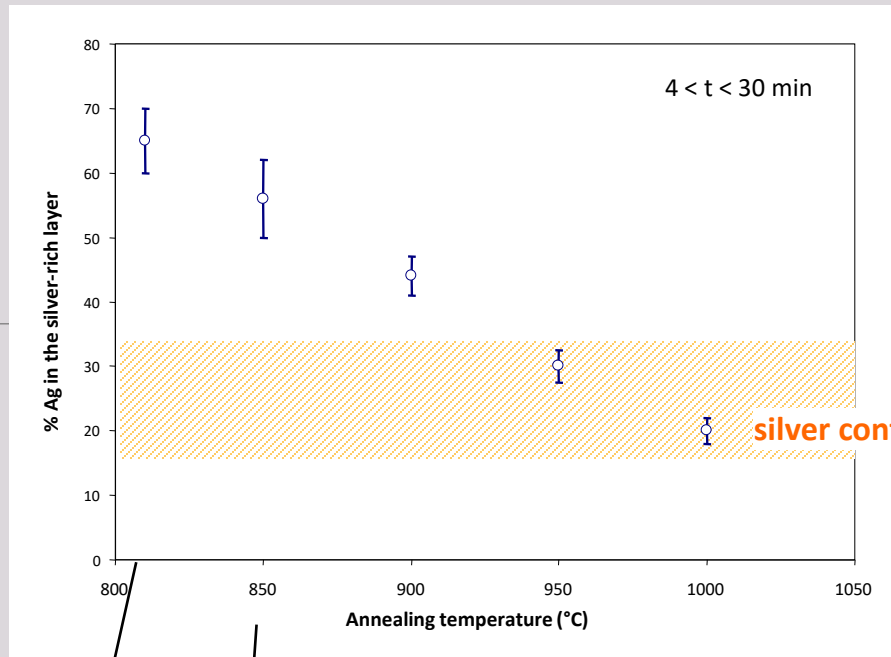
from Walker, 1976-78 and
Klockenkämper et al., 1999

→ Reducing the coin weight: lower mass

→ Reducing the fineness: gold or silver mixed with base metal, generally copper

Replication





Official versus Non-official in the 3rd c.

**Official Roman coin
Postumus (262 AD)**

versus

**Non official
Postumus
(~ 262-268 AD)**



According to
the
numismatist:

Fine design

versus

Bad quality
of engraving

According to
the
chemist
using
FNAA:

20 % of
silver

versus

< 3 %

(+ traces
elements)

According to
the
metallurgist:

Homogeneous
silver/copper
alloy

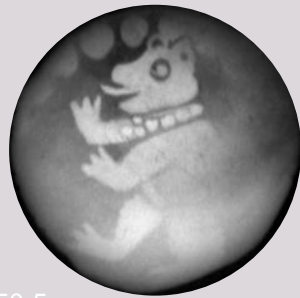
versus

~ 50 µm thick
layer of
silver/copper
alloy on a
copper core

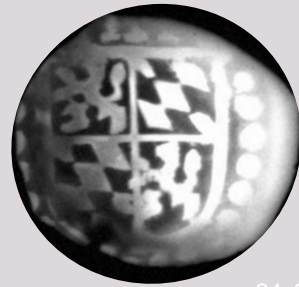
Official versus Non-official in the 16th-17th c.

Official coin

versus



50-5



81-9

According to
the
numismatist:

Fine design

versus

Bad quality
of engraving

According to
the chemist
using PIXE:

20-50 % of
silver

versus

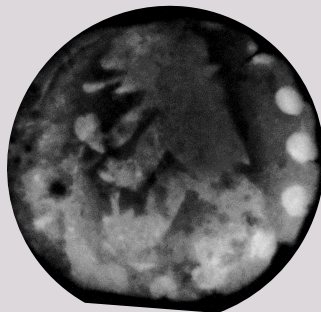
< 5 %
(+ mercury)

According to the
chemist using PIXE-
RBS:

Homogeneous
silver/copper alloy

versus

~ 1-2 μm thick layer
of
▪ **silver**
or
▪ **silver + mercury**
on a copper core



23-35



63-65

Non-official

Counterfeit, Fake, Forgery...

From an exhibition by the Victoria and Albert Museum in London, U.K

Counterfeit is a general term: **imitate something authentic**, with the intent to steal, destroy, or replace the original, for use in illegal transactions, or otherwise to **deceive individuals into believing that the fake is of equal or greater value than the real thing** (Wikipedia)

What is a fake?

... an object that has been tampered with – e.g. a signature has been added or false indications of the object's history have been introduced with **the intention to defraud and increase the item's value.**

What is a forgery

... an object that is created from scratch with the intention to deceive – it is a **fraudulent imitation of an existing work.**

What is fraud?

... “the act of making people believe something is not what it really is for criminal benefit.”

What is a copy?

... a direct replica of a pre-existing work or a work that imitates or was created in the style of a given artist. If the work is in the public domain, it is not illegal to make a copy of it provided there is no attempt to deceive or make anyone believe it is an original work. To reproduce a contemporary work protected under copyright law requires the permission of the artist whose work is being copied.

What is misattribution?

... this arises when a mistake is made in determining the original artist of a work and typically occurs when works have been restored and original details masked. This is considered a genuine mistake as there is no intention to deceive.

Common features:

Imitation with similar materials, but

- Lower value

- Low quality

→ different in composition



Material analysis

and

→ made at different or same time



Absolute dating methods

Ancient coins

Gold, silver and bronze or copper were the coinage metals of the ancient world

Denomination → intrinsic value → precious metal content (weight and fineness)

Example:
Augustus
monetary
system in
19 BC



1 AUREUS
= 25 denarii
7.85 g - Ø 20 mm

Pure gold
(at the beginning...)



1 DENARIUS
= 16 asses
3.9 g - Ø 18 mm

Pure silver



1 SESTERTIUS
= 4 asses
27 g - Ø 33 mm



1 AS
11 g - Ø 26 mm

After 1850 : ELECTROPLATING



Cu, approx. 30 μm

Coin production in the 16th c.

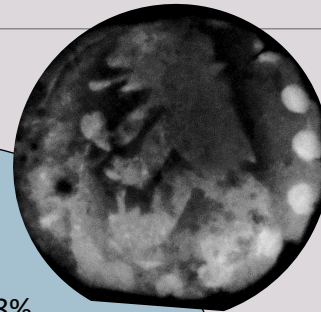
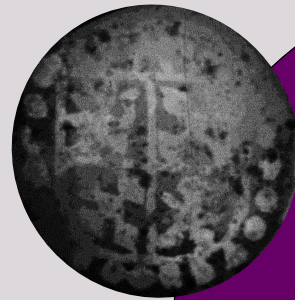


Focus on the silvering process

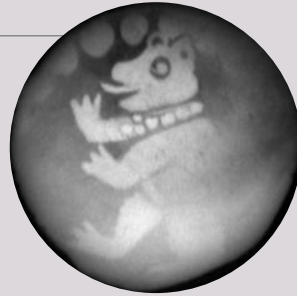


81-9

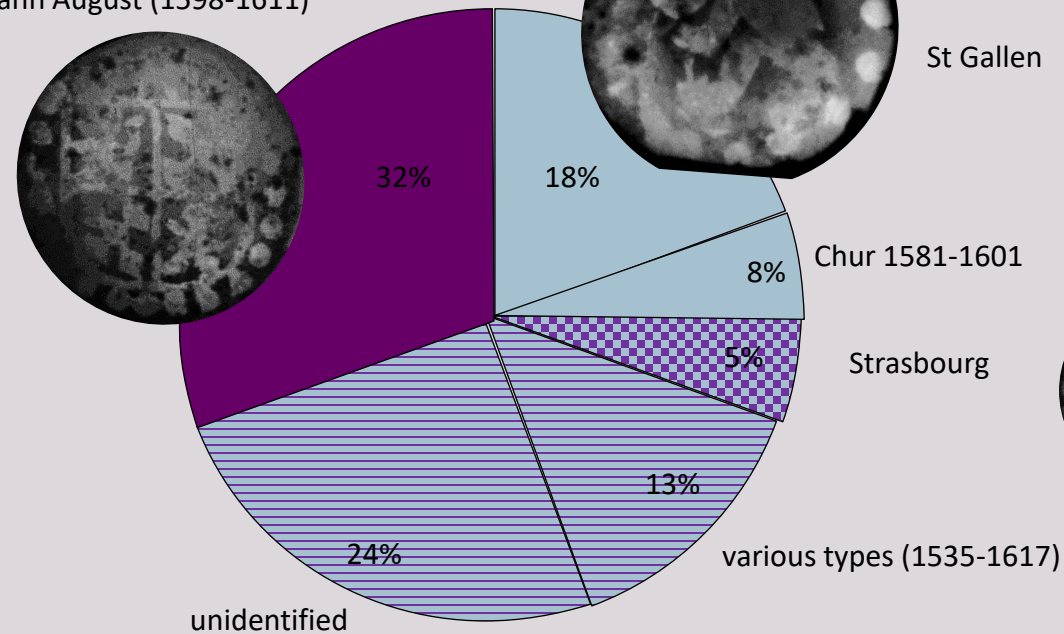
County of **Palatinat**-Veldenz
Johann August (1598-1611)



St Gallen



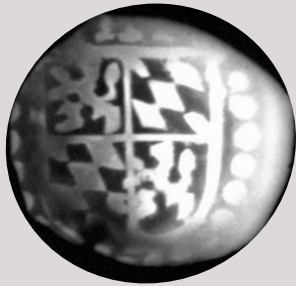
50-5



40 % mercury silvering

60 % thin layer of pure silver

Focus on the silvering process



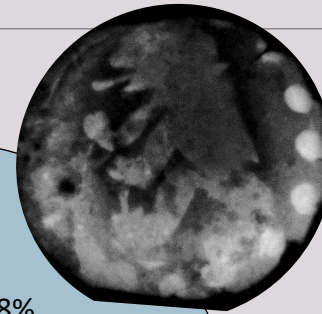
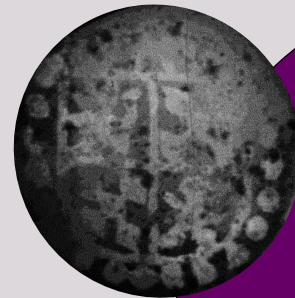
81-9

Mines of mercury

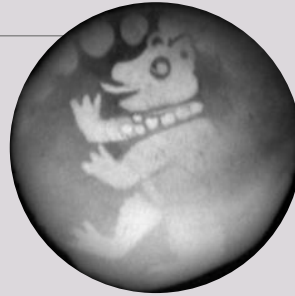


Moschellandsbergite
Landsberg near Obermoschel,
Rheinland-Palatinate
Germany

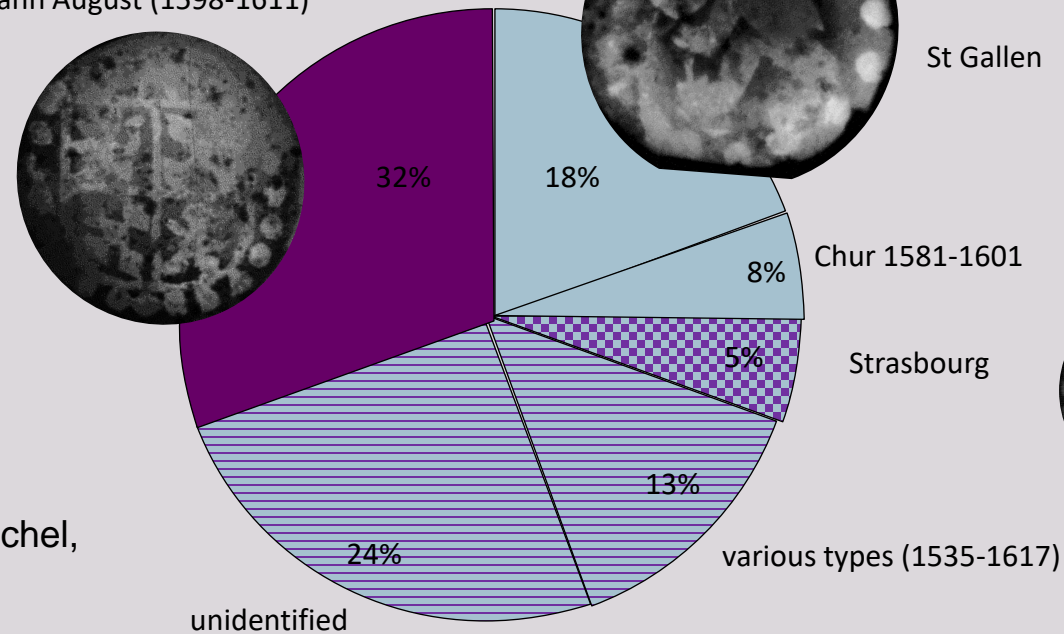
County of **Palatinat**-Veldenz
Johann August (1598-1611)



St Gallen



50-5



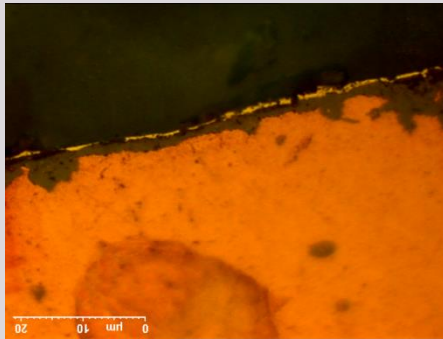
40 % mercury silvering

60 % thin layer of pure silver

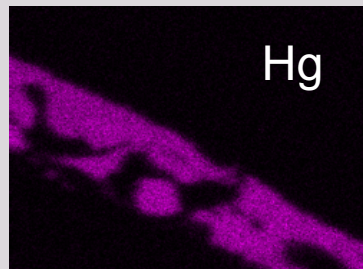
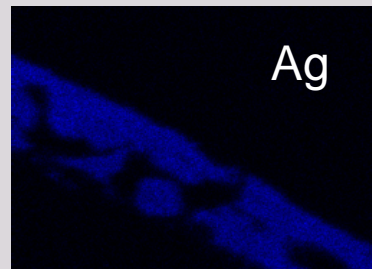
Silvering process by RBS (Rutherford backscattering spectrometry)

Non destructive analysis with 3 MeV protons

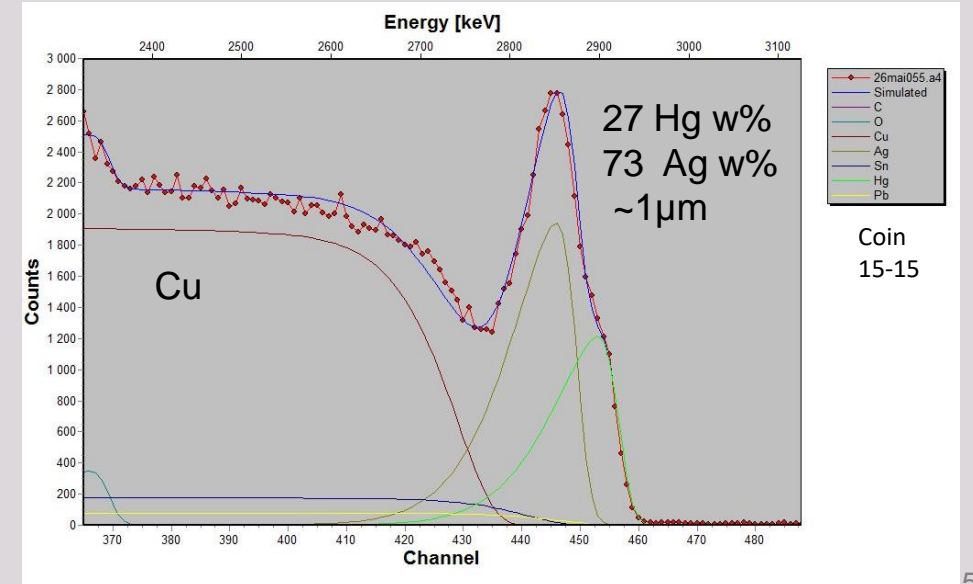
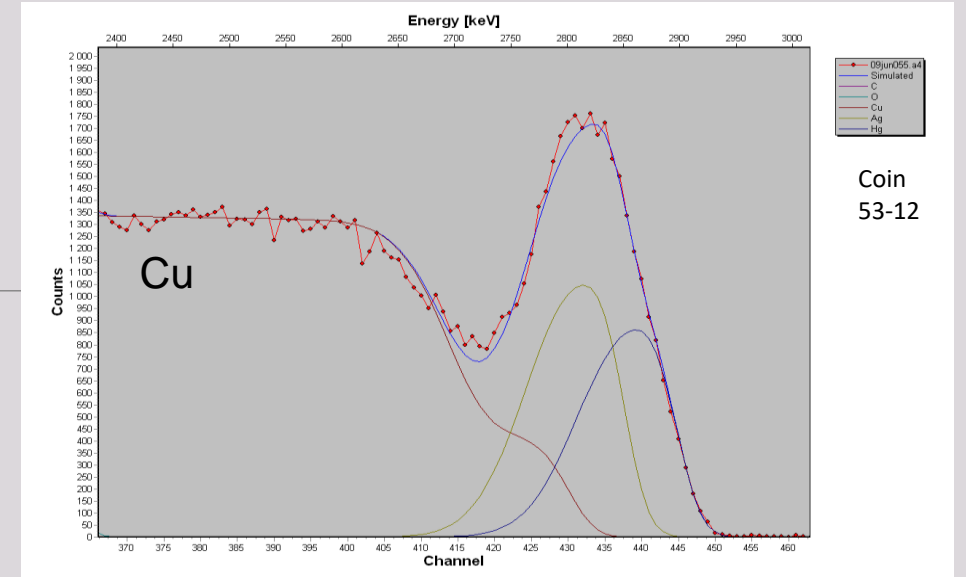
Very thin layer (1-2 μm)



Presence of mercury



⇒ One of the earliest case of **mercury** silvering!



In summary, how to make counterfeit plated coins (for scientific purposes, only) ?



1st c. BC

3rd c. AD



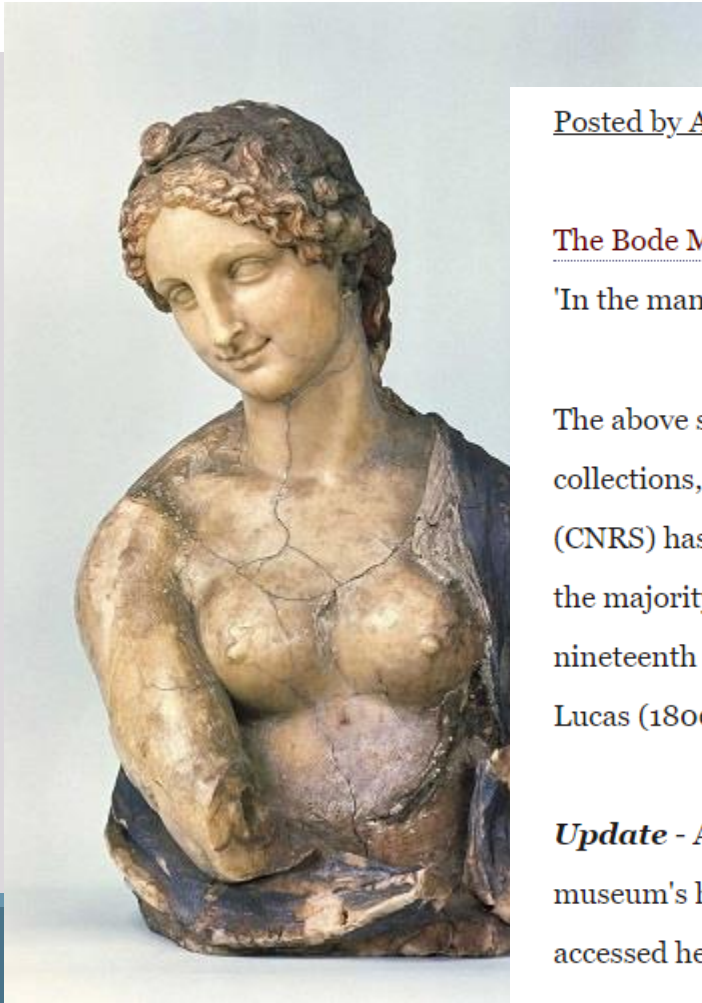
16th-17th c. AD





Bode Museum Finally Describes their 'Leonardo' as 'Manner of'

April 20 2021



Posted by [Adam Busiakiewicz](#):

The Bode Museum in Berlin have finally come round to re-cataloguing a dubious sculpture in their collection as 'In the manner of Leonardo Da Vinci'.

The above sculpture of Flora was purchased as a Leonardo in full in 1909 by the then director of Prussian art collections, Wilhelm von Bode. However, recent analysis by the French National Centre for Scientific Research (CNRS) has concluded that the piece must be a nineteenth century imitation. Scientific analysis has shown that the majority of the sculpture is made from spermaceti wax, a type of wax harvested for candles during the nineteenth century. Strong comparisons have been made with several works by the sculptor Richard Cockle Lucas (1800-1883), who has been suggested as the likely creator of the piece.

Update - A reader has kindly alerted me to the fact the sculpture is included within a new exhibition on the museum's history entitled [Klartext \(Plain Talk\)](#). [A free virtual tour of the exhibition](#), plus audio guides, can be accessed [here](#).

Counterfeit coins

Exist from the beginning

Denarius issued by Cassius and Brutus following the assassination of Caesar.



- Forged by individual or organization not authorized
 - Usurpation of issuing rights (even if the coin is of good quality)
 - *identified by numismatists and historians*

AND OFTEN (BUT NOT NECESSARILY)

- Debasement = decreasing the precious metal content
 - Reducing the coin weight: lower mass
 - Reducing the fineness: gold or silver mixed with base metal, generally copper
 - Gold or silver plating a copper/iron/bronze core

OR

- Intentionally degraded (abrasion etc.)
 - Reduction of the coin weight (mass)

Non
destructive
Nuclear
Techniques

Postumus (262 AD)



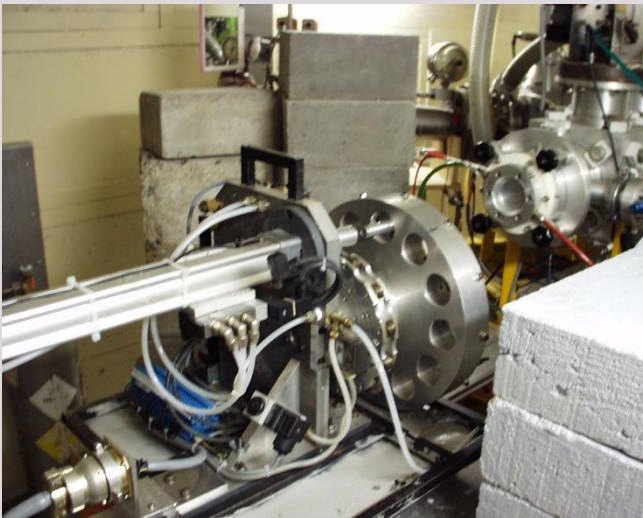
Non official Postumus (262-268 AD)



Roman coins: Fast neutron activation analysis

from accelerator ${}^2\text{H} + {}^9\text{Be} \rightarrow {}^{10}\text{B} + \text{n}$
 $E_d = 17.5 \text{ MeV} \rightarrow E_n = 20 \text{ MeV}$

→ Bulk analysis



CEMHTI (Orléans, France)

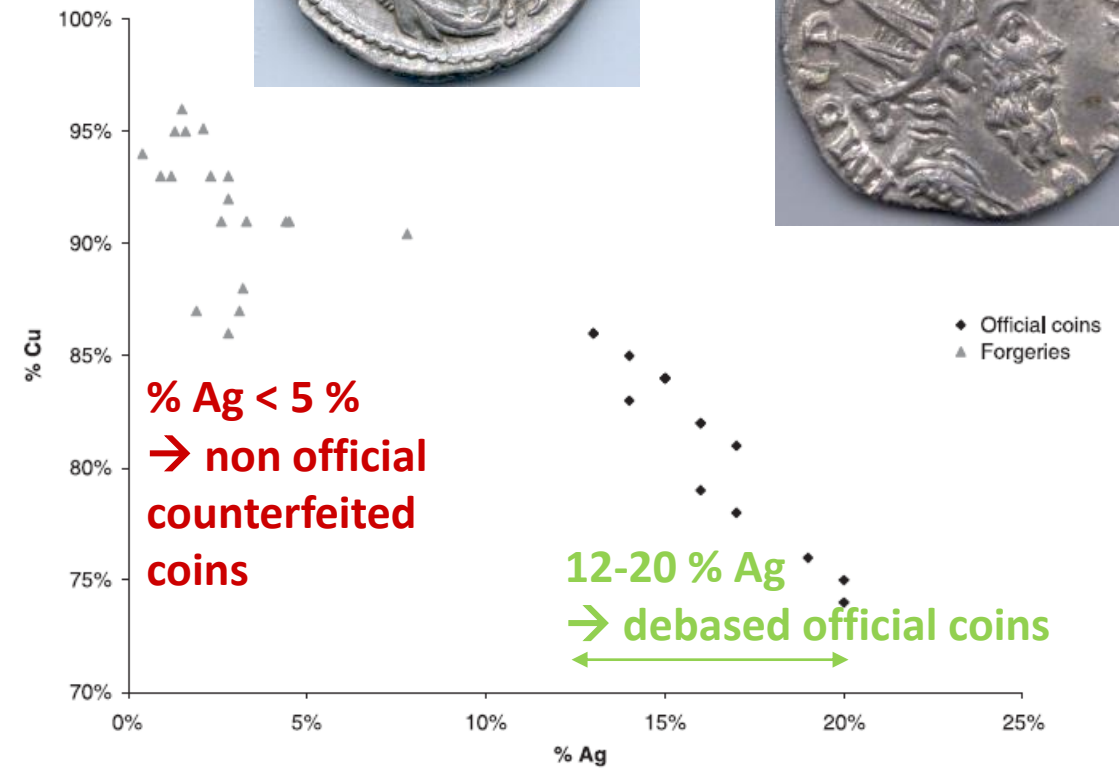


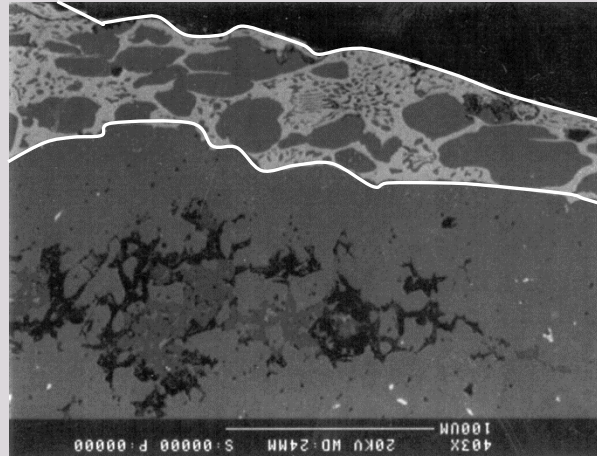
Figure 2 A silver content scatter diagram for the official and unofficial coinages of Postumus.

A STUDY OF THE SILVERING PROCESS OF THE GALLO-ROMAN COINS FORGED DURING THE THIRD CENTURY AD*

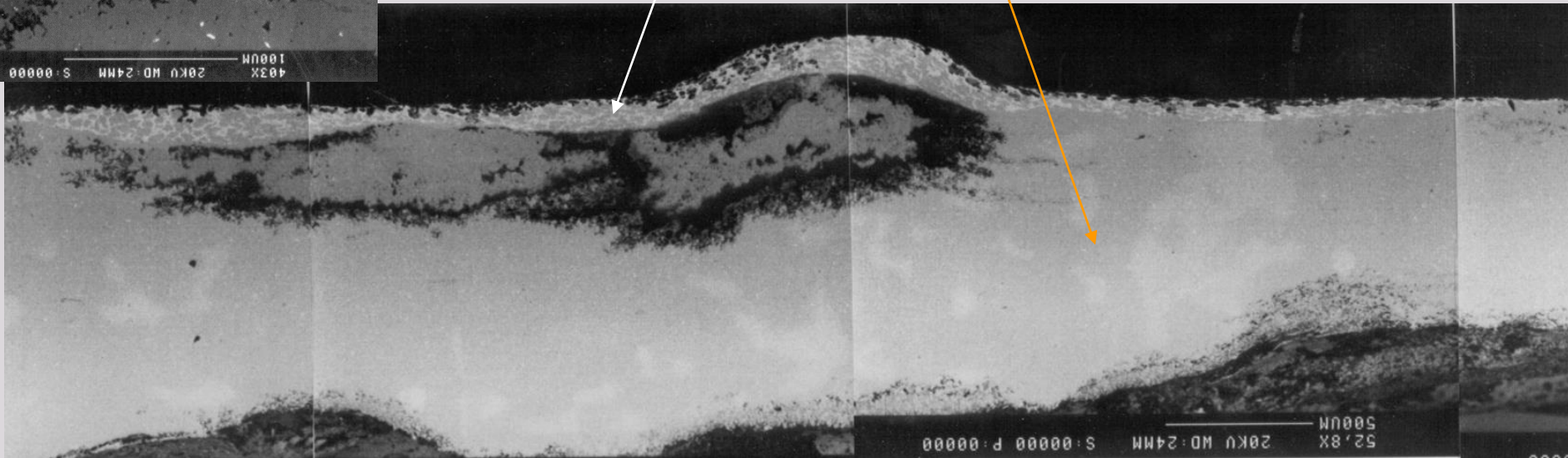
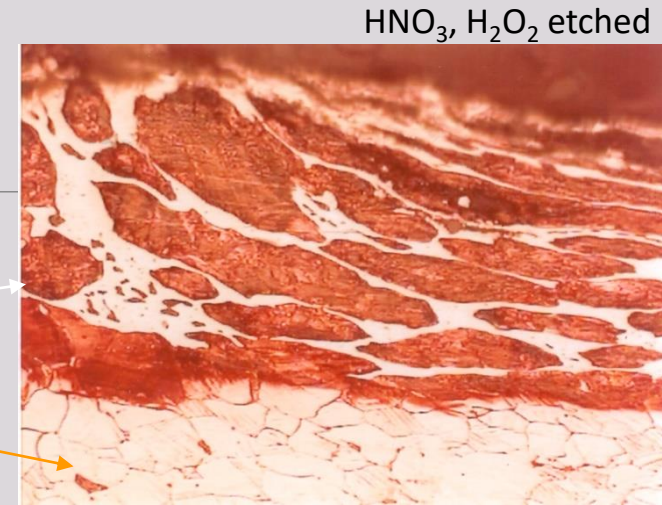
A. DERAISME,¹ L. BECK,² F. PILON³ and J.-N. BARRANDON¹

© University of Oxford, 2006, *Archaeometry* 48, 3 (2006) 469–480

Deeper under the surface...



A layer ~50 μm thick
Silver-copper alloy on pure copper



*L. Beck, D. Bregiroux,
S. Bossonnet, D. Eliot ,
S. Reveillon, F. Pilon
Geoarchaeological and
Bioarchaeological studies 3,
2005, 293-296*

Replication evidenced a diffusion process to produce silver-plated coins



Copper disc
wrapped by a
50 μm thick
silver foil

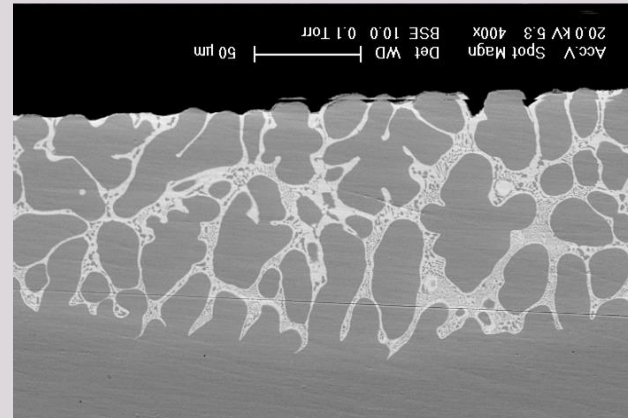


⇒ Annealing
in a furnace at
 $T^\circ = 900^\circ\text{C}$, $t =$
4 min



Silver fully
covers copper

Replication

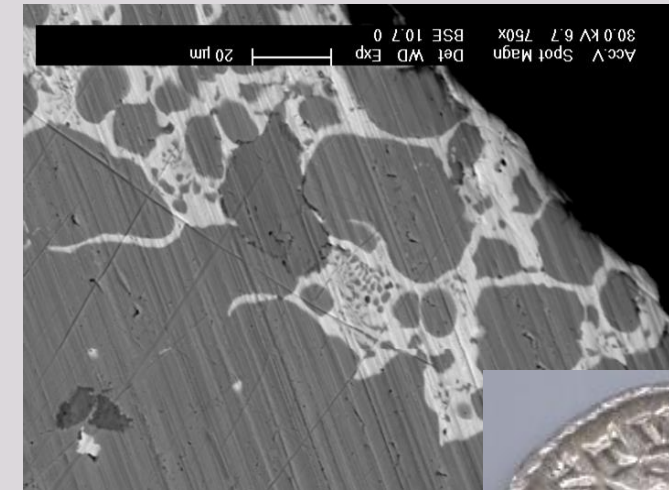


Plating layer : 30 % silver – 70 % copper

Diffusion – Solidification at $950 - 1000^\circ\text{C}$ → soldering process

Ancient coin

Counterfeit of Postumus



Other times, other manners (or not)



Hoard of coins found in
Preuschdorf (Alsace, France)

- 7327 coins,
mainly *pfennig*
- **End of the 15th
century to the
beginning of the 17th
century**
- 87 different official
workshops, from the
Holy Roman Empire
and Swiss
confederation
+ counterfeits

Ion beam analysis using AGLAE (Louvre palace, Paris, France)

(now NewAGLAE)



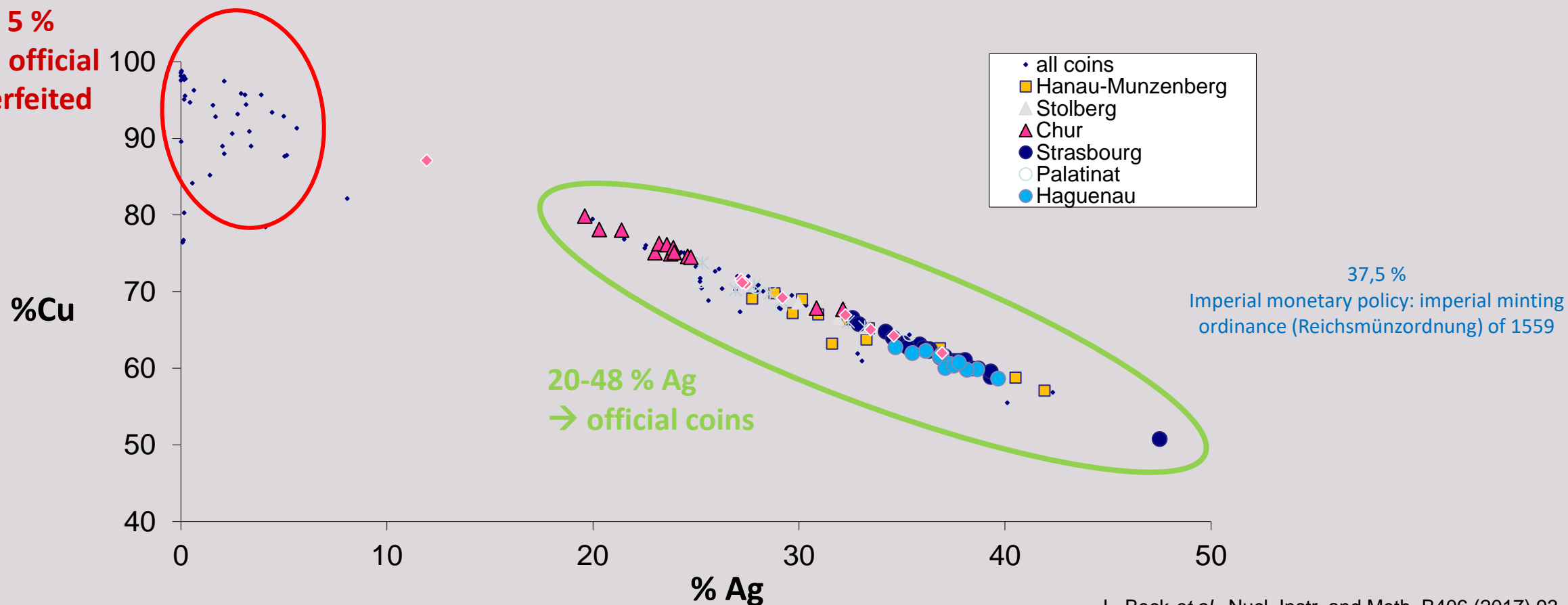
Simultaneous PIXE
and RBS spectra with
3 MeV proton beam

- Elemental composition
- Homogeneity in depth

L. Beck *et al.*, Nucl. Instr. and Meth. B226 (2004) 153
L. Beck *et al.*, Nucl. Instr. and Meth. B266 (2008) 2320

Silver-copper content by PIXE

% Ag < 5 %
→ non official
counterfeited
coins
+ Hg

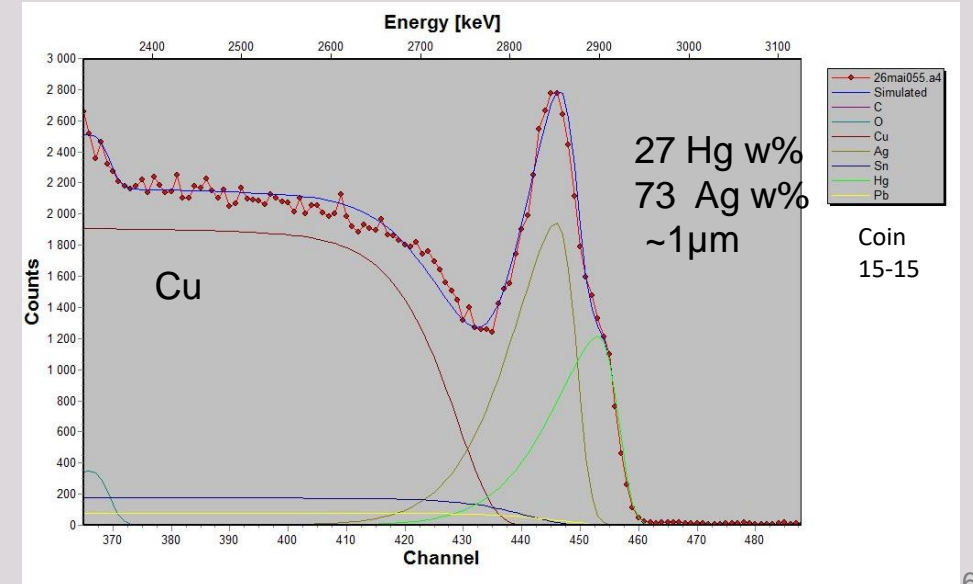
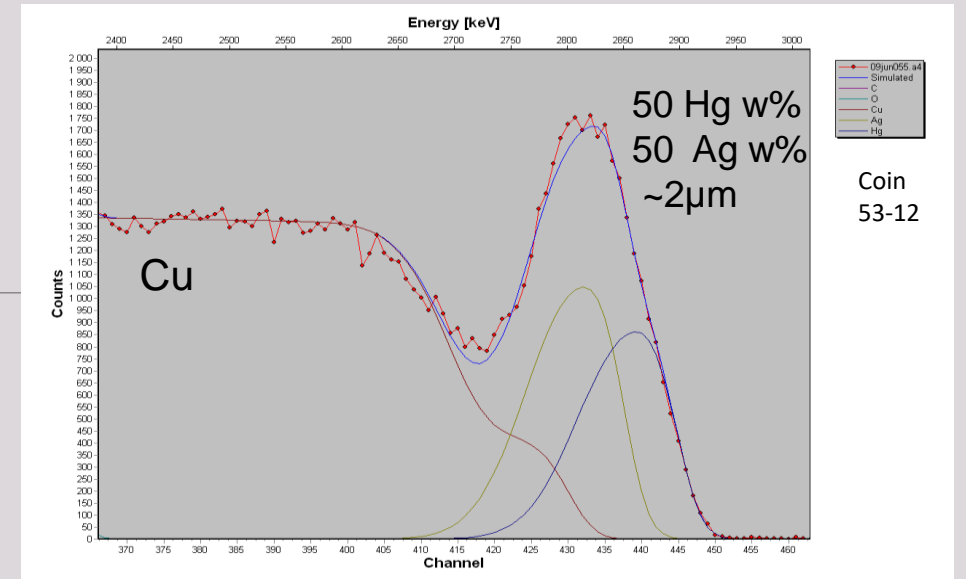


L. Beck *et al.*, Nucl. Instr. and Meth. B406 (2017) 93

Silvering process by RBS

(Rutherford backscattering spectrometry)

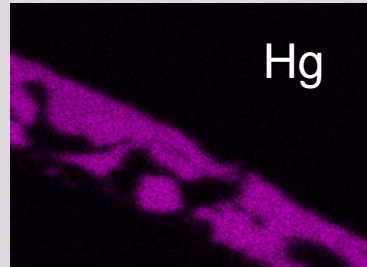
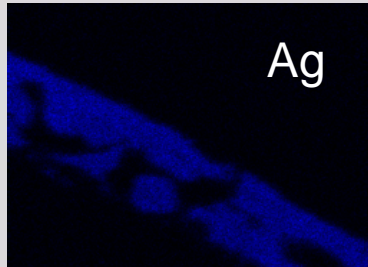
Non destructive analysis with 3 MeV protons



Silvering process by RBS (Rutherford backscattering spectrometry)

Non destructive analysis with 3 MeV protons

Presence of mercury

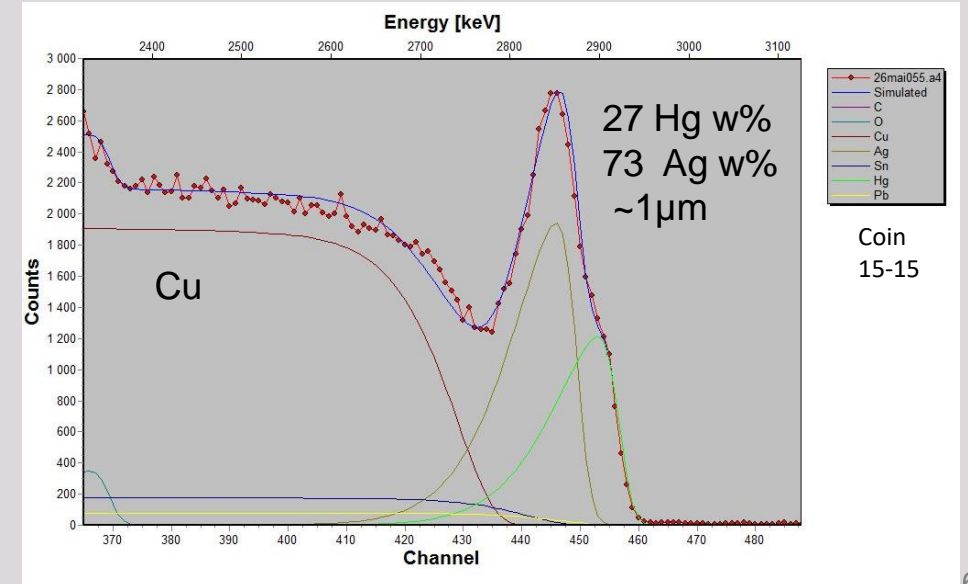
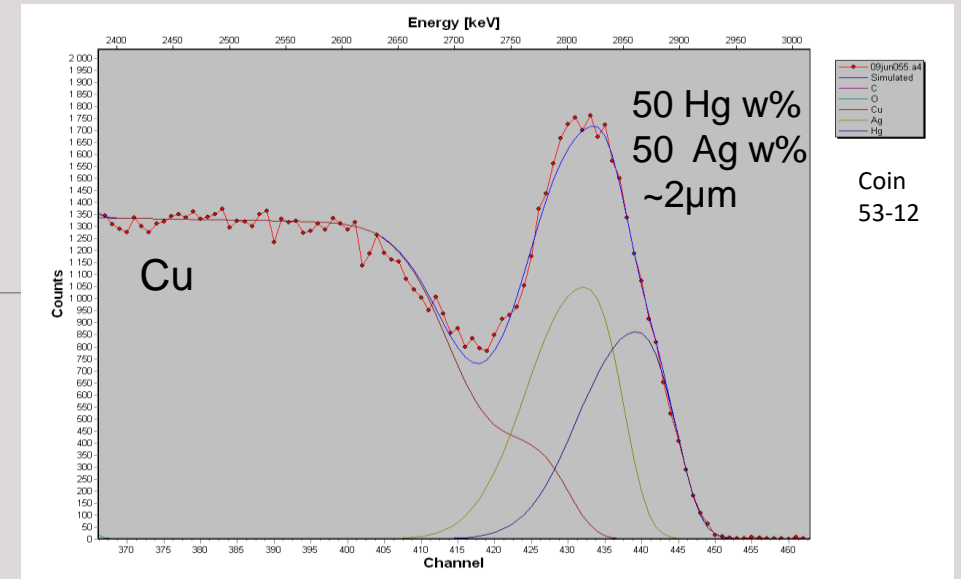


⇒ One of the earliest cases of **mercury** silvering!

Mines of mercury
and natural silver-
mercury amalgam



Moschellandsbergite
Landsberg near Obermoschel,
Rheinland-Palatinate
Germany



In summary, how to make counterfeit plated coins (for scientific purposes, only)



Thick foil of pure silver
mechanically attached

1st c. BC

*(See the presentation of K A
Sheedy on Wednesday)*

3rd c. AD



Thick layer of silver/copper
alloy attached by soldering

16th-17th c. AD



Thin layer of
silver/mercury amalgam



Very thin envelope of pure
silver chemically deposited

From money to art

Why study counterfeiting?

1. Ancient counterfeit coins (IBA, FNAA)

- Economical aspect
- Alternative metallurgical practices

➤ **History**

➤ **History of technology**

2. Art forgeries (AMS ^{14}C)

- Misattribution
- Protect art market and museums
- Fight against illicit trade in art
- ...

➤ **Current issues**

➤ **Art history**

Metal screen from Japan



Metal screen from Japan



Paravent japonais présenté à l'Exposition
Universelle de Paris de 1878

Attribué à un artiste appelé Yoshida
Représentatif des techniques d'artisanat
japonais ayant inspirées le mouvement
du japonisme

Collection du musée des Arts Décoratifs



^{14}C AMS at LMC14 with ARTEMIS (Saclay, France) – National laboratory

3MV Pelletron from NEC

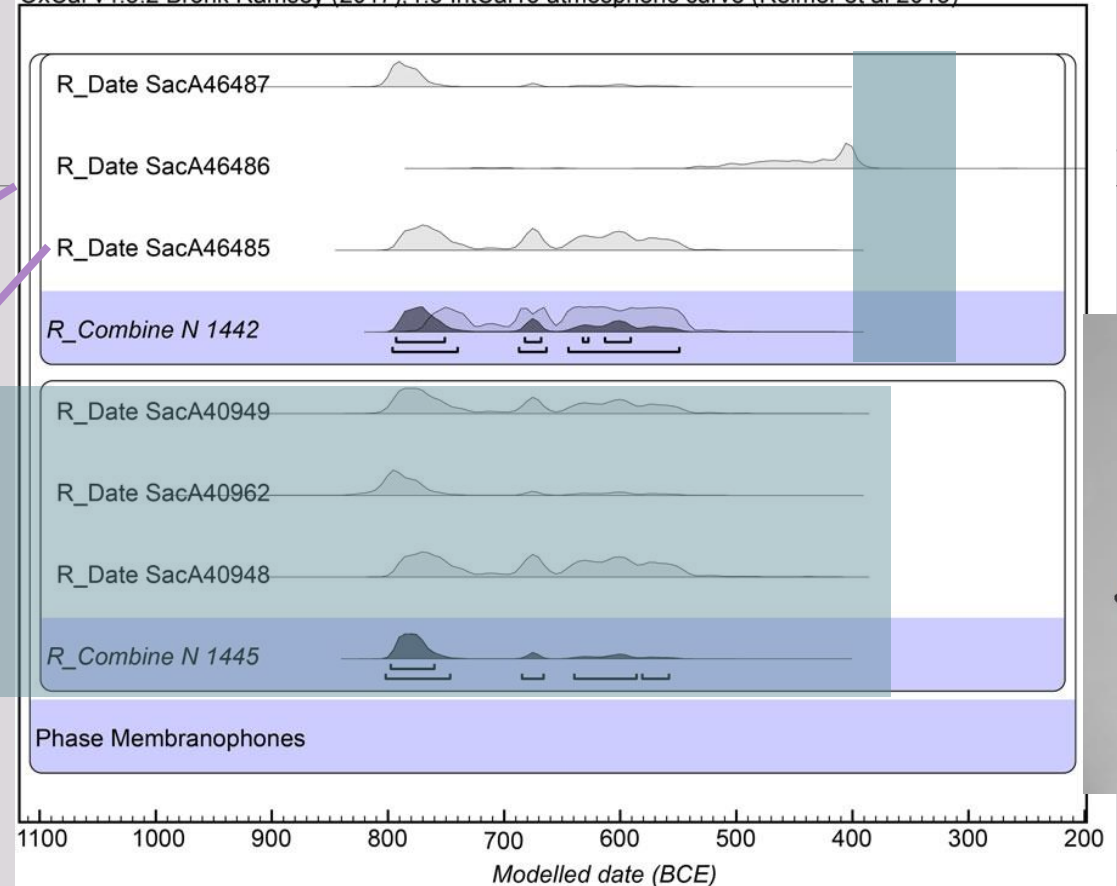


2800 samples to be dated per year $\rightarrow \approx 4000$ samples including calibration, normalisation, blanks
11 permanent positions (mainly engineers and technicians)
80% service/20 % research

The drum N 1442 was
attributed to the
4th c. BC



OxCal v4.3.2 Bronk Ramsey (2017); r:5 IntCal13 atmospheric curve (Reimer et al 2013)



The tambourine
N 1445 was
attributed from
between
the 19th and
30th Dynasties
(1300 to 340 BC)



Same period → end of the Third Intermediate Period

Quiles, A., Emerit, S., Asensi-Amorós, V., Beck, L., et al.. Radiocarbon 63, 2021

<http://www.cea.fr/pages/actualites/sciences-de-la-matiere/carbone-14-musique-antiquite.aspx>

Résultat scientifique | Datation | Physique | Outils & instruments de recherche

"Accord" majeur entre carbone 14 et musiques de l'Antiquité



© Musée du Louvre, dist. RMN-GP/Hervé Lewandowski

Quinze instruments de musique de l'Égypte ancienne ont été datés par le Laboratoire de mesure du carbone 14, dans le cadre d'une collaboration scientifique avec l'Institut français d'archéologie orientale du Caire, le département des Antiquités égyptiennes du Louvre et le CNRS (HiSoMA, UMR 5189). Ces instruments de musiques composent, parmi d'autres objets, la nouvelle exposition du Louvre-Lens « Musiques ! Échos de l'Antiquité », un voyage passionnant à la découverte des musiques de l'Antiquité.



Des harpes et des « claquoirs » (sortes de castagnettes) en bois, des tambours en cuir et peau, conservés au musée du Louvre, ont pu être datés par la mesure du carbone 14 par spectrométrie de masse par accélérateur (SMA ARTEMIS). Outre la détermination de leur période de fabrication – pour la plupart entre le Nouvel Empire et la Troisième Période intermédiaire (entre 1600 et 660 av. J.-C.) – les mesures réalisées au Laboratoire de mesure du carbone 14 (Instrument National CEA, CNRS, IRSN, IRD, Ministère de la Culture et de la communication, et rattaché au LSCE) ont permis d'identifier les parties ajoutées ou restaurées au XIXe siècle. C'est le cas, par exemple, des cordes de la harpe égyptienne ci-dessous. Le laboratoire a participé à l'ensemble des étapes nécessaire à la datation, du prélèvement à la mesure des isotopes du carbone en passant par la préparation chimique des échantillons.

Menées dans le cadre d'une démarche interdisciplinaire visant à appréhender l'instrument de musique antique dans toute sa complexité, ces analyses apportent un éclairage unique sur les périodes de fabrication d'objets de la culture matérielle à si haute valeur patrimoniale. Un article du catalogue de l'exposition présente en avant-première une partie des résultats avant la publication d'un article complet dans une revue scientifique.

En adoptant la musique pour fil conducteur, la nouvelle exposition du Louvre-Lens « Musiques ! Échos de l'Antiquité » offre un regard singulier sur les grandes civilisations antiques, tout en croisant histoire, archéologie, conservation du patrimoine et recherche scientifique.

