INFN diagnostic campaigns in the ADAMO project

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Why scientific analyses are applied on cultural heritage?

- Characterization of the materials employed and manufacture processes

  → Knowledge of the technical advances of an artists and/or cultures

- Diagnostic analyses of the original chemical composition and restoration treatments

  → Supporting the activities of restorers before-during-after the restoration

- Authentication of the artefacts based on the chemical-physical properties of the materials used

  → Supporting the activities of historian, art critics and art dealers

- Monitoring of the environmental conservative conditions and the *status quo* of the artefacts

  → Evaluation of the conservative practices. Performing a systematic check of the *status* of an artefact, before and after temporary loans

Which techniques are more successful for our aims?

There is NO general answer

It depends on the chemical and physical properties of the artefact and on the aims. However, it is important knowing that scientific techniques could be divided in:

Non-Destructive and Non-invasive Analyses

Micro-Destructive Analyses

Elemental analyses

- X-ray Fluorescence Spectroscopy
- Scanning Electron Microscopy (SEM) coupled with Energy Dispersive X-ray micro-analysis (EDX)

Molecular analyses

- Imaging multispettrale (UV, VIS, NIR, SWIR)
- Portable Raman Spectroscopy
- Portable Infrared Spectroscopy
- Reflectance Spectroscopy
- Micro-Raman Spectroscopy
- Micro-FT-IR Spectroscopy with conventional and Syncrotron radiation Source

Structural analyses

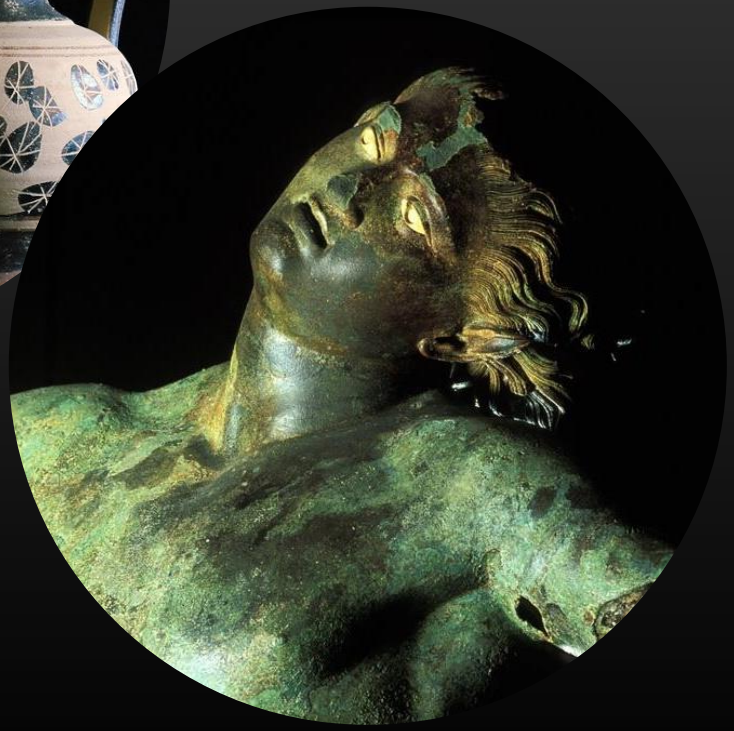
- Termography

SCIENTIFIC INVESTIGATIONS OF CULTURAL HERITAGE
Case studies

Easel Paintings

Pottery

Metals and corrosion products



SCIENTIFIC INVESTIGATIONS OF CULTURAL HERITAGE
Easel Paintings

ADAMO site of interest:
Palazzo Chigi (Ariccia, Rome)




"The Drunkenness of Noah" painted by Andrea Sacchi

PURPOSE:
Visualization of the underdrawings and ''*pentimenti*''

Reconstruction of the artistic production of the artist


Catanzaro, Museo Provinciale


Berlino, Staatliche Museen, Gemäldegalerie

TECHINIQUE: Infrared Reflectography (IRR)

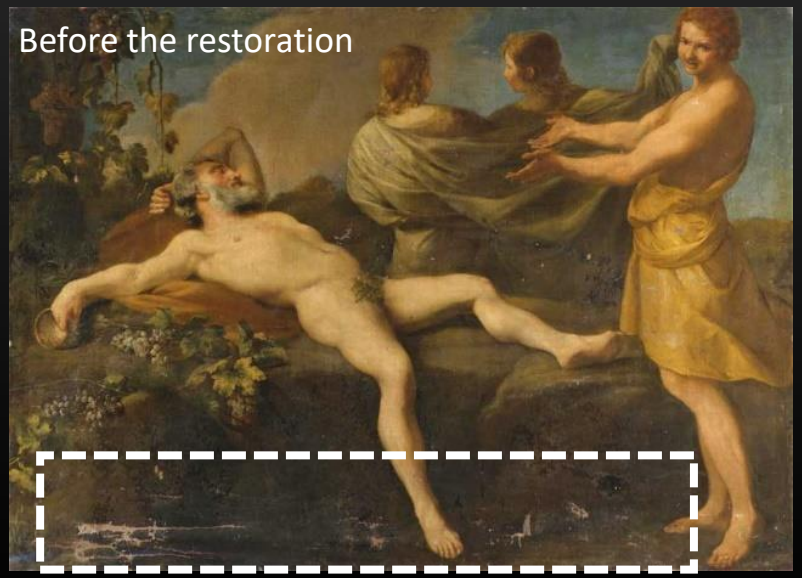
“The Drunkenness of Noah” painted by Andrea Sacchi

VISIBLE

REFLECTOGRAPHY Near Infrared (NIR)

REFLECTOGRAPHY Shortwave Infrared (SWIR)

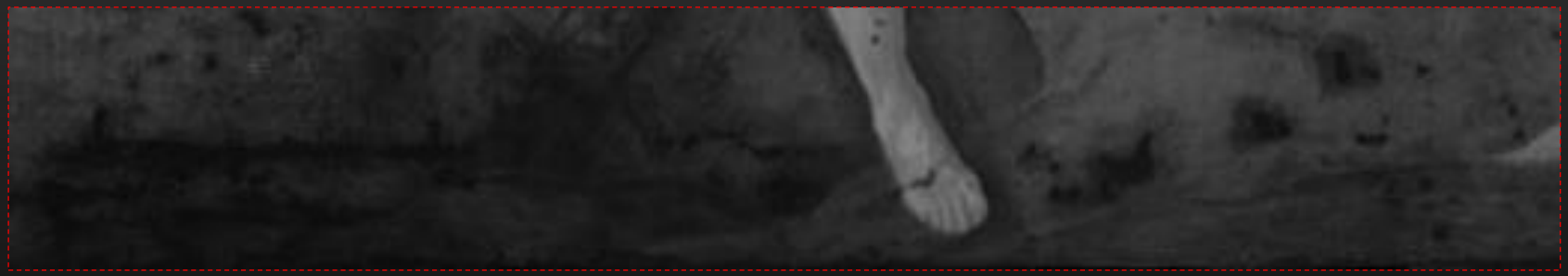
Before the restoration



“The Drunkenness of Noah” painted by Andrea Sacchi

Before the restoration

REFLECTOGRAPHY Shortwave Infrared (SWIR)



The infrared reflectography may highlights modern restoration due the infrared absorption of the materials used

“The Drunkenness of Noah” painted by Andrea Sacchi

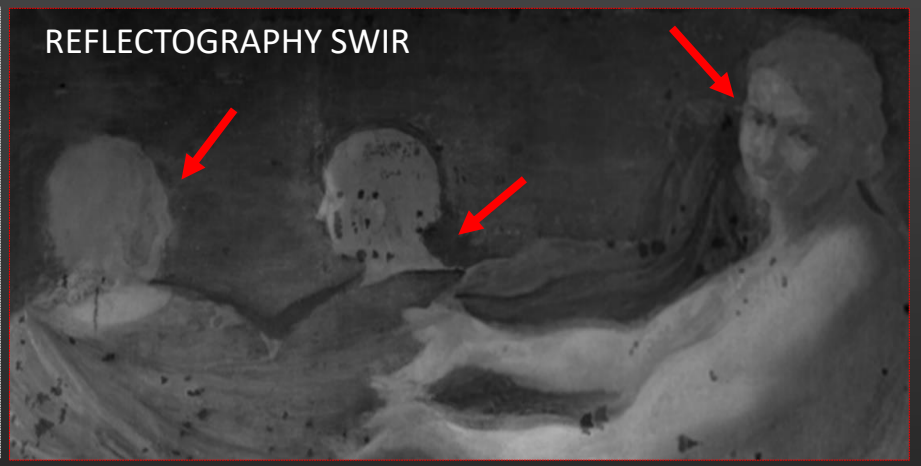
VISIBLE

REFLECTOGRAPHY Near Infrared (NIR)

REFLECTOGRAPHY Shortwave Infrared (SWIR)

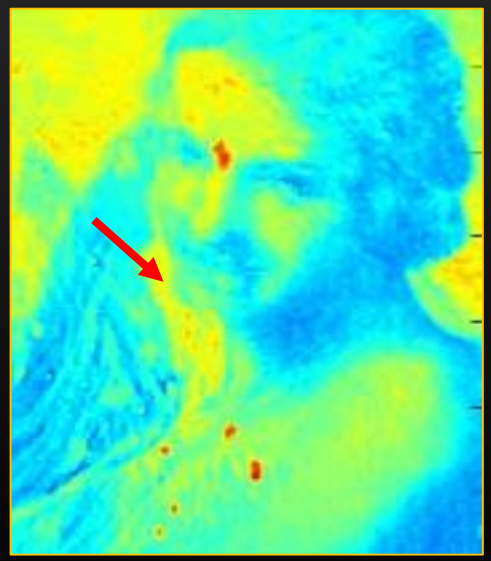
Before the restoration

“The Drunkenness of Noah” painted by Andrea Sacchi



Three important pentimenti: 1) the face of the figure placed on the left side was shifted; 2) the figure placed in the background right side shows short hair in the reflectograms.

REFLECTOGRAPHY SWIR



PRINCIPAL COMPONENT ANALYSIS (PCA)

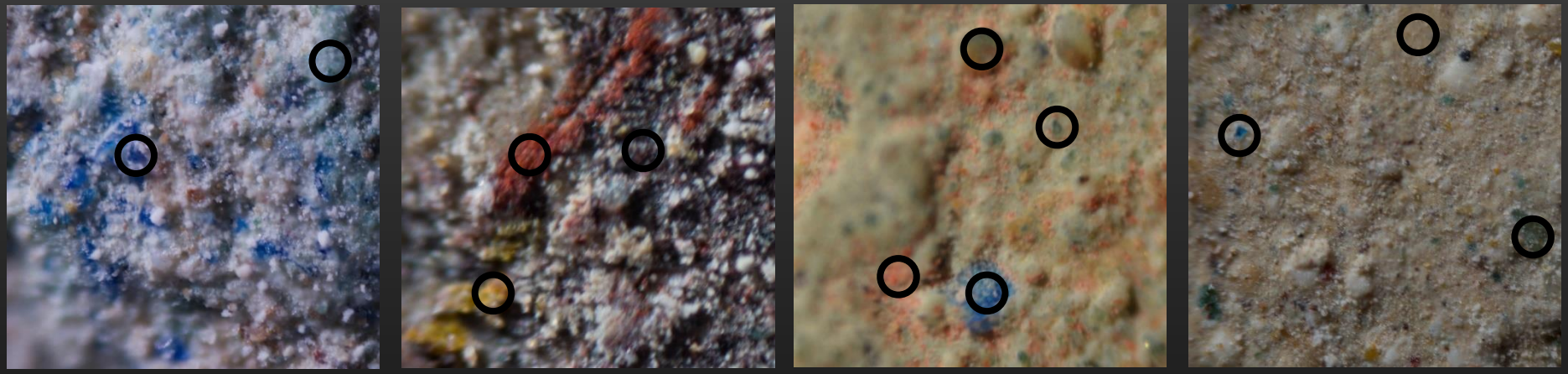
3) the figure in the foreground shows two faces: the older version seems smaller than the last one.

On the other hand, PC2 evidences few details not clearly identified both in the InGaAs image: here the chin of the earlier version of the Ham’s face seems to have undergone changes

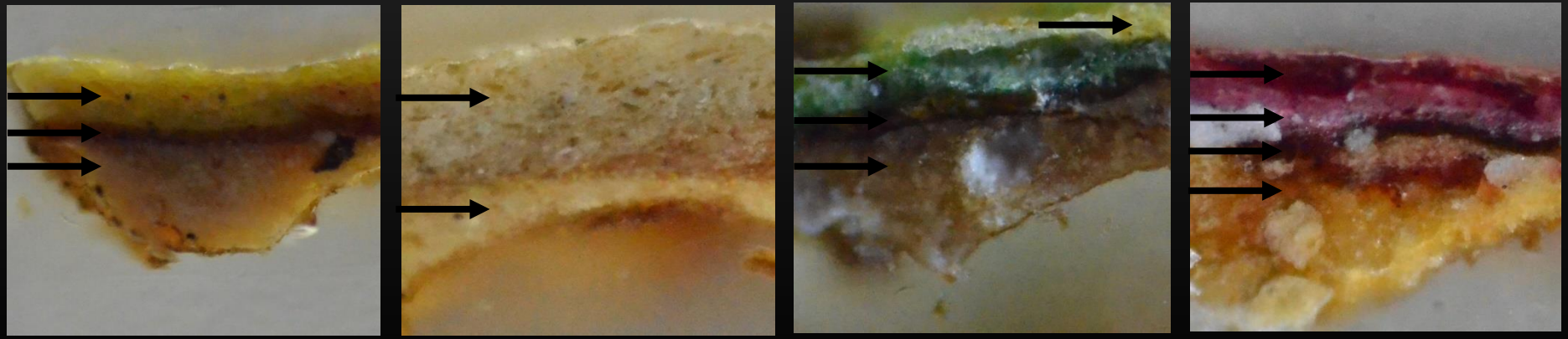
Why it is necessary to perform micro-destructive analyses?

The composition of materials used for realizing artefacts is generally composed by inhomogeneous and stratified structures

Pictorial Surfaces



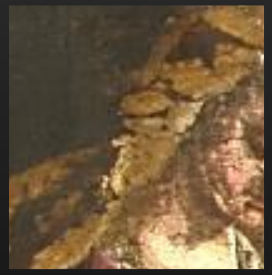
Cross sections of paintings



Restoration of “Adoration of the Magi” attributed to El Greco

QUESTION:
Why the painting is brown?

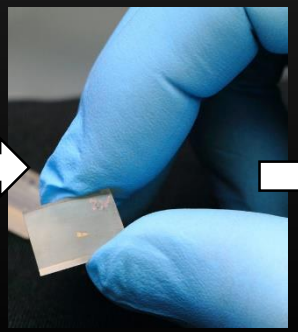
- It is covered by several varnish layers
- Some pictorial layers are brown, such as the Virgin’s veil, the sky



Realization of microsamples

Microsampling

Embedding in resin

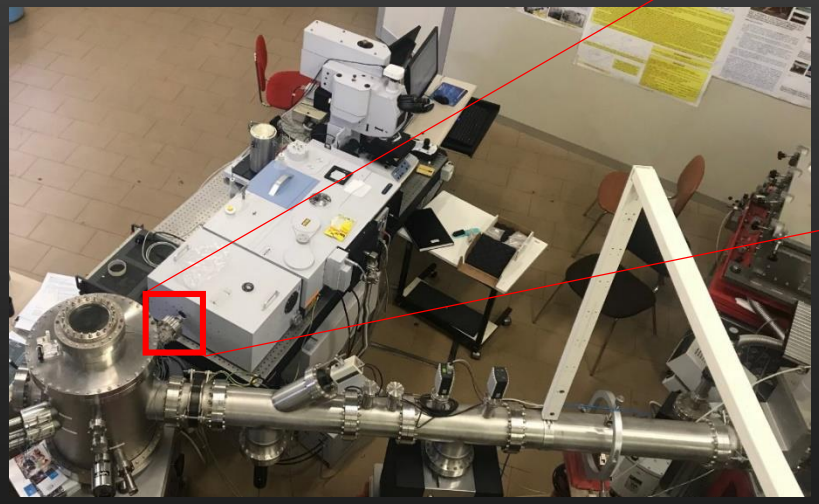


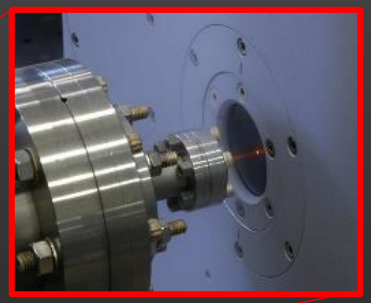
Trasversal cut

Polishing

Which kind of analyses may be performed on cross sections for the molecular and elemental analyses?

Micro-infrared Spectroscopy (FTIR) with Synchrotron radiation source





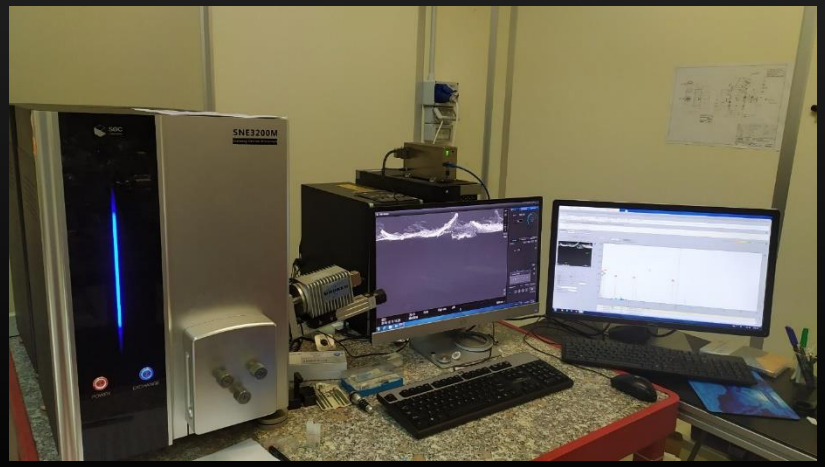
1

2

3

4

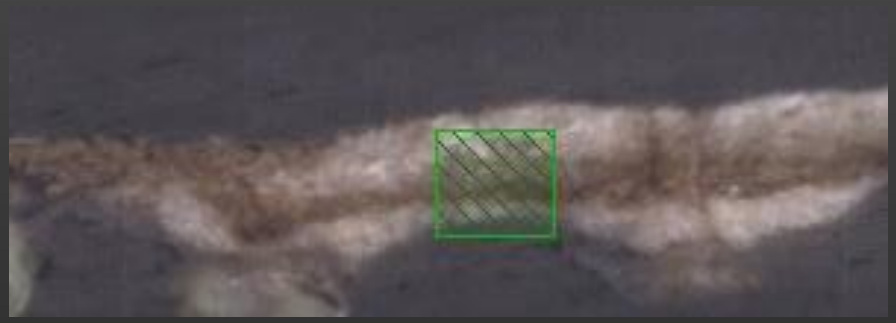
1 Synctroton source
2 Schematic overview of a Syntrotron Facility
3 Synchrotron Radiation Facility at Frascati (Dafne - Light)
4 Synchrotron Radiation Facility at Trieste (Elettra)



Scanning Electron Microscopy (SEM) coupled with Energy Dispersive X-ray micro-analysis (EDX)

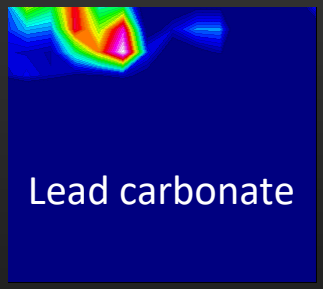
Restoration of “Adoration of the Magi” attributed to El Greco (Accademia di San Luca, Rome)

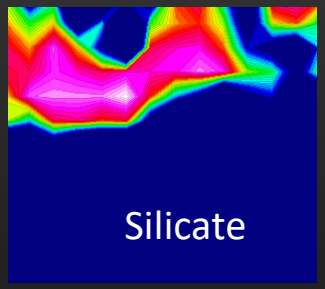
Molecular composition

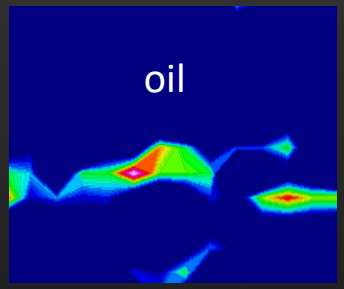


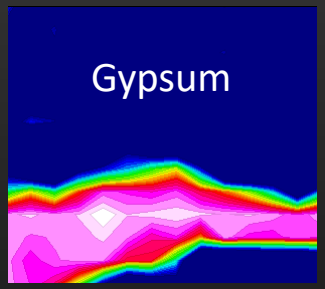
Lead carbonate
Silicate
Oil
Gypsum
Epoxy resin

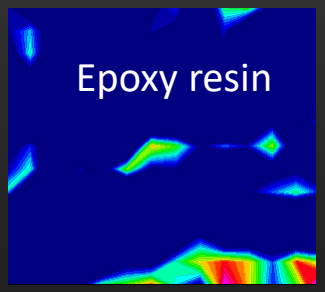
Infrared spectroscopy imaging (Synchrotron radiation source)





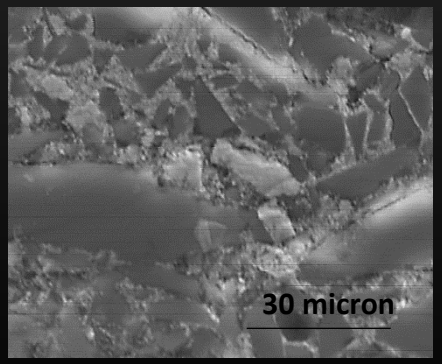


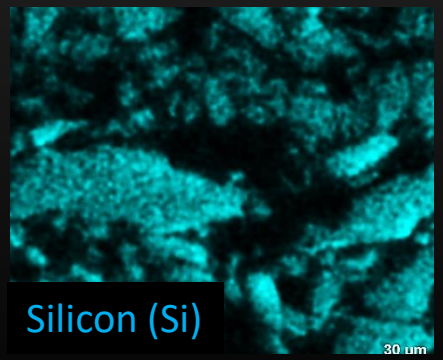


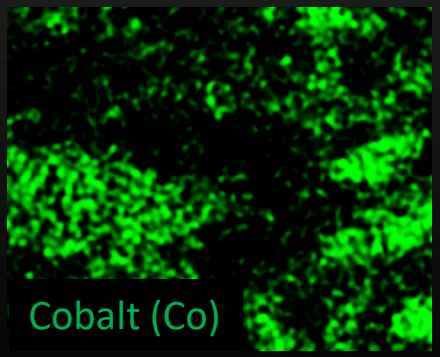


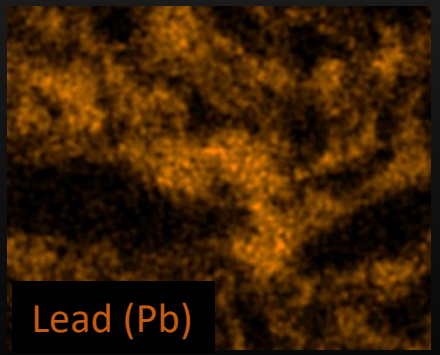
Elemental composition

Scanning Electron Microscopy (SEM) coupled with Energy Dispersive X-ray micro-analysis (EDX)









Brown pigment ➡ Smalt (Cobalt glass)

Smalt degradation

Blue mantles of the Vergin

Browning of the Christ's mantle

Optical microscopy

UV fluorescence optical microscopy

SCIENTIFIC INVESTIGATIONS OF CULTURAL HERITAGE

Pottery

Campana reliefs from the Palatine Hill and Colosseum Valley in Rome

PURPOSE:
Which pigments are used?

↓

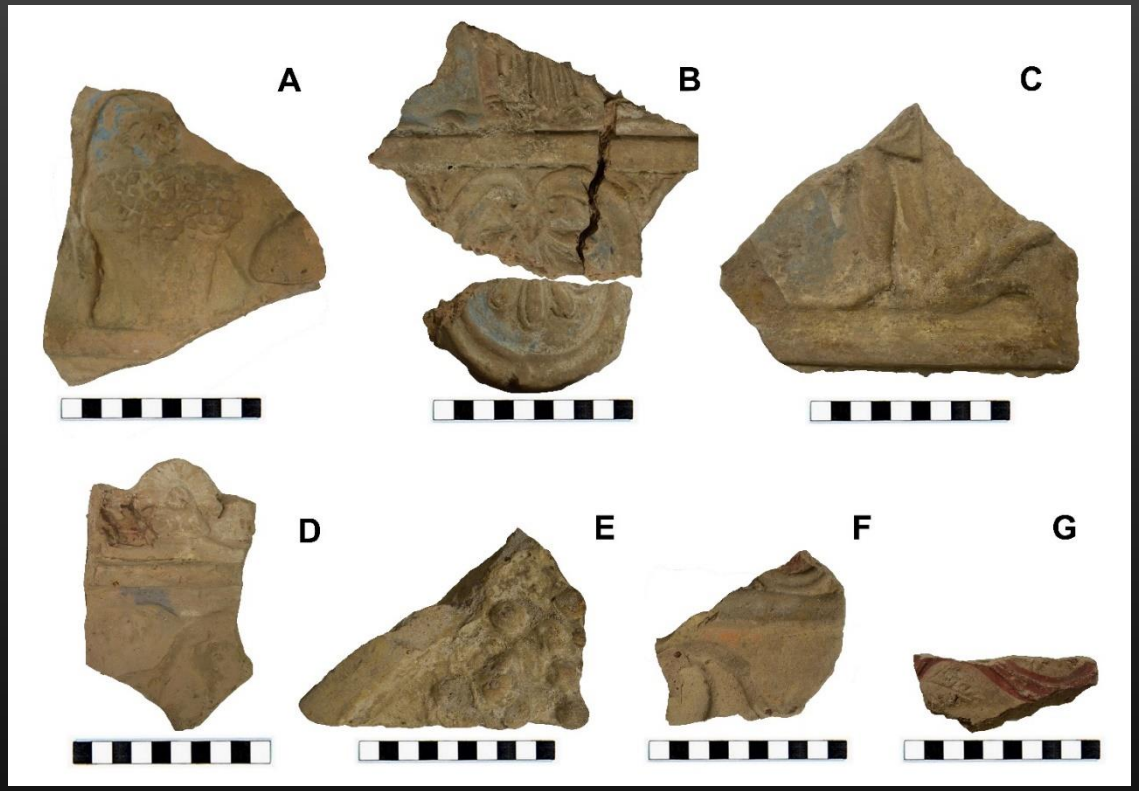
Is it possible to take micro-samples?

NO

↓

Non invasive
and
non-destructive approach

↓

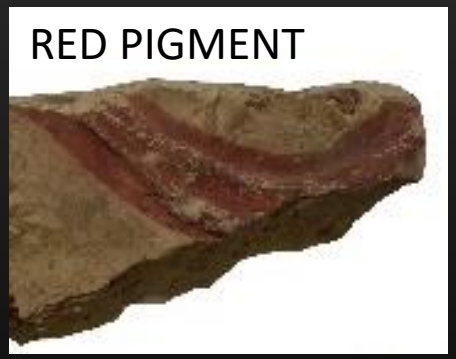


X-ray fluorescence (XRF) Spectroscopy
Fiber Optical Reflectance Spectroscopy (FORS)
Photo-induced luminescence (PIL) imaging

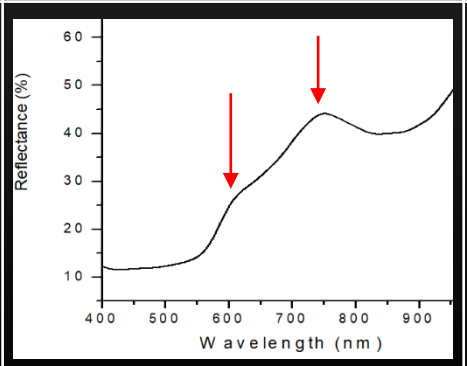
Campana reliefs from the Palatine Hill and Colosseum Valley in Rome

X-ray fluorescence (XRF)	Fiber Optical Reflectance Spectroscopy (FORS)	Photo-induced luminescence (PIL) imaging
Detection of LEAD (Pb)	No characteristic spectral features	NO

MINIUM (Pb_3O_4)

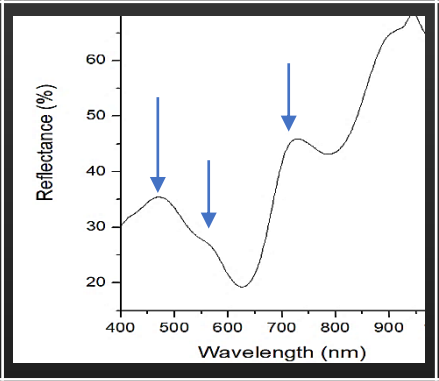
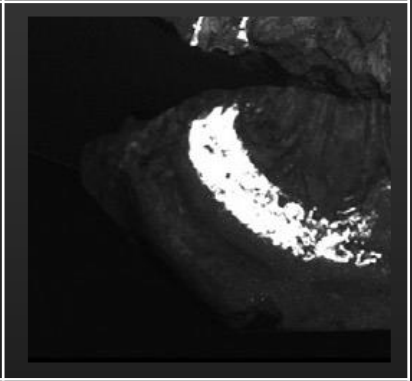


HEMATITE (Fe_2O_3)
or
RED OCHRE
(hematite and silicates)

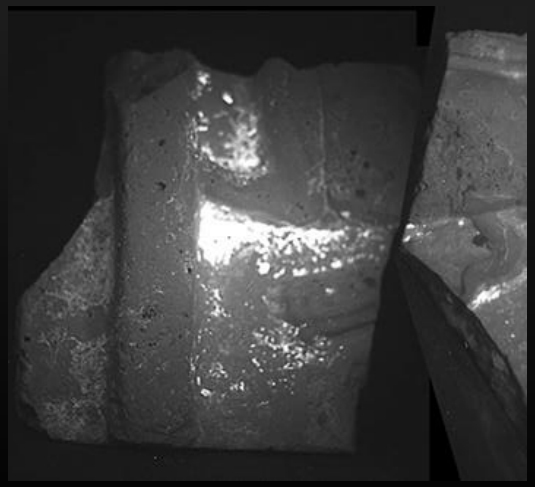
X-ray fluorescence (XRF)	Fiber Optical Reflectance Spectroscopy (FORS)	Photo-induced luminescence (PIL) imaging
Detection of IRON (Fe)		NO

Campana reliefs from the Palatine Hill and Colosseum Valley in Rome

EGYPTIAN BLUE (cuprorivaite $CaCuSi_4O_{10}$ and quartz SiO_2)

X-ray fluorescence (XRF)	Fiber Optical Reflectance Spectroscopy (FORS)	Photo-induced luminescence (PIL) imaging
Detection of COPPER (Cu)		

Egyptian blue could be detected by PIL imaging also in absence of evident traces of colour



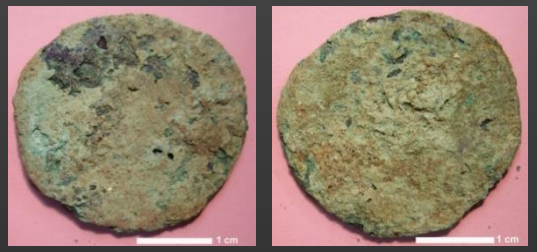
SCIENTIFIC INVESTIGATIONS OF CULTURAL HERITAGE

Metals and corrosion products

Copper-based Greek and Roman coins from Pompeii

Inv. no.	Coin	Inv. no.	Coin
C1-9	Republican as (III-II century BC)	C11-12	Republican as (II-I century BC)
C1-41	Republican as (III-II century BC)	C11-56	Pseudo-Ebusus (II century-early I century BC)
C1-12	Republican as (III-II century BC)	C14-15	Imperial quadrans (Caligula, 39-41 AD)
C1-38	Ebusus or pseudo-Ebusus (II century-early I century BC)	C14-6	Unknown coin
C7-12	Imperial quadrans (Caligula, 39-41 AD)	C18-9	Imperial as (early I century AD)
C5-1	Pseudo-Ebusus (II century-early I century BC)	C19-40	Republican as (153 BC)
		C19-51	Republican as (III-II century BC)
C11-11	Unknown coin	C24-31	Massalia (150/130-100 BC)

Imperial as

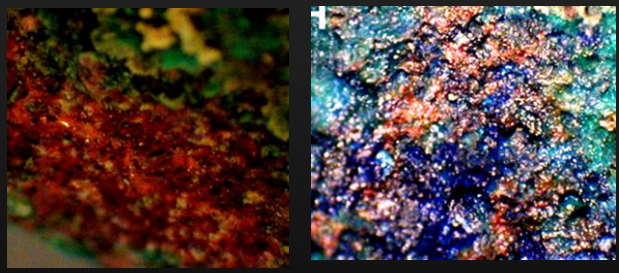


Pseudo-Ebusus

QUESTION:

- Which is the alloy of these coins?

  → X-ray fluorescence spectroscopy
  Scanning Electron Microscopy (SEM) coupled with Energy Dispersive X-ray micro-analysis (EDX)



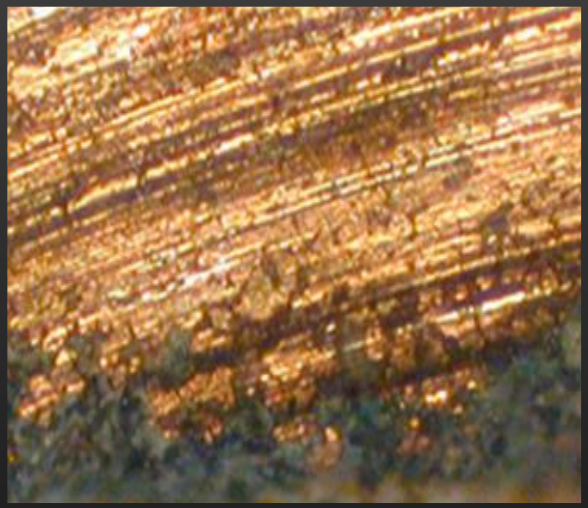
- Which corrosion products cover the bulk?

  → Is it possible to take micro-samples? **YES**

micro-destructive approach → Infrared Spectroscopy (conventional source) – FTIR -ATR
Micro-raman spectroscopy

Copper-based Greek and Roman coins from Pompeii

X-ray fluorescence spectroscopy

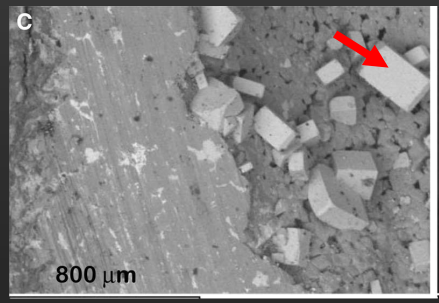


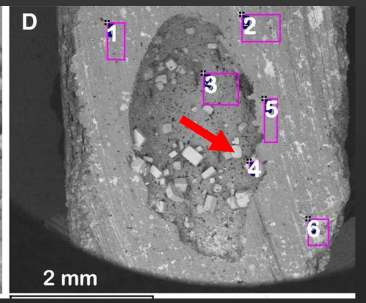
Imperial as, Ebusus and Massalia coins contain copper, tin and lead → **Bronze**
Imperial as and quadrants have been minted with copper

Inv. No.	Cu	Sn	Pb
C1-9	x	x	x
C1-41	x	x	x
C1-12	x	x	x
C1-38	x	x	x
C7-12	x	n.d.	n.d.
C5-1	x	x	x
C11-11	x	x	n.d.
C11-12	x	x	x
C11-56	x	x	x
C14-15	x	n.d.	n.d.
C14-6	x	x	x
C18-9	x	n.d.	n.d.
C19-40	x	tr	x
C19-51	x	x	x
C24-31	x	n.d.	x

x, present; tr, low concentration (<1 wt.%); n.d., not detected

Scanning Electron Microscopy (SEM) coupled with Energy Dispersive X-ray micro-analysis (EDX)





SEM-EDS analysis (mass %)

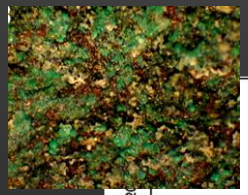
Area	Fe	Cu	As	Sn	Pb
1	n.d.	86.5	1.1	4.0	8.4
2	n.d.	84.6	n.d.	3.4	12.0
3	n.d.	70.1	2.2	3.1	24.6
4	n.d.	10.0	n.d.	n.d.	90.0
5	0.9	83.0	n.d.	3.6	12.5
6	n.d.	19.9	n.d.	1.7	78.4

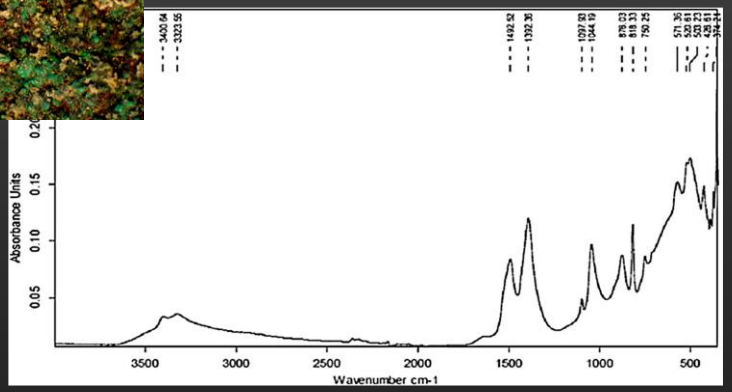
Several parallelepiped-shaped small crystals are found inside pore. The EDS analysis of a small crystal (4 area) revealed a high amount of Pb. Lead crystallizes in the cubic system and it is quite uncommon in nature. In this coin, optimal conditions for the growth of lead micro-crystals might have occurred.

Copper-based Greek and Roman coins from Pompeii

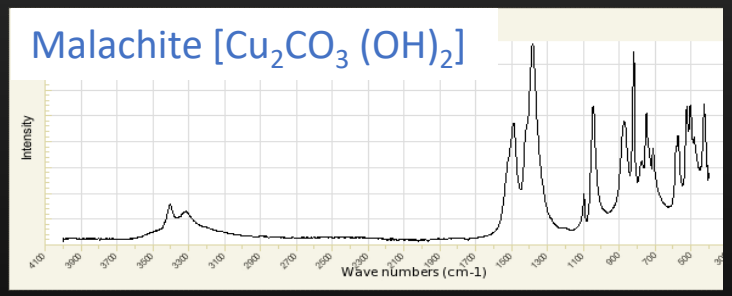
Infrared Spectroscopy (conventional source)

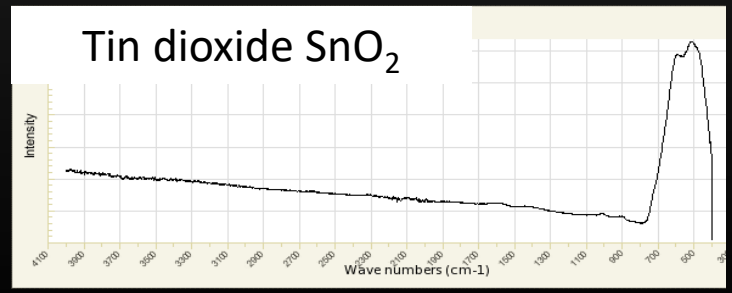
FTIR - ATR



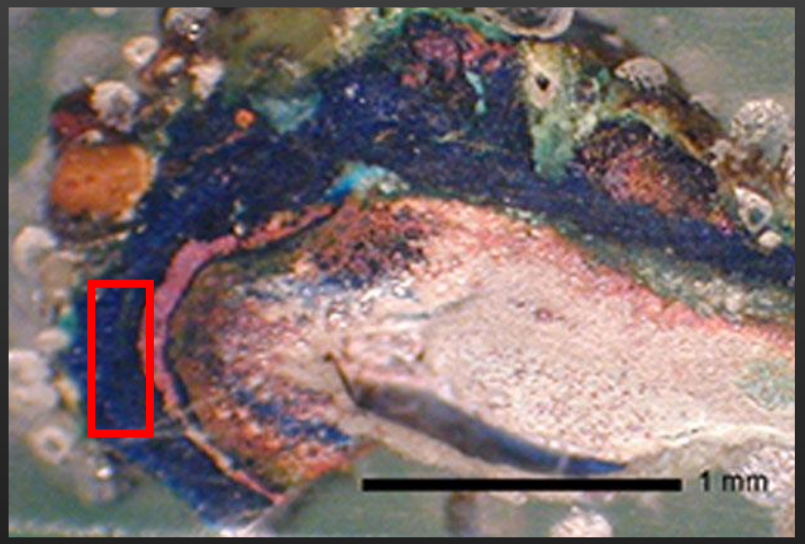


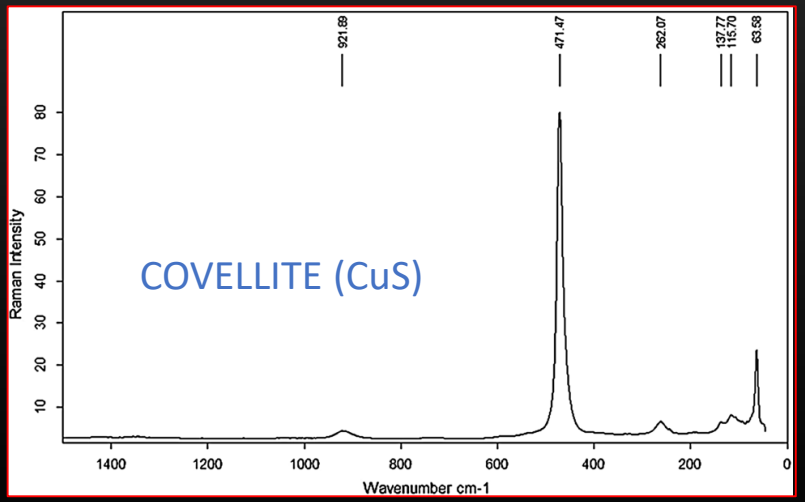
Reference spectra





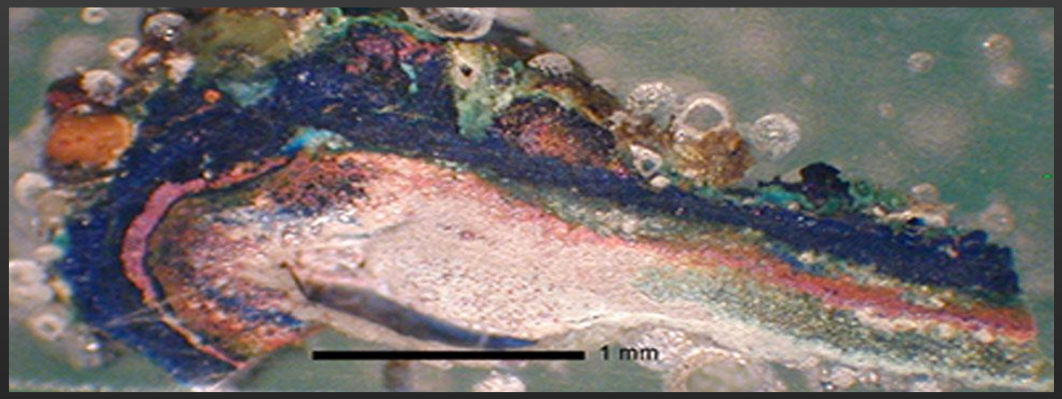
Micro-raman spectroscopy





Copper-based Greek and Roman coins from Pompeii

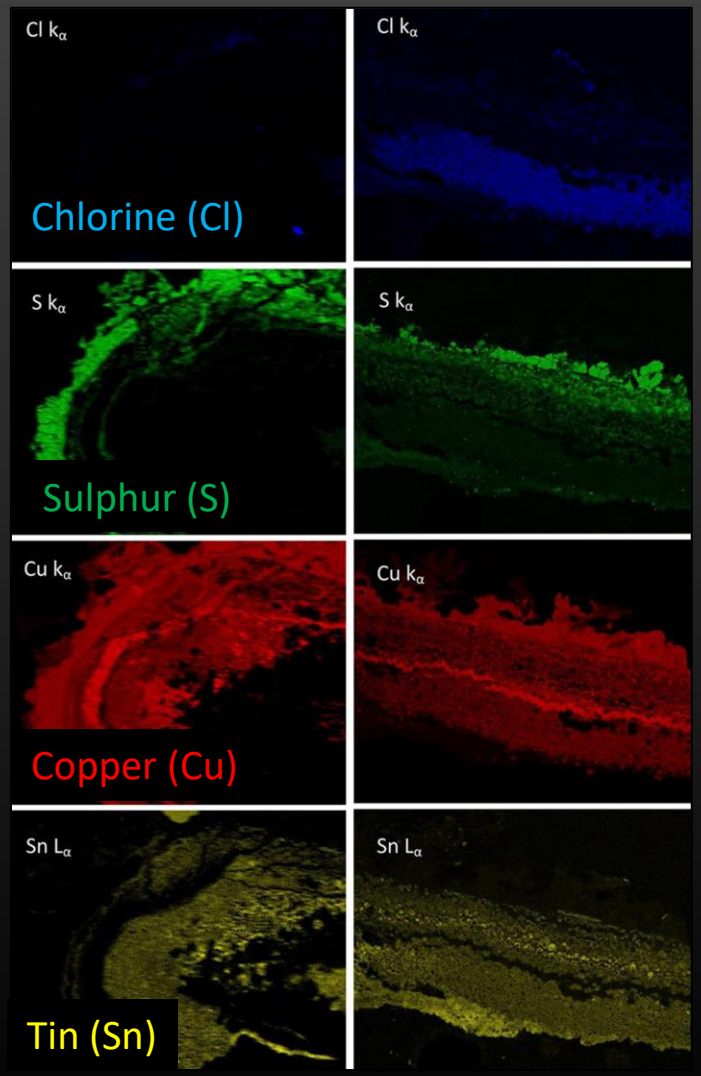
Scanning Electron Microscopy (SEM) coupled with Energy Dispersive X-ray micro-analysis (EDX)



The entire corrosion stratigraphy is well described in terms of the distribution of copper, tin, chlorine, sulphur elements, obtained by SEM–EDS mapping

The external dark blue patinas are enriched with copper and sulphur (covellite), while the chlorine content suggests the presence of *bronze desease*

The elemental maps of Cu and Sn showed banded corrosion products in which copper-based layers alternate with Cu–Sn ones



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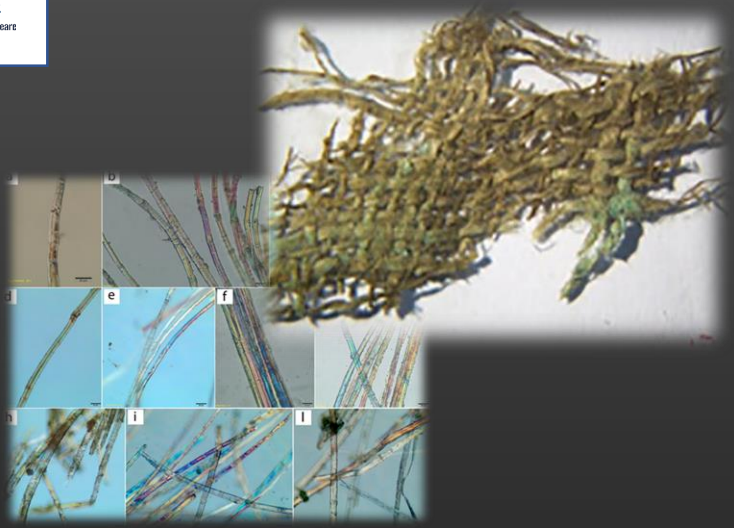
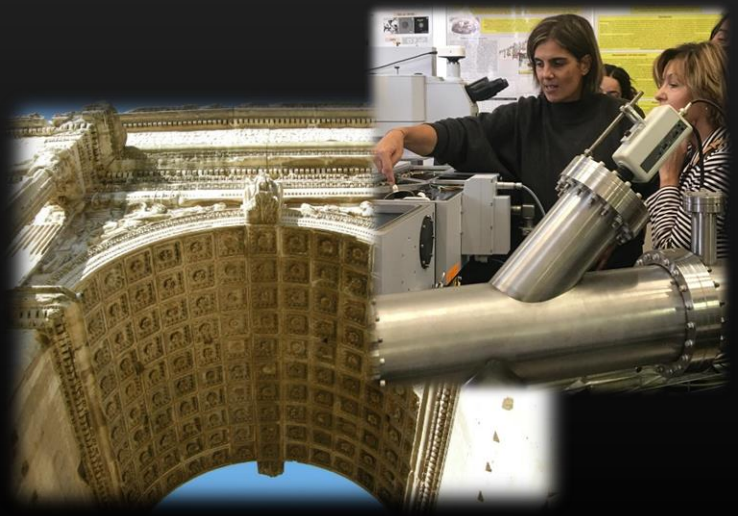


Cases Study:
Mural Paintings, Historical Monuments and Archeological textiles



DIAGNOSTIC ISSUES RELATED TO:

MURAL PAINTIGS AND ARCHITECTURE:

Impossibility to move the artworks (frescoes, mural paintings) / insurance problems related to movement of fragments:

- *In situ* application of analytical techniques → The case of Palazzo Chigi, Ariccia
- Microsampling → The case of Septimus Severus Arch, Rome

ARCHEOLOGICAL TEXTILES

- Could be found in bad conservation conditions (burnt)
- No reference standard (difficult comparing modern fibers with ancient ones

WHY TO APPLY DIAGNOSTIC ANALYSES?

- Characterization of constituent's materials
- Characterization of degradation products
- Information about the conservation state of the studied artwork

To plan restoration and/or conservation interventions.

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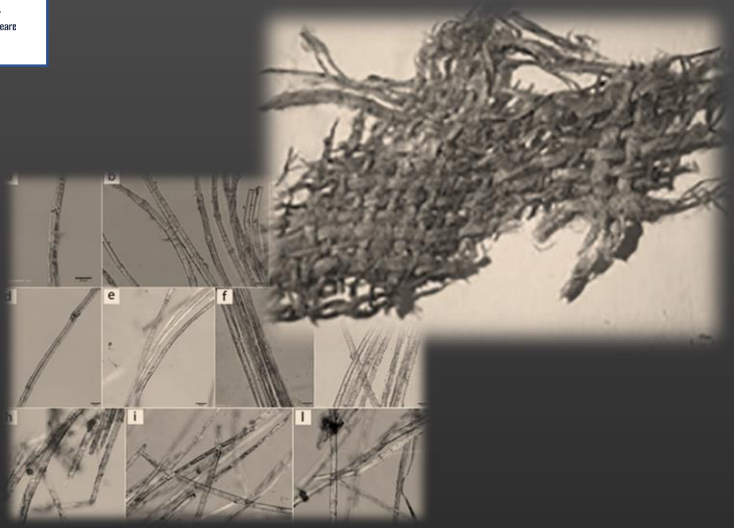
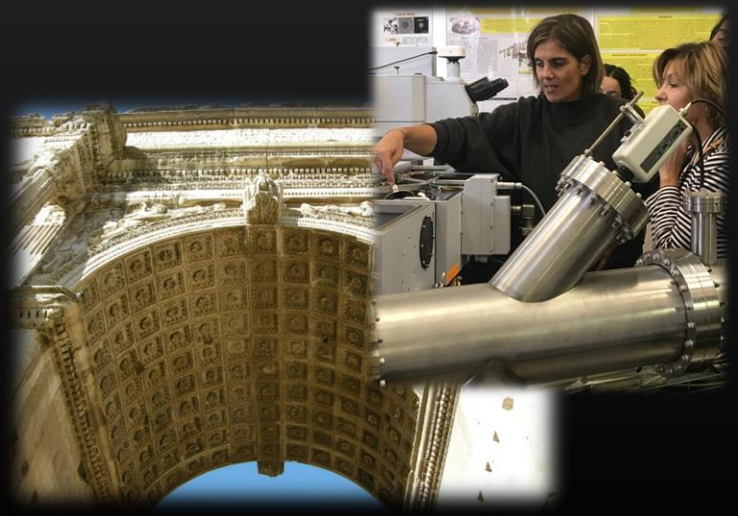


Mural Paintings and Historical Monuments



SCIENTIFIC INVESTIGATIONS OF CULTURAL HERITAGE
Mural Paintings

ADAMO site of interest:
Palazzo Chigi (Ariccia, Rome)

San Giuseppe con il Bambino by Gian Lorenzo Bernini (1663)

PURPOSE:

Characterization of painting's materials

Represents the unique autograph artwork of Bernini, considered the most important artist of Italy's baroque

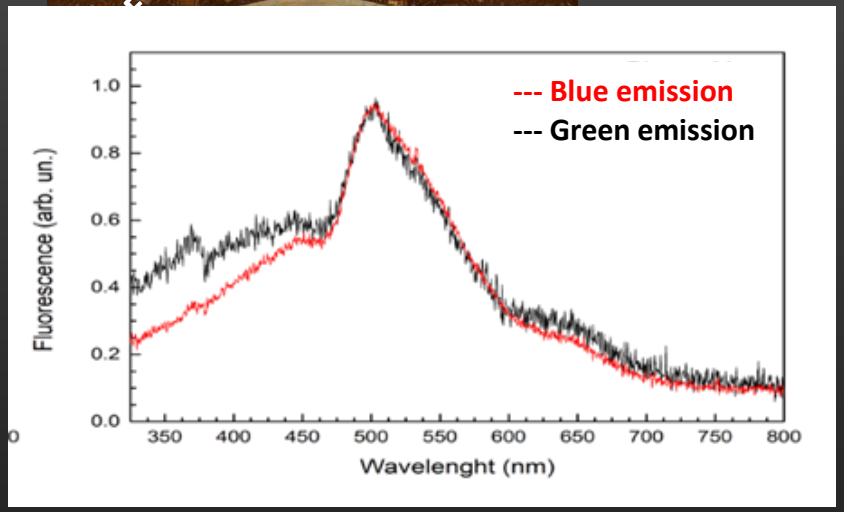
STUDY OF THE CONSERVATION STATE: GRAZING LIGTH

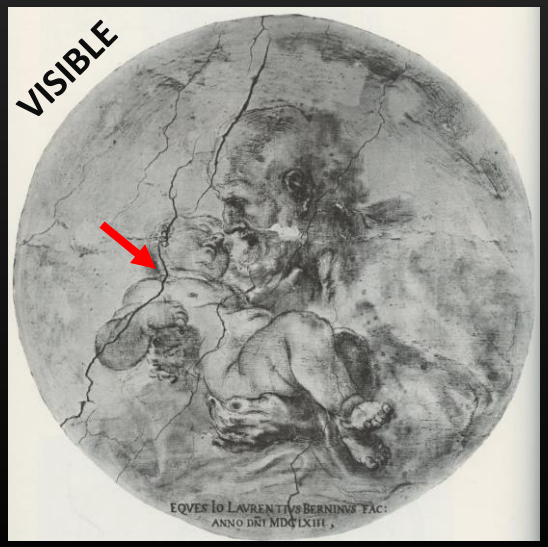
VISIBLE

GRAZING LIGTH

- Obtained by illuminating the surface on one side by using a halogen lamp with angles of incidence always higher than 80° compared to the normal object.
- An amplification of the three-dimensional aspect of the surface is obtained.
- Useful to obtain information on the technique of execution and the state of conservation.

STUDY OF THE CONSERVATION STATE: UV FLUORESCENCE

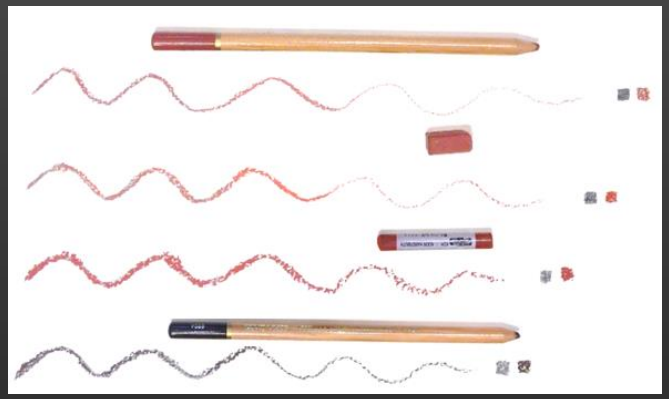




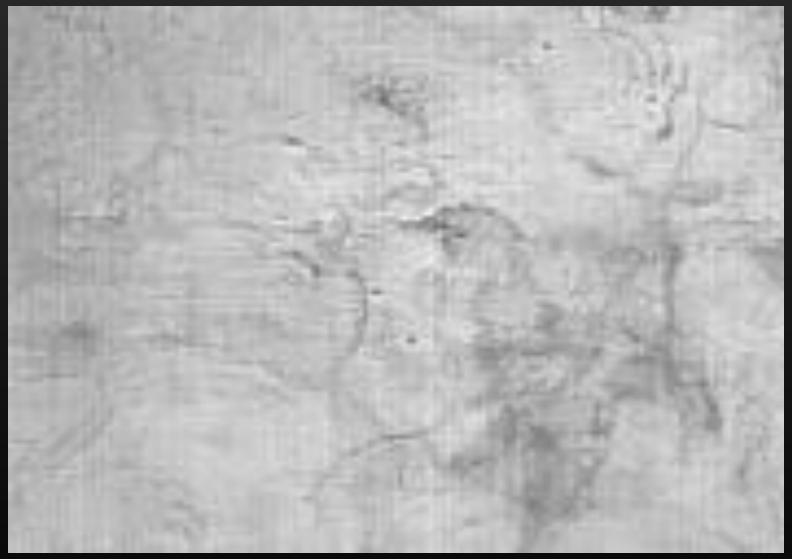
- Obtained by illuminating the artwork with an UV lamp
- Information about the superficial layer
- Absence of syntetich materials (dark areas)
- Two areas characterized by different fluorescence (blue and green)

CHARACTERIZATION OF CONSTITUENT'S MATERIALS: IR REFLECTORGAPHY

VISIBLE



INFRARED REFLECTOGRAPHY

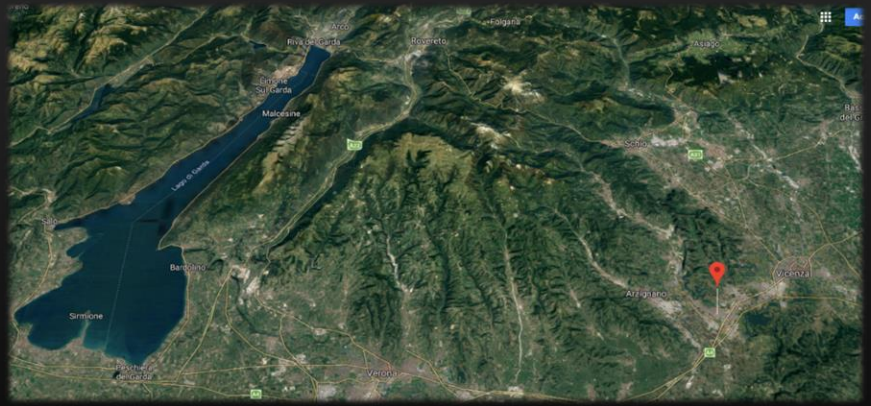


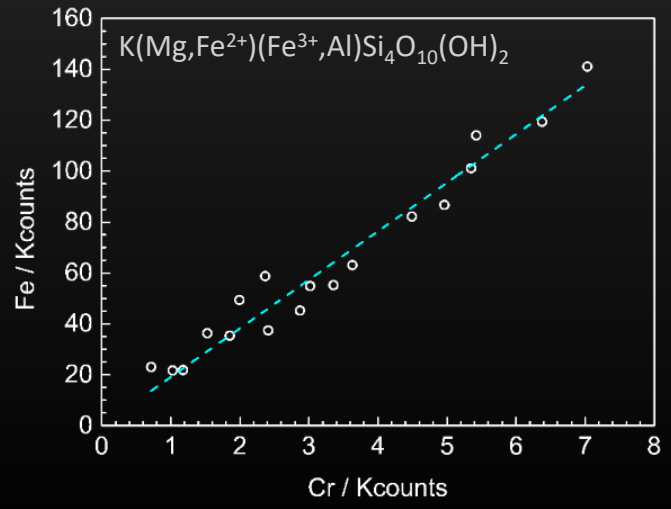
Different behavior of materials in the IR region → means different chemical composition

ELEMENTAL CHARACTERIZATION OF CONSTITUENT'S MATERIALS

Study of pigments provenience by XRF analyses

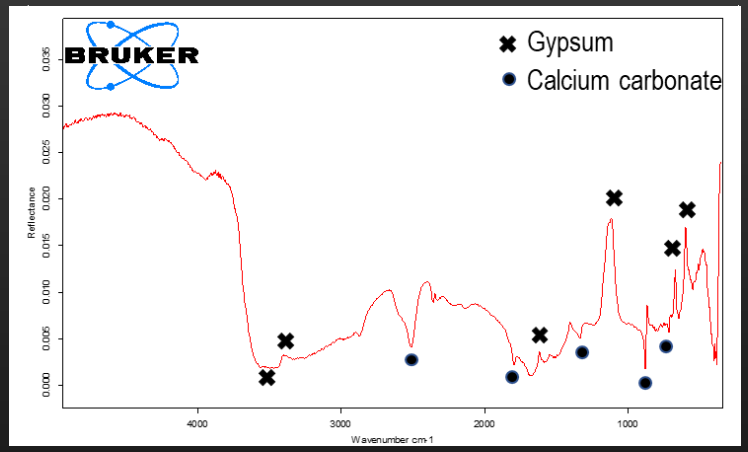
- Characterization of chemical elements of specific geographical areas
- Correlations
- Determination of provenience





MOLECULAR CHARACTERIZATION OF CONSTITUENT'S MATERIALS

In situ Fourier Transform Infrared Spectroscopy (FT-IR).



Identification of Calcium Carbonate and Gypsum

Absence of organic protective materials characterized by a characteristic IR spectrum

Absence of degradation products: (oxalates)

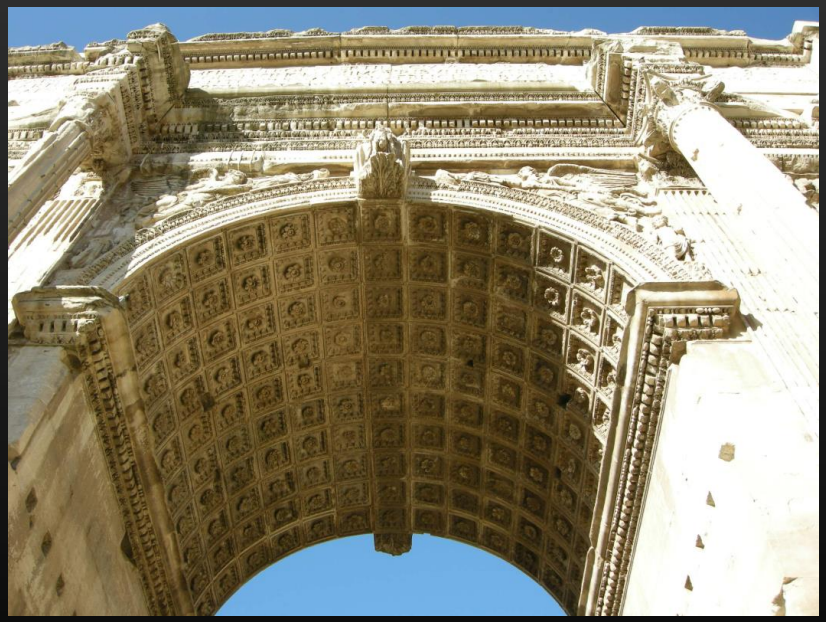
SCIENTIFIC INVESTIGATIONS OF CULTURAL HERITAGE
Historical Monuments

Arch of Septimus Severus, III sec B.C.

PURPOSE:

Characterization of degradation effects due to pollution of Rome

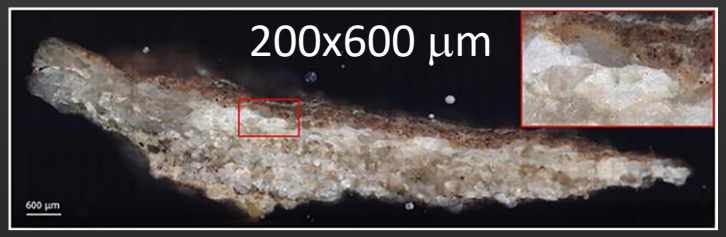
Establishing the distribution of materials and their degradation products in historical monuments is fundamental to understanding their state of preservation

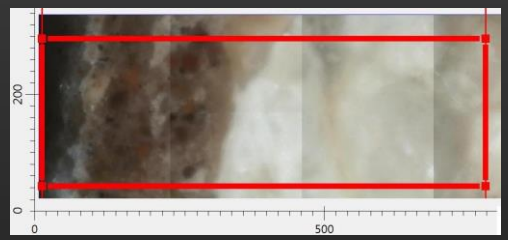


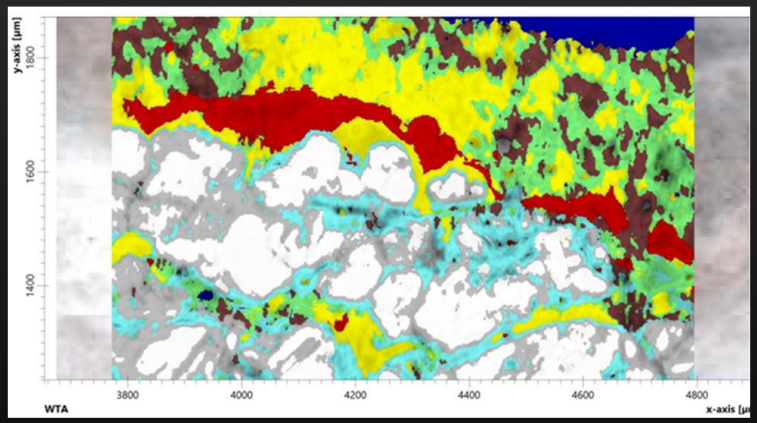
CASE STUDY: STUDY OF DEGRADATION PRODUCTS IN CROSS SECTION

MICRO FT-IR chemical imaging

- FT-IR imaging: molecular composition of the material on a micrometer scale.
- Each colour correspond to a different chemical compound!







Resin (Cluster 1)

Silicates +Gypsum (Cluster 3-4-5 average)

Gypsum (Cluster 9)

Gypsum+Silicates (Cluster 8)

Oxalate+Silicates (Cluster 10)

Gypsum+Calcite+Silicates (Cluster 7)

Calcite+Gypsum (Cluster 6)

Calcite (Cluster 2)

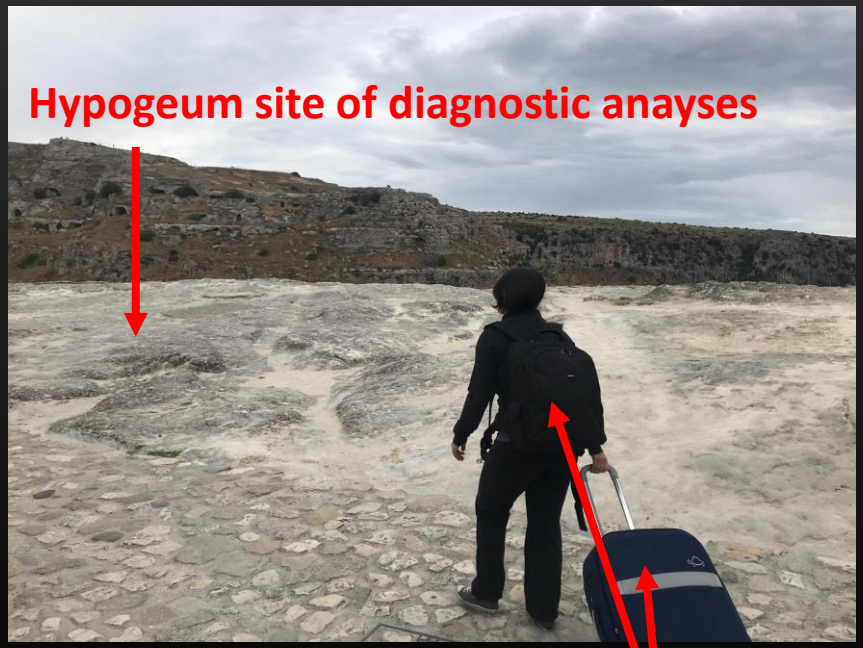
SCIENTIFIC INVESTIGATIONS OF CULTURAL HERITAGE
Mural Paintings in Hypogeus sites

Mural Paintings in Hypogeus Sites

PURPOSE:

Characterization of painting's materials

- Logistical difficulties related to the hypogeus sites
- Needs of compact and light instrumentation
- Microsampling for laboratory analyses



CASE STUDY: IN SITU MEASURMENTS IN HYPOGEUS SITES

Working at restoration site…

1. Imaging analysis

VISIBLE

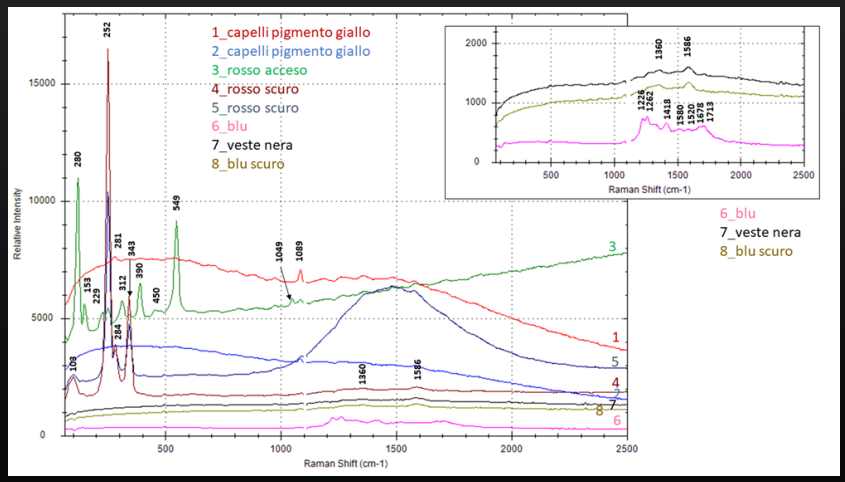
INFRARED REFLECTOGRAPHY

Characterization of previous restoration treatments

CASE STUDY: IN SITU MEASURMENTS IN HYPOGEUS SITES

Working at restoration site…

2. Spectroscopic analyses

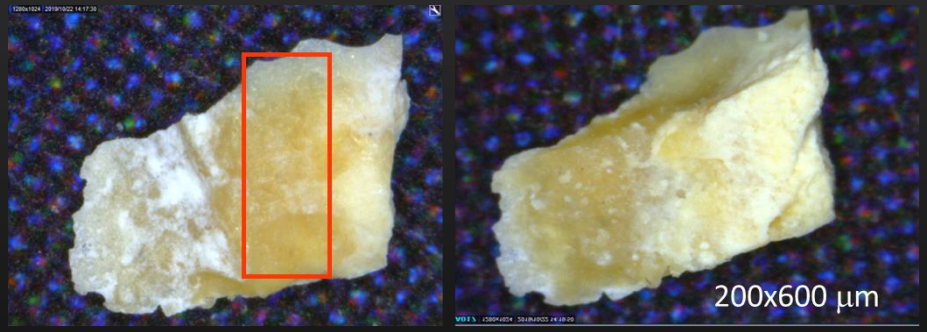


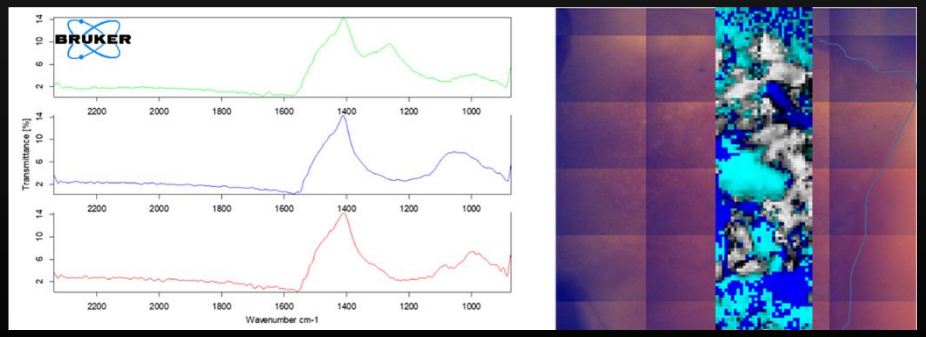
Pigments characterization by in situ Raman analyses

CASE STUDY: IN SITU MEASURMENTS IN HYPOGEUS SITES

Working at restoration site…

3. Choice of areas of interest for microsampling





Laboratory analyses onto microsampling for stratigraphic characterization

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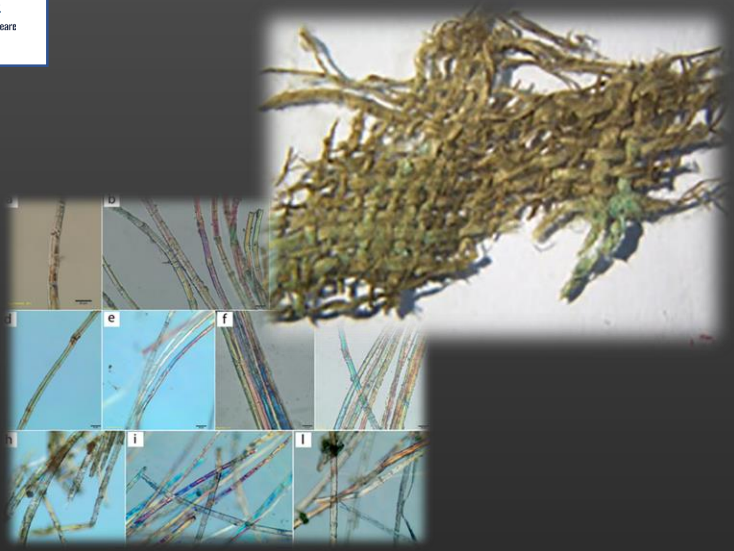
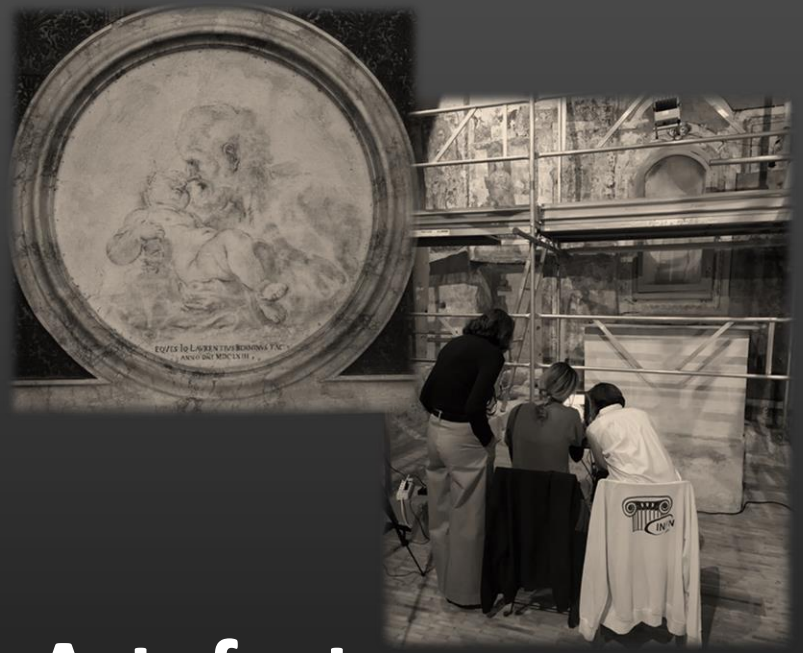
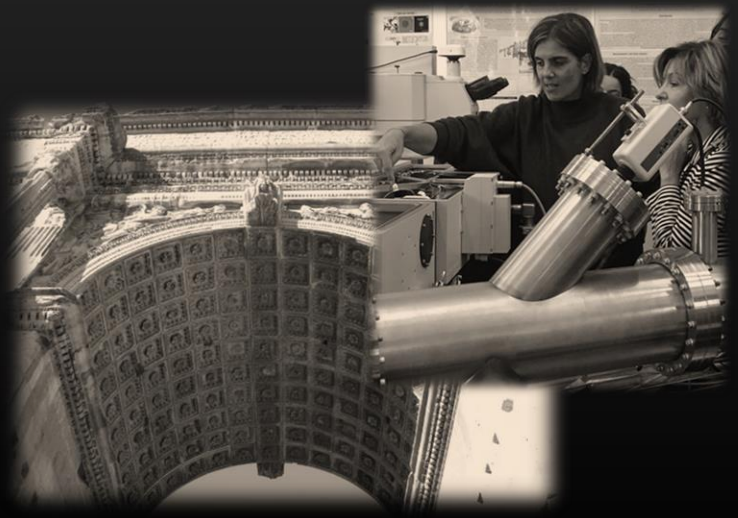




Ancient Texitle Artefacts



SCIENTIFIC INVESTIGATIONS OF CULTURAL HERITAGE
Ancient Texitle Artefacts

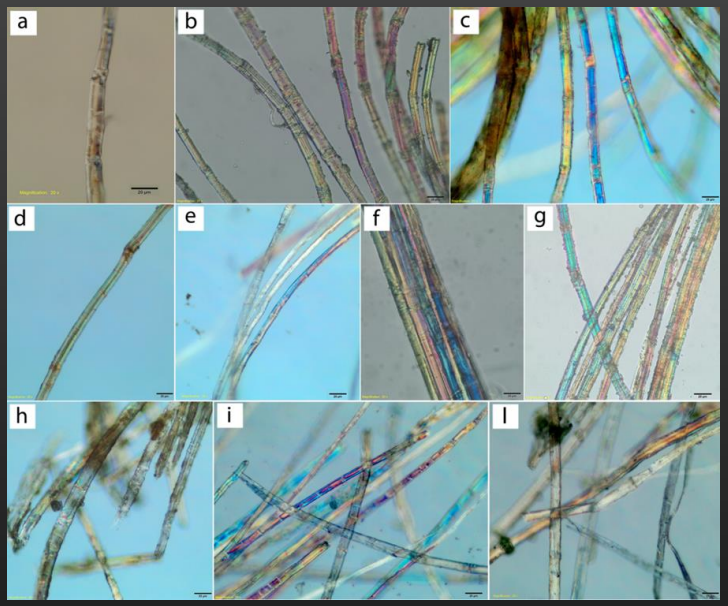
Archeological Fibers of the Vesuvian Area, dated between the II century BC - I century AD characterized by a high historical value.

PURPOSE:

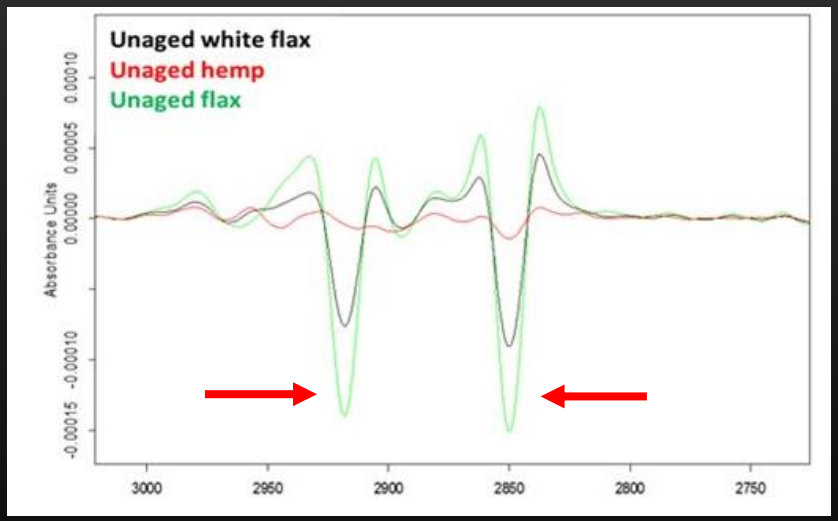
Characterization by ATR-FTIR spectroscopy of flax and hemp

- Flax and hemp are the most common fibers in the archaeological context of the Vesuvian Areas
- Problematic related to their conservation state

CHARACTERIZATION OF ARCHEOLOGICAL FIBERS OF THE VESUVIAN AREA



Very difficult to distinguish by morphological analyses such as optical microscopy or SEM

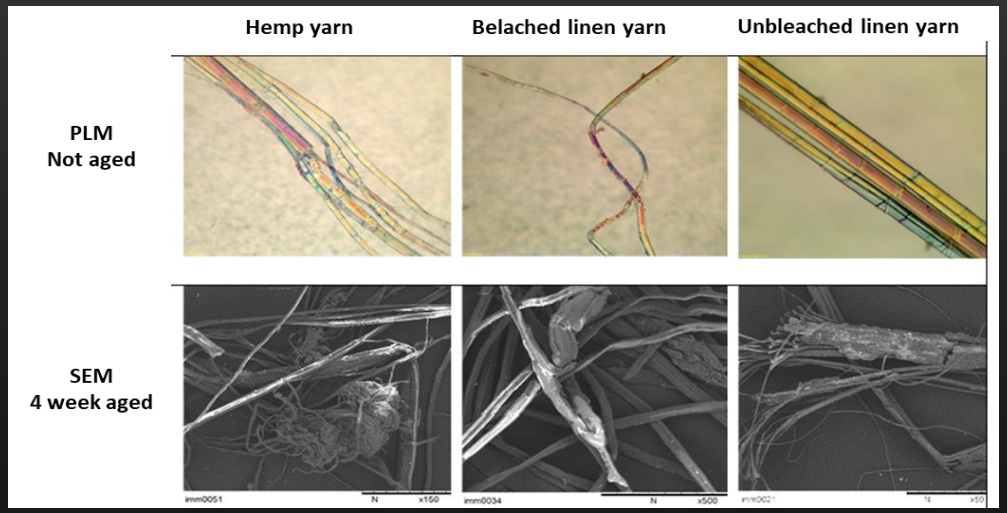


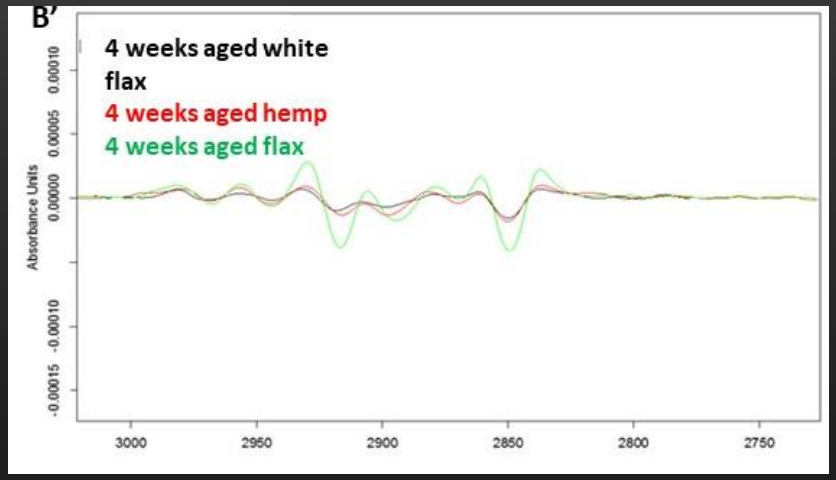
The FT-IR analysis allows the recognition of the two modern fibers thanks to the presence of the CH groups ...

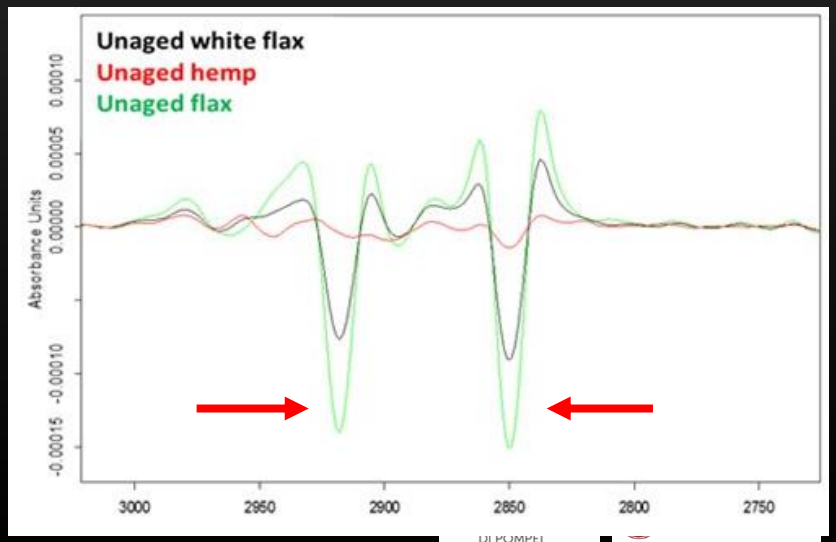
But in archaeological contexts ???

CHARACTERIZATION OF ARCHEOLOGICAL FIBERS OF THE VESUVIAN AREA

We decided to simulate artifical ageeing by using a climatic chamber…in order to study how the ageeing influenced the capability to recognize flax and hemp







After just four weeks of aging they become spectrally and morphologically indistinguishable!

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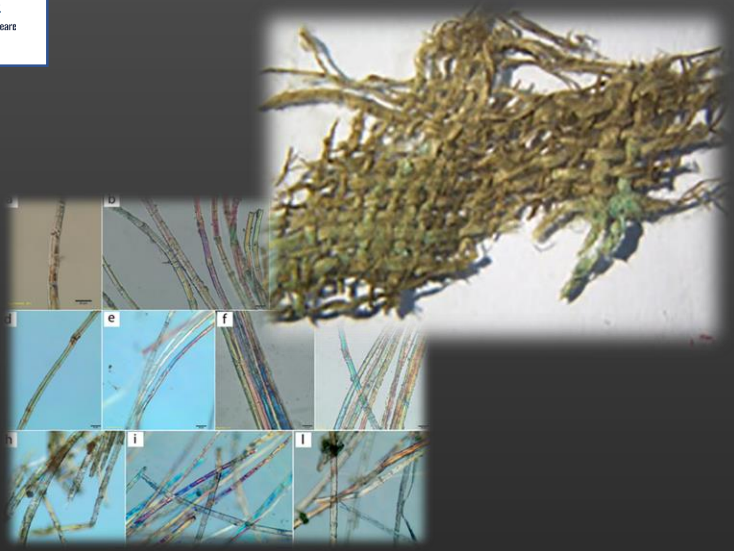

THANKS FOR YOUR ATTENTION