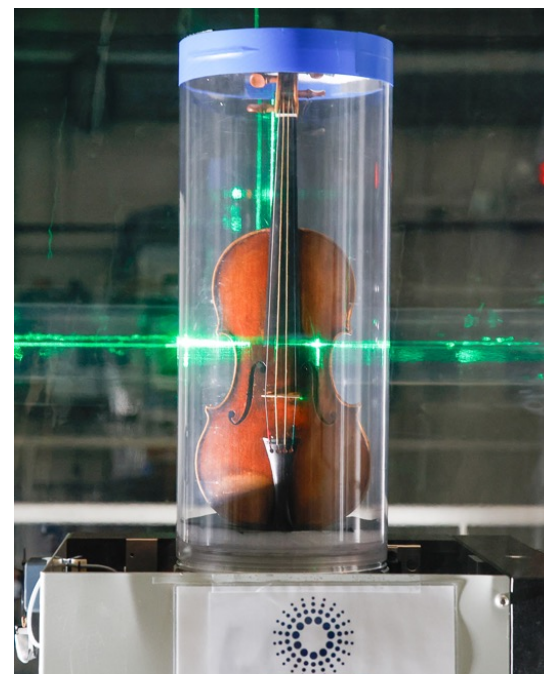


Synchrotron radiation-based X-ray techniques & cultural heritage objects



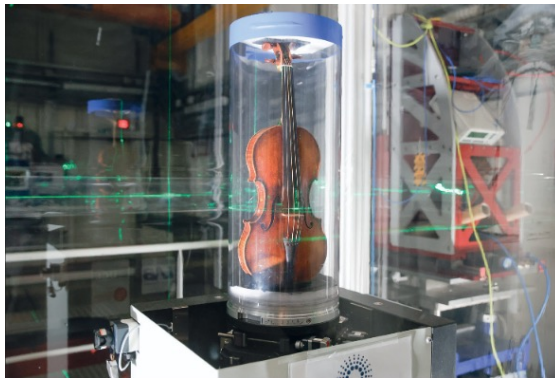
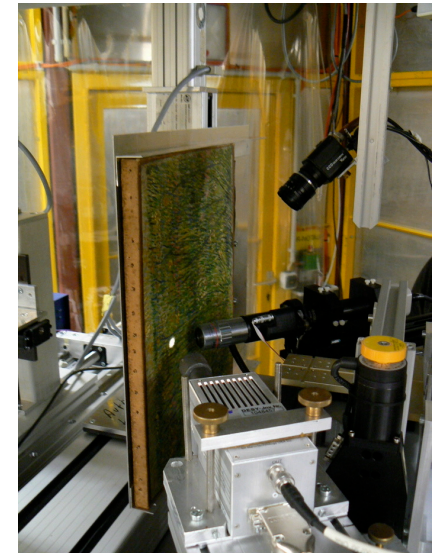
*An integrated multi-material,
multi-technique and multi-
scale approach to study their
composition and evolution*

Georgina P. Robertson,
Marine Cotte



CONTENTS

1. What is heritage research?
2. Challenges
3. Synchrotron techniques
4. Case studies



CULTURAL AND NATURAL HERITAGE

Cultural Heritage



Manufactured objects: processes during and after creation

- Evolution of technologies. Intentions of the artists/craftsmen
- Authentication
- Degradation, preservation, conservation

Natural Heritage



Non-manufactured objects: evolution of Life.

Natural processes involved at all time scales:

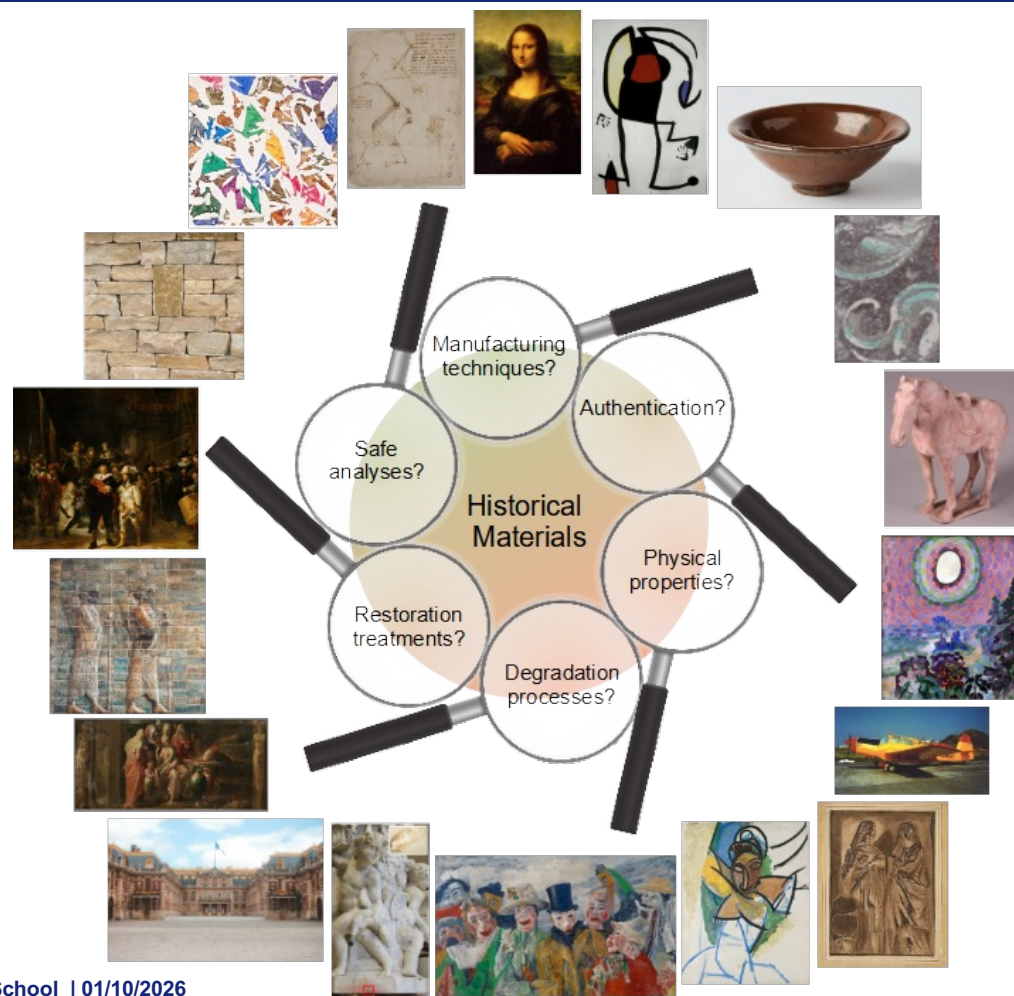
days-months (e.g. embryonic development)

months-years (e.g. growth from child to adult)

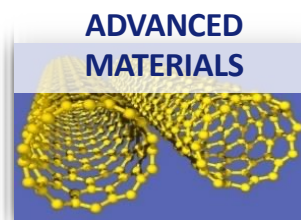
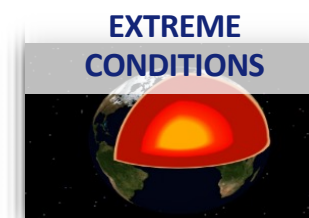
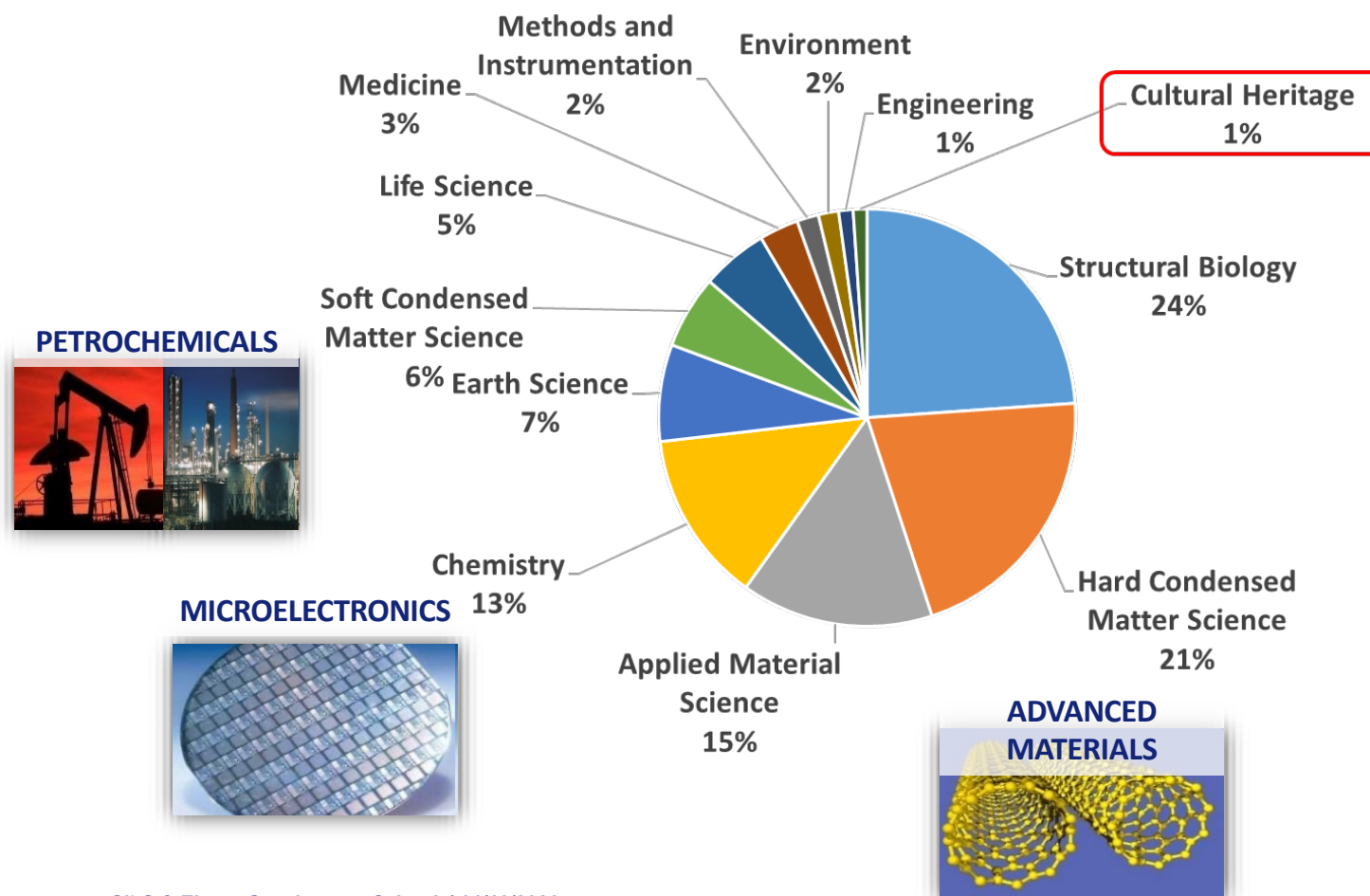
centuries-millenia (e.g. species domestication)

1M-1B years (life evolution)

CULTURAL HERITAGE RESEARCH



ALLOCATED BEAMTIME AT ESRF IN 2021



SOME OF THE HERITAGE RESEARCH AT ESRF



Inks on Papyri
Carlsberg Collection,
Copenhagen, Christiansen
Herculaneum, Brun



**Cimabue's Maestà of
Santa Maria dei Servi**
(1280–1285),
L. Monico,
Perugia



Ming porcelains
Beijing Archaeological
Institute (15th-16th C.),
Ph. Sciau,
Toulouse



**Ultramarine pigment
in Girl with a Pearl Earring,**
Mauritshuis, (1665),
A. Gambardella,
Amsterdam



Van Gogh's Sunflowers
van Gogh Museum,
(1888-1889),
L. Monico,
Perugia, Antwerp



Munch's Scream,
Munch Museum
(1910),
L. Monico,
Perugia



Rodin's modelling clay
Rodin museum
(1908-1913),
J. Langlois,
Paris



**Miro's Femme
dans la rue**
(1973),
M. Ghirardello,
Milano

Antiquity



**Hellenistic Egyptian
Blue**
Kos, (1st C. BCE)
A. Kostomistopoulou,
Oslo
Page 6



**Bamiyan Buddhist
paintings**
Afghanistan, (6th-9th C.)
Y. Taniguchi,
Tokyo



**Leonardo da Vinci's
last Supper**
Santa Maria Delle Grazie
(1495-1498)
M. Cotte, ESRF



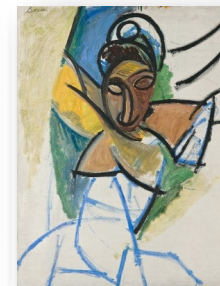
Rembrandt's Night watch
Rijksmuseum
(1642),
V. Gonzalez,
Delft



**Caspar David
Friedrich's Wanderer
above the Sea of Fog**
Hamburger Kunsthalle,
(1818),
I. Reiche, Paris



**Porcelains,
Sèvres manufacture**
End 19th Beg. 20th C.
L. Verger,
Paris



Picasso's Femmes
Foundation Beyeler,
(1907),
M. Ghirardello,
Milano



**Ducos du Hauron early
color photographs,**
1870's, M. Cotte,
ESRF

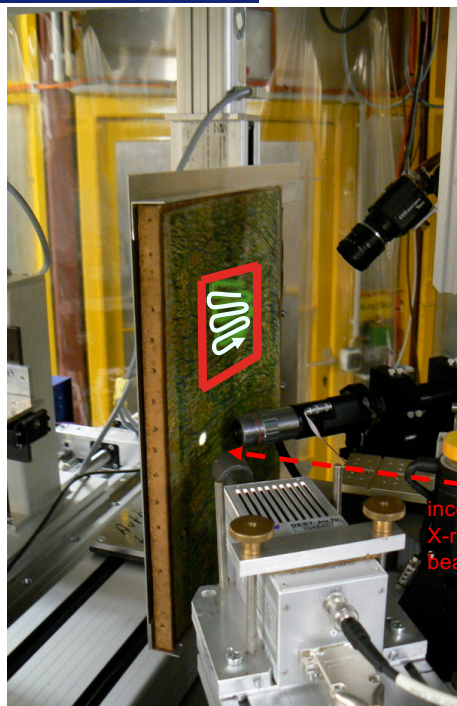
Today

FORMS OF HERITAGE RESEARCH

Direct analysis of

artwork

L, DORIS III, DESY



J. Dik *et al.* Visualization of a Lost Painting by
Based X-ray Fluorescence Elemental Mapping

Preparation and analysis of micro

ment



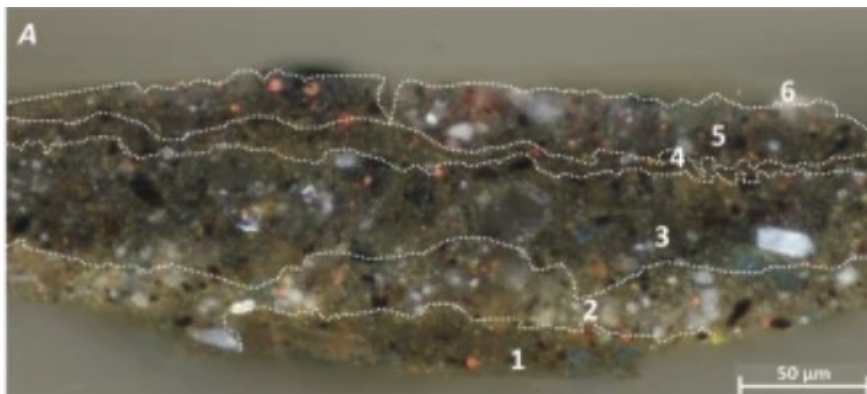
Vincent van Gogh
Patch of Grass
Paris, 1886

Kroeller Mueller Museum
Otterlo, the Netherlands



ID21, ESRF

CROSS-SECTION/THIN-SECTION



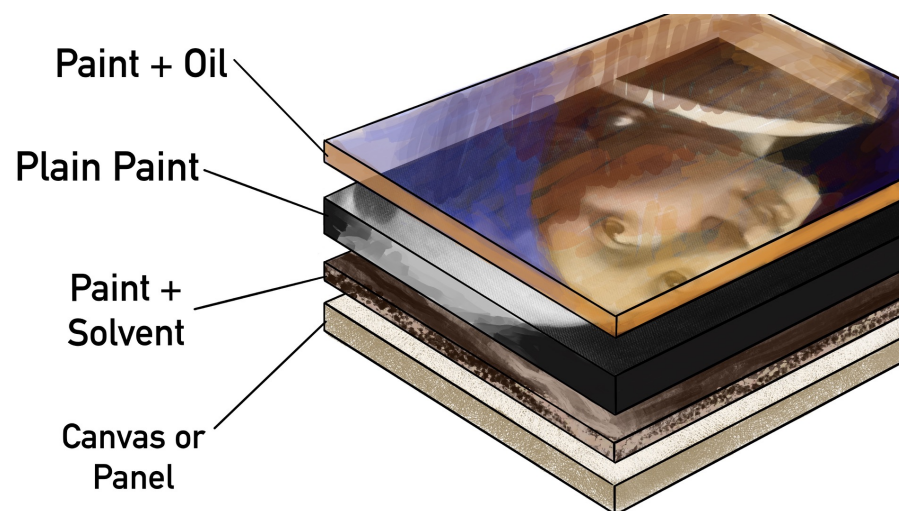
1: Earth pigments, bone or ivory black, lead white, azurite (probably), red lake, vermillion, some chalk, possibly smalt

2: Components of 1 + organic brown (maybe Kassel earth), traces of gypsum, chalk, and lead-tin yellow

3 and 5: Same as 2 but higher amount of bone or ivory black

4: Interfacial material (eg. oil skin)

6: Natural resin varnish



<https://www.schoolofrealistart.com/blog/fat-over-lean-rule>

CHALLENGES OF HERITAGE RESEARCH

1. Weird sample sizes/shapes
2. Timeframe
3. Damage
4. Access to and control over data



Crafted in 1743 by Bartolomeo Giuseppe Guarneri “del Gesù”



Image and information credits:

Paul Tafforeau et al. **Synchrotron scan of the Paganini's violin**, Genoa, 24th Oct 2025

Rhapsody as European synchrotron examines Niccolò Paganini's violin

Michael Banks 2024 *Phys. World* **37** (4) 11ii

<https://iopscience.iop.org/article/10.1088/2058-7058/37/04/15>

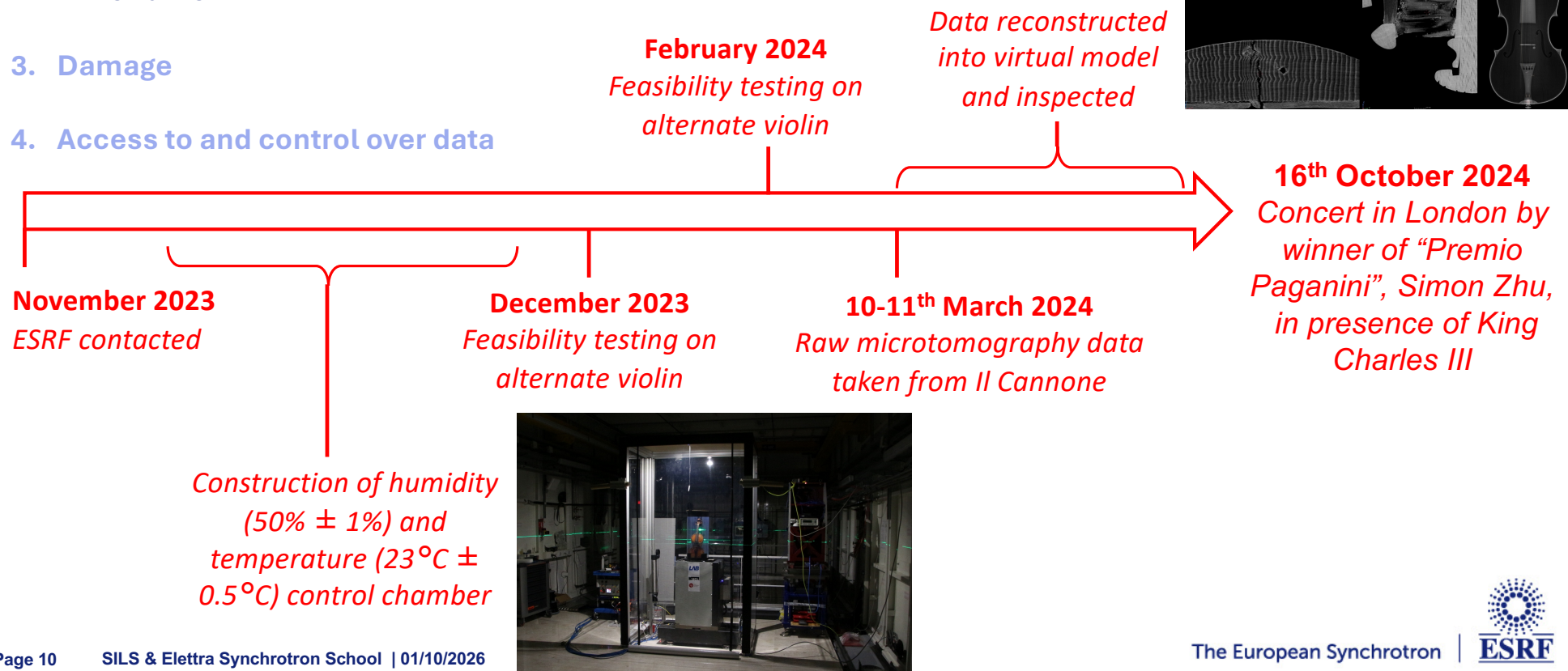
CHALLENGES OF HERITAGE RESEARCH

1. Weird sample sizes/shapes

2. Timeframe

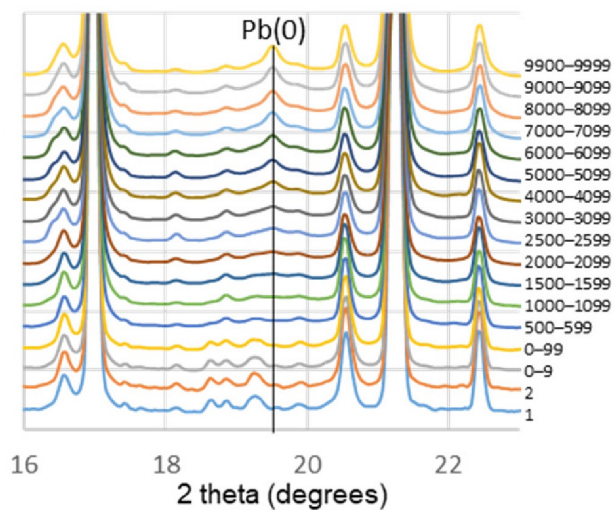
3. Damage

4. Access to and control over data

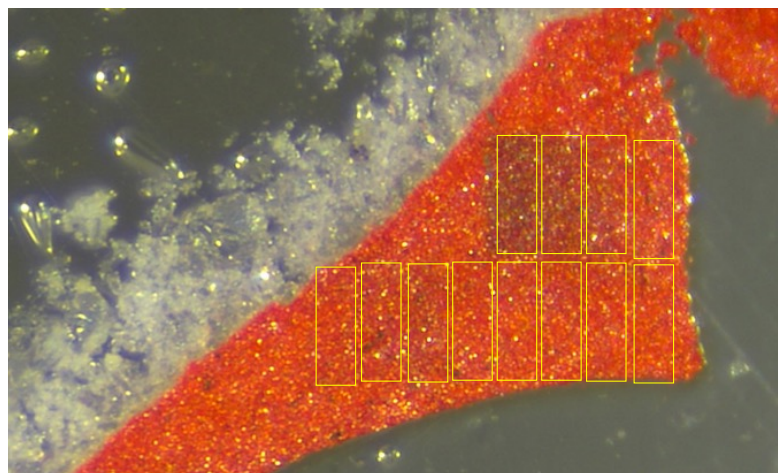


CHALLENGES OF HERITAGE RESEARCH

1. Weird sample sizes/shapes
2. Timeframe
3. Damage
4. Access to and control over data



Lead white (hydrocerussite), $\text{Pb}_3(\text{CO}_3)_2(\text{OH})_2$



Cinnabar/Vermilion, HgS

Exposure time (s)
Step size between
pixels (μm)

0.1s 0.05s 0.02s 0.1s
1 μm 1 μm 1 μm 10 μm

0.02s	0.05s	0.1s	0.02s	0.05s	0.1s	0.02s	0.05s
2 μm	2 μm	2 μm	5 μm	5 μm	5 μm	10 μm	10 μm

CHALLENGES OF HERITAGE RESEARCH

1. Weird sample sizes/shapes
2. Timeframe
3. Damage
4. Access to and control over data

Comment | [Open access](#) | Published: 16 April 2021

Operationalizing the CARE and FAIR Principles for Indigenous data futures

[Stephanie Russo Carroll](#) , [Edit Herczog](#), [Maui Hudson](#), [Keith Russell](#) & [Shelley Stall](#)

[Scientific Data](#) **8**, Article number: 108 (2021) | [Cite this article](#)



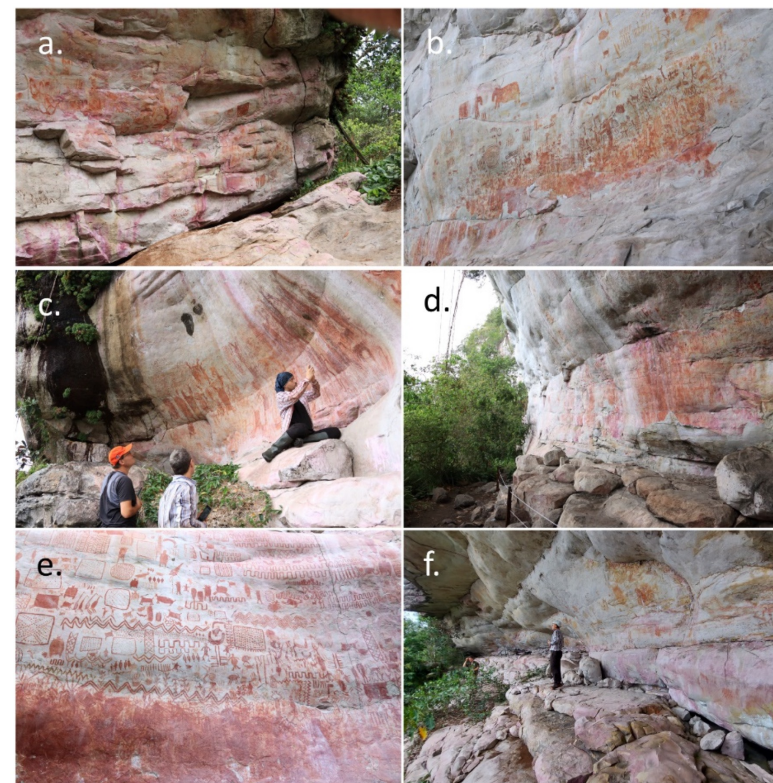
Endangered Archaeology in the Middle East & North Africa



Open Access Policy

Access to the data is based on the principle of “As Open as possible, as closed as necessary” – and in line with Arcadia, we seek to follow the FAIR (Findability, Accessibility, Interoperability, Reusability) principles. EAMENA aims to promote best practices in FAIR and serve as a reference platform for managing heritage and archaeological data, accommodating contributions from multiple projects across different chronological, spatial, and thematic dimensions in an open, cumulative, and transparent framework.

Full Open Access is not possible as there are genuine concerns that open access to precise location information may facilitate looting, while some details on the management of sites and their condition may include personal data. We therefore only limit



Hampson *et al.* ‘A World of Knowledge’: Rock Art, Ritual, and Indigenous Belief at Serranía De La Lindosa in the Colombian Amazon, *Arts*, 2024, 13, 4-135

MAIN SYNCHROTRON TECHNIQUES

Techniques:

1. X-ray diffraction

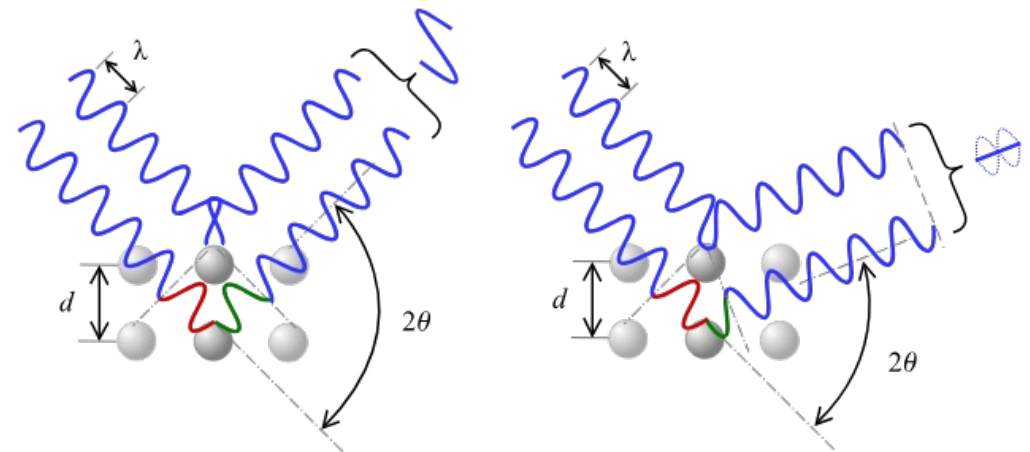
2. X-ray Absorption Spectroscopy

3. X-ray fluorescence

4. Computed tomography

5. 3DXRD – Diffraction tomography

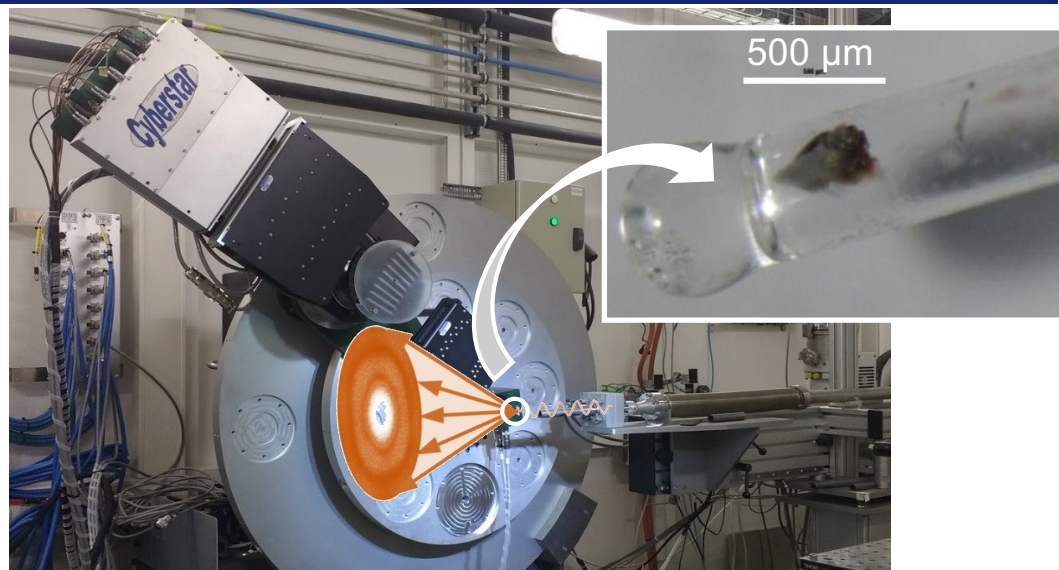
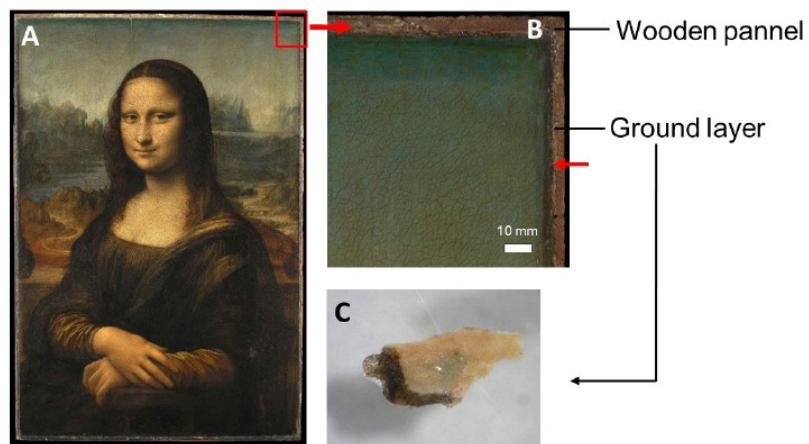
X-ray Diffraction (XRD)



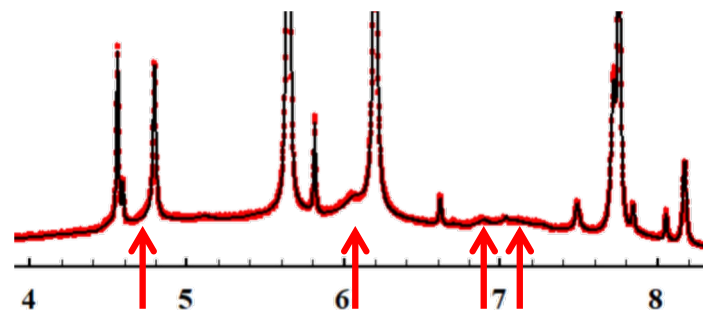
- Bulk crystalline structure (identification)
- Strain of lattice
- Crystallite size

POWDER X-RAY DIFFRACTION

V. Gonzalez et al. **X-ray and Infrared Microanalyses of *Mona Lisa's* Ground Layer and Significance Regarding Leonardo da Vinci's Palette** (2023) J. Am. Chem. Soc., 145, 42, 23205-23213

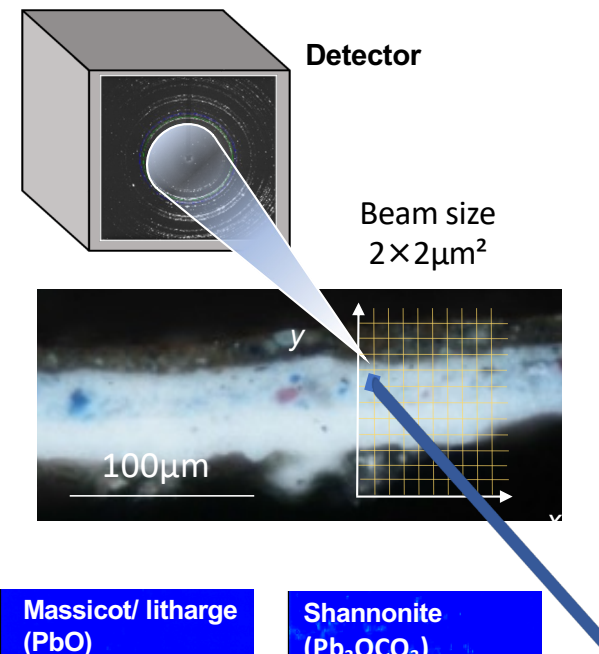


- Da Vinci used a wide range of oil-based ground layers, all containing Lead White ($\text{PbCO}_3 + \text{Pb}_3(\text{CO}_3)_2(\text{OH})_2$)
- Detection of **plumbonacrite** $\text{Pb}_5(\text{CO}_3)_3\text{O}(\text{OH})_2$, very unusual
- How was this formed?

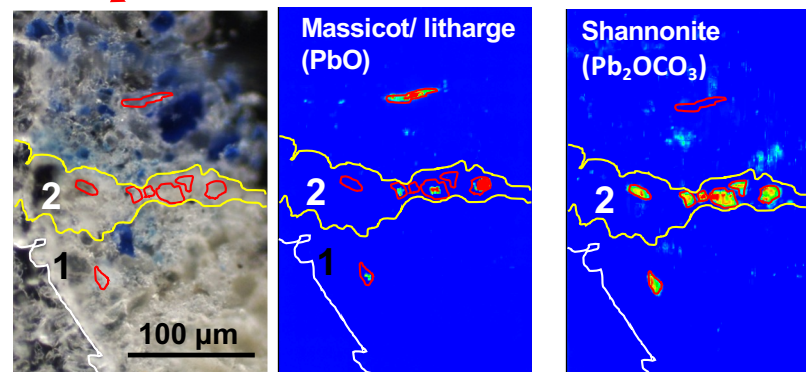


MICRO-X-RAY DIFFRACTION MAPPING

V. Gonzalez et al. **X-ray and Infrared Microanalyses of *Mona Lisa's* Ground Layer and Significance Regarding Leonardo da Vinci's Palette** (2023) J. Am. Chem. Soc., 145, 42, 23205-23213



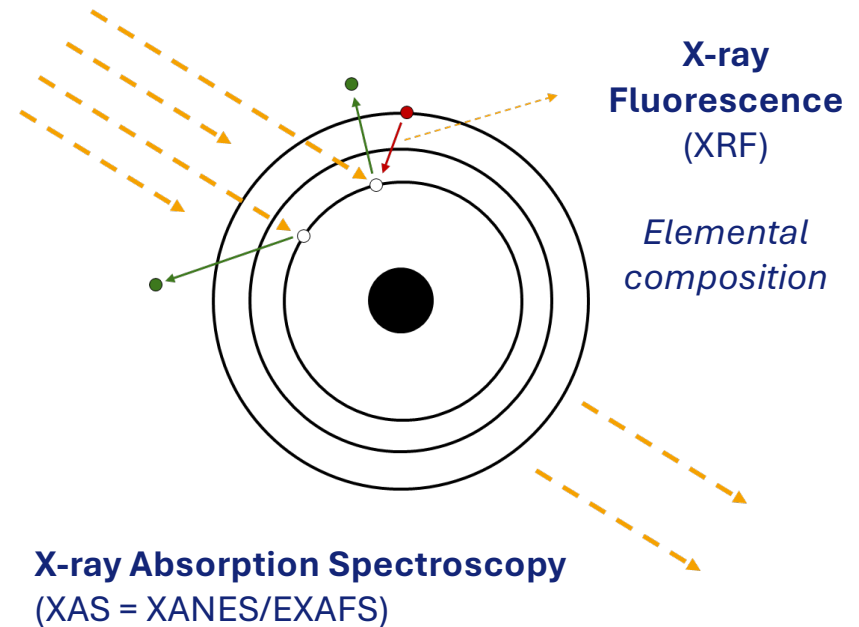
- Confirming the use of PbO by Leonardo *da Vinci* in his paintings
- Saw layers of plumbonacrite and shannonite around PbO particles -> *in situ* formation likely
- Indicates the aim to speed up the drying of paint by applying metal salt PbO
- *Possibility of further ageing/degradation through this reaction*



MAIN SYNCHROTRON TECHNIQUES

Techniques:

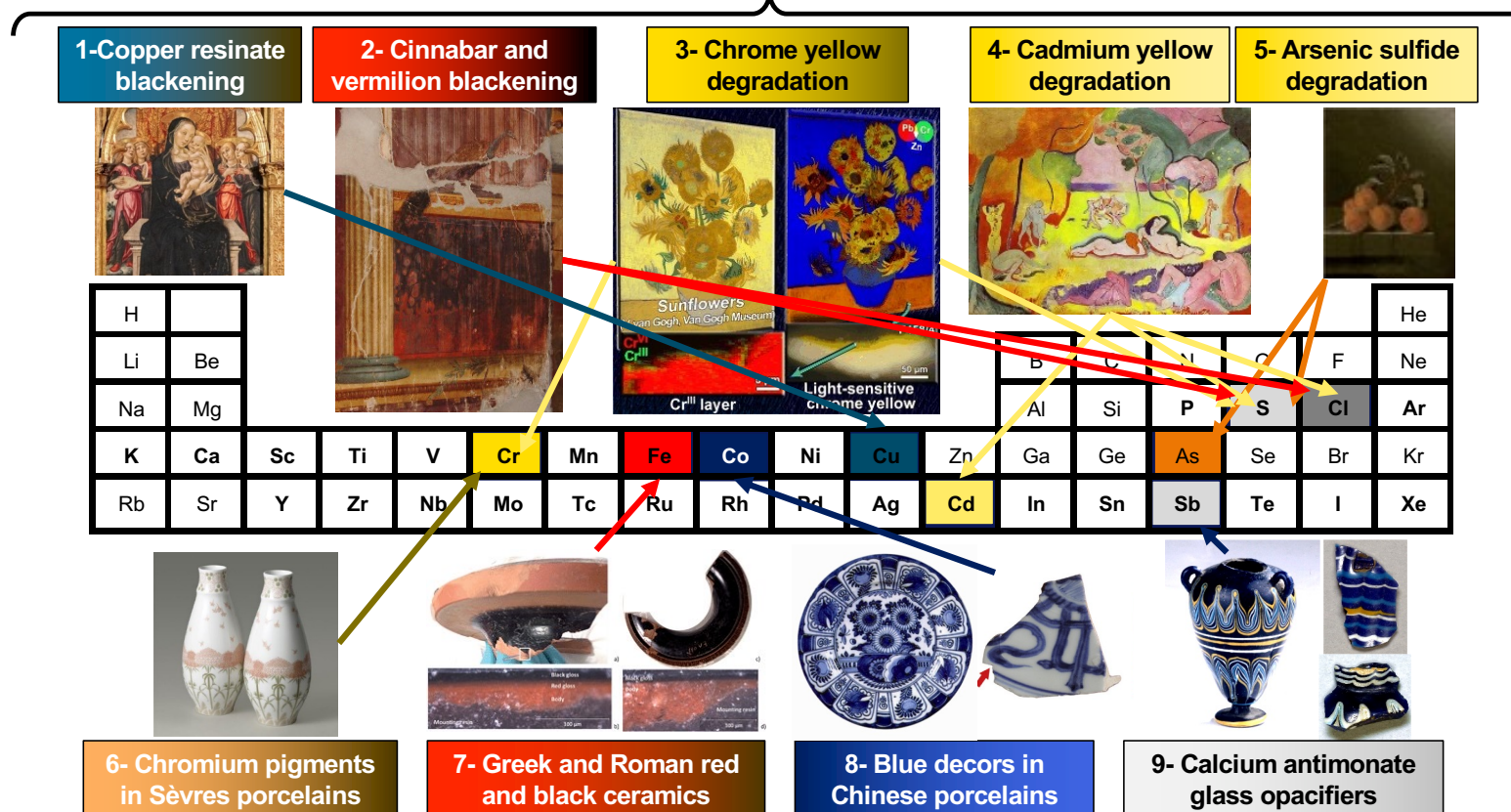
1. X-ray diffraction
2. X-ray Absorption Spectroscopy
3. X-ray fluorescence
4. Computed tomography
5. 3DXRD – Diffraction tomography



- *Chemistry of target element (identification)*
- *Structural nearest-neighbour information*

X-RAY ABSORPTION SPECTROSCOPY

Material degradation



MAIN SYNCHROTRON TECHNIQUES

Techniques:

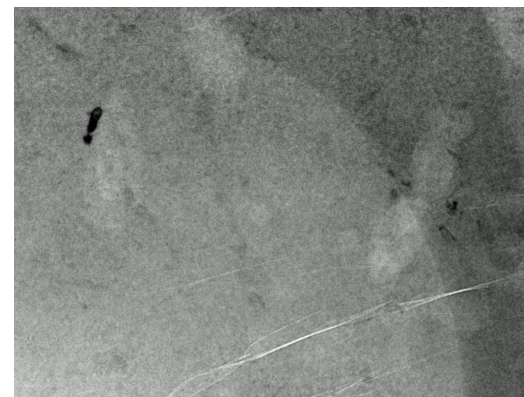
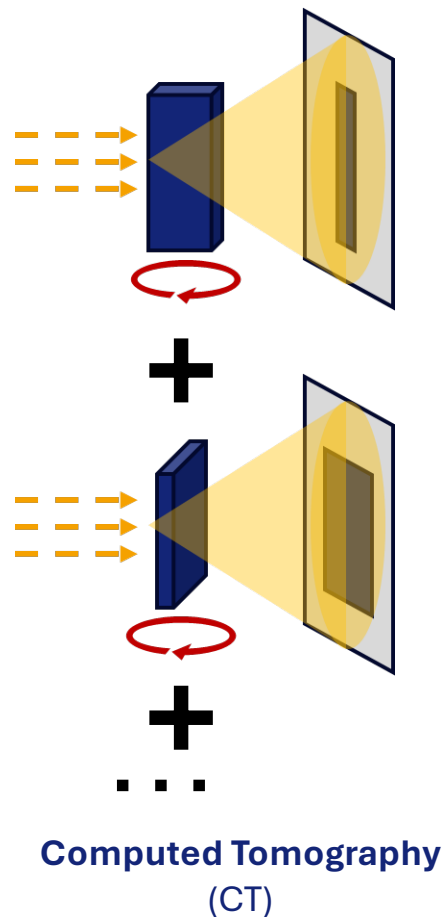
1. X-ray diffraction

2. X-ray Absorption Spectroscopy

3. X-ray fluorescence

4. Computed tomography

5. 3DXRD – Diffraction tomography



Normal (absorption) contrast



Phase contrast

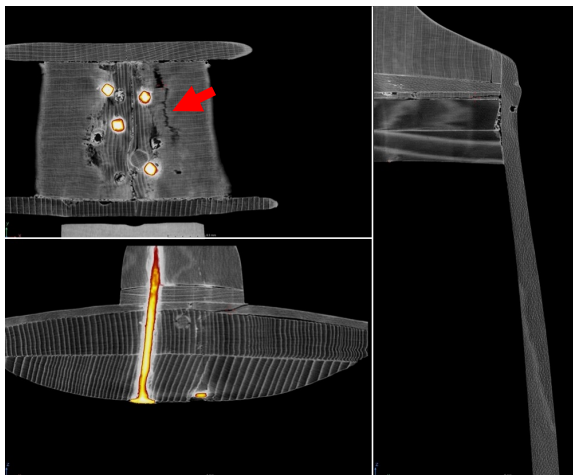
COMPUTED TOMOGRAPHY

Paul Tafforeau 2025 (ESRF, BM18)

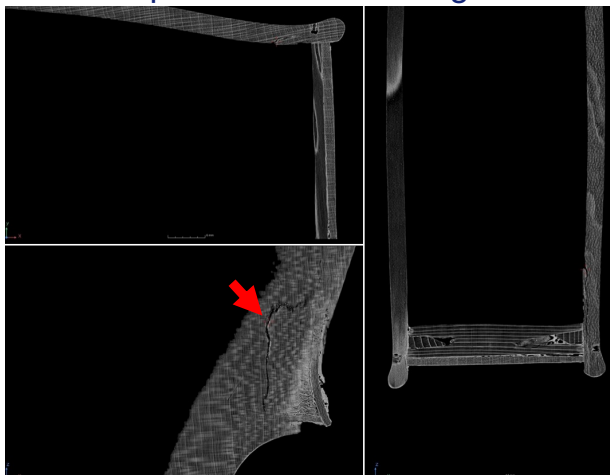


COMPUTED TOMOGRAPHY

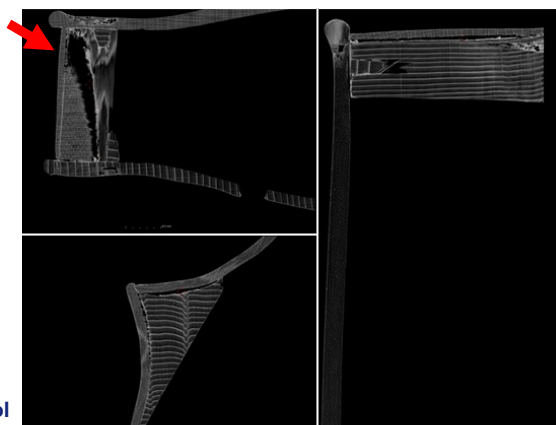
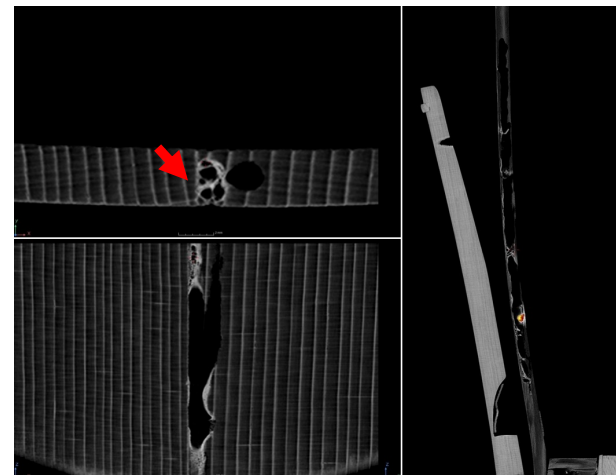
Fractures network in the neck fixation



Crack in the back, possibly due to a previous dismounting



Insect track along the midline of the table



Unglued corner due to distortion of the side

Il Cannone team

Paul Tafforeau

Luigi Paolasini

Bruce Carlson

Nicola Sodini

Alberto Giordano

Alessandro Mirone

Yves Watier

Clémence Muzelle

Christophe Jarnias

Kamel Madi

Loïc Courtois

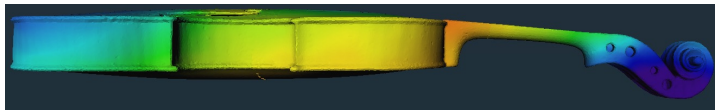
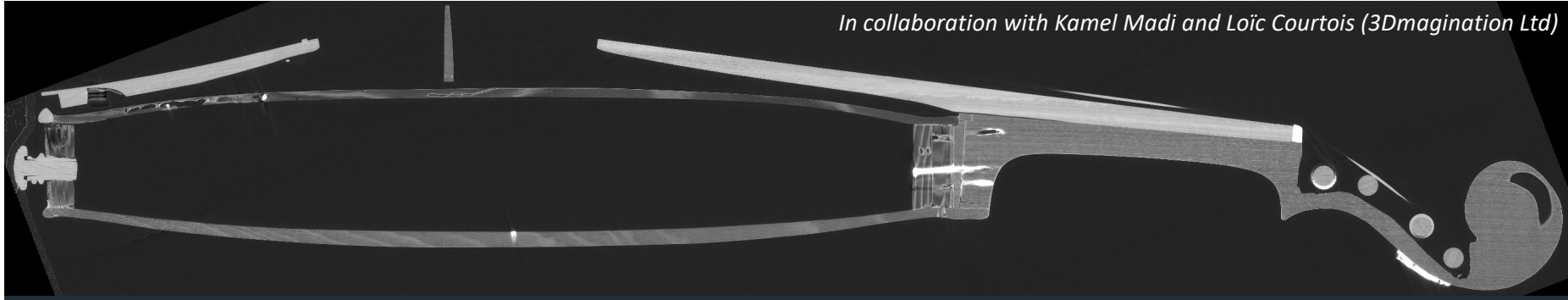
Francesco Sette

Paul Tafforeau 2025 (ESRF, BM18)

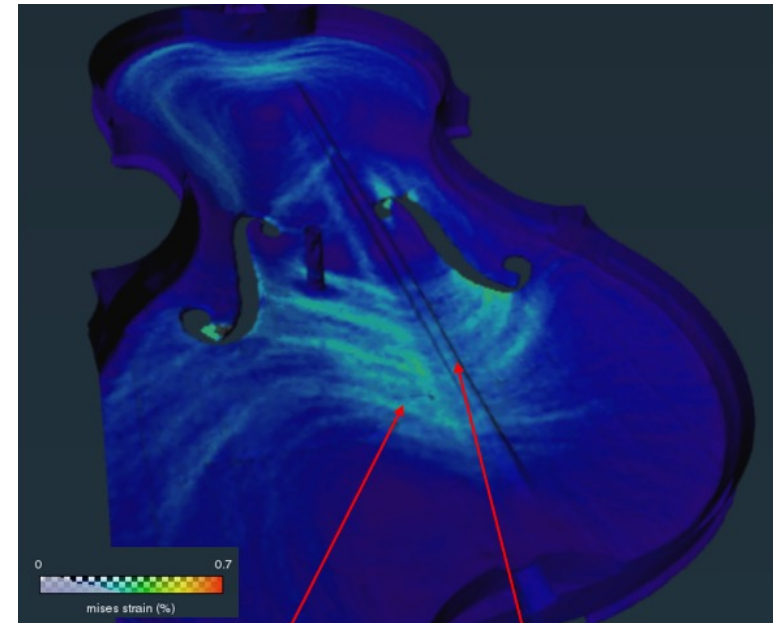
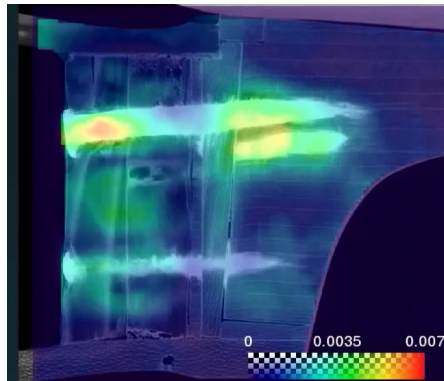


COMPUTED TOMOMOGRAPHY (DVC)

In collaboration with Kamel Madi and Loïc Courtois (3Dmagination Ltd)



- No movement of the cracks in the wood block during flexing
- Nails are still supporting the stress in the neck fixation
- Deformation of the table is homogenous, not effected by insect tracks
- Safe to play, areas identified for future monitoring



MAIN SYNCHROTRON TECHNIQUES

Techniques:

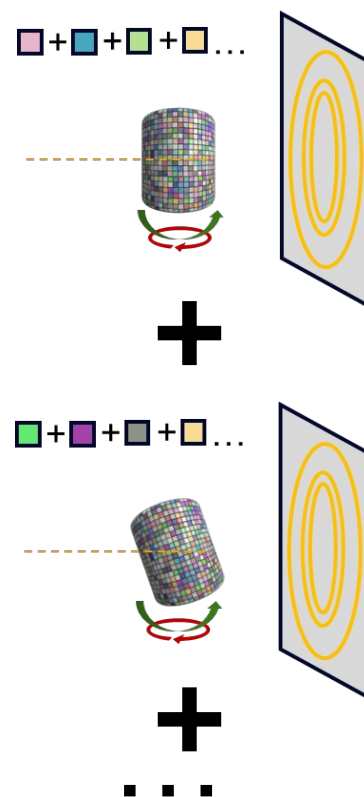
1. X-ray diffraction

2. X-ray Absorption Spectroscopy

3. X-ray fluorescence

4. Computed tomography

5. 3DXRD – Diffraction tomography



Diffraction Tomography
(3DXRD)

3D X-RAY DIFFRACTION

Angewandte
Chemie

DOI: 10.1002/ange.201411691

Pigment Discoloration

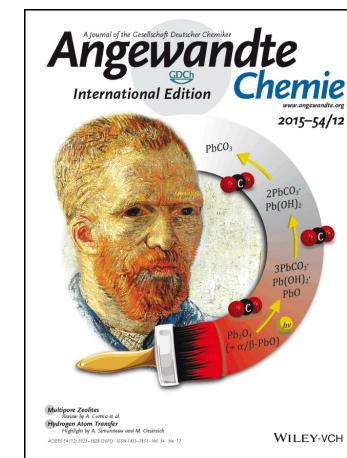
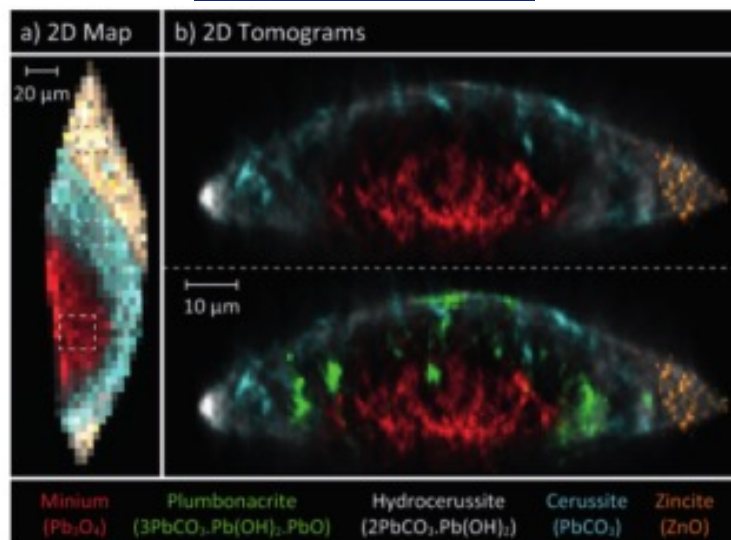
Plumbonacrite Identified by X-ray Powder Diffraction Tomography as a Missing Link during Degradation of Red Lead in a Van Gogh Painting**

Frederik Vanmeert, Geert Van der Snickt, and Koen Janssens*



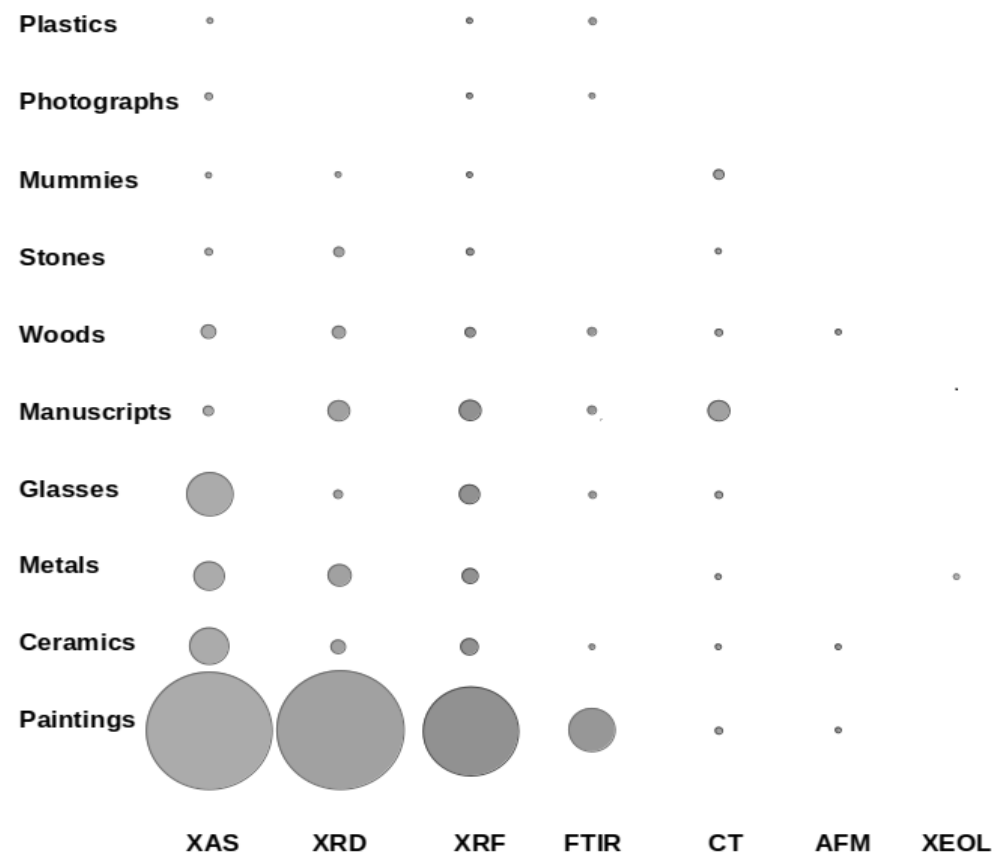
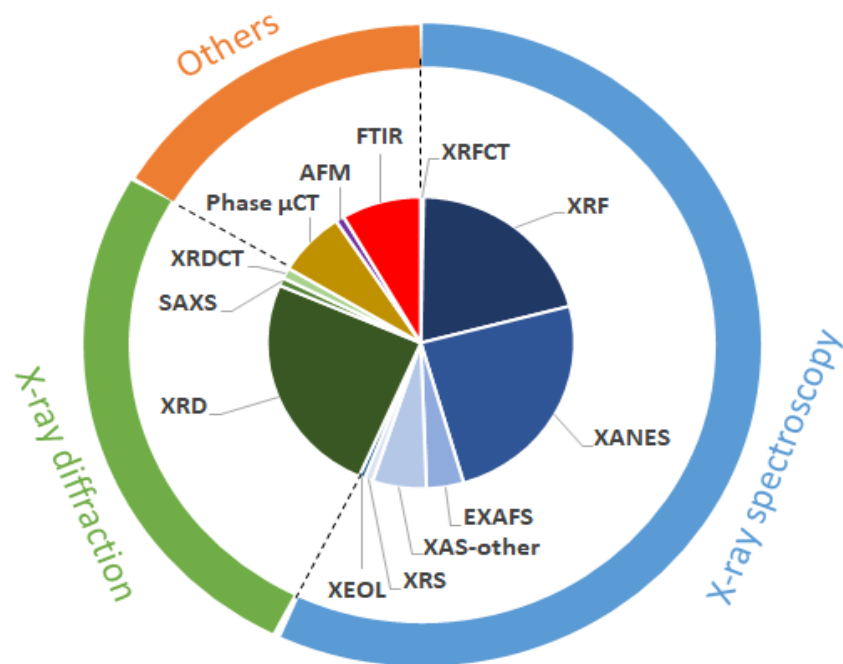
Figure 1. a) Photograph of *Wheat Stack Under a Cloudy Sky* by Van Gogh (October 1889, oil on canvas, Kröller-Müller Museum, NL). The sample area is indicated by the white circle. b) Detail of the severed pustular mass on the painting surface. c) Detail of the paint sample.

P06, PETRA III, DESY



CULTURAL AND NATURAL HERITAGE

Cultural Heritage



ESRF cross-cut review Heritage, 2024

CULTURAL HERITAGE RESEARCH

Case studies:

1. Vermeer's *Girl with a Pearl Earring*



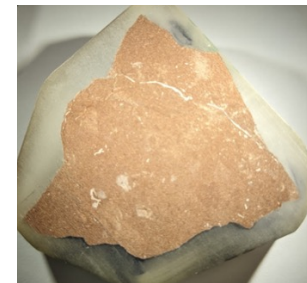
2. Acid Attack on Rembrandt's *The Night Watch*



3. Van Gogh's *Sunflowers*



4. Fossilised eggshell of *Massospondylus* dinosaur



CASE STUDY: GIRL WITH A PEARL EARRING

Which were the materials used?

Where did these materials come from?

Did Vermeer use different qualities of the same pigment?

What steps did Vermeer take to create the painting?



Are the present colors the original ones?

What did the painting look like originally, and how has it changed?

Did the painting suffer from previous restoration campaigns?

What is the chemical and physical condition of the painting?

NON-SYNCHROTRON TECHNIQUES

a) X-ray fluorescence

- ⇒ Elemental maps
- ⇒ High penetration

b) Computer-assisted thread-level canvas analysis, ML analysis of X-ray radiographs

d) UV-induced fluorescence photography

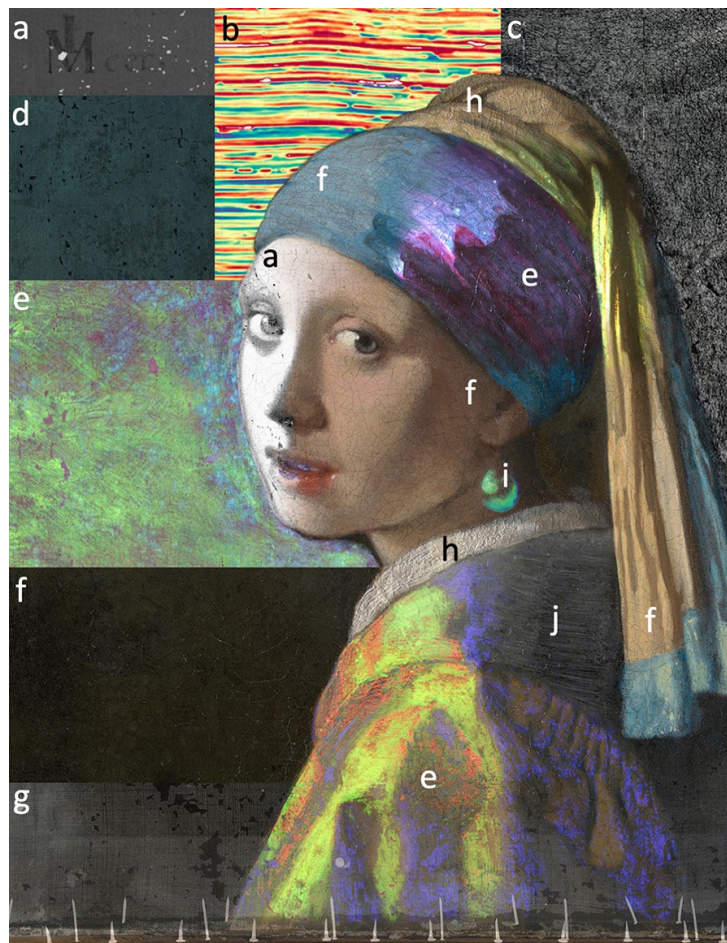
- Retouched area, varnish layer

h) Raking light photography

- ⇒ surface topography, cracks

g) X-radiography

- ⇒ Thickness, composition, density of the ground, nails...



c) Multi-scale optical coherence tomography, (reflected near-infrared light, in-depth image of semi-transparent layers)

e) Reflectance imaging spectroscopy false-colour, visible and near-infrared

- ⇒ Electronic transitions, molecular groups (pigments)

f) Polarised light photography: greater contrast between the figure and background

i) 3D scanning based on fringe-encoded stereo imaging

j) Multispectral infrared reflectography, 900-2500nm

- ⇒ painted underlayers and underdrawing containing IR absorbing materials (carbon black or umber)

Composite image: Sylvain Fleur and the *Girl in the Spotlight* team.
A. Vandivere, "The technical (re-) examination of Vermeer's *Girl with a Pearl Earring*", *Heritage Science* (2020).

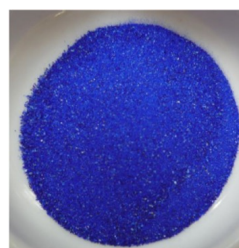
CASE STUDY: GIRL WITH A PEARL EARRING

Lapis lazuli
(lazurite + pyrite +
diopside + calcite)

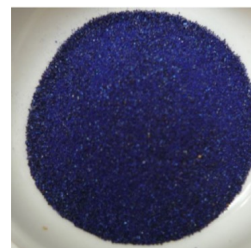


(Optional heat
treatment of rock)
→
Ground & processed,
lazurite extracted

Ultramarine pigment
 $(\text{Na,Ca})_8(\text{AlSiO}_4)_6(\text{SO}_4, \text{S}, \text{Cl})_2$



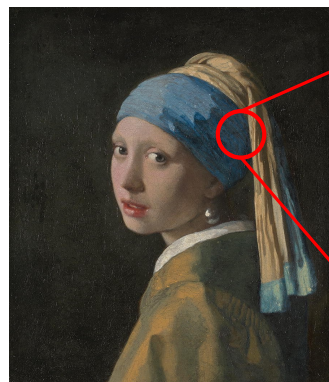
No heat
treatment



With heat
treatment

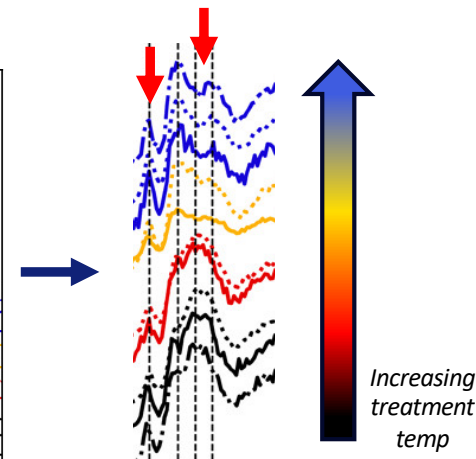
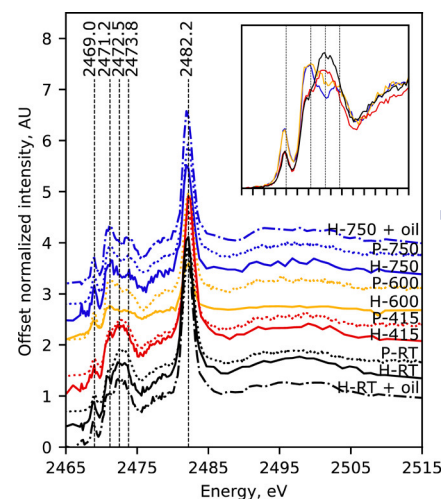
Gambardella et al., "Sulfur K-edge micro- and full-field XANES identify marker for preparation method of ultramarine pigment from lapis lazuli in historical paints", Science Advances, 6, eaay8782 (2020).

Trisulphur radical shows
distinct chemistry in XANES
for heat-treated lapis lazuli



Did Vermeer use
a heat-treated
lapis lazuli?

What is the
pigment quality
and state of
conservation?



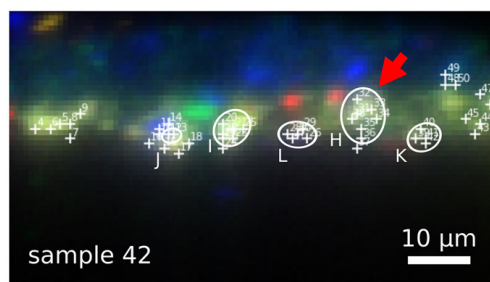
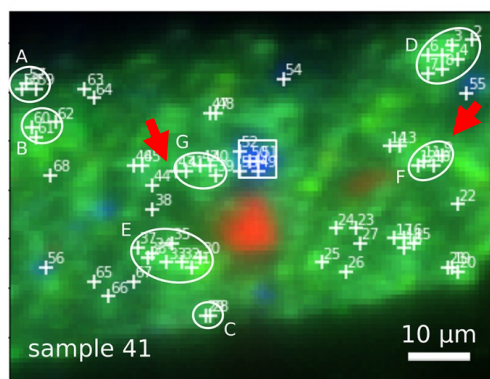
The European Synchrotron



CASE STUDY: GIRL WITH A PEARL EARRING



Micro X-ray fluorescence map

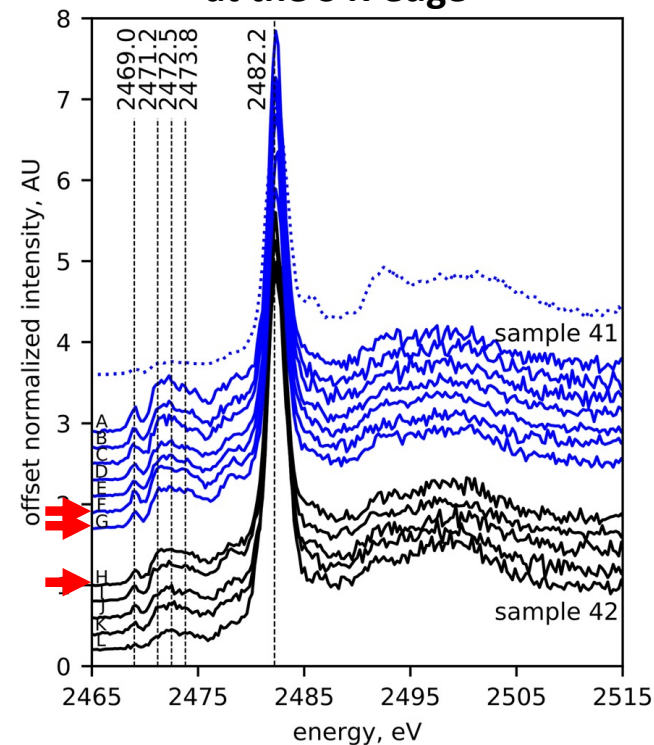


- Similarity indicates consistent ultramarine
- ➔ matches spectra of 600°C treatment, others between ambient and 600°C
- Indicates heterogeneity in treatment

Ultramarine pigment
 $(\text{Na}, \text{Ca})_8(\text{AlSiO}_4)_6(\text{SO}_4, \text{S}, \text{Cl})_2$



Micro X-ray absorption spectroscopy at the S K-edge



A. van Loon, A. A. Gambardella, V. Gonzalez, M. Cotte, W. De Nolf, K. Keune, E. Leonhardt, S. de Groot, A. N. Proaño Gaibor and A. Vandivere, "Out of the blue: Vermeer's use of ultramarine in Girl with a Pearl Earring", *Heritage Science*, 8, 19 (2020).

CULTURAL HERITAGE RESEARCH

Case studies:

1. Vermeer's *Girl with a Pearl Earring*



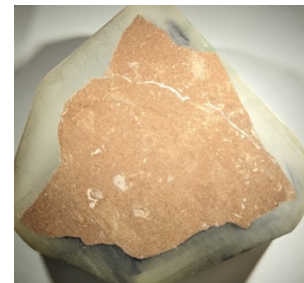
2. Acid Attack on Rembrandt's *The Night Watch*



3. Van Gogh's *Sunflowers*



4. Fossilised eggshell of *Massospondylus* dinosaur



CASE STUDY: THE NIGHT WATCH



- 1642** Painted by Rembrandt
- 1698** Reparation of holes mentioned in city ledgers (not painting-specific)
- 1840s** Hammer damage
- 1851** Lining replaced (advent of wax-resin)
- 1936** Vapour treatment for varnish (unsuccessful)
- 1939-45** Kept in various shelters
- 1945-47** Post-war treatment
 - Lining replaced
 - Varnish replaced
- Oct 1975** Slashed with a bread knife
- 1975/76** Damaged areas restored
 - Previous repairs updated
 - Back lined with wax-resin
 - Linen replaced
 - Varnished replaced
- 1981** Varnish replaced
- Apr 1990** Acid attack
- 2019-...** Operation Night Watch



[1] <https://www.rijksmuseum.nl/>

[2] van Duijn, 'As much as is necessary for the harmony of the picture not to be disturbed': The materials and methods used during the 1945-47 treatment of *The Night Watch* by Rembrandt, ICOM-CC 2021 Beijing

[3] L. Raven et al. The acid attack (1990) on Rembrandt's *The Night Watch* (1642). Reassessing the painting's condition through a multimodal analytical approach. *npj Herit. Sci.* 14, 130 (2026)

CASE STUDY: THE NIGHT WATCH



1. Sprayed with demineralized water by guard
2. Paint layer reported as undamaged, only varnish affected
3. Damaged varnish removed and replaced

“It is unclear whether solvents were employed in the removal process, and to which extent residual varnish was left on the paint surface.”

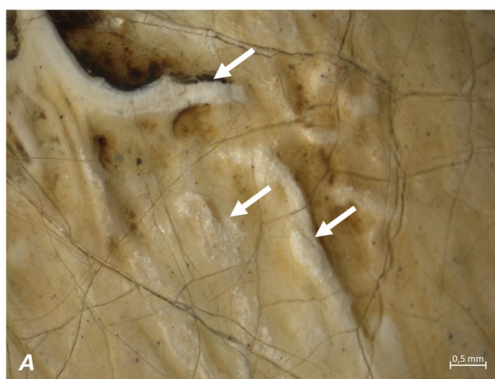
- Common for calcium and lead sulphates to form
- These can affect consistency/texture of paint
- At the time, no visible damage to paint layers was observed
- No further analysis/monitoring carried out until now
- Potential for acid to react with paint layers/remnants of old varnish/new varnish to form calcium and/or lead sulphates



Operation Night Watch

CASE STUDY: THE NIGHT WATCH

Visible effect of acid



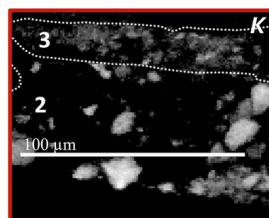
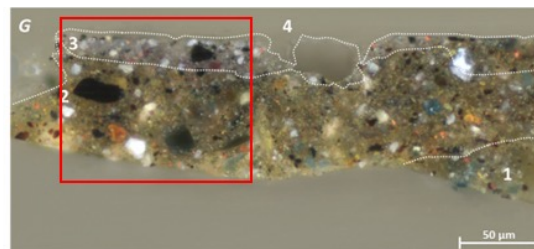
- surface deposits (reaction)
- flattening (reaction or abrasion?)



Varnish removed:

- top layer gone (reaction)
- porosity (CO₂ bubbles?)

Unaffected by acid

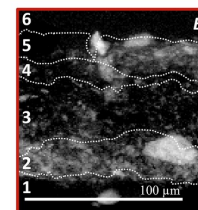
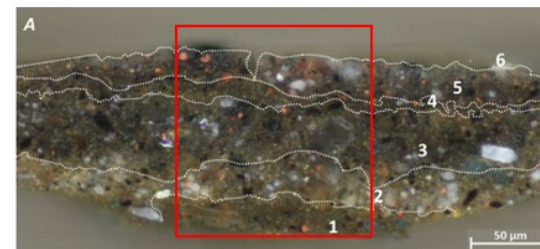


Hydrocerussite
(Lead white)

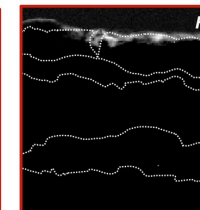


Anglesite

Affected by acid



Hydrocerussite
(Lead white)



Anglesite

Presence of other calcium and lead sulphates?

- Palmierite $K_2Pb(SO_4)_2$ and Weddellite $CaC_2O_4 \cdot 2H_2O$ found in wider area (MA-XRF)
- Ageing product only

P06 (PETRA III, DESY)

CASE STUDY: THE NIGHT WATCH

Mock-up samples

Pigment

Pigment
Varnish

Preparation
Ground
Pigment

Preparation
Ground
Pigment
Varnish

Results:

- More exposure time to acid -> more anglesite
- More lead white -> more anglesite
- Varnish makes reaction worse if not fully removed
- No palmierite formed, shows inadequacy of artificial ageing
- Testing of damage reveal during varnish removal – some samples showed surface breakup (useful for Operation Nightwatch)



Lead white
 $Pb_3(CO_3)_2(OH)_2 + PbCO_3$



Ochre
 $Fe_2O_3, \alpha-FeOOH$



Bone black
 $C + Ca_5OH(PO_4)_3$



Vermillion
 HgS



Madder lake
alizarin, purpurine,
pseudopurpurine

Images from <https://www.kremer-pigmente.com/>

P06 (PETRA III, DESY)
+ ID13 (ESRF)

CULTURAL HERITAGE RESEARCH

Case studies:

1. Vermeer's *Girl with a Pearl Earring*



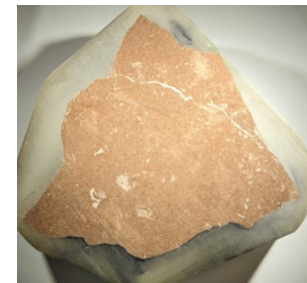
2. Acid Attack on Rembrandt's *The Night Watch*



3. Van Gogh's *Sunflowers*



4. Fossilised eggshell of *Massospondylus* dinosaur



CASE STUDY: VAN GOGH'S SUNFLOWERS



PbCrO_4 unaffected by light
 $\text{PbCr}_{1-x}\text{S}_x\text{O}_4$ ($x > 0.4$)
 subject to photoreduction
 of Cr ions

Macroscopic XRF

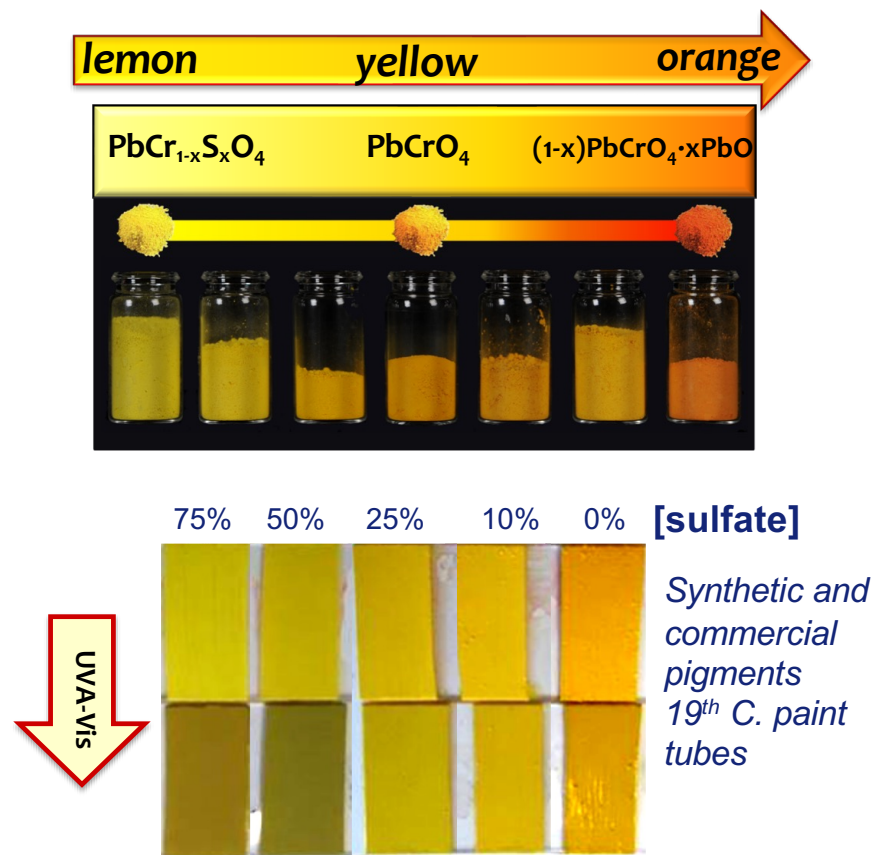


Letter from Vincent van Gogh to his brother
 Théo, 11 Avril, 1888

qui s'en vont en Hollande. Je suis même
 assés sûr les aurais aussi, et de cette façon
 il n'y a pas d'imprudence.
 Tu as eu raison de dire à Jansel qu'il fallait
 s'attendre la laque porcelaine. Quant de même
 il l'a envoyée je viens de vérifier. Toutes
 les couleurs qui à l'impressionisme a
 mises à la mode sont chargées de plomb
 de plus de les employer hardiment trop
 crues. Le temps les adoucira que trop
 ainsi toute la commande que j'ai faite
 soit les 3 chromes (l'orange, le jaune
 le citron) le bleu de Prusse, l'ébène et
 les laques de garance. Je t'en envoie
 tout cela en sa faveur que je mets sur la palette
 hollandaise. Mais montre et sois sûr -
 seulement cela de trouver sur celles
 de Delacroix qui avait la rage des
 deux couleurs les plus condamnées et bon
 pour les meilleures raisons. Le citron et
 le bleu de Prusse. Cependant il me semble
 qu'il en a fait de superbes avec cela des
 bleus et des jaunes citrons. Poursuive
 de main à l'oeil à Rome et encore une
 fois bien merci des couleurs. Le L. Vincent

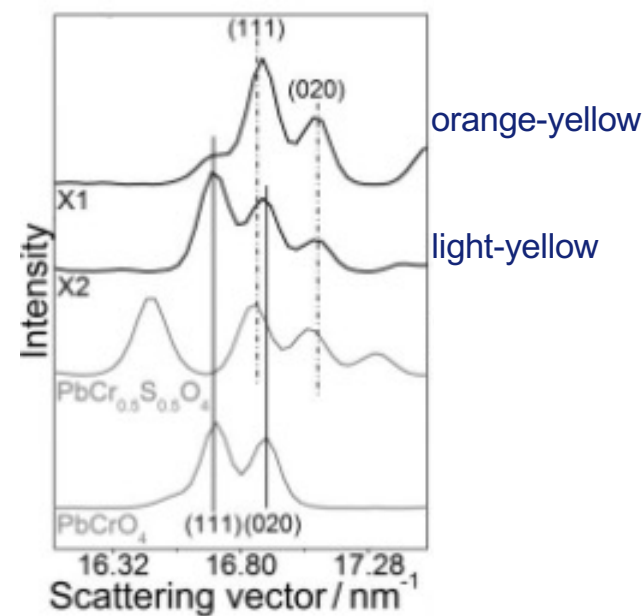
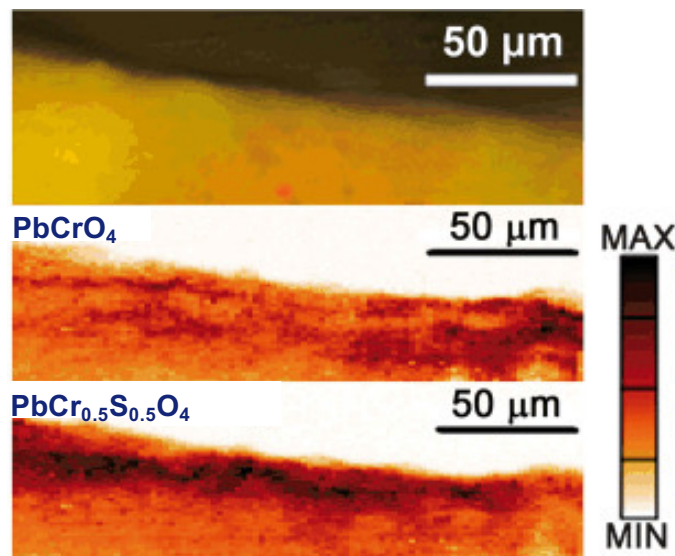
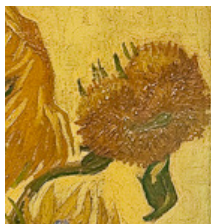
L. Monico et al., Degradation Process of Lead Chromate in Paintings by Vincent van Gogh Studied by Means of Synchrotron X-ray Spectromicroscopy and Related Methods. 1. Artificially Aged Model Samples, Analytical Chemistry, 83, 1214-1223 (2011). And following publications (Anal Chem, JAAS, Angew. Chemie)

CASE STUDY: VAN GOGH'S SUNFLOWERS



L. Monico *et al.*, Degradation Process of Lead Chromate in Paintings by Vincent van Gogh Studied by Means of Synchrotron X-ray Spectromicroscopy and Related Methods. 1. Artificially Aged Model Samples, Analytical Chemistry, 83, 1214-1223 (2011). And following publications (Anal Chem, JAAS, Angew. Chemie)

CASE STUDY: VAN GOGH'S SUNFLOWERS



Confirms presence of light-sensitive $\text{PbCr}_{1-x}\text{S}_x\text{O}_4$

P06 (PETRA III, DESY)

CASE STUDY: VAN GOGH'S SUNFLOWERS

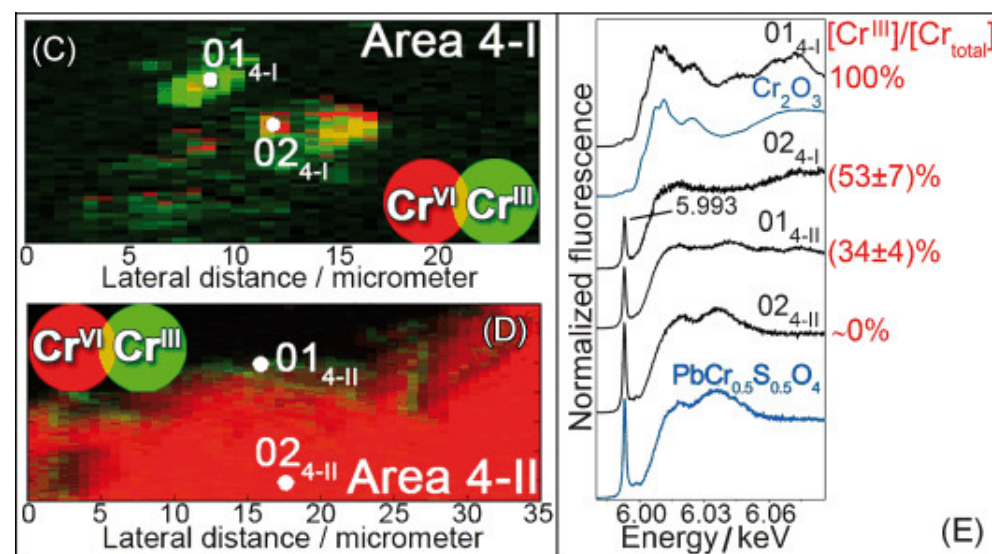
μ XRF and μ XANES at ID21, ESRF



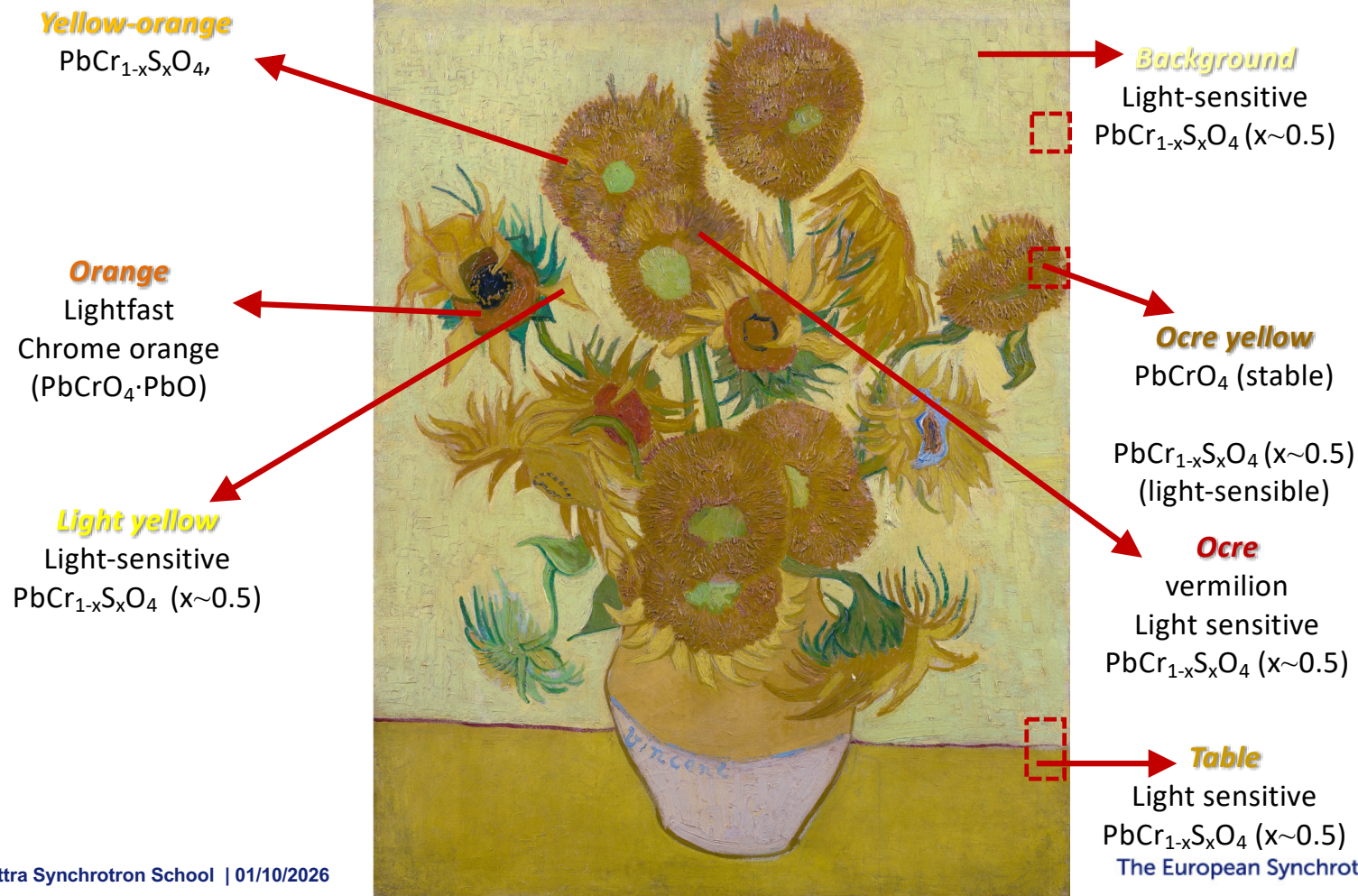
More Cr III (degradation product) in 2-3 mm thick at yellow layer/varnish surface



Confirms light-sensitive pigment has degraded, indicates interfacial effect



NON-SYNCHROTRON RAMAN SPECTROSCOPY + REFLECTION MID-FTIR



CULTURAL HERITAGE RESEARCH

Case studies:

1. Vermeer's *Girl with a Pearl Earring*



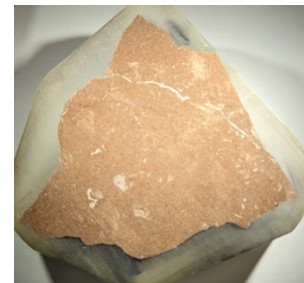
2. Acid Attack on Rembrandt's *The Night Watch*



3. Van Gogh's *Sunflowers*



4. Fossilised eggshell of *Massospondylus* dinosaur



CASE STUDY: MASSOSPONDYLUS EGGSHELL

Article | Published: 17 June 2020

The first dinosaur egg was soft

[Mark A. Norell](#) , [Jasmina Wiemann](#) , [Matteo Fabbri](#) , [Congyu Yu](#), [Claudia A. Marsicano](#), [Anita Moore-Nall](#),

[David J. Varricchio](#), [Diego Pol](#) & [Darla K. Zelenitsky](#)

[Nature](#) **583**, 406–410 (2020) | [Cite this article](#)

Matters Arising | Published: 19 October 2022

Triassic sauropodomorph eggshell might not be soft

[Seung Choi](#) , [Tzu-Ruei Yang](#), [Miguel Moreno-Azanza](#), [Shukang Zhang](#) & [Noe-Heon Kim](#)

[Nature](#) **610**, E8–E10 (2022) | [Cite this article](#)

Review

> [J Anat.](#) 2022 Sep;241(3):641–666. doi: 10.1111/joa.13723. Epub 2022 Jun 27.

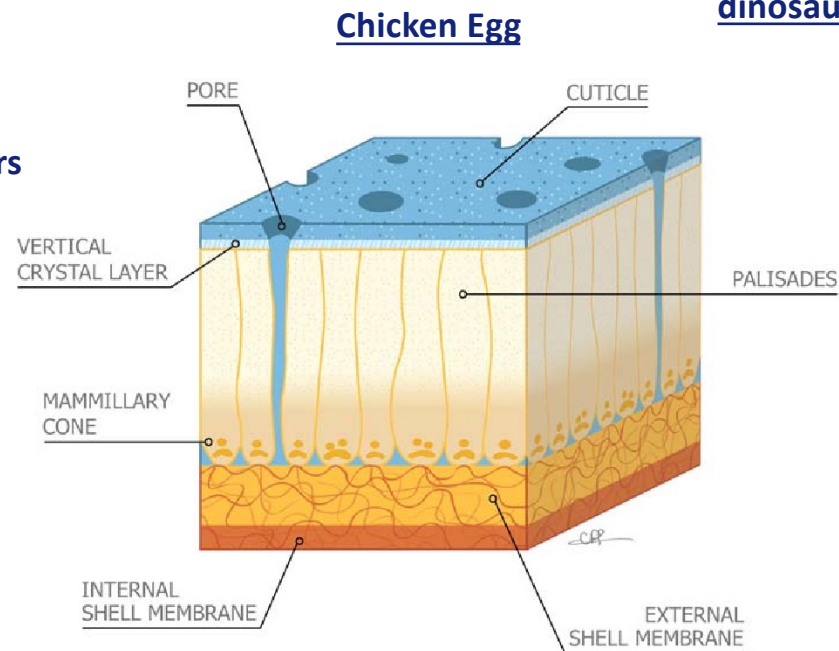
The diverse terminology of reptile eggshell microstructure and its effect on phylogenetic comparative analyses

[Lucas J Legendre](#) ¹, [Seung Choi](#) ^{2 3}, [Julia A Clarke](#) ¹

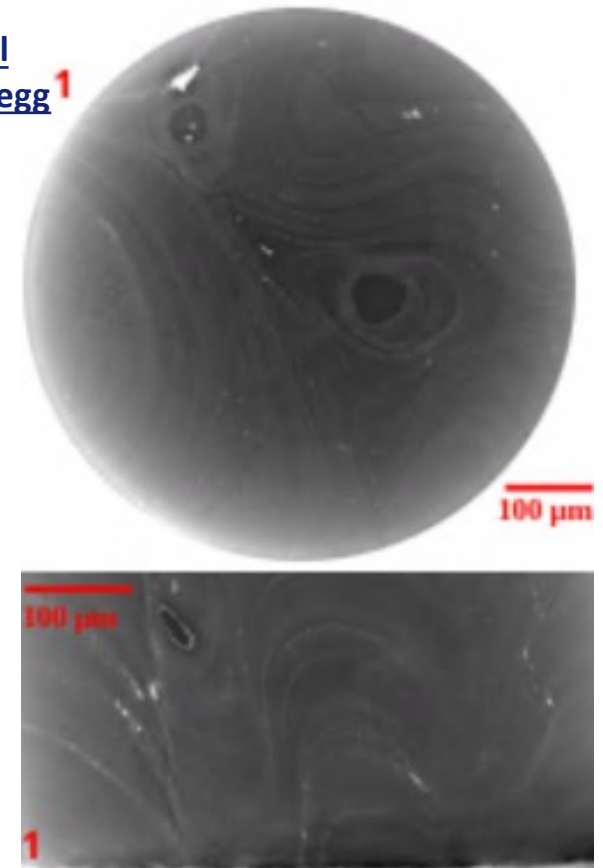
CASE STUDY: MASSOSPONDYLUS EGGSHELL

To consider:

1. Presence of layers
2. Relative thickness layers
3. Cell units
4. Porosity

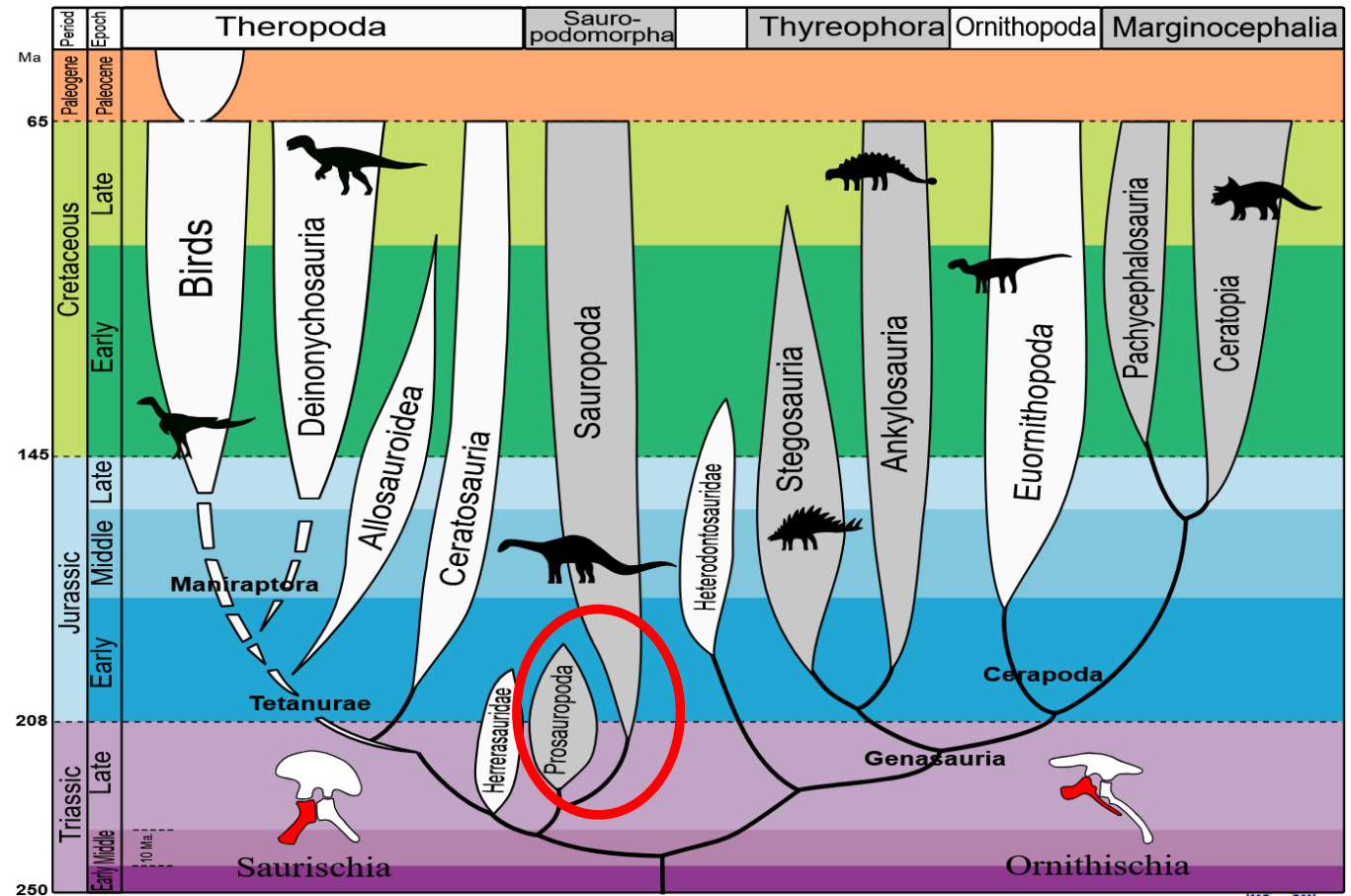
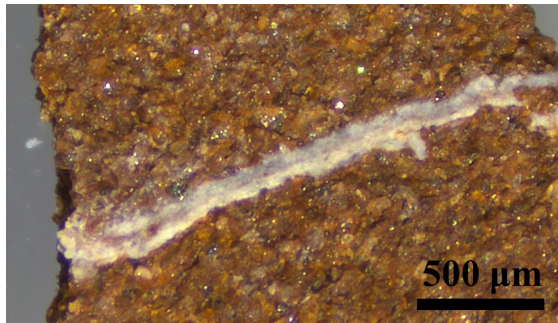


**Hard-shell
dinosaur egg¹**

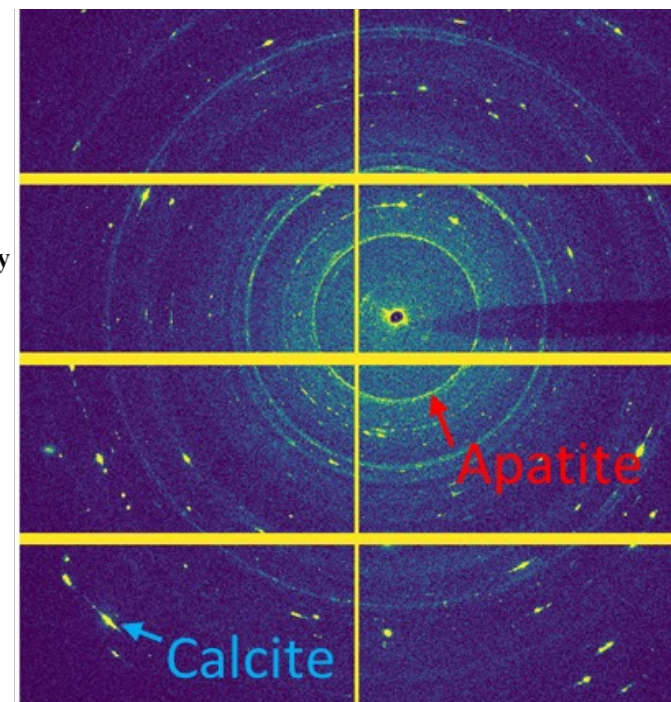
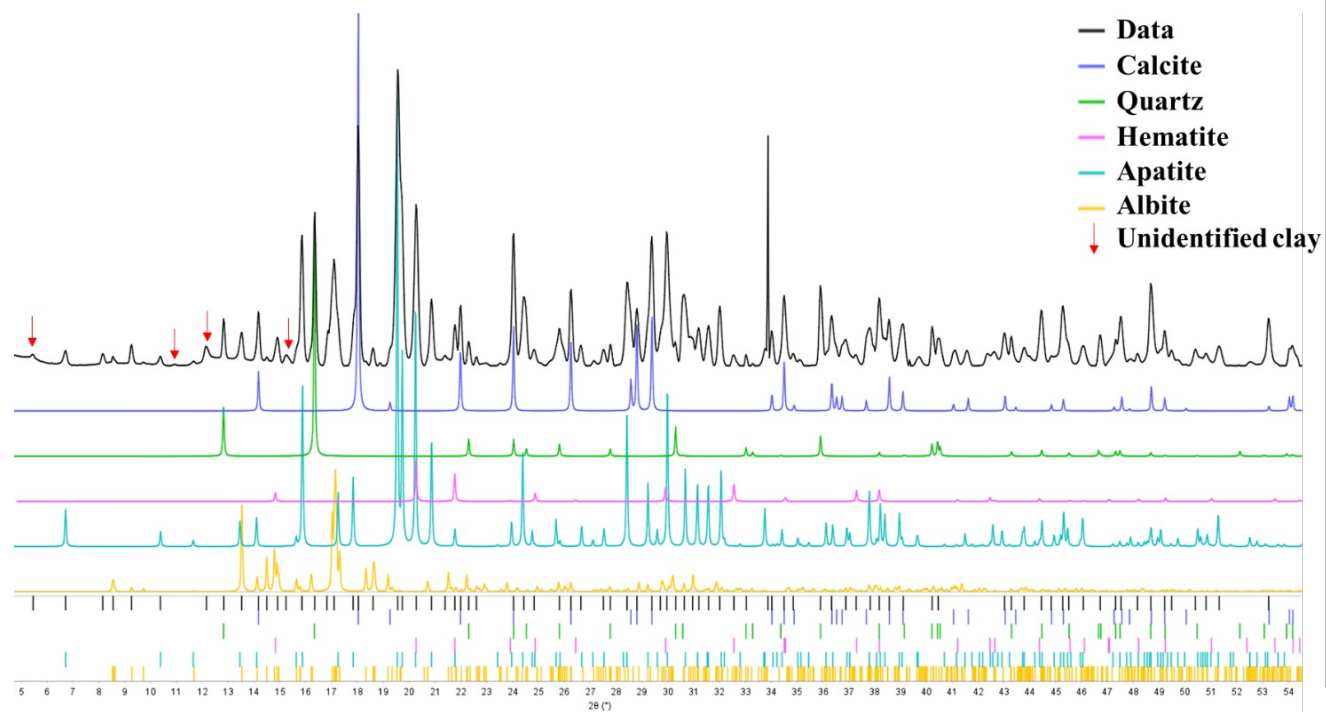


M. T. Hincke, et al., "The eggshell: structure, composition and mineralization." *Frontiers in bioscience* 17 (2012): 1266-80

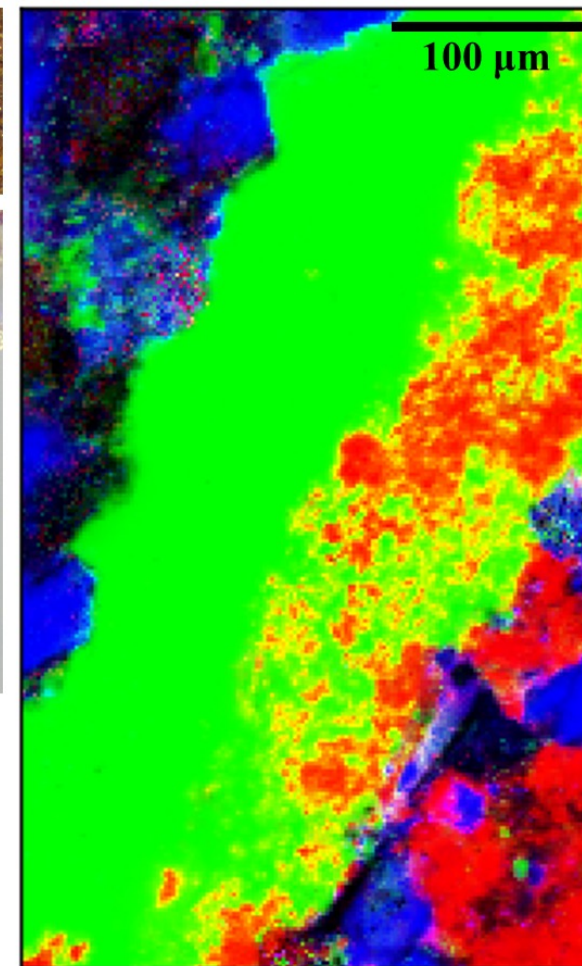
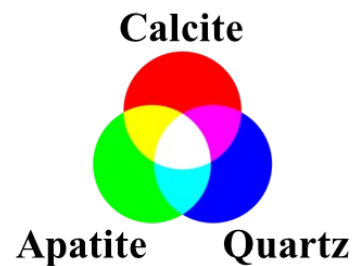
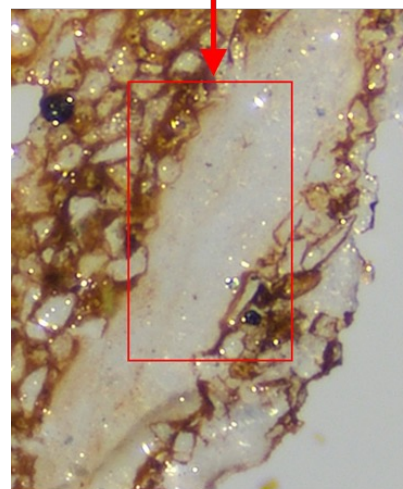
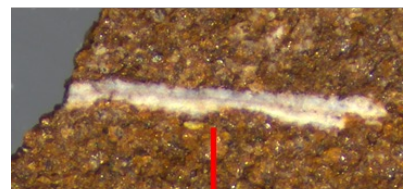
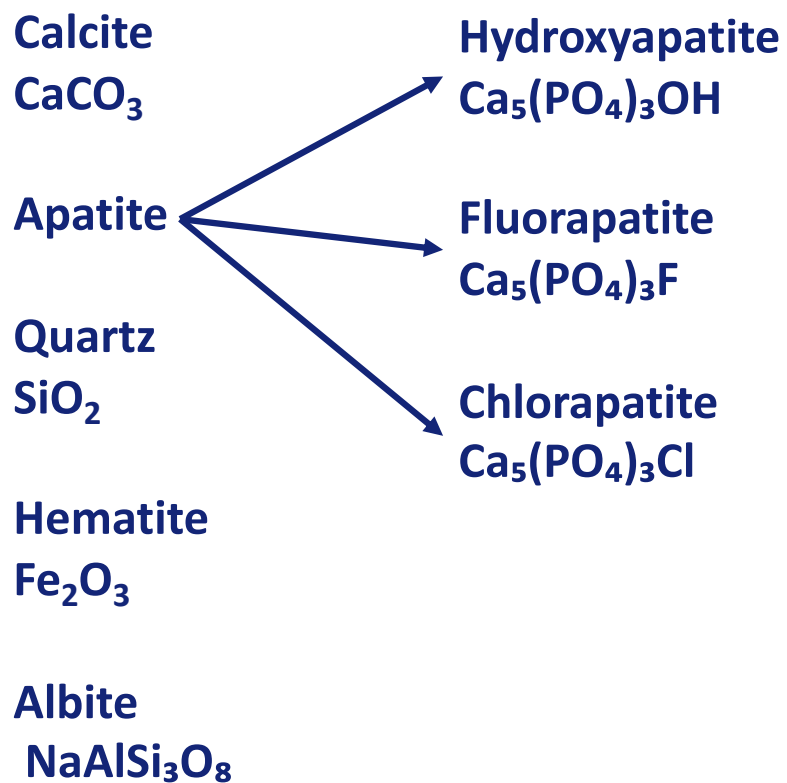
CASE STUDY: MASSOSPONDYLUS EGG SHELL



CASE STUDY: MASSOSPONDYLUS EGGSHELL

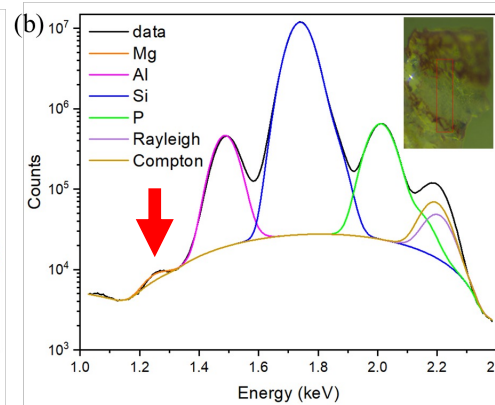
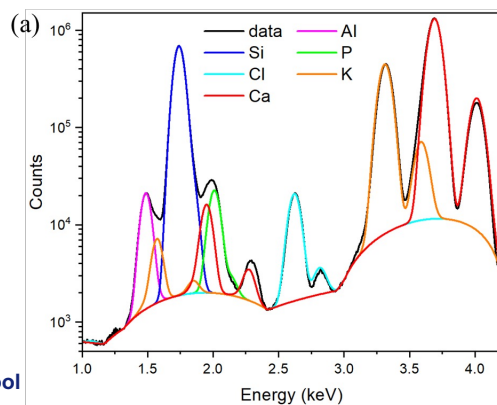
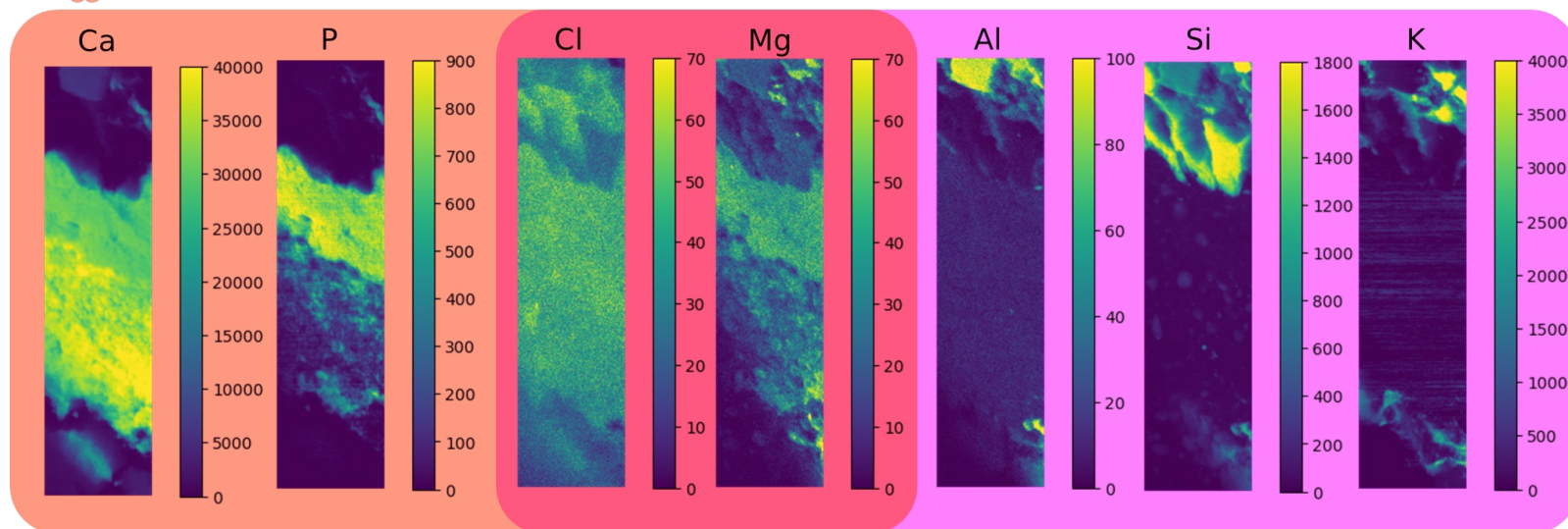


CASE STUDY: MASSOSPONDYLUS EGG SHELL

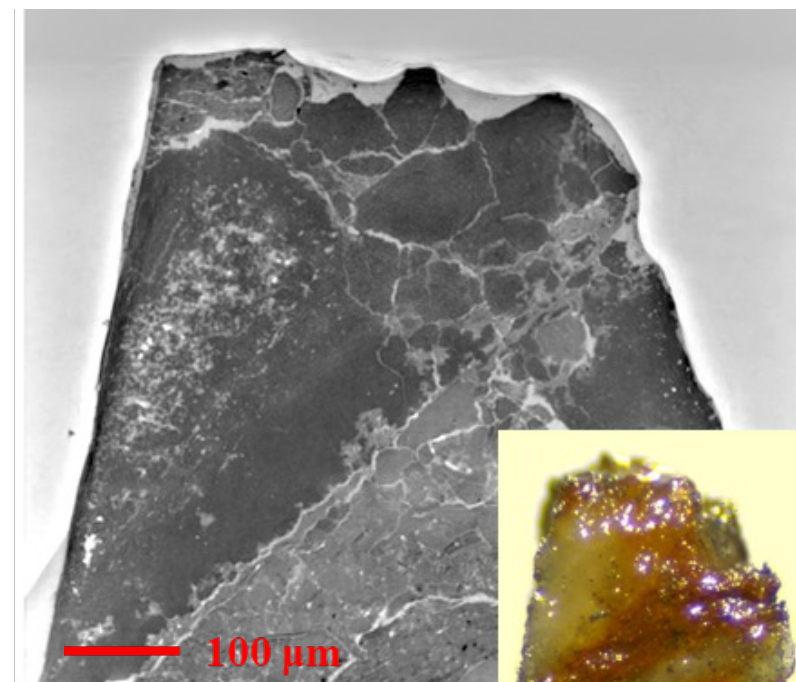
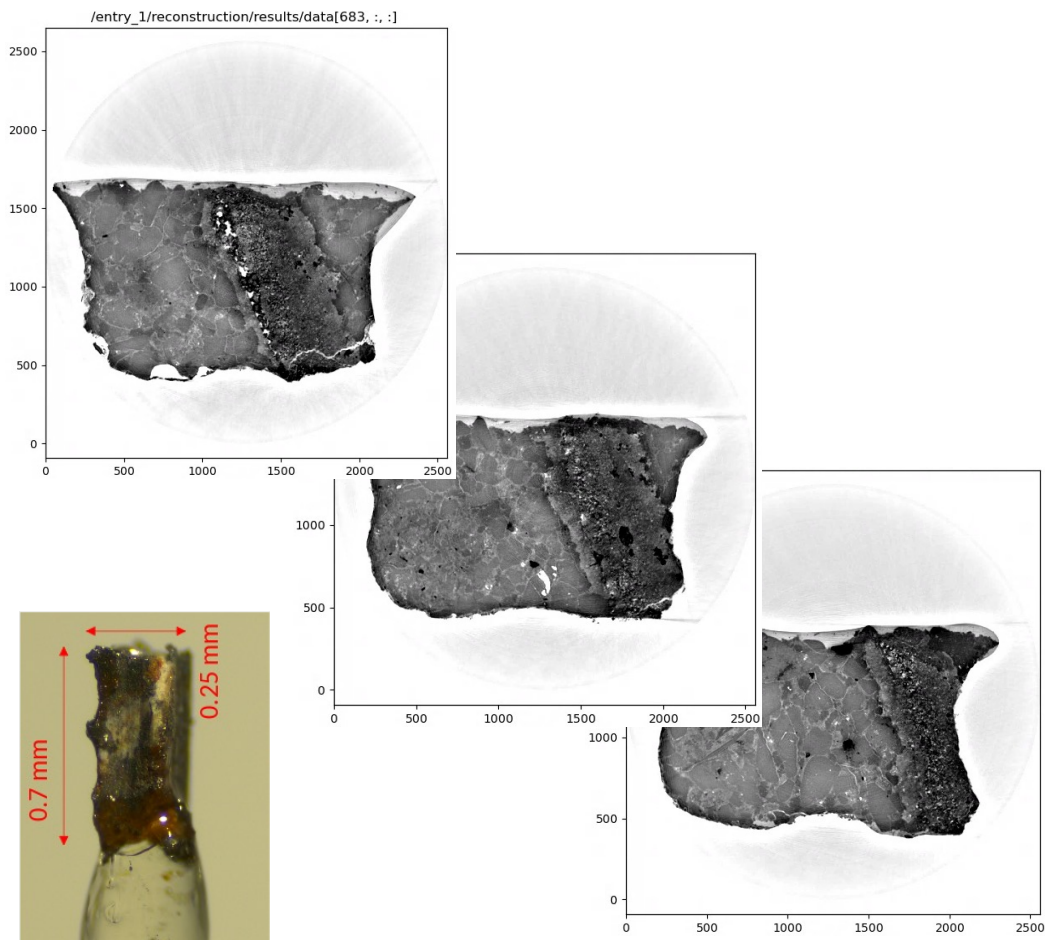


FOSSILISED MASSOSPONDYLUS EGGSHELL

Eggshell elements



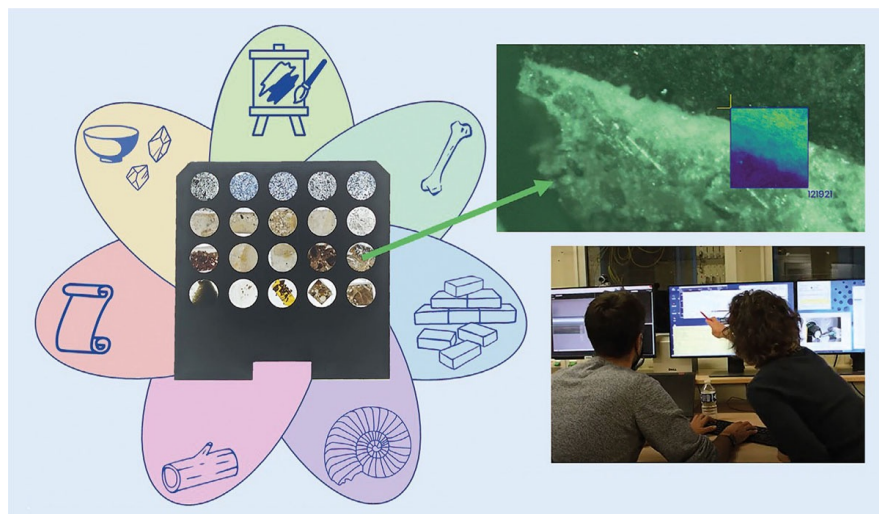
CASE STUDY: MASSOSPONDYLUS EGG SHELL



GROUP ACCESS MODES FOR HERITAGE

Challenges for first time use of synchrotrons :

- Knowledge of beamlines and techniques for proposal writing
- Allocation of beamtime to unknown groups
- Operation of beamline
- Data processing and analysis



SOLEIL IPERION-HS scheme: closed in 2024, moved to E-RIHS

Application through dedicated access calls

DIFFABS — synchrotron μ XRD, XRF and XAS

PUMA — hard-X-ray imaging specifically optimised for heritage science

DISCO — UV/VUV techniques

E-RIHS:

Access scheme for non-synchrotron methods in Europe

Synchrotrons planned to be added

ESRF Historical Materials BAG

Application through contacting current organiser

ID22 – High resolution X-ray diffraction

ID13 – microXRD mapping

Conservation Science EASL at CHESS, USA

Currently pilot stage

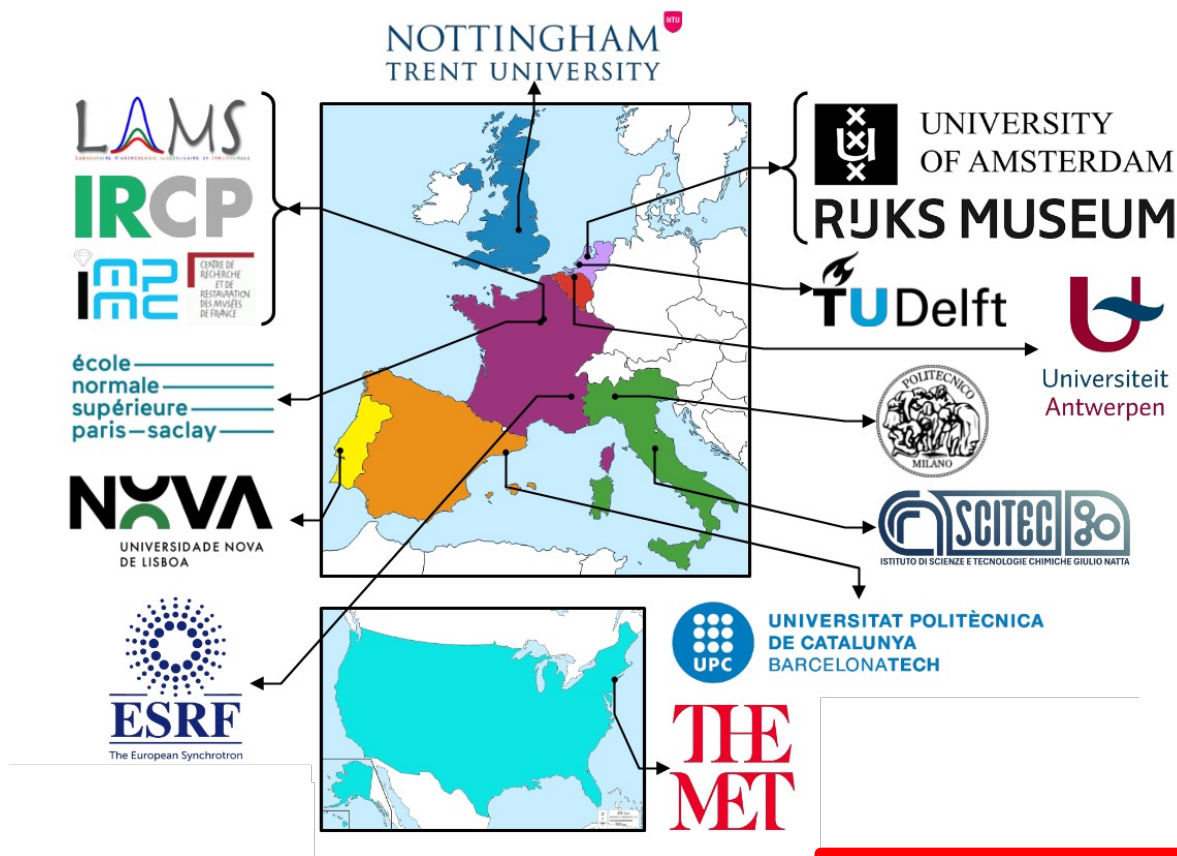
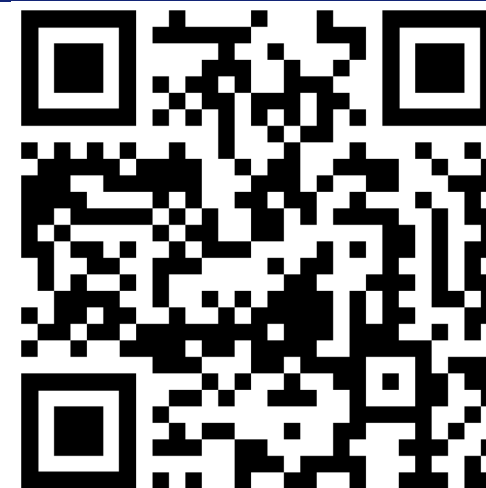
SMB – XRD and microXRD mapping

PIPOXS – XAS & emission spectroscopy

FAST – XRD and microXRD mapping, CT

FMB – XRD, CT

THE ESRF HISTORICAL MATERIALS BAG



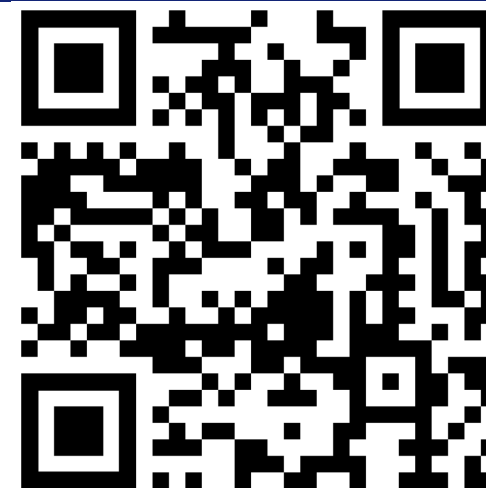
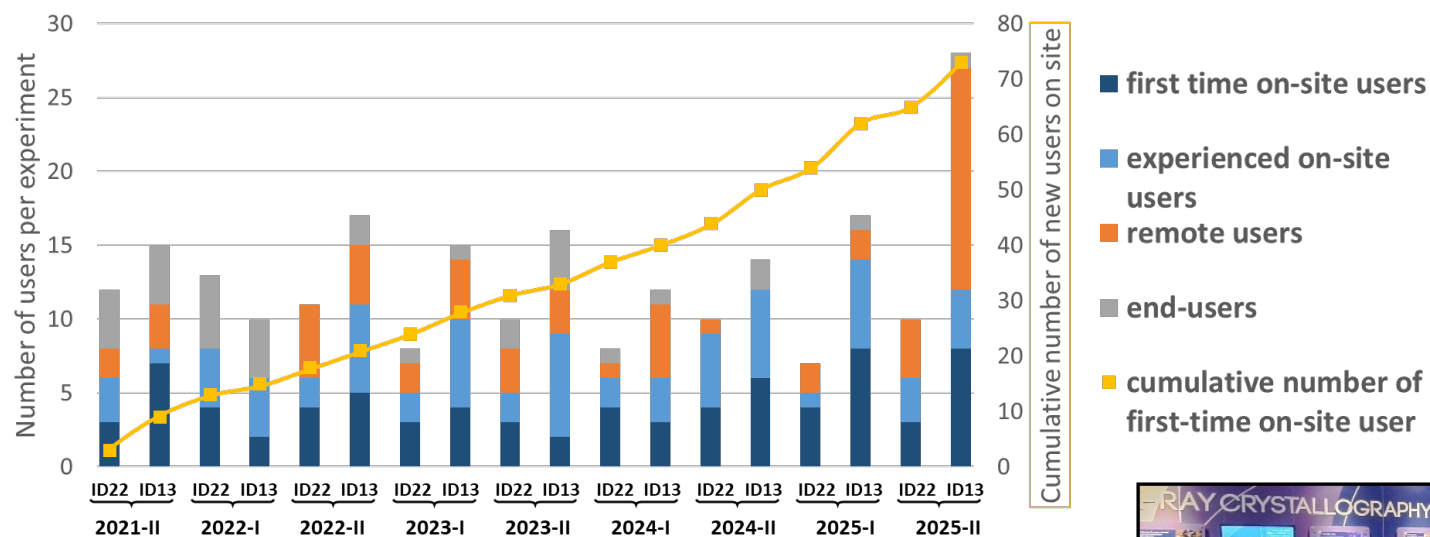
Open Access Article

The “Historical Materials BAG”: A New Facilitated Access to Synchrotron X-ray Diffraction Analyses for Cultural Heritage Materials at the European Synchrotron Radiation Facility

by Marine Cotte 1,2,* , Victor Gonzalez 3,* , Frederik Vanmeert 4,5,* , Letizia Monico 4,6,7,* , Catherine Dejoie 1 , Manfred Burghammer 1 , Loïc Huder 1 , Wout de Nolf 1 , Stuart Fisher 1 , Ida Fazlic 1,8 , Christelle Chauffeton 9,10,11 , Gilles Wallez 9,11,12 , Núria Jiménez 13 , Francesc Albert-Tortosa 13 , Nati Salvadó 13 , Elena Possenti 14 , Chiara Colombo 14 , Marta Ghirardello 15 , Daniela Comelli 15 , Ermanno Avranovich Clerici 4,16 , + Show full author list

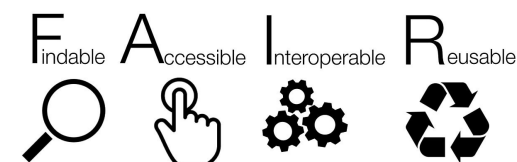
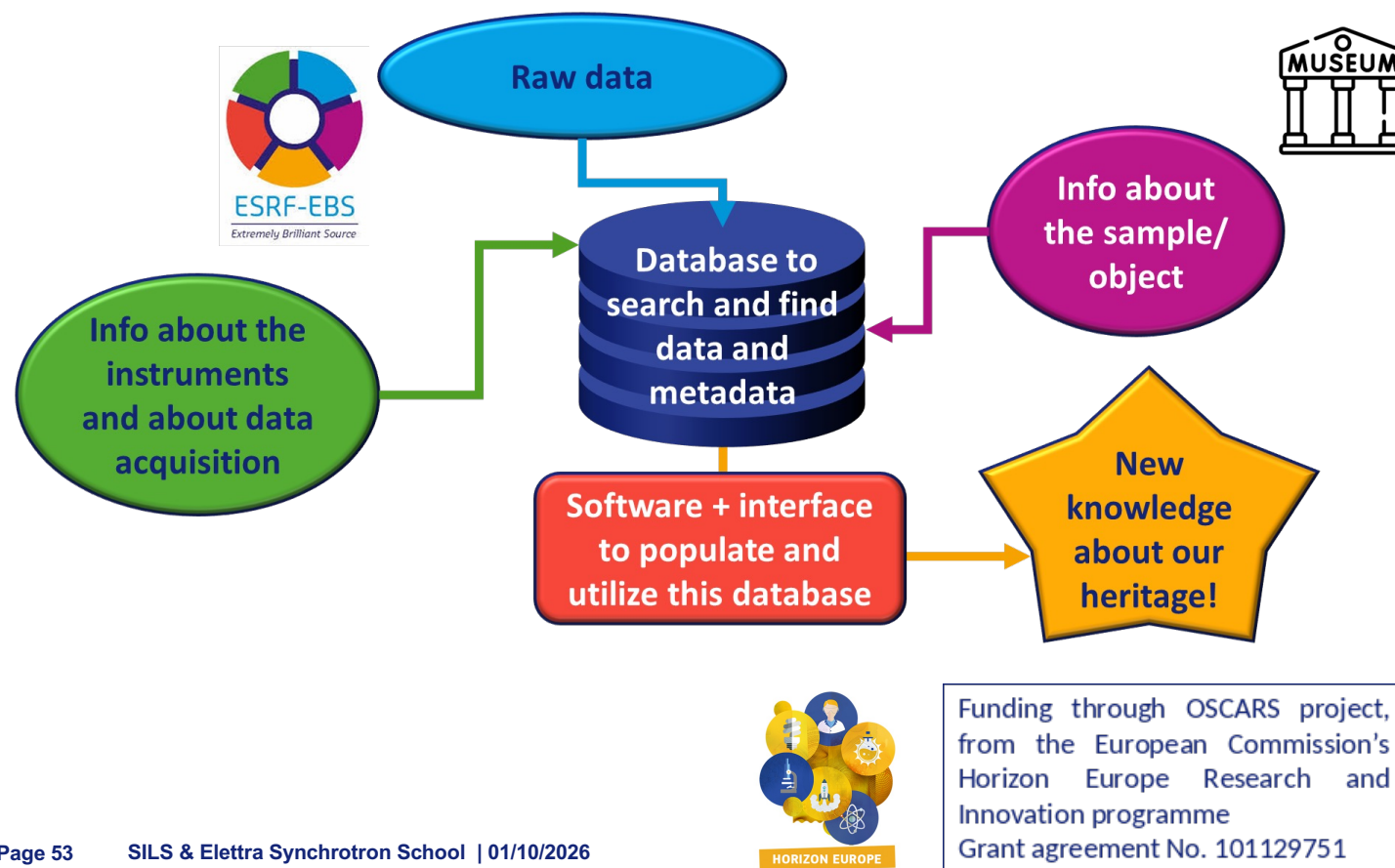
Contact:
heritage-bag@esrf.fr

THE ESRF HISTORICAL MATERIALS BAG



THE SHARE DATABASE

SHARE: *S*ynchrotron X-ray analysis of *H*eritage *A*ccessible to and *R*eusable by *E*veryone



Funding through OSCARS project,
from the European Commission's
Horizon Europe Research and
Innovation programme
Grant agreement No. 101129751

FURTHER READING - TECHNIQUES

L. Monico *et al.* **Advanced X-ray techniques to study the alteration of pigments in paintings.** *Riv. Nuovo Cim.* 2025, 48, 315–434

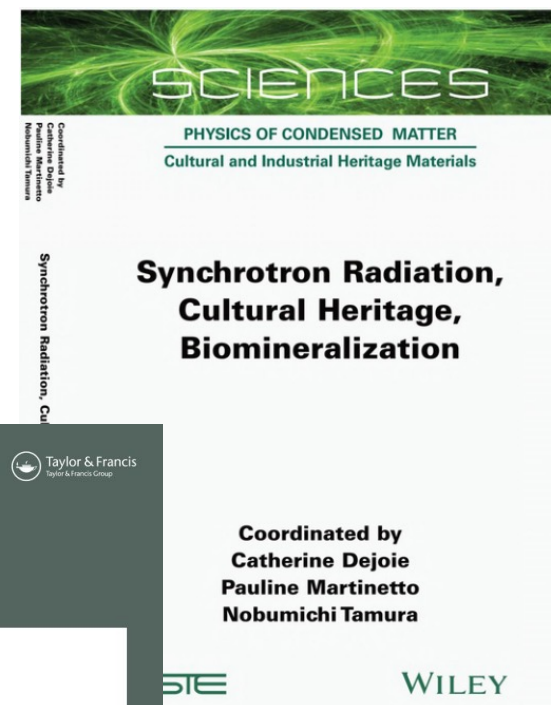
E. Possenti *et al.*, **Potential of synchrotron X-ray diffraction computed tomography (XRDCCT) for a 3D non-destructive and/or non-invasive characterisation of cultural heritage geomaterials (CHG),** *Journal of Cultural Heritage*, 2024, 68, 28-37

A. Gianoncelli *et al.*, **X-ray Synchrotron Radiation to Look at Pigments in Antiquities: Overview and Examples.** *Heritage* 2024, 7, 2118-2137

L. Bertrand *et al.* **Emerging Approaches in Synchrotron Studies of Materials from Cultural and Natural History Collections.** *Top Curr Chem (Z)* 2016, 374, 7

Artioli, G. **Science for the cultural heritage: the contribution of X-ray diffraction.** *Rend. Fis. Acc. Lincei* 2013, 24 (Suppl 1), 55–62

Janssens, K., Cotte, M., **Using Synchrotron Radiation for Characterization of Cultural Heritage Materials.** In: Jaeschke, E., Khan, S., Schneider, J., Hastings, J. (eds) *Synchrotron Light Sources and Free-Electron Lasers.* Springer, Cham. 2020



2022, Vol. 35, No. 5

European Synchrotron |  ESRF

FURTHER READING - FACILITIES

M. Amati *et al.*, **Looking at ancient objects under a different light: cultural heritage science at Elettra**. *Radiation Effects and Defects in Solids* 2022, 177, 1271–1287



Elettra Sincrotrone Trieste

G. P. Robertson *et al.*, **Simplifying access and usability of advanced synchrotron radiation microscopes for heritage science** *Europhysics News* 2025, 56/4, 15–18

M. Cotte *et al.*, **The “Historical Materials BAG”: A New Facilitated Access to Synchrotron X-ray Diffraction Analyses for Cultural Heritage Materials at the European Synchrotron Radiation Facility**. *Molecules* 2022, 27, 1997



H. E. A. Brand, *et al.*, **Research in Art and Archaeology: Capabilities and Investigations at the Australian Synchrotron**. *Synchrotron Radiation News* 2019, 32(6), 3–10



S. Reguer *et al.*, **Fifteen Years of Study of Cultural and Natural Heritage Materials at SOLEIL**. *Synchrotron Radiation News* 2022, 35(5), 10–20



THANKS TO

ESRF BAG team

Clement Hole
Victor Gonzalez
Letizia Monico
Frederik Vanmeert
Marine Cotte

SHARE development team

S. Delcamp
M. Bodin
A. Götz

ID13 and ADA team

Manfred Burghammer
Nicolas Charpentier
Bastien Harnoux
Clemens Schmid

Il Cannone team

Paul Tafforeau
Luigi Paolasini
Bruce Carlson
Nicola Sodini
Alberto Giordano
Alessandro Mirone
Yves Watier
Clémence Muzelle
Christophe Jarnias
Kamel Madi
Loïc Courtois
Francesco Sette

Beam damage team

Amelia Suzuki
Sammy Cheung

Eggshell team

Vincent Fernandez
Julia Villanova
Kimberley Chapelle
Jonah Choiliere

Sunflowers team

Letizia Monico
Geert Van der Snickt
Koen Janssens
Wout De Nolf
Costanza Miliani
Johan Verbeeck
He Tian
Haiyan Tan
Joris Dik
Marie Radepon
Marine Cotte
Ella Hendriks
Muriel Geldof

Night watch team

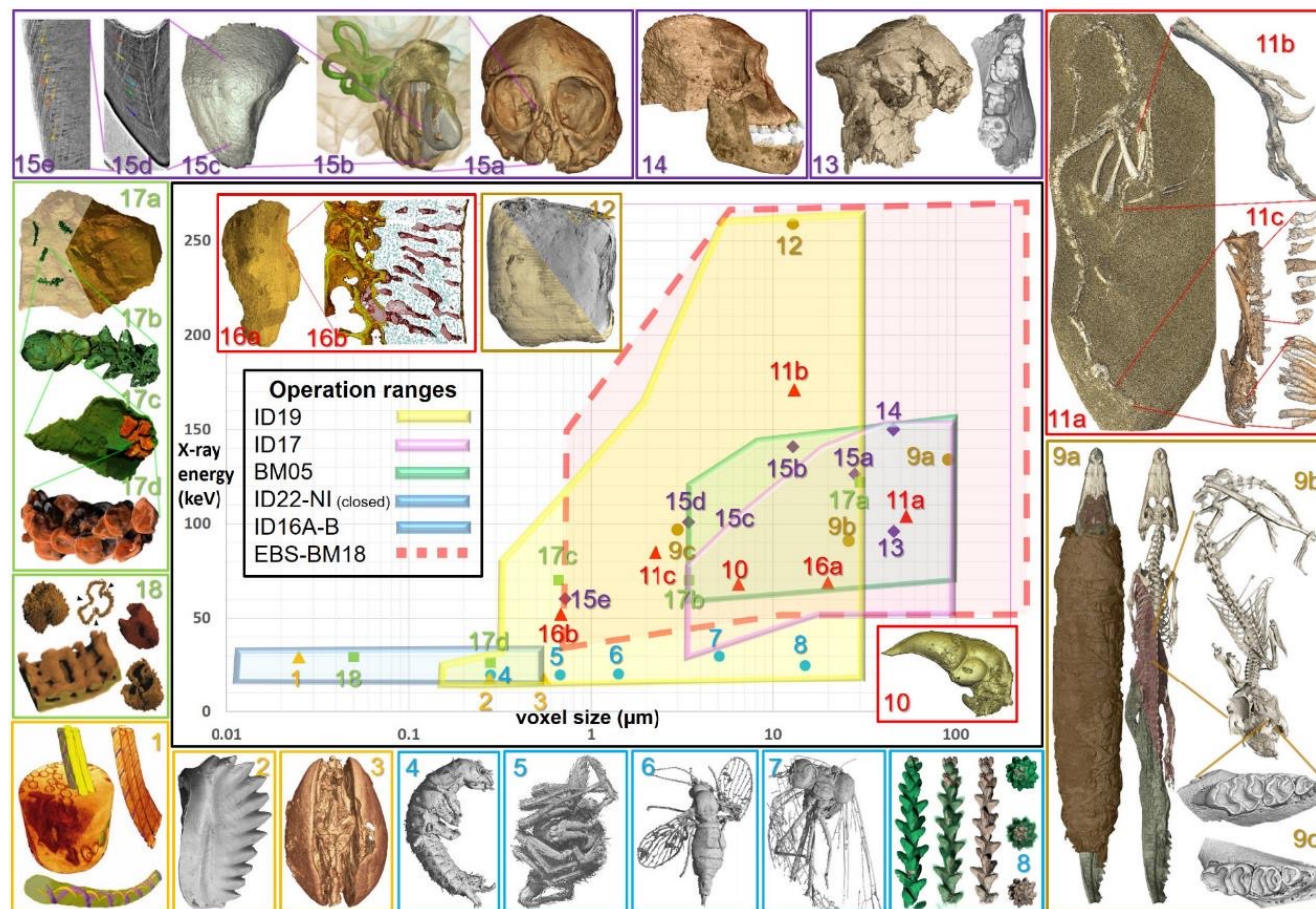
Laura Raven
Arthur Gestels
Annelies van Loon
Ermanno Avranovich Clerici
Esther van Duijn
Mitra Almasian
Frederik Vanmeert
Steven de Meyer
Victor Gonzalez
Koen Janssens
Katrien Keune

Girl with a pearl earring team

Annelies van Loon
Alessa A. Gambardella
Victor Gonzalez
Marine Cotte
Wout De Nolf
Katrien Keune
Emilien Leonhardt
Suzan de Groot
Art Ness Proaño Gaibor
Abbie Vandivere

SILS & Elettra for their kind invitation

PHASE CONTRAST COMPUTED TOMOGRAPHY



X-RAY DIFFRACTION



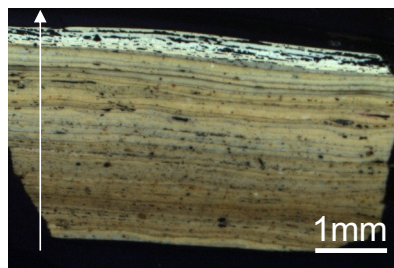
Sample from de Witte Roos, Oude delft 73, Delft

Provided by Edwin Verwij
Woodwork regularly repainted in white

Hageraats et al. "Microchemical Imaging of Oil Paint Composition and Degradation: State-of-the-Art and Future Prospects", Analytical Chemistry for the Study of Paintings and the Detection of Forgeries (2022) Springer International Publishing, Champp. 359-418

The evolution of whites composition across centuries

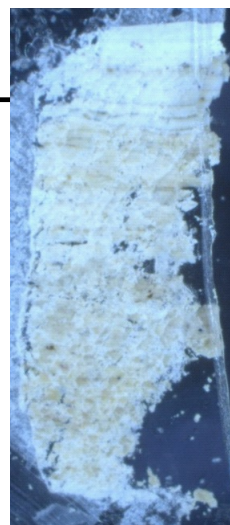
2005



Map: 3.6mm v x 2mm h,
step: ver 0.5µm, hor 5µm,
7200x 400 pixels
1s/pixel = 1 month
5ms/pixel = 4h

first half 18th C.

1mm



- Sphalerite (ZnS)
- Lead titanate (PbTiO₃)
- Rutile (TiO₂)
- Zincite (ZnO)
- Hydrocerussite (Pb₃(CO₃)₂(OH)₂)
- Anglesite (PbSO₄)
- Barite (BaSO₄)
- Cerussite (PbCO₃)
- Gypsum (CaSO₄·2H₂O)
- Calcite (CaCO₃)