



ORMYLIA FOUNDATION
ART DIAGNOSIS CENTER

*WORKSHOP on Novel non-invasive technologies
assisted by robotic & Artificial Intelligence
for Cultural Heritage preservation & documentation
September 25th, 2018*

**Knowledge basis and annotation
tools on FTIR spectroscopy, μ -Raman Spectroscopy,
XRF analysis, Ultrasonic Scanning and Ultraviolet –
Visible spectroscopy data**

Sca4Reco

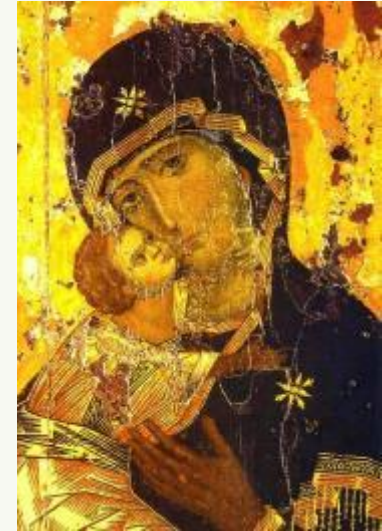
EU Sca4Reco project

“Multimodal Scanning of Cultural Heritage Assets for their multi-layered digitization and preventive conservation via spatiotemporal 4D Reconstruction and 3D Printing

Introduction



© Can Stock Photo - csp9232105



- **Problem:** decay of byzantine iconography and metallic objects that need restoration
- Decay obvious by the **human eye perspective**.
- Are all kinds of decay obvious? Decay that cannot be distinguished by human eye perspective.
- Which and how many are the kinds of decay? How can they be sorted?
- How many kinds can happen in the same time?
- How could kinds of decay be distinguished from the unaffected matrix of the object. Experience is necessary.
Expertise opinion. → **Subjective**
- **Scientific measurements** that display the kind and extend of the decay. → **Objective**

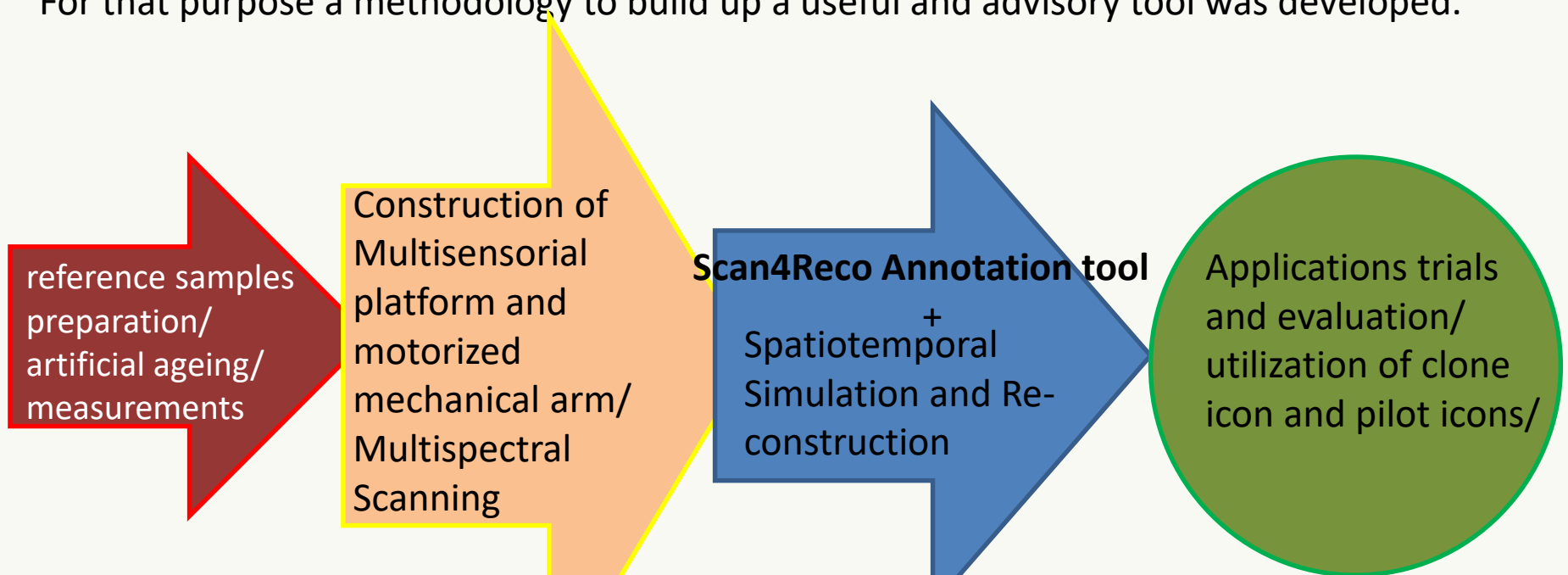
Introduction

Scientific documentation of the type of decay of painted and metallic (silver and bronze) objects by crosschecking measurements from different techniques-instrumentation.

Create an assisting tool for the user, that will facilitate the decision-taking.

The close to reality correct diagnosis is based on properly structured database and correct simulation based on aging.

For that purpose a methodology to build up a useful and advisory tool was developed.



Target

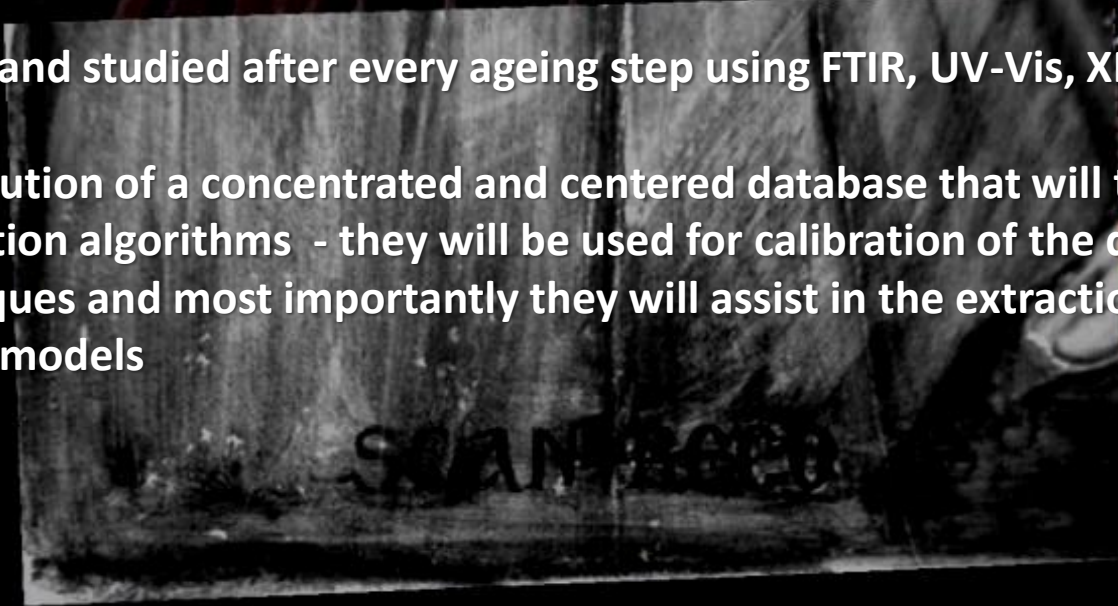
Main aim of Scan4Reco project related to the knowledge base:

Preparation of reference samples/ panel of colors based on materials used, techniques and stratigraphy of byzantine iconography/ metallic samples silver and bronze

Artificial ageing of reference samples (T0 up to T3, under temperature and UV variations)

Tested and studied after every ageing step using FTIR, UV-Vis, XRF, Raman, Ultrasound

Constitution of a concentrated and centered database that will train the spatiotemporal simulation algorithms - they will be used for calibration of the developing scanning techniques and most importantly they will assist in the extraction of the material specific ageing models



The construction of a software that brought all data together and lead to simulation potentialities and to an effort to subjective diagnosis based on ageing models.

Target



How could the scientific documentation be expressed, in order to categorize the decay, evaluate the degree and the combination of decays and propose restoration steps the for a painted object?

How could a documentation be evaluated and serve the purpose of diagnosis?

Does the stratigraphy of pigments influence the documentation results? Do the signals differentiate?

What factors influence the detectability of decay results on artwork?

Creation of knowledge base

Creation and preparation of a wooden panel with combinations of inorganic pigments based on the already existing ones in the Lab of "ORMYLIA" Foundation



measurements

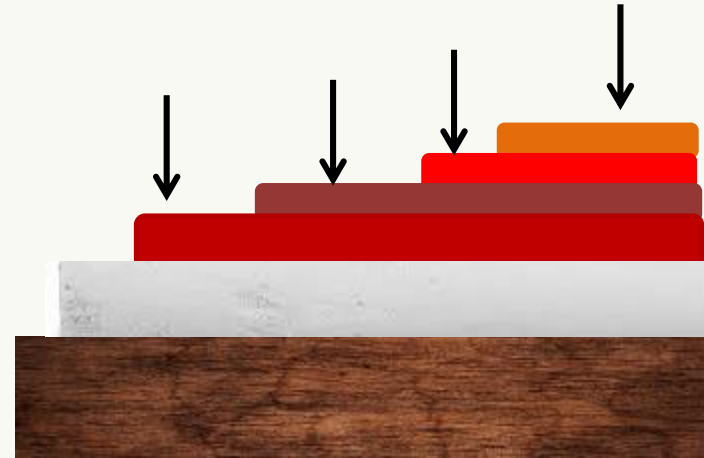
List of inorganic pigments

- massicot
- yellow, red and warm ochre
- hematite
- burnt sienna
- caput mortuum
- minium
- cinnabar
- green earth
- verdigris
- malachite
- ultramarine
- cobalt blue
- prussian blue
- indigo
- azurite
- carbon black

Creation of knowledge base



Layers of a single pigment



different pigment layers

Stratigraphy: Wooden carrier, preparation layer (chalk or plaster), pigment layers, coating (varnish mostly)

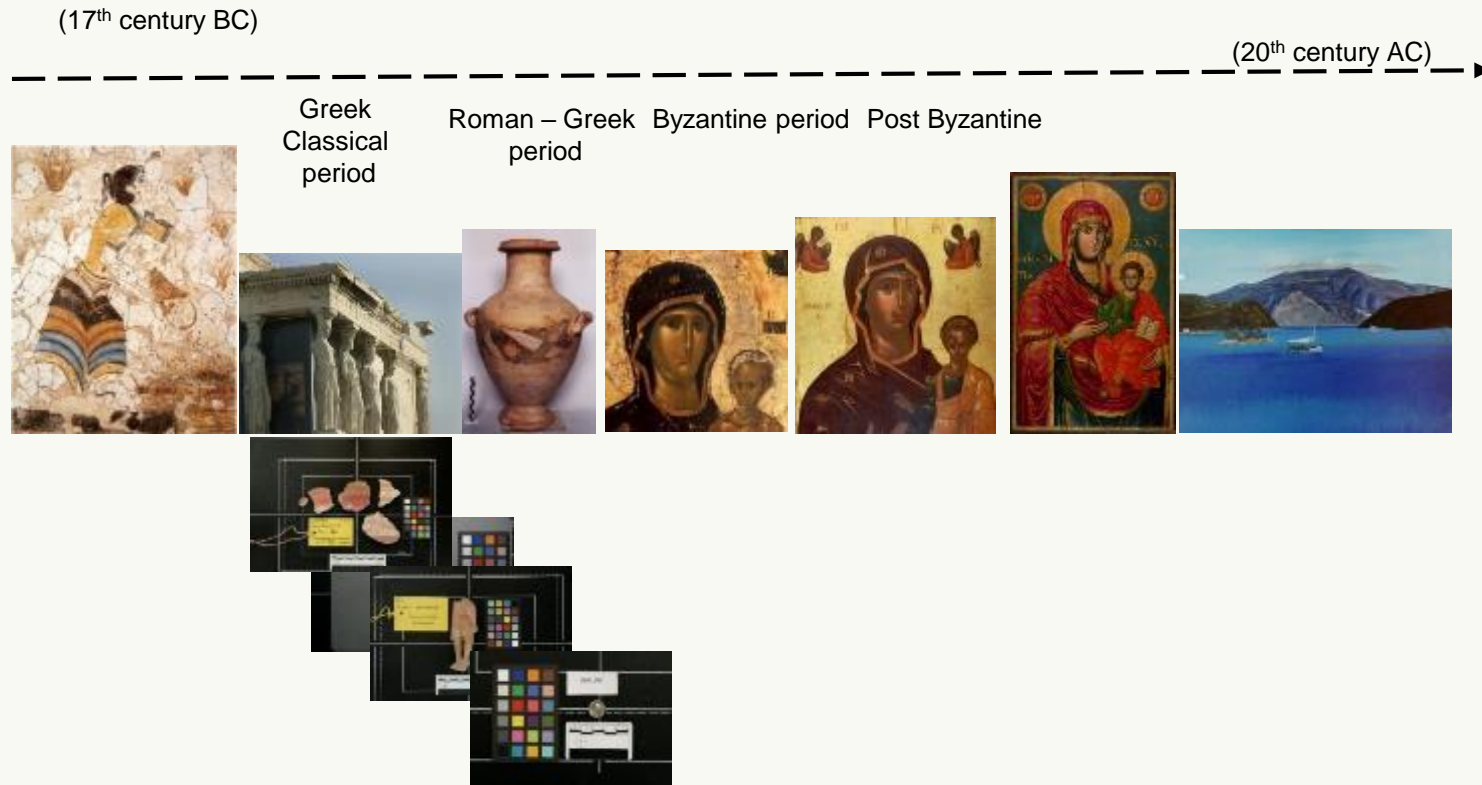
Measurements of all cases in order to cover all probable combinations

- Samples with stratigraphy of same pigment in some cases or a single layer of a pigment
- Samples with stratigraphy of different pigments
- Measurements on every layer and after every ageing step, that are called T0, T1, T2 and T3
- Measurements on varnished and un-varnished areas

Existing Knowledge base

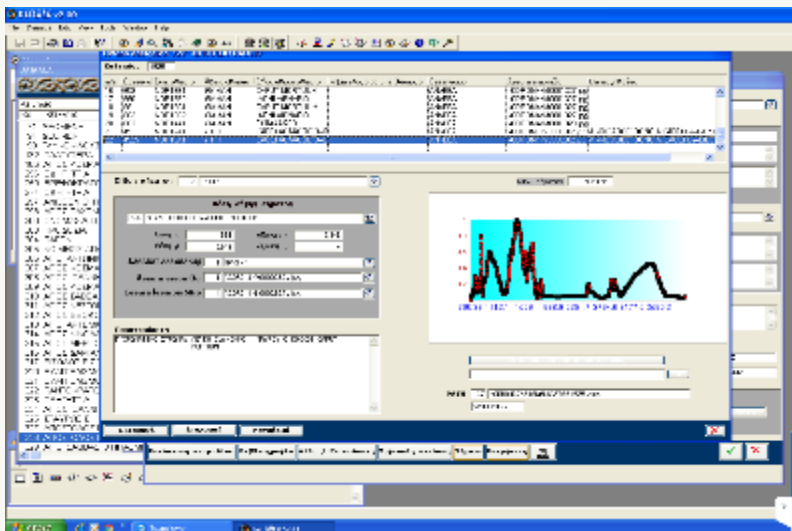
“ORMYLIA” Foundation Database from over 20 years of study on artworks and byzantine iconography

Research – Documented knowledge – Interdisciplinary study



Existing Knowledge base

“ORMYLIA” Foundation Database from over 20 years of study on artworks and byzantine iconography, over 8,500 samples



The screenshot shows a website interface for the ORMYLIA Foundation. It features a list of items with their IDs and names in Greek. A logo with the letters 'TRKO' is visible. Below the list, there is a circular icon of a saint. The text 'ΔΙΑΔΙΟΡΘΩΤΙΚΟ ΚΟΙΤΩΝ ΕΡΓΩΝ ΤΕΛΗΟΣ "ΟΡΜΥΛΙΑ"' is prominently displayed.

ID	Name
532	ΜΕΣΟΚΕΝΤΡΙΧΟΣΗ
533	ΤΟ ΣΑΡΕ ΤΩΝ ΜΥΡΩΝΩΝ
534	ΜΕΤΑΜΟΡΦΩΣΗ
535	ΑΡΧΑΓΓΕΛΟΣ
536	ΜΥΣΤΙΚΟΣ ΒΕΛΤΙΟΣ
537	ΠΕΝΤΗΚΟΣΤΗ
538	ΒΟΛΒΟΝ ΕΥΑΓΓΕΛΙΟ ΚΑΙ 12:30 ΠΟΡΕΙΑ ΠΡΟΣ ΕΜΜΑΥΣ
539	ΓΕΝΕΣΙΣ ΤΗΣ ΒΕΛΤΙΟΥ
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541	ΠΑΥΤΟΚΡΑΤΩΡ ΤΥΠΟΥ ΤΕΜΠΛΟΥ
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543	ΕΥΑΓΓΕΛΙΟ ΤΗΣ ΒΕΛΤΙΟΥ
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546	ΑΓΙΟΣ ΑΔΑΜΑΝΟΣ Ο ΜΕΤΕΩΡΤΗΣ
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548	ΑΓΙΟΣ ΒΕΛΤΙΟΣ Ο ΚΟΝΟΒΙΑΡΗΣ
549	ΑΓΙΟΣ ΒΕΛΤΙΟΣ Ο ΣΤΟΥΔΑΙΟΣ
550	ΤΕΛΗΟΣ
551	ΤΕΛΗΟΣ
552	ΕΞΑΓΓΕΛΙΟΝ
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558	ΑΓΙΟΥ ΙΩΑΝΝΗΣ Ο ΒΕΛΤΙΟΣ
559	ΕΙΣΟΔΟΣ ΤΗΣ ΒΕΛΤΙΟΥ
560	ΑΓΙΟΥ ΠΡΩΤΟΡΟΥ
561	ΣΤΑΥΡΟΣ - ΑΠΟΒΟΝΟΣ ΤΟΥ ΠΡΟΤΟΜΑΡΤΥΡΟΣ ΣΤΕΦΑΝΟΥ
562	ΕΥΑΓΓΕΛΙΟ ΤΗΣ ΒΕΛΤΙΟΥ, ΑΓΙΟΣ ΔΗΜΗΤΡΙΟΣ
563	Α ΟΥΚΟΝΟΜΟΣ ΕΥΑΓΓΕΛΙΟ
564	ΤΙΣΙΝ ΠΡΟΣΕΝΕΡΓΗΜΕΝΩΝ ΔΕΣΠΕΡΟΝ ΠΡΕΤΟΥ ΤΕΜΠΛΟΥ
565	ΕΣ ΤΗΝ ΤΕΛΗΟΣ ΑΓΙΟΣ ΙΩΑΝΝΗ ΤΟΥ ΣΑΜΑΝΟΥ
566	ΑΓΙΟΥ ΙΩΑΝΝΗΣ Ο ΠΡΟΦΗΤΑΣ



Knowledge base

- “Ormylia” Foundation Database from over 20 years of study of byzantine iconography
- Scientific techniques – instrumentation

Contribution

Elementary analysis

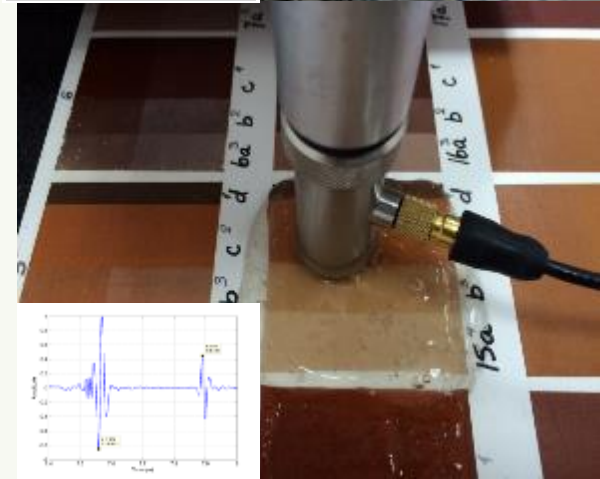
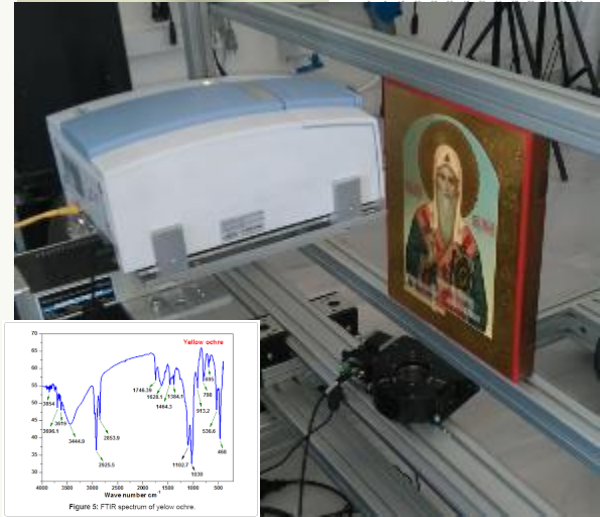
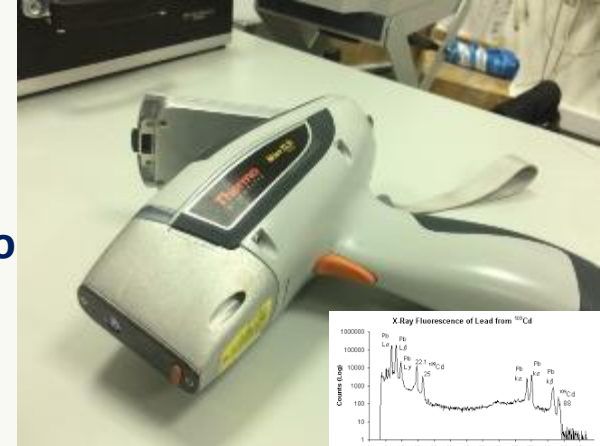
X-Ray Fluorescence

FTIR Spectroscopy

Detection of variations of organic carrier - matrix of inorganic pigments

Ultrasonic scanning

Imaging of internal structure –
changing of roughness of the surface
– surface layers, μ Tomography



Knowledge base

- Ormylia Foundation_Database from over 20 years of study on artworks and byzantine iconography
- Scientific techniques – instrumentation

Contribution

IR Imaging

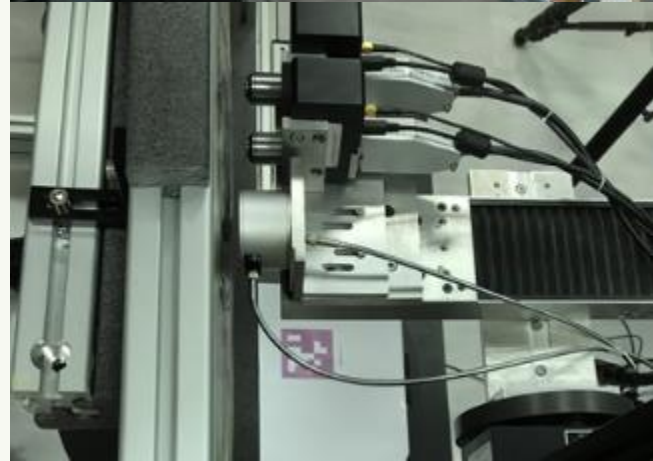
Reveal underpainting and initial drawing, technology and style of creation, Pentimenti,

μ Raman Spectroscopy




Identification of inorganic pigments

Ultraviolet –
Visible Spectroscopy

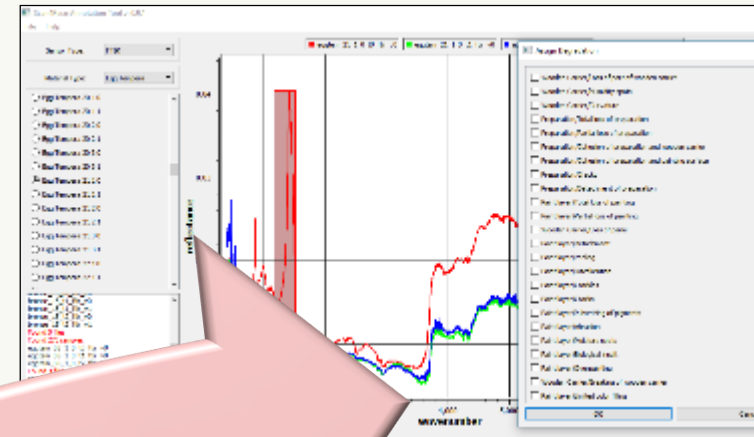
Characterization of color
(L*a*b color space)



Annotation tool – Ontology of the Pathology of a painted object

<p>Wooden Carrier</p>	<p>LOSS OF PART OF WOODEN CARRIER</p> <p>LOSS OF PANEL</p>	<p>Paint layer</p>	<p>TOTAL LOSS OF PAINTING</p> <p>PARTIAL LOSS OF PAINTING</p>
	<p>BREAKING OF WOODEN CARRIER</p> <p>CRACKS OF WOODEN CARRIER</p>		<p>DETACHMENT</p> <p>PEELING</p>
	<p>ADDITION OF NEWER WOODEN SUPPLEMENT</p> <p>INSULT OF XYLOPHAGOUS PESTS (LIMITED, EXCESSIVE , NONE DAMAGE)</p> <p>INSULT OF FUNGUS</p> <p>BACKSIDE COATING : OIL, PREPARATION, PAINTING, INSCRIPTION , NUMBER</p> <p>MOISTURE SPOTS , KNOTS</p> <p>HUMIDITY SPOTS</p> <p>CURVATURE : NONE , SMALL, LARGE</p>		<p>DISCOLORATION</p> <p>CRACKLES</p> <p>CRACKS</p> <p>PULVERIZING OF PIGMENTS</p> <p>ABRASION</p> <p>MOISTURE SPOTS</p> <p>BIOLOGICAL INSULT</p> <p>LOSS OF BONDED WATER</p> <p>OVERPAINTING : TOTAL , LOCAL , BACKGROUND, PERIMETRICAL , ELSE</p> <p>COLOR FILLING : LIMITED , EXCESSIVE</p>
<p>Preparation layer</p>	<p>TOTAL LOSS OF PREPARATION</p> <p>PARTIAL LOSS OF PREPARATION</p>	<p>Protecting coating</p>	<p>VARNISH LOSS : LIMITED , EXCESSIVE</p> <p>OXIDATION</p> <p>WAX DEPOSITS</p> <p>SOOT AND REST AIR POLLUTANTS' DEPOSITS</p>
	<p>COHESION OF PREPARATION AND WOODEN CARRIER (HIGH , MEDIUM , LOW)</p> <p>COHESION OF PREPARATION AND PAINTING SURFACE (HIGH, MEDIUM , LOW)</p> <p>Cracks</p> <p>DETACHMENT OF PREPARATION</p>		

Knowledge base – Scan4Reco



● Already existed database from recent knowledge

● Annotation tool Software designed and implemented for Scan4Reco

● Measurements at T0, T1, T2 and T3, after ageing step, created a new database

Experts

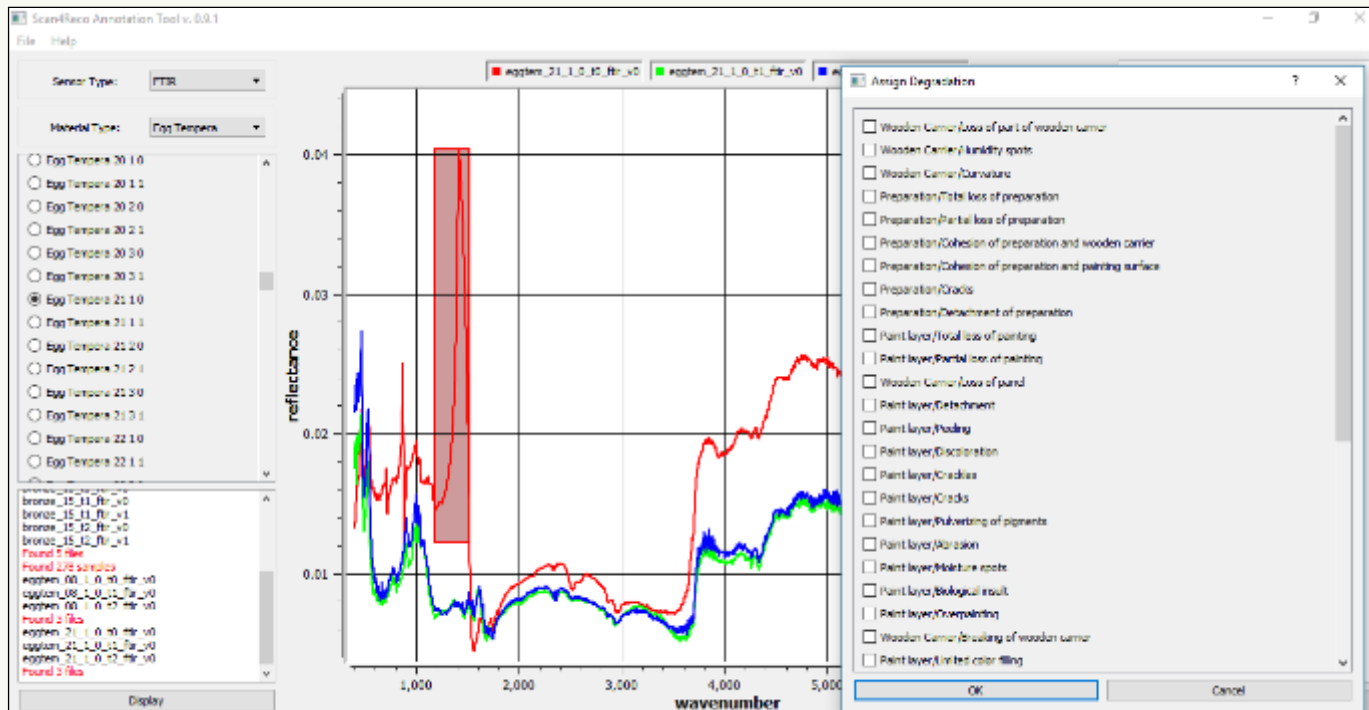
Ontology of Pathology

Wooden Carver	LOSS OF PART OF AXONNEM CARBON LOSS OF PART CLEANING OF WOODEN CARVER CRACKS OF WOODEN CARVER DETENTION OF WOODEN CARVER WALD OF WOODEN CARVER INTERNAL AND EXTERNAL WATER DAMAGE	Pillar base	TOTAL LOSS OF PARTS PARTIAL LOSS OF PARTS NO CHANGE CHANGE DEFORMATION CRACKS CHANGE POLYMERIZATION OF PARTS ADHESION REPAIRMENT REPAIRMENT LOSS OF WOODEN CARVER INCREASED WOOD CARVER WATER DAMAGE INTERNAL AND EXTERNAL WATER DAMAGE
Preparation base	TOTAL LOSS OF PREPARATION PARTIAL LOSS OF PREPARATION CHANGE OF PREPARATION WOOD CARVER CHANGE OF PREPARATION WOOD CARVER CHANGE OF PREPARATION WOOD CARVER CHANGE OF PREPARATION WOOD CARVER CHANGE OF PREPARATION WOOD CARVER CHANGE OF PREPARATION WOOD CARVER	Preparation base	LOSS OF WOODEN CARVER INCREASED WOOD CARVER WATER DAMAGE INTERNAL AND EXTERNAL WATER DAMAGE POLYMERIZATION OF PARTS ADHESION REPAIRMENT REPAIRMENT LOSS OF WOODEN CARVER INCREASED WOOD CARVER WATER DAMAGE INTERNAL AND EXTERNAL WATER DAMAGE

Annotation tool

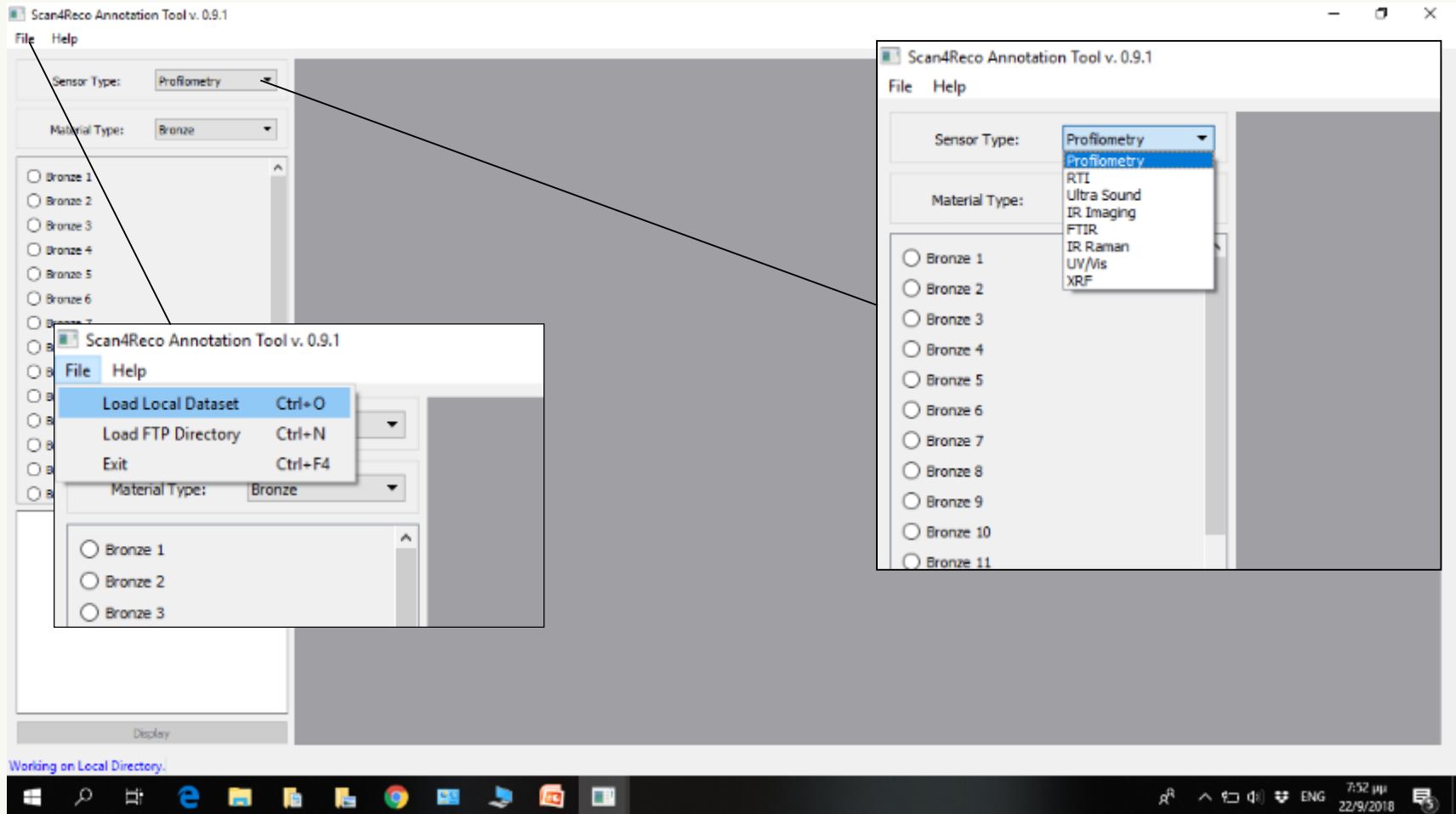
Problem: Too many scientific data, Raman spectra, FTIR spectra, XRF spectra, UV-Vis spectra, profilometry data, Ultrasonic signal values, IR imaging data. Measurements at initial time and measurements at every ageing step. All these data should be rearranged and given in a data base that could facilitate and emerge the impact of ageing on samples by relating the latter to a defined pathology.

Solution: Annotation tool arranged the measurements according to ageing time and according to Infra Structure. Pathology was cross-checked to each peak shift and each variation that could be attributed to decay due to ageing.



Annotation tool

Software that offers the ability to load our dataset, the measurements that a scientist produced, supporting data from 8 different techniques
Overlay diagrams allowed the annotation of spectra and connection to the pathology

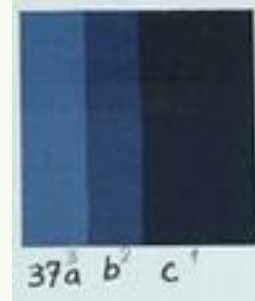


Annotation tool – FTIR overlay spectra



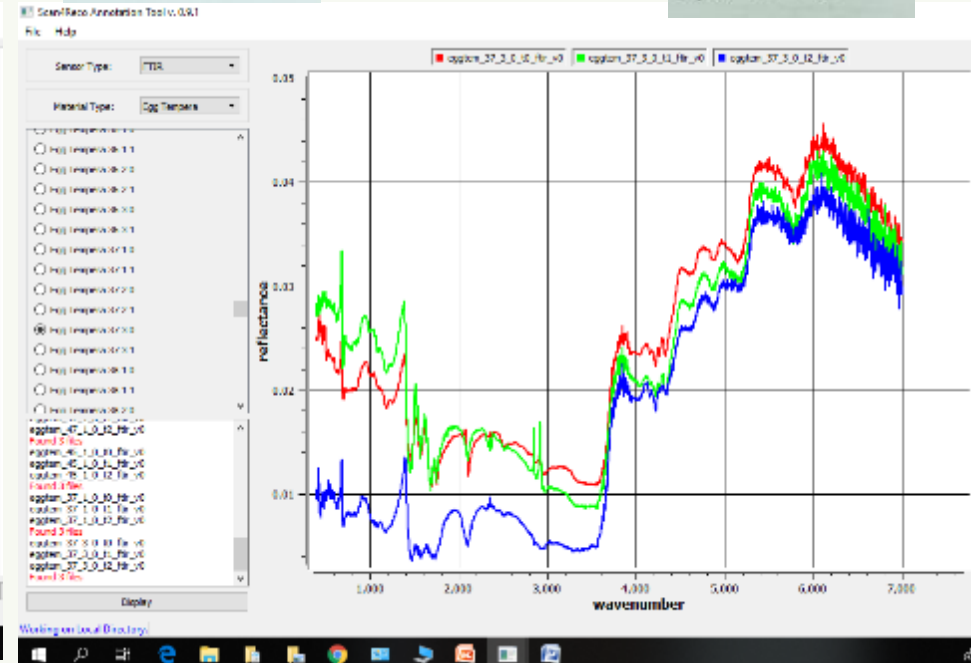
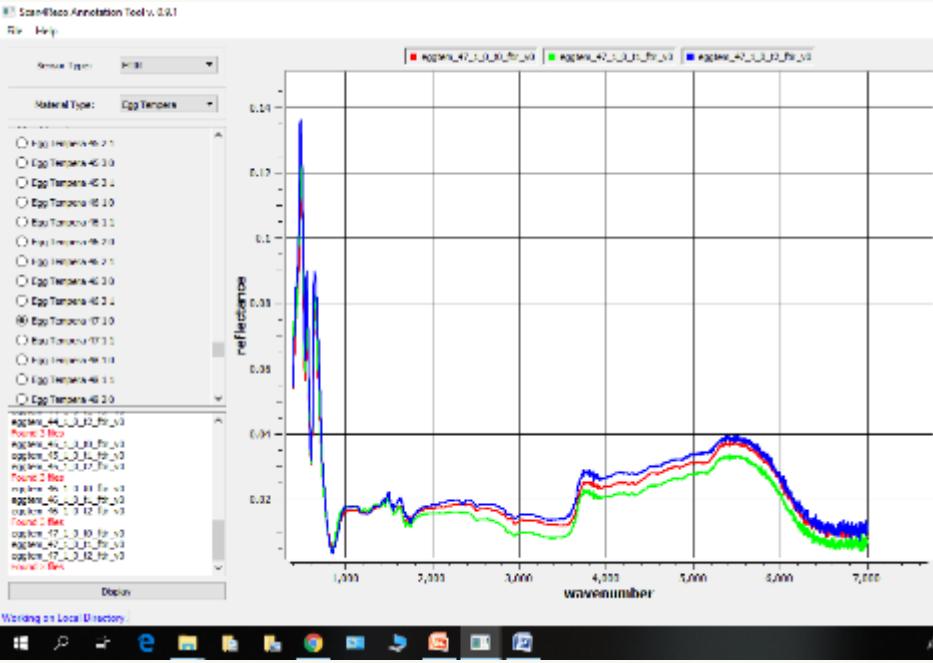
Cobalt blue

at T0, T1 and T2
Stable behavior
of the pigments carrier



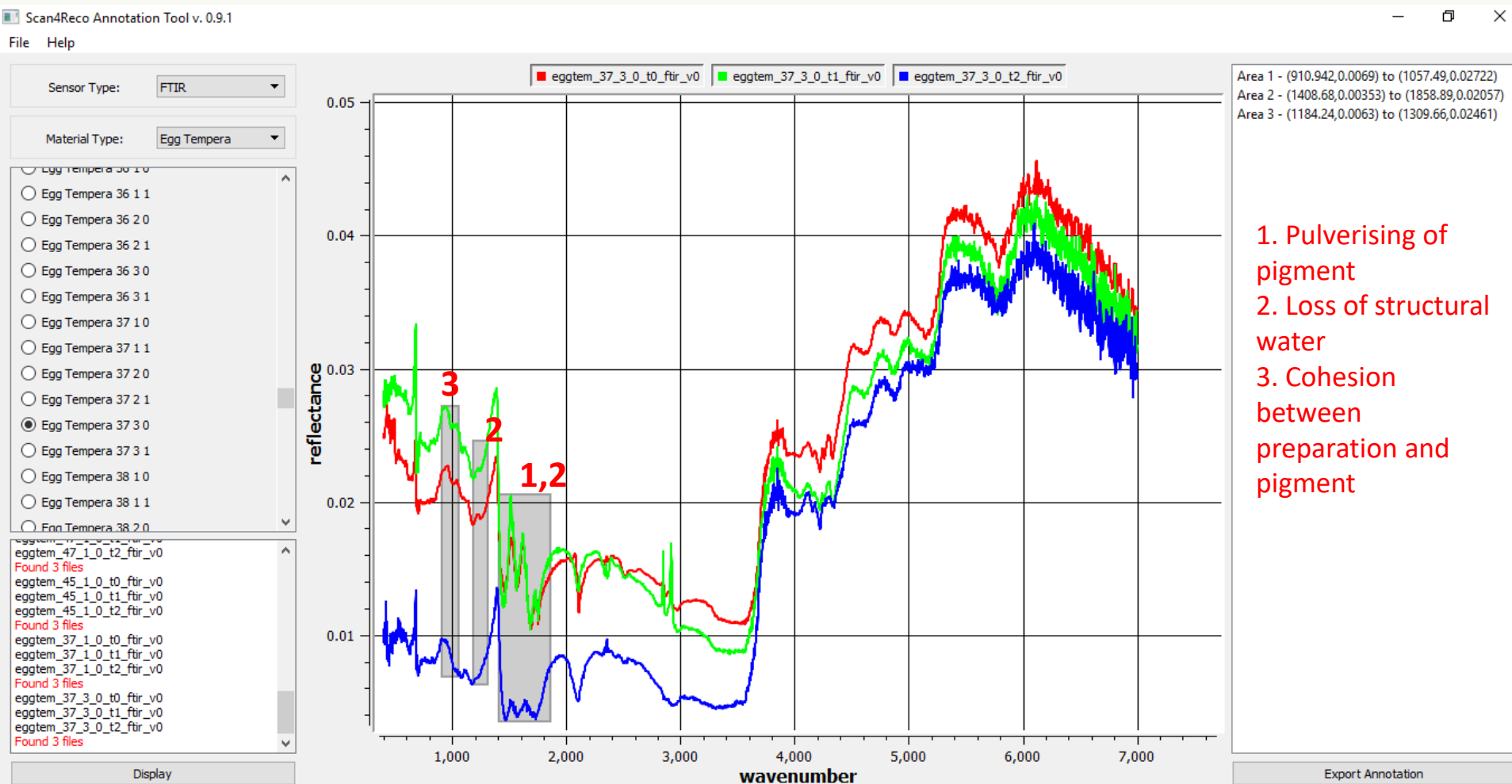
Prussian blue

at T0, T1 and T2
Pigments peaks
unaffected



Annotation tool – FTIR overlay spectra

FTIR measurement of **Prussian blue** at T0, T1 and T2

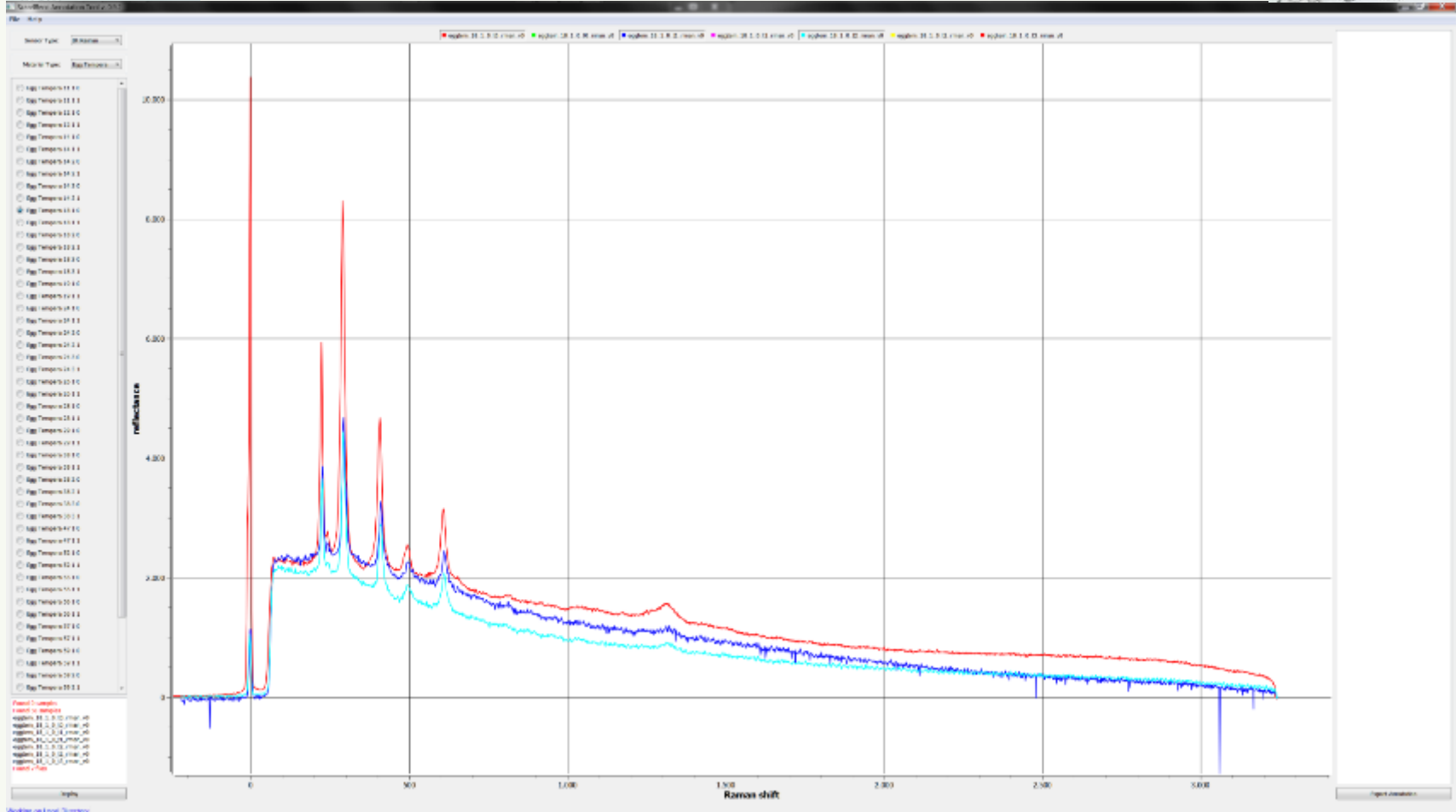
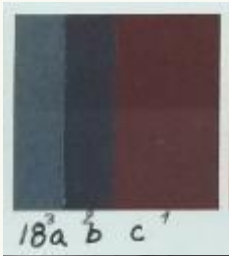


Working on Local Directory.

Annotation tool – μ Raman overlay spectra

Caput mortuum + **azurite** at T0, T1, T2 and T3

Quality of pigment remained unaffected. Intensity of signal is connected to pulverizing of the pigment

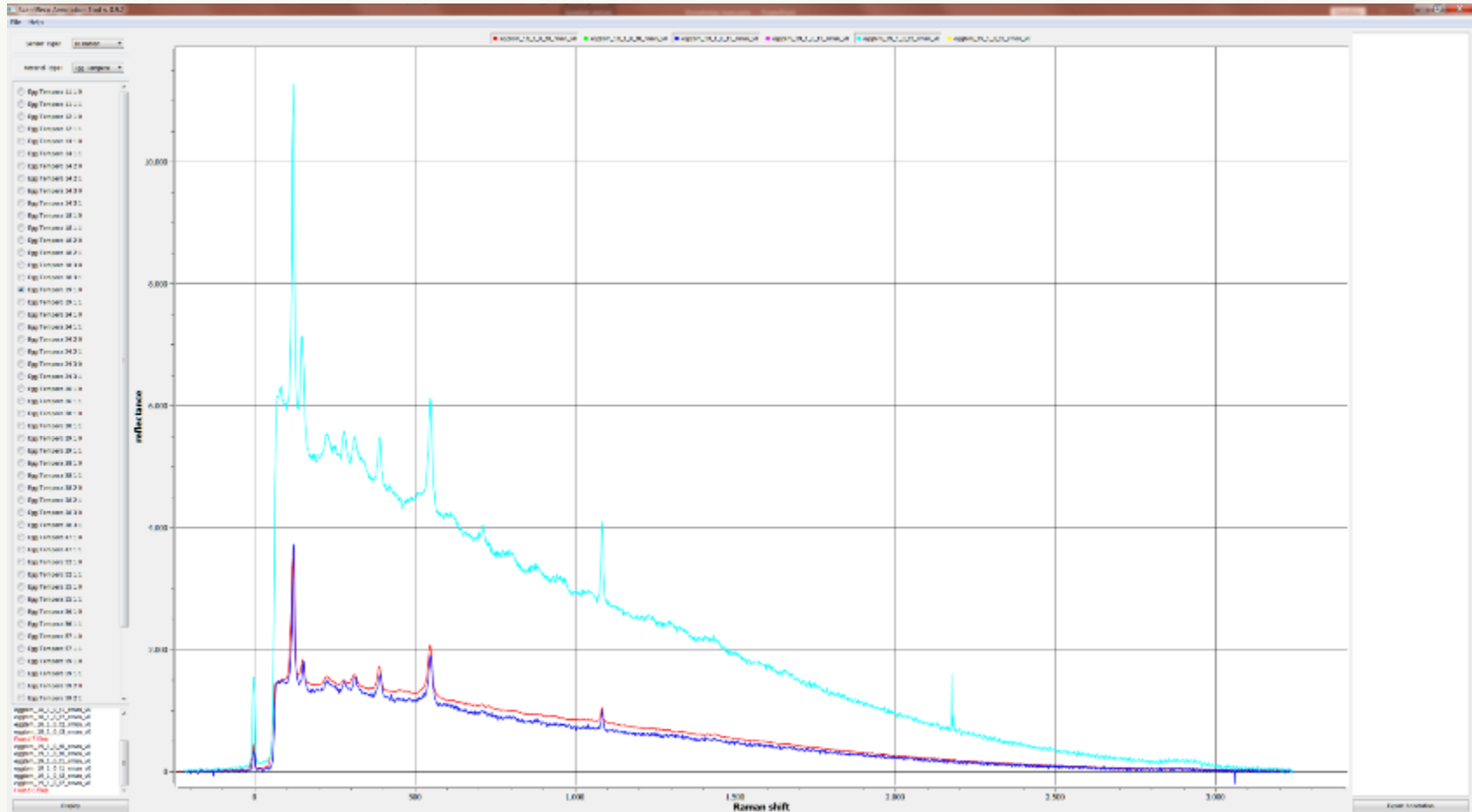


Annotation tool – μ Raman overlay spectra



Minium at T0, T1, T2 and T3

Quality of pigment remained unaffected. Intensity of signal is connected to pulverizing of the pigment

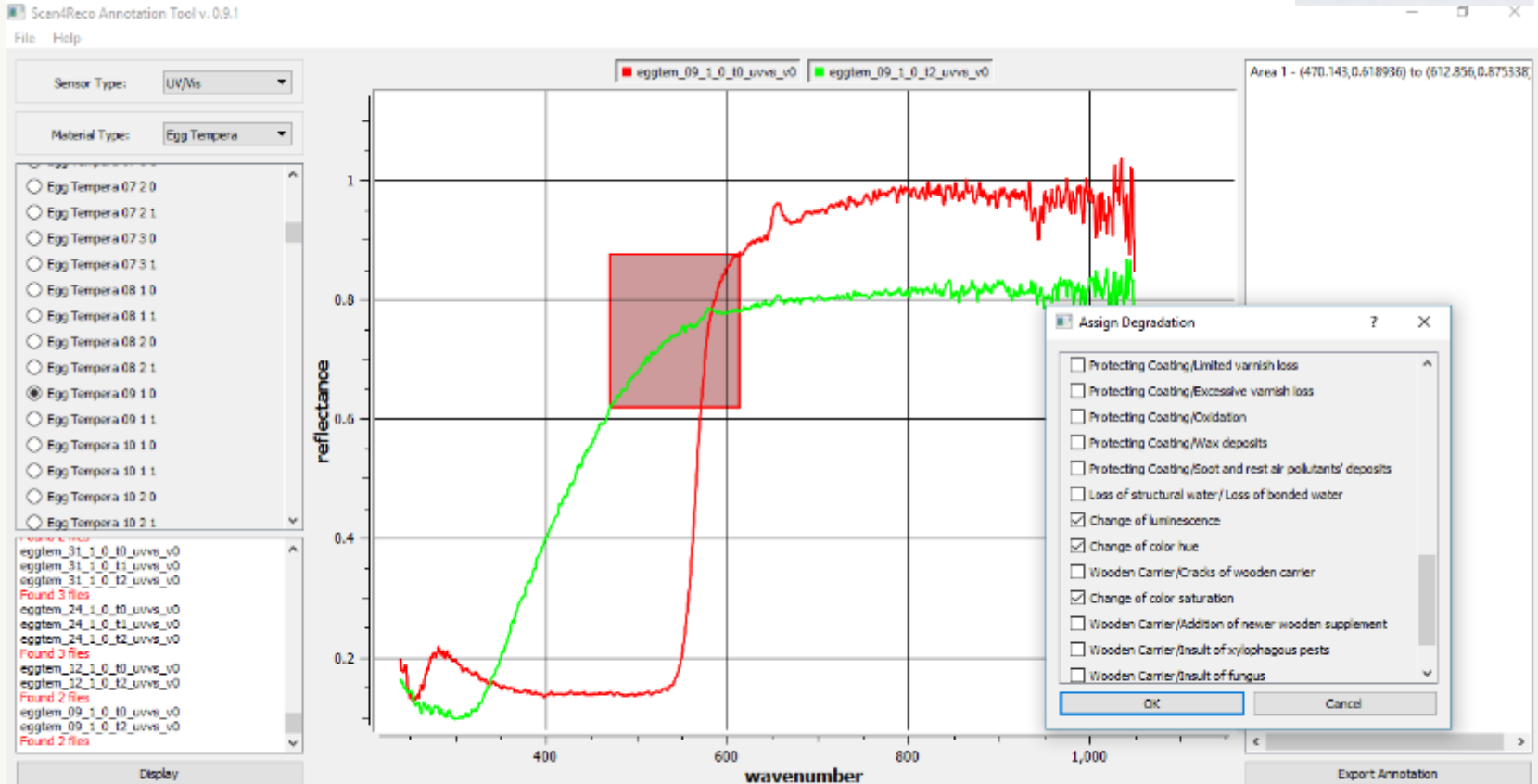
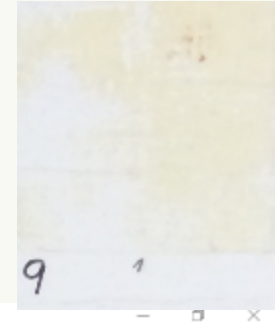


Annotation tool – UV-Vis overlay spectra



Minium at T0 and T1

Change of luminescence, change of hue and change of saturation of the color



Annotation tool – UV-Vis overlay spectra



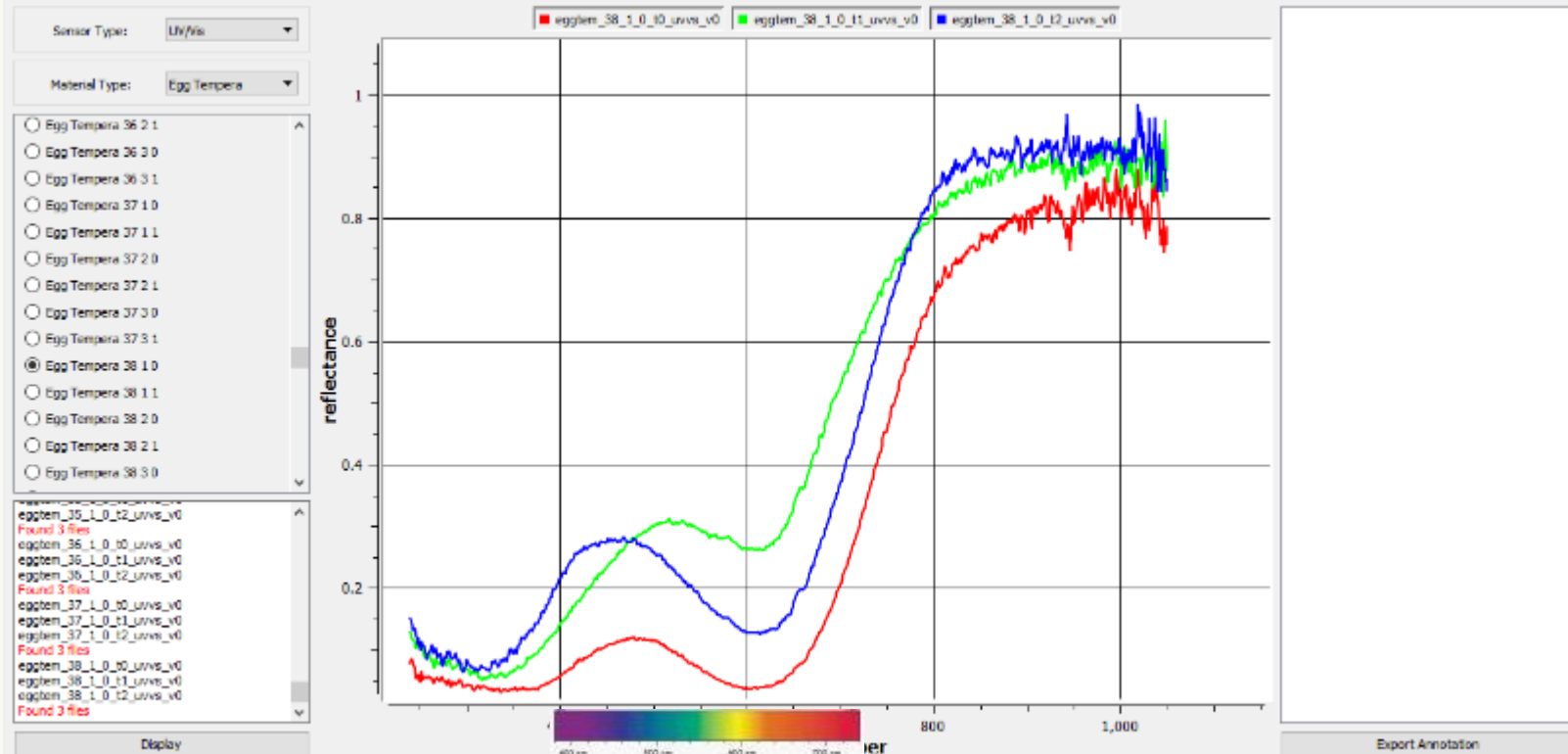
Indigo at T0, T1 and T2

Change of luminescence, change of hue and change of saturation of the color



ScanReco Annotation Tool v. 0.9.1

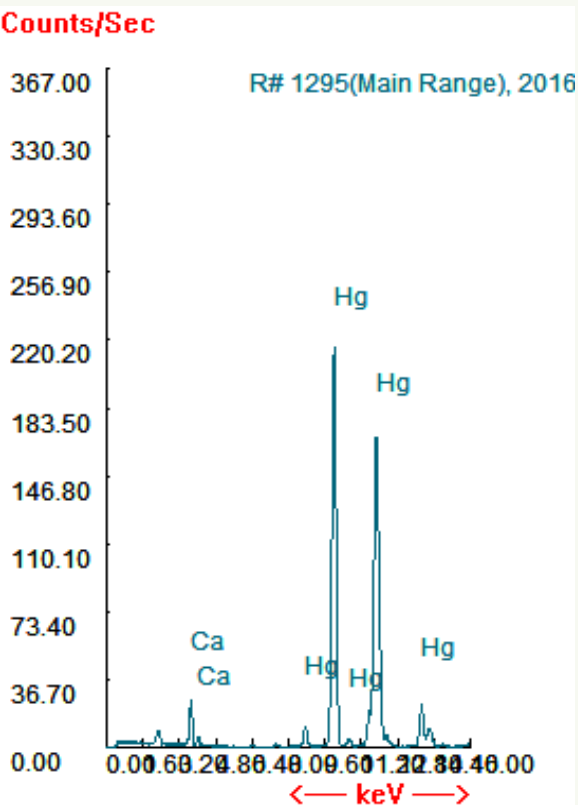
File Help



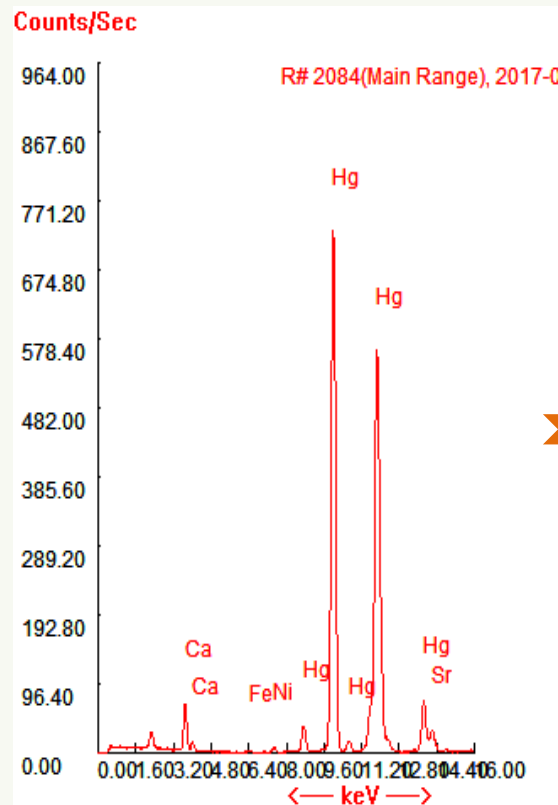
Working on Local Directory.

Annotation tool – XRF

Cinnabar at T0



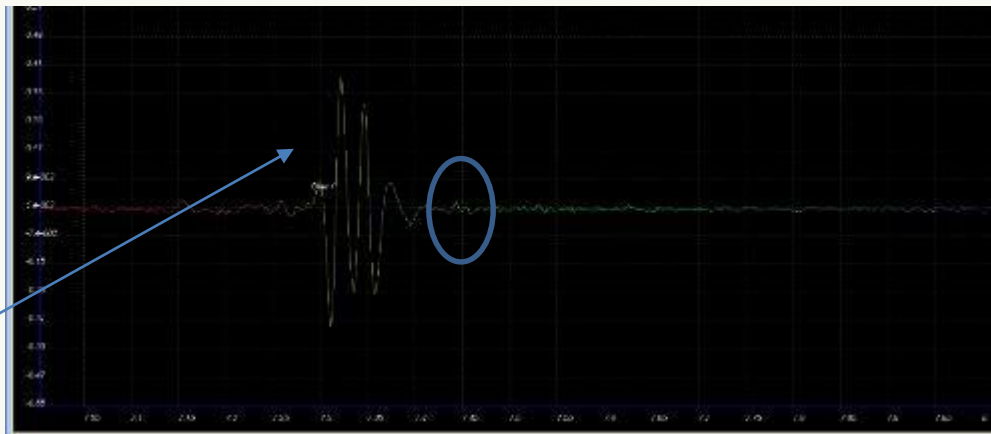
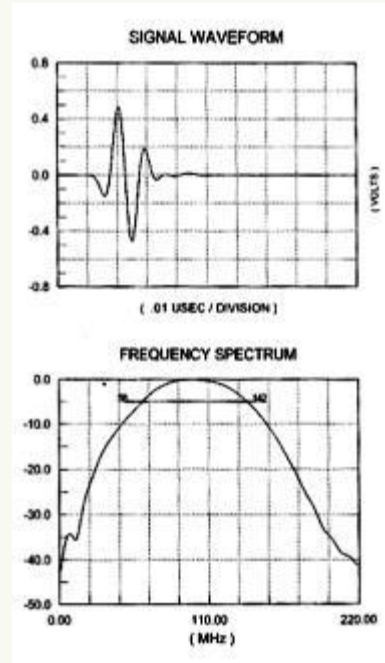
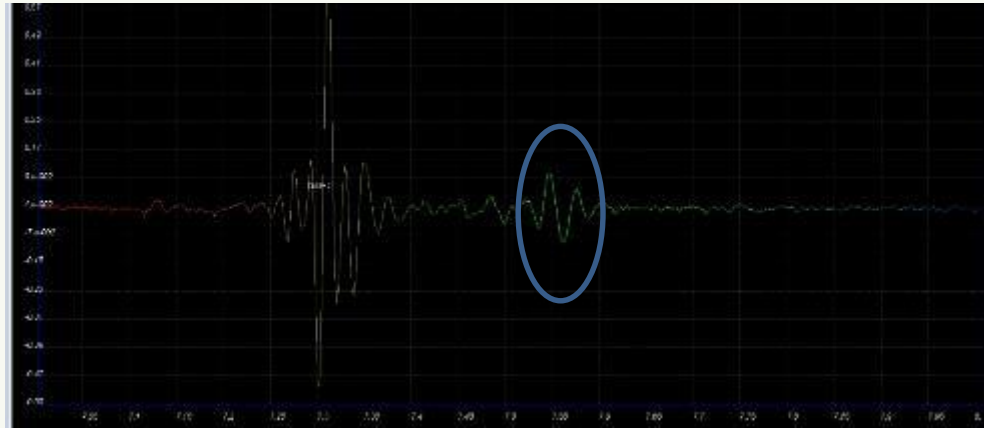
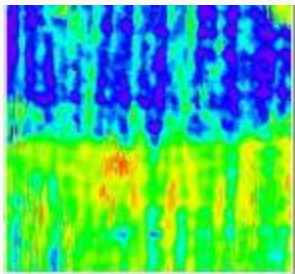
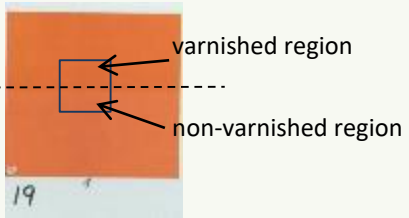
Cinnabar at T2



1. Pulverising of pigments
2. Damage of carrier of pigment
3. Cohesion between preparation and pigment layer

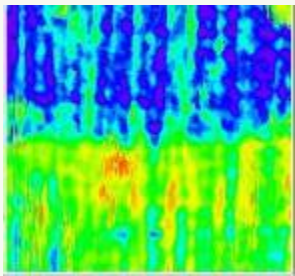
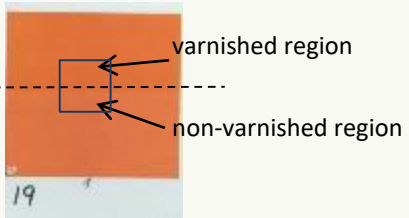
Percentage of heavy metals is given as a proportion of measured area

Annotation tool – Ultrasonic scanning

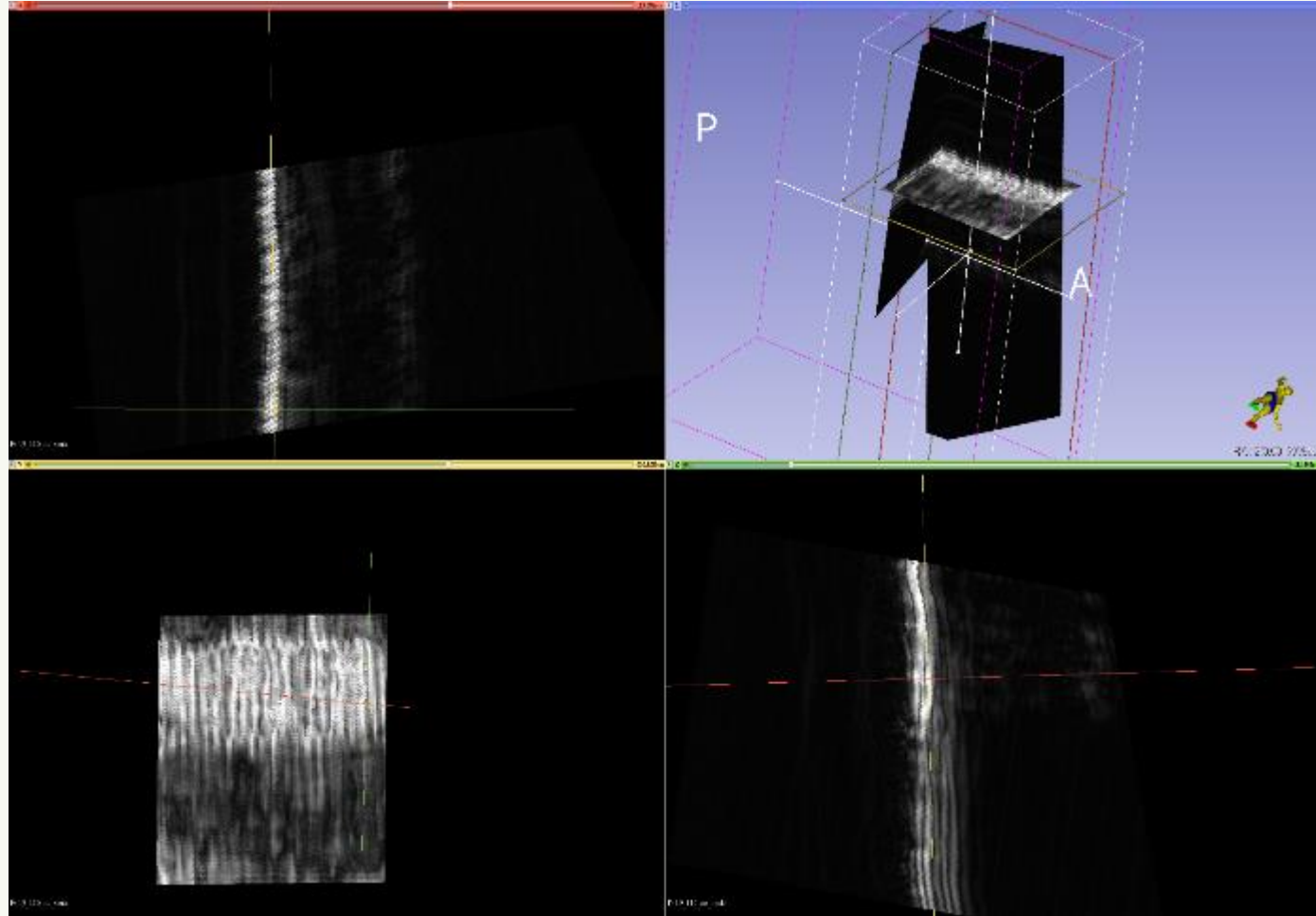


Time Of Flight of the first echo
Image or Amplitude Image
revealing the roughness

Annotation tool – Ultrasonic scanning



Time Of Flight of the first echo
Image or Amplitude Image
revealing the roughness



Annotation tool – On-line database

www.scan4Reco.gr and sign in to a friendly on-line database, containing techniques, measurements at every ageing step, sorted by material type.

The screenshot displays the scan4Reco web application interface. The dashboard provides a summary of the database content:

- 4,884** Scan4Reco
- 113** Samples
- 8** Methods
- 9** Partners

Top Partners

Partner	Count
OF-ADC	1265
CR54	2461
UNIVR	618

Top Items

Item	Count
Silver	2,205
Egg Tempera Paintings	1,591
Bronze	1,088

Top Samples by Date

The interface includes a navigation menu on the left with options: Home, Partners (9), Methods (8), Scans4Reco (4884), Reports, Support files & docs, and Administration. A search bar at the top right allows searching for partners, items, and samples. The user is logged in as memagkinds.dimitris.

Annotation tool – On-line database

www.scan4Reco.gr and sign in to a friendly on-line database, containing techniques, measurements at every ageing step, sorted by material type.

The screenshot displays the scan4Reco website interface. The browser address bar shows the URL www.scan4Reco.gr. The page title is "Scan 4 Recos". A navigation menu on the left includes Home, Partners, Methods, Scan4Reco, Reports, Support files & docs, and Administration. The main content area features a project title: "Project Title: Multimodal Scanning of Cultural Heritage Assets for their multi-layered digitization and preventive conservation via spatiotemporal 4D Reconstruction and 3D Printing". Below this, three material categories are listed:

- Bronze (BR)**: For this study a 90% copper - 10% tin was chosen, since it is representative of most ancient alloys used for statuary, apart from impurities or trace elements. A binary alloy with an approximate tin content of 10% was also much employed in the Renaissance. No of Items: 19, No of Recos: 1085.
- Egg Tempera Paintings (ET)**: For this study the painting samples were prepared on a plywood board of 45 x 30.5cm on which comfortably fit 60 samples of 4 x 4cm. The preparation of colour samples, the choices for the preparation conditioning materials, the binder and colours were made. No of Items: 40, No of Recos: 1331.
- Silver (SI)**: Silver 95%-Copper 5% sheet, size 7 cm x 2.5 cm, thickness 1 mm. On each sample, a strip is left untreated as reference. The treatments applied are among the most popular ones used by silver heritage conservators. No of Items: 84, No of Recos: 2285.

At the bottom right, there is a page number "1 - 3" and a "Set Screen Reader Mode On" button.

Annotation tool – On-line database

www.scan4Reco.gr and sign in to a friendly on-line database, containing techniques, measurements at every ageing step, sorted by material type.

The screenshot displays the scan4Reco web application interface. The browser address bar shows the URL www.scan4Reco.gr/scan4RecoFiles/101851679015381661P85_ID3. The application header includes the scan4Reco logo, a help icon, and the user name 'mamaglinidis dimitrios'. A left sidebar contains navigation options: Home, Partners (9), Methods (8), Scans4Reco (4884), Reports, Support files & docs, and Administration. The main content area is titled 'Scan 4 Reco Files' and displays details for an object named 'Egg Tempera Paintings'. The description states: 'For this study the painting samples were prepared on a plywood board of 45 x 30.5cm on which comfortably fit 60 samples of 4 x 4cm. The preparation of colour samples, the choices for the preparation conditioning materials, the binder and colours were made'. The short name is 'EggTempera'. A table below lists the measurement methods and the number of records for each, grouped by time table (T0, T1, T2).

Sample	Time table	Method	No of Reco
EggTempera_01	T0	FTIR	2
		Optical profilometry (MPF)	3
		Reflectance Transformation Imaging (RTI)	17
		UV-Vis	2
		X-ray fluorescence (XRF)	2
	T1	FTIR	2
		Optical profilometry (MPF)	4
		Reflectance Transformation Imaging (RTI)	17
		UV-Vis	2
		X-ray fluorescence (XRF)	2
	T2	FTIR	2
		Optical profilometry (MPF)	4

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www.scan4Reco.gr and sign in to a friendly on-line database, containing techniques, measurements at every ageing step, sorted by material type. **Download of data is available.**

The screenshot displays the scan4Reco web application interface. The top navigation bar includes a hamburger menu, the logo 'scan4Reco', and a user profile 'mamagkinidis dimitrios'. A left sidebar contains navigation options: Home, Partners (9), Methods (8), Scans4Reco (4884), Reports, Support files & docs, and Administration. The main content area is titled 'Scan4Reco files' and shows a sample description: '(1) Preparatory Underpainting; Massicot (4 coats/layers), Light; -, Glaze; - // (1) realgar resin, (0) unvarnished.' Below this is a table of files:

Sample	Time	Directory	Filename	Document Size	Download
EggTempera_01	T0	FTIR	eggtem_01_1_1_10_fir_v0.csv	97.26 kb	
			eggtem_01_1_0_10_fir_v0.csv	97.26 kb	

A 'Download all' button is located to the right of the table. On the far right, a table shows the number of records for each sample, with values ranging from 2 to 17.

Conclusions

- ❖ The application of annotation tool facilitated the connection of ageing impact on samples to the pathology
- ❖ Data from 8 different instrumentation techniques were collected and grouped in a single tool providing the possibility to observe and annotate them in parallel
- ❖ The decay of materials and pigments in time was recorded and displayed by overlay diagrams, still to be used for the evaluation of measurements on objects under restoration
- ❖ Evaluation of the impact of stratigraphy on every measurement technique
- ❖ Relation of the decay with the pathology
- ❖ Information about the ageing behavior of every inorganic pigment separately or not
- ❖ A useful tool-database for experts on internet

