Heritage Research and international cooperation

the HERCULES Lab Experience

António Candeias

UNIVERSIDADE DE ÉVORA

LABORATORIO HERCULES
HERANÇA CULTURAL, ESTUDOS E SALVAGUARDA

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E-RIHS.pt
EUROPEAN RESEARCH INFRASTRUCTURE FOR HERITAGE SCIENCE

China-Portugal Joint Laboratory of Cultural Heritage Conservation Science
supported by the Belt and Road Initiative

City U Macau Chair in Sustainable Heritage

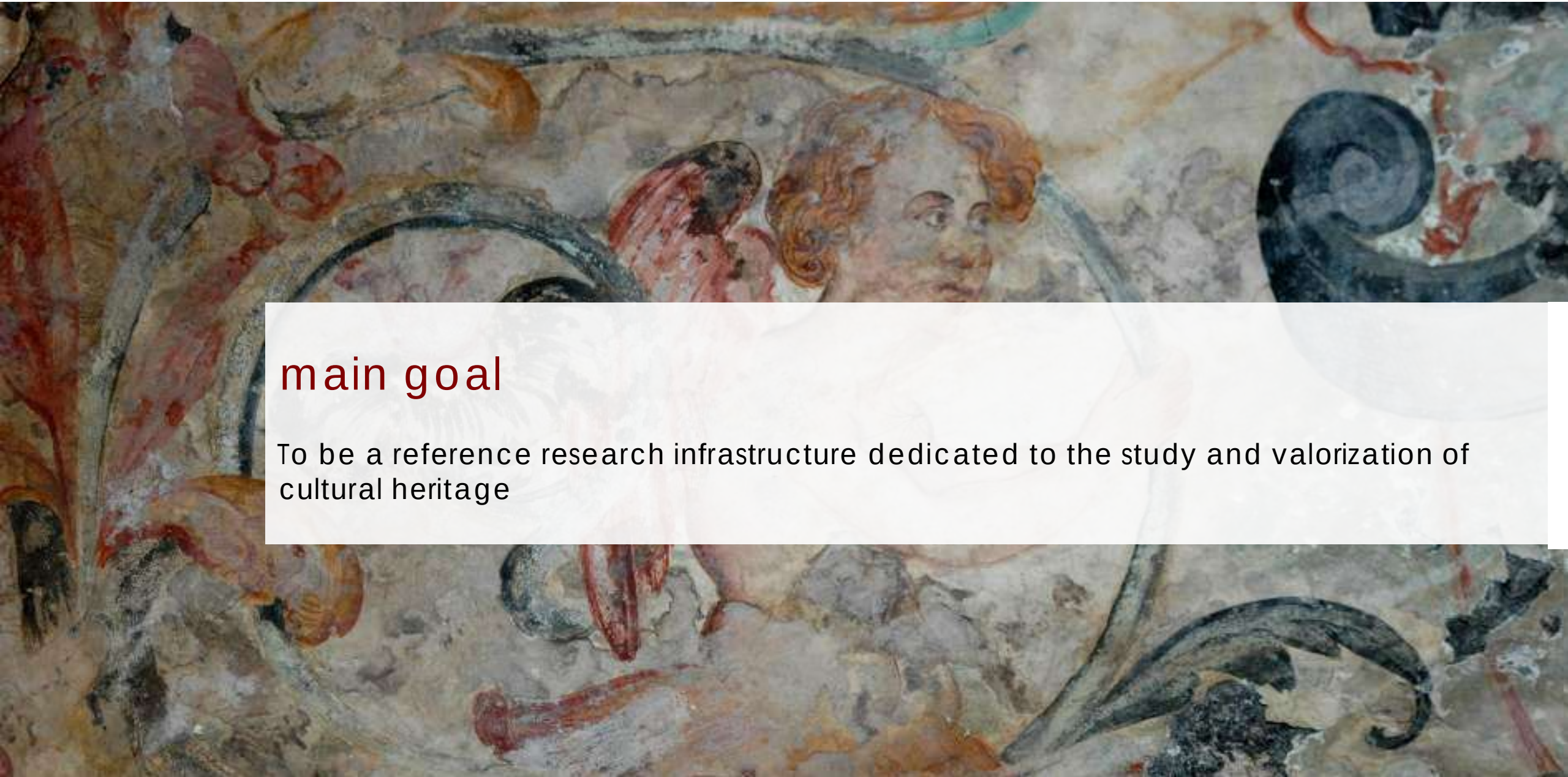
LABORATORIO

HERCULES

HERANÇA CULTURAL, ESTUDOS E SALVAGUARDA

CULTURAL HERITAGE, STUDIES AND SAFEGUARD

2009



main goal

To be a reference research infrastructure dedicated to the study and valorization of cultural heritage

LABORATORIO HERCULES
HERANÇA CULTURAL, ESTUDOS E SALVAGUARDA

How do we operate?

LABORATORIO HERCULES
HERANÇA CULTURAL, ESTUDOS E SALVAGUARDA

Research Lines

1. Archaeometric approaches to Past Cultures
2. Sciences for the Arts
3. Science for Heritage Conservation
4. Novel materials and tools for Cultural Heritage

What we want do?

meet the needs of the Heritage and Art Sector

develop collaborative research projects

develop reference Heritage conservation integrated projects

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HERANÇA CULTURAL, ESTUDOS E SALVAGUARDA

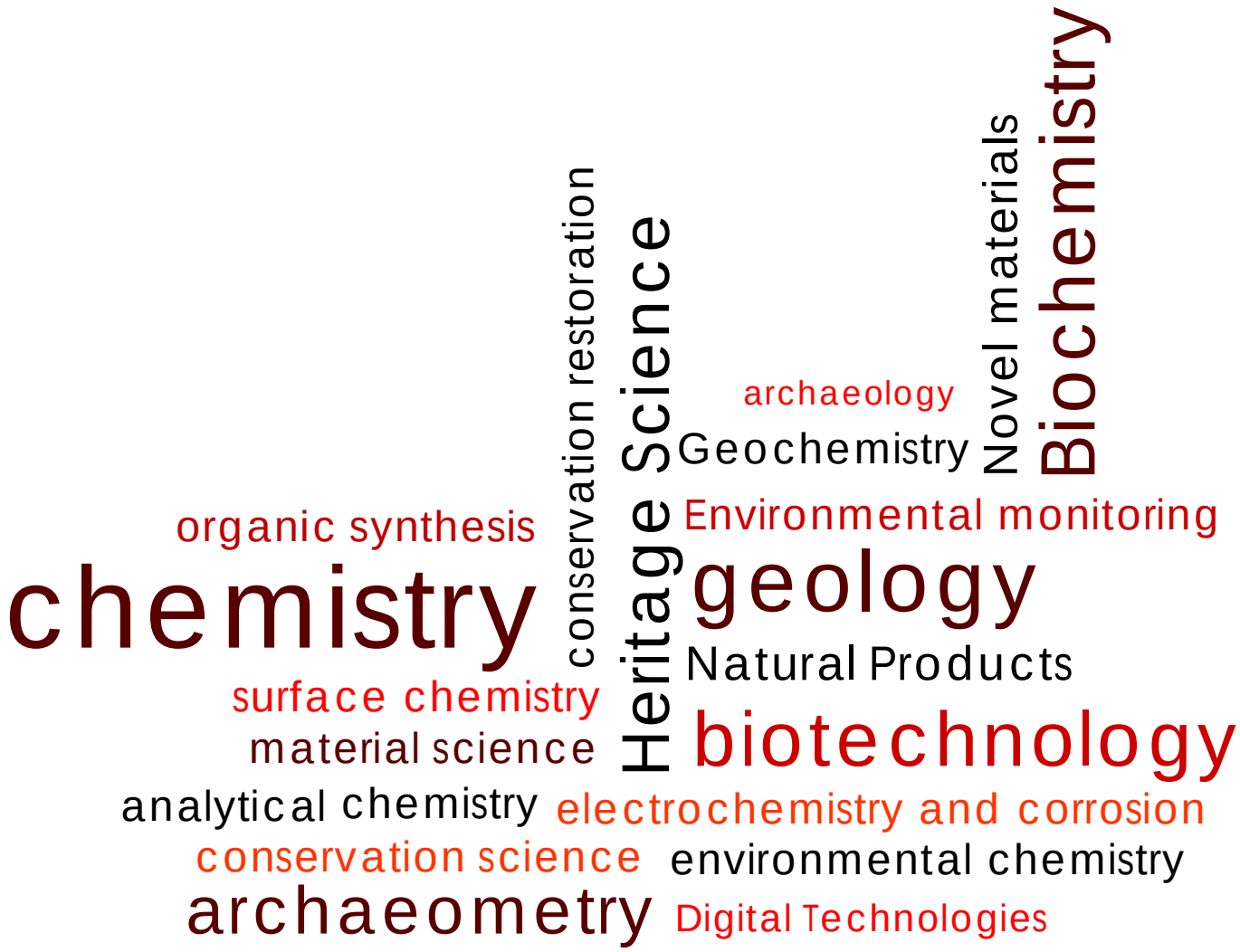
Who are we ?

team

40
doctorates

35
PhD
students

2
technicians



Instrumentation

Microscopy and Microanalysis Lab

- FEG-SEM-EDS TESCAN CLARA with EDS Bruker XFlash 6130SDD
- VP-SEM-EDS HITACHI 3700N with EDS BRUKER Xflash 5010SDD
- Raman microspectrometer HORIBA Xplora
- Imaging micro-FTIR-FPA BRUKER Hyperion
- Optical microscope LEICA DM2500M
- Optical microscope LEICA DM2500P
- Inverted optical microscope MOTIC
- 2x epifluorescence microscope MOTIC BA-410
- Stereozoom microscope LEICA M205C
- Digital microscope HIROX

Materials characterization Lab

- TG-DTA NETZSCH STA 449F3 Jupiter
- X-ray Microdifractometer BRUKER Discovery
- EDXRF BRUKER S2PUMA

Mass spectrometry Lab

- LA-ICP-MS Agillent 8800 TriQuad
- IR-MS Thermo Delta V Advantage
- GC-IR-MS Thermo Delta V

Chromatography Lab

- LC-DAD-MS THERMO LCQ Fleet
- GC-MS SHIMADZU GCMS-QP2010 Plus
- Py-GC-MS SHIMADZU GCMS-QP2010Plus
- High resolution Q TOFF-LC-MS THERMO

Biotechnology and Biodegradation

- New generation DNA sequencer Illumina MySeq
- DNA PCR Biorad
- Electroforesis system Biorad
- Image acquisition DNA Biorad
- Incubation system VWR
- Cell analizer Millipore Muse
- UV/Vis microplate Thermo Multicscan Go





HERCULES mobile unit

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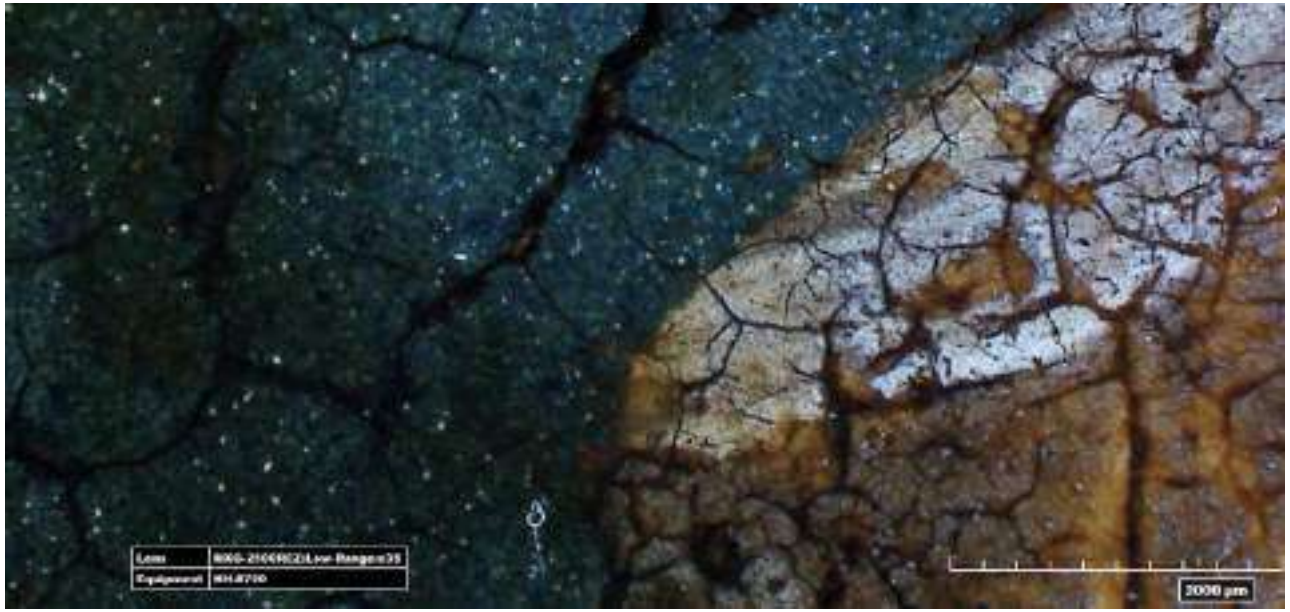
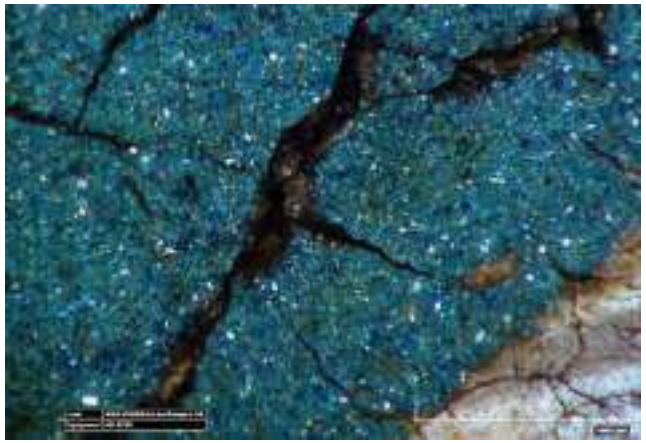
- High resolution infrared reflectography OSIRIS with InGaAs detector
- digital radiography (pulse X-ray source SCANNA XR200 -150kV- and XRS3 -300kV- with digital scanner SCANNA CR35)
- photographic equipment (visible, UV and IR)
- macro 2D XRF Bruker CRONO
- macro 2D XRF Bruker XGLAB ELIO
- handheld XRF Bruker tracer IIID
- handheld XRF Bruker tracer V
- portable SEM-EDS PHENOM PRO-X
- several handheld digital microscopes
- FTIR spectrometer Bruker ALPHA (with reflection, transmission, and ATR module)
- laser scanner 3D (FARO) for architectonic structures (c/ ICT)
- laser scanners 3D ARTEC SPIDER and ARTEC EVA for artefacts
- FORS BWTEK (NIR-UV)
- Hyperspectral camera Specim IQ
- Multispectral camera XpectralteK XPECAM
- Portable Raman spectrometer BWTEK
- DNA sequencer Minilon

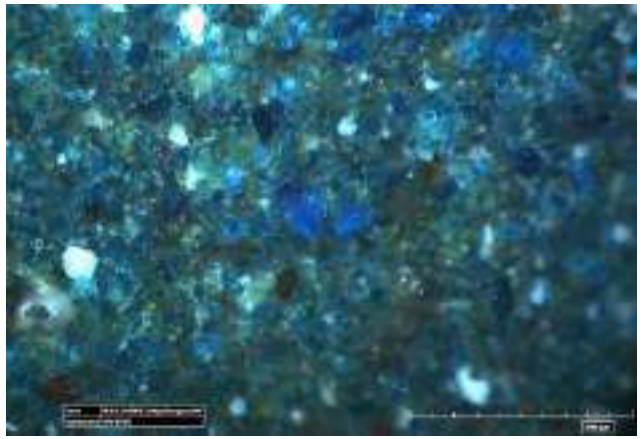
Integrated conservation-restoration project of St. Vicent panels

PATRIMÓNIO CULTURAL
Direção-Geral do Património Cultural
MNAA
UNIVERSIDADE DE ÉVORA
LABORATÓRIO HERCULES
CHAIA
Sustainable Heritage
GHENT UNIVERSITY
MUSEO NACIONAL DEL PRADO
THE MET

High resolution digital microscopy - HIROX







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Sustainable Heritage
City University of Macau (Chair)

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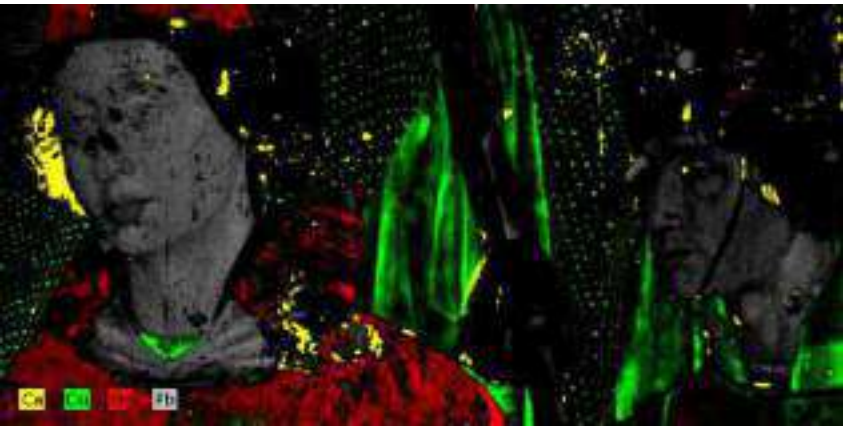
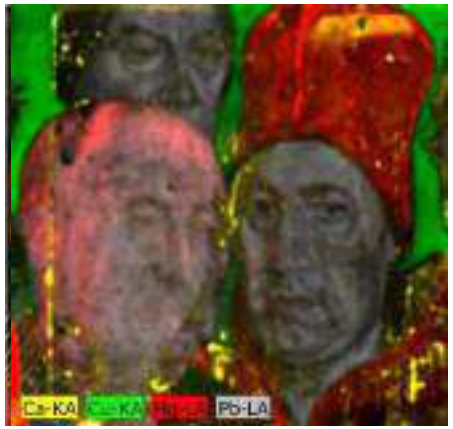
UNIVERSITEIT GENT

XRF
elemental mapping



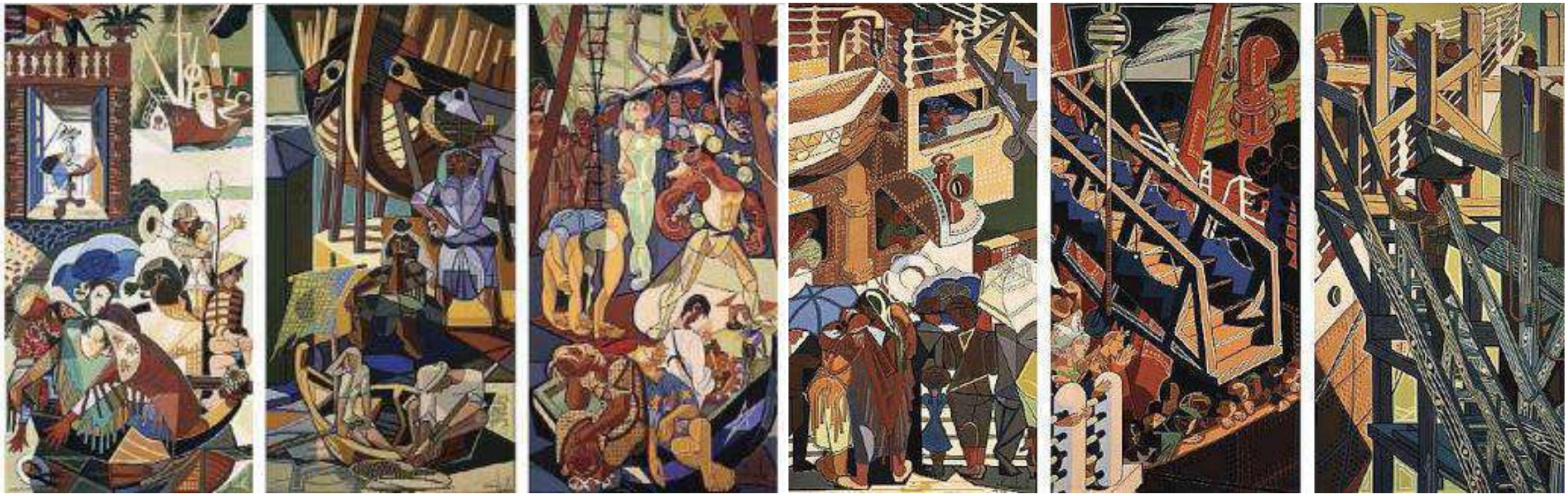


current appearance of the central panels

possible appearance of the panels before changes

Project PTDC/ART-HIS/1370/2020

The Unveiling of the Art of Mural Painting by Almada Negreiros (1938-1956): Scientific study of Pictorial Techniques, Materials and Diagnosis as guides for their conservation and enjoyment



FCT
Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

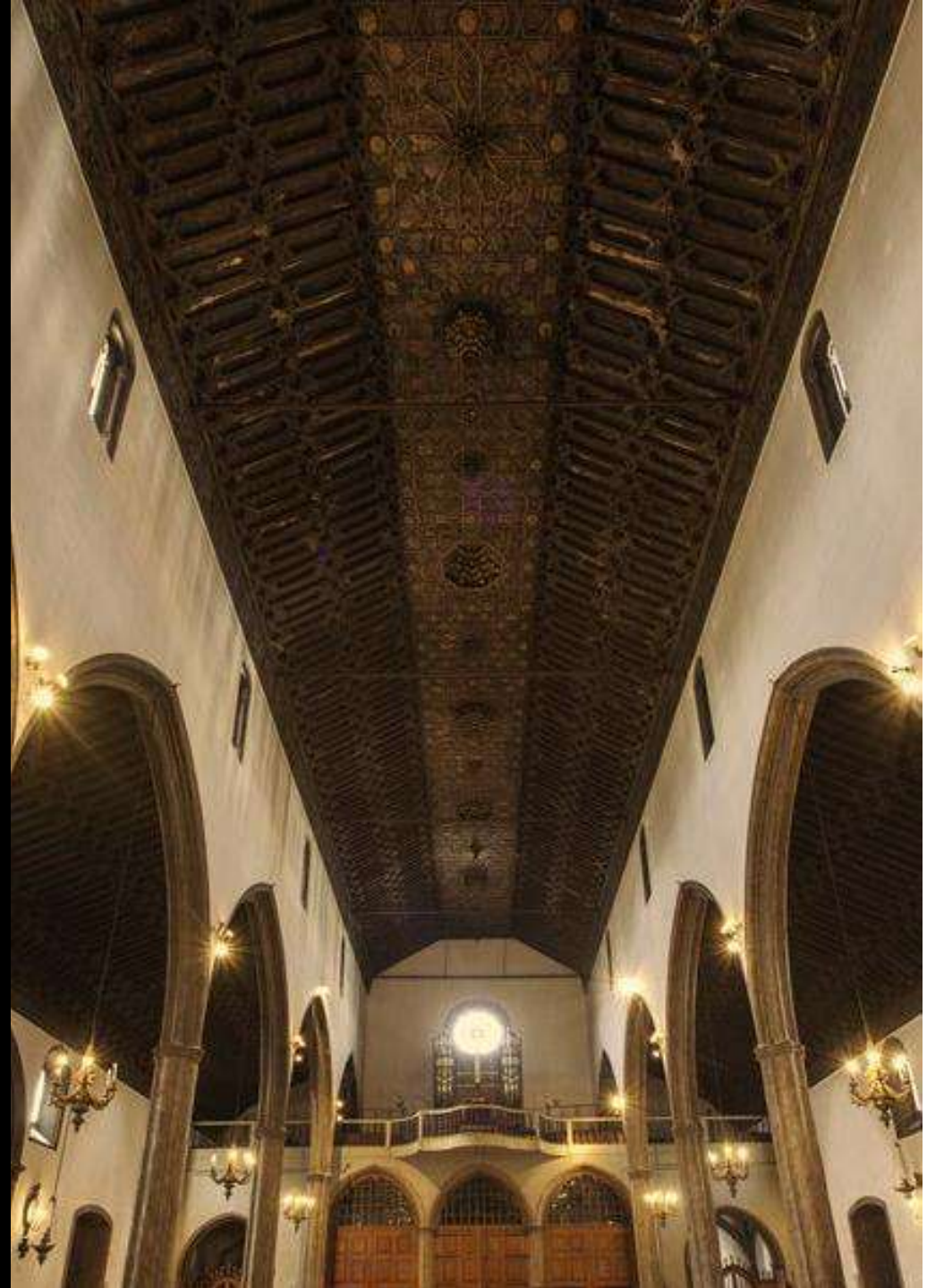
Funding: 229 keuros

Starting date: March, 29th 2021
End date: March 2025

2023 WINNERS
CITIZENS' ENGAGEMENT
AND AWARENESS-RAISING

Almada project - Unveiling the Mural Painting Art of Almada Negreiros

Coordinator: HERCULES Lab
Partners: General Directorate for Cultural Heritage,
Lisbon Harbour Administration,
NOVA Lisbon University



Integrated conservation project of the Mudejar ceilings of Funchal Cathedral

Coordinator: Madeira Regional Directorate for Culture

Partners: HERCULES Lab

General Directorate for Cultural Heritage

EUROPEAN UNION PRIZE FOR CULTURAL HERITAGE
EUROPA NOSTRA AWARD

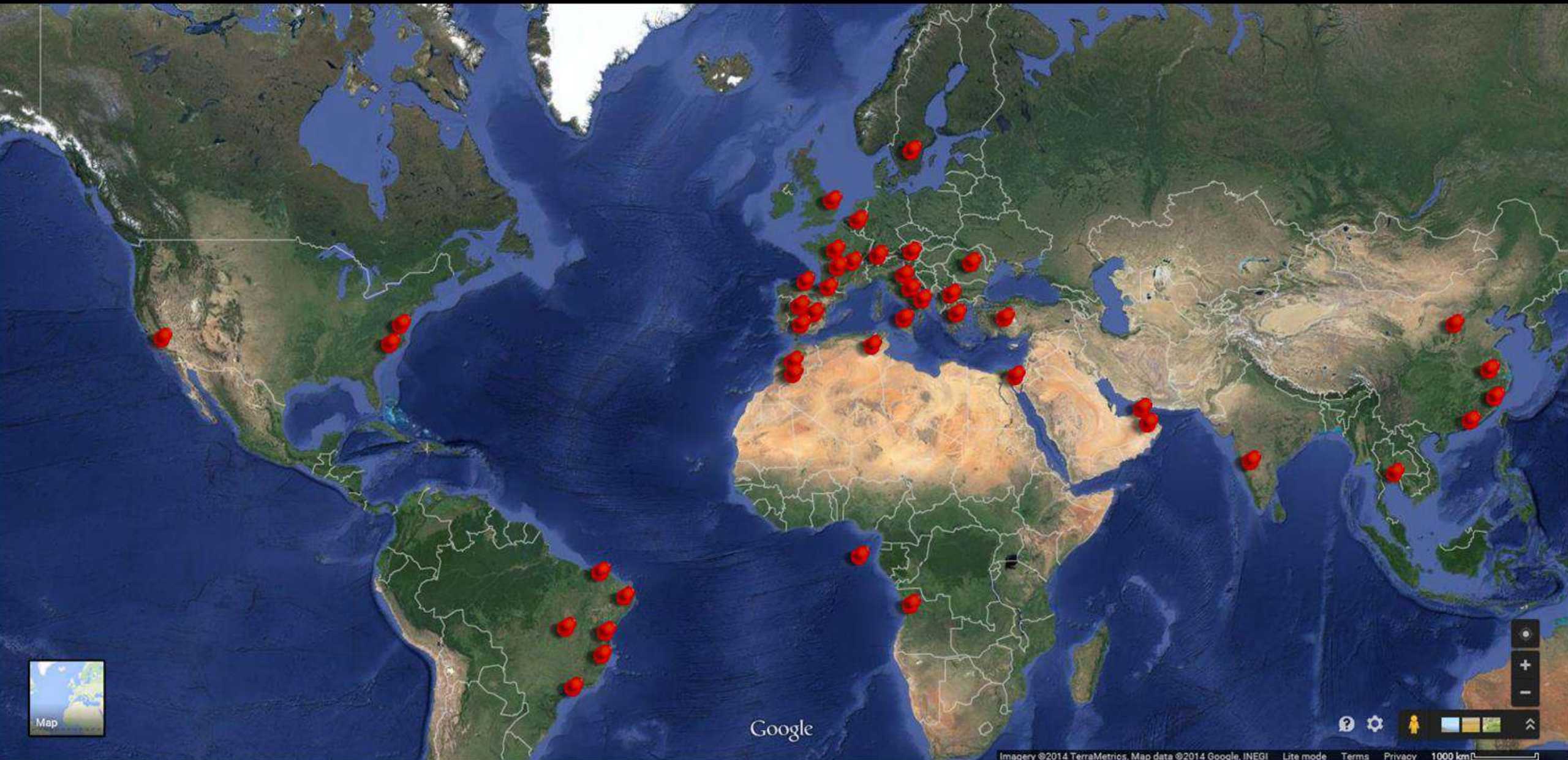
2023 WINNERS
CONSERVATION AND ADAPTIVE REUSE

Integrated conservation project of the Mudejar ceilings of Funchal Cathedral

Coordinator: Madeira Regional Directorate for Culture
Partners: HERCULES Lab
General Directorate for Cultural Heritage

Art Kaplan
Hercule Florence project

internacionalization



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coordination infrastructure

coordination Associate Laboratory

reference projects

partnership
joint activities

PATRIMÓNIO CULTURAL
Direção-Geral do Património Cultural
LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

filiação Labs, DGPC

partnership
joint activities

INSTITUTO DE HISTÓRIA CONTEMPORÂNEA
INSTITUTO DE HISTÓRIA DA ARTE
lab2pt Laboratório de Paisagens, Património e Território
CESEM CENTRO DE ESTUDOS DE SOCIOLOGIA E ESTÉTICA MUSICAL
CHAIA CENTRO DE HISTÓRIA DA ARTE E INVESTIGAÇÃO ARTÍSTICA
CRIA CENTRO EM REDE DE INVESTIGAÇÃO EM ANTROPOLOGIA

Sustainable Heritage
City U Macau Chair

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EUROPEAN RESEARCH INFRASTRUCTURE FOR HERITAGE SCIENCE. portuguese platform

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PATRIMÓNIO | ARTE | SUSTENTABILIDADE | TERRITÓRIO

support public policies
Affiliate other RD Units and entities

joint activities
advanced training

澳門城市大學
Universidade da Cidade de Macau
City University of Macau

蘇州大學
SOOCHOW UNIVERSITY

creation collaborative laboratory

creation European infrastructure

access to infrastructure
demonstration activities

researchers, R&D units
companies, other entities,
Portuguese state

PORTUGAL

E-RIHS
EUROPEAN RESEARCH INFRASTRUCTURE FOR HERITAGE SCIENCE

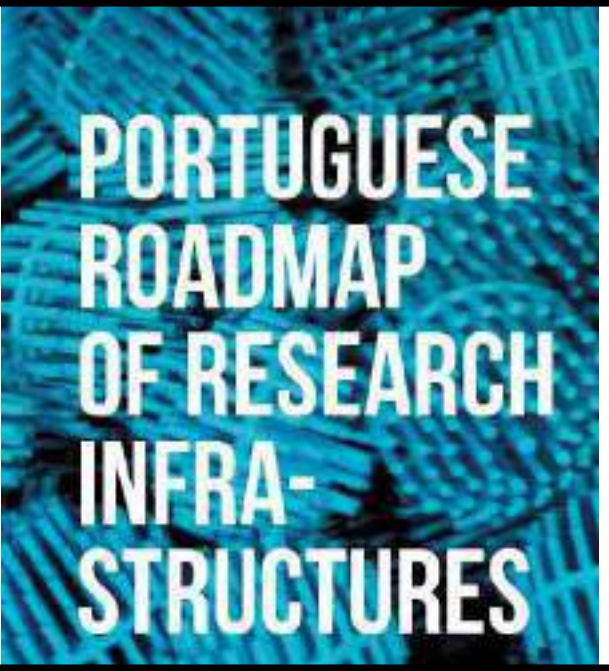
Apan-European access to infrastructures

researchers
R&D units

International cooperation

E-RIHS hubs

European Research Area



E-RIHS.pt

EUROPEAN RESEARCH INFRASTRUCTURE
FOR HERITAGE SCIENCE . portuguese platform

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Direção-Geral do Património Cultural

LABORATORIO HERCULES
HERANÇA CULTURAL, ESTUDOS E SALVAGUARDA

a groundbreaking infrastructure for Cultural Heritage Research

started 2016

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LNEC
PATRIMÓNIO CULTURAL
Direção-Geral do Património Cultural
Jose de Figueiredo Lab
UNIVERSIDADE DE ÉVORA
LABORATORIO HERCULES
HERANÇA CULTURAL, ESTUDOS E SALVAGUARDA
National Laboratory
Central Gov Laboratory
Research Unit

Projecto «Livro das Fortalezas»
Biblioteca Nacional de Espanha

PATRIMÓNIO CULTURAL
Direção-Geral do Património Cultural

UNIVERSIDADE DE ÉVORA

E-RIHS.pt

E-RIHS will be the pan-European distributed research infrastructure in the form of a European Research Infrastructure Consortium (ERIC).

http://www.e-rihs.eu

Belgium
Cyprus
Denmark
France
Germany
Greece
Hungary
Italy
Malta
The Netherlands
Poland
Portugal
Romania
Spain
Slovenia
Sweden
United Kingdom

E-RIHS will have a star design, with a Central Hub in Italy and National Hubs in all participating countries

started 2020

IN2PAST

LABORATÓRIO ASSOCIADO PARA A INVESTIGAÇÃO E INOVAÇÃO
EM PATRIMÓNIO, ARTES, SUSTENTABILIDADE E TERRITÓRIO

ASSOCIATE LABORATORY FOR RESEARCH AND INNOVATION
IN HERITAGE, ARTS, SUSTAINABILITY AND TERRITORY

CENTRO DE ESTUDOS DE SOCIOLOGIA E ESTÉTICA MUSICAL CESEM
CHAIA CENTRO DE HISTÓRIA DA ARTE E INVESTIGAÇÃO ARTÍSTICA
CRIA CENTRO EM REDE DE INVESTIGAÇÃO EM ANTROPOLOGIA
INSTITUTO DE HISTÓRIA DA ARTE
INSTITUTO DE HISTÓRIA CONTEMPORÂNEA
LABORATORIO HERCULES HERANÇA CULTURAL, ESTUDOS E SALVAGUARDA
lab2pt Laboratório de Paisagens, Património e Território

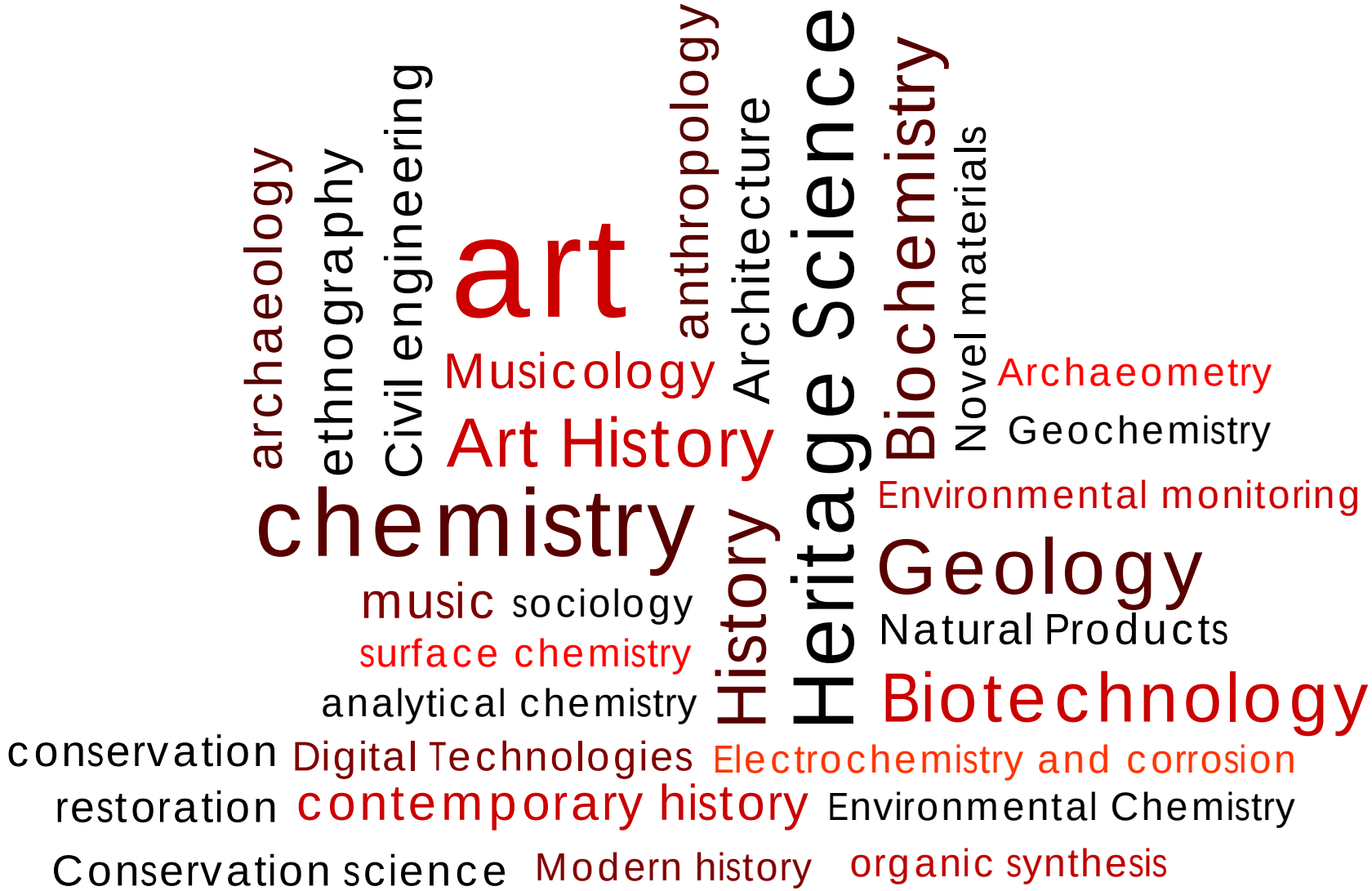
5
universities

UNIVERSIDADE DE ÉVORA
iscte INSTITUTO UNIVERSITÁRIO DE LISBOA
UNIVERSIDADE DE COIMBRA
Universidade do Minho
UNIVERSIDADE NOVA DE LISBOA

7
R&D units

CENTRO DE ESTUDOS DE SOCIOLOGIA E ESTÉTICA MUSICAL CESEM
CHAIA CENTRO DE HISTÓRIA DA ARTE E INVESTIGAÇÃO ARTÍSTICA
CRIA CENTRO EM REDE DE INVESTIGAÇÃO EM ANTROPOLOGIA
INSTITUTO DE HISTÓRIA DA ARTE
INSTITUTO DE HISTÓRIA CONTEMPORÂNEA
LABORATORIO HERCULES
lab2pt Laboratório de Paisagens, Património e Território

331
Highly qualified human resources


archaeology
ethnography
Civil engineering
art
anthropology
Architecture
Heritage Science
Biochemistry
Novel materials
Musicology
Archaeometry
Art History
Geochemistry
chemistry
Environmental monitoring
History
Geology
music
sociology
Natural Products
surface chemistry
analytical chemistry
Biotechnology
conservation
Digital Technologies
Electrochemistry and corrosion
restoration
contemporary history
Environmental Chemistry
Conservation science
Modern history
organic synthesis

澳門城市大學
Universidade da Cidade de Macau
City University of Macau

Creation of an Endowed chair on *Sustainable Heritage*

March 2019

Sustainable Heritage Chair

City University Macau

澳門城市大學
Universidade da Cidade de Macau
City University of Macau

UNIVERSIDADE DE ÉVORA

LABORATORIO HERCULES
HERANÇA CULTURAL, ESTUDOS E SALVAGUARDA

- Jointly supervised Post-doc programs
- Collaborative and Reference Research projects
- Creation of a laboratory at CityUMacau with scientific counseling by HERCULES Lab

BELT and ROAD
一帶一路

SOOCHOW UNIVERSITY
蘇州大學
澳門城市大學
Universidade da Cidade de Macau
City University of Macau
UNIVERSIDADE DE ÉVORA
LABORATORIO HERCULES
HERANÇA CULTURAL, ESTUDOS E SALVAGUARDA

creation of the China-Portugal Joint Laboratory for Heritage Conservation Science

中国-葡萄牙文化遗产保护科学“一带一路”联合实验室

China-Portugal Joint Laboratory of Cultural Heritage Conservation Science supported by the Belt and Road Initiative

China-Portugal Joint Laboratory
of Cultural Heritage Conservation Science supported by the Belt and Road Initiative

management board

Prof. Yongfa WU

Director of JLBRI
Dean of School of Architecture
Doctoral Supervisor

Prof. Yao WU

Deputy Director of JLBRI
Deputy Dean of School of Architecture
Doctoral Supervisor

Prof. Jinghua SHEN

Chief Scientist of JLBRI
Academician of European Academy of Sciences and Arts
Doctoral Supervisor

Prof. Jun LIU

Regional Director of JLBRI
Rector of City Univ of Macau
Doctoral Supervisor

Prof. António Candeias

International Director of JLBRI
Director of HERCULES
Director of IN2PAST
Doctoral Supervisor

SOOCHOW UNIVERSITY
澳門城市大學 Universidade da Cidade de Macau City University of Macau
UNIVERSIDADE DE ÉVORA
LABORATORIO HERCULES HERANÇA CULTURAL, ESTUDOS E SALVAGUARDA

research focus

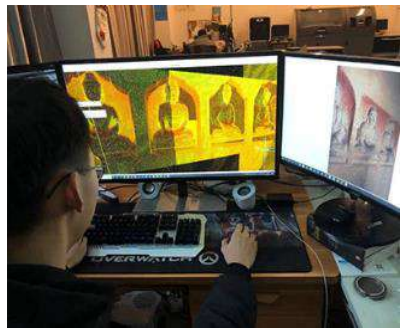
1. New Materials and Crafts for Heritage Conservation

The cross-disciplinary research between architecture and material chemistry, focusing on the material analysis of heritage, the research and development of new materials, and the industrialization of heritage conservation research.

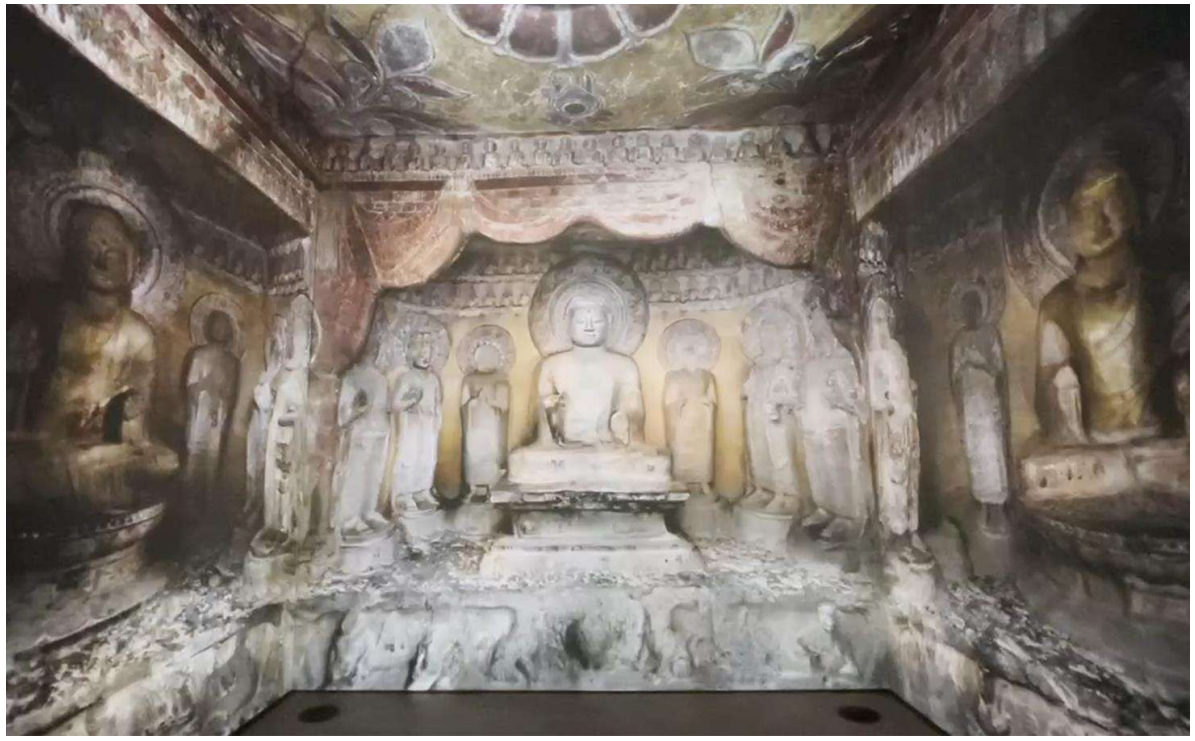
Non-destructive analysis of the Portuguese tiles on the walls of Sun Yat Sen Municipal Park in Macau

2. Digitalization of Heritage Conservation Technology

The research on the digital conservation of architectural and urban heritage, focusing on the data collection, storage, and conservation of digitalized cultural heritage, and the application of virtual reality on heritage conservation, safeguard and monitorization of heritages, existing building performance elevating; cultural landscape conservation and eco-restoration.



3. Sustainable Conservation and Demonstrative Projects

Based on a collaborative entrepreneurship and innovation platform established by internal and external design institutions, which aims to undertake projects related to architectural heritage conservation, urban renewal, and traditional village conservation, and provide services to support urban and rural development and socio-economic progress.






Physical Performance Testings of Heritage Protected at the National Level

research focus

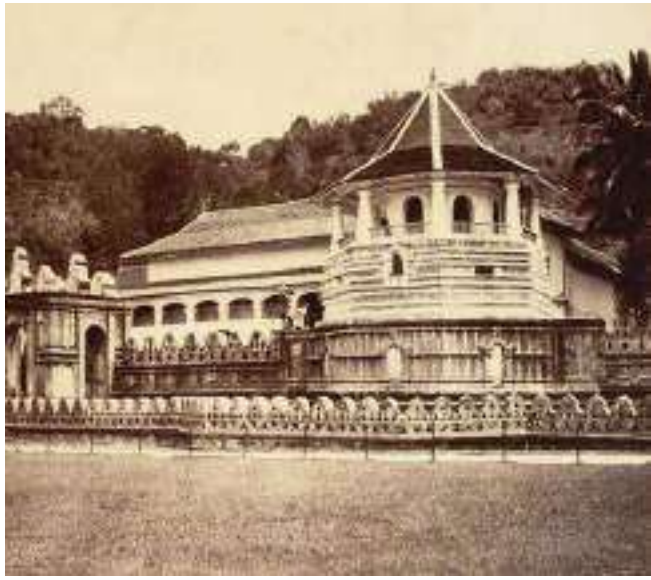
4. Cultural Heritage History and Theories

The cross-disciplinary research on architecture, humanities, and arts, focusing on the studies on the architectural forms, crafts, regional and geographical characters of typical heritage sites, highlighting the cultural heritage conservation theories on B&R regions.

Ruins of St. Paul's, Macau

Protection of the Chiado Neighborhood in Lisbon

Inheritance of Japanese Restoration Crafts



Post-disaster Restoration of the Buddha Tooth Temple in Sri Lanka

training

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Erasmus Mundus Master Course (2013-2027)

ARCHMAT – Archaeological Materials Science

UNIVERSIDADE DE ÉVORA
SAPIENZA UNIVERSITÀ DI ROMA
ARISTOTLE UNIVERSITY OF THESSALONIKI
Education and Culture
Erasmus Mundus

2013-2024: ~200 MSc theses

MARIE Skłodowska-CURIE ACTIONS Innovative Training Networks (ITN) (2017-2022)

ED-ARCHMAT | European Doctorate in Archaeological and Cultural Heritage Materials Science

UNIVERSIDADE DE ÉVORA

LABORATORIO HERCULES
HERANÇA CULTURAL, ESTUDOS E SALVAGUARDA

13 PhD theses

SAPIENZA
UNIVERSITÀ DI ROMA

UNIVERSIDAD DE BURGOS

université de BORDEAUX

AVIGNON UNIVERSITÉ

Ben-Gurion University of the Negev

CSIC
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

- Bangladesh
- Brazil
- China
- Croatia
- Ethiopia
- France
- Germany
- India

ED-ARCHMAT

European Commission

Workshop “Scientific analysis of Artworks and Cultural Heritage”

Instructors: António Candeias, Teresa Caldeira, Catarina Miguel, Nick Schiavon

Participants: 15 professors and researchers Silpakorn University

Place: Silpakorn University (Thailand)

(18-19 Nov 2022)

Rio de Janeiro, Brazil

September 2019

FIOCRUZ
Fundação Oswaldo Cruz

International Course on Science for the Arts – a new look into Heritage

Curso Internacional Ciência para as Artes – um novo olhar sobre o património

(training with non-invasive techniques including ED-XRF, digital microscopy, ATR-FTIR – participants: 20 technicians from different Brazilian institutions)

Rio de Janeiro, Brazil

October 2023

FIOCRUZ
Fundação Oswaldo Cruz

Workshop on studies and scientific research in cultural heritage

Oficina de estudos e investigações científicas do património cultural

(training with non-invasive techniques including ED-XRF, digital microscopy, FORS, hyperspectral imaging, NGS, IR reflectography)
participants: 32 technicians

Rio de Janeiro, Brazil

October 2023

FIOCRUZ
Fundação Oswaldo Cruz

Workshop on studies and scientific research in cultural heritage

Oficina de estudos e investigações científicas do património cultural

(training with non-invasive techniques including ED-XRF, digital microscopy, FORS, hyperspectral imaging, NGS, IR reflectography)
participants: 32 technicians





OLD GOA REVELATIONS

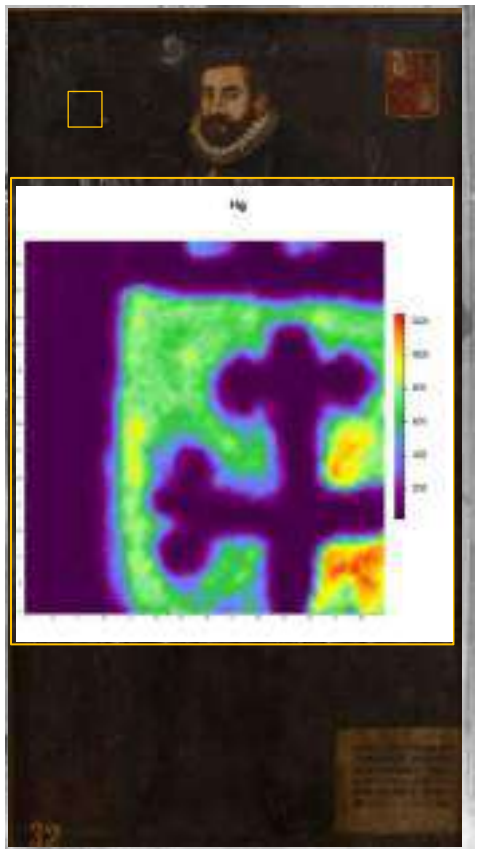
NEW INSIGHTS ON THE VICE-ROYS PORTRAIT GALLERY

Workshop on non-invasive painting analysis

X-ray radiography, IRR, XRF, 2D-XRF, IR, OM, biotech

Archaeological Survey of India

प्रत्नकीर्तिमपावृणु



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LABORATORIO HERCULES

Sustainable Heritage City U Macau Chair

b a

cieba

belas-artes ulisboa

FUNDAÇÃO CALOUSTE GULBENKIAN

Jan12th – Jan 27th 2019

OLD GOA REVELATIONS

NEW INSIGHTS ON THE VICE-ROYS PORTRAIT GALLERY

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MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

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GHENT UNIVERSITY

REPÚBLICA PORTUGUESA
CULTURA

PATRIMÓNIO CULTURAL
Direção-Geral do Património Cultural

Ministry of Culture
Government of India
सत्यमेव जयते

REPÚBLICA PORTUGUESA
NEGÓCIOS ESTRANGEIROS

FUNDAÇÃO ORIENTE

fct Fundação para a Ciência e a Tecnologia

COMPETE 2020

PORTUGAL 2020

ALENTEJO 2020

fieldwork mission

Jan 9th – Feb 10 th 2023

OLD GOA REVELATIONS

NEW INSIGHTS ON THE VICE-ROYS PORTRAIT GALLERY

FCT Fundação para a Ciência e a Tecnologia

MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

fieldwork mission

Jan 9th – Feb 10 th 2023

OLD GOA REVELATIONS

NEW INSIGHTS ON THE VICE-ROYS PORTRAIT GALLERY

fieldwork mission

Jan 9th – Feb 10 th 2023

Archaeological Survey of India

प्रत्नकीर्तिमपावृणु

Lisbon

Goa

OLD GOA REVELATIONS

NEW INSIGHTS ON THE VICE-ROYS PORTRAIT GALLERY

fieldwork mission

Jan 9th – Feb 10 th 2023

Archaeological Survey of India

प्रत्नकीर्तिमपावृणु

IR reflectography

X-ray radiography

racking light photography

UV photography

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OLD GOA REVELATIONS

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Archaeological Survey of India

प्रत्नकीर्तिमपावृणु

biofilm collection

Raman spectroscopy

X-ray spectrometry

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OLD GOA REVELATIONS

NEW INSIGHTS ON THE VICE-ROYS PORTRAIT GALLERY

fieldwork mission

Jan 9th – Feb 10 th 2023

Archaeological Survey of India

प्रत्नकीर्तिमपावृणु

X-ray Fluorescence Spectrometry

elemental composition

macro elemental mapping

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Credits: David Teves Reis
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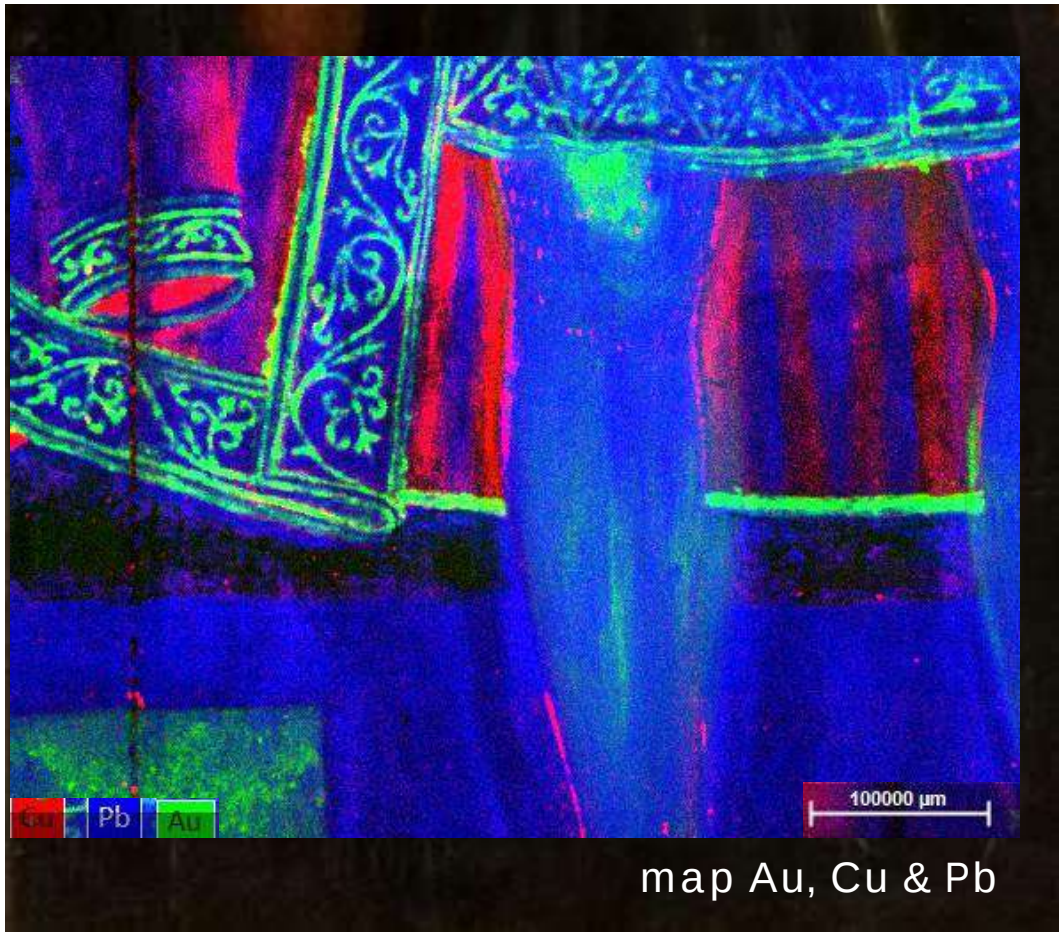

map Au, Cu & Pb

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next steps:

Creation of a new exhibition concept for the collection of the Gallery of the Viceroy of India (with ASI, in progress)

Implementation of an environmental monitoring program and risk management plan (1st semester 2024)

Inauguration of the new exhibition (1st semester 2024)

Innovation and Development

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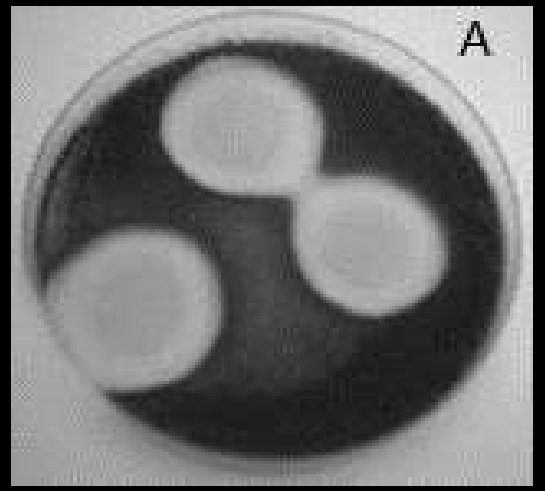
1. Production of novel green biocides

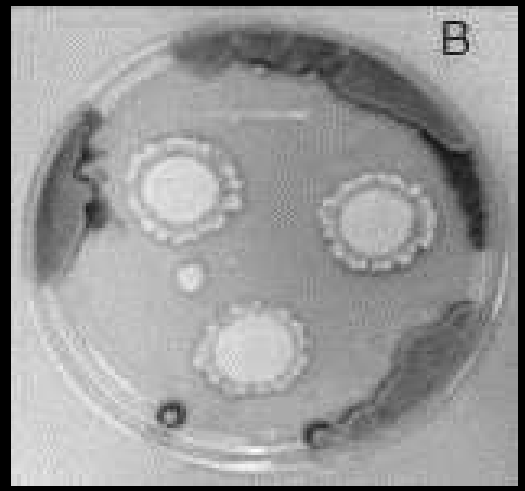
BEVOTECH (Biocide EVOra TECHnology)

New biocide developed at our Lab

From cultures of Bacillus amyloliquefaciens (GenBank AY785775) with broad spectrum of fungal inhibition



comercial biocides



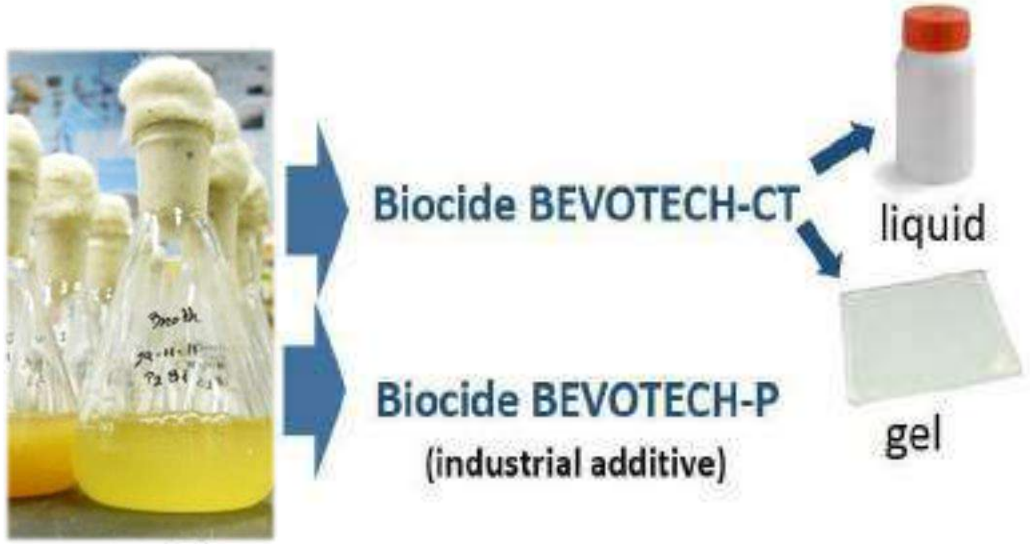
iturinic lipopeptide

product design

two products are being developed:

Biocide BEVOTECH-CT new biocide for conservation and conservation treatment or preventive conservation and testing of its antimicrobial effect. This product is being tested as solution as well as gel formulation.

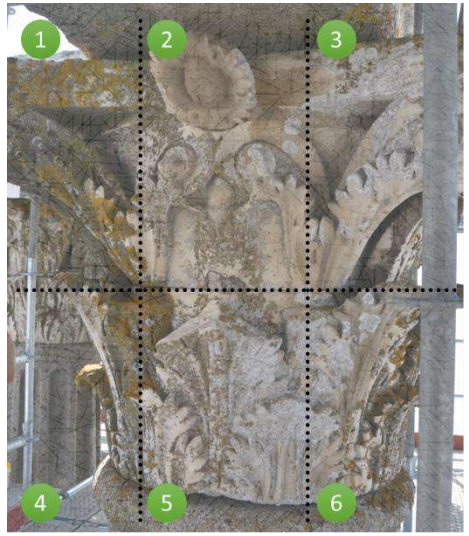
Additive BEVOTECH-P biocidal additive for the production of paints / coatings to be used in the field of built heritage rehabilitation and construction



LAB tests

In situ tests

BEVOTECH ® (Biocide EVOra TECHnology)



Local	Biocida
1	Bev_A
2	Bev_B
3	Bev_D
4	Bev_D
5	Bev_C
6	Bev_A

	Inicio tratamento	Fim tratamento
Este (A)		
Norte (B)		
Oeste (C)		
Sul (D)		

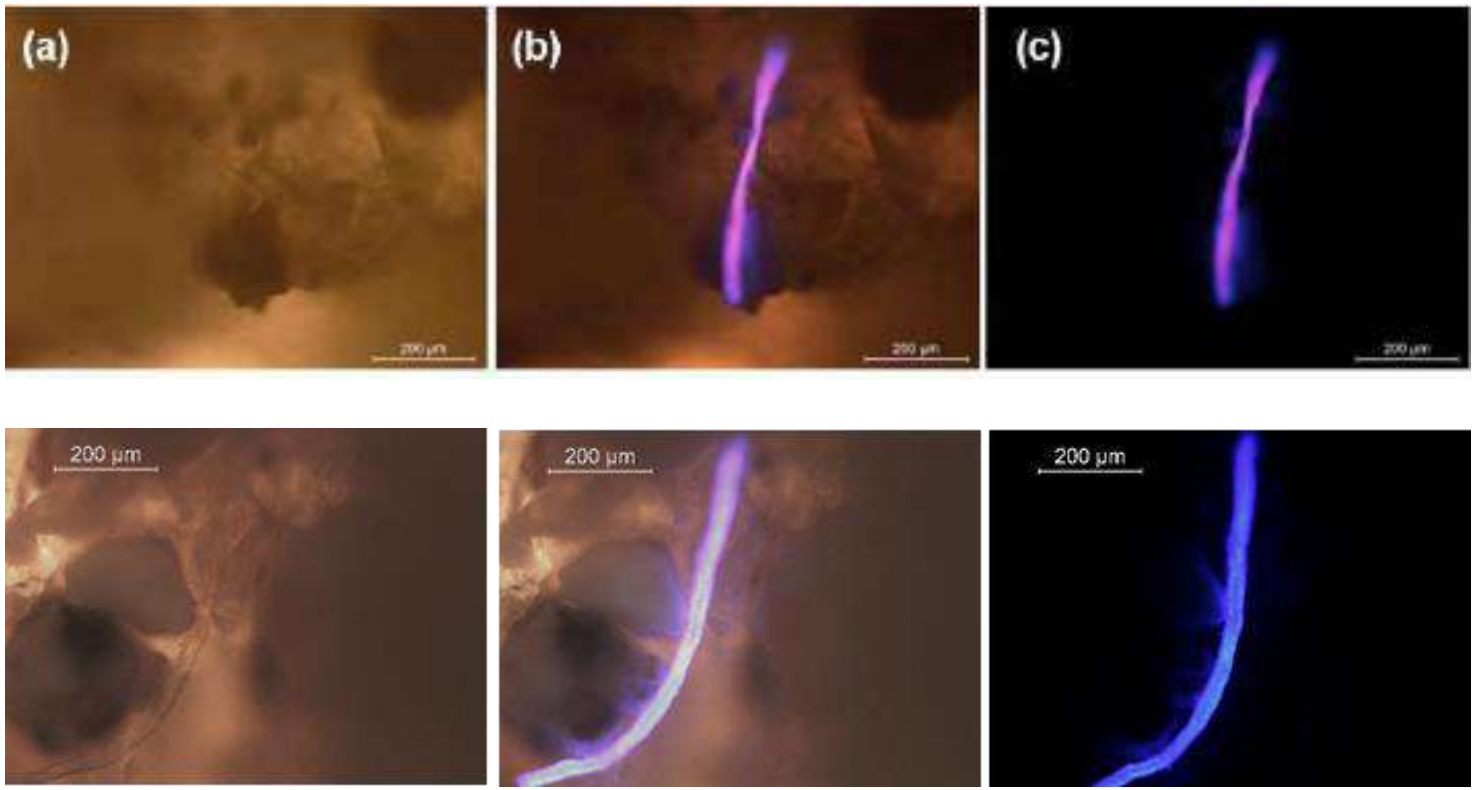
biochemistry and heritage, understand, innovate, act

Évora, 2018

2. design of probes for microrganisms identification

Fluorescence *In Situ* Hybridisation (FISH)

In 2013, the HERCULES Laboratory team began an exploratory project to evaluate the use and applicability of Fluorescence *In Situ* Hybridization (FISH) ribosomal RNA probes to detect the presence of microorganisms in heritage assets at point-of-care.



Microscopic images of real mortars colonized by Nectria fungii under

(a) visible light(b) combined visible and UV light and (c) UV light

for A) probes with comercial fluorophore Cy3 and B) probes with novel esculetine fluorophore

molecules

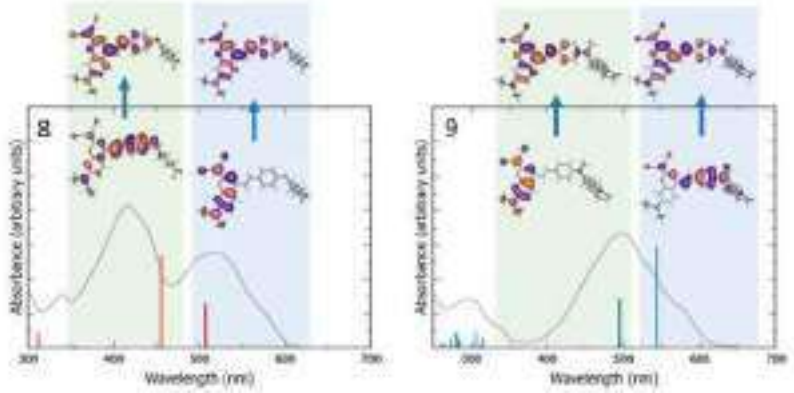
Published: 27 September 2023 MDPI

Article

Rational Design of Cost-Effective 4-Styrylcoumarin Fluorescent Derivatives for Biomolecule Labeling

Raquel Eustáquio [1], João P. Prates Ramalho [2,3], Ana Teresa Caldeira [1,2,4] and António Pereira [1,2,*]

Figure 1. Photographic images of the synthesized fluorescent labels (**8**, **9**, 14, **15**, **19**, and **20**) in MeCN at 365 nm.



- Synthesis of new fluorophores for marking biomolecules
- Styryl coumarins derivatives as fluorescent labels for biomolecules: application to cultural heritage.

much cheaper than commercial ones

European Patent, 2023

FISH

What's next?

produce a cost effective and non-toxic kit based on the novel FISH probes for identification of microorganisms at point-of-care

conceive a sequential step-by-step protocol and reaction test components / materials and detection methodology.

3. novel materials for heritage conservation

coatings for preservation Natural Stone

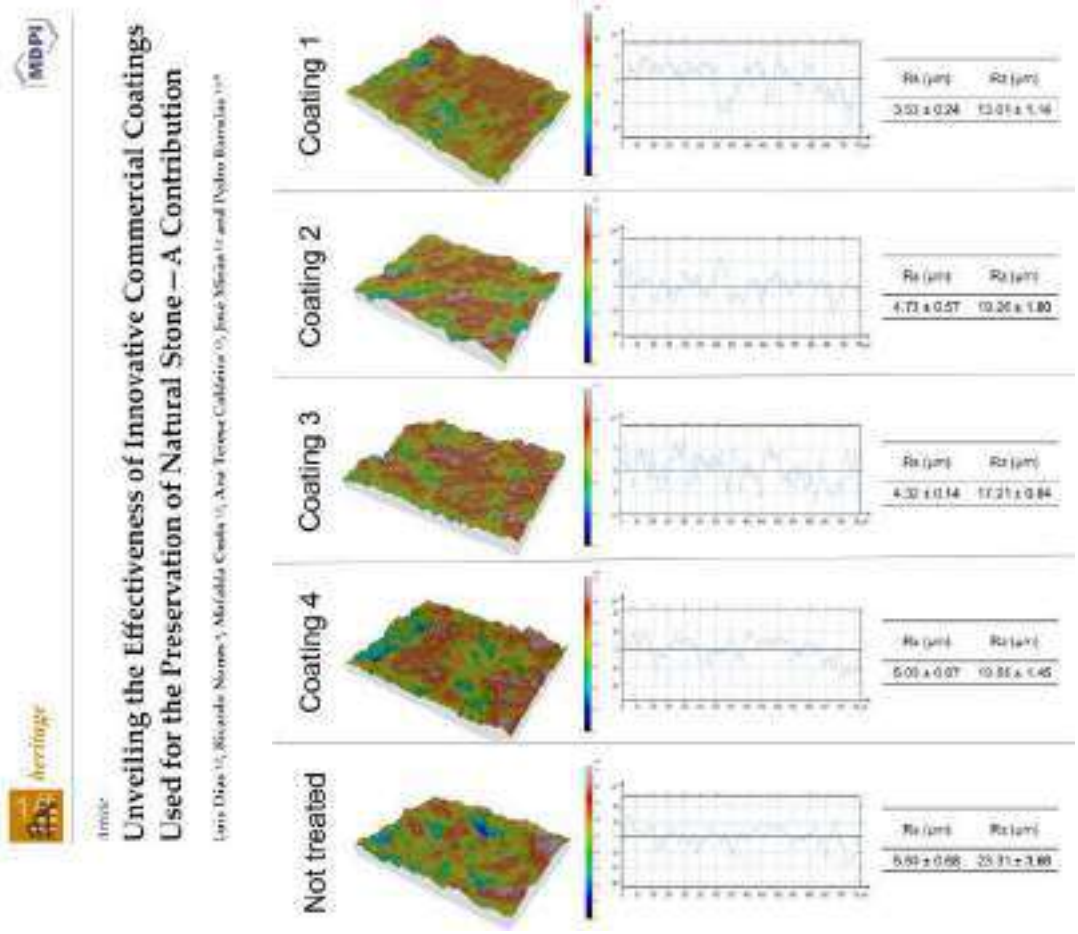


Figure. Determination of the roughness parameters after accelerated ageing of the mock-ups of lithotype C, using 3D surface micro-reconstructions..

Hybrid protective coatings for marbles and limestones, consisting of formulations of inorganic nanoparticles combined with organic matrices (polysiloxanes and fluorinated polymers), have shown promising hydrophobic and self-cleaning properties. However, these hybrid coatings still have limitations

Developing hybrid superhydrophobic coatings, based on low-cost, natural and non-petroleum materials for their preparation and consequent application in carbonated stones

PPP Eco-HERITAGEPROTEC: Eco-friendly superhydrophobic hybrid coatings for HERITAGE PROTECtion.

inventors: P. Barrulas, L. Dias, S. Martins, E. Carreiro, J. Mirão, A. Candeias, A. Caldeira, V. Pires, F. Sitzia.

biosynthesis of nanoparticles

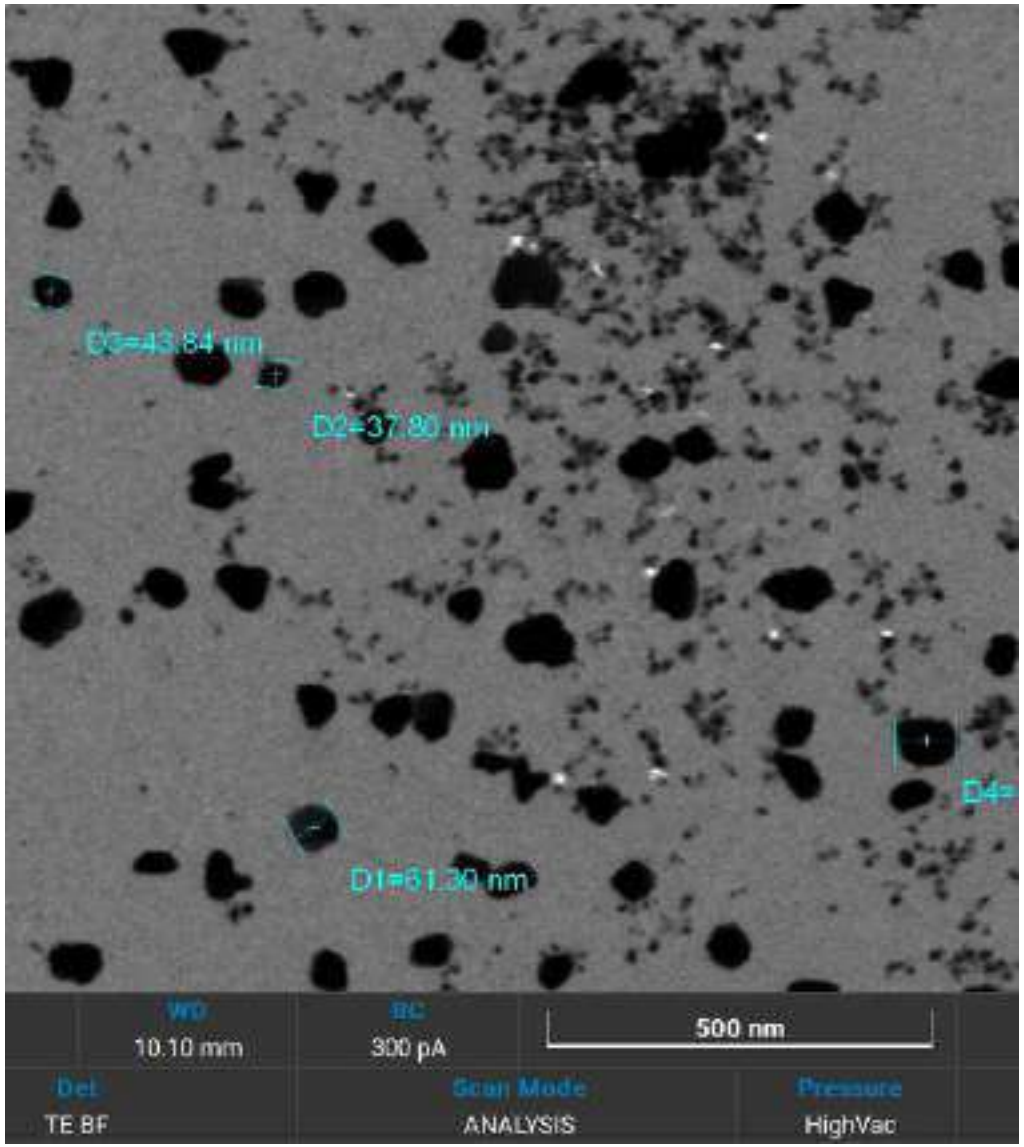


Figure. Example of biologically synthesized silver nanoparticles, obtained by scanning electron microscopy using a STEM detector

screening microorganisms producing silver nanoparticles in an effective way

Set of microorganisms in our culture collection

microorganisms that produce silver nanoparticles

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bioconsolidation of built heritage

Figure. Example of biomineralization of carbon carbonate

screening microorganisms that promote biomineralization in an effective way

Set of microorganisms in our culture collection collected from extreme and hypogenic environments

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thank you for your attention