

Characterisation of old mortars



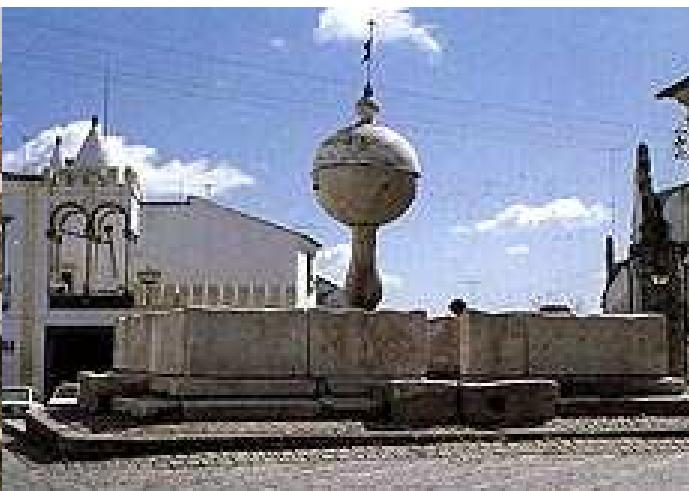
António Estêvão Candeias

Workshop “Science for Cultural Heritage”

Trieste, October 23-28, 2006

City of Évora

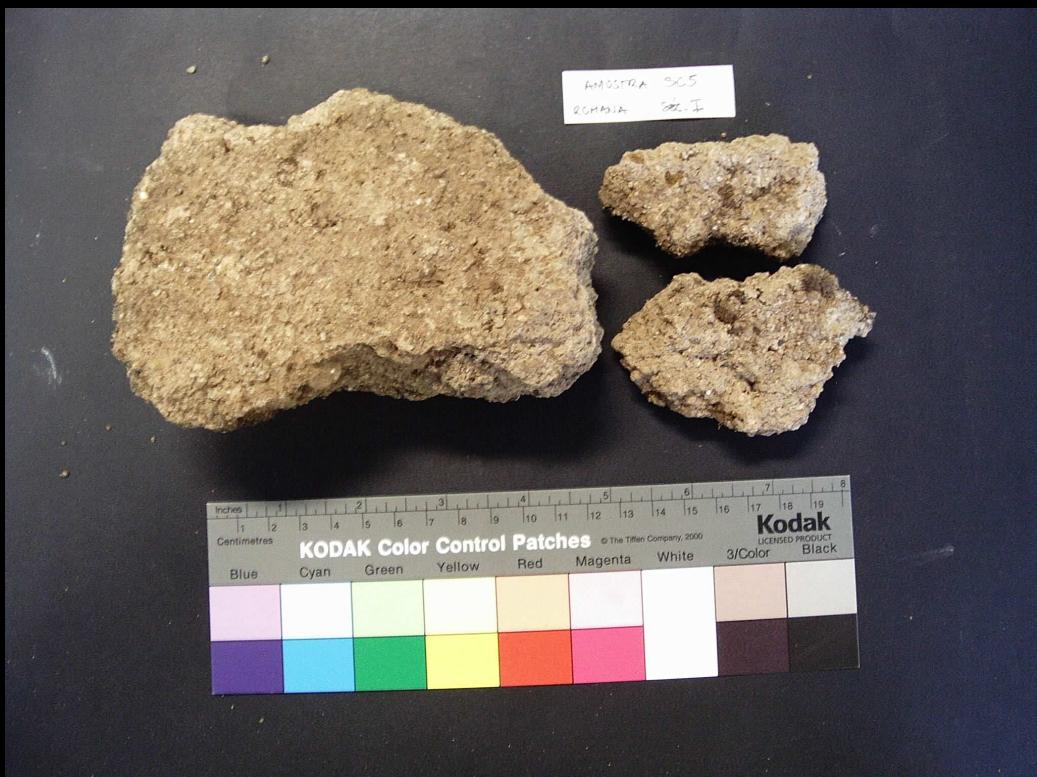
UNESCO World Heritage Site since 1986



Trieste, October 23-28, 2006

What is a mortar?

A **mortar** is a composite material made of :



one or two binders

(lime, clay, gypsum, cement)

aggregates

(siliceous, dolomitic or calcareous sands)

water

additives

(ceramics, pozzolans, fibers, etc.)

and occasionally **painted layers**

Mortars are classified according to the type of binder used.

The study of old mortars

- Evaluate their macro- and micro-structural properties
- Can give valuable information about a monuments history, namely the techniques of construction, past interventions and degradation processes
- The information is essential for the design of new aesthetic and functional compatible mortars.





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Rosário Veiga (civil engineer)
Patrícia Adriano (chemist, grant student)
Ana Christian (civil engineer, PhD student)



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Margarida Botto (art historian)
Sofia Salema (architect)
Deolinda Tavares (conservator, Master student)



Portuguese Institute of Conservation and Restoration (IPCR)

Isabel Seruya (physicist)
Milene Gil Casal (conservator; PhD student)
Isabel Ribeiro (chemist)



Polytechnic Institute of Tomar (IPT)

João Coroado (geologist)

Roman Period

II AC



Villa of S. Cucufate



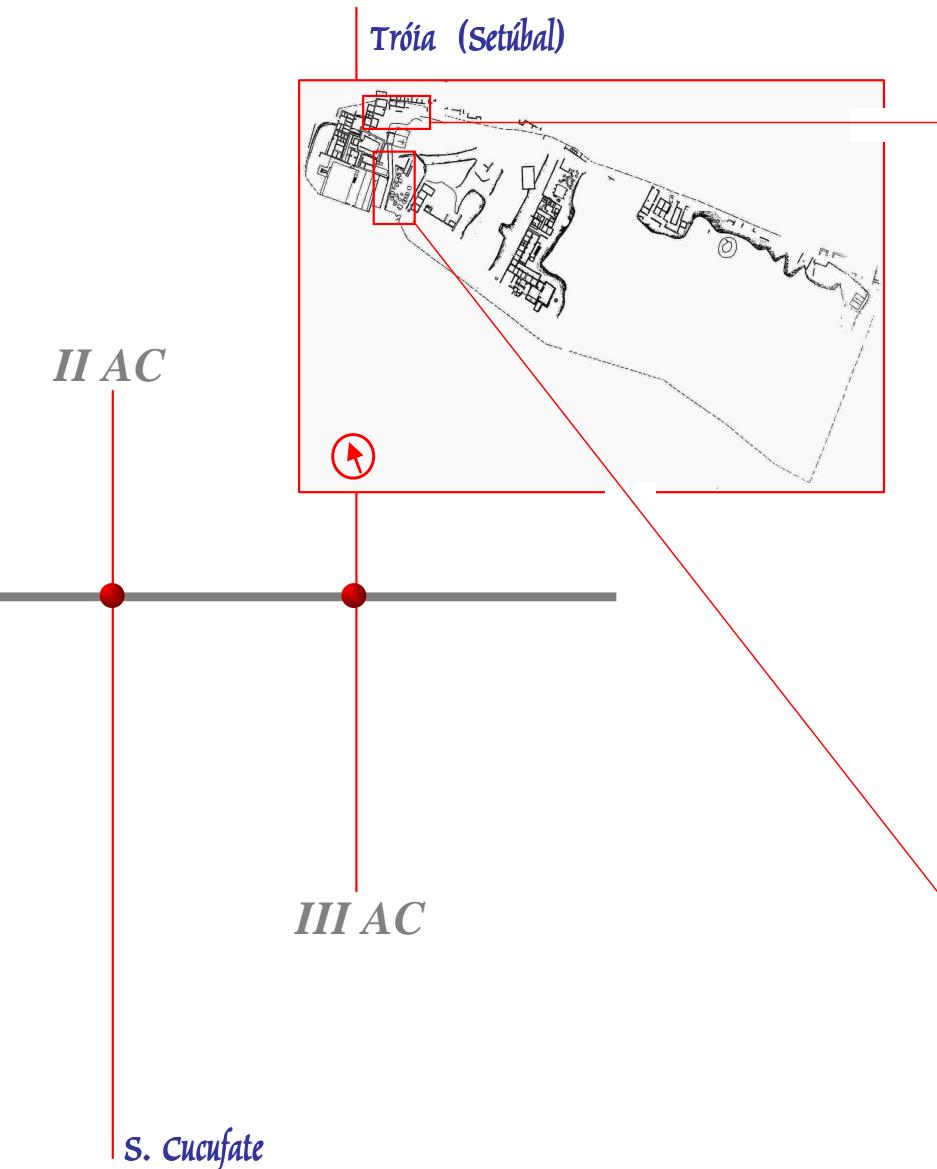
Tank



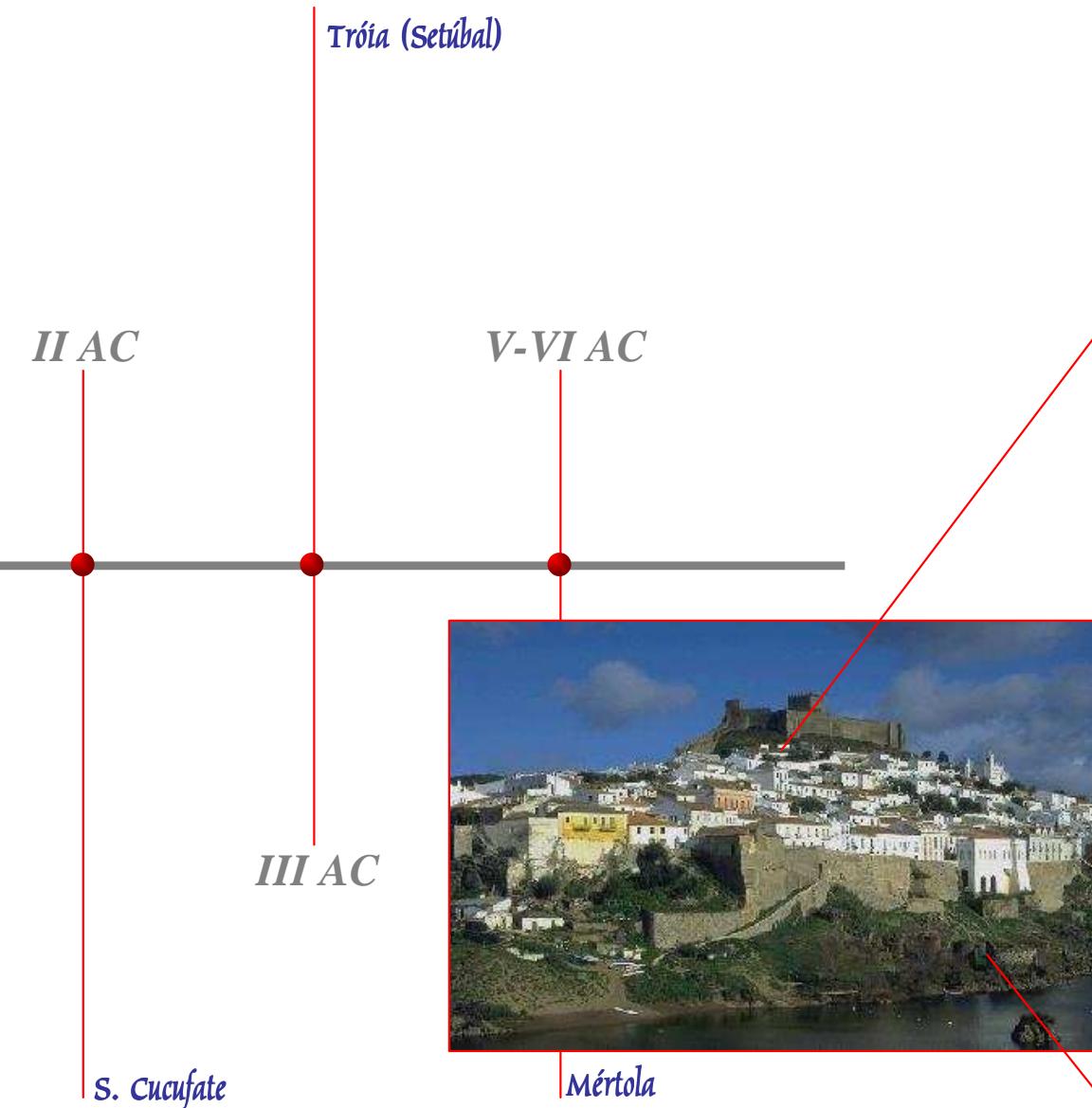
Main House wall



Roman Period



Roman Period



Cryptoportic



River Tower



Muslim period

Tróia (Setúbal)

II AC

V-VI AC

S. Cucufate

Mértola

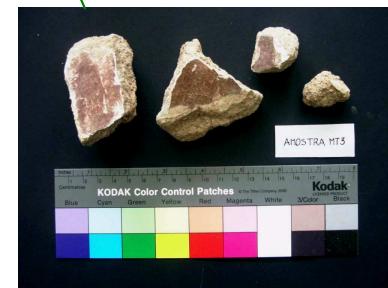
Mosque / Mértola's main church



XII



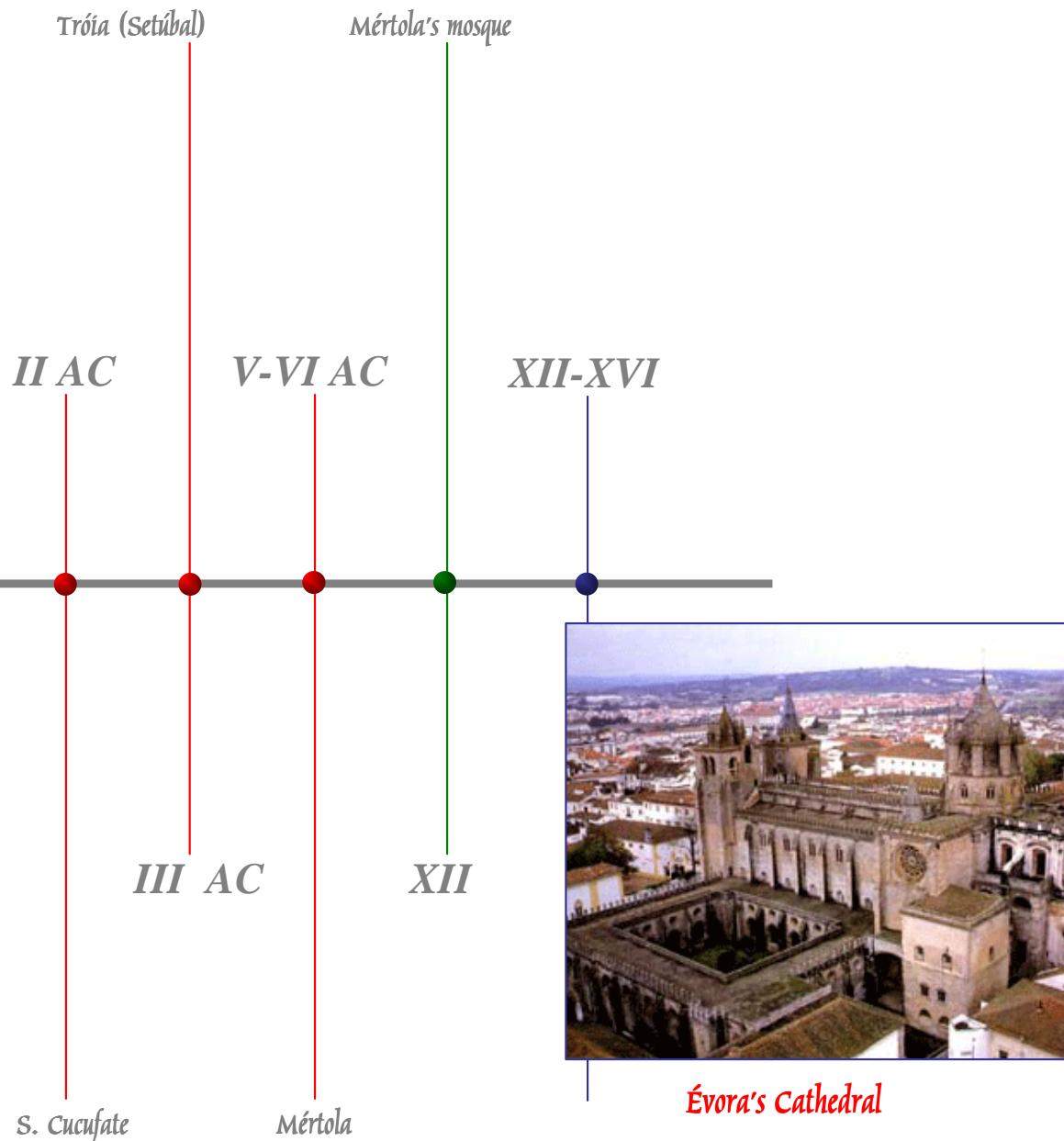
III AC



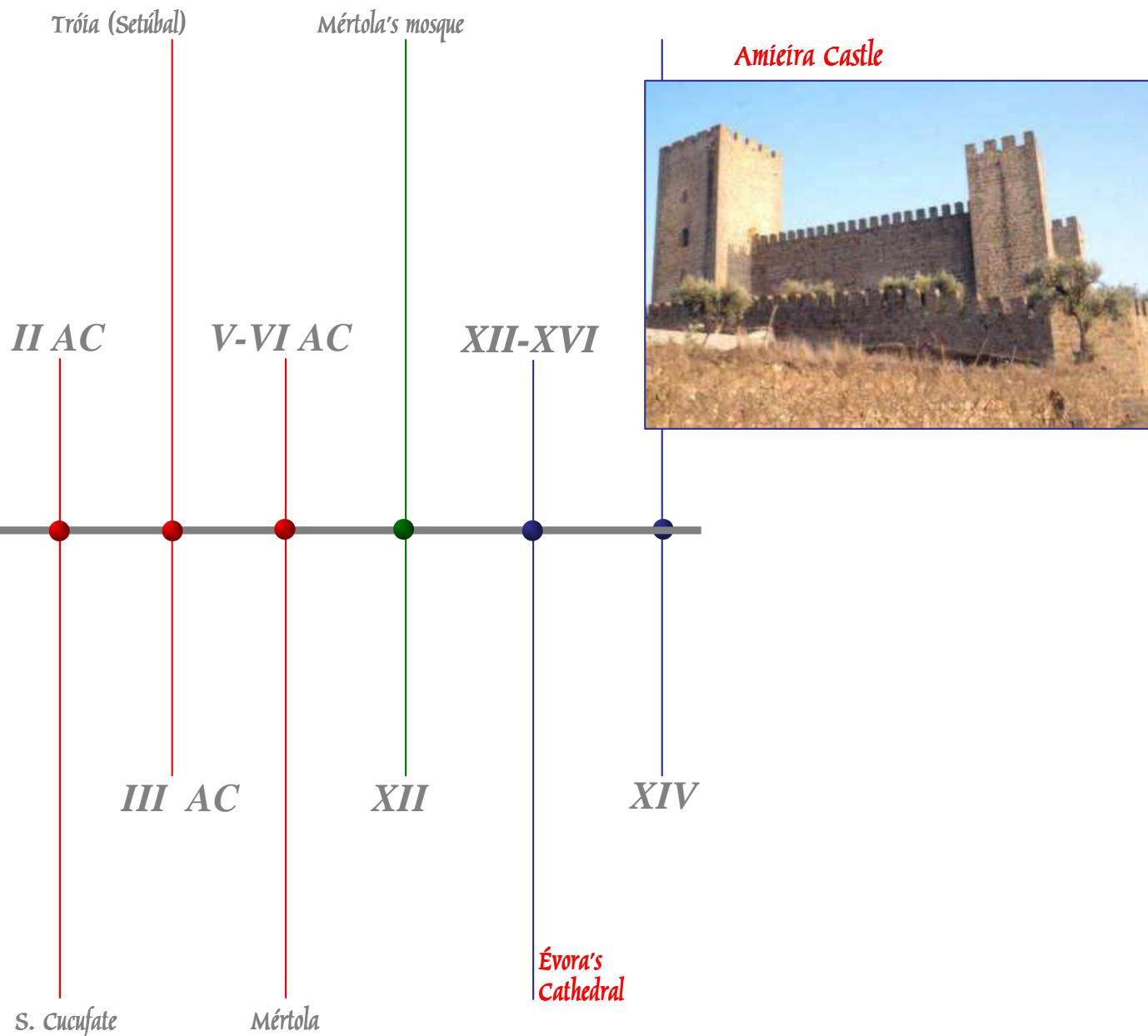
Mihrab



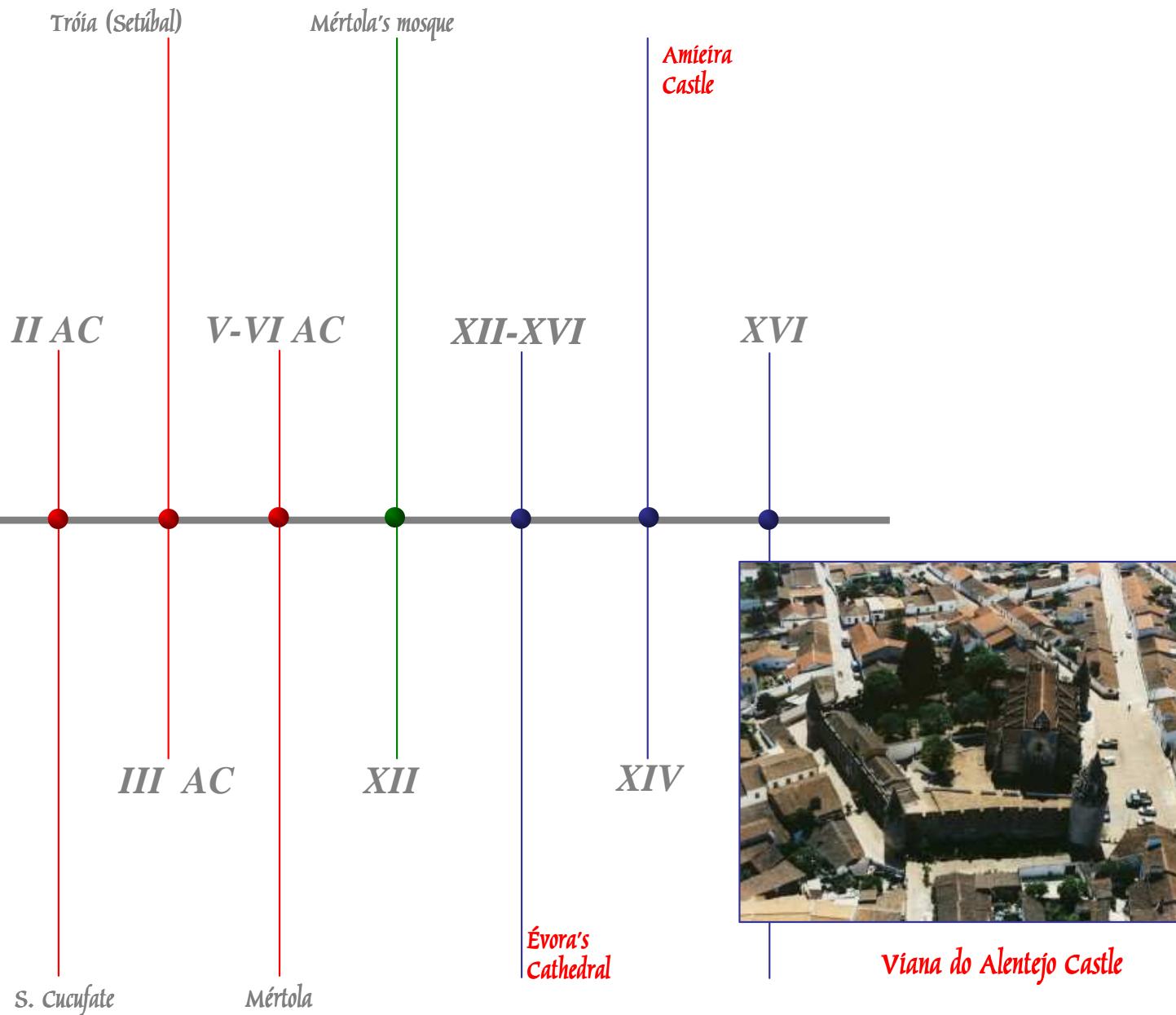
Christian Era



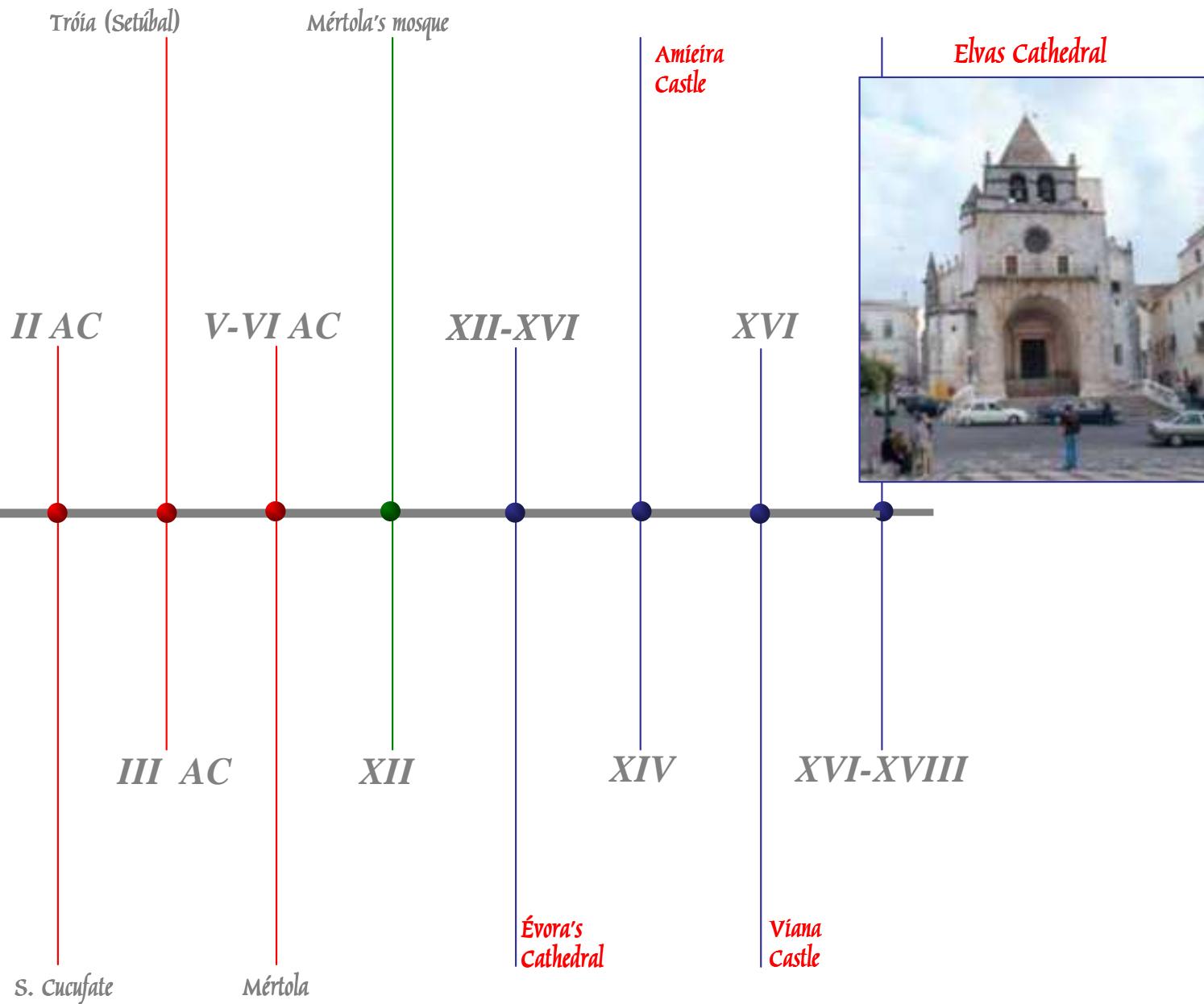
Christian Era



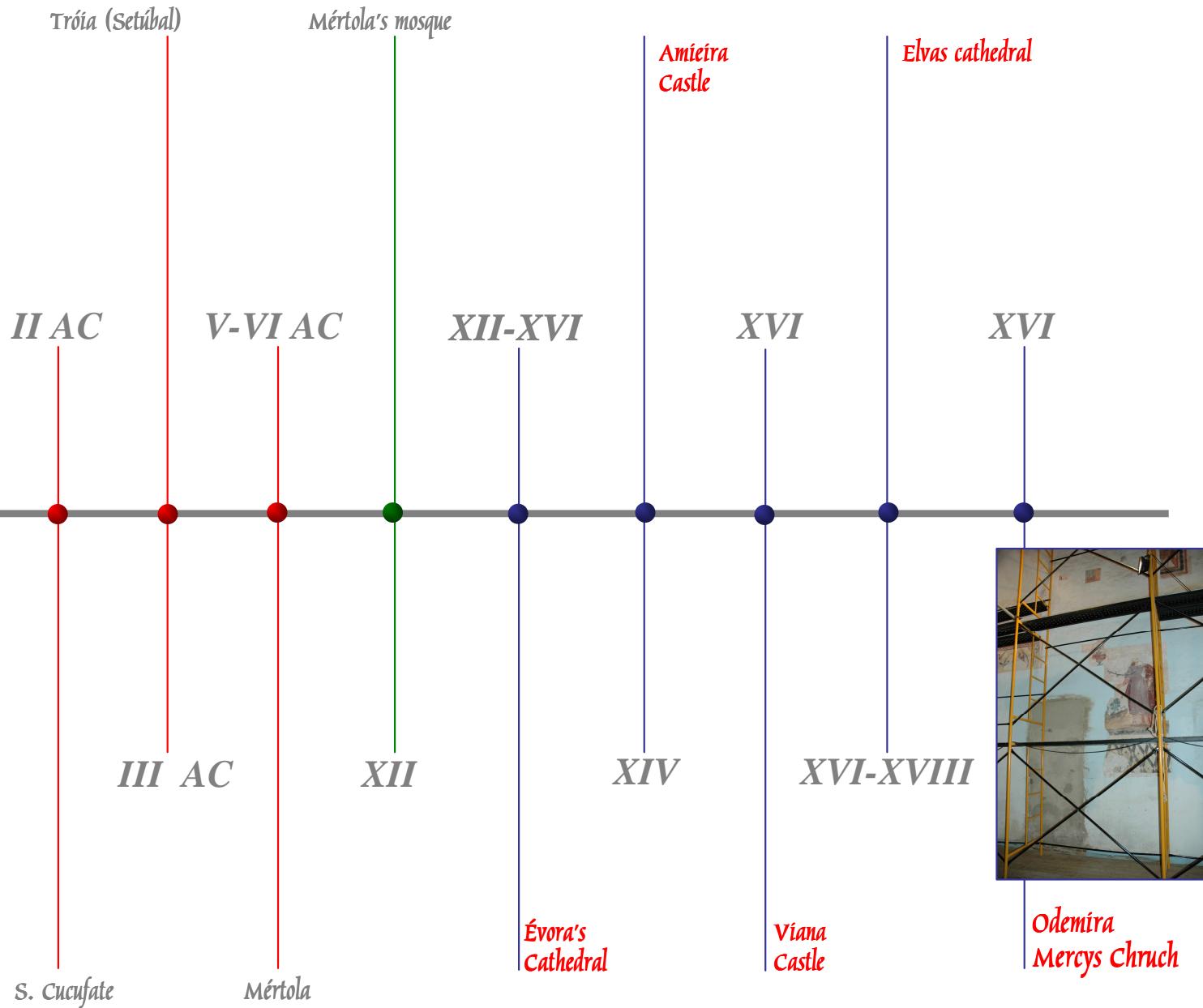
Christian Era



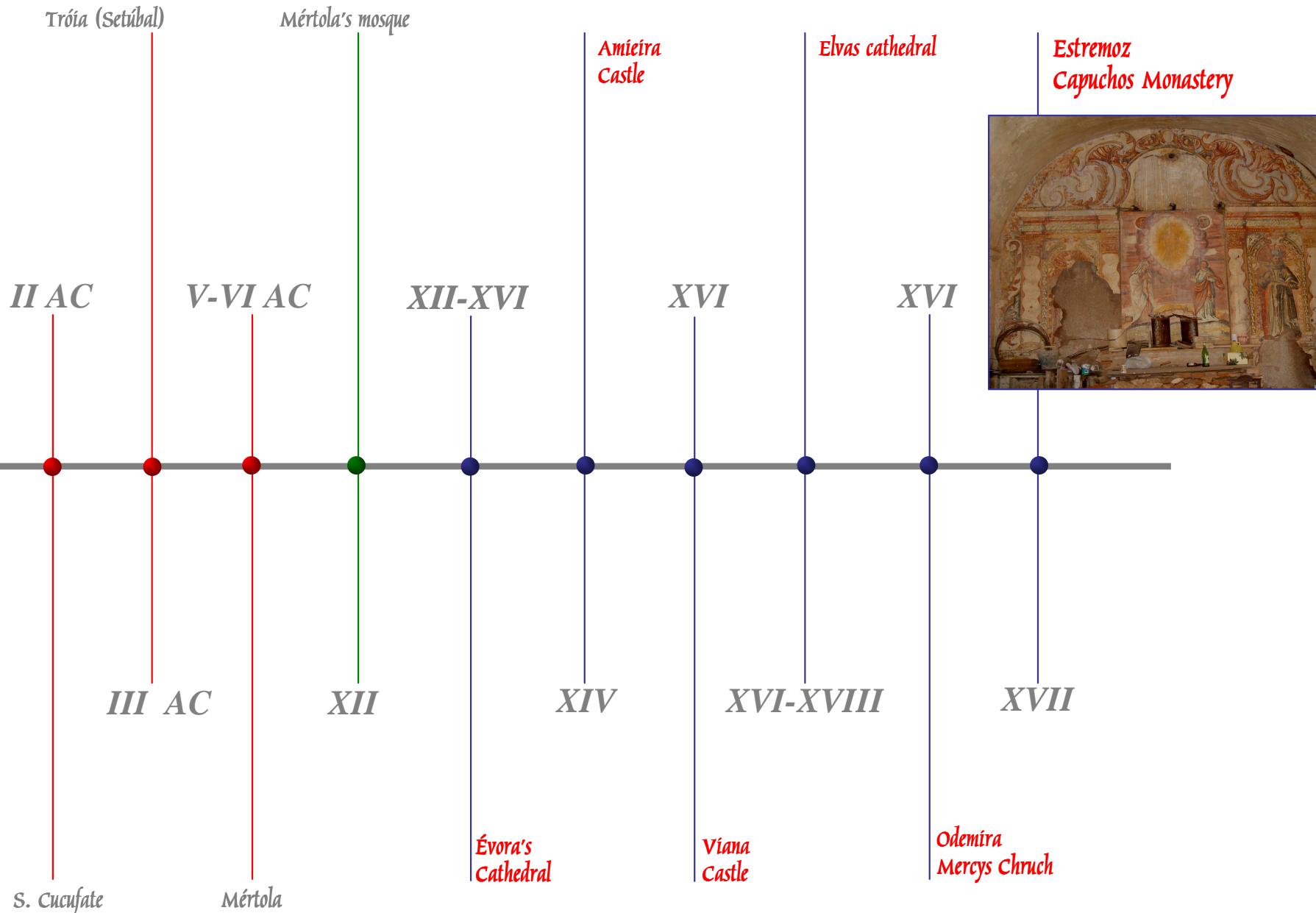
Christian Era



Christian Era



Christian Era



Characterisation Methodology

MORTARS



Drying at 40 °C

Stereo-zoom microscope
(7.5- 120x)

Sample disaggregation and preparation for characterisation

Chemical analysis

XRD

SEM-EDX

Water sorption

mercury porosimetry

Soluble fraction

Insoluble residue

TG - DTA

optical microscopy

mechanical resistance

AAS
....

Soluble salts
Binder composition

Aggregates composition
Particle size distribution

Mineralogical composition

Binder composition
and classification

Mortar composition
and morphology
Degradation diagnosis

Nature, color
and morphology
of the aggregates

Capillary coefficient

Compressive
resistance

Porosity
Pore size distribution

Chemical analysis

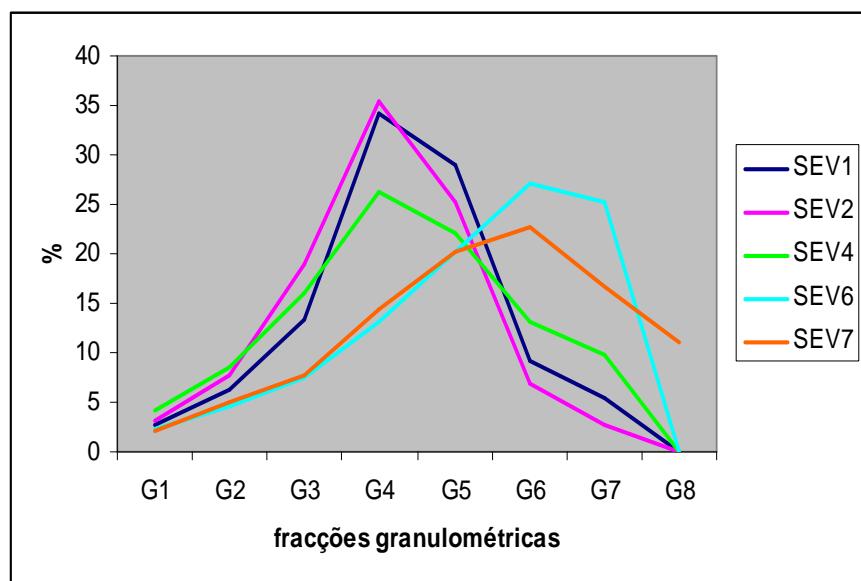
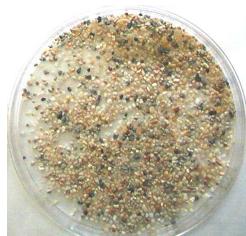
MORTARS

Soluble fraction

- Soluble salts (NO_3^- , Cl^- , SO_4^{2-})
- Elemental analysis (Si, Al, Fe, Na, K, Ca, Mg)

Insoluble fraction

- Aggregates composition and morphology
- Particle size distribution



Évora Cathedral



Mertola Cryptoportic



Rose and green quartz

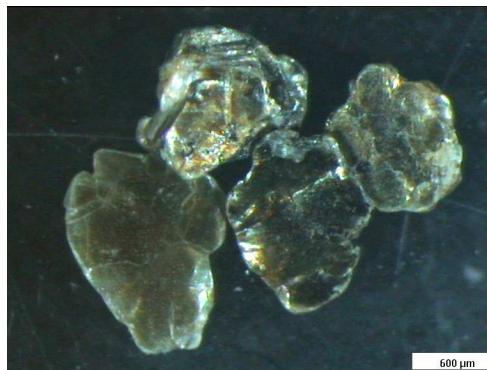


Quartz with mica

Quartz (rolled)



Schist



Biotite



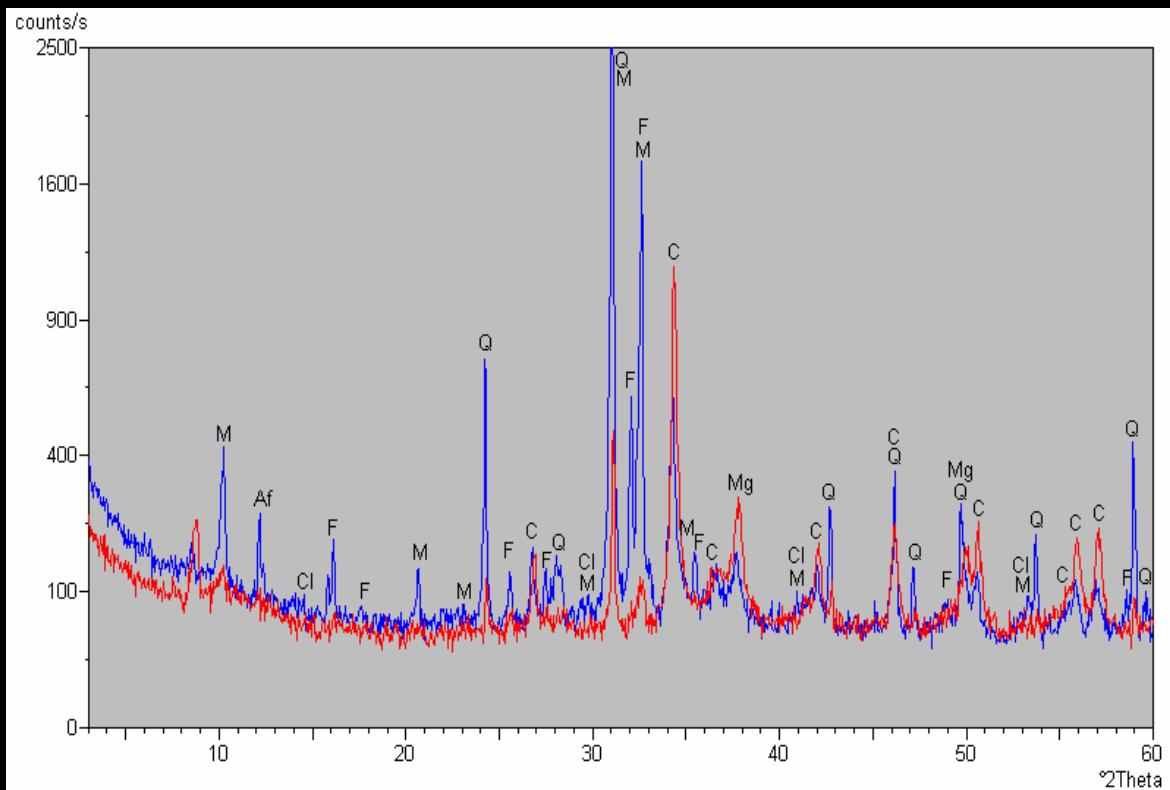
Ceramic fragments

x-ray diffraction

MORTARS



Mineralogical composition of crystalline fases



TGA / DTA

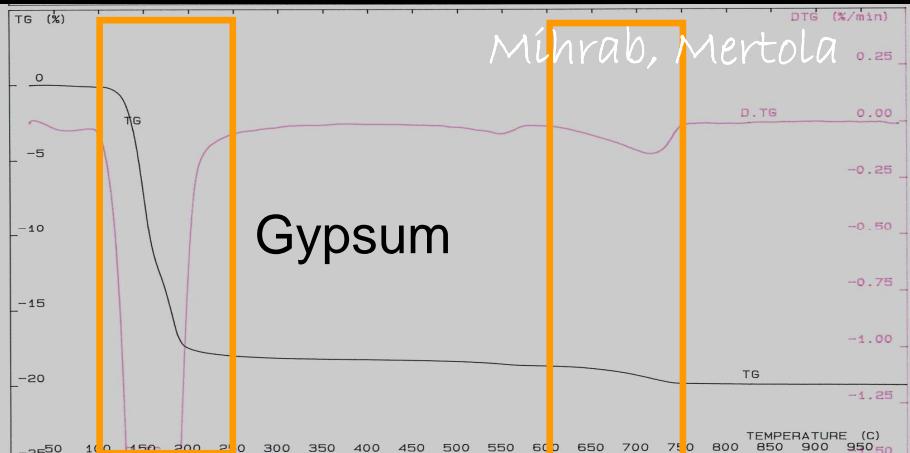
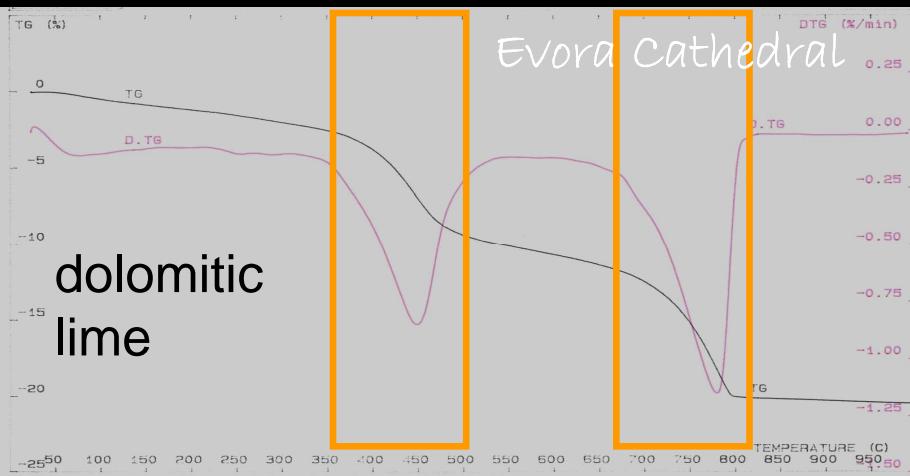
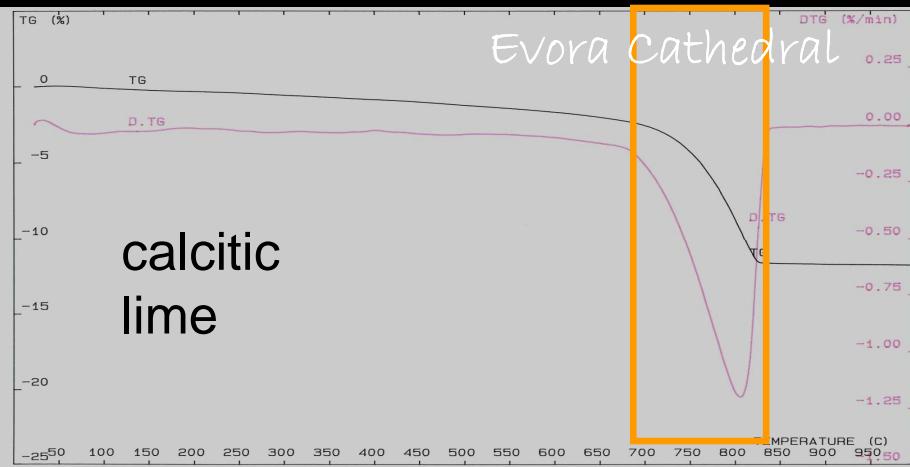
MORTARS



**Mortars binder composition
and CO₂ content**

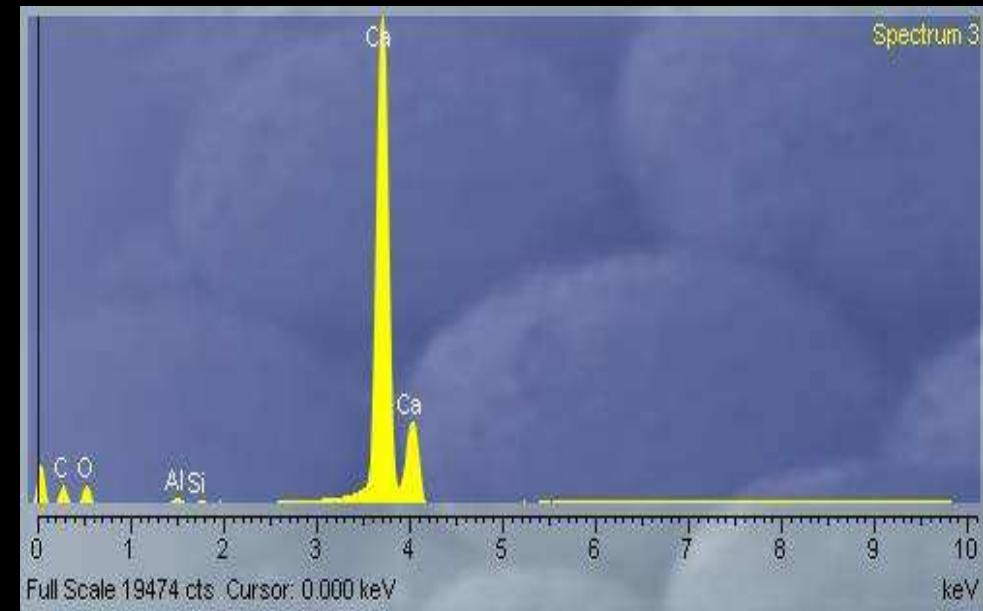
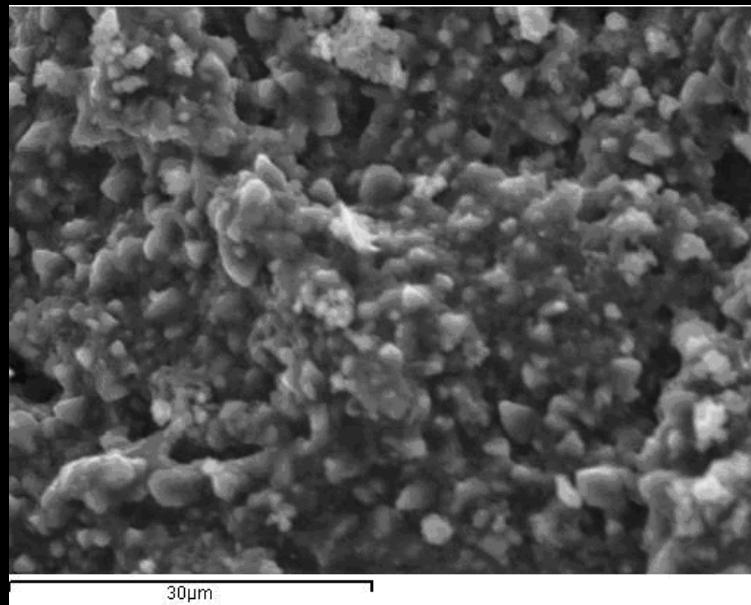
Combined with chemical analysis
allows determination of the:

aggregates / binder ratio





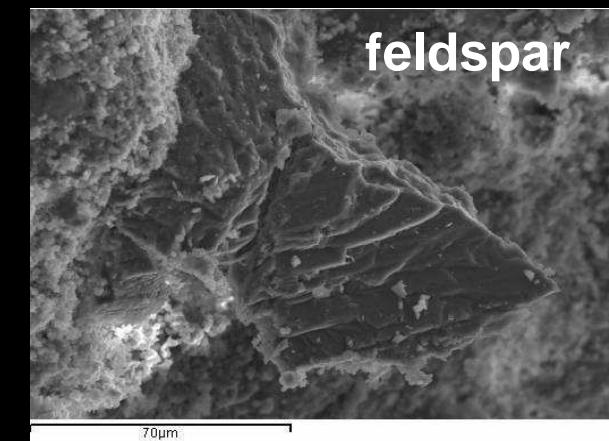
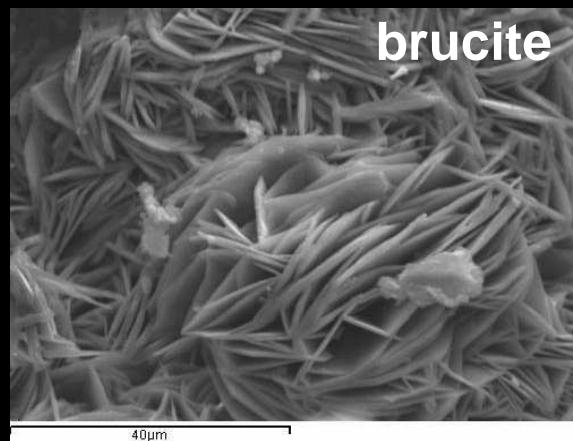
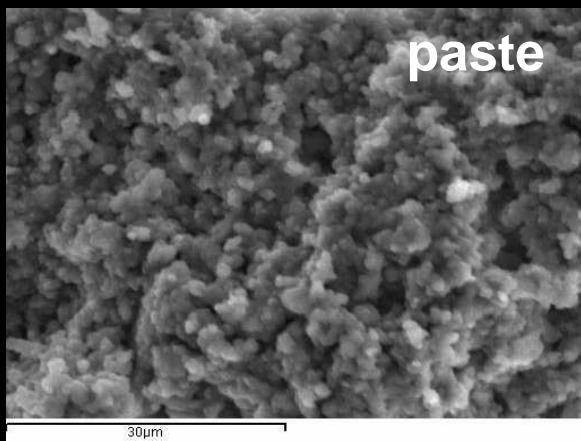
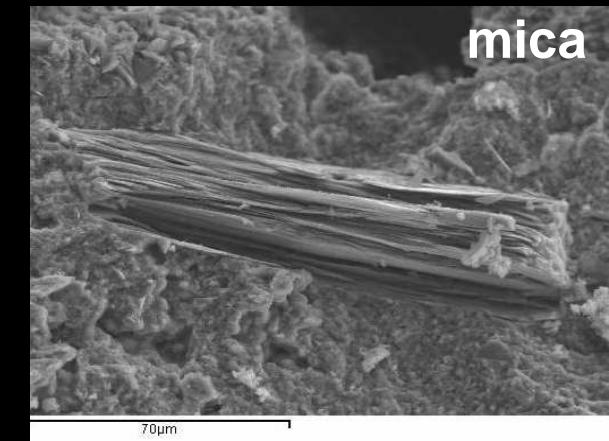
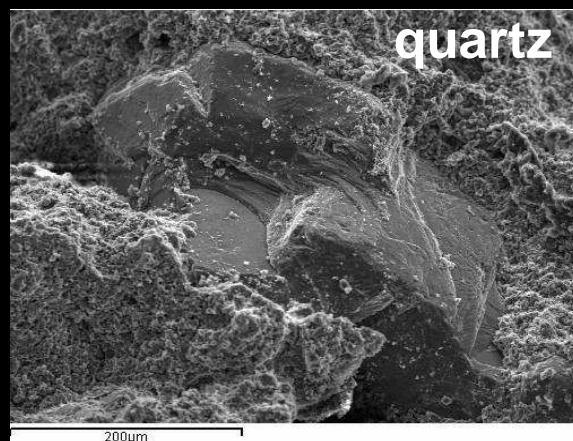
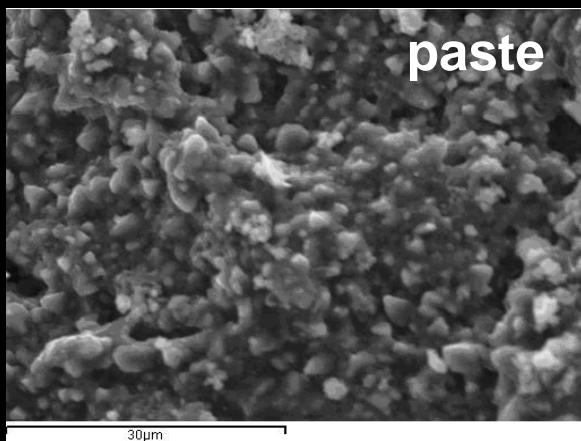
Elemental analysis / composition





Elemental analysis / composition

Aggregates and binder morphology

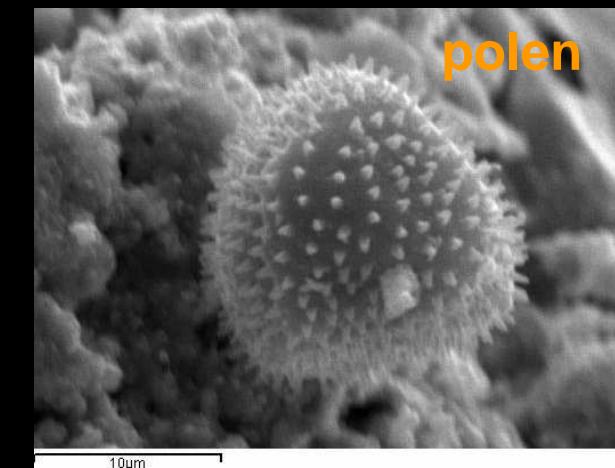
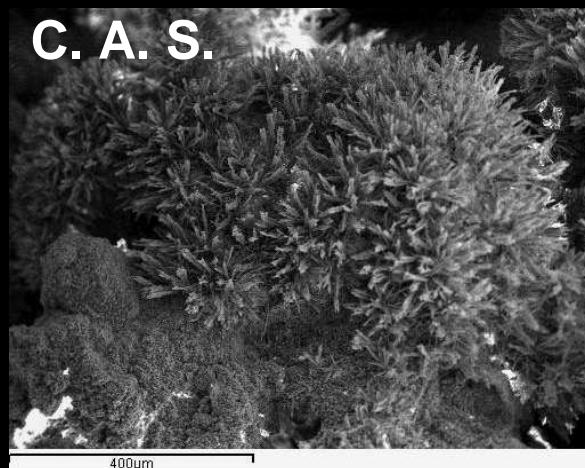
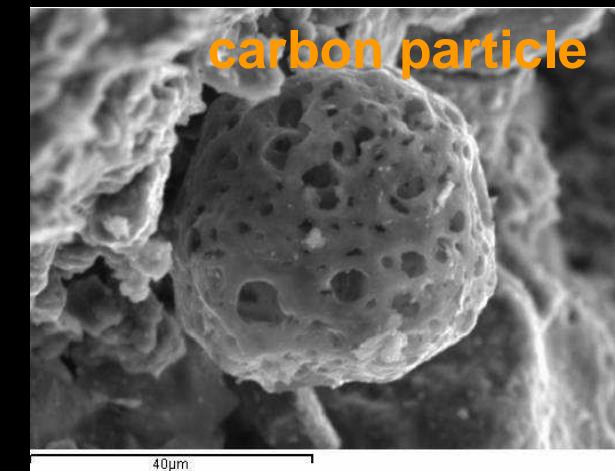
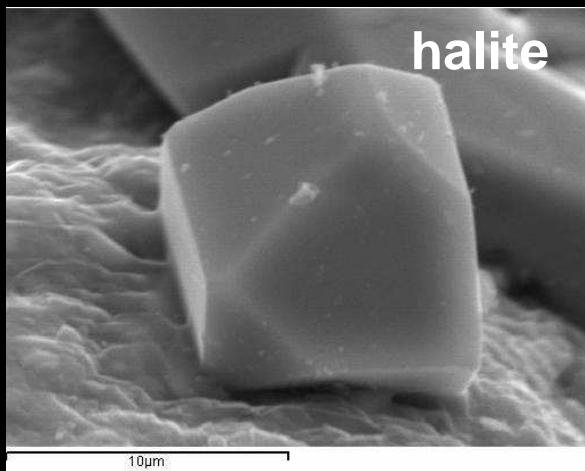




Elemental analysis / composition

Aggregates and binder morphology

Neoformation / degradation products



POLISHED SURFACES

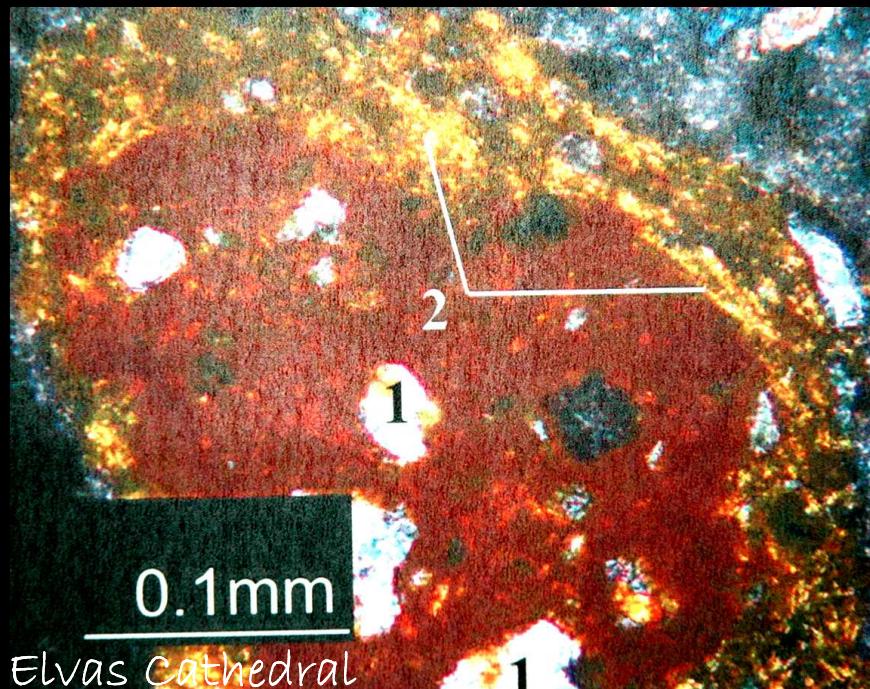
Aggregates nature, color and morphology
Spatial interrelations of mortar components



Optical Microscopy

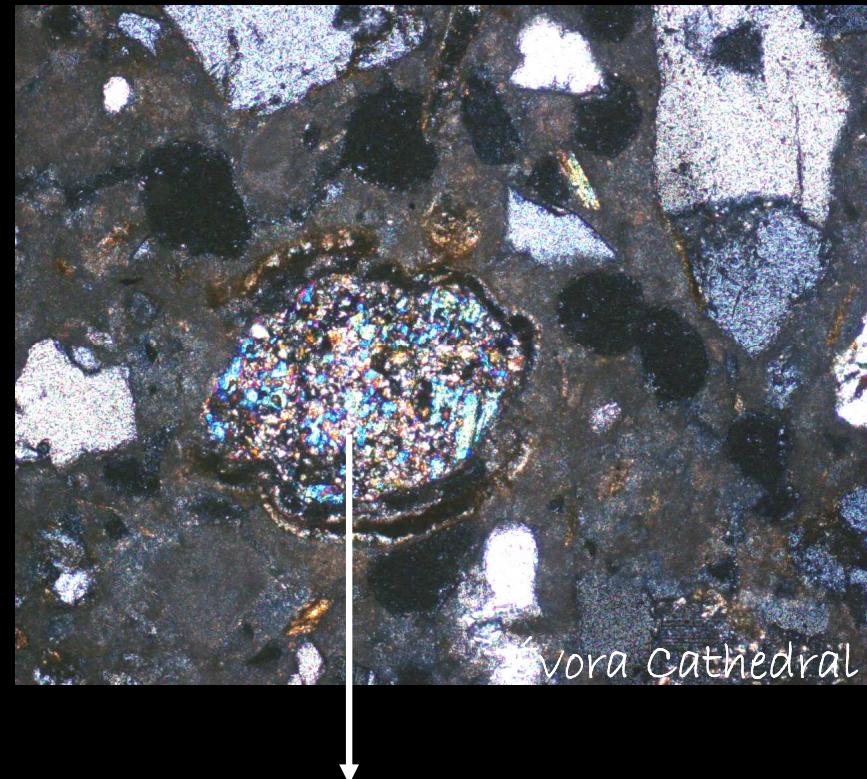
MORTARS

THIN SECTIONS



Sometimes

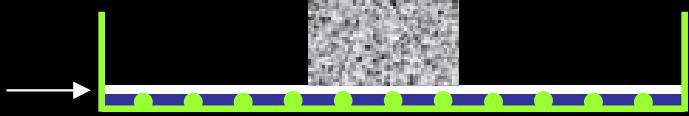
Aggregates nature, color and morphology
Spatial interrelations of mortar components
aggregate / binder interfacial reactions



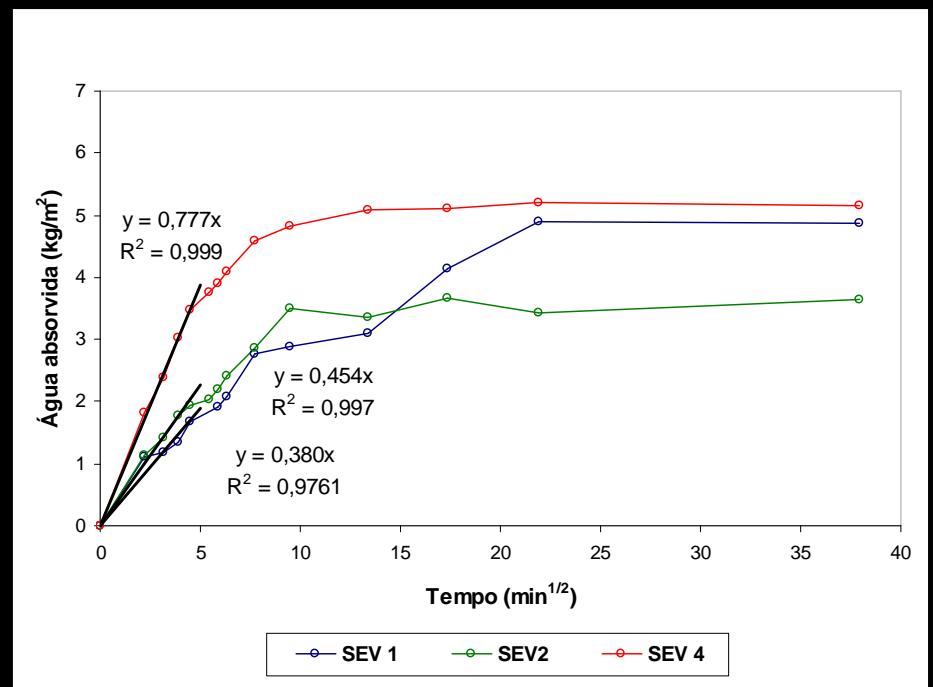
... origin of the aggregates



geotextile
impregnated
with water



Cappillary coeficients



compression resistance

MORTARS



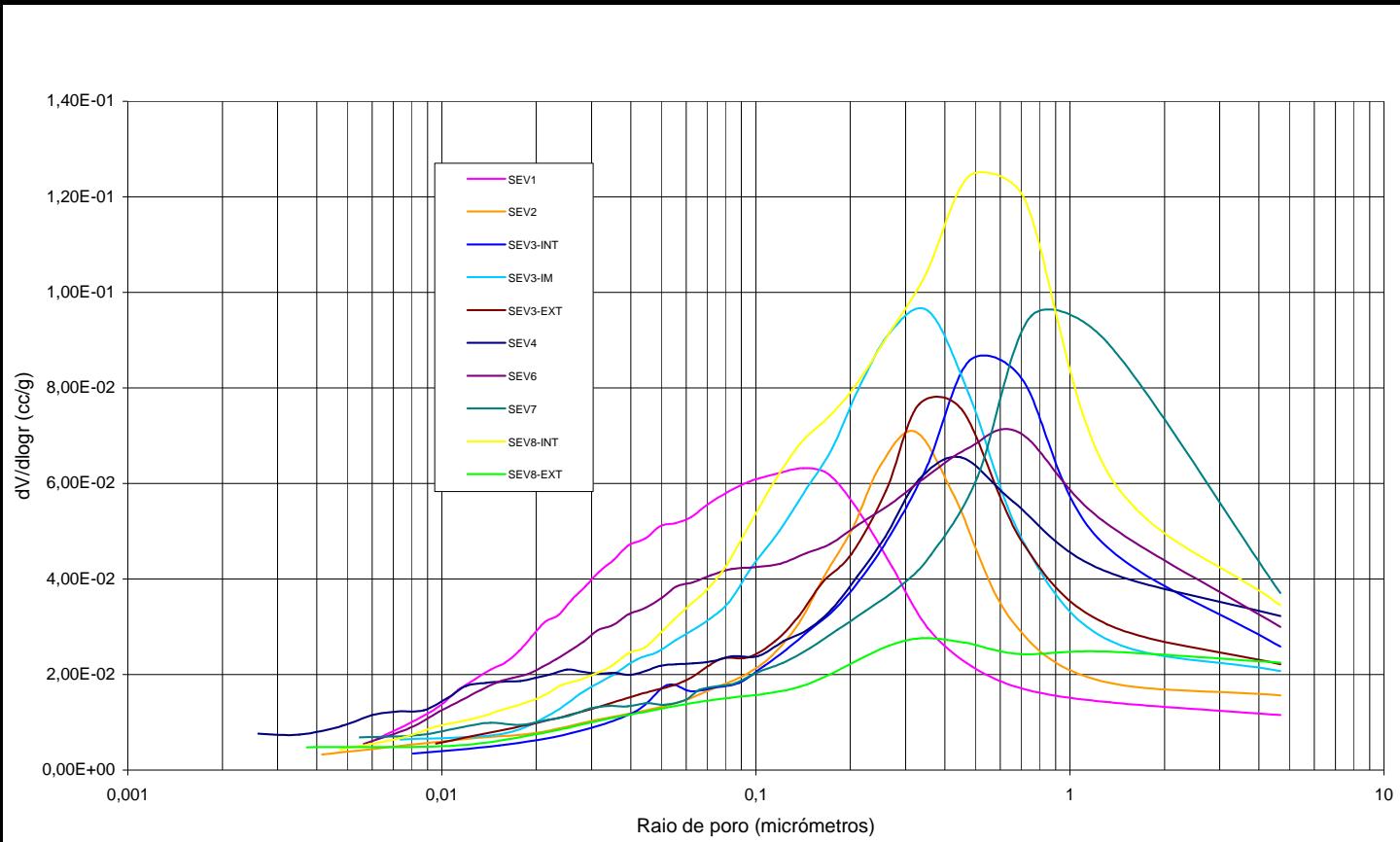
Mechanical resistance is correlated with the chemical composition of the mortars

Mercury porosimetry and nitrogen adsorption

MORTARS



pore size distribution

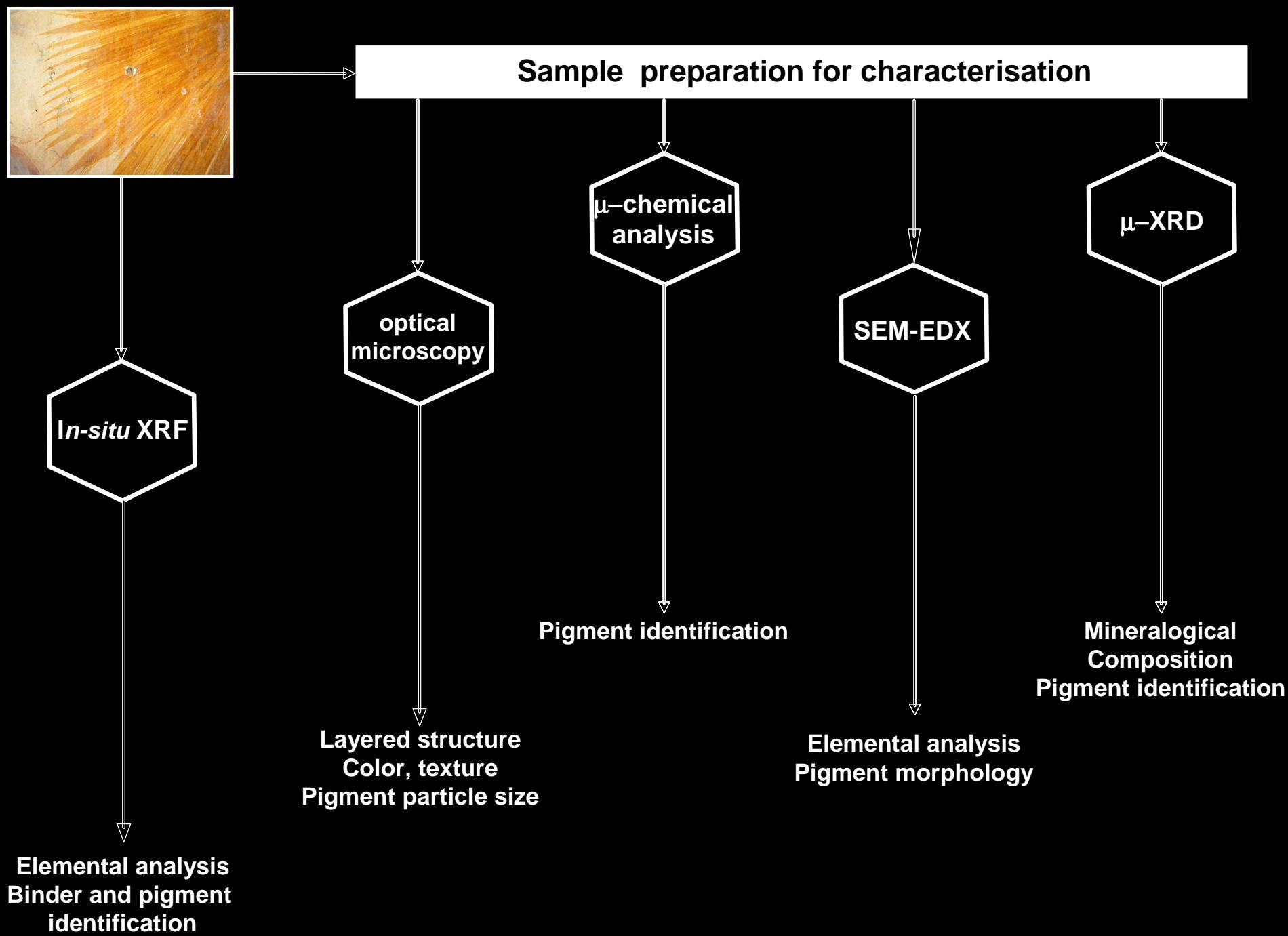


Mural paintings / painted layers



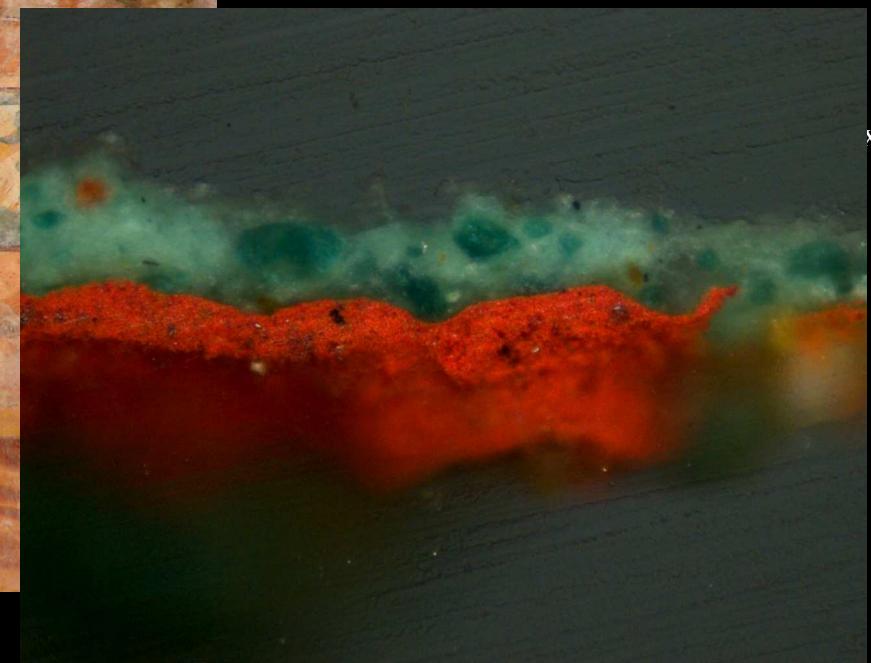
Characterisation Methodology

Painted layers



Optical microscopy

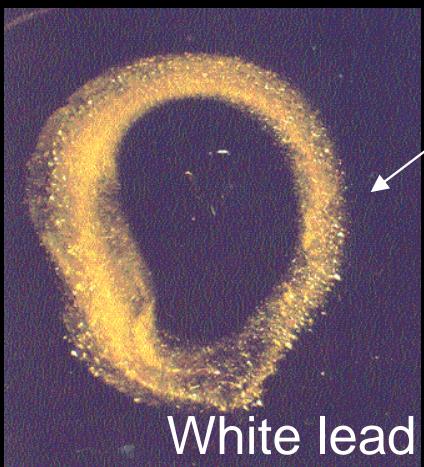
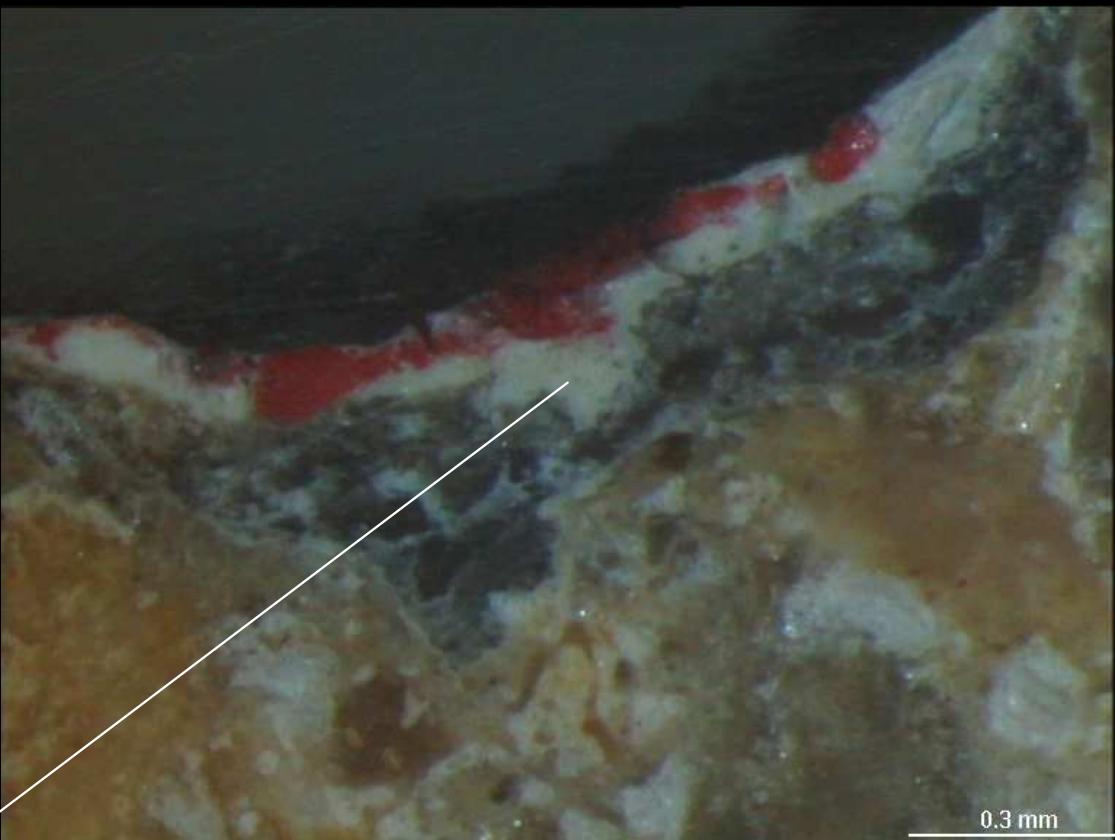
Painted layers



Layered structure
Color
Texture
Pigment particle size

Microchemical analysis

Painted layers

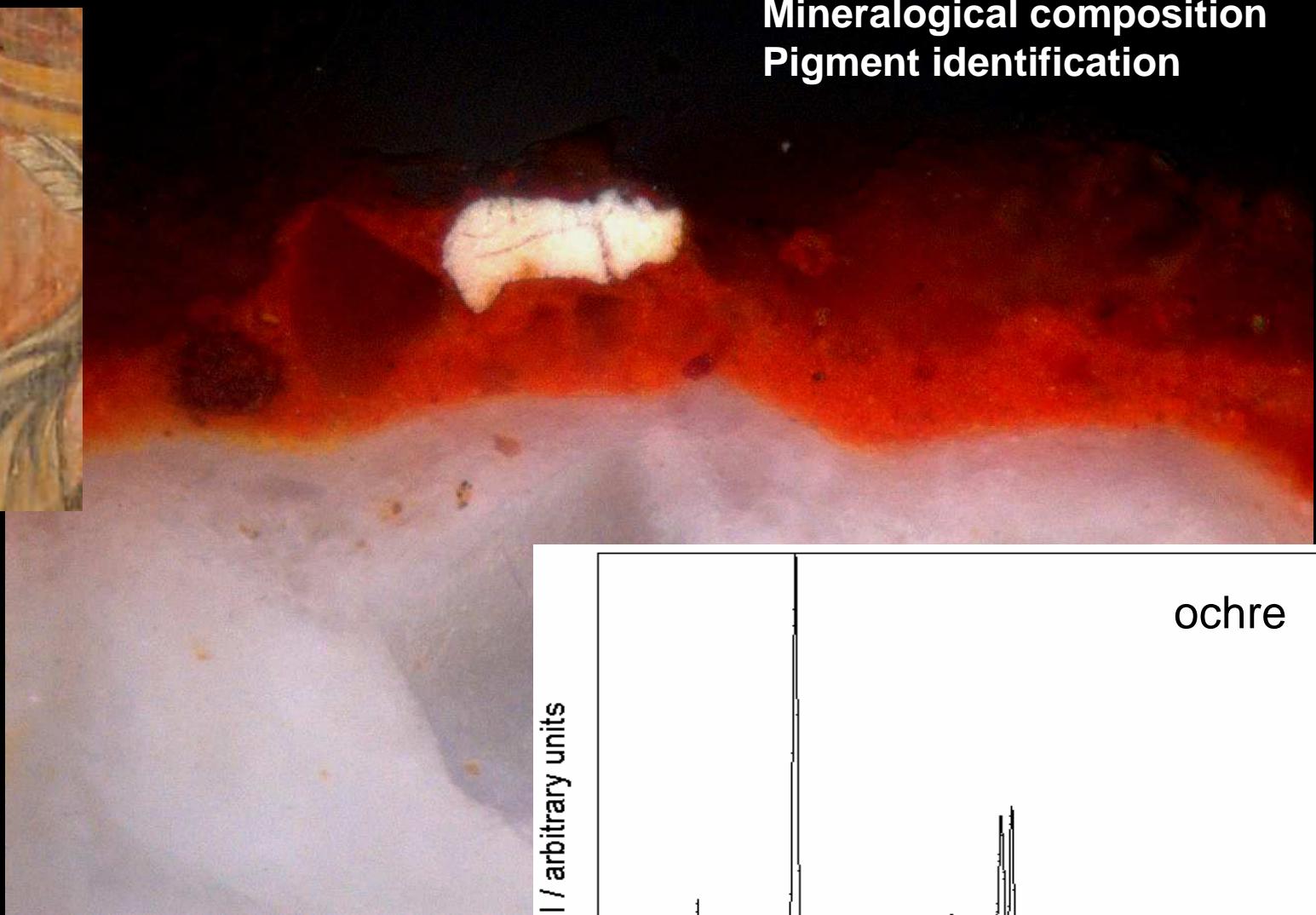
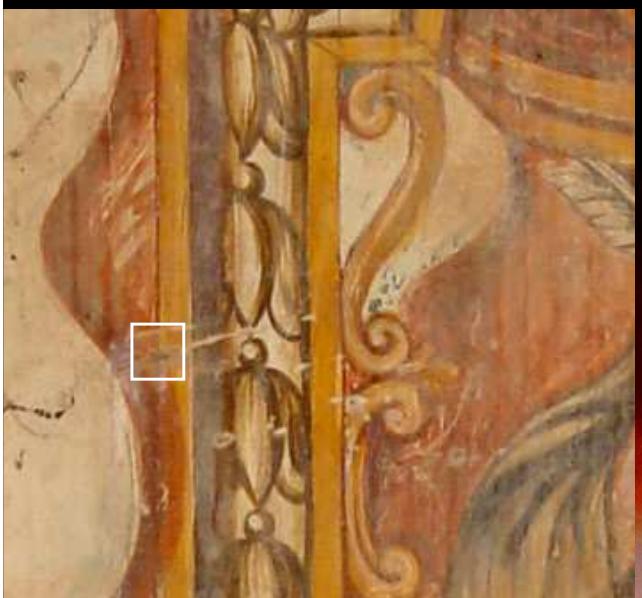


White lead

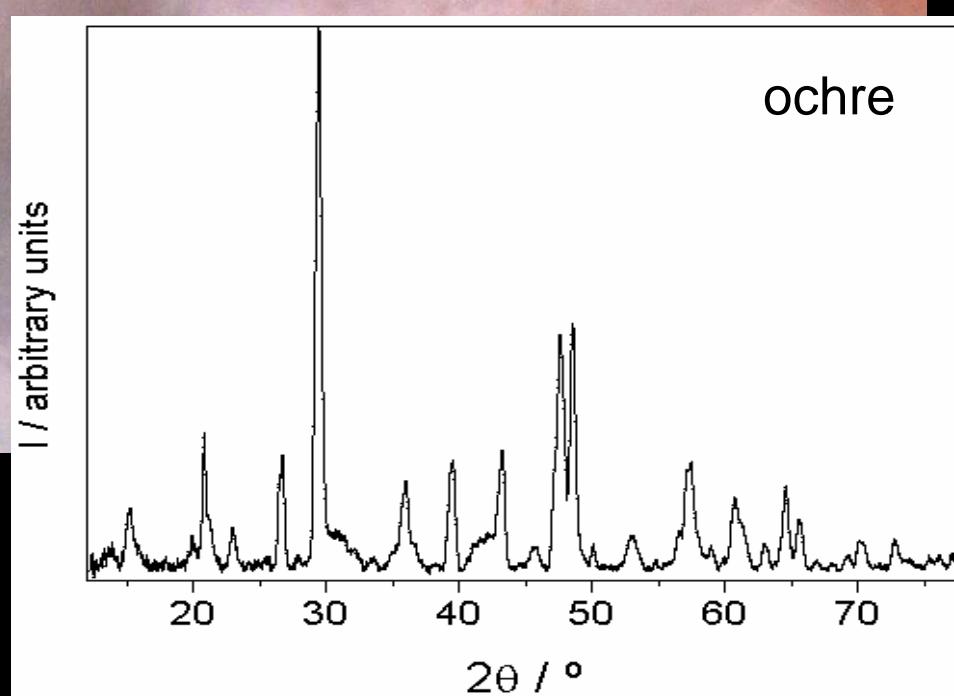
Pigment identification

Micro X-ray diffraction

Painted layers



Mineralogical composition
Pigment identification



ochre

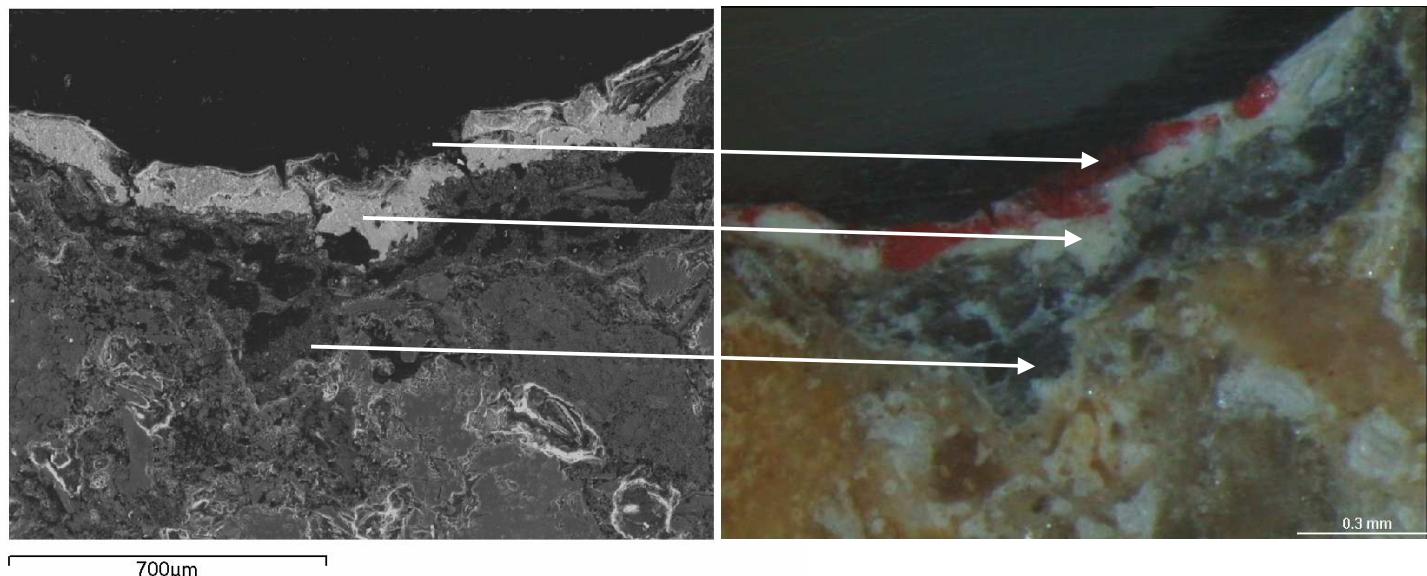
S. António dos capuchos Monastery (XVII century)

SEM/EDX

Painted layers

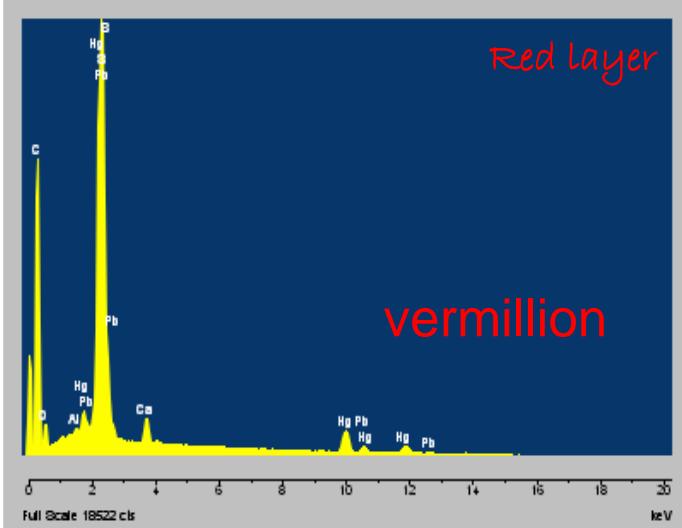
Elemental analysis

Pigment morphology



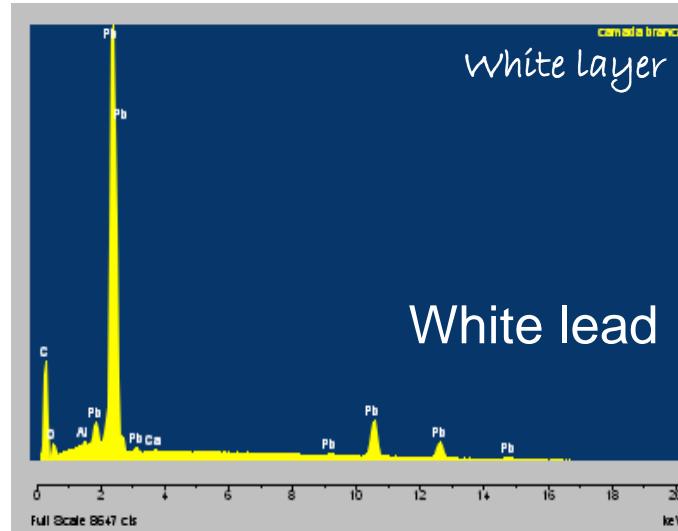
Red layer

vermillion



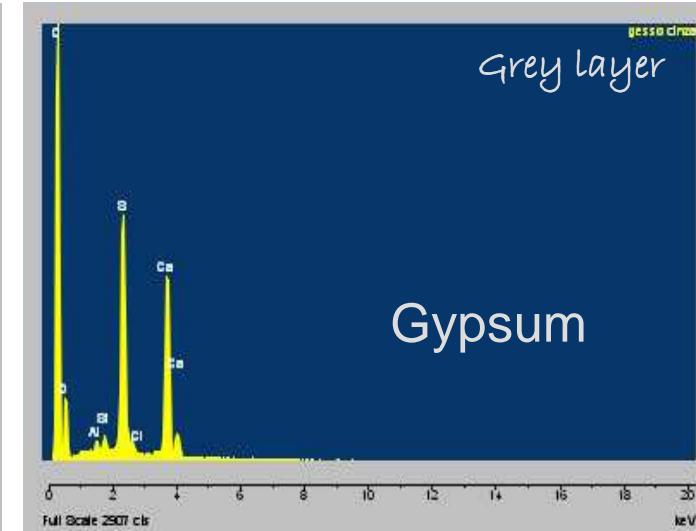
White layer

White lead



Grey layer

Gypsum



Fréixo de Espada a Cinta Church

final considerations

Methodology gives information about:

- Binder
- Aggregates
- Additives
- Mortars composition (binder/aggregates ratio)
- State of conservation / degradation products
- Physical properties
- Insight on technical knowledge

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