

# Technical studies of historical earthen plasters: a case study on the earthen plasters from the inner-wall of the Longhu Hall in the Yuzhen Palace of Ancient Building Complex in the Wudang Mountains

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## Introduction

Some facts about the Yuzhen Palace:

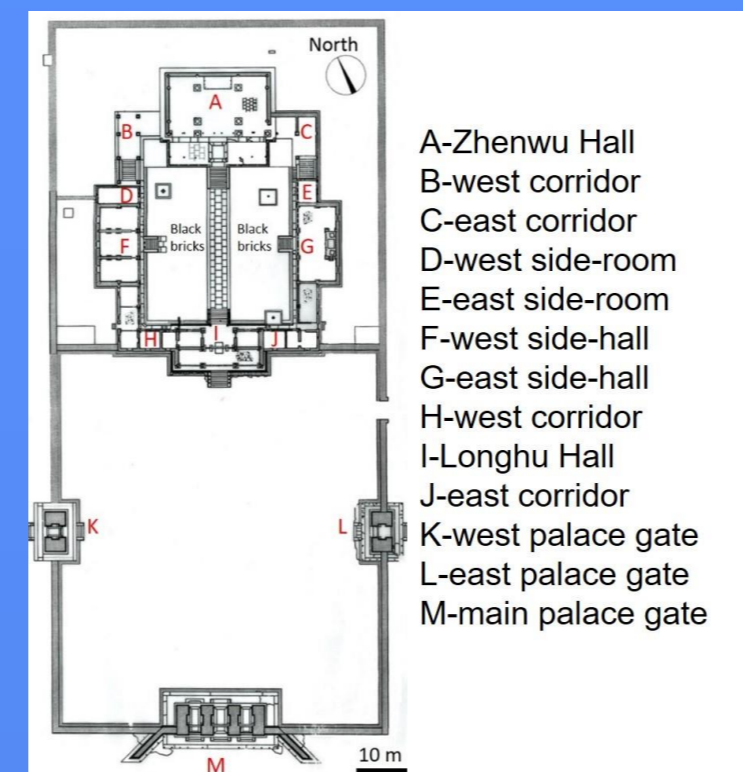
- ❖ Location: Southwest of the Danjiangkou City, Hubei Province, China
- ❖ An imperial construction built under the order of Yongle Emperor in the Ming dynasty (1412-1423 A.D.)
- ❖ One of the 9 palaces in the Ancient Building Complex of Wudang Mountains (UNESCO world heritage site, birth place of Wudang Martial Art-Taichi, famous for Taoism)
- ❖ Consisted of 3 gates (west palace gate, east palace gate, main palace gate), Longhu Hall, east and west-side halls, corridors.
- ❖ Built with black bricks dressed with exterior earthen plasters (outter-wall surfaces have been painted red)



Location of Wudang Mountains in China



Aerial photograph of the Yuzhen Palace



Floor plan of the Yuzhen Palace

As a result of the planned National South-North Water Diversion project by the Government of China, the water level in the Danjiangkou Reservoir that surrounds the Yuzhen Palace will rise approximately 15 meters. To avoid submersion permanently in the water:

- ❖ Three gates (Gate K, L and M in the floor plan) were elevated by 15 meters in 2012-2013
- ❖ Other buildings were dismantled and will be re-erected in the near future



During the elevation: all the other buildings have already been dismantled



Gates after 15 meters in-situ elevation!

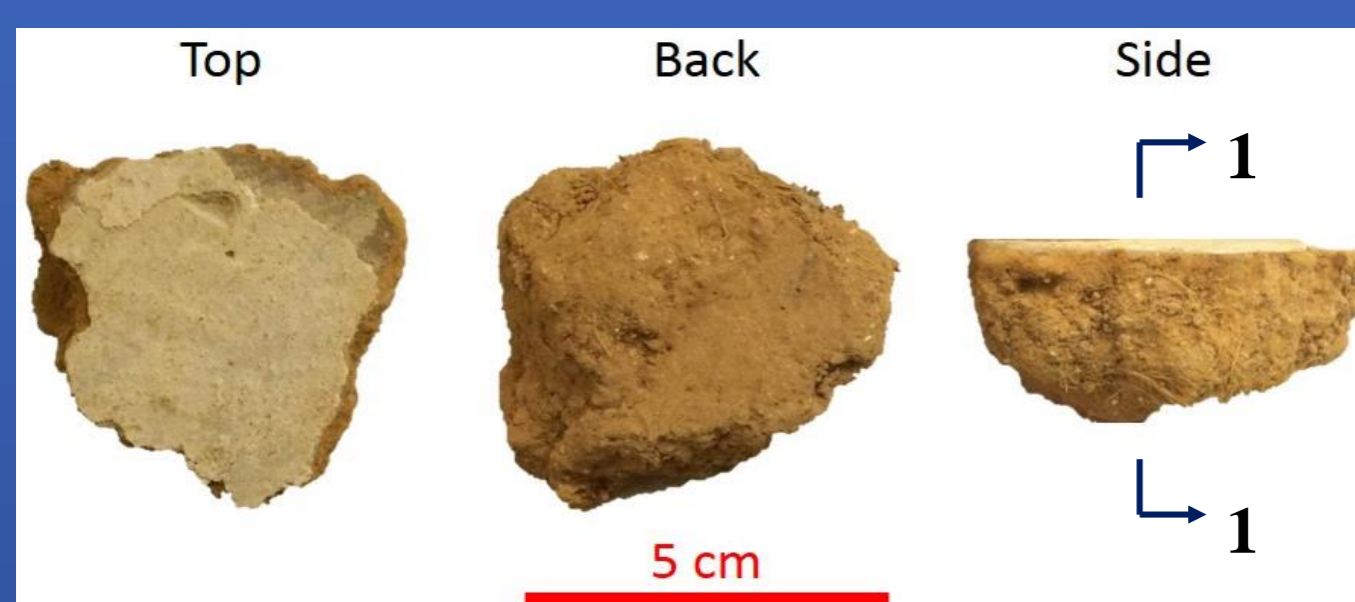
Questions of archaeological and conservation science importance:

- What is the construction technology of this imperial building?
- How many layers of plasters make up the wall preparation and what are the main constituents (raw materials) in each layer?
- Are there any plant fibers? Are these of plant or animal origin?

## Materials and Methods

Archaeological fragments of the earthen plasters were sampled from the inner wall of Longhu Hall.

Size: 3-5 cm in length, 2-3 cm in thickness.

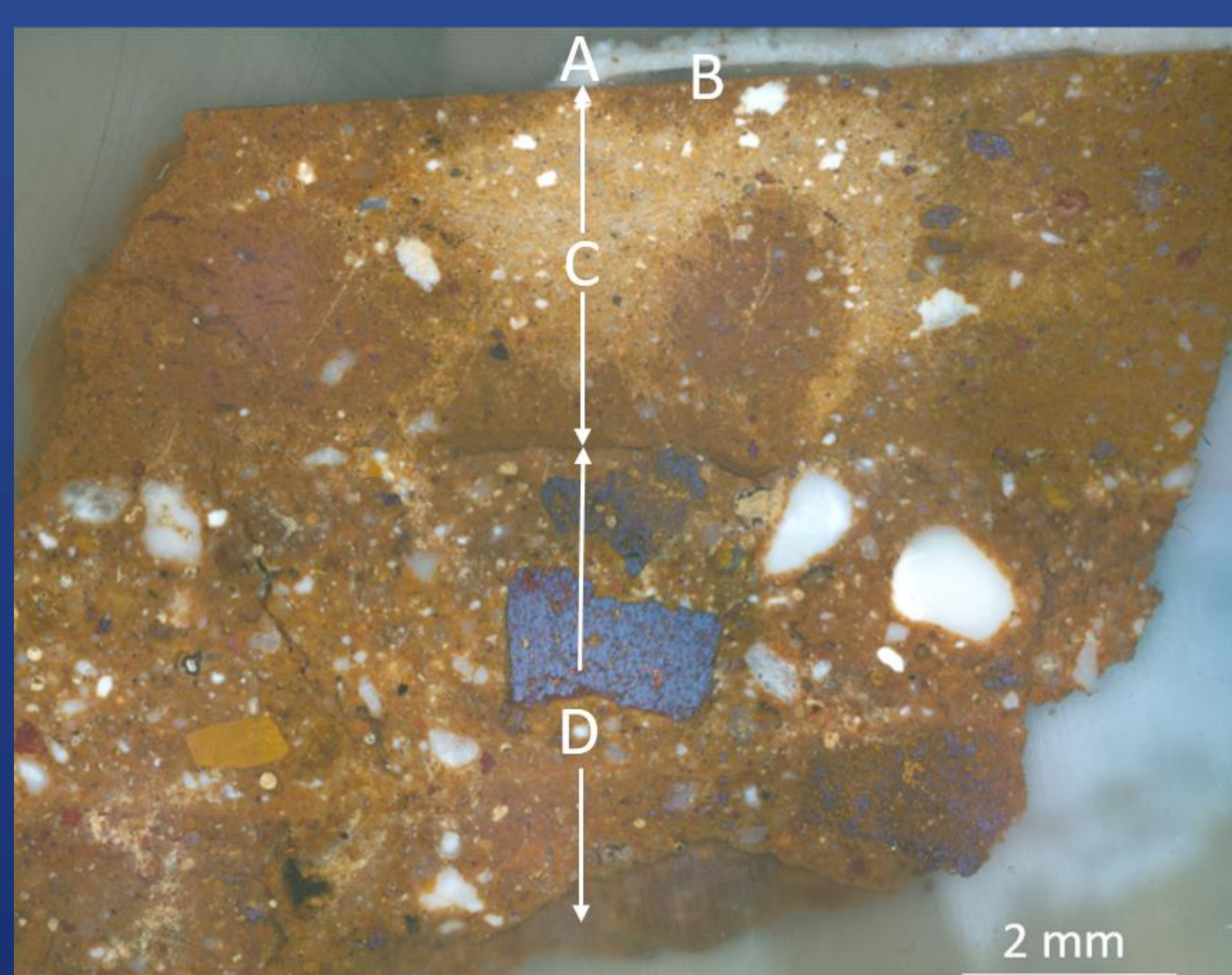


Photomicrographs of the archaeological fragments brought to lab for analysis

**Characterization Techniques:** 1. Optical Microscopy (OM); 2. Polarized Light Microscopy (PLM); 3. X-ray Florescence (XRF); 4. Scanning Electron Microscopy-Energy dispersive spectroscopy (SEM-EDS); 5. X-ray Diffraction (XRD); 6. Fourier Transform Infrared Spectroscopy (FTIR); 7. Thermogravimetric Analysis (TGA)

## Results

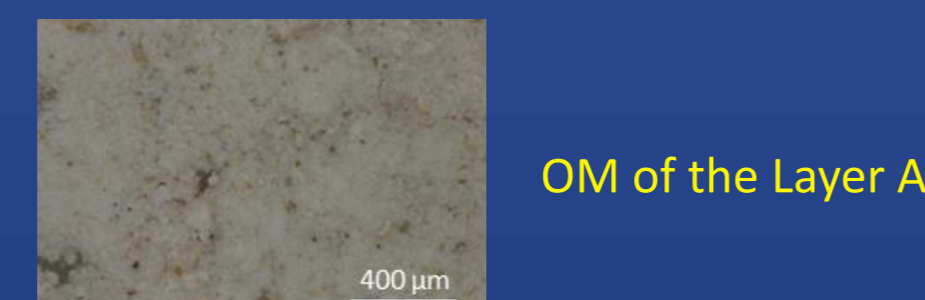
The stratigraphy of the earthen plaster sample consists of 4 different layers:



Cross-section: 1-1

Stratigraphy of the earthen plaster sample Showing a four-layer structure

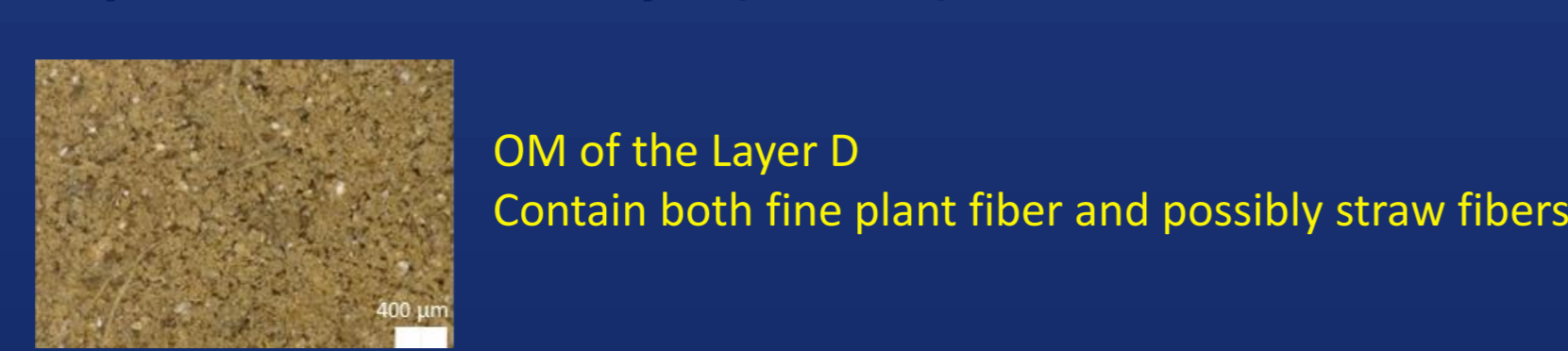
**Layer A: Surface lime wash (250- 380 μm)**



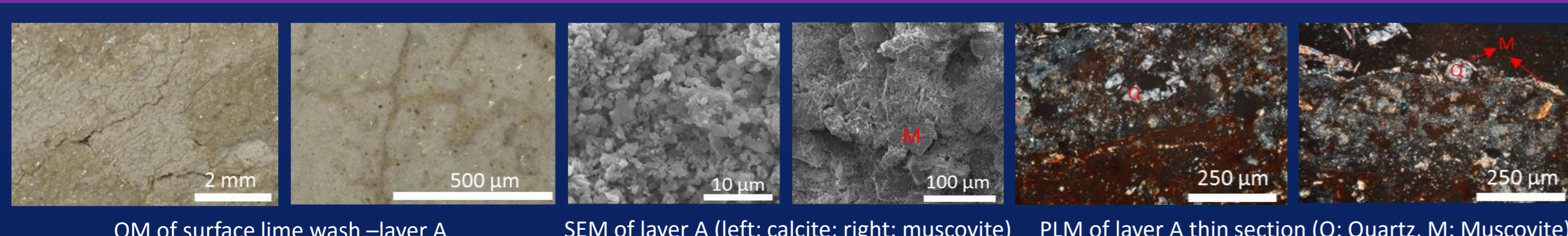
**Layer B: Intermediate layer (0- 140 μm)**  
**Layer C: Fine earth layer (~ 3.5 mm)**



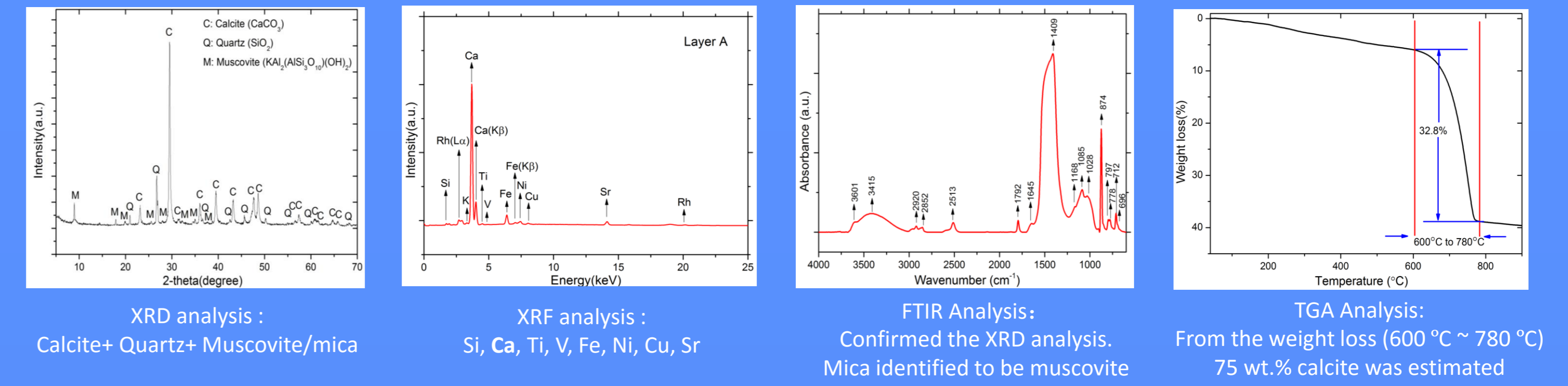
**Layer D: Coarse earth layer (> 5 mm)**



## Layer A (surface lime wash) Analysis



OM of surface lime wash -layer A SEM of layer A (left: calcite; right: muscovite) PLM of layer A thin section (Q: Quartz, M: Muscovite)



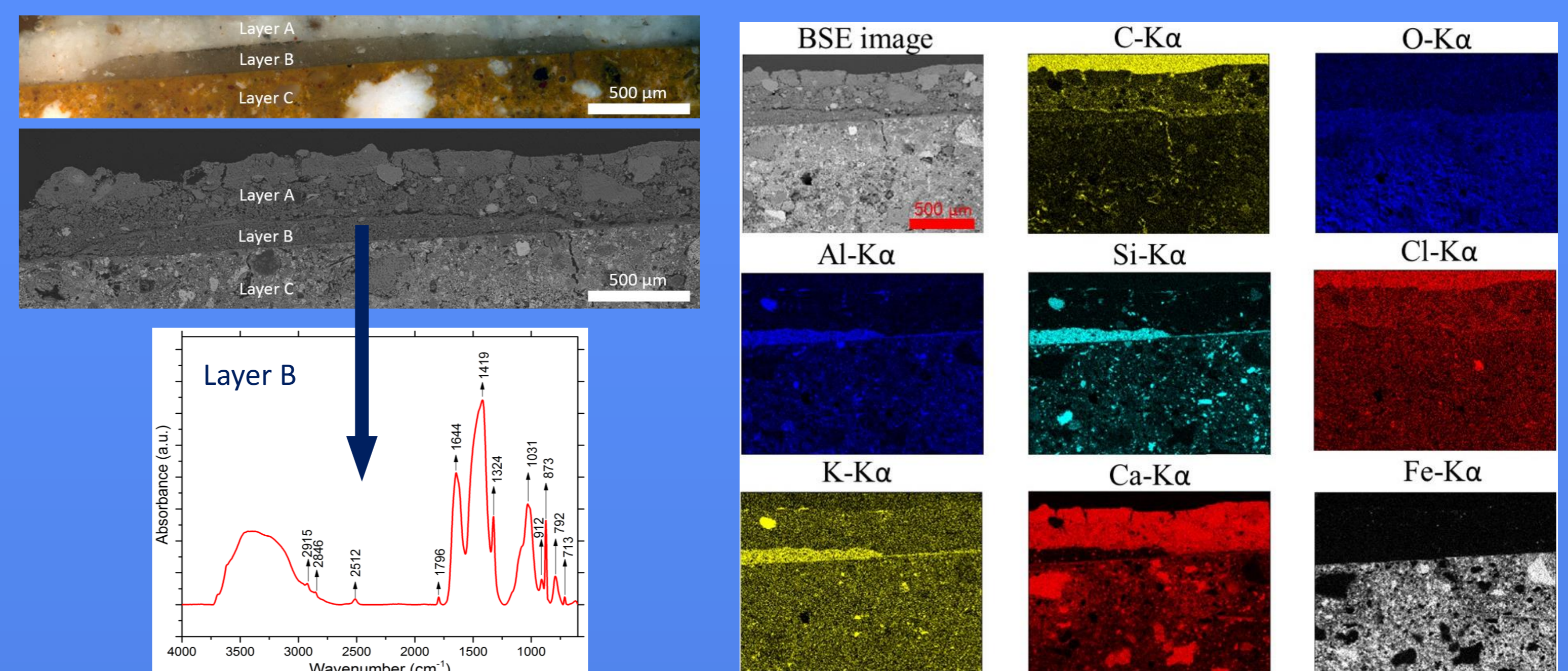
XRD analysis : Calcite+ Quartz+ Muscovite/mica

XRF analysis : Si, Ca, Ti, V, Fe, Ni, Cu, Sr

FTIR Analysis: Confirmed the XRD analysis. Mica identified to be muscovite

TGA Analysis: From the weight loss (600 °C ~ 780 °C) 75 wt.% calcite was estimated

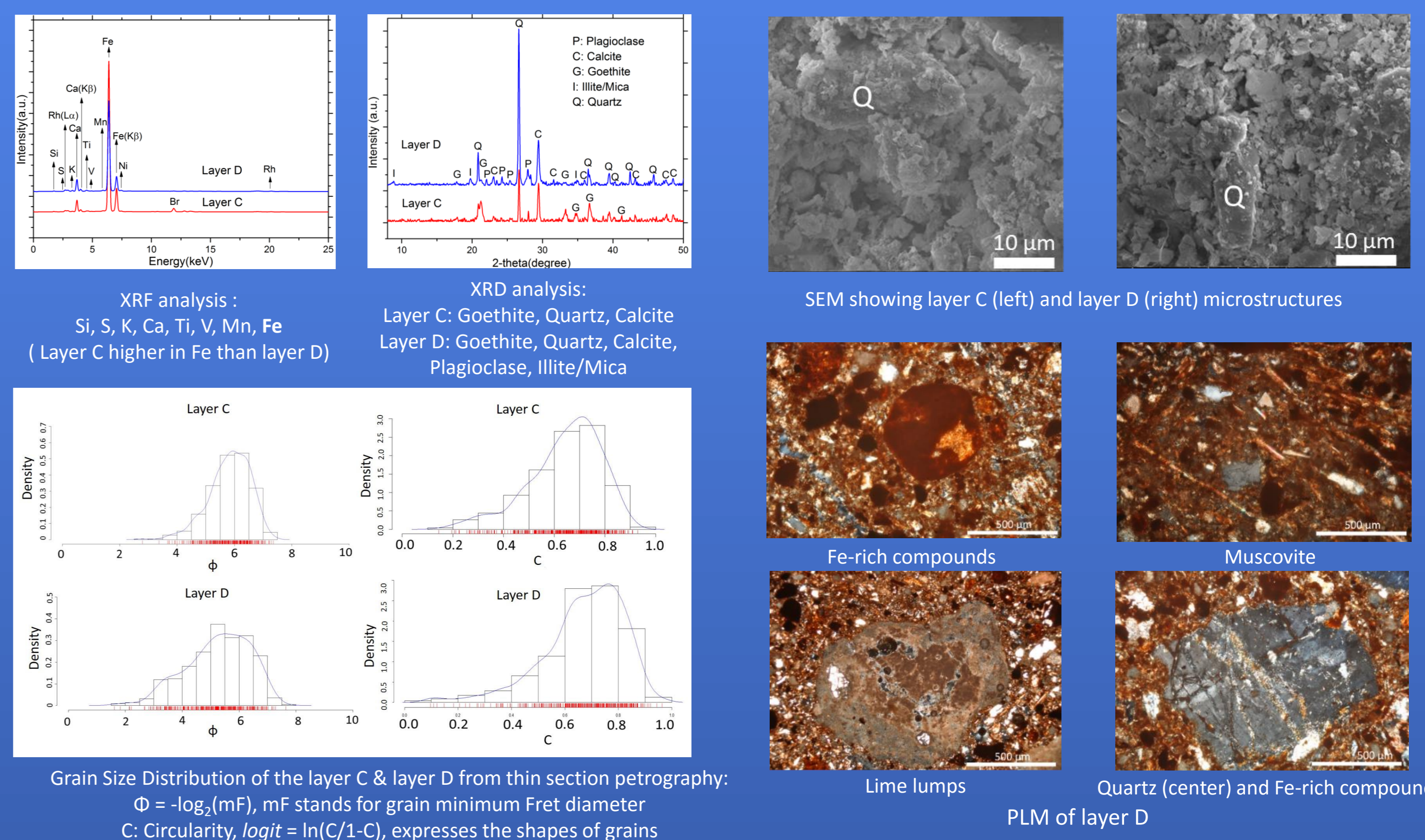
## Layer B (intermediate layer) Analysis



The μFTIR shows the existence of calcium oxalate  
Possibly degradation product of proteinaceous additives

Elemental mapping shows layer B is rich in Al, Si, K, O  
Very likely to contain clay

## Layer C (fine earth layer) & Layer D (coarse earth layer) Analysis



XRF analysis : Si, S, K, Ca, Ti, V, Mn, Fe (Layer C higher in Fe than layer D)

XRD analysis: Layer C: Goethite, Quartz, Calcite Layer D: Goethite, Quartz, Calcite, Plagioclase, Illite/Mica

SEM showing layer C (left) and layer D (right) microstructures

Fe-rich compounds

Muscovite

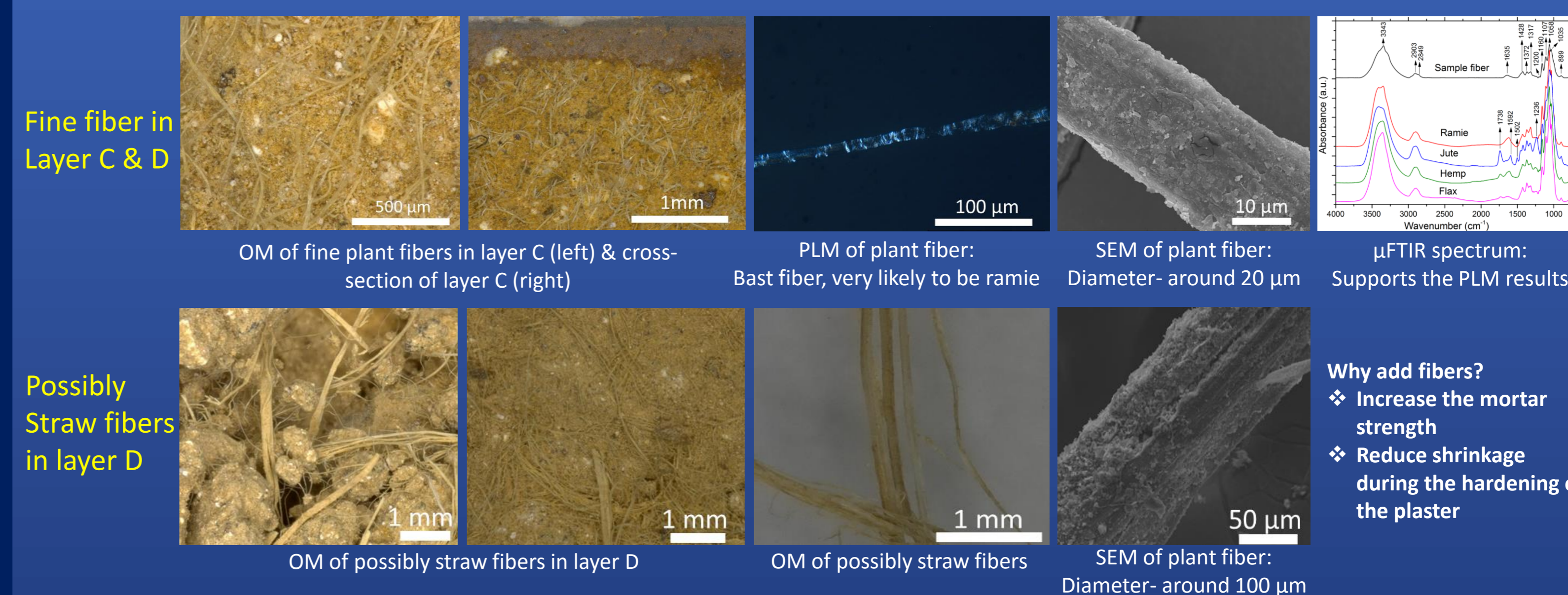
Lime lumps

Quartz (center) and Fe-rich compounds

PLM of layer D

Grain Size Distribution of the layer C & layer D from thin section petrography:  $\Phi = -\log_2(mF)$ , mF stands for grain minimum Fret diameter C: Circularity,  $\logit = \ln(C/1-C)$ , expresses the shapes of grains

## Plant Fibers Analysis



Fine fiber in Layer C & D

OM of fine plant fibers in layer C (left) & cross-section of layer C (right)

PLM of plant fiber: Bast fiber, very likely to be ramie

SEM of plant fiber: Diameter- around 20 μm

μFTIR spectrum: Supports the PLM results

Possibly Straw fibers in layer D

OM of possibly straw fibers in layer D

OM of possibly straw fibers

SEM of plant fiber: Diameter- around 100 μm

Why add fibers?  
❖ Increase the mortar strength  
❖ Reduce shrinkage during the hardening of the plaster

## Conclusions

1. A comprehensive analysis of historical earthen plasters from Yuzhen Palace has been performed.
2. The inner wall earthen plasters consist of four layers (from top to the bottom):  
A. Surface lime wash (lime-binder + sand-aggregates + muscovite/mica)  
B. Clay + proteinaceous matter ( calcium oxalate)  
C & D: earthen plaster layer, containing goethite, calcite, quartz, muscovite  
Layer C has a Fe concentration higher and an average size smaller than layer D. The lime lumps and ramie & straw fibers were added on purpose during the preparation.
3. The extraction of the organic additives within mortars and analysis is under progress.

## Acknowledgement

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