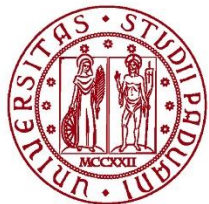


Materials Properties, Use and Conservation: Construction Materials and Binders

Petrographic analysis of binding composites

Simone Dilaria



UNIVERSITÀ
DEGLI STUDI
DI PADOVA

dbc
DIPARTIMENTO
DEI BENI CULTURALI
ARCHEOLOGIA, STORIA
DELL'ARTE, DEL CINEMA
E DELLA MUSICA



DIPARTIMENTO
DI GEOSCIENZE

CIRCe

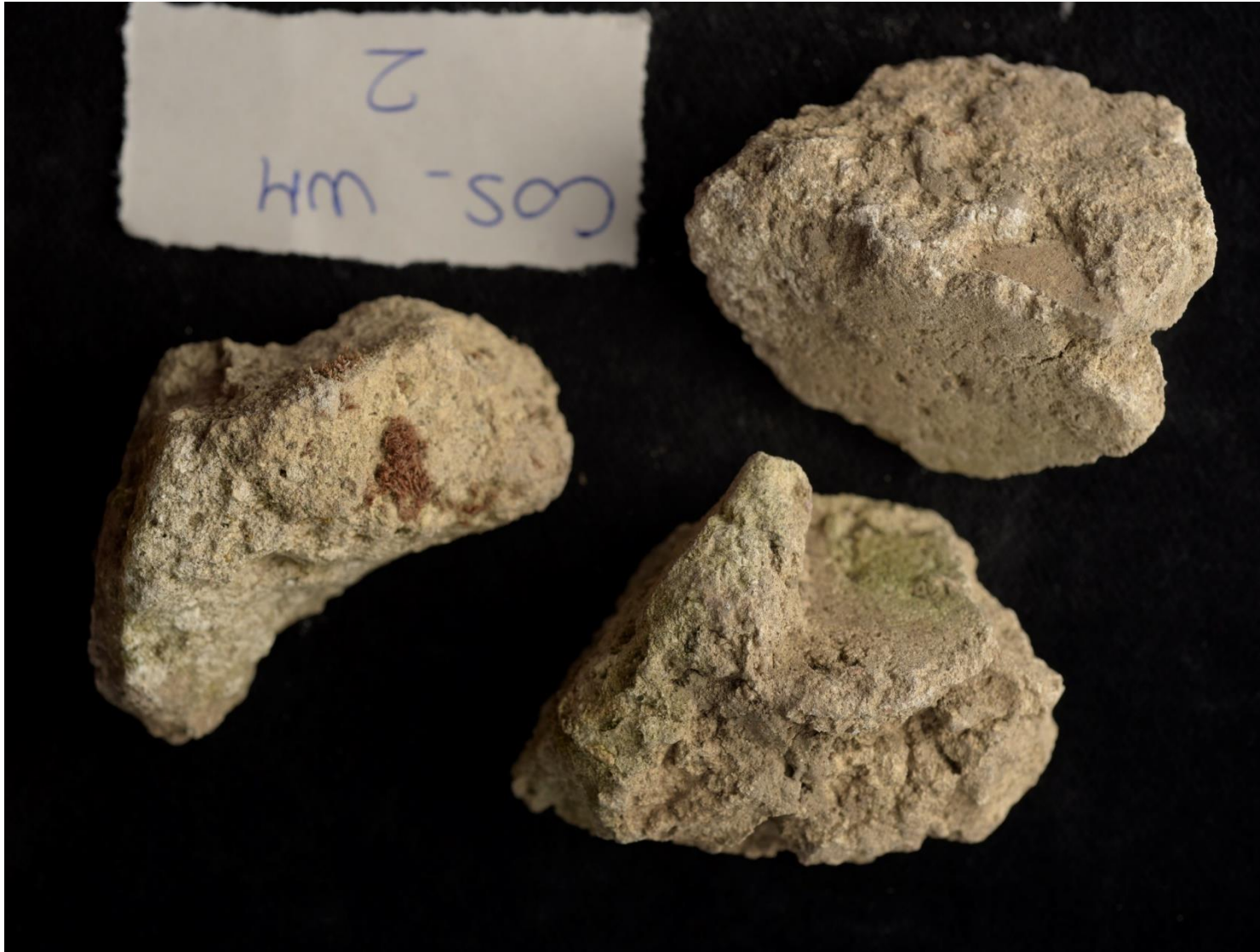
Centro Interdipartimentale di Ricerca
per lo Studio dei Materiali Cementizi
e dei Leganti Idraulici

CIBA

CENTRO PER I
BENI CULTURALI

DIAGNOSTICA . RILIEVO . TECNOLOGIE

Petrographic analysis of binding composites

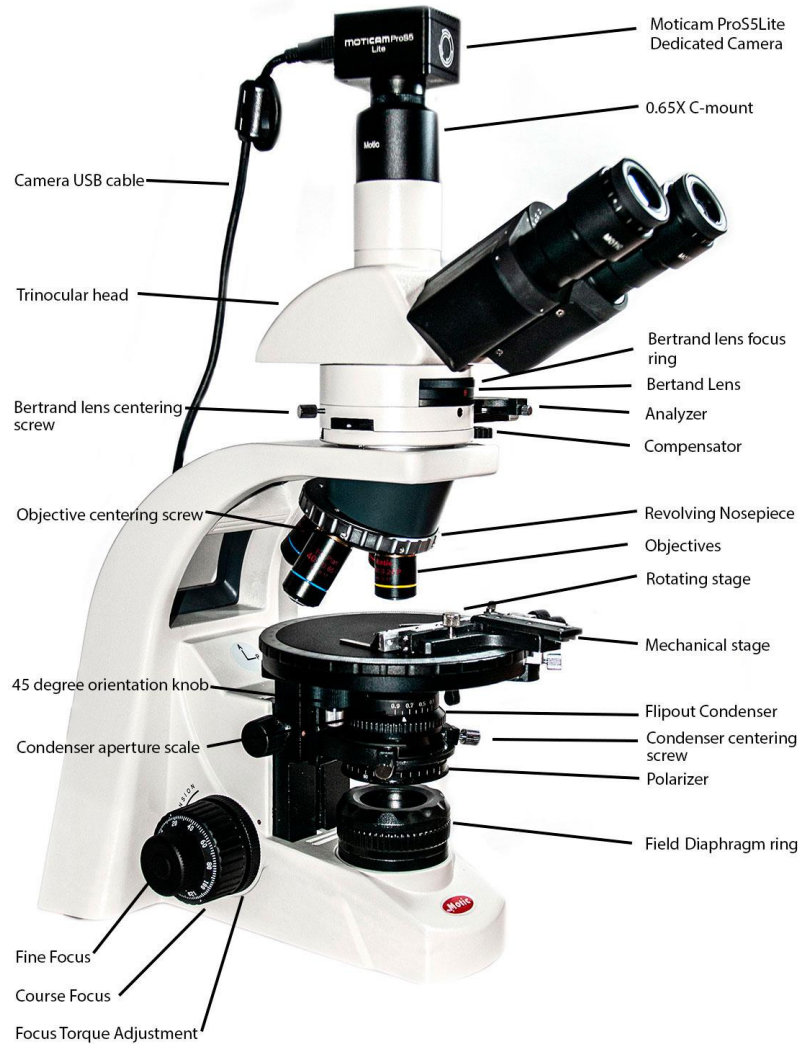


Petrographic analysis of binding composites

- 1) To define what was the ancient builders' awareness of the resources available in their territory;
- 2) To determine when the functionality criterion prevailed over that of availability or vice versa;
- 4) To answer all those "whys" that follow the provenance issue's resolution and require a thorough knowledge of both the territory and the ancient production techniques (which type of binder? where the aggregates were collected?)
- 3) To find rational explanations to technologically choices (i.e. How they manufactured the mixture? Do they need to waterproof? They searched for a structural reinforcement?)



Petrographic analysis of binding composites



Petrographic analysis of binding composites

DESCRIPTION OF SAMPLE

Type (bedding mortar, plaster, etc.)

Stratigraphy (from the substrate)

Number of layers

Thickness of the layers (total and of each single layer)

Adhesion

- To the substrate (to be determined at the sampling stage)
- Between the individual layers (good, poor)

Staining, protective coatings or other

Neoformation products (efflorescence, biological patina, etc.)

MACROSCOPIC DESCRIPTION OF THE SINGLE LAYERS

Dimensional appearance (maximum dimensions)

- Coarse conglomeratic (over 4 mm)
- Fine conglomeratic (between 2 mm and 4 mm)
- Arenaceous (less than 2 mm)
- Siltstone (undetectable)

Color

- Mass
- Of the individual clasts.

Cohesion

- Very tough (won't break).
- Tenacious (fragments without crumbling).
- Crumbly (crumbles by finger pressure or flakes).
- Inconsistent.

BINDER

Texture (homogeneous, clumped, plagued, etc.).

Structure (microcrystalline, sparitic).

Mineralogical composition

Interactions with the aggregate (reaction rims, etc.).

Lumps (type, morphology)

VOIDS

Location

Form

AGGREGATE

Grain size

Sorting/distribution

Form (natural, from comminution)

- Sphericity (see figure 2)
- Roundness (see figure 2)

Areal distribution (homogeneous, banded, etc.)

Orientation

Presence of reaction rims

Mineralogical and petrographic composition

ADDITIVES

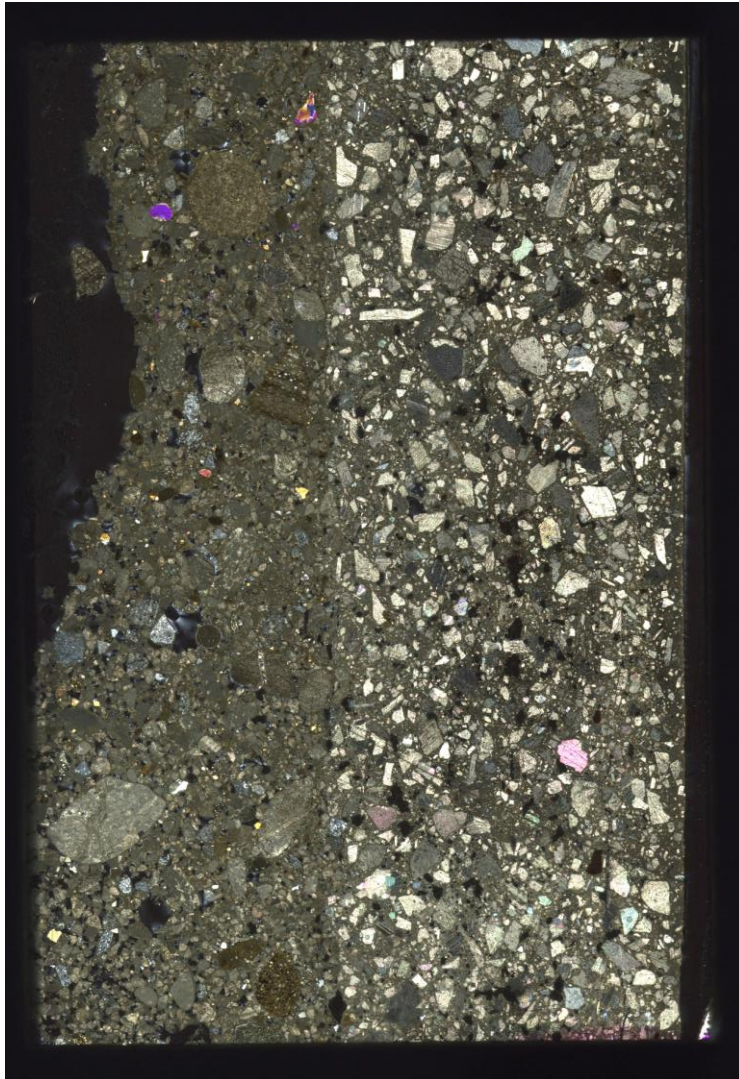
- Classification
- Dimensions

BINDER TO AGGREGATE RATIO QUANTIFICATION OF ELEMENTS

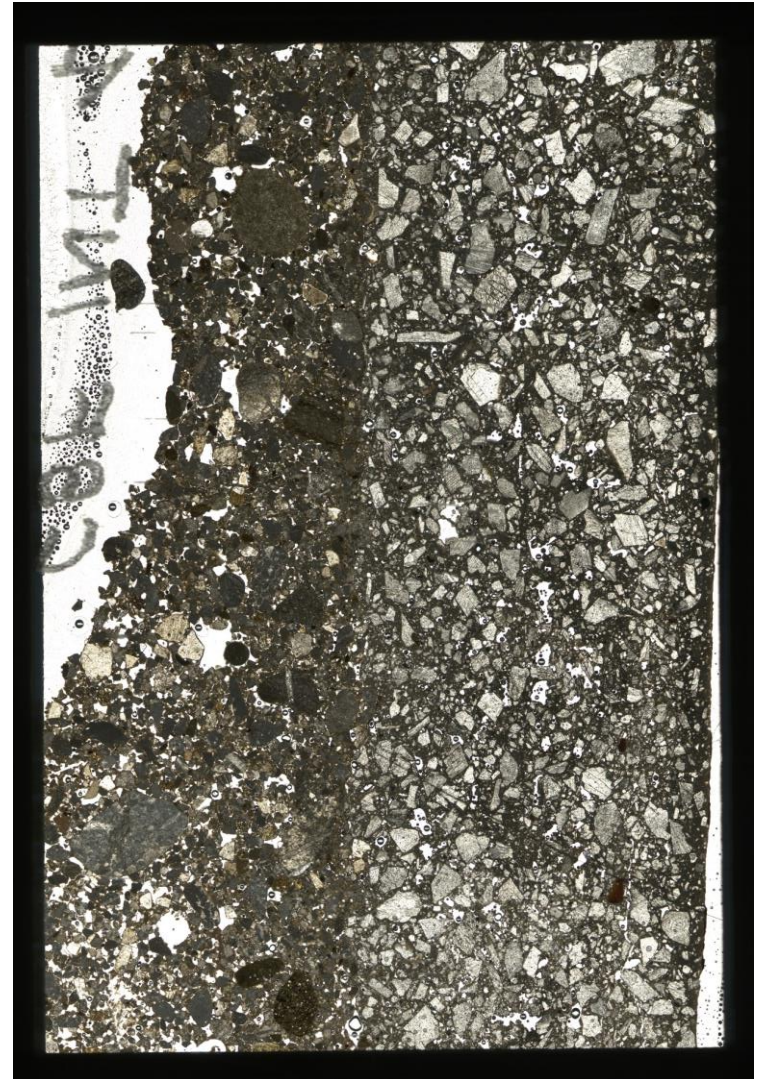


Petrographic analysis of binding composites

TRANSMITTED LIGHT – CROSSED NICOL

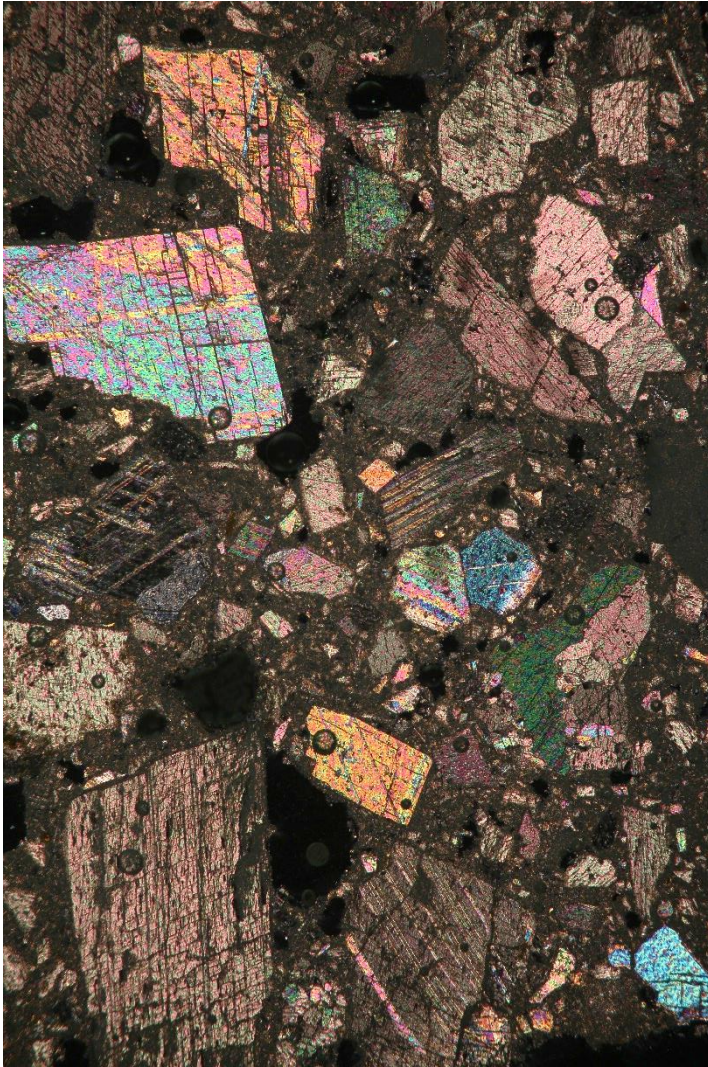


TRANSMITTED LIGHT – PARALLEL NICOL

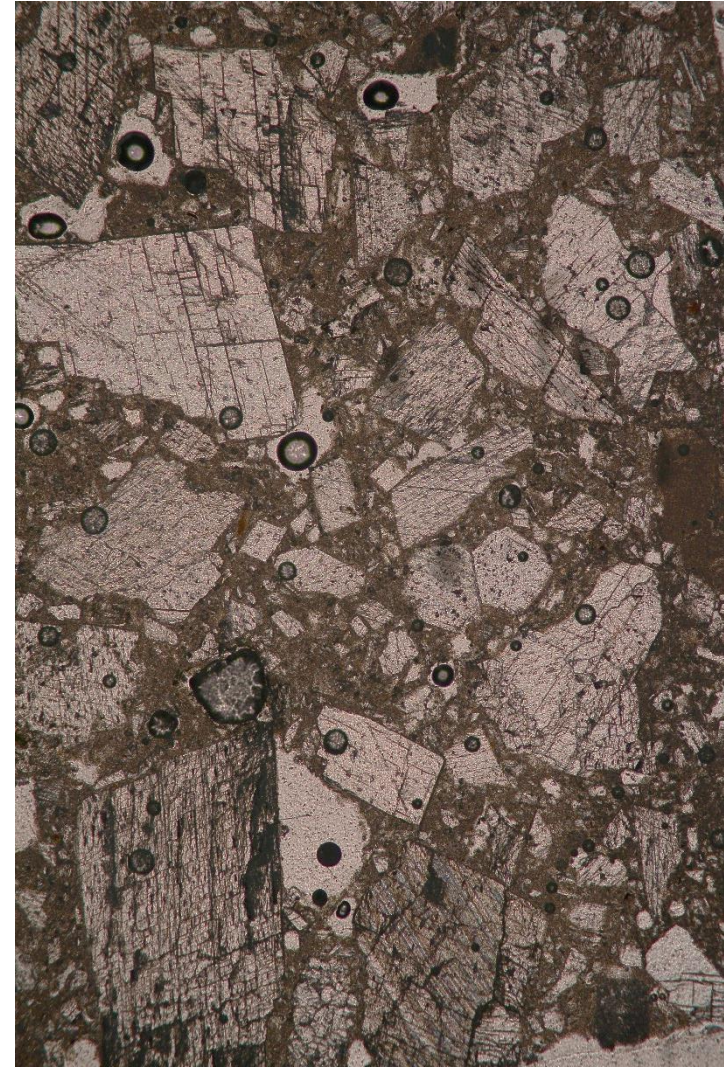


Petrographic analysis of binding composites

TRANSMITTED LIGHT – CROSSED NICOL



TRANSMITTED LIGHT – PARALLEL NICOL



Petrographic analysis of binding composites

BINDER

Texture

(homogeneous, clumped, plagued, etc.).

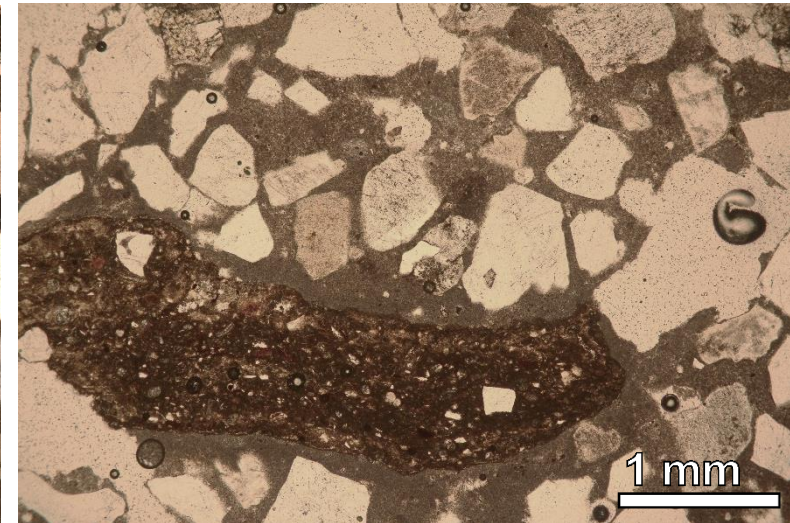
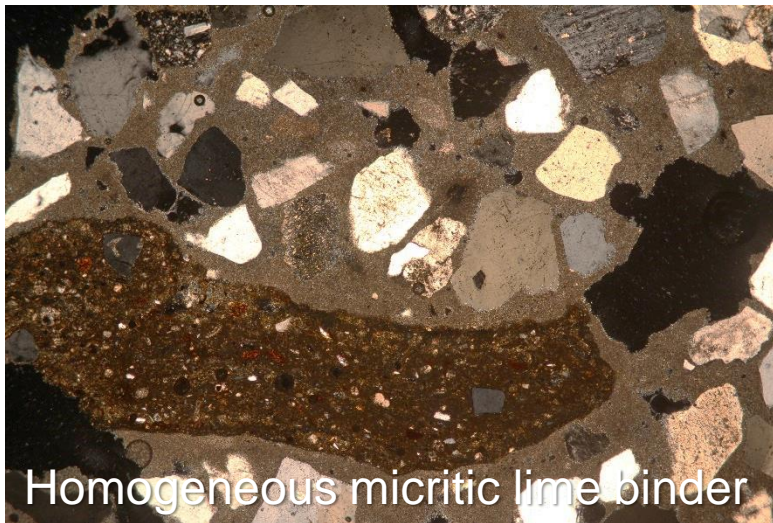
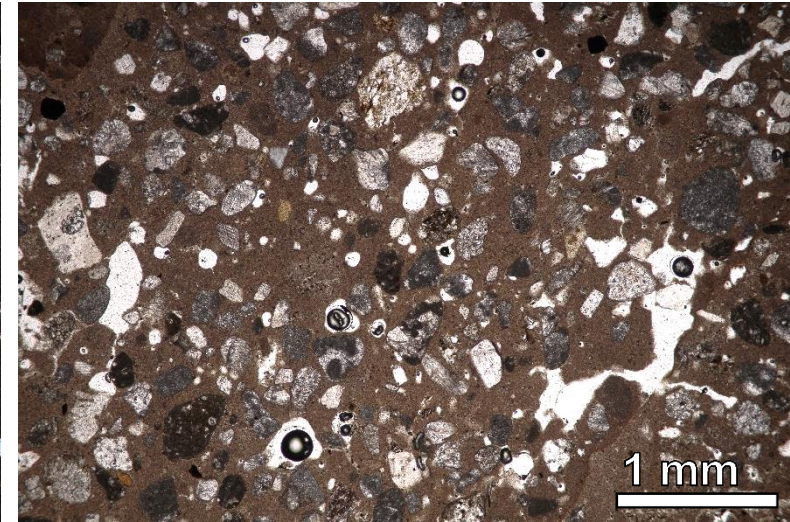
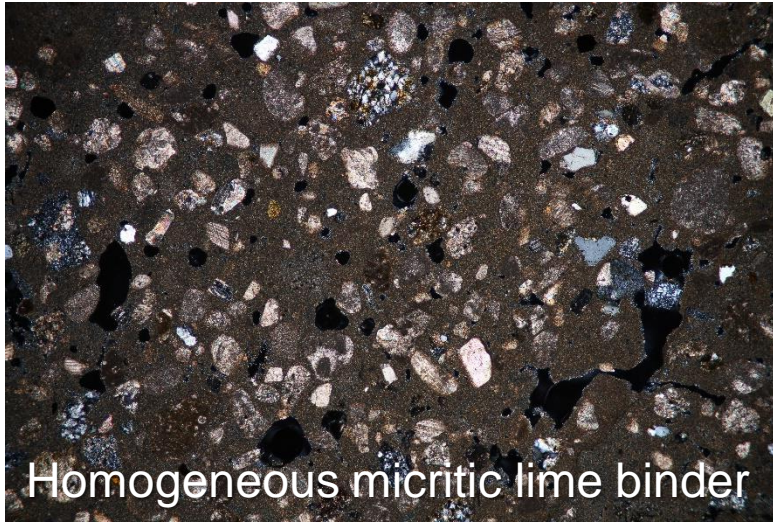
Structure

(microcrystalline, sparitic)

Mineralogical composition

Interactions with the aggregate (reaction rims, etc.)

Lumps (type, morphology)



Petrographic analysis of binding composites

BINDER

Texture

(homogeneous, clumped, plagued, etc.)

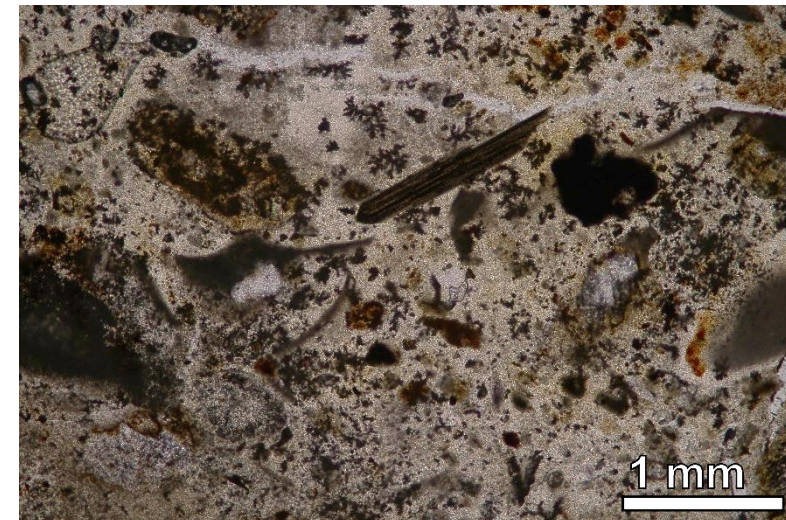
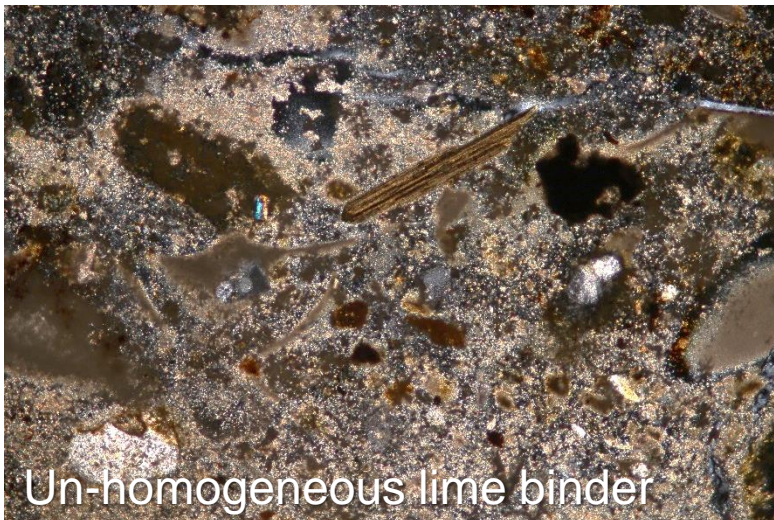
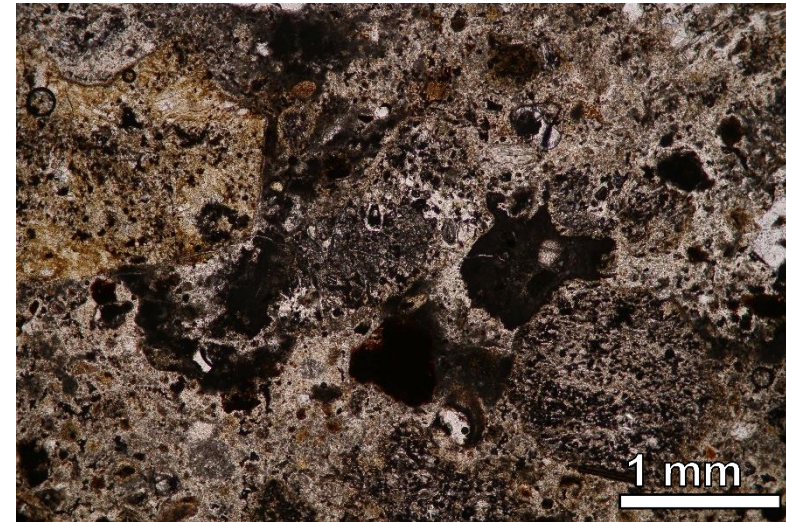
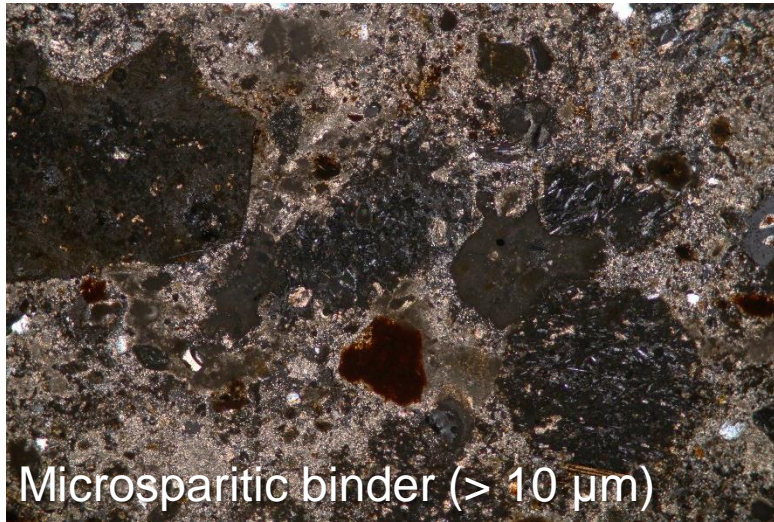
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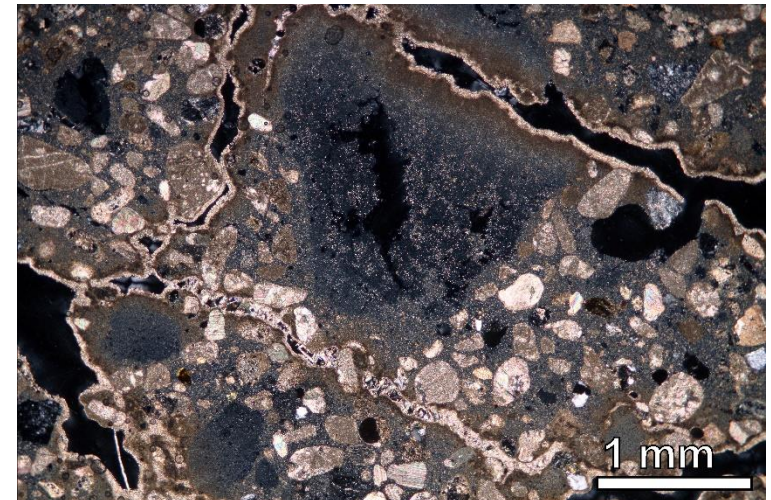
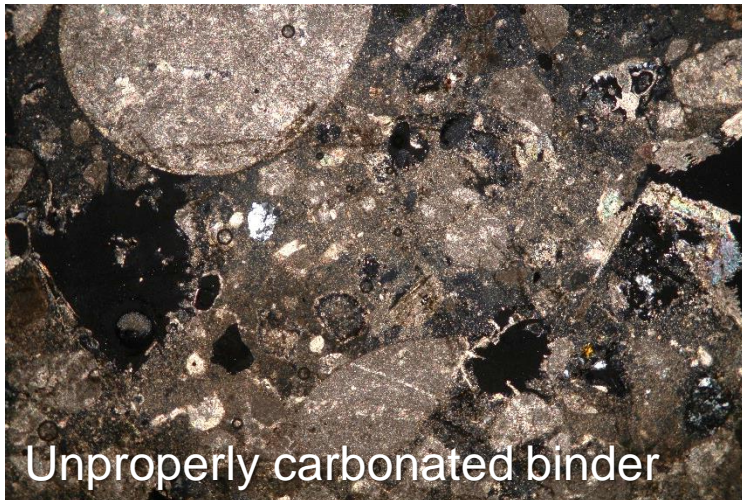
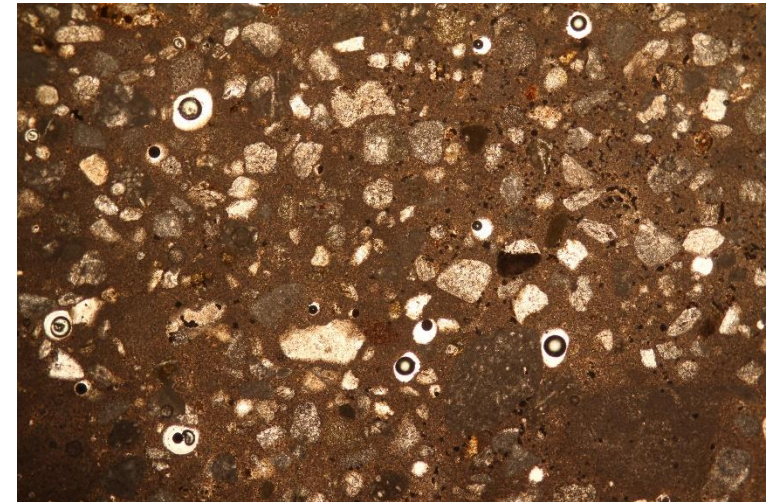
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Petrographic analysis of binding composites

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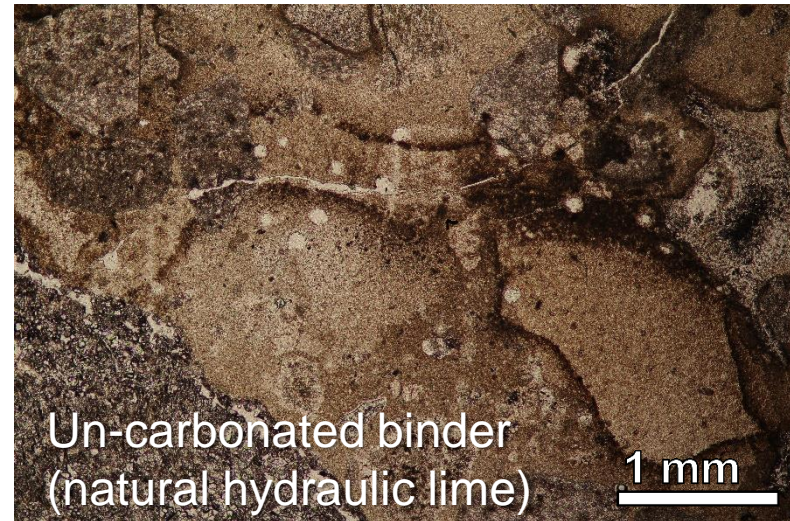
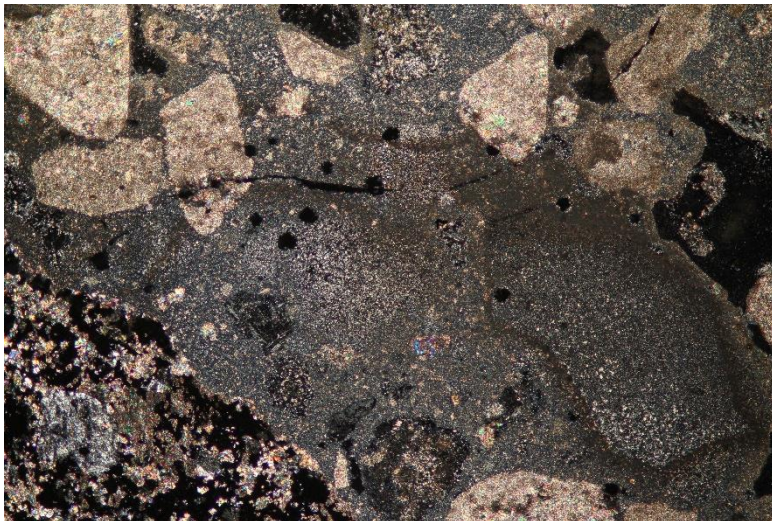
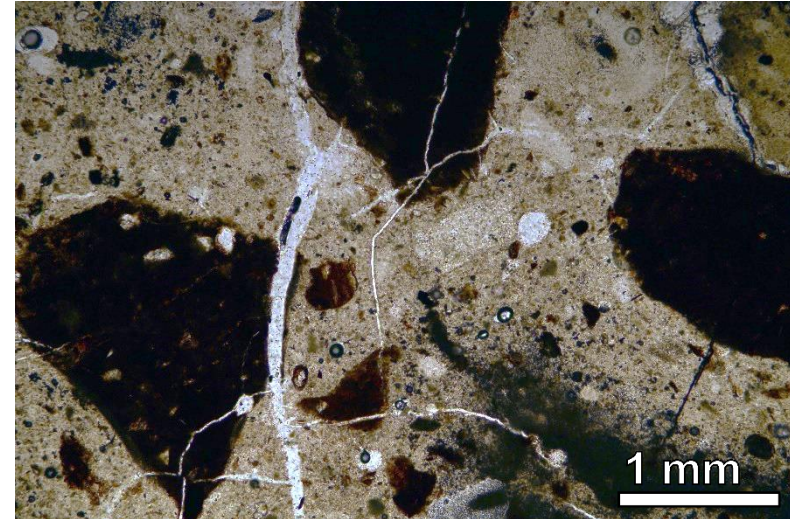
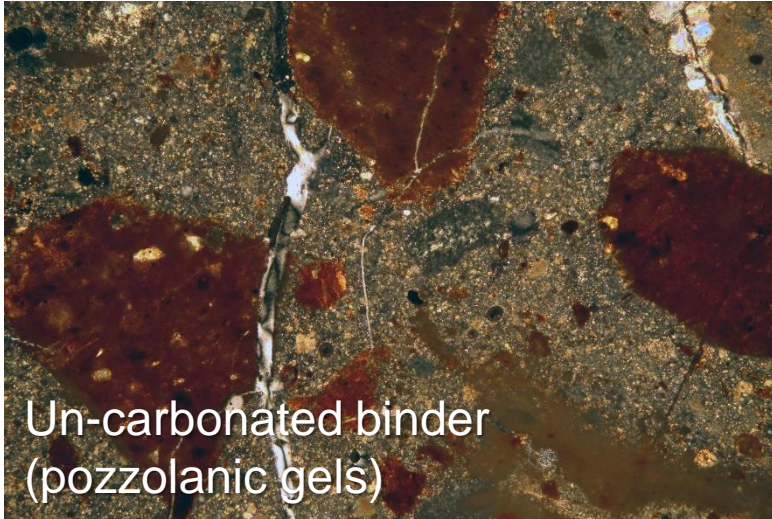
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Petrographic analysis of binding composites

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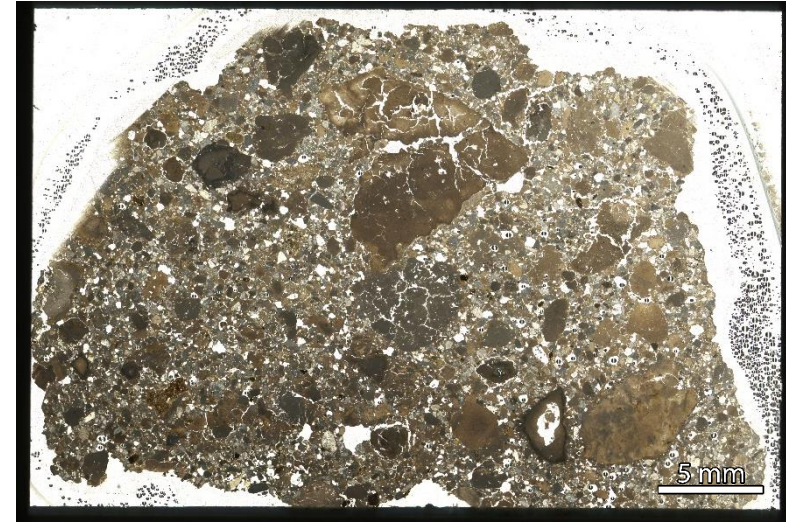
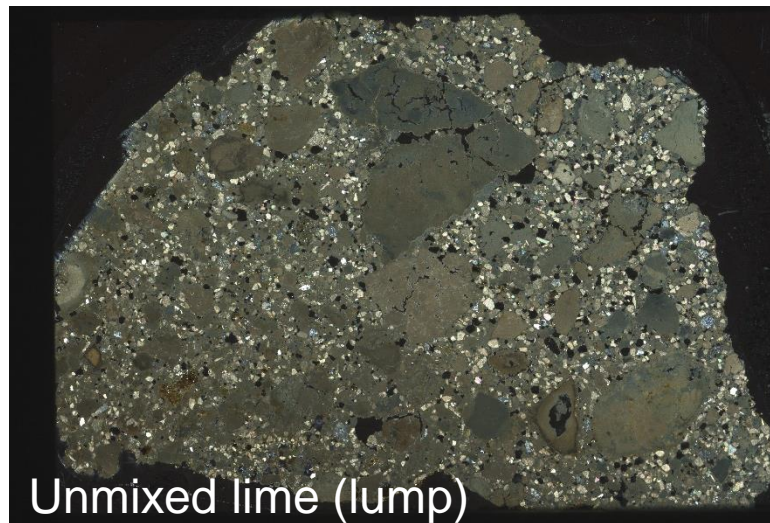
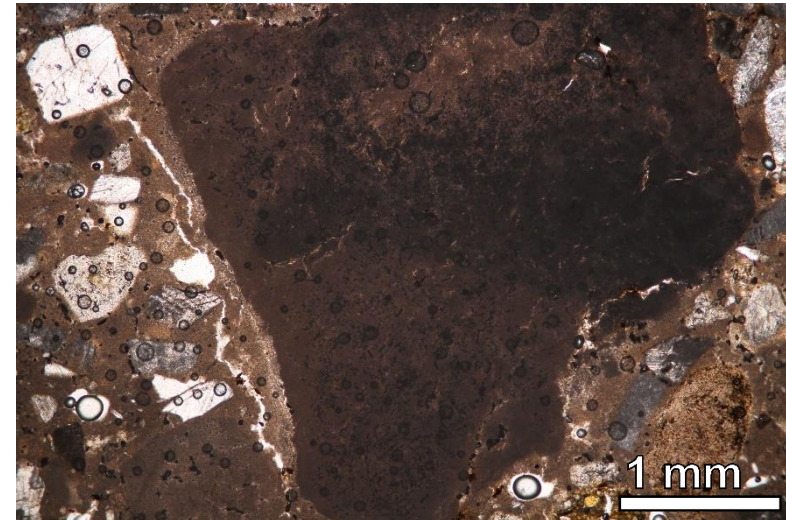
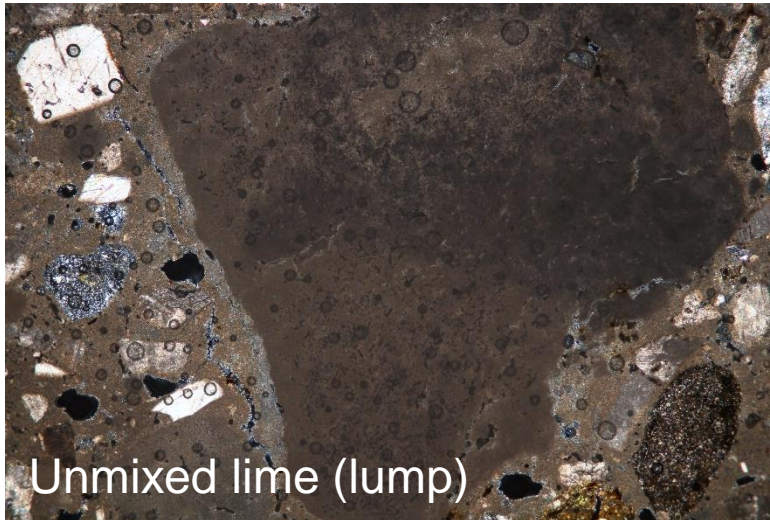
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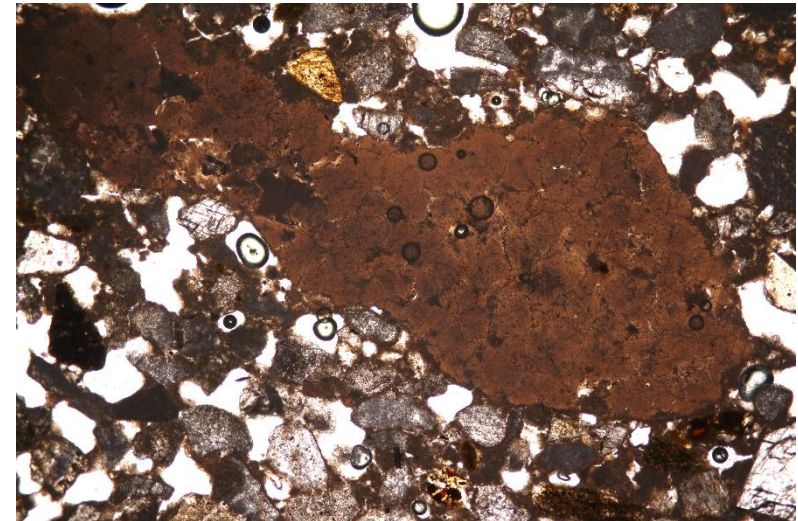
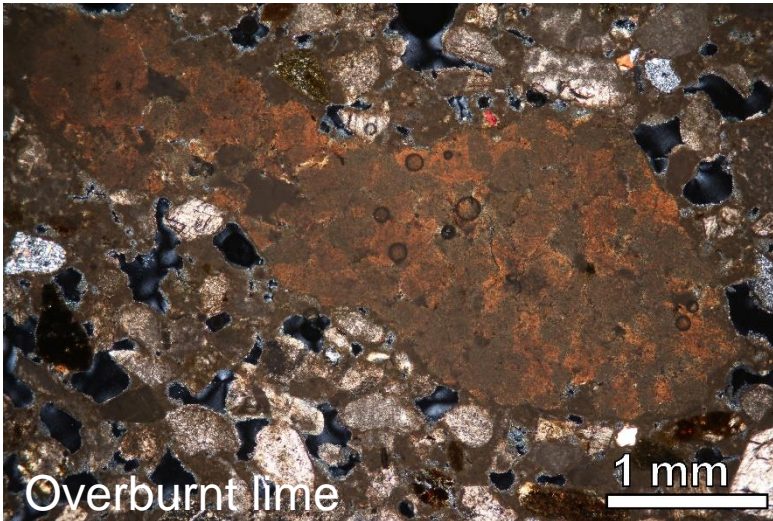
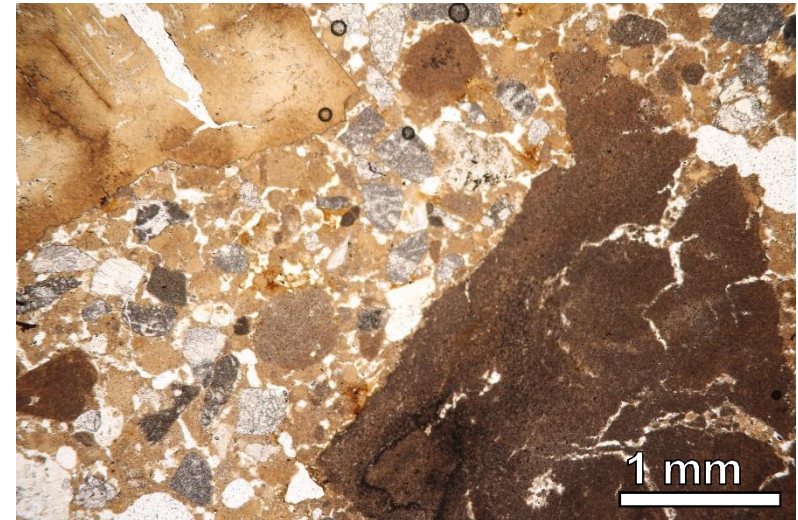
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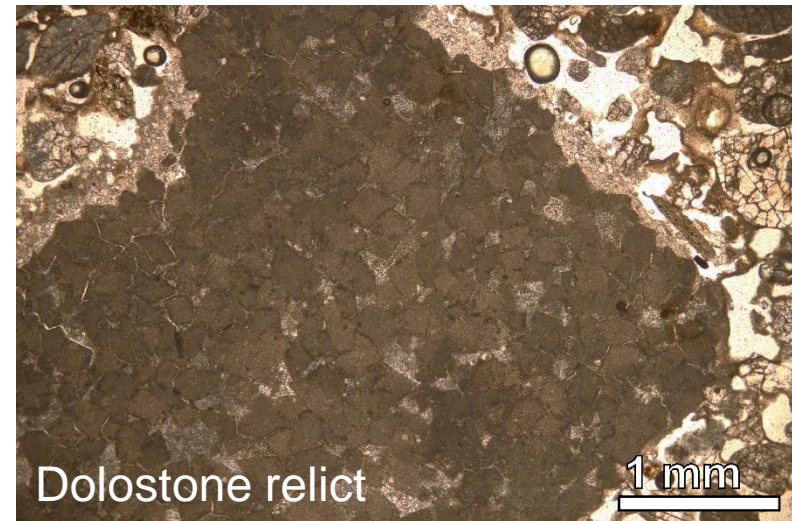
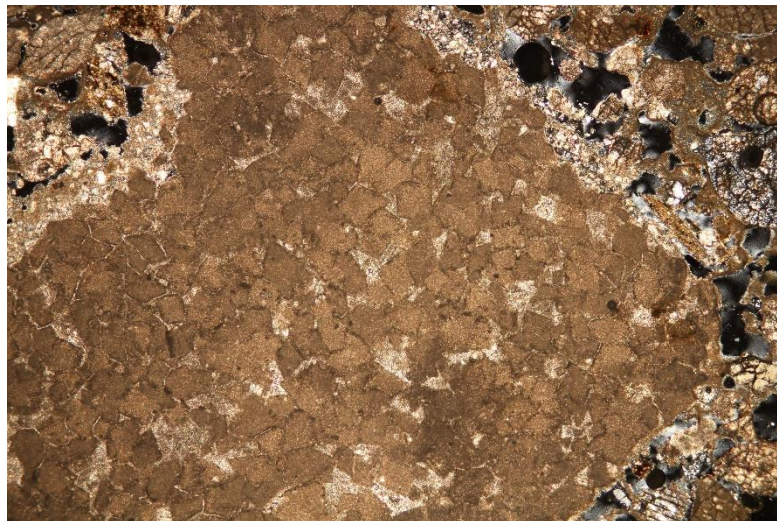
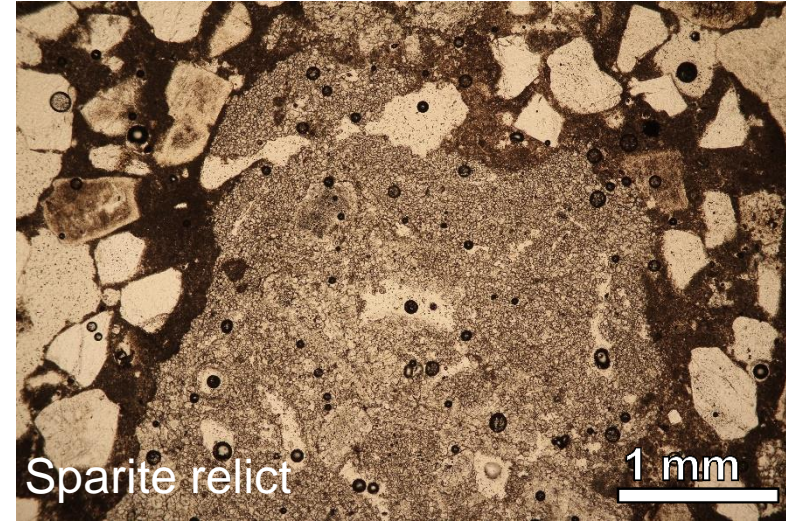
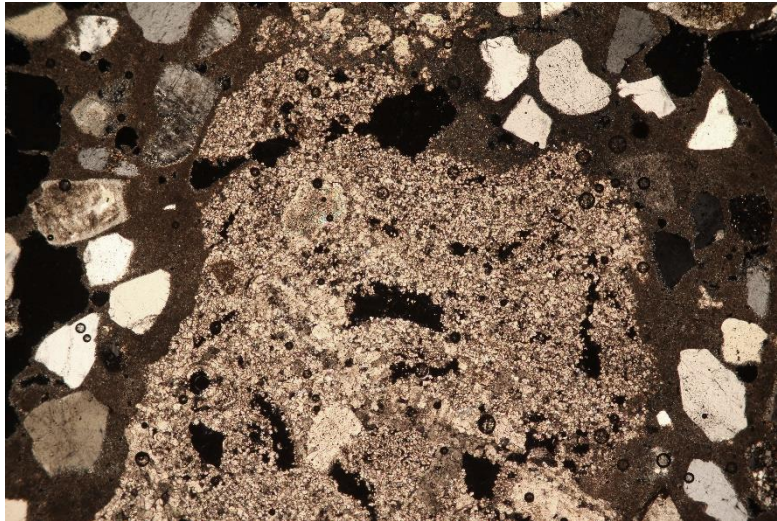
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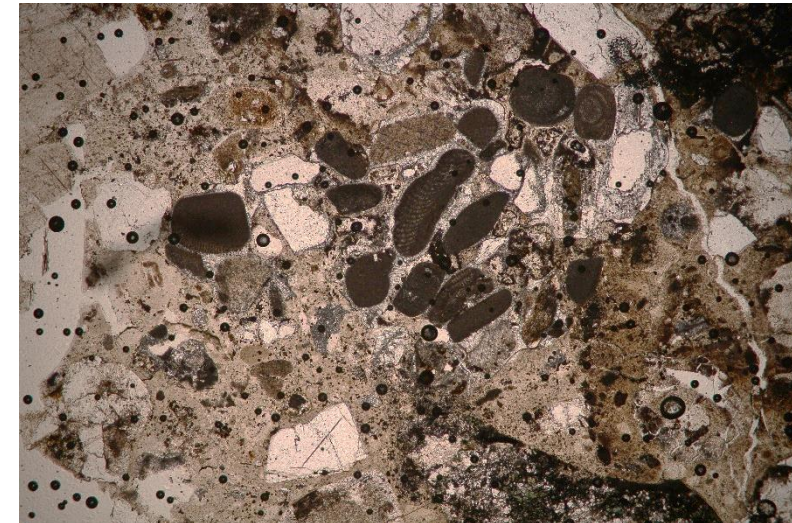
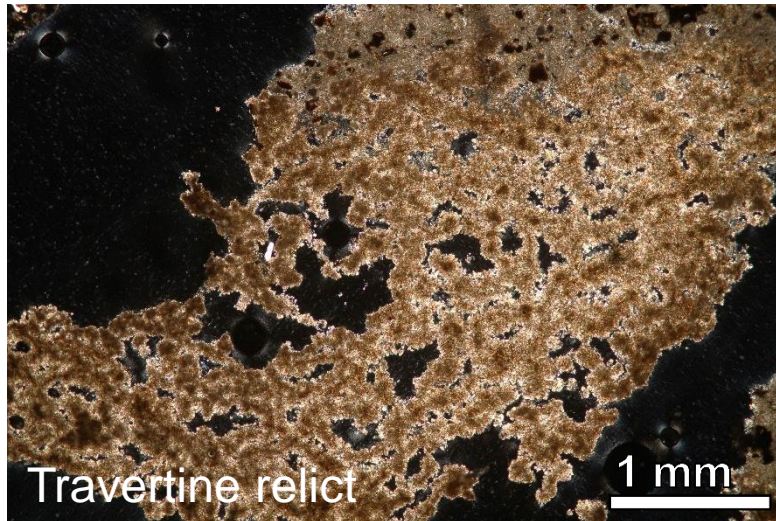
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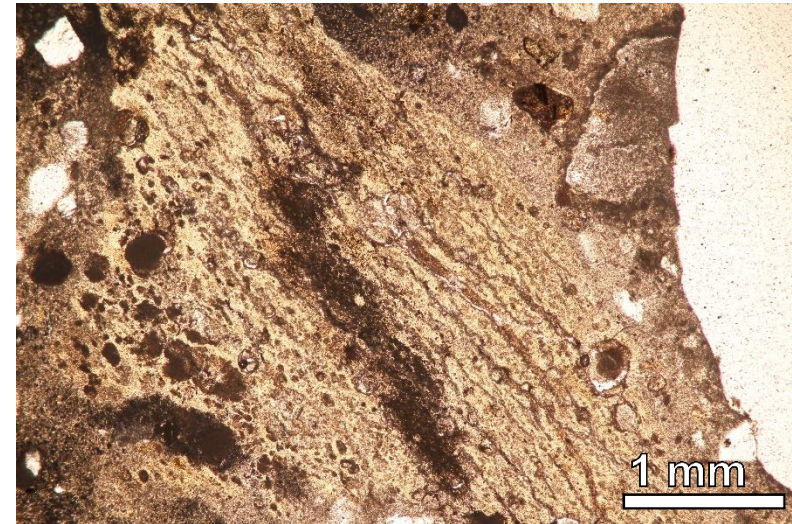
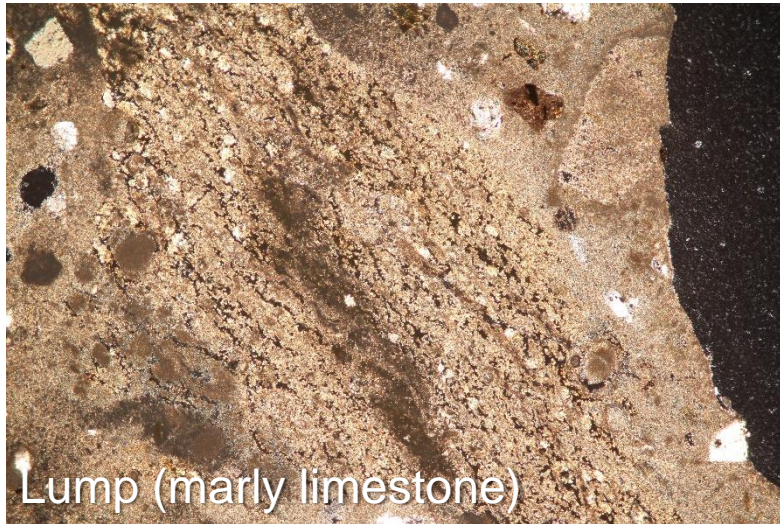
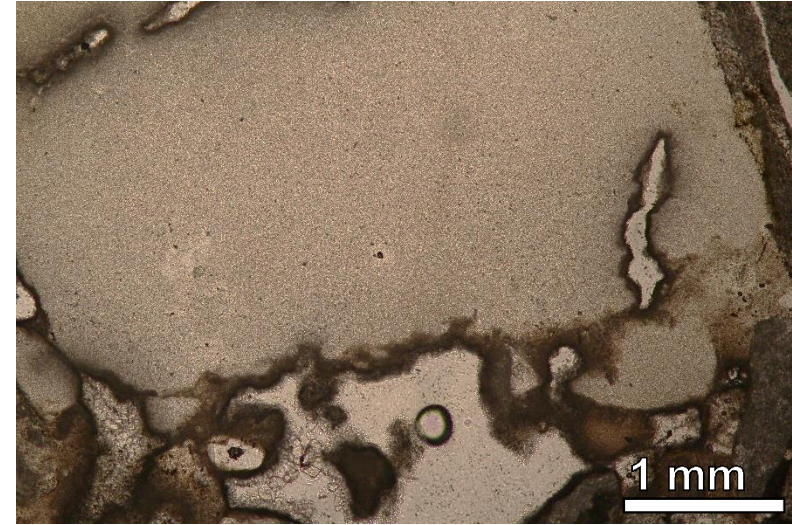
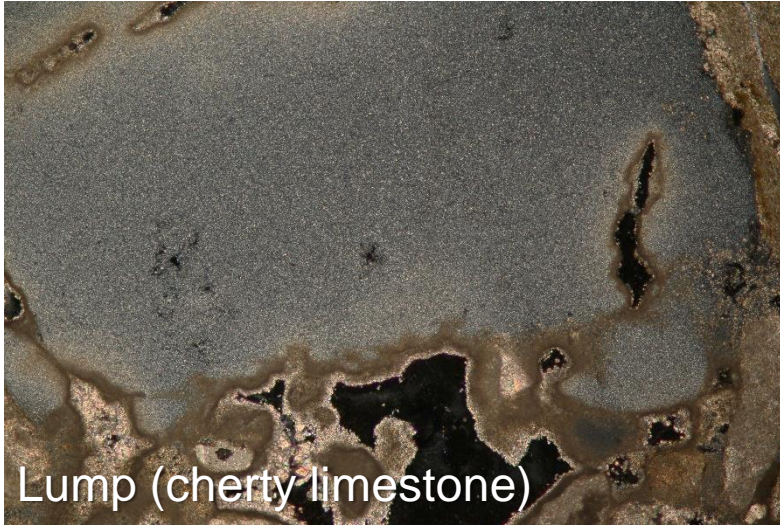
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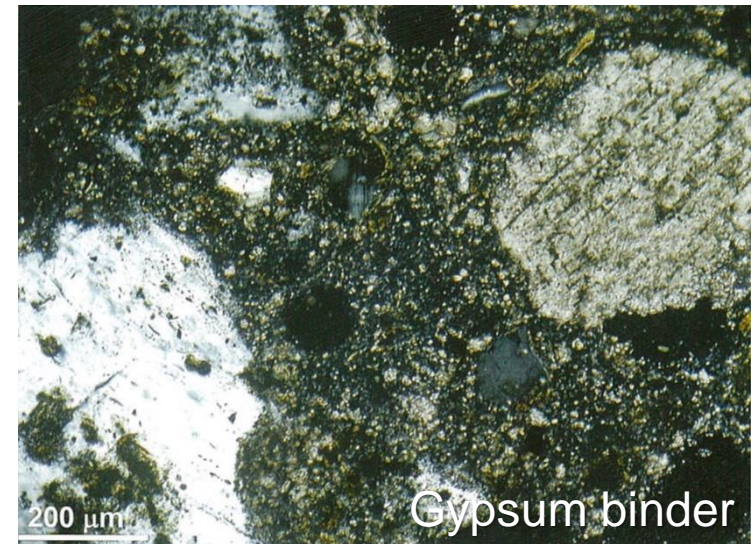
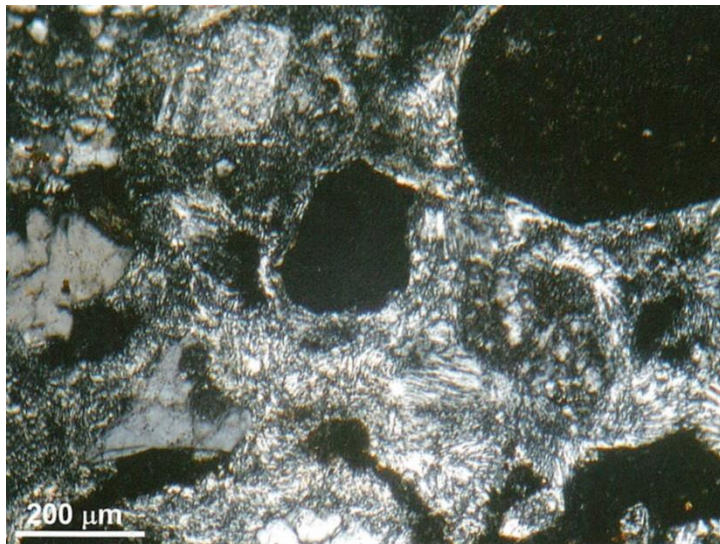
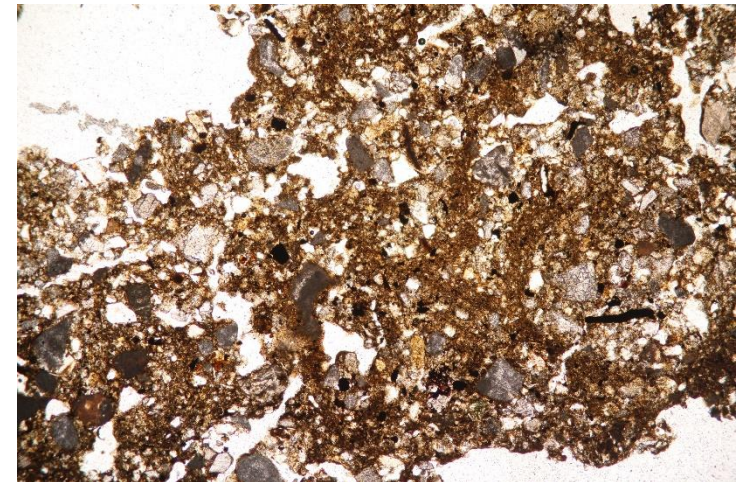
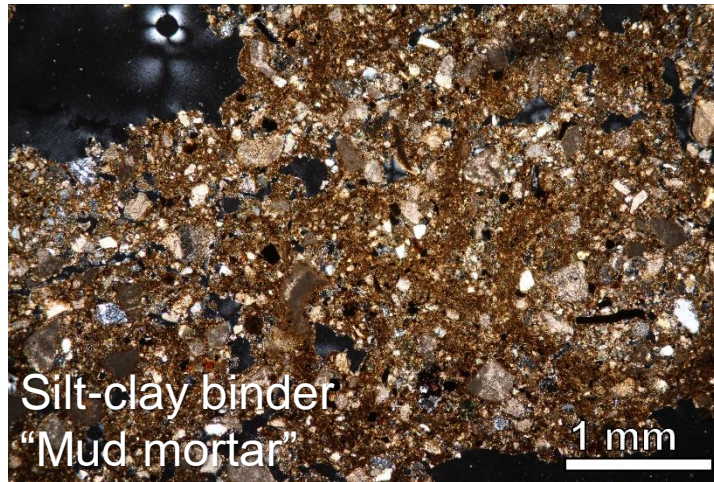
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Mineralogical composition

Interactions with the aggregate (reaction rims, etc.).

Lumps (type, morphology)



Pecchioni et al. 2014

Pecchioni et al. 2014

Petrographic analysis of binding composites

BINDER

Texture

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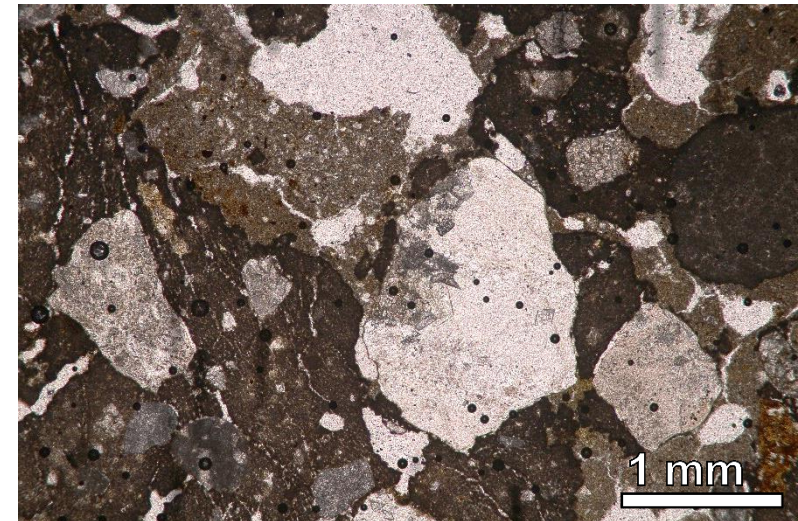
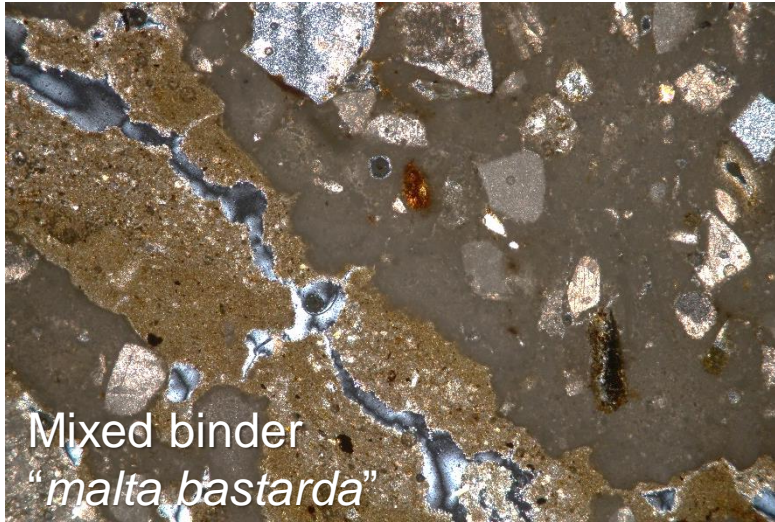
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Mineralogical composition

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Lumps (type, morphology)



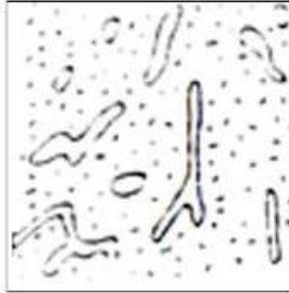
Petrographic analysis of binding composites

VOIDS

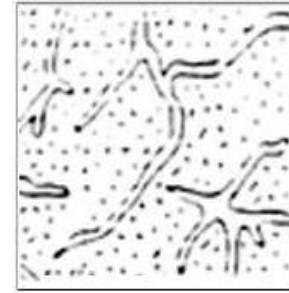
Location

Form

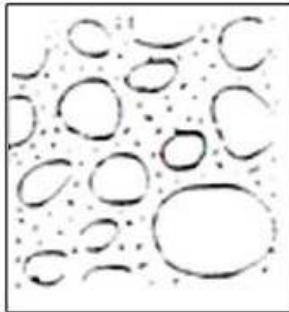
Volume %



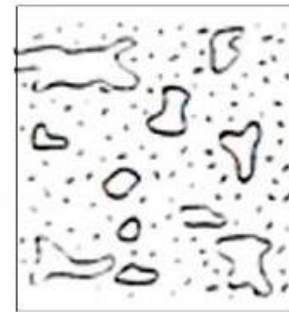
Channels



Planar Voids



Vesicles

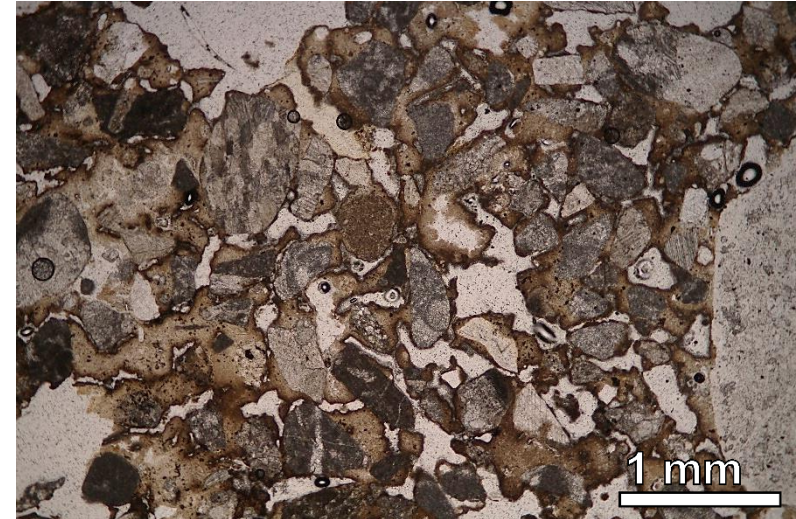


Vughs

Kemp 1995

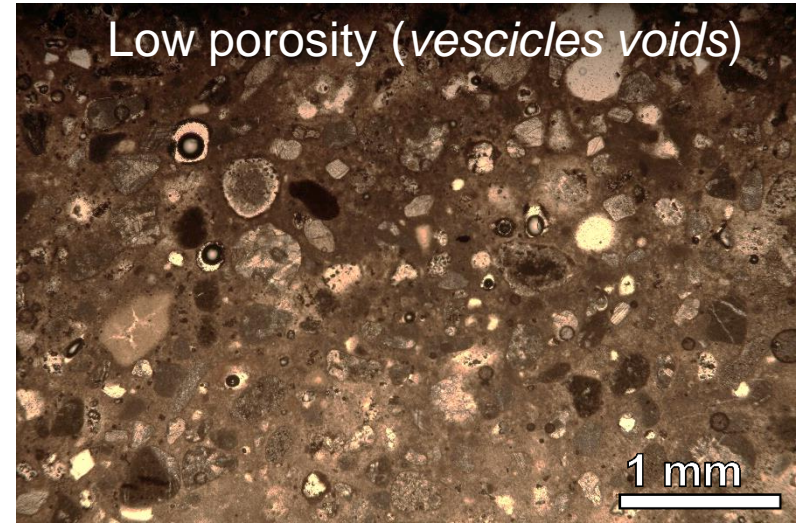
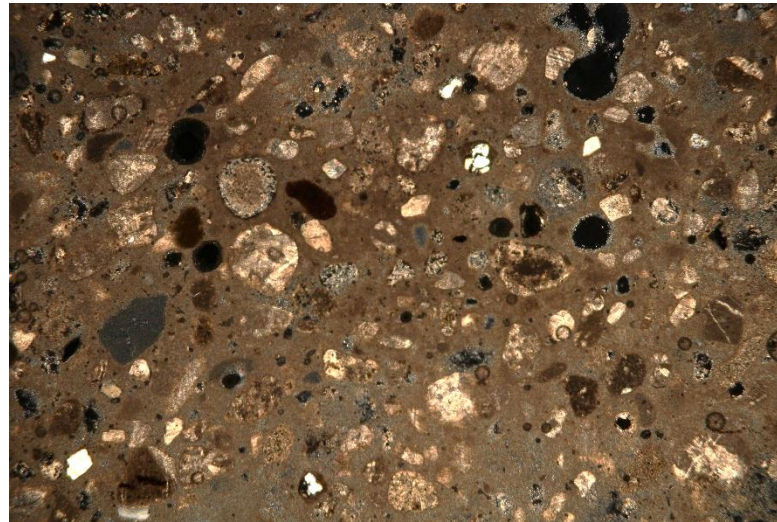
Petrographic analysis of binding composites

VOIDS



Location

Form



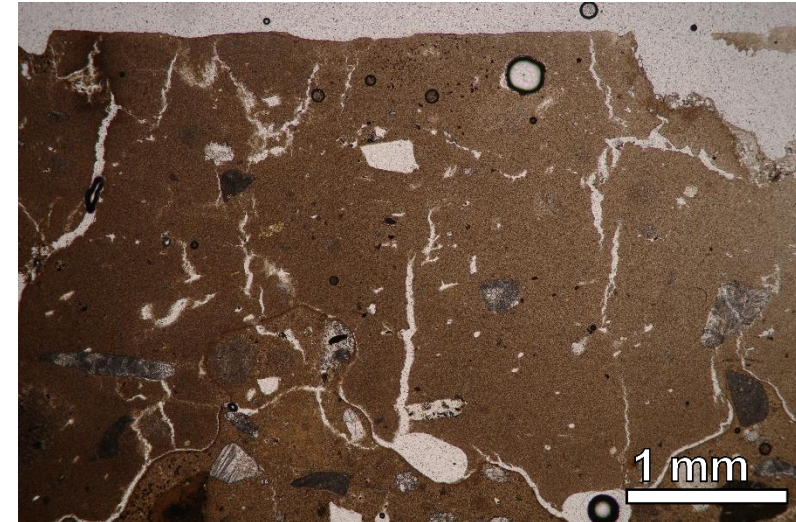
Volume %

Petrographic analysis of binding composites

VOIDS



Distributed porosity (*channel voids*)

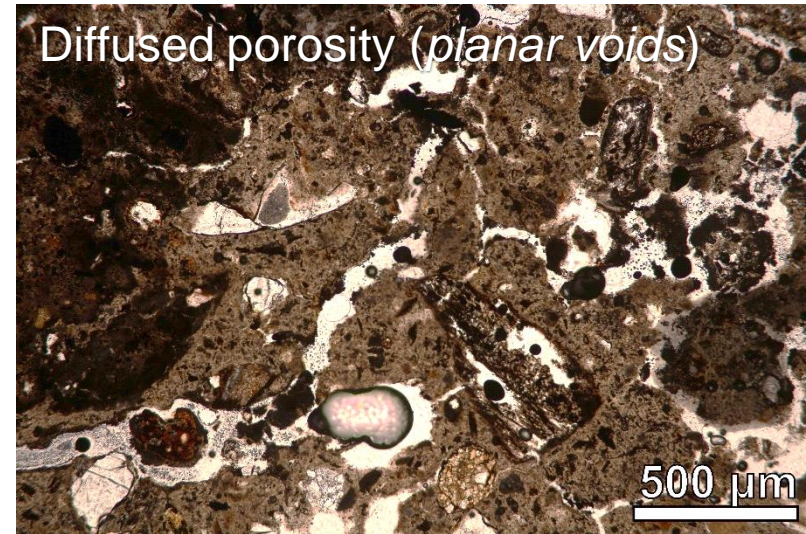
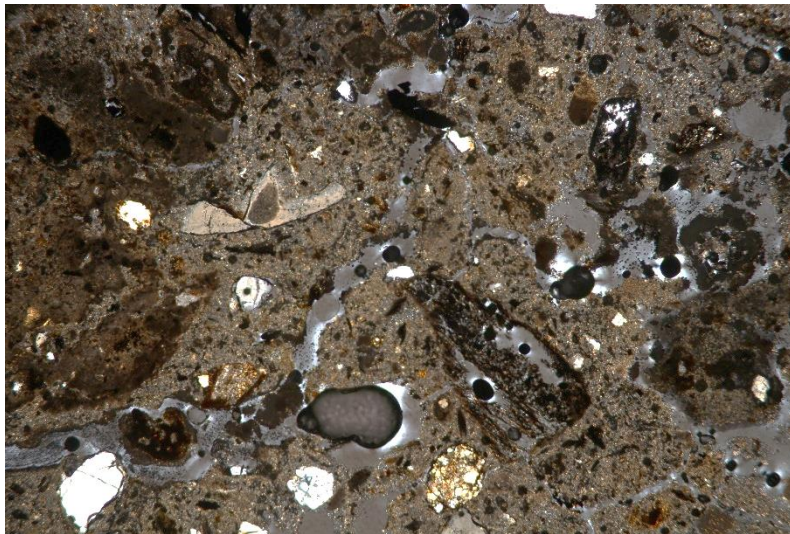


Diffused porosity (*planar voids*)

Location

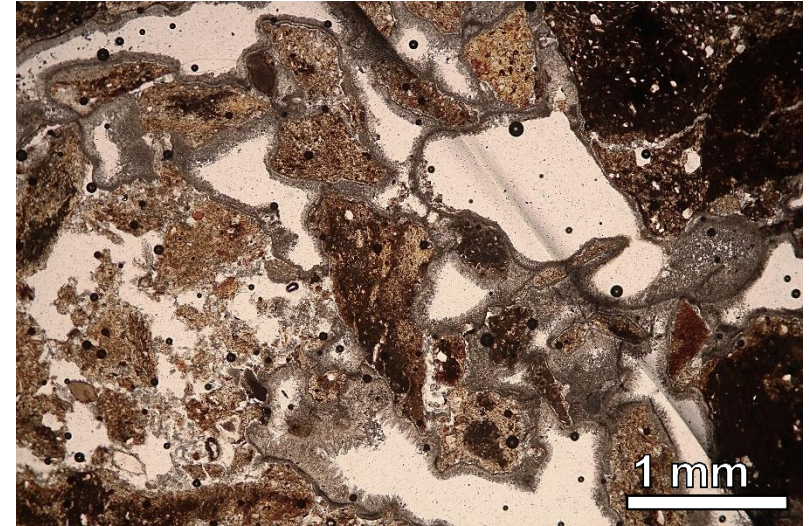
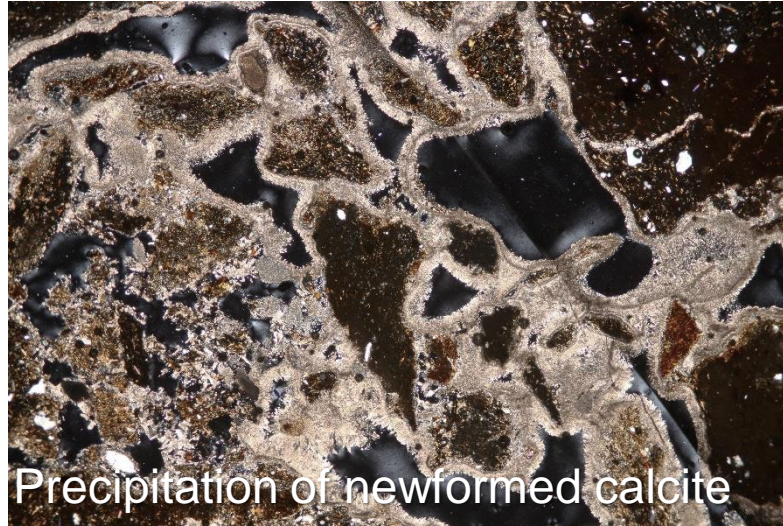
Form

Volume %



Petrographic analysis of binding composites

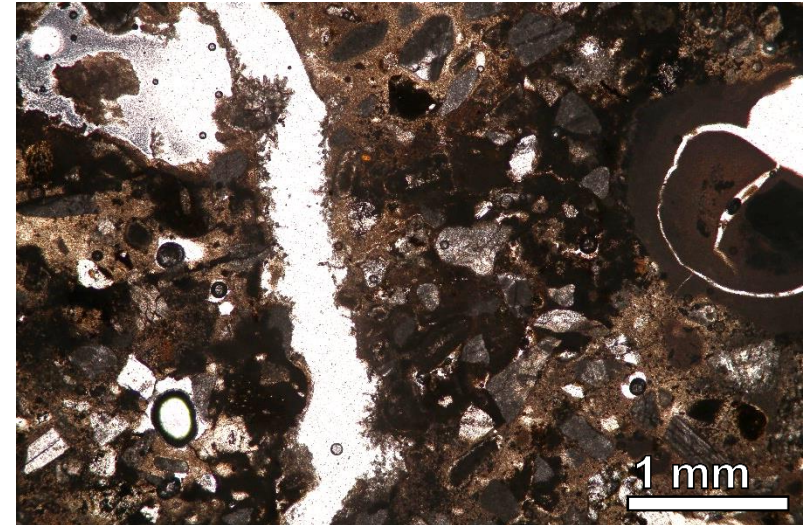
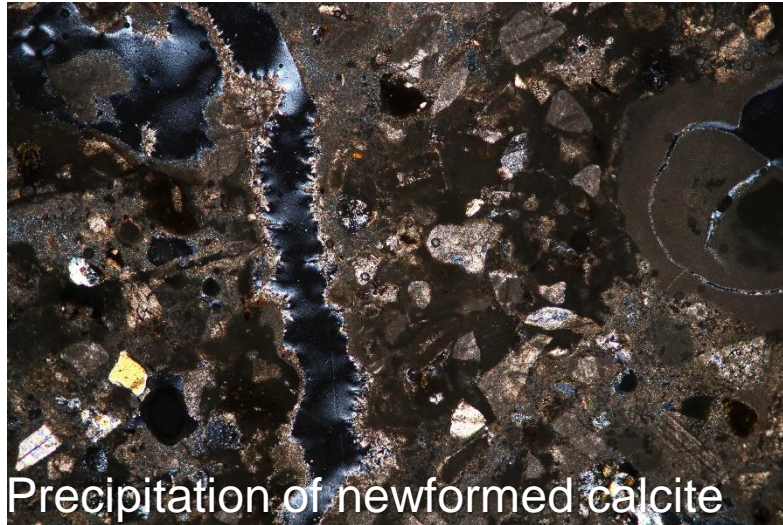
VOIDS



Location

Form

Volume %



Petrographic analysis of binding composites

AGGREGATE

- Grain size
- Sorting / Distribution
- Form (natural, from comminution)
- Sphericity
- Roundness
- Areal distribution (homogeneous, banded, etc.)
- Orientation
- Presence of reaction rims
- Mineralogical and petrographic composition

ϕ scale	Size range (metric)	Size range (approx. inches)	Aggregate name (Wentworth class)	Other names
<-8	>256 mm	>10.1 in	Boulder	
-6 to -8	64-256 mm	2.5-10.1 in	Cobble	
-5 to -6	32-64 mm	1.26-2.5 in	Very coarse gravel	Pebble
-4 to -5	16-32 mm	0.63-1.26 in	Coarse gravel	Pebble
-3 to -4	8-16 mm	0.31-0.63 in	Medium gravel	Pebble
-2 to -3	4-8 mm	0.157-0.31 in	Fine gravel	Pebble
-1 to -2	2-4 mm	0.079-0.157 in	Very fine gravel	Granule
0 to -1	1-2 mm	0.039-0.079 in	Very coarse sand	
1 to 0	0.5-1 mm	0.020-0.039 in	Coarse sand	
2 to 1	0.25-0.5 mm	0.010-0.020 in	Medium sand	
3 to 2	125-250 μ m	0.0049-0.010 in	Fine sand	
4 to 3	62.5-125 μ m	0.0025-0.0049 in	Very fine sand	
8 to 4	3.9-62.5 μ m	0.00015-0.0025 in	Silt	Mud
10 to 8	0.98-3.9 μ m	3.8×10^{-5} -0.00015 in	Clay	Mud
20 to 10	0.95-977 nm	3.8×10^{-8} - 3.8×10^{-5} in	Colloid	Mud

Wentworth 1922



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DIPARTIMENTO
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Materials Properties, Use and Conservation:
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Petrographic analysis of binding composites

AGGREGATE

Grain size

Sorting / Distribution

Form (natural, from comminution)

- Sphericity

- Roundness

Area distribution
(homogeneous, banded, etc.)

Orientation

Presence of reaction
rims

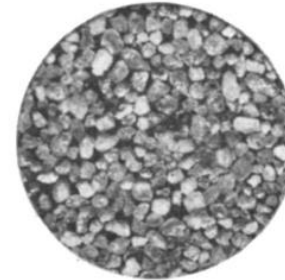
Mineralogical and
petrographic
composition



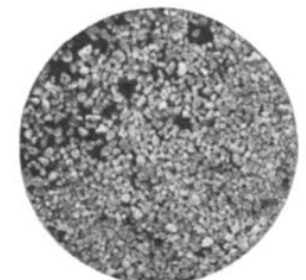
8-4 mm
Pebble gravel



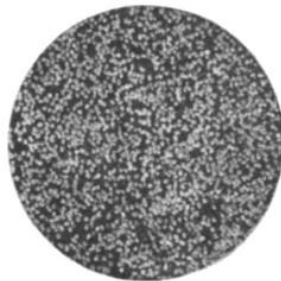
4-2 mm
Granule grave



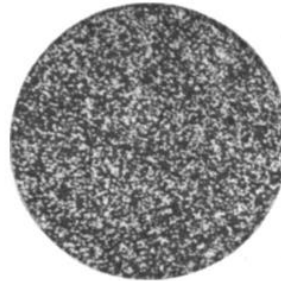
2-1 mm
Very coarse sand



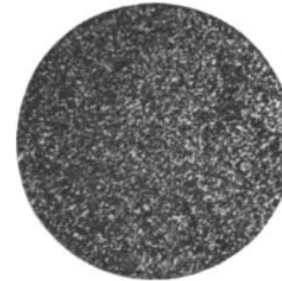
1-1/2 mm
Coarse sand



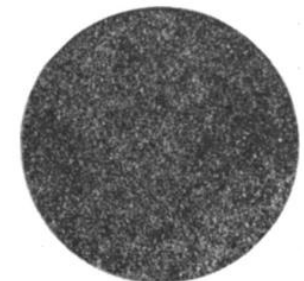
1/2-1/4 mm
Medium sand



1/4-1/8 mm
Fine sand



1/8-1/16 mm
Very fine sand



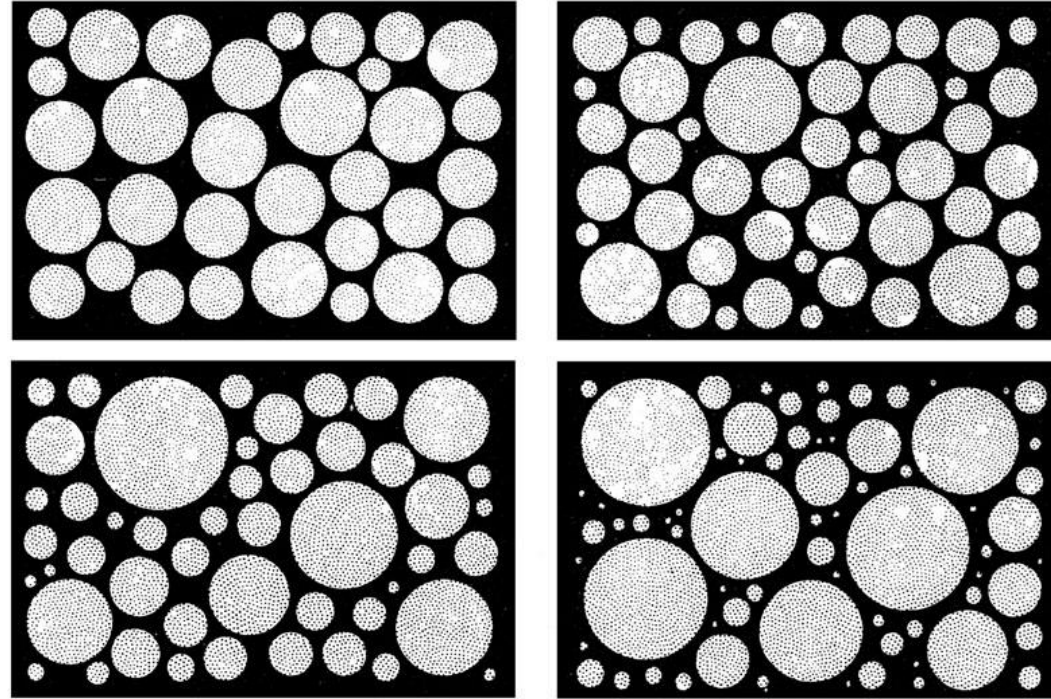
1/16-1/32 mm
Silt

Wentworth 1922

Petrographic analysis of binding composites

- AGGREGATE**
- Grain size
- Sorting / Distribution
- Form (natural, from comminution)
 - Sphericity
 - Roundness
- Area distribution (homogeneous, banded, etc.)
- Orientation
- Presence of reaction rims
- Mineralogical and petrographic composition

GRAIN SIZE AND SORTING



SPHERICITY AND ROUNDNESS

alta sfericità						
bassa sfericità						
	molto angoloso	angoloso	sub-angoloso	sub-arrotondato	arrotondato	molto arrotondato



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**Materials Properties, Use and Conservation:
Construction Materials and Binders**

Petrographic analysis of binding composites

AGGREGATE

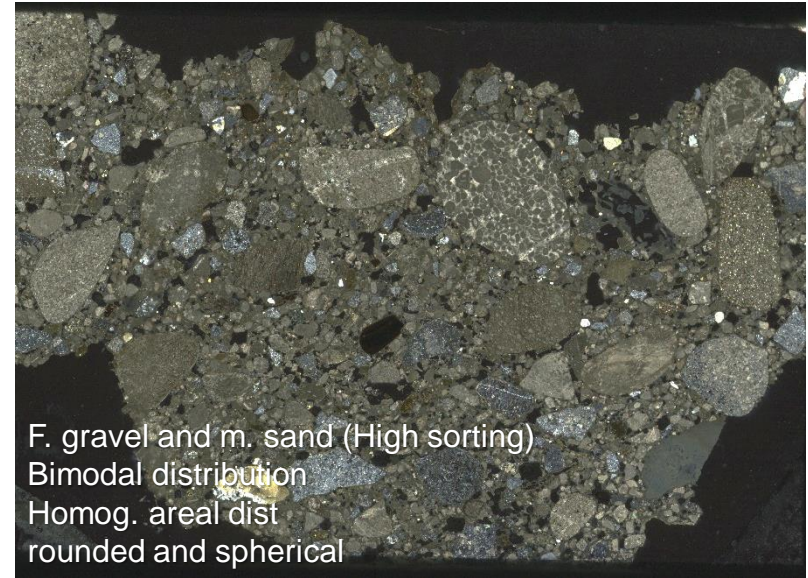
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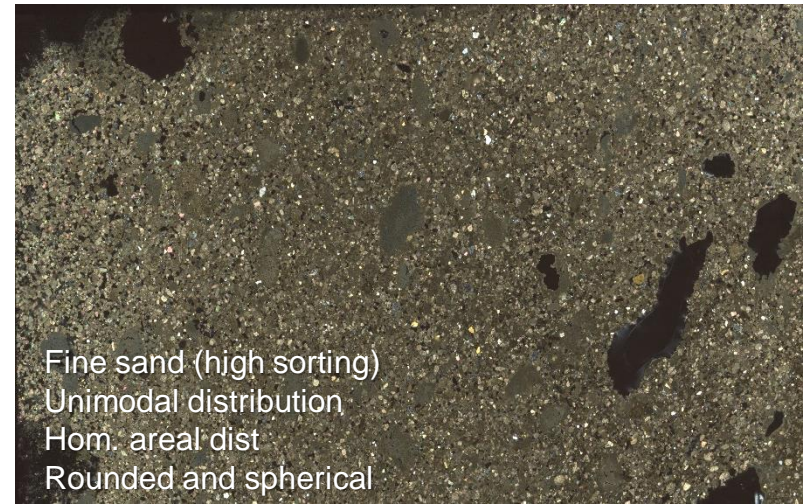
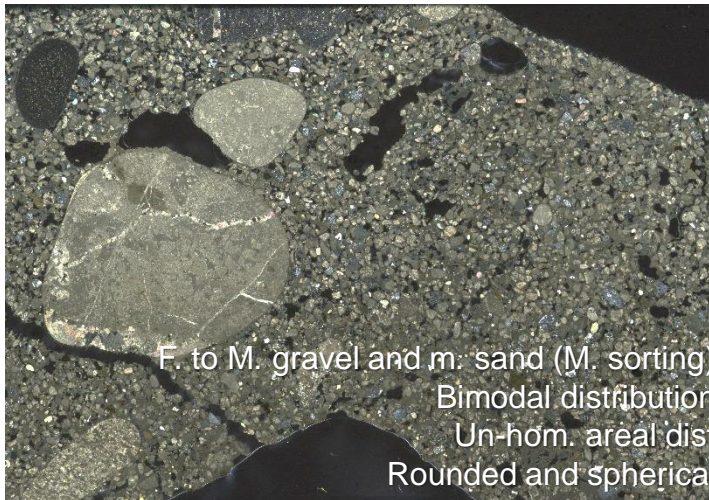
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Area distribution
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Mineralogical and petrographic composition

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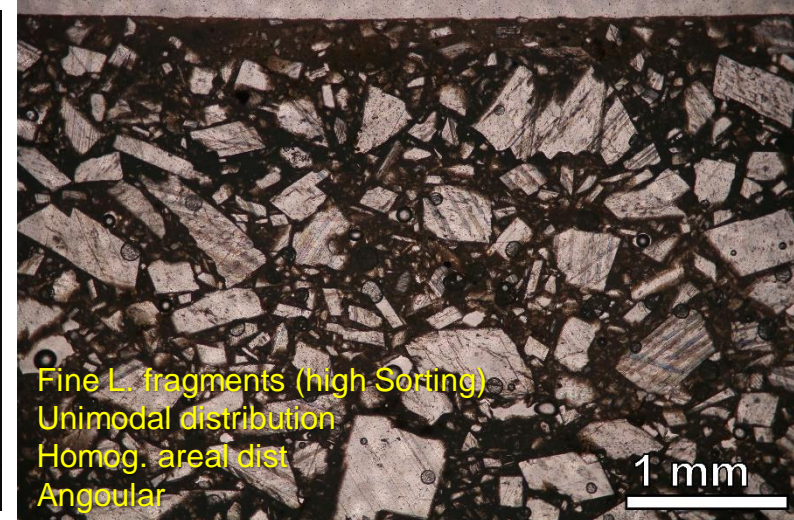
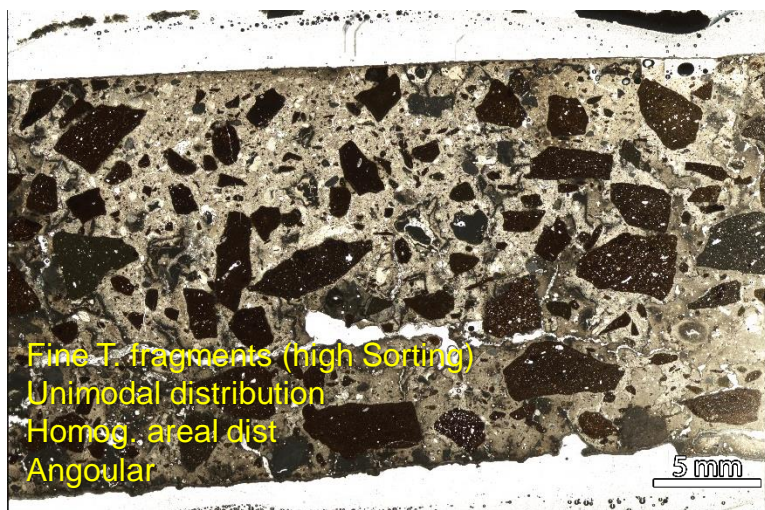
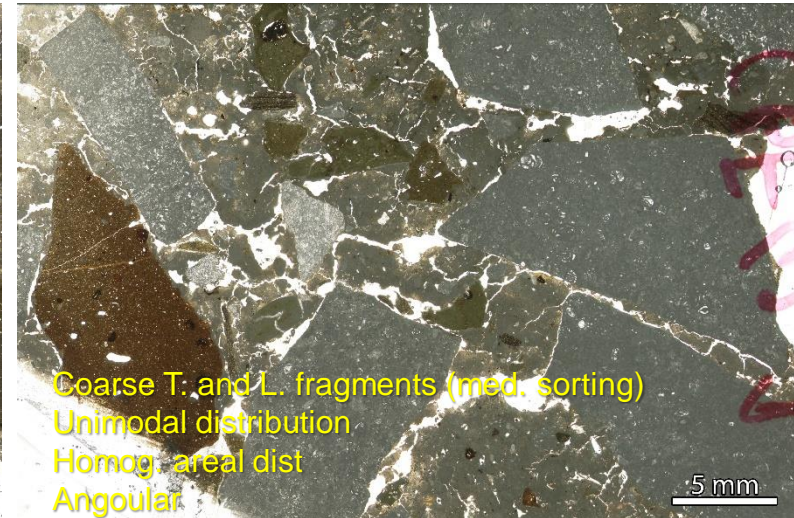
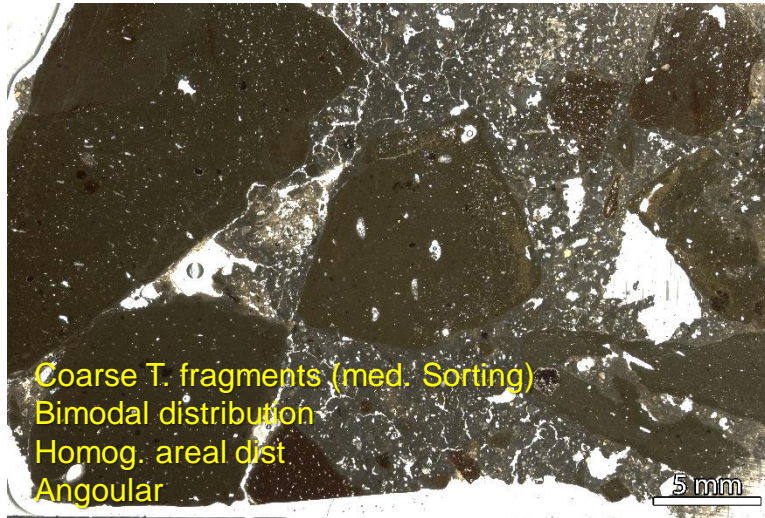
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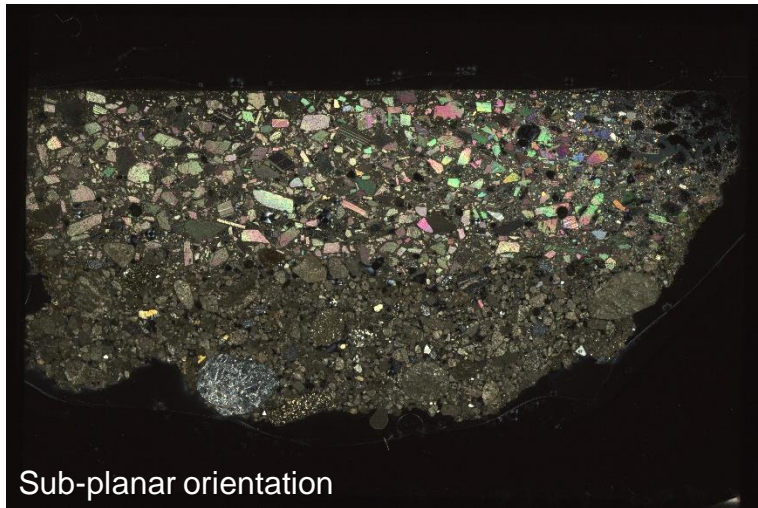
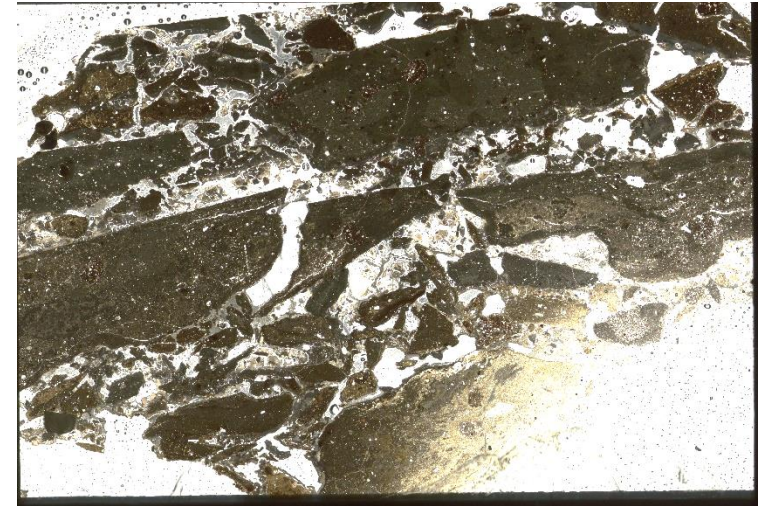
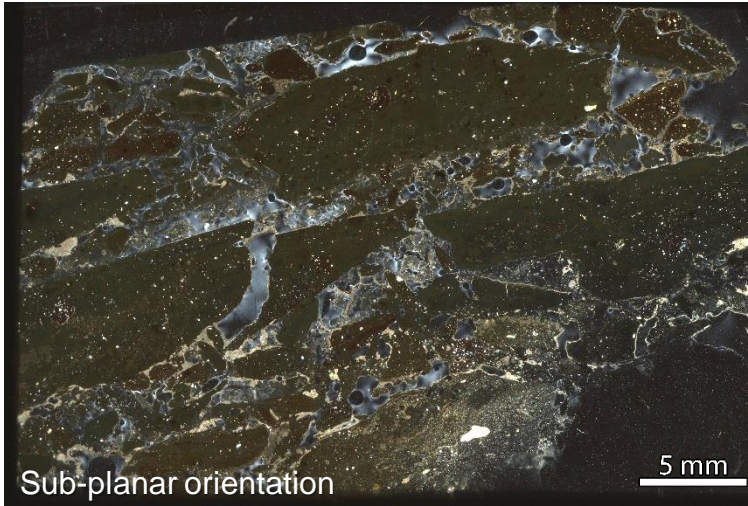
- Roundness

Area distribution
(homogeneous, banded, etc.)

Orientation

Presence of reaction
rims

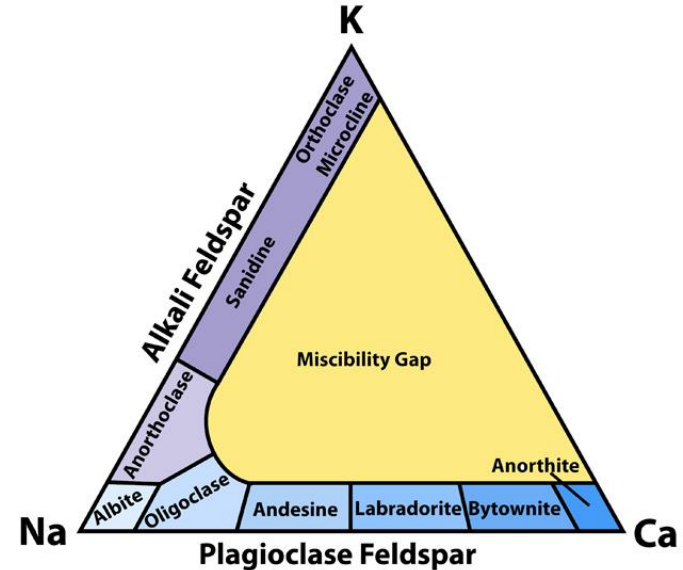
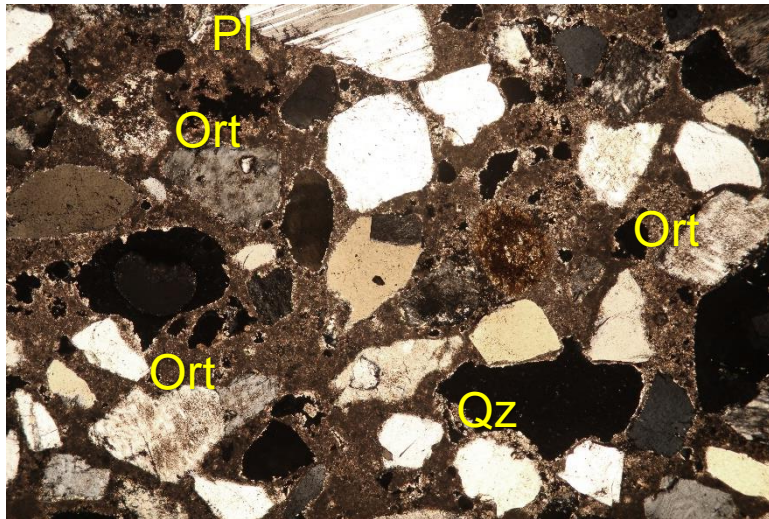
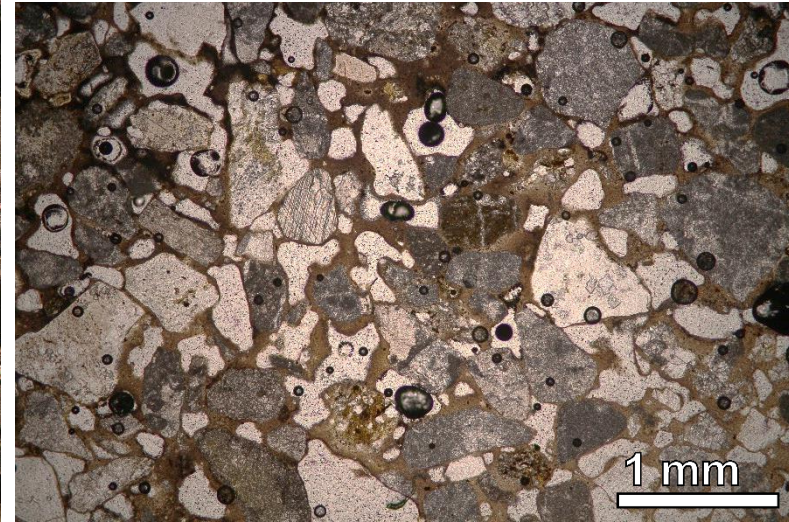
Mineralogical and
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Petrographic analysis of binding composites

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Petrographic analysis of binding composites

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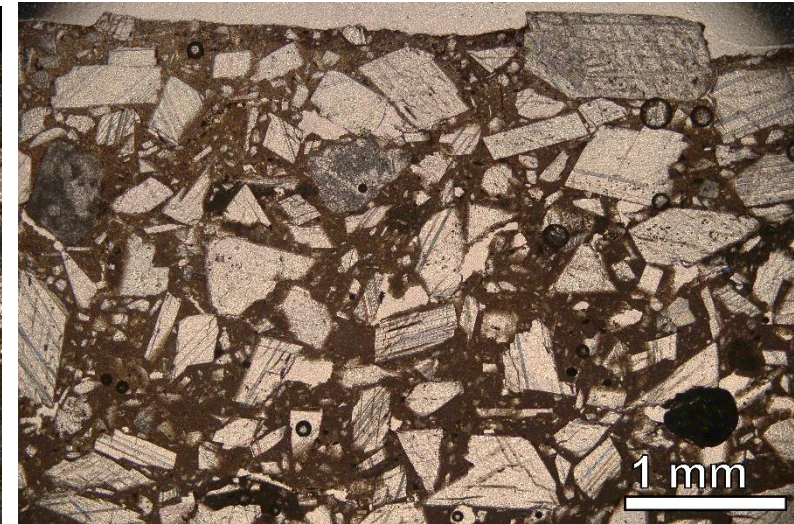
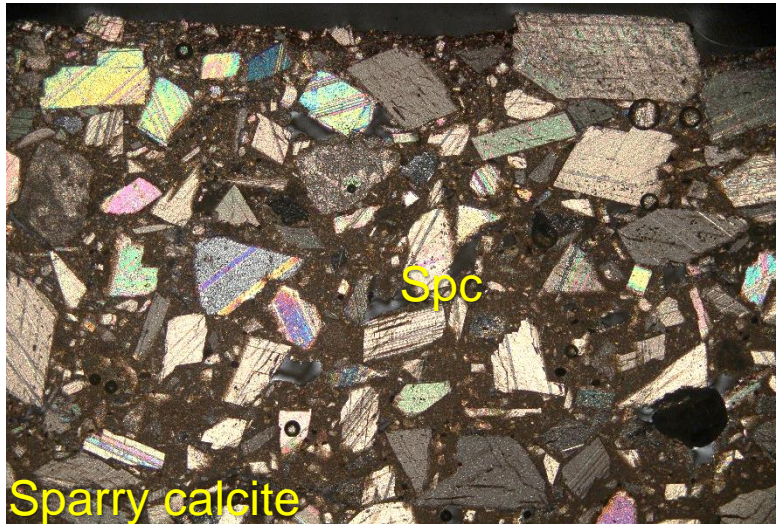
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Presence of reaction rims

Mineralogical and petrographic composition



Sparry calcite
vein in limestone



Petrographic analysis of binding composites

AGGREGATE

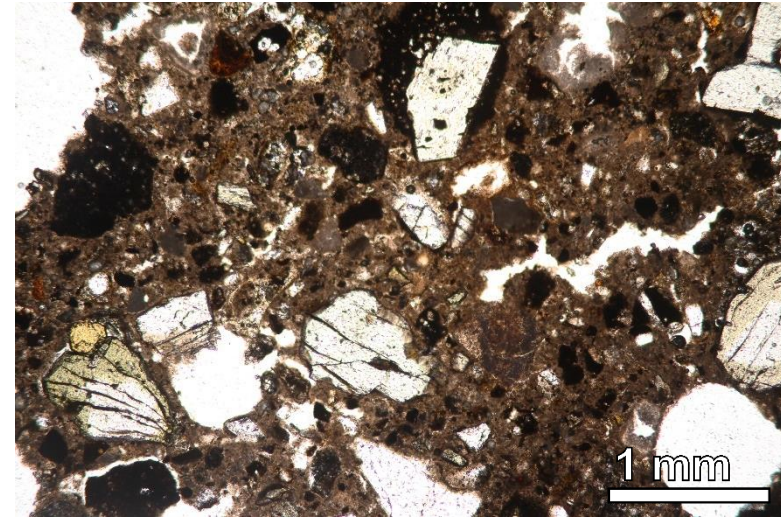
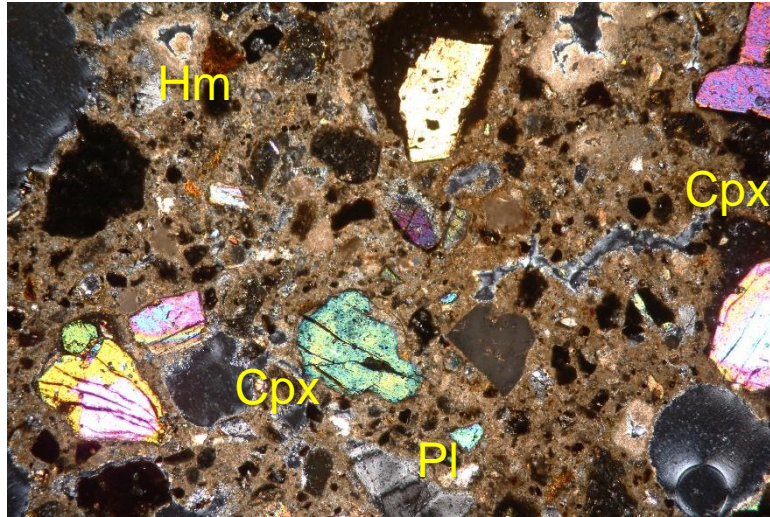
Grain size

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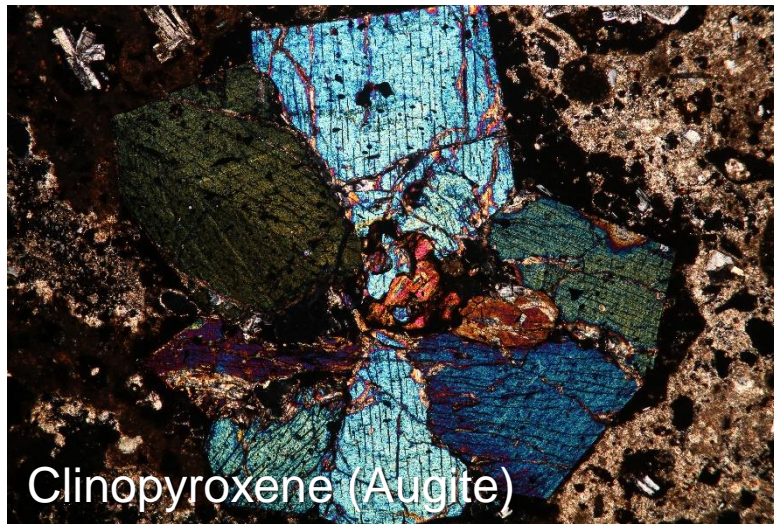
- Roundness



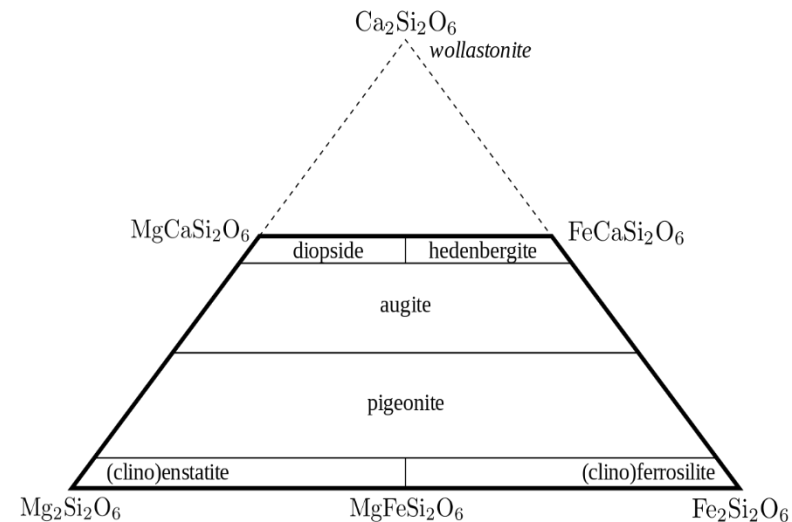
Area distribution (homogeneous, banded, etc.)

Orientation

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Mineralogical and petrographic composition



Petrographic analysis of binding composites

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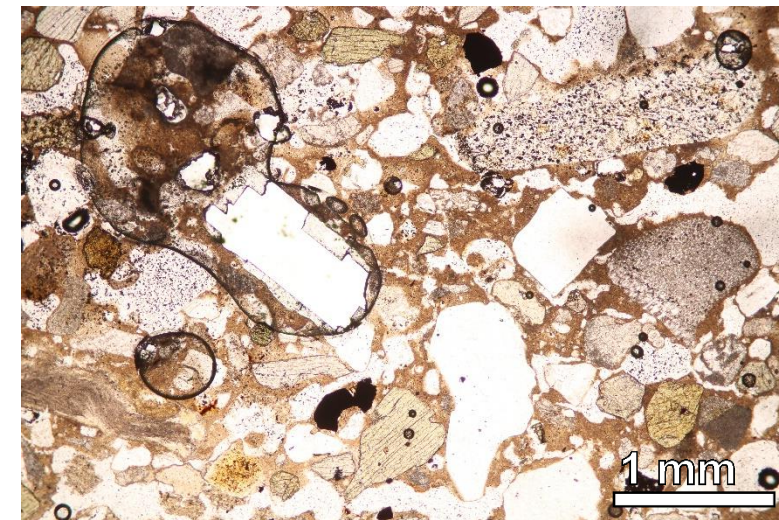
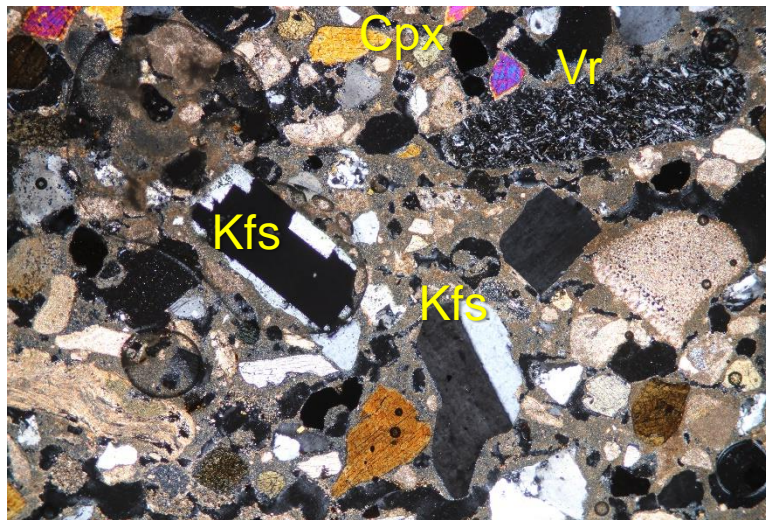
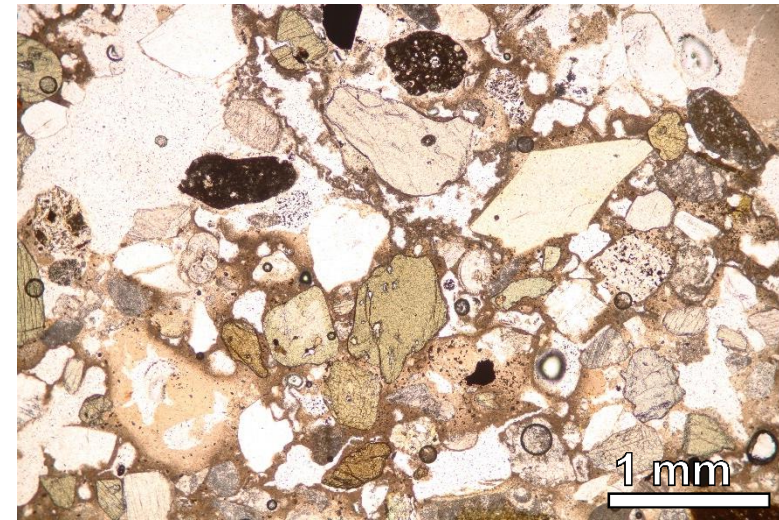
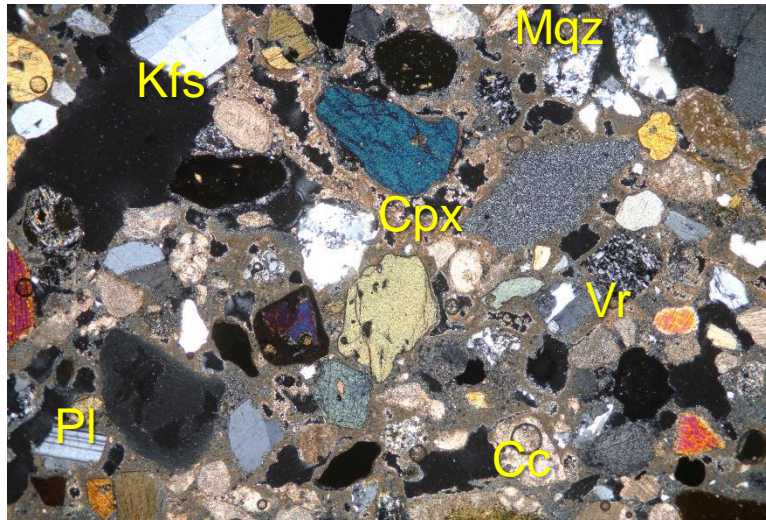
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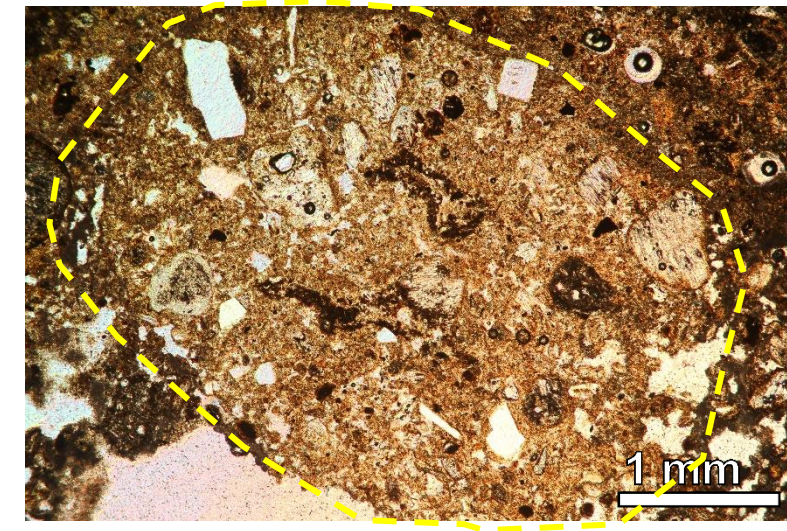
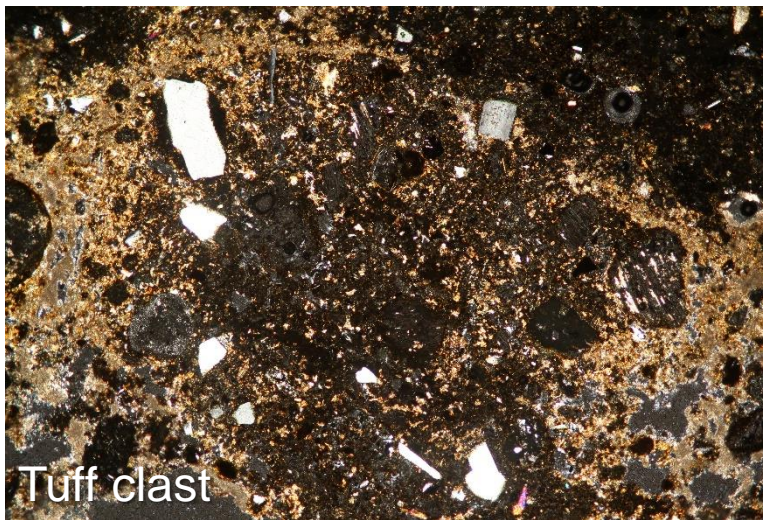
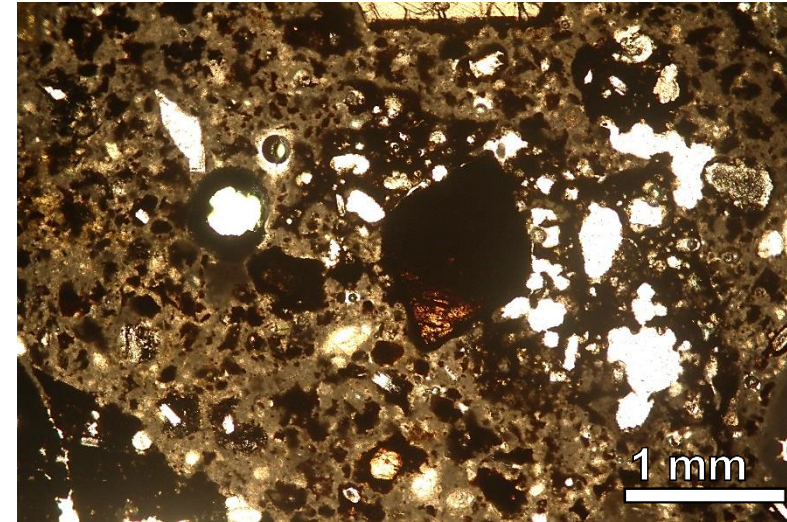
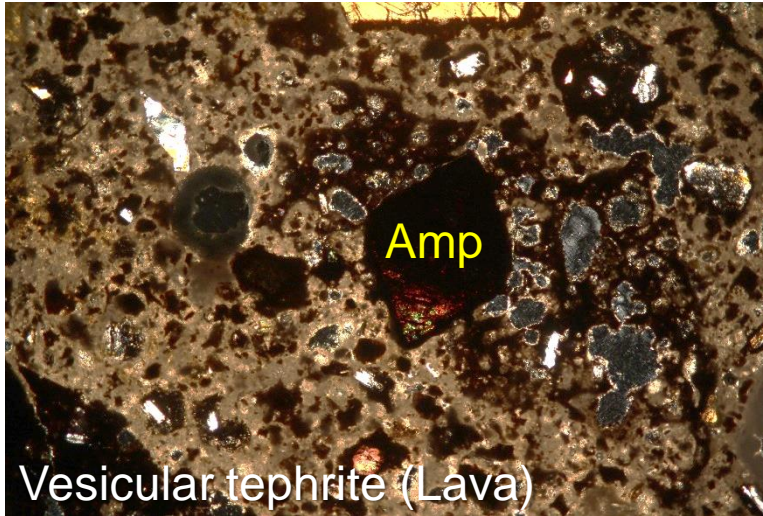
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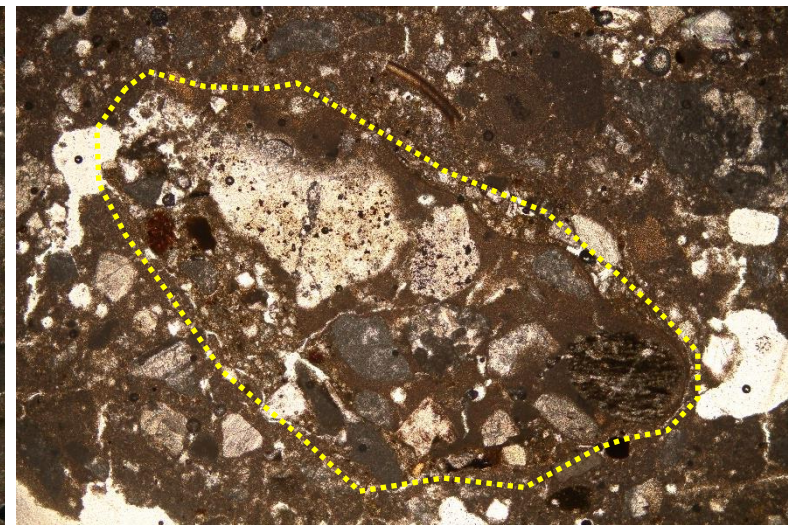
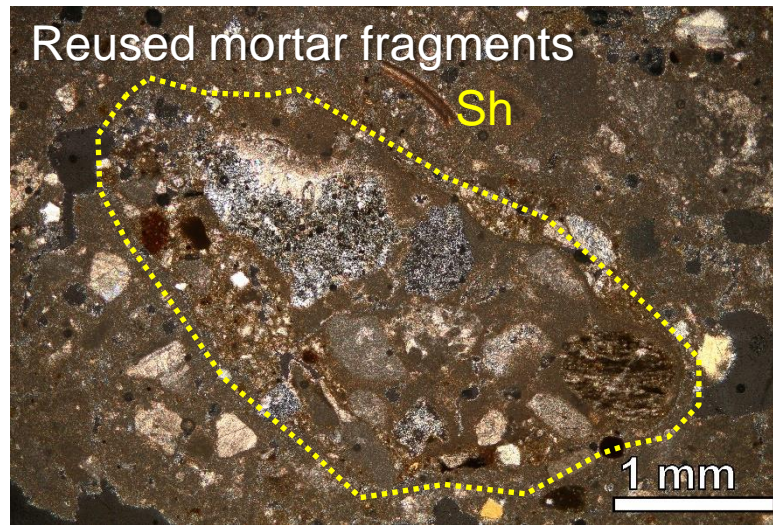
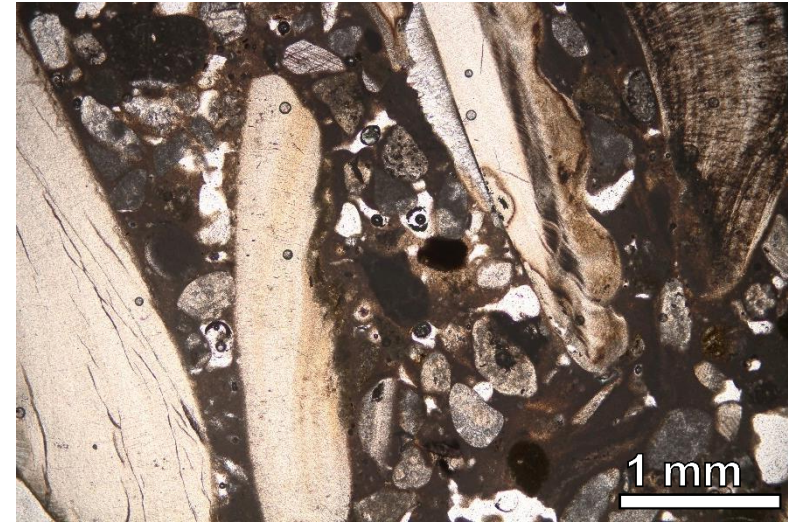
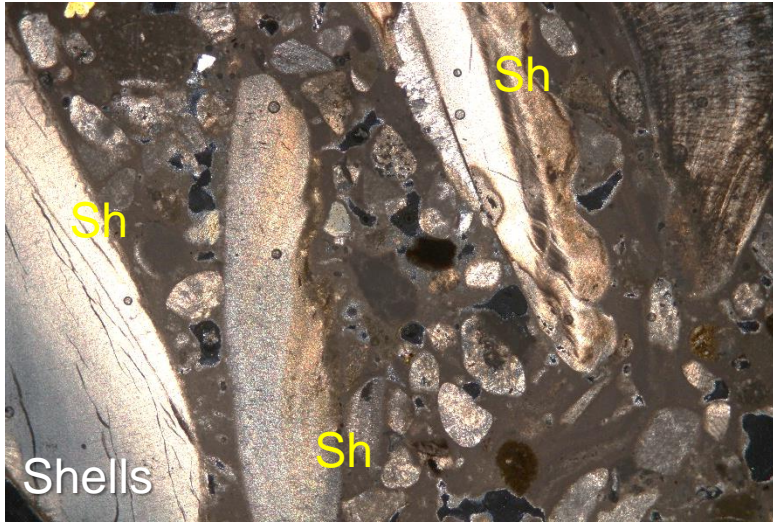
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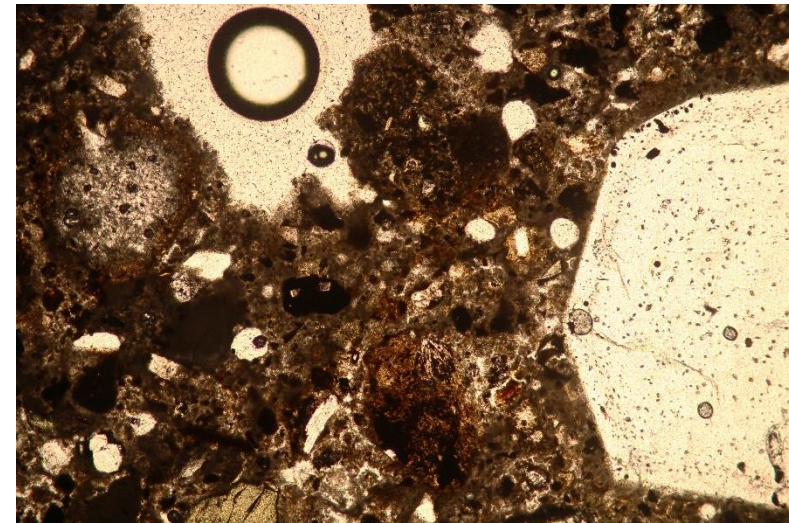
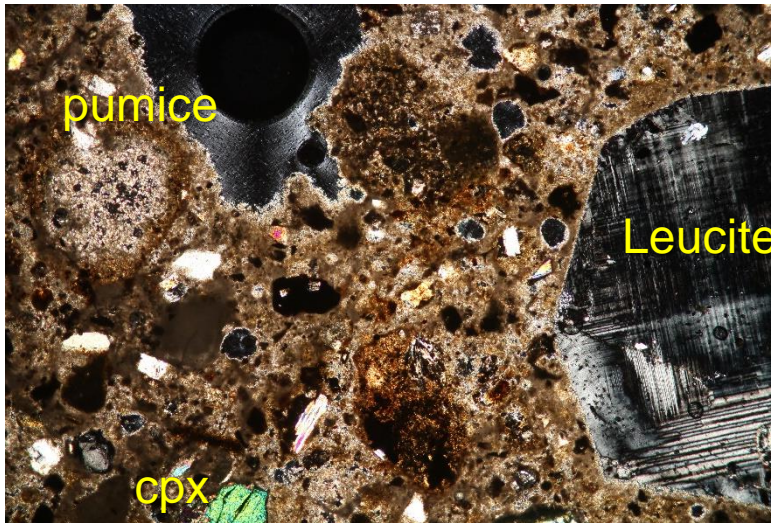
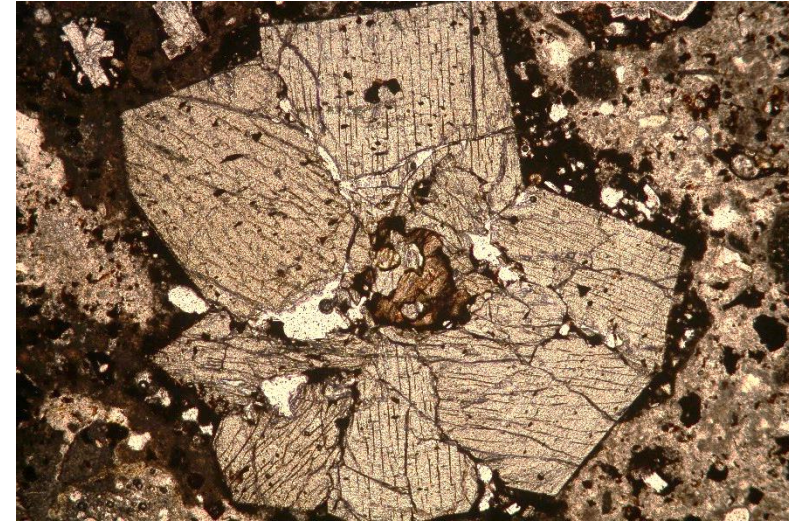
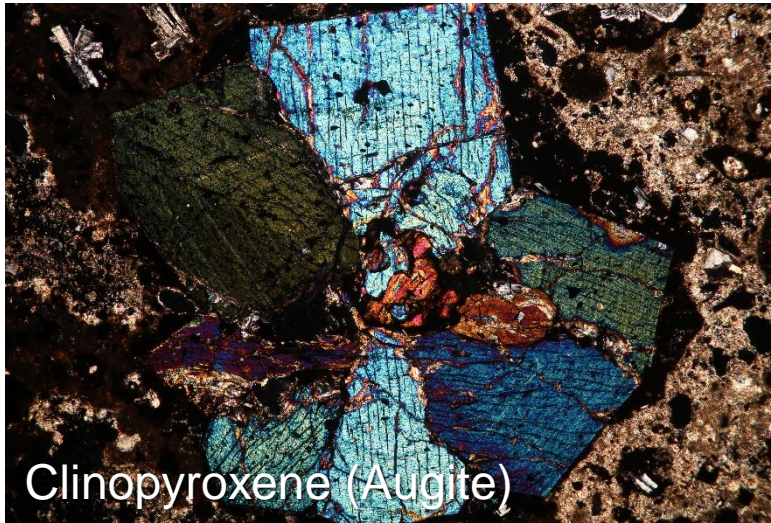
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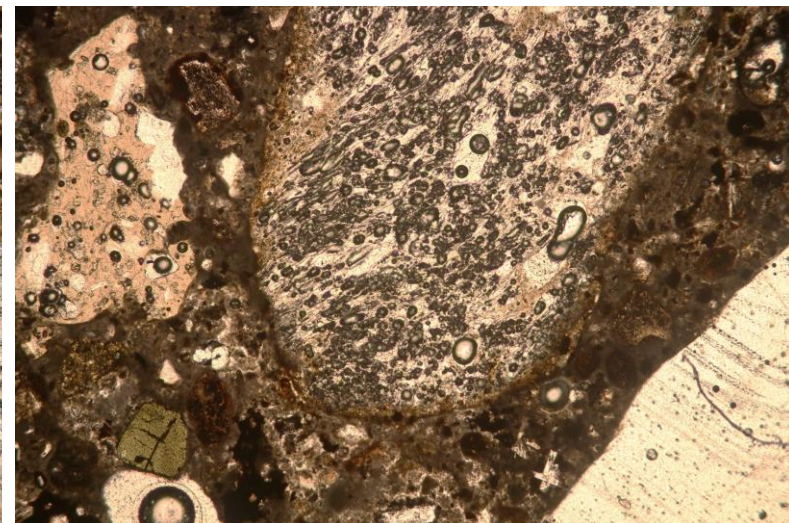
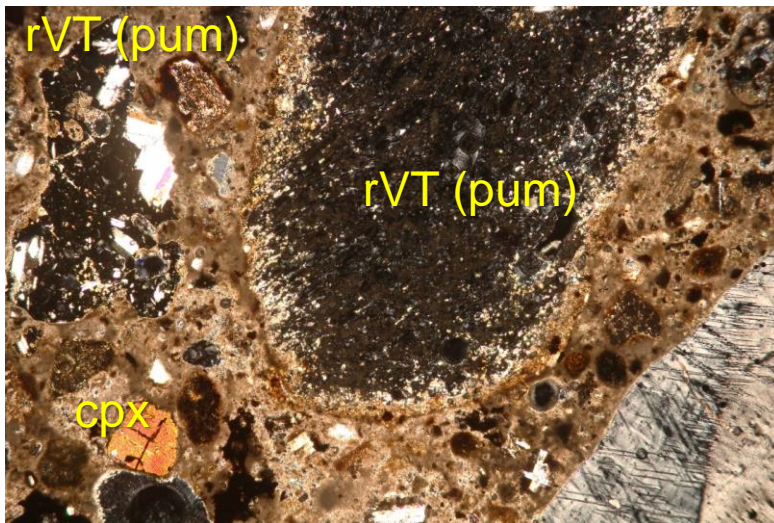
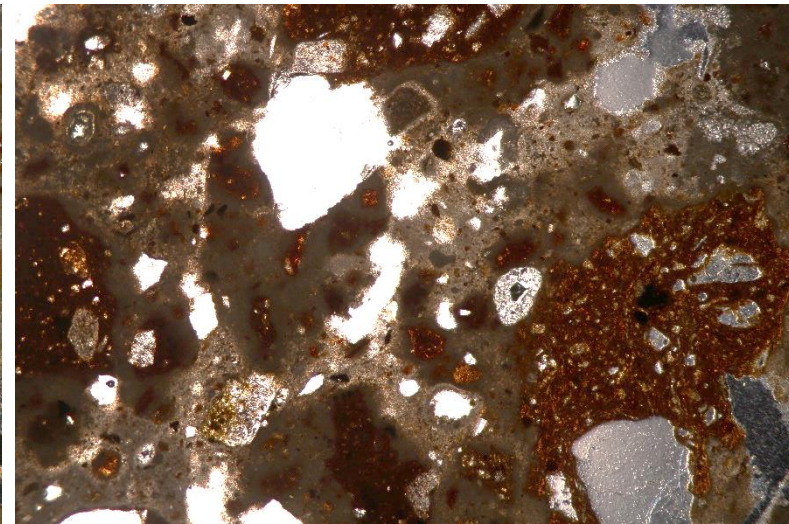
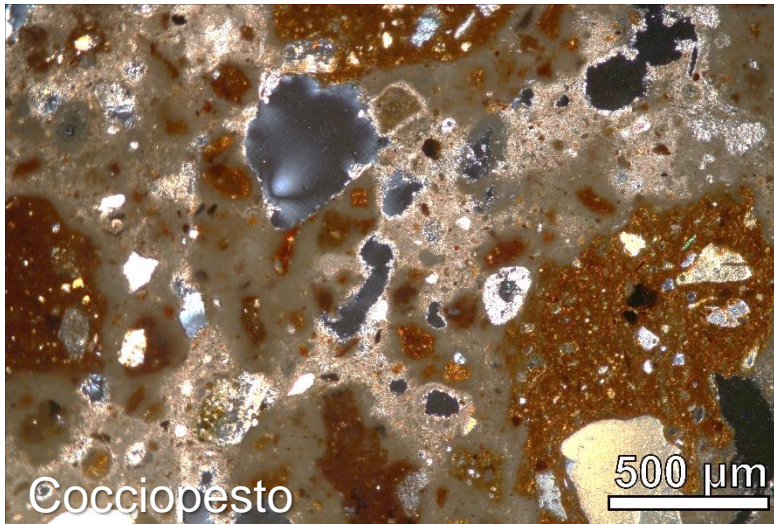
- Roundness

Area distribution
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Orientation

Presence of reaction
rims

Mineralogical and
petrographic
composition



Reacted volcanic tephra (pumice)

Petrographic analysis of binding composites

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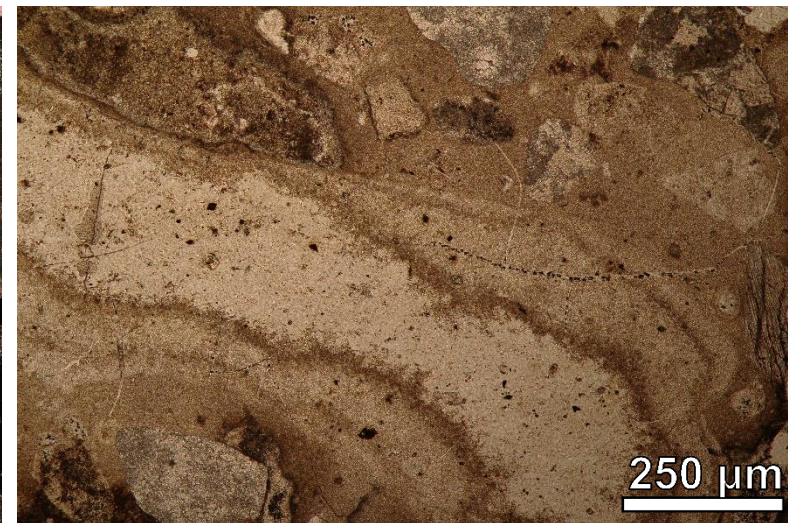
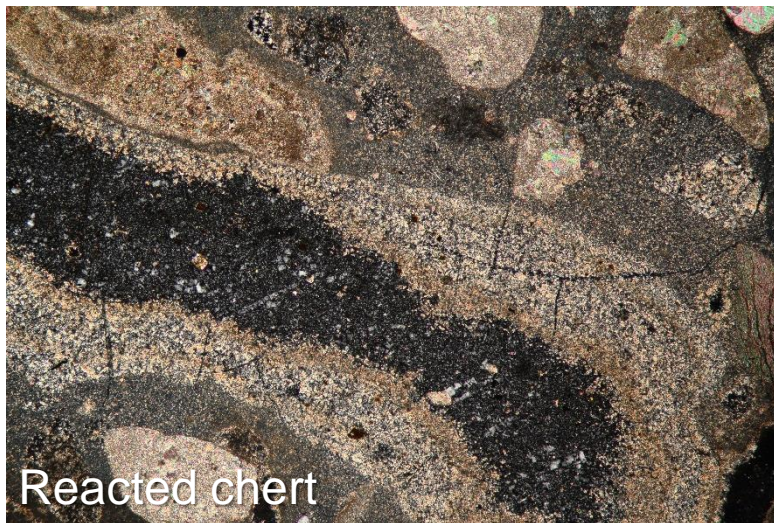
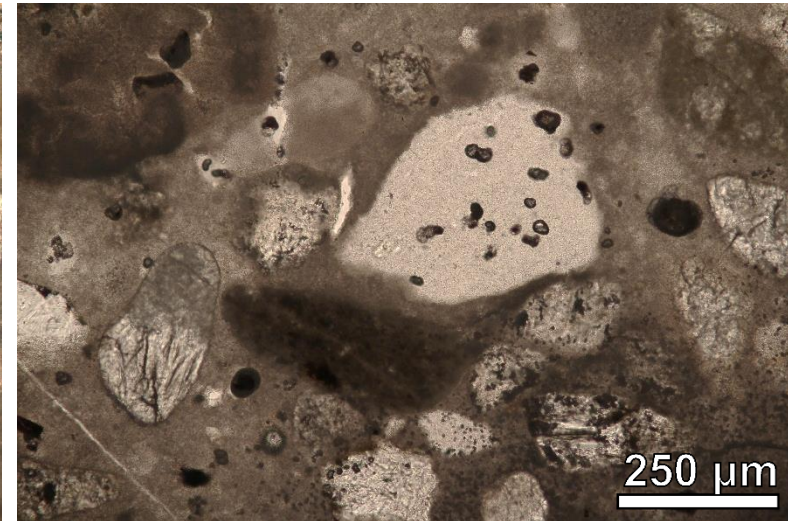
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Orientation

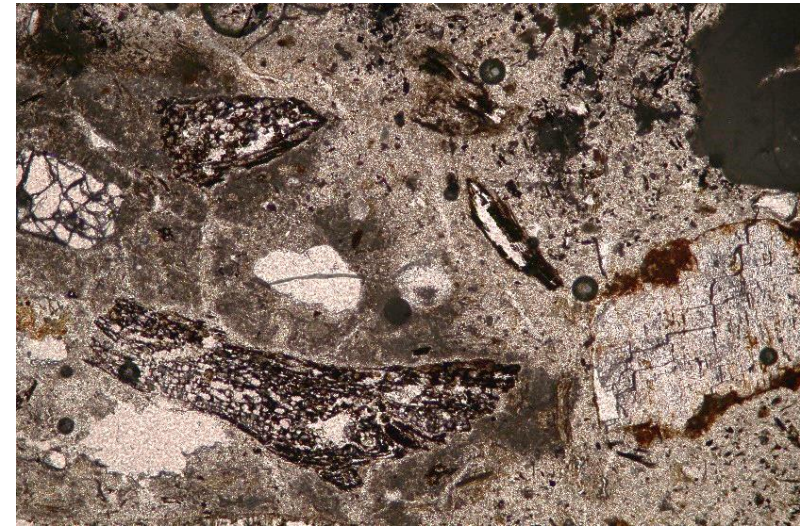
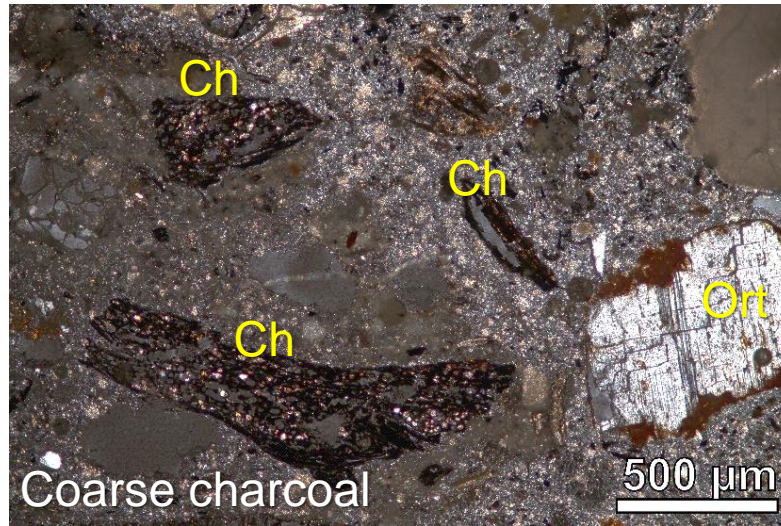
Presence of reaction
rims

Mineralogical and
petrographic
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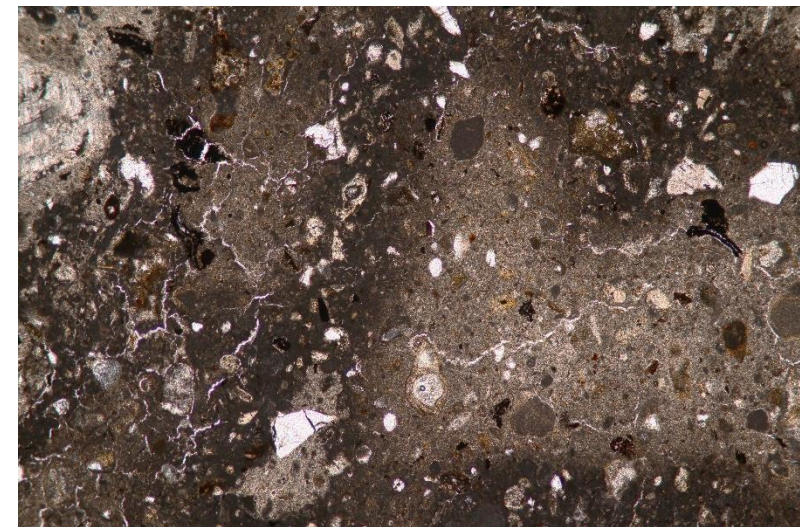
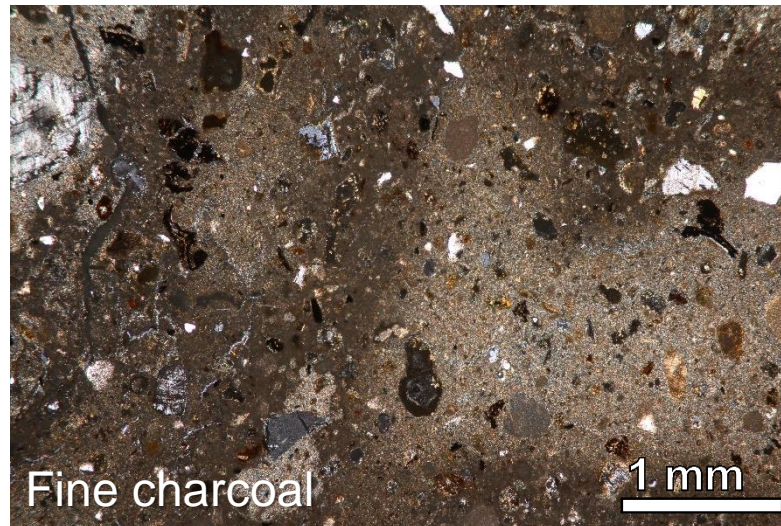


Petrographic analysis of binding composites

ADDITIVES



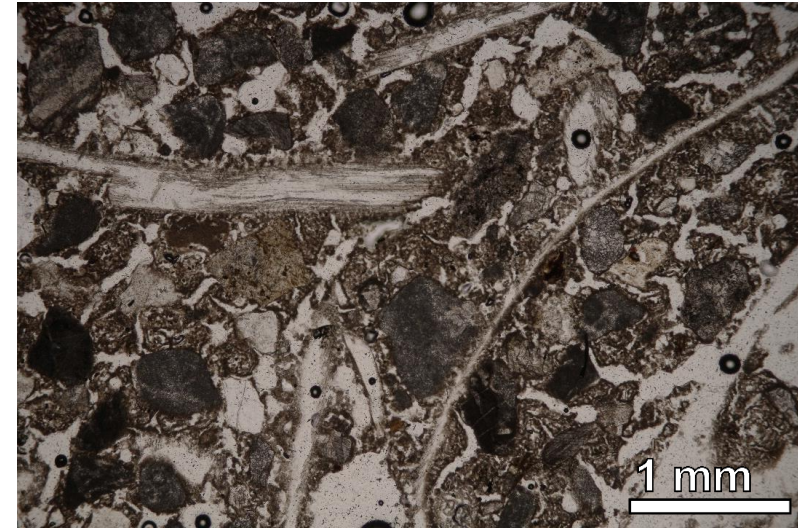
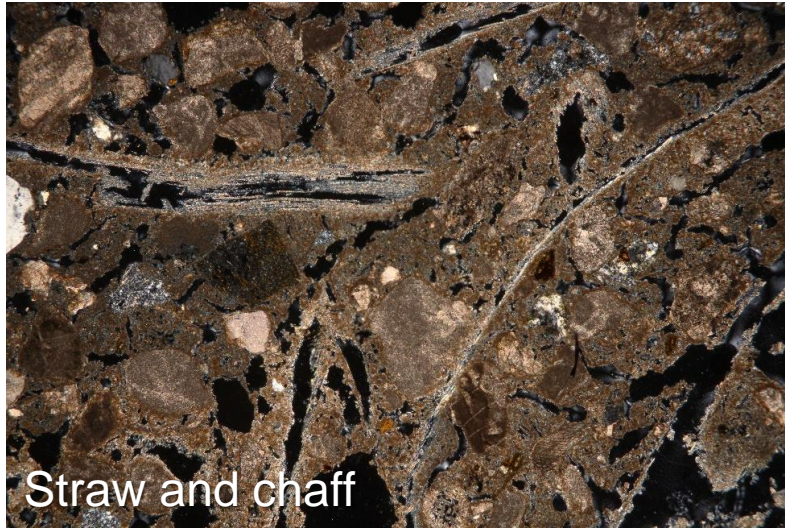
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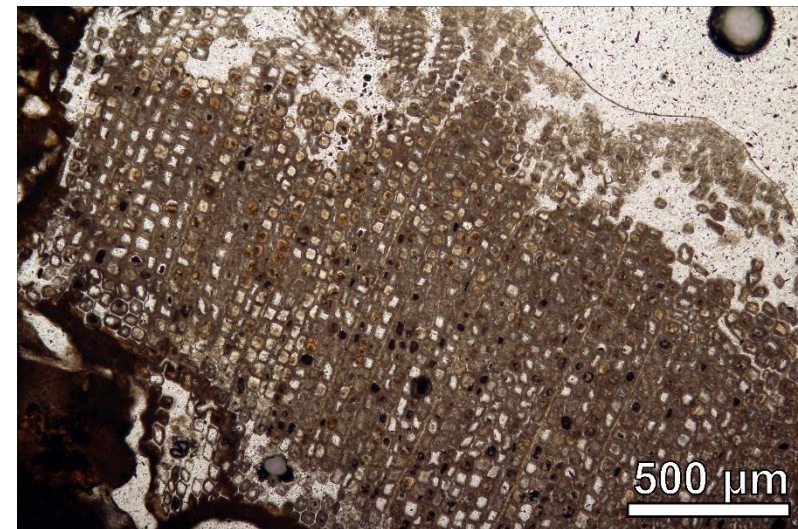
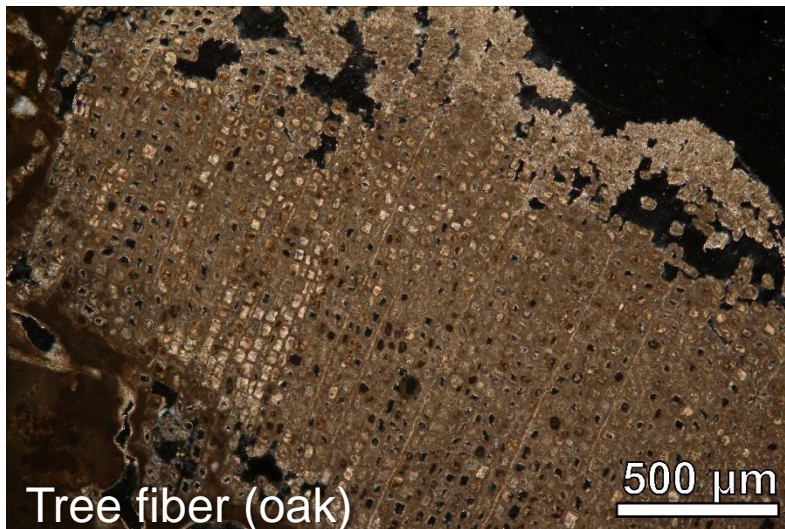
- Dimensions

Petrographic analysis of binding composites

ADDITIVES



- Classification



- Dimensions



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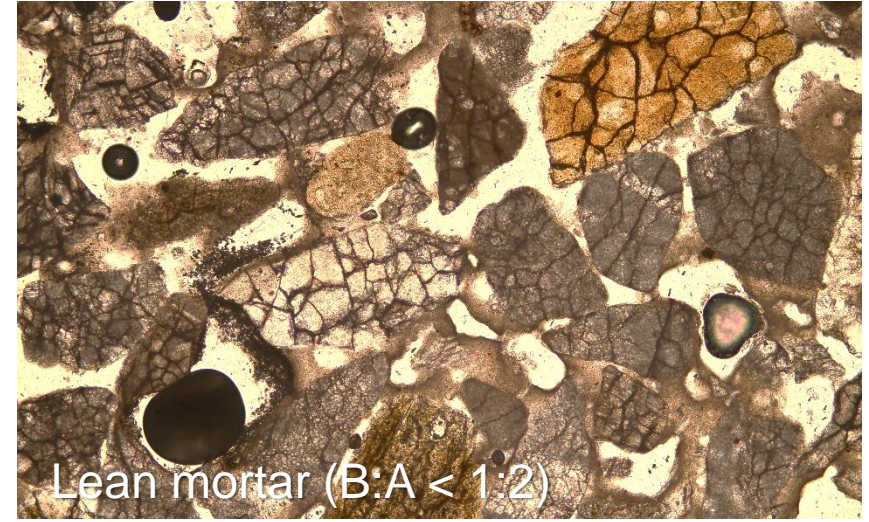
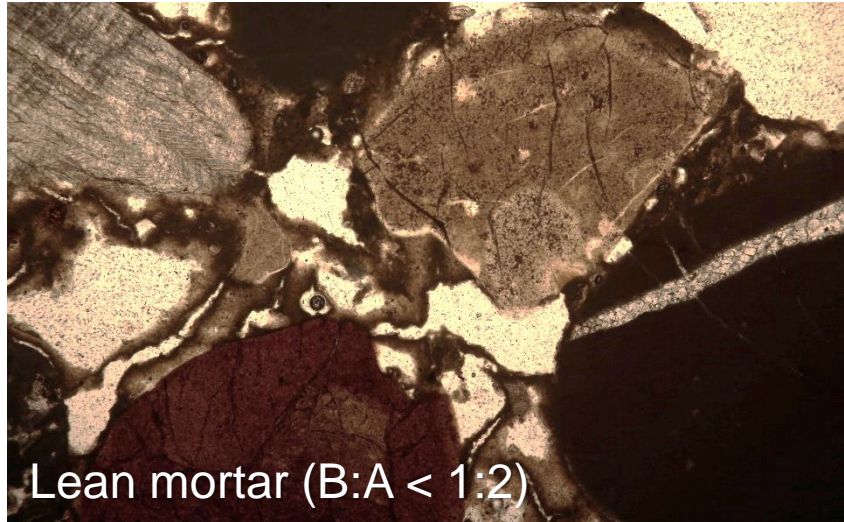
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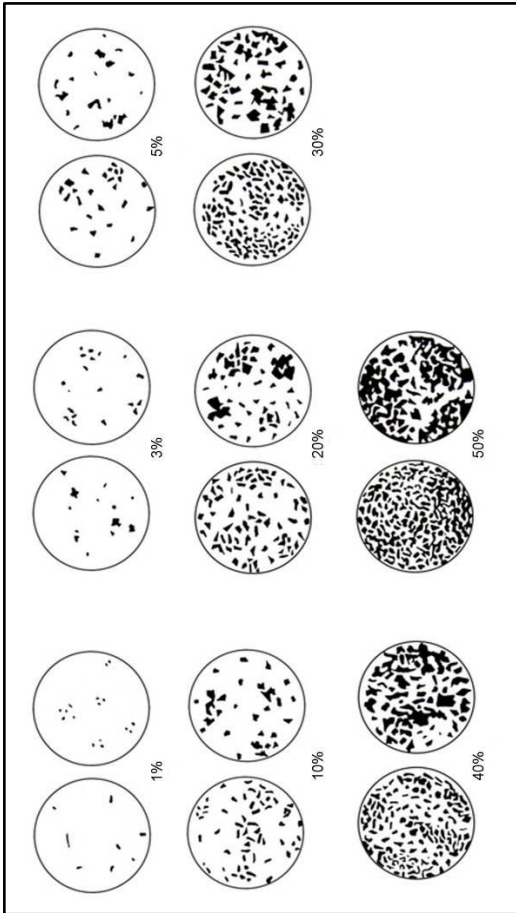
BINDER TO AGGREGATE RATIO (B:A) QUANTIFICATION OF COMPONENTS



Petrographic analysis of binding composites

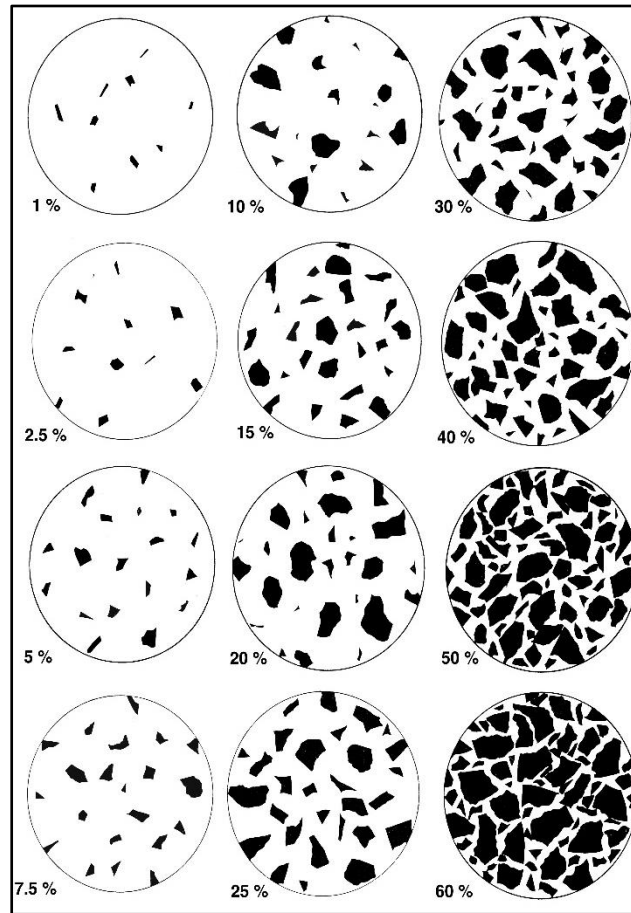
BINDER TO AGGREGATE RATIO QUANTIFICATION OF COMPONENTS

Voids

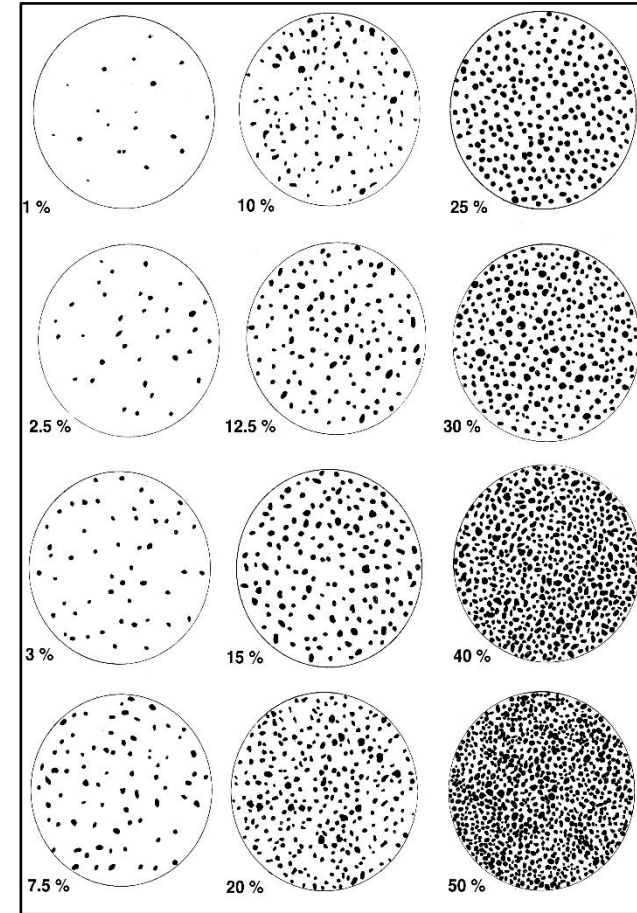


Müller, 1964

Coarse Aggregates



Fine Aggregates



Baccelle et al., 1965

Petrographic analysis of binding composites

BINDER TO AGGREGATE RATIO
QUANTIFICATION OF COMPONENTS

Image analysis

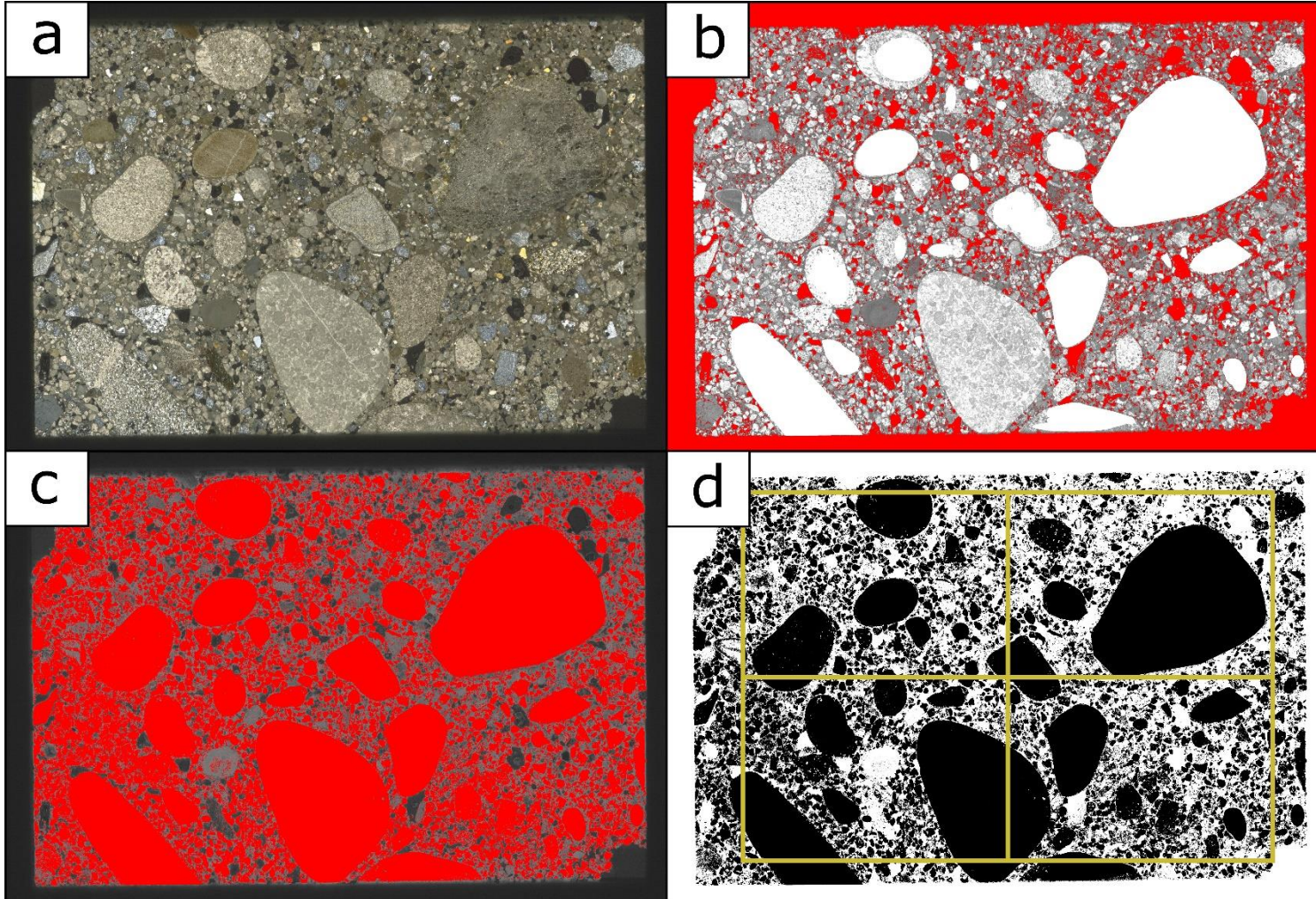


Image-J
software
(free)



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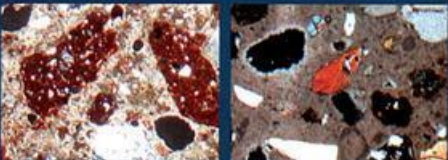
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ATLANTE DELLE MALTE ANTICHE

IN SEZIONE SOTTILE AL MICROSCOPIO OTTICO




ATLAS OF THE ANCIENT MORTARS

IN THIN SECTION UNDER OPTICAL MICROSCOPE

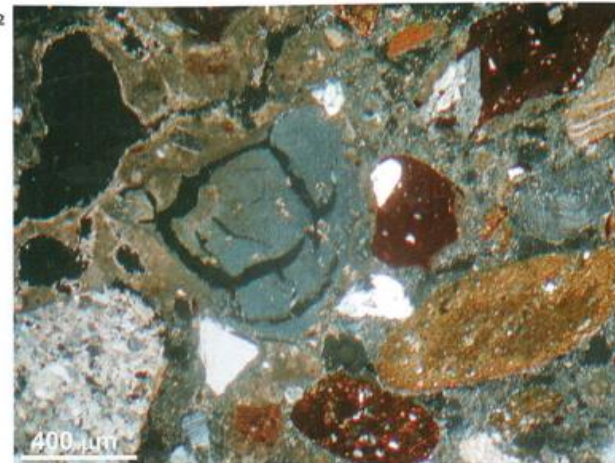
Elena Pecchioni, Fabio Fratini, Emma Cantisani

NARDINI EDITORE

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52



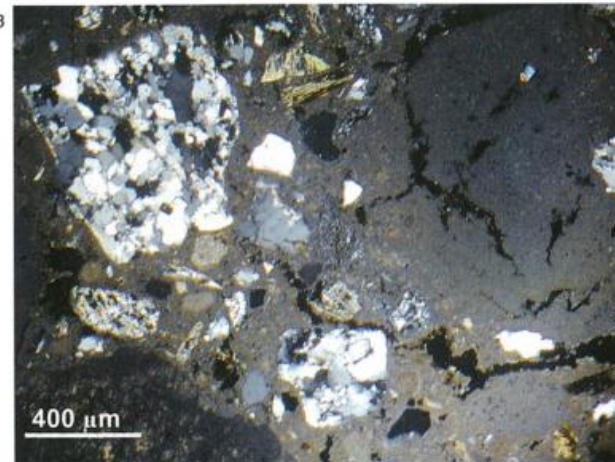
52 MALTA DI RIVESTIMENTO, PALAZZO TE, MANTOVA (XVI SEC.)

Al centro un grumo fessurato. La fessurazione dei grumi è spesso riscontrata nelle malte. Ciò è dovuto a fenomeni di ritiro che caratterizzano proprio la porzione della matrice legante di una malta e tanto più una zona è fessurata, tanto più sarà soggetta a possibile disgregazione. L'impasto è relativamente grasso con un aggregato costituito da frammenti di rocce arenacee (in basso a sinistra), cocciopesto, siltiti (frammento di forma ovale a destra).

52 PLASTER MORTAR, PALAZZO TE, MANTUA (XVIth CENTURY)

Cracked lump in the center of the image. The cracking of the lumps is often found in mortars and this is due to shrinkage phenomena that characterize precisely the binder of a mortar. Much more an area is fissured, the more will be subject to possible disintegration. The mix is relatively fat with an aggregate consisting of sandstone fragments (bottom left), ground fired bricks and siltstones (oval shape fragment on the right).

53



53 MALTA DI ALLETTAMENTO DEL CAMPANILE DEL DUOMO DI PIETRASANTA (LUCCA) (XVI SEC.)

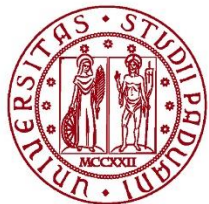
Nell'immagine è evidente al centro un grumo di legante fessurato per fenomeni di ritiro. L'aggregato della malta è costituito da frammenti di quarziti.

53 MORTAR OF THE BELL TOWER OF THE CATHEDRAL OF PIETRASANTA (LUCCA) (XVIth CENTURY)

A cracked lump is visible in the center of the image. The aggregate of the mortar is made of quartzite fragments.

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THANK YOU FOR YOUR
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