PETROGRAPHY OF THE TRENTON AND BLACK RIVER GROUPS CARBONATE ROCKS IN THE APPALACHIAN BASIN

Christopher D. Laughrey

and Jaime Kostelnik

Pennsylvania Geological Survey

October, 2005

October 5, 2005 Presentation

- Regional petrography of Trenton and Black River Carbonates:
  - Methods
  - Constituents:
    - Skeletal grains
    - Non-skeletal grains
    - Matrix
    - Other components
  - Carbonate rock classification
- Microfacies and depositional environments
- Diagenesis:
  - Microbial micritization
  - Cementation:
    - Peloidal cements
    - Fibrous and bladed calcite rinds
    - Meniscus calcite cement
    - Syntaxial calcite overgrowths
    - Calcite spar
    - Poikilotopic calcite spar
    - Hardgrounds
    - Dolomite
    - Other minerals

October 5, 2005 Presentation

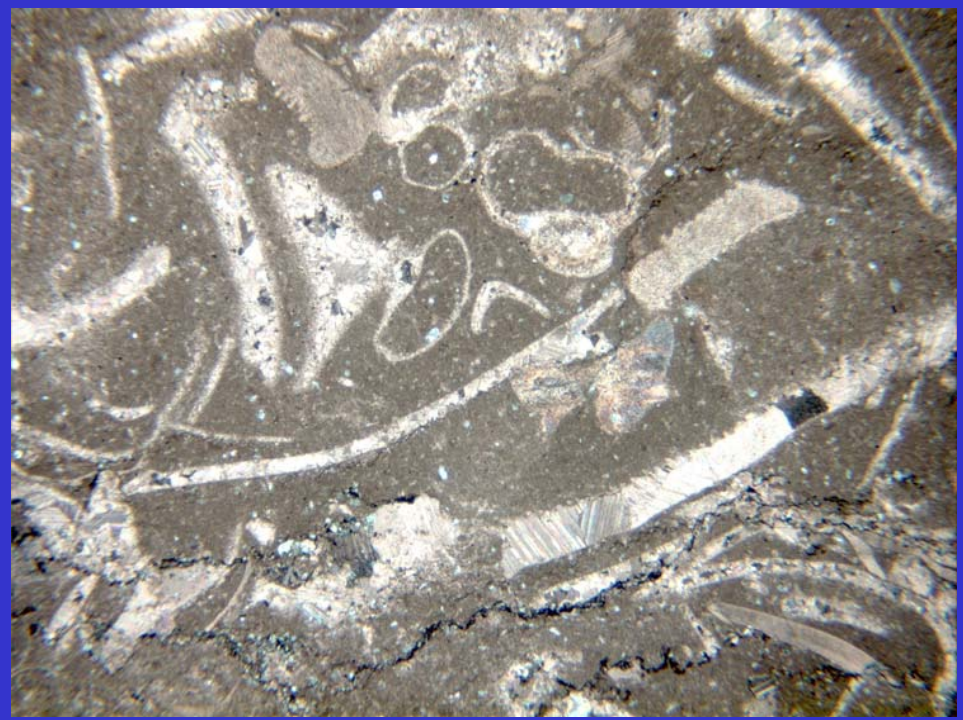
- Diagenesis:
  - Neomorphism
  - Replacement
  - Compaction
  - Dissolution
  - **Dolomite textures**
- Porosity and permeability
- Petrophysical considerations
- Case histories

Methods

- **Thin section petrography:**
  - 1,018 thin sections (core and cuttings samples from 20 wells and two major outcrops)
  - Leica DMLP polarized light microscope with Leica DFC digital camera and dedicated Dell Precision 360 desktop
  - Adobe Photoshop
- **Scanning electron microscopy**
- **Energy dispersive spectroscopy**

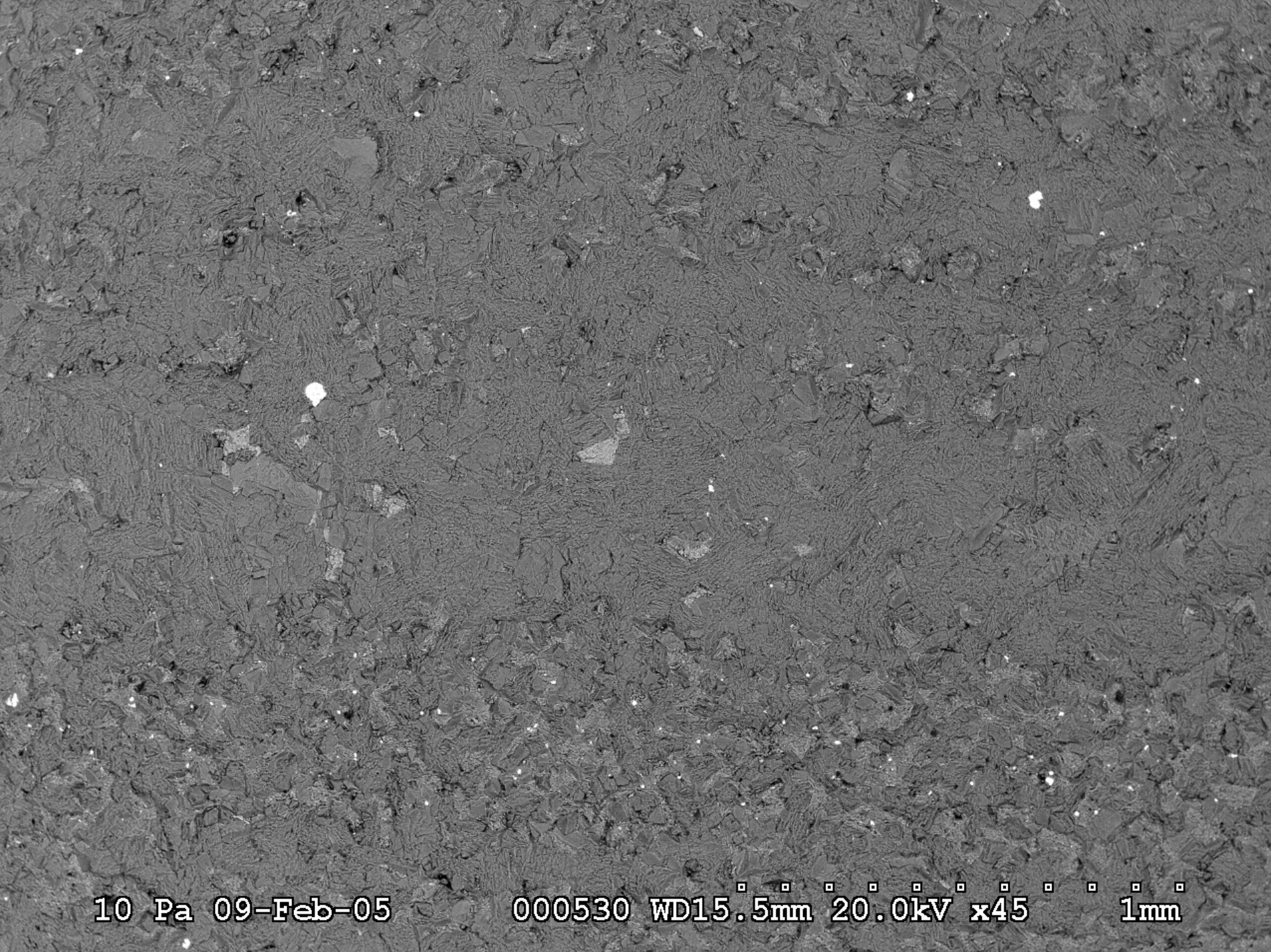
Constituents

- Blue-Green Algae (calcimicrobes/cyanobacteria)
- Skeletal grains
- Non-skeletal grains
- Matrix
- Other components



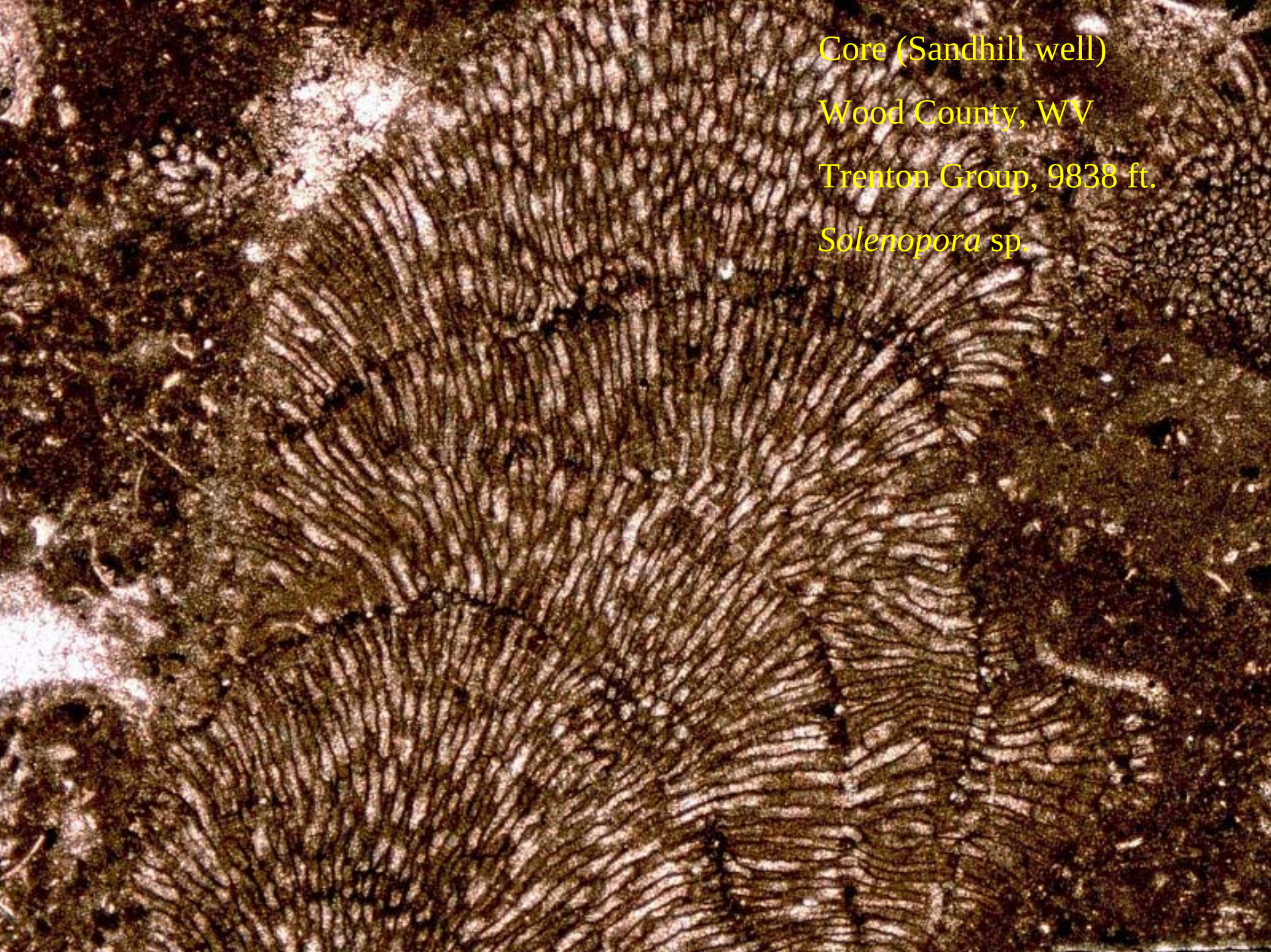

Outcrop
Union Furnace, PA
Black River Group

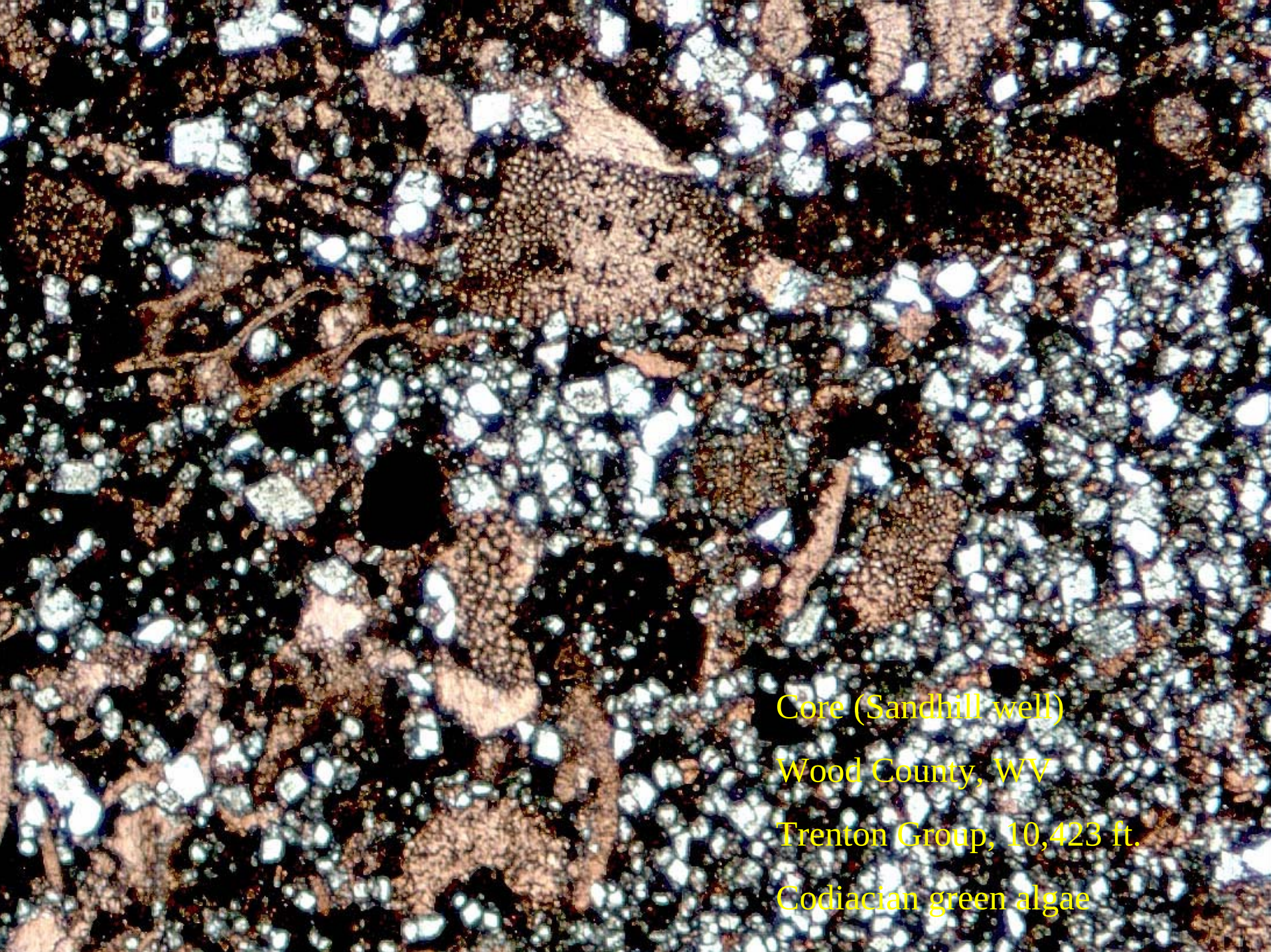

Core (OH 2854)
Delaware Co., OH
Trenton Group

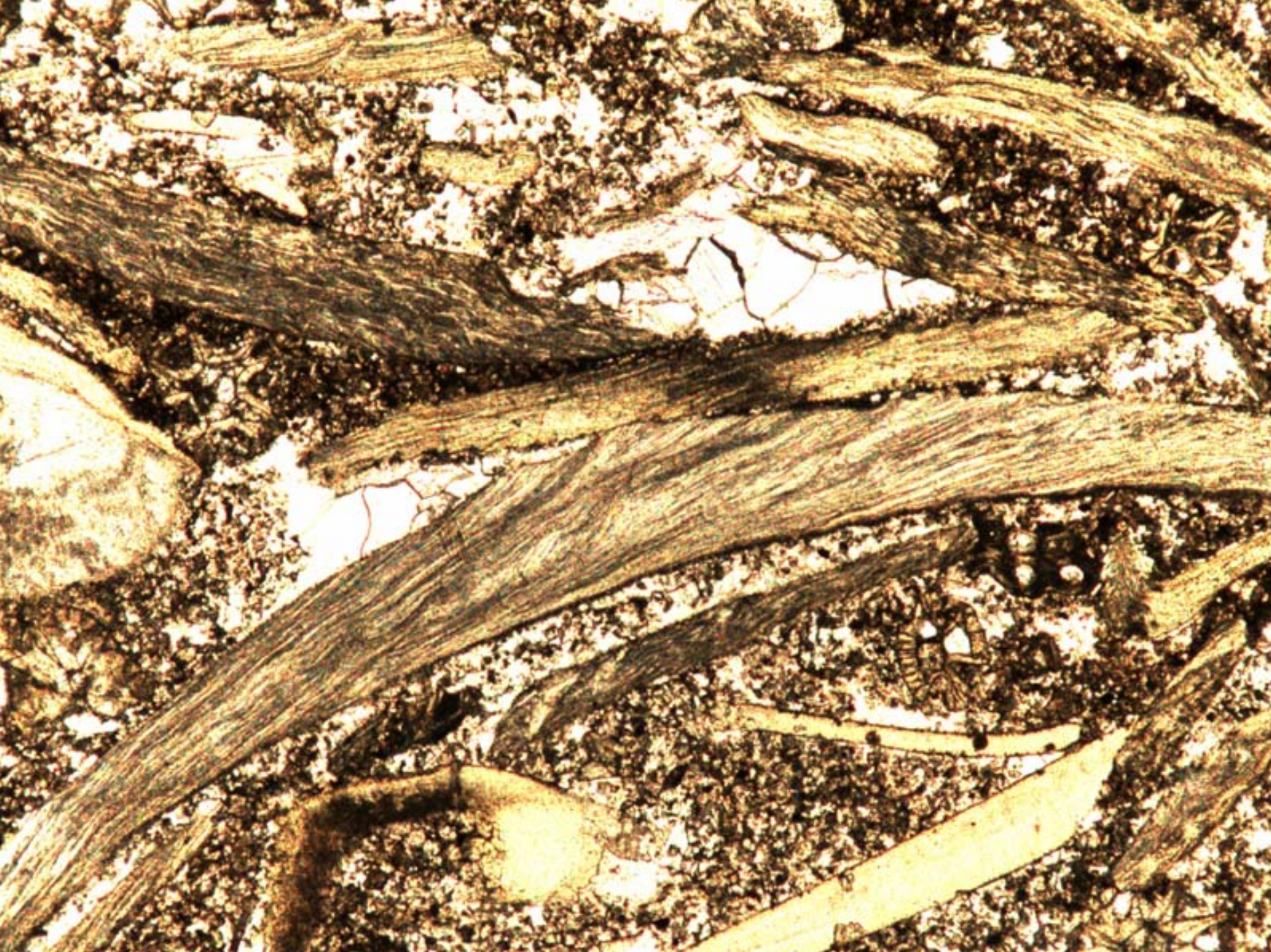

10 Pa 09-Feb-05 000530 WD15.5mm 20.0kV x45 1mm

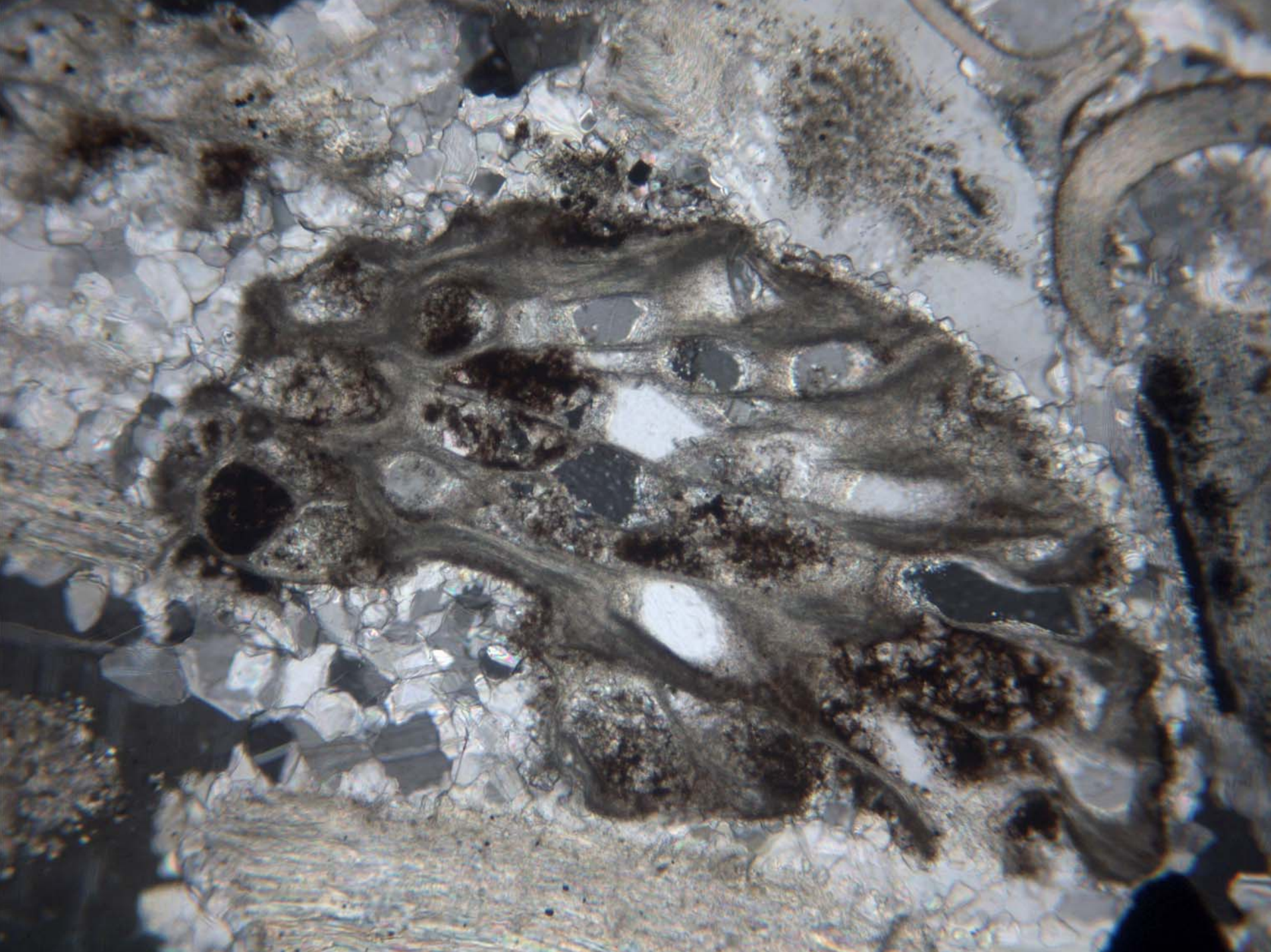
Skeletal Grains

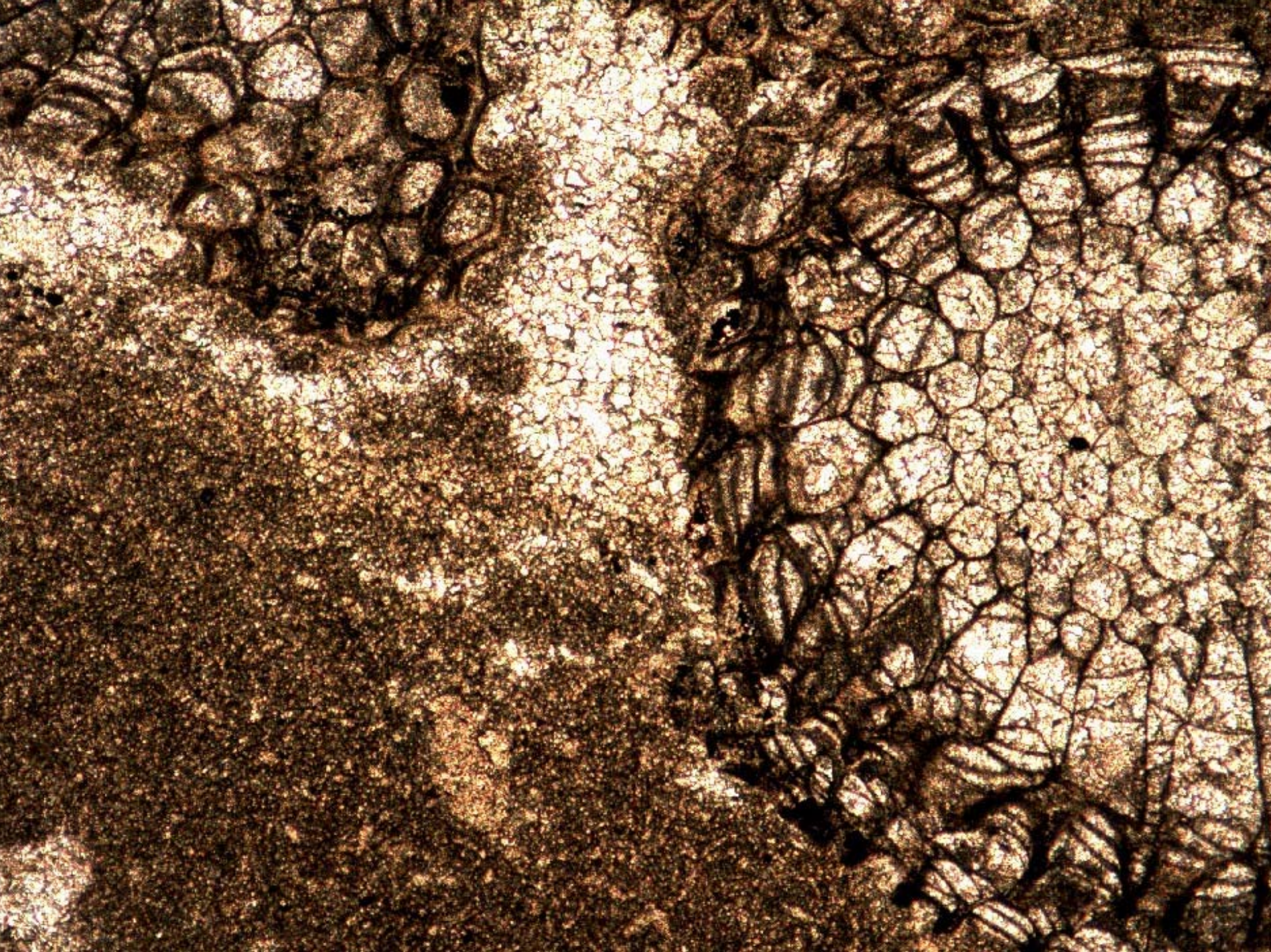
- Red Algae
- Green Algae
- Brachiopods
- Bryozoans
- Corals
- Echinoderms
- Mollusks
- Arthropods

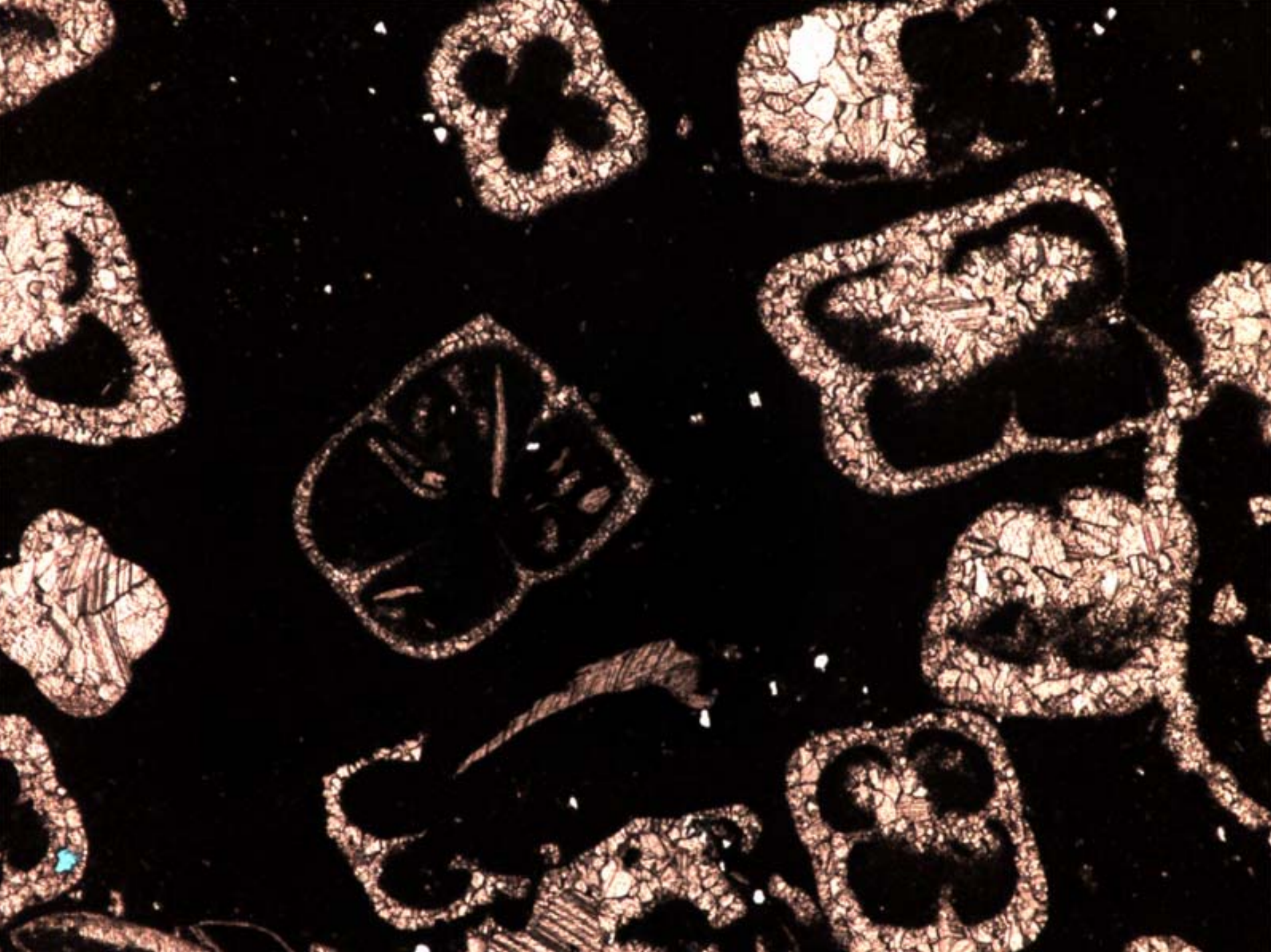

Core (Sandhill well)
Wood County, WV
Trenton Group, 9838 ft.
Solenopora sp.

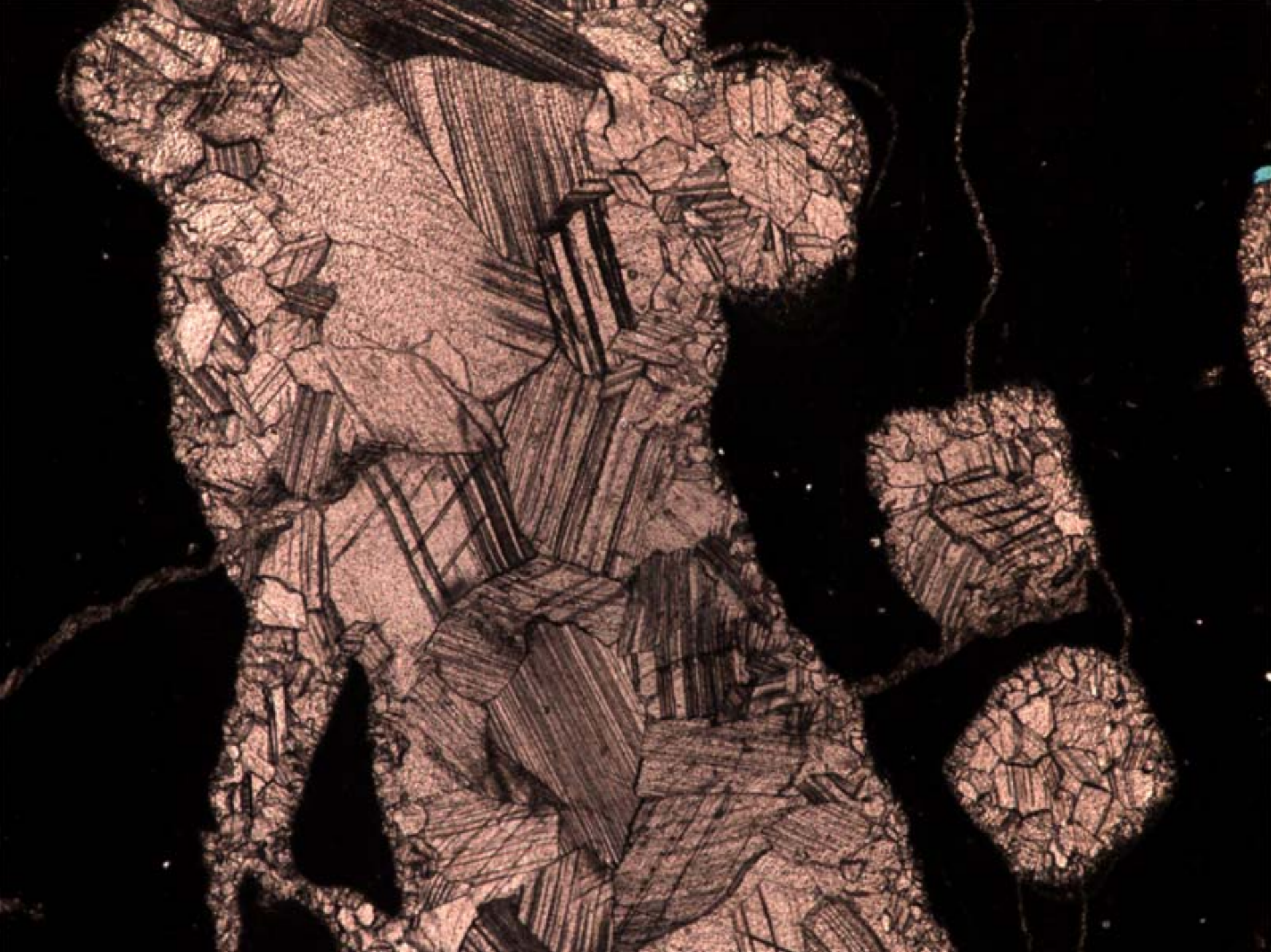

Core (Sandhill well)
Wood County, WV
Trenton Group, 10,423 ft.
Codiacian green algae

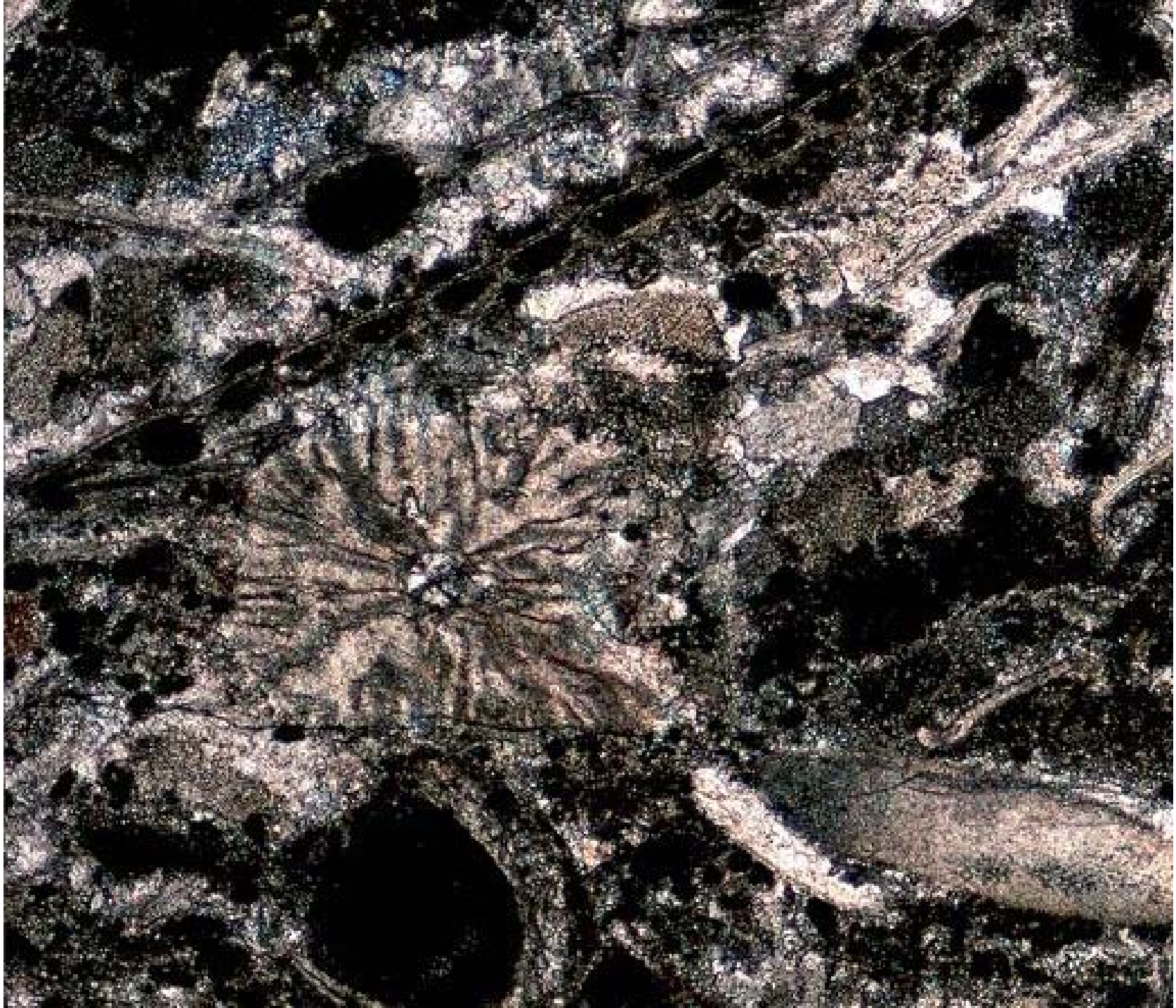


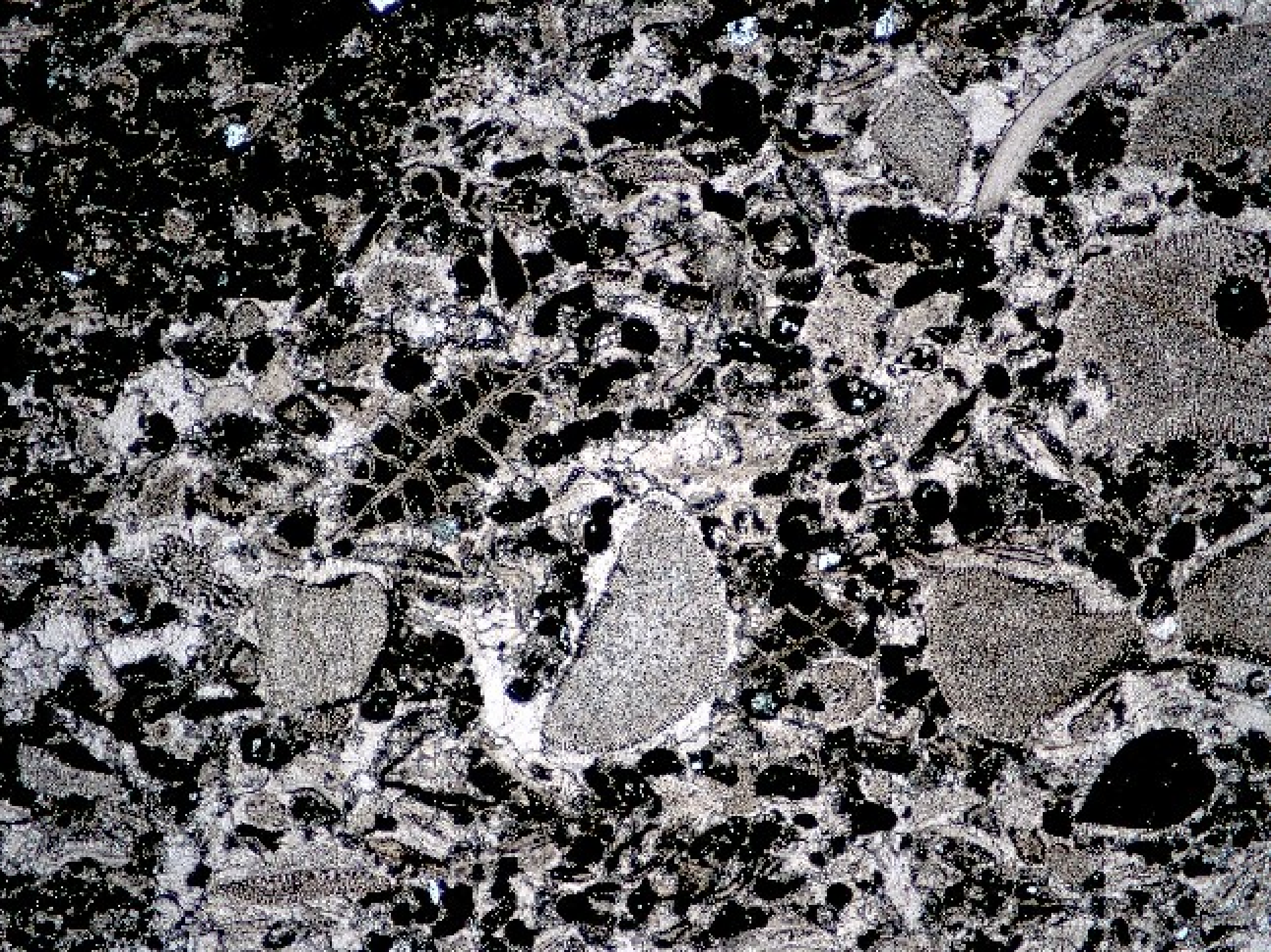


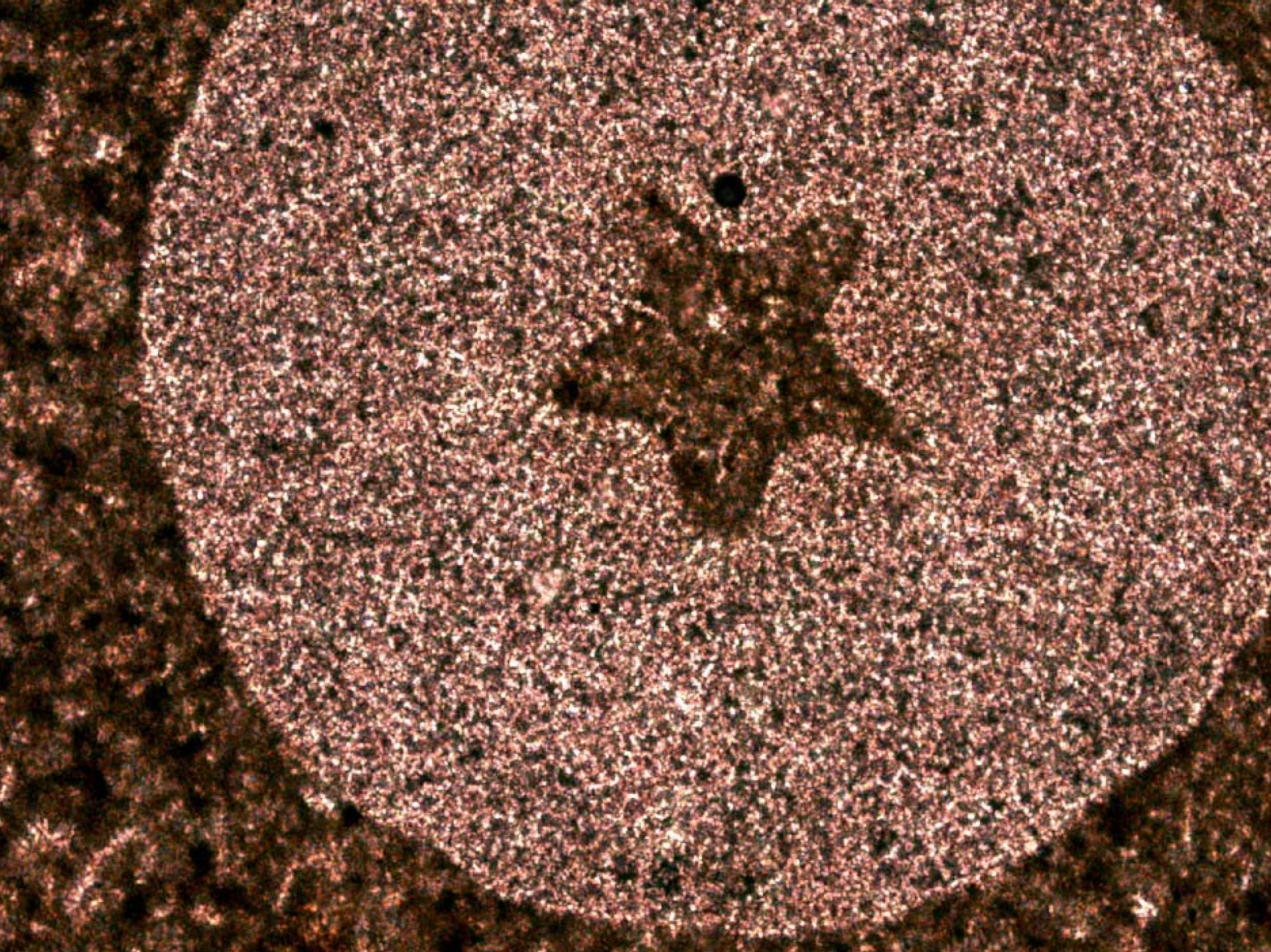


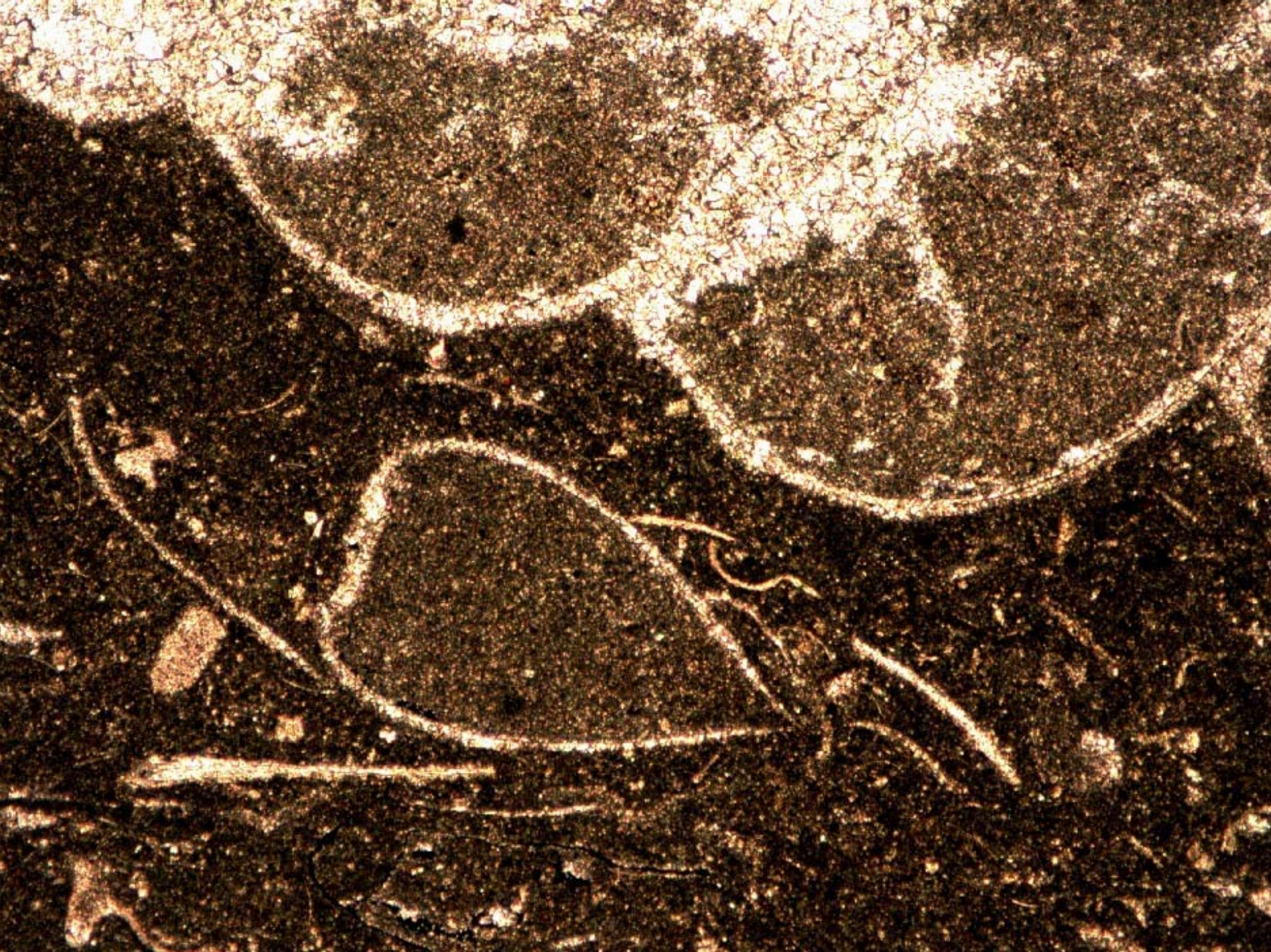


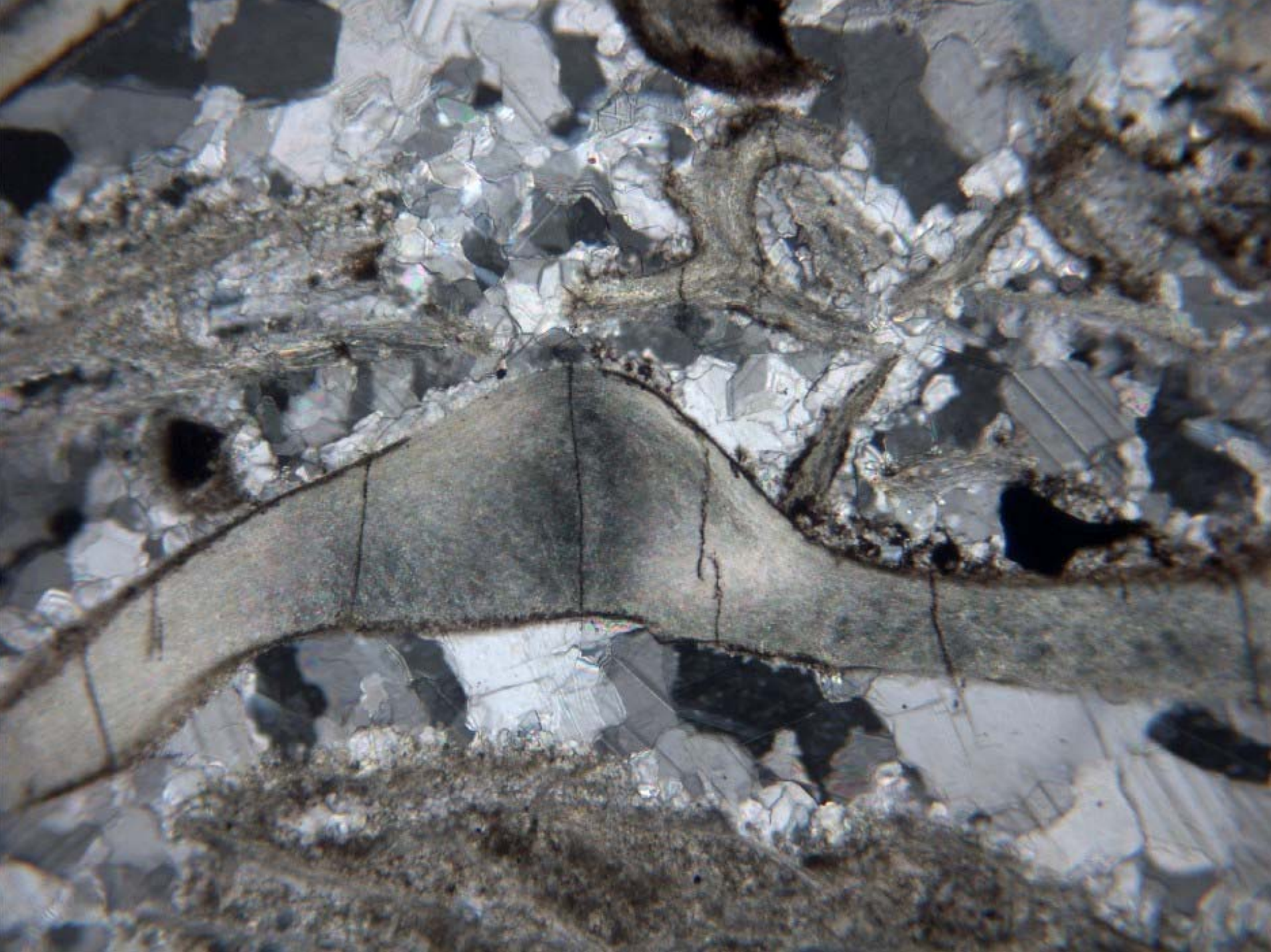






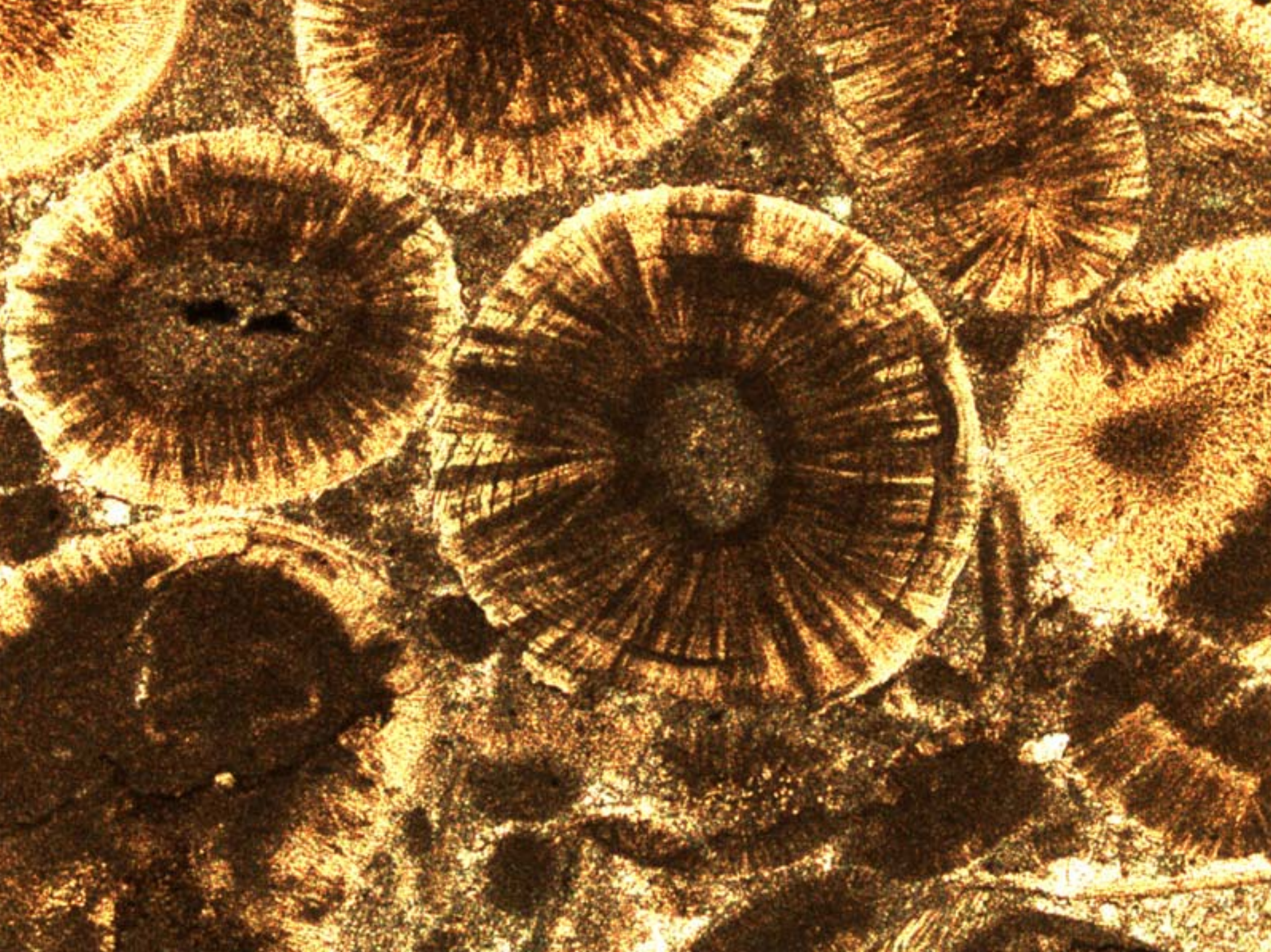


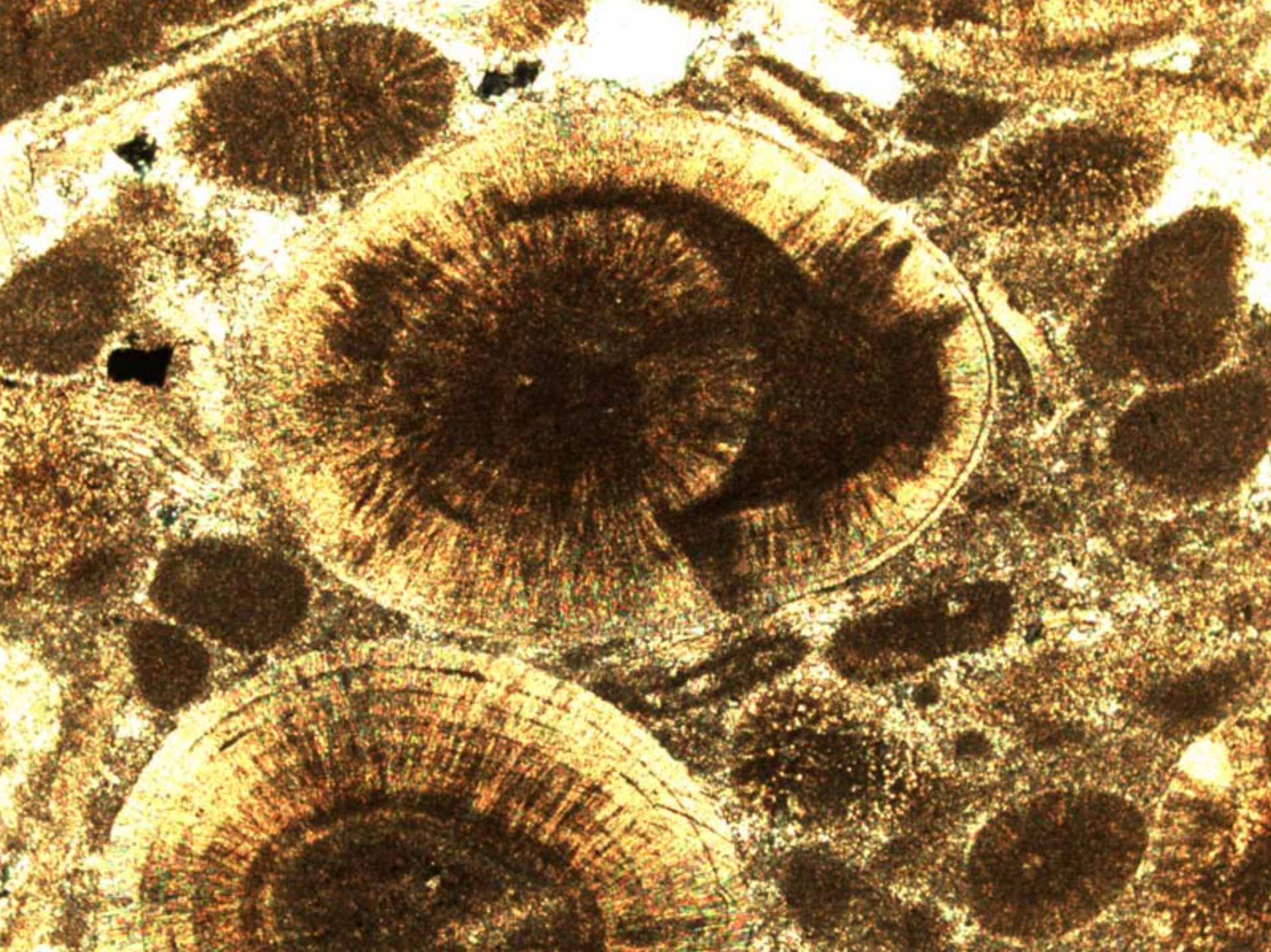


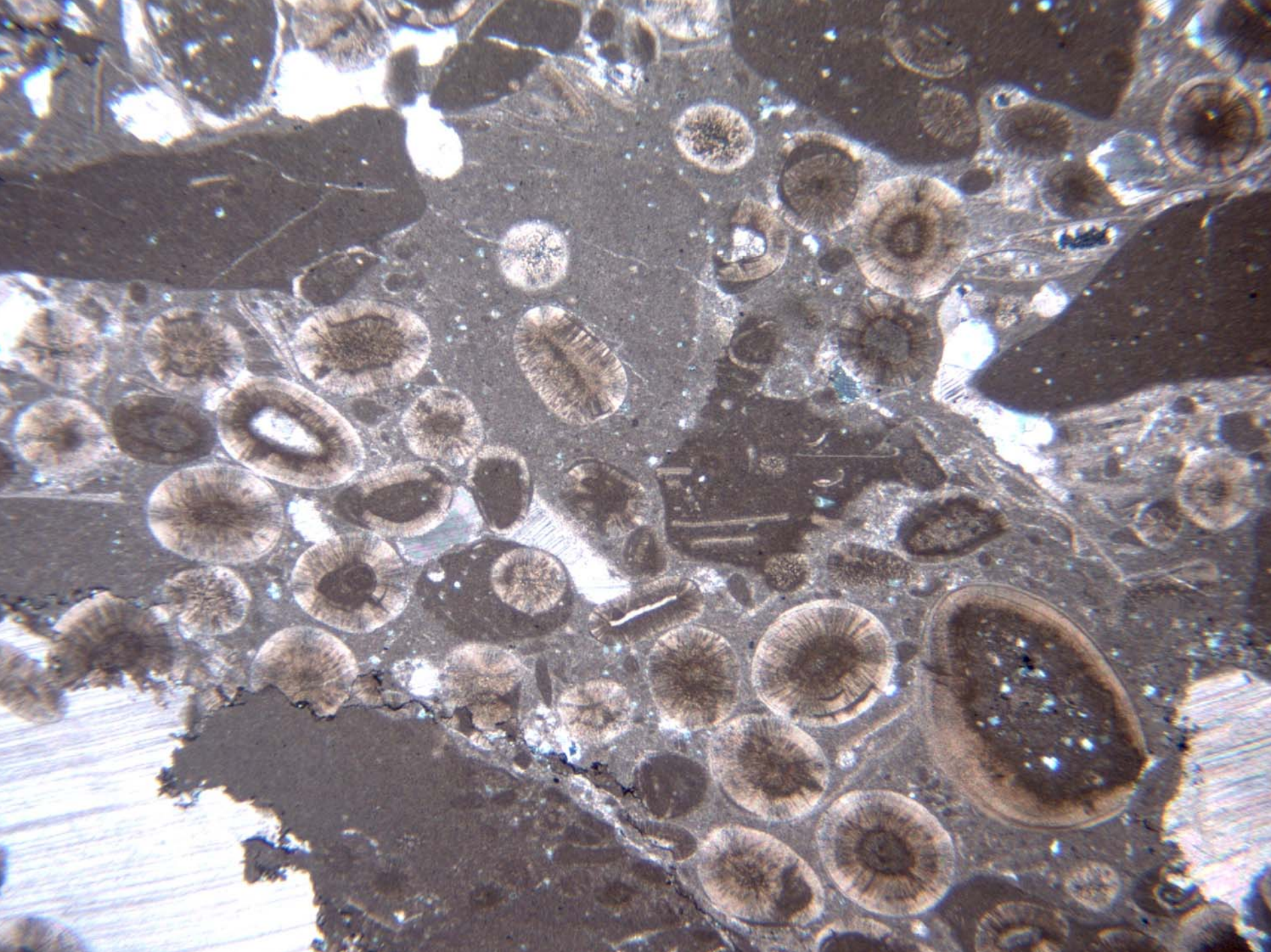


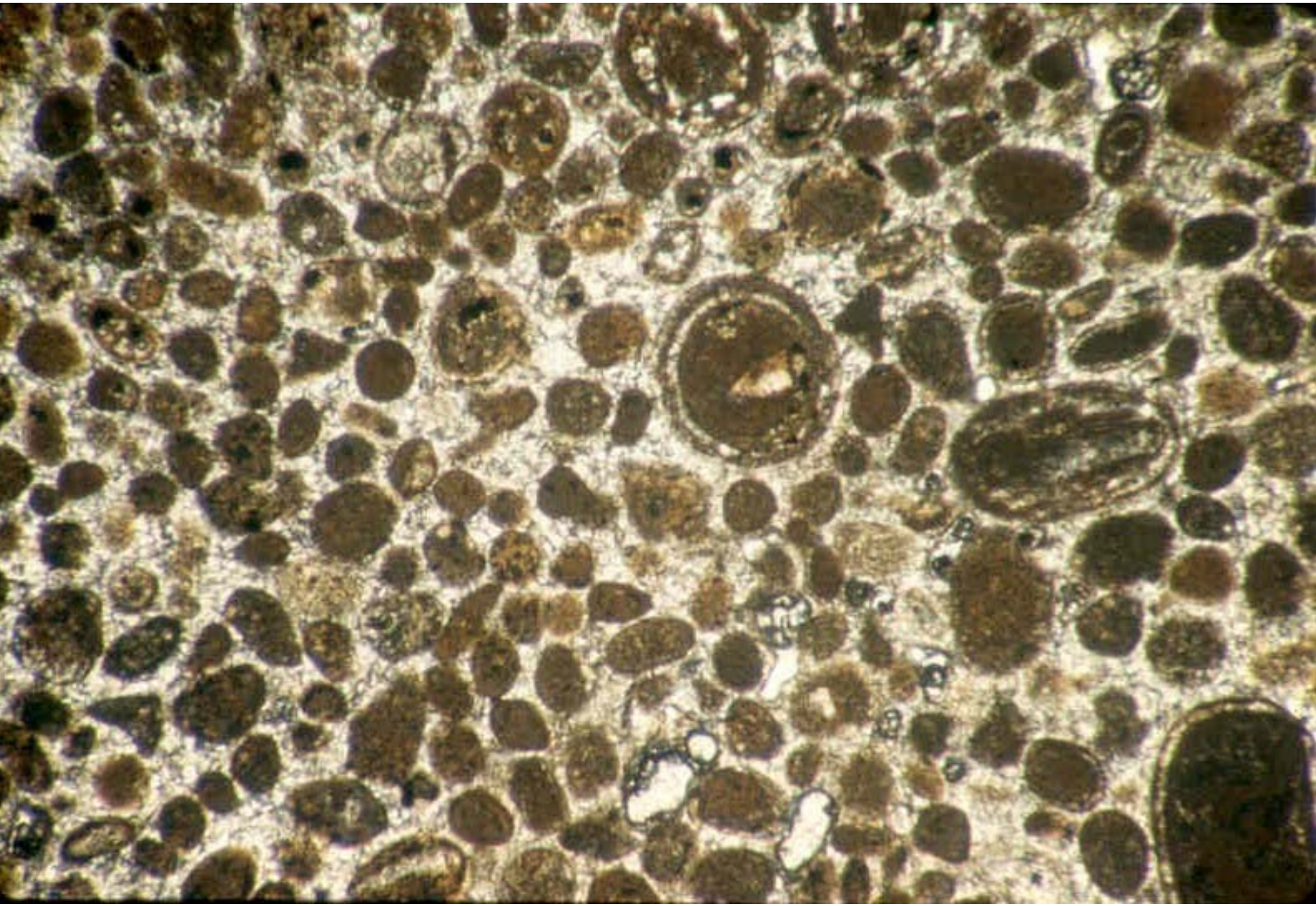
Non-skeletal grains

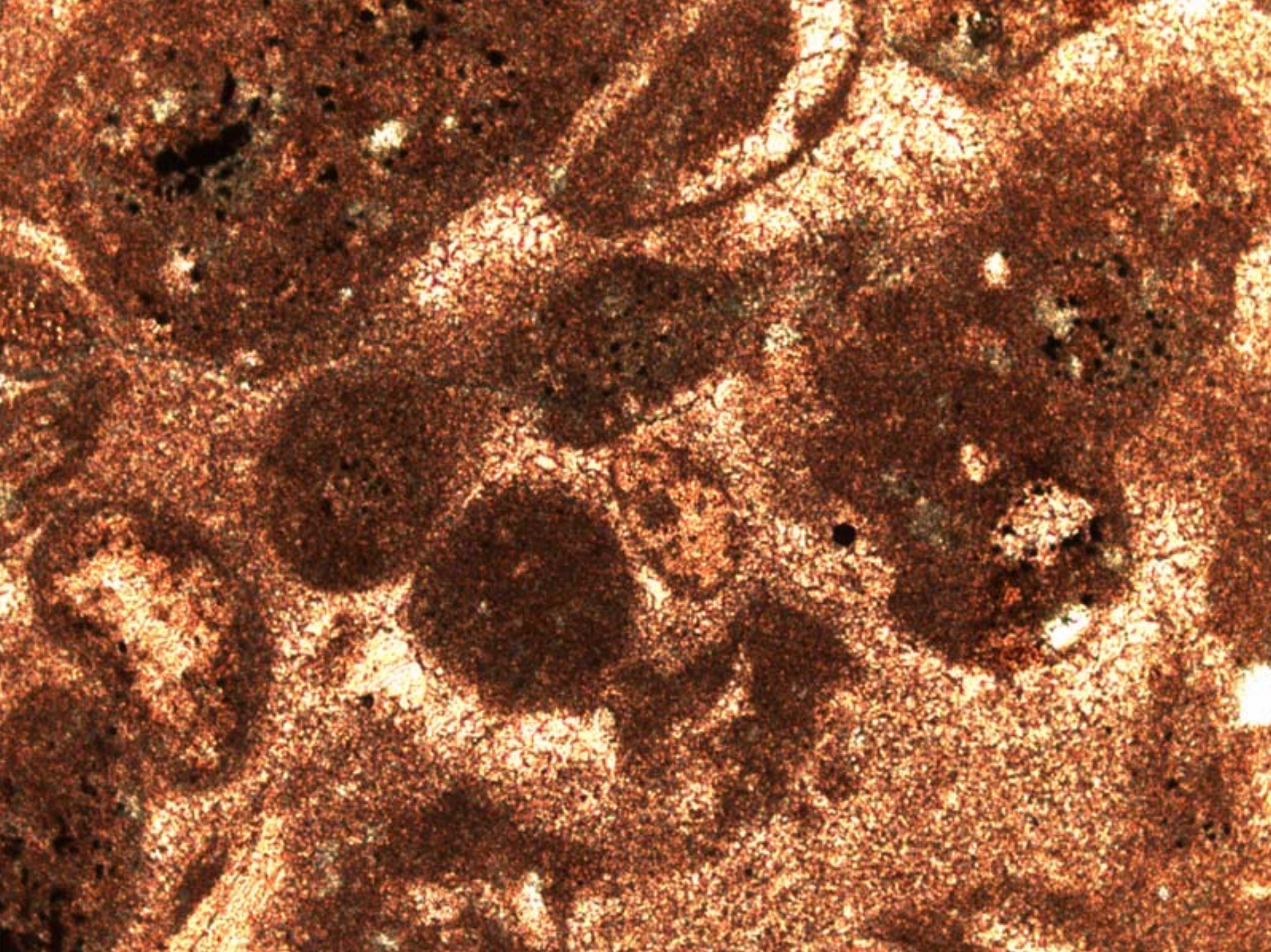
- Ooids
- Peloids
- Grain aggregates
- Clasts





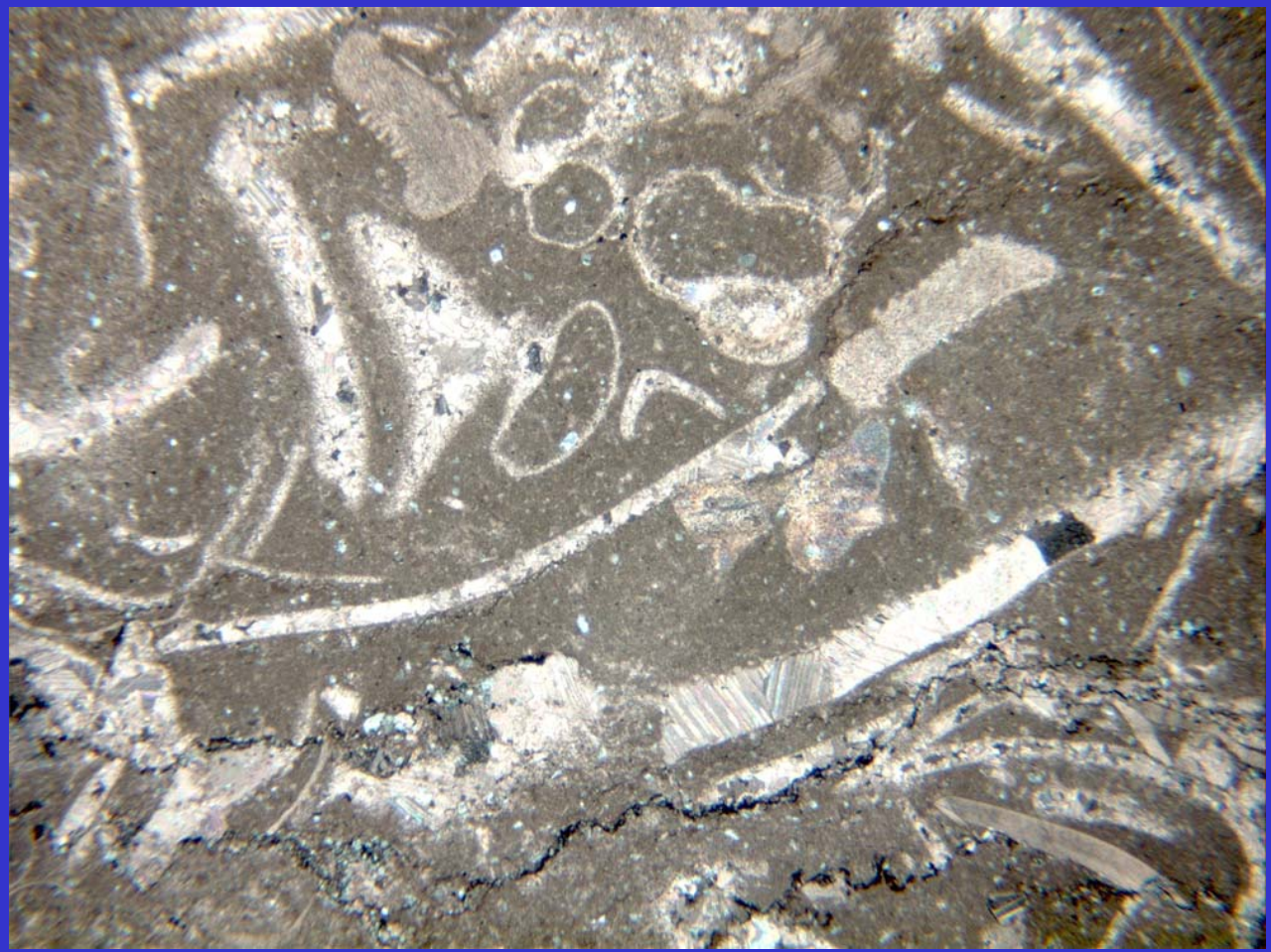






Matrix

- Micrite
- Microspar
- Pseudospar



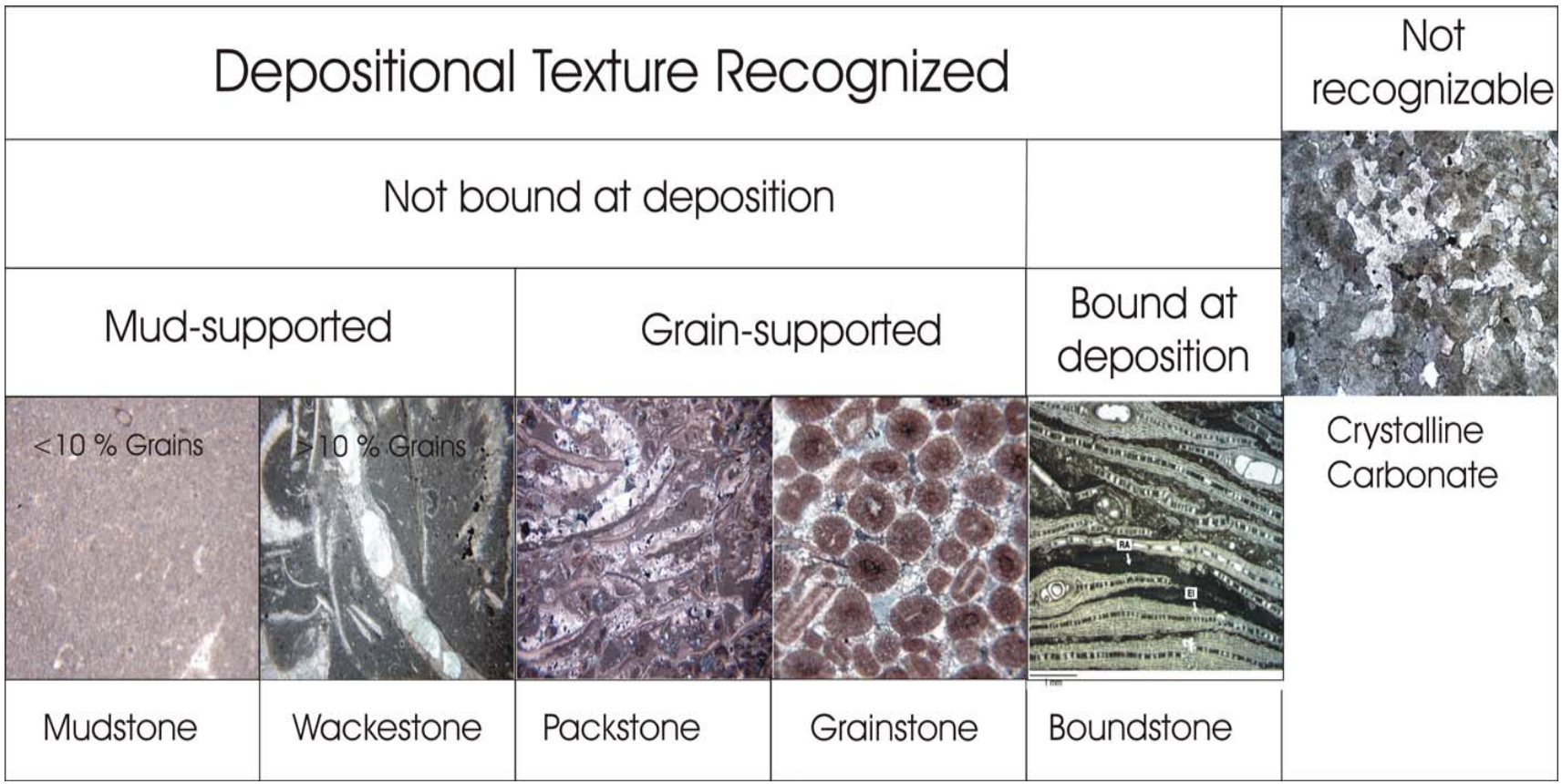
Other Components

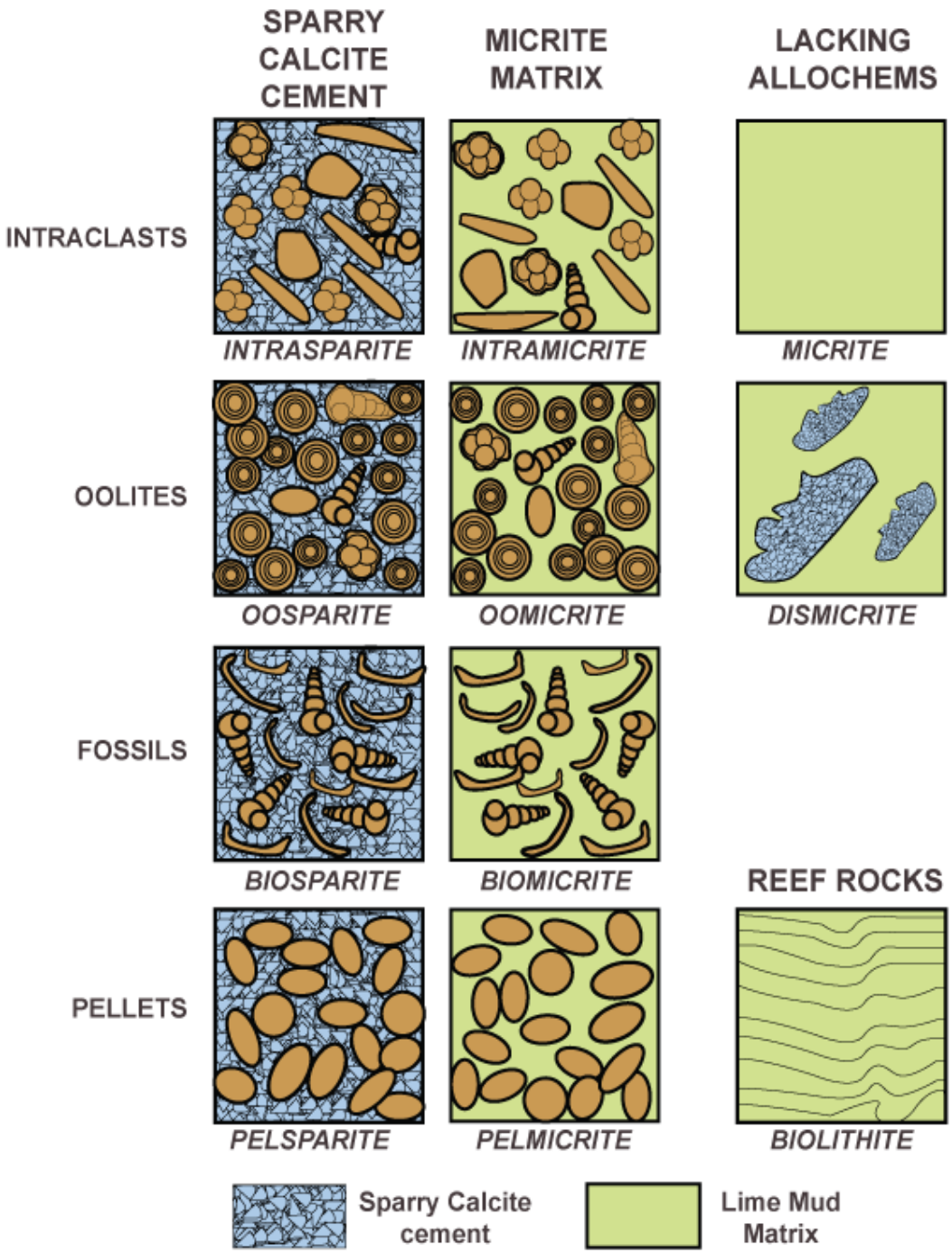
- Detritial siliciclastics
- Phosphate
- Authigenic sulfides, oxides, feldspar, quartz, sulfates, fluorite

Carbonate Rock Classification

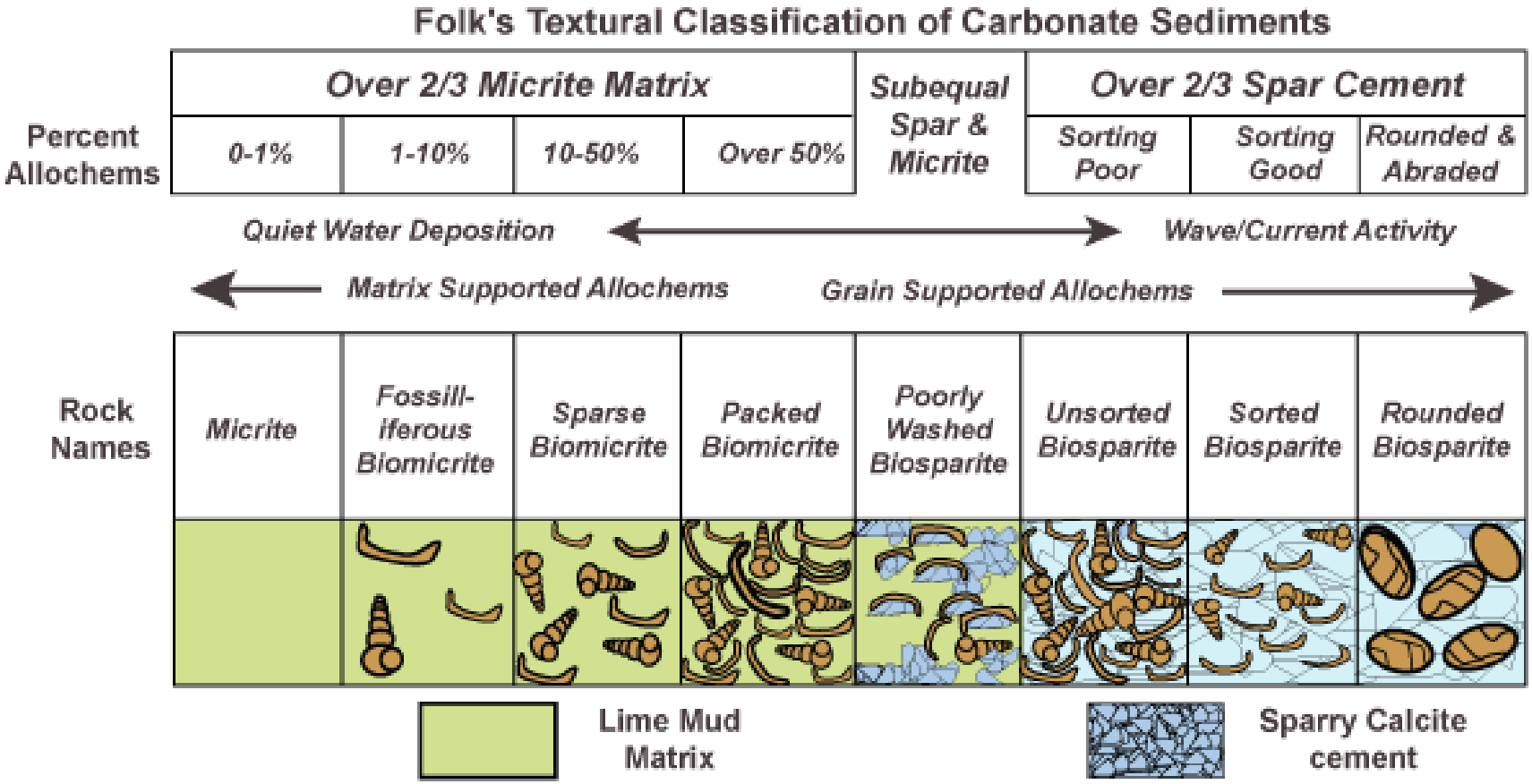
- Dunham, 1962
- Folk, 1962
- Wright, 1992

Dunham's (1962) Classification of Carbonates




SPARRY CALCITE CEMENT
MICRITE MATRIX
LACKING ALLOCHEMS
INTRACLASTS
INTRASPARITE
INTRAMICRITE
MICRITE
OOLITES
OOSPARITE
OOMICRITE
DISMICRITE
FOSSILS
BIOSPARITE
BIOMICRITE
REEF ROCKS
PELLETS
PELSPARITE
PELMICRITE
BIOLITHITE
Sparry Calcite cement
Lime Mud Matrix

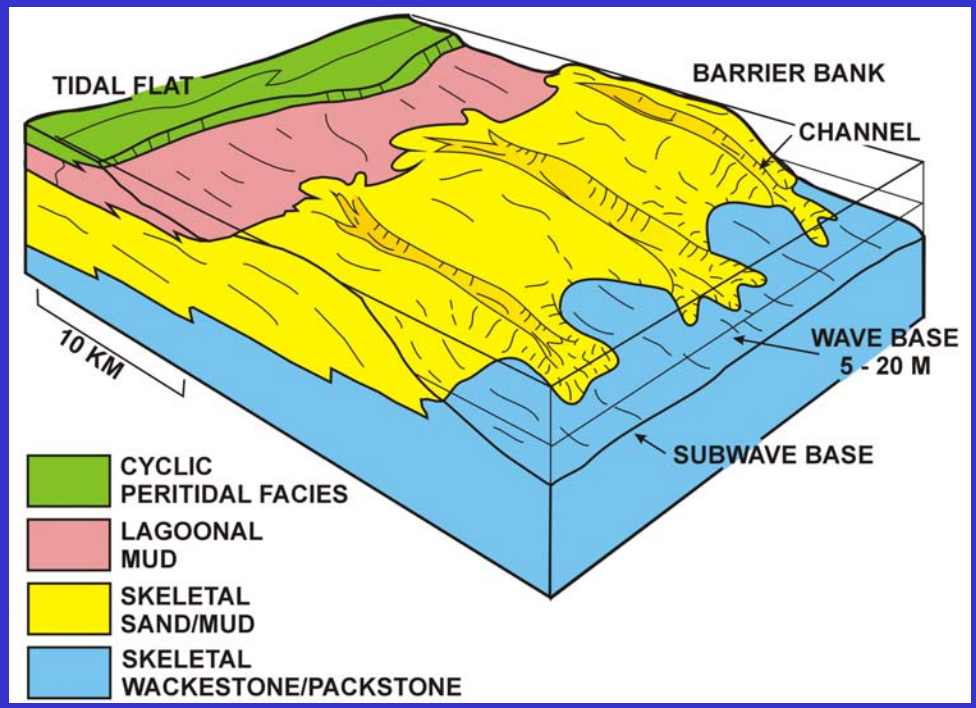
Folk, 1962


Folk's Textural Classification of Carbonate Sediments
Over 2/3 Micrite Matrix
Subequal Spar & Micrite
Over 2/3 Spar Cement
Percent Allochems
0-1%
1-10%
10-50%
Over 50%
Sorting Poor
Sorting Good
Rounded & Abraded
Quiet Water Deposition
Wave/Current Activity
Matrix Supported Allochems
Grain Supported Allochems
Rock Names
Micrite
Fossill-iferous Biomicrite
Sparse Biomicrite
Packed Biomicrite
Poorly Washed Biosparite
Unsorted Biosparite
Sorted Biosparite
Rounded Biosparite
Lime Mud Matrix
Sparry Calcite cement

Wright, 1992

- Depositional
- Biological
- Diagenetic:
  - Non-obliterative:
    - Cementstone
    - Condensed grainstone
    - Fitted grainstone
  - Obliterative:
    - Sparstone
    - Microsparstone

Overall Depositional Setting

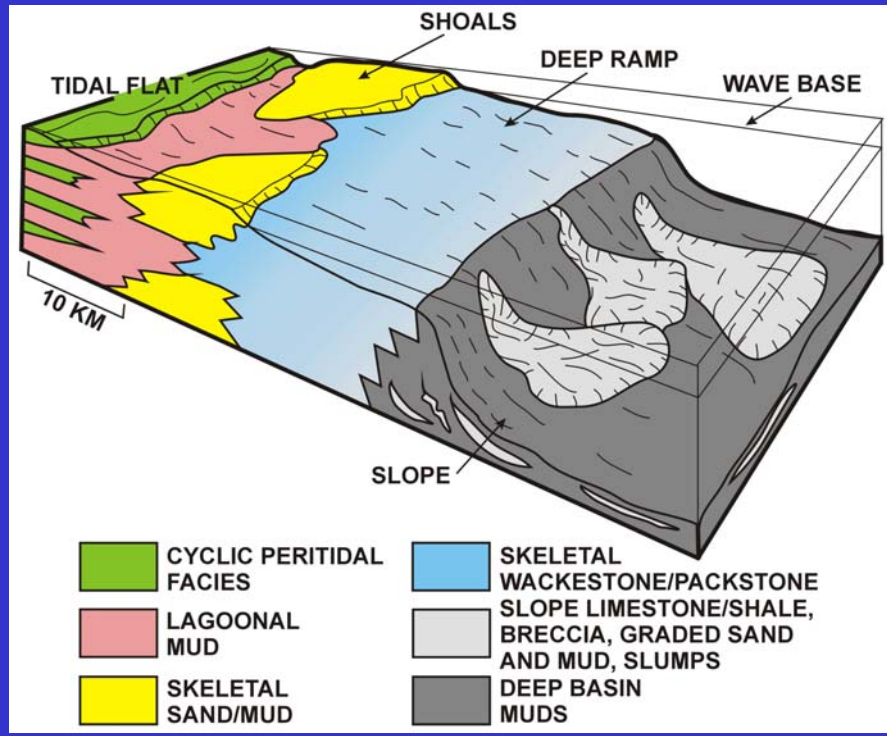


Homoclinal Ramp

Black River

Distally steepened ramp

Trenton

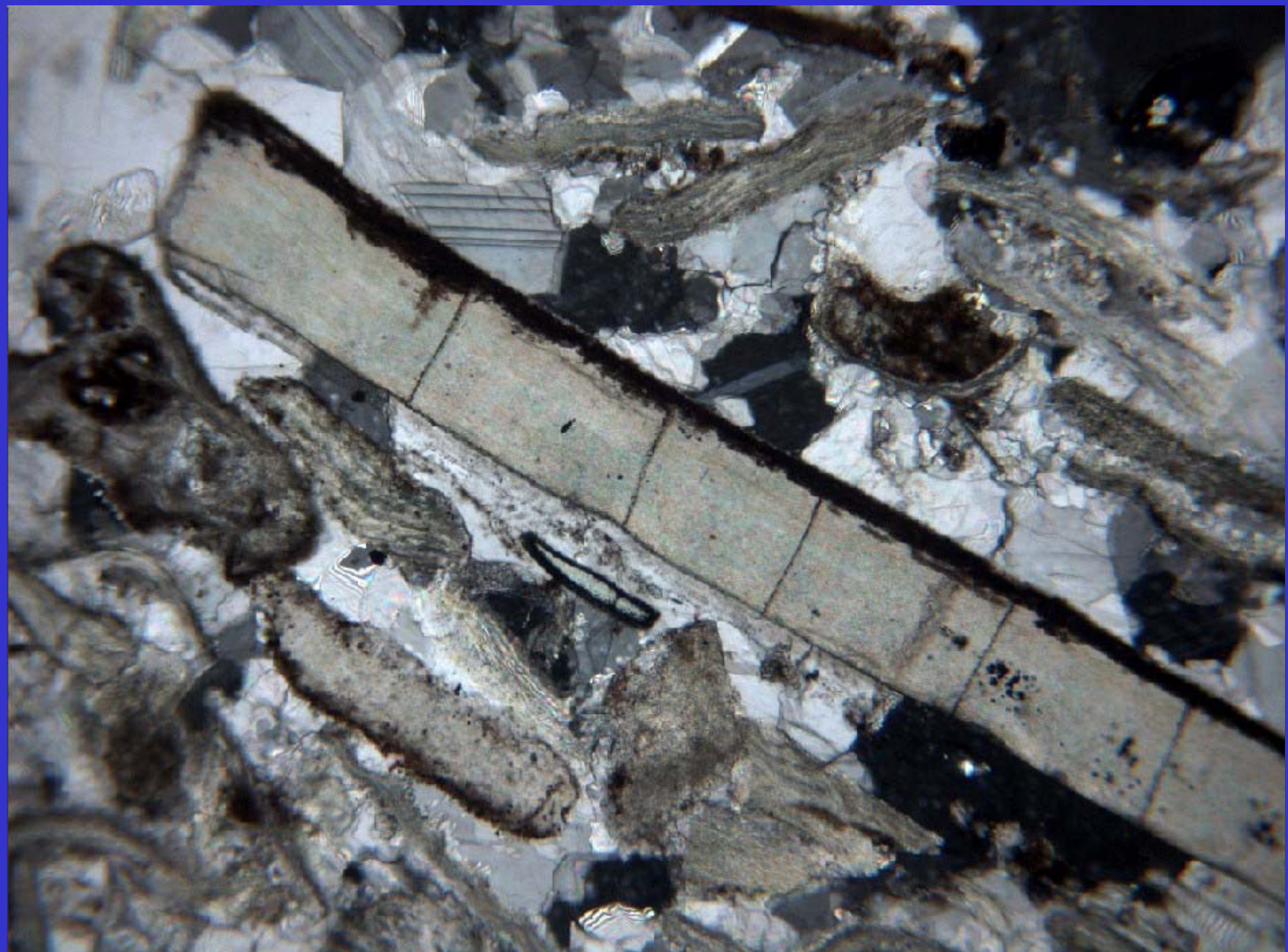


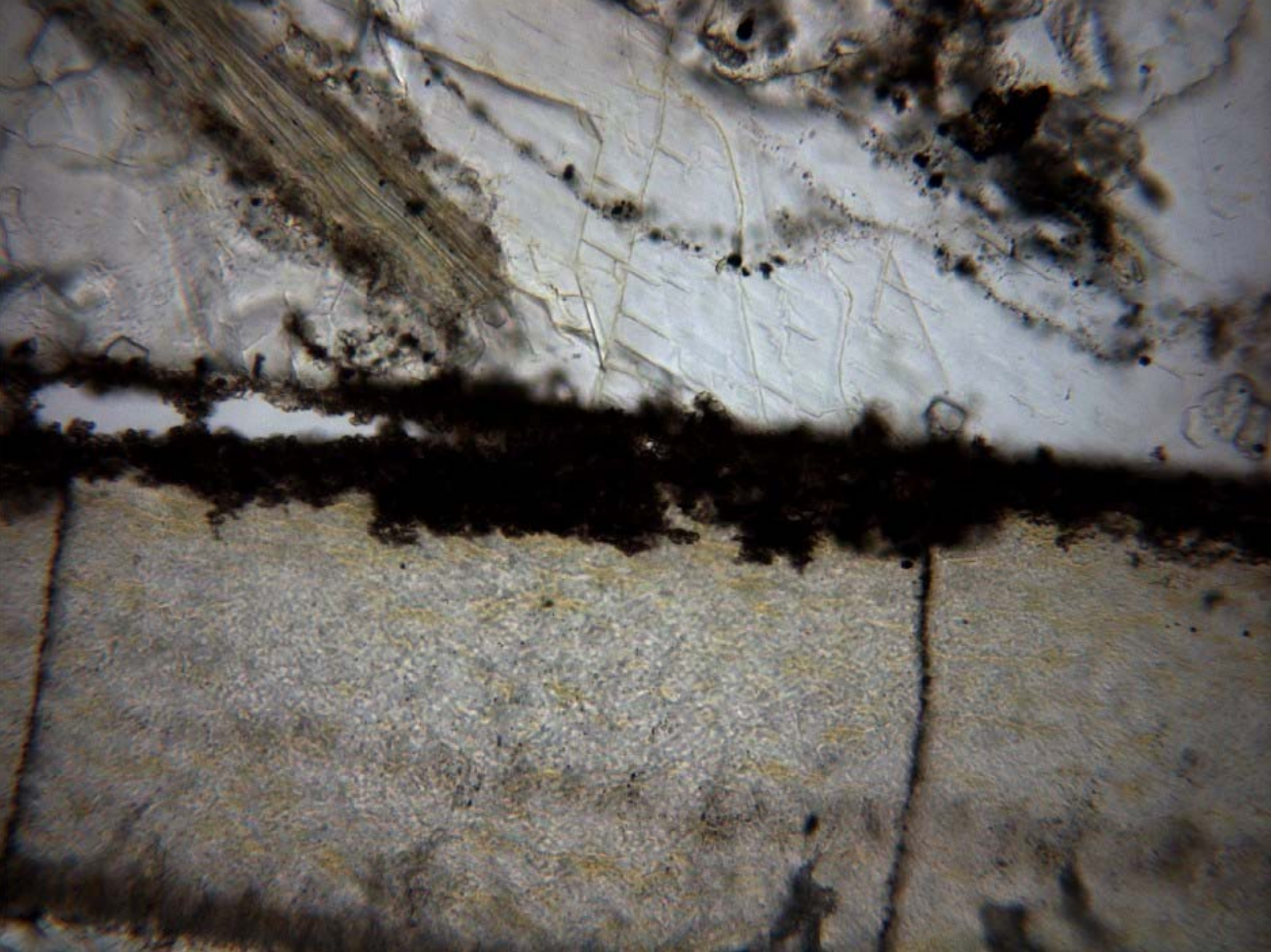
From Read, 1985

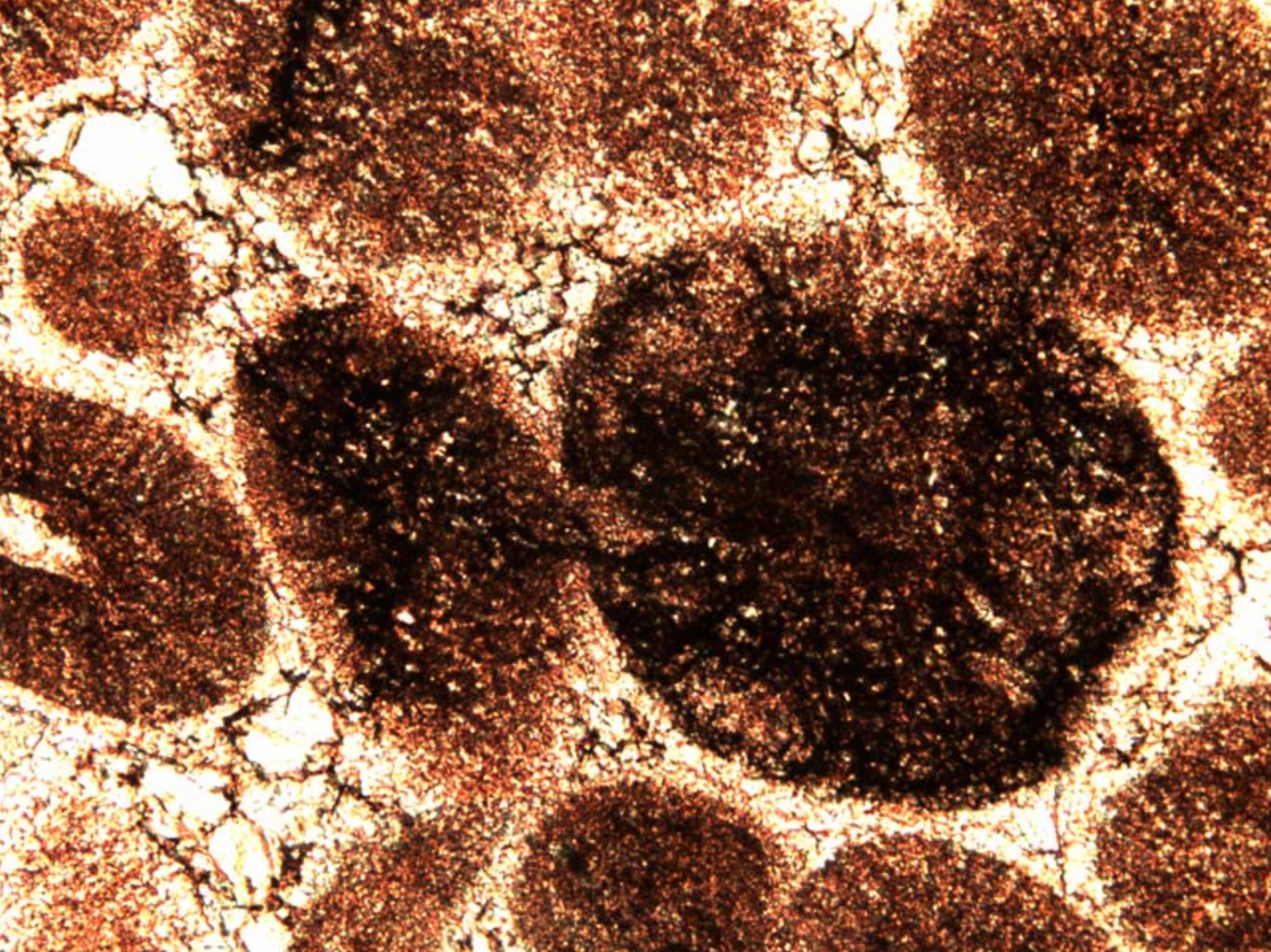
Diagenesis

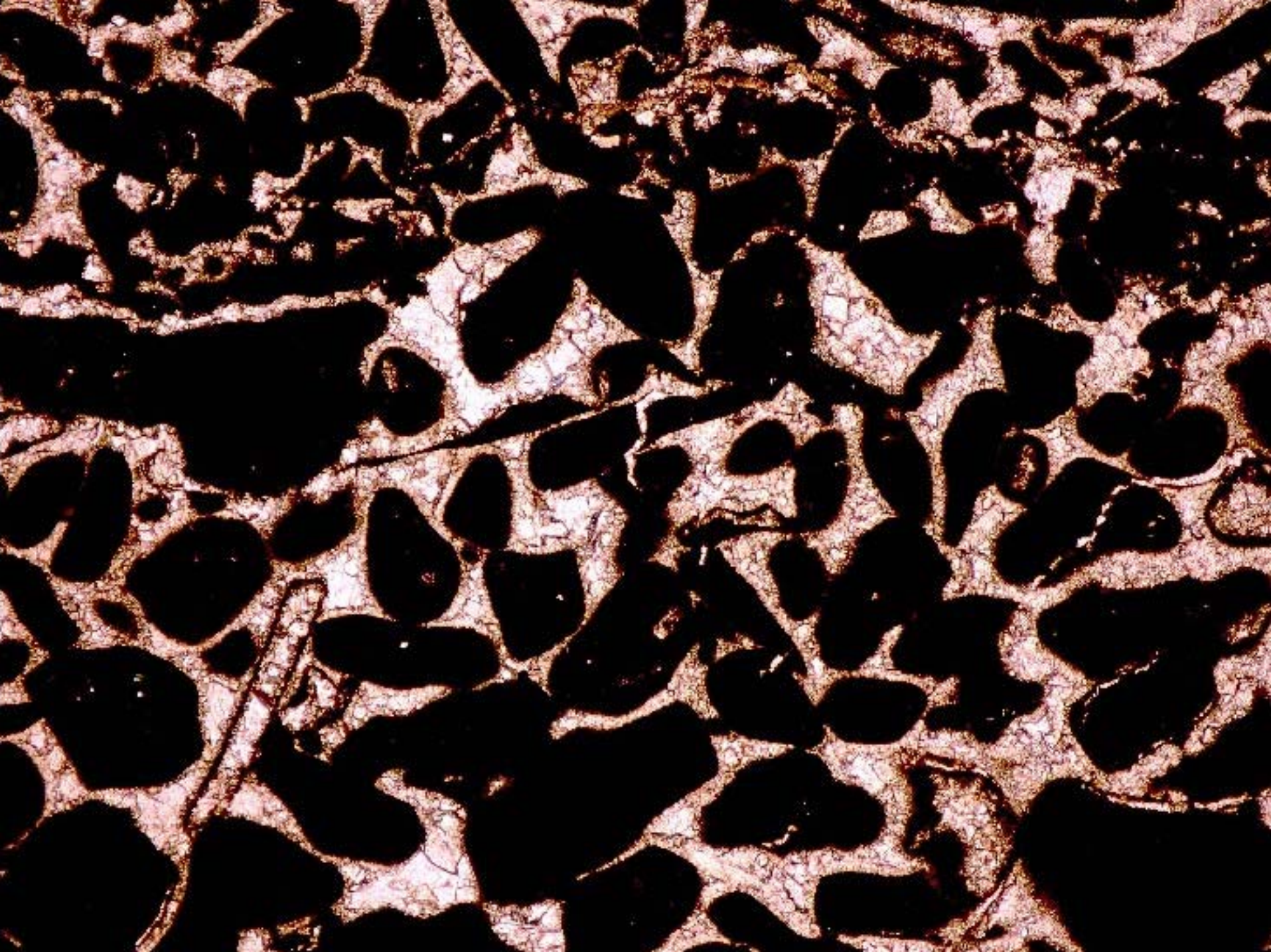
- Microbial micritization
- Cementation
- Neomorphism
- Replacement
- Compaction
- Dissolution

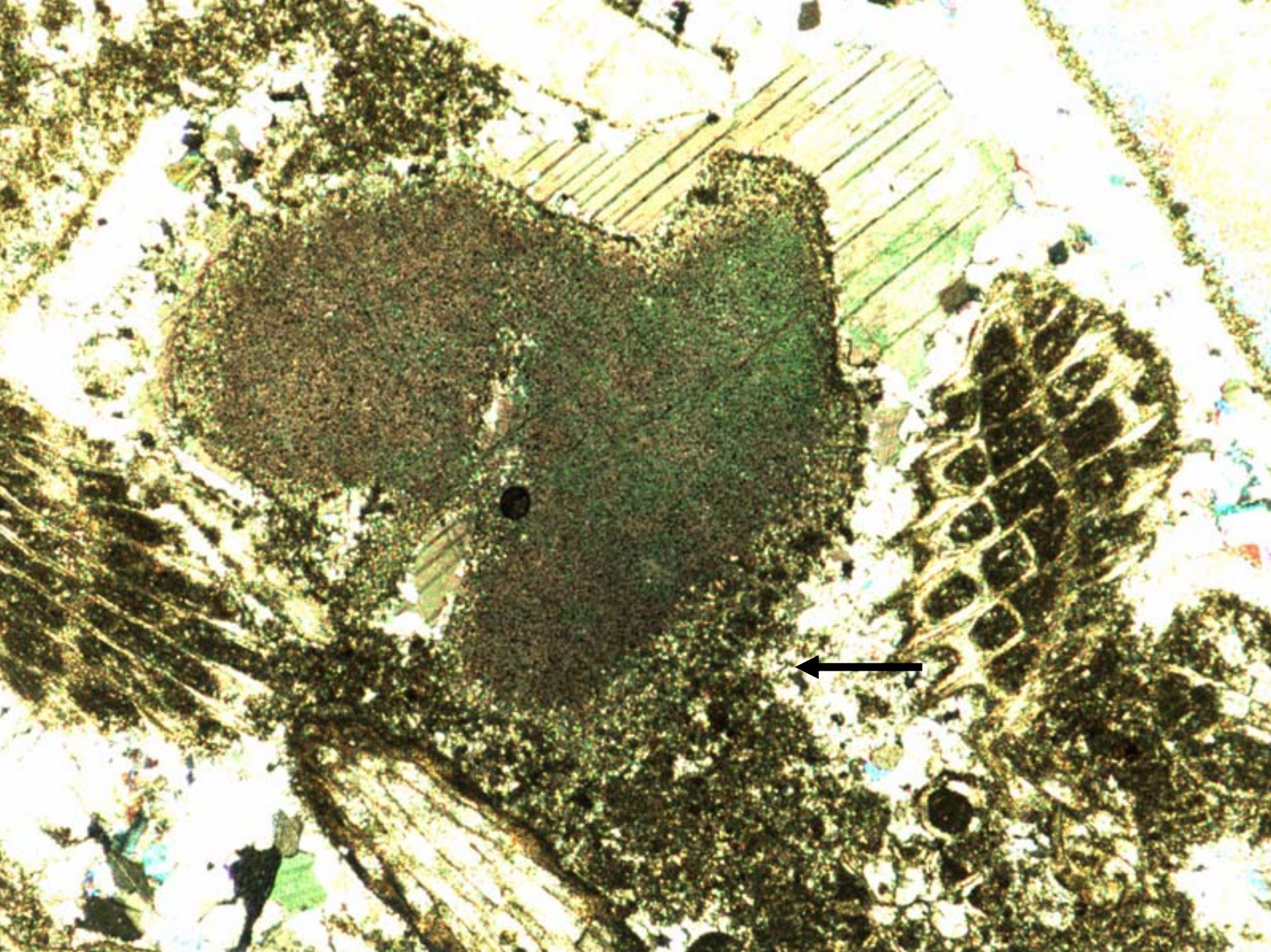
Microbial Micritization

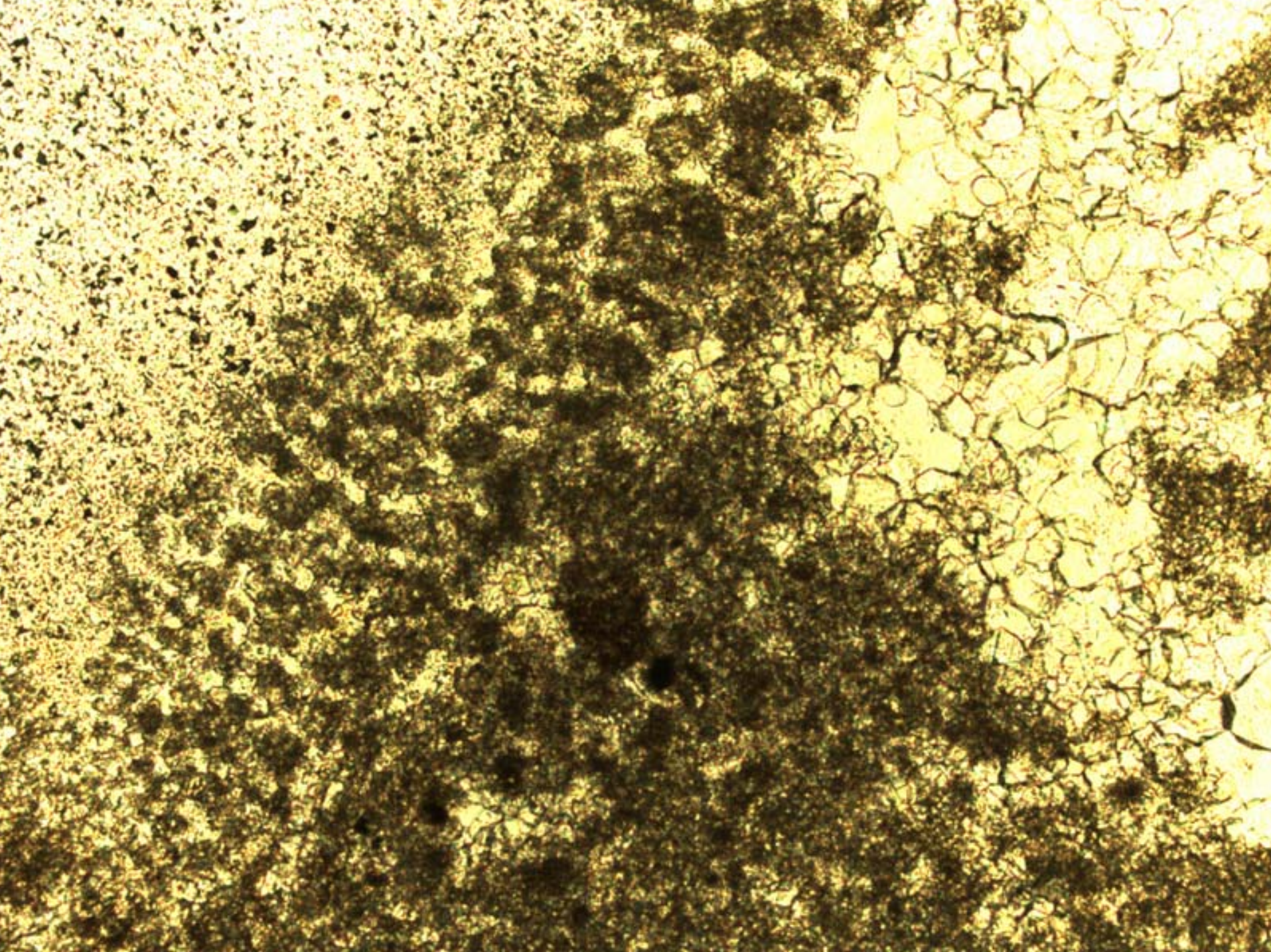




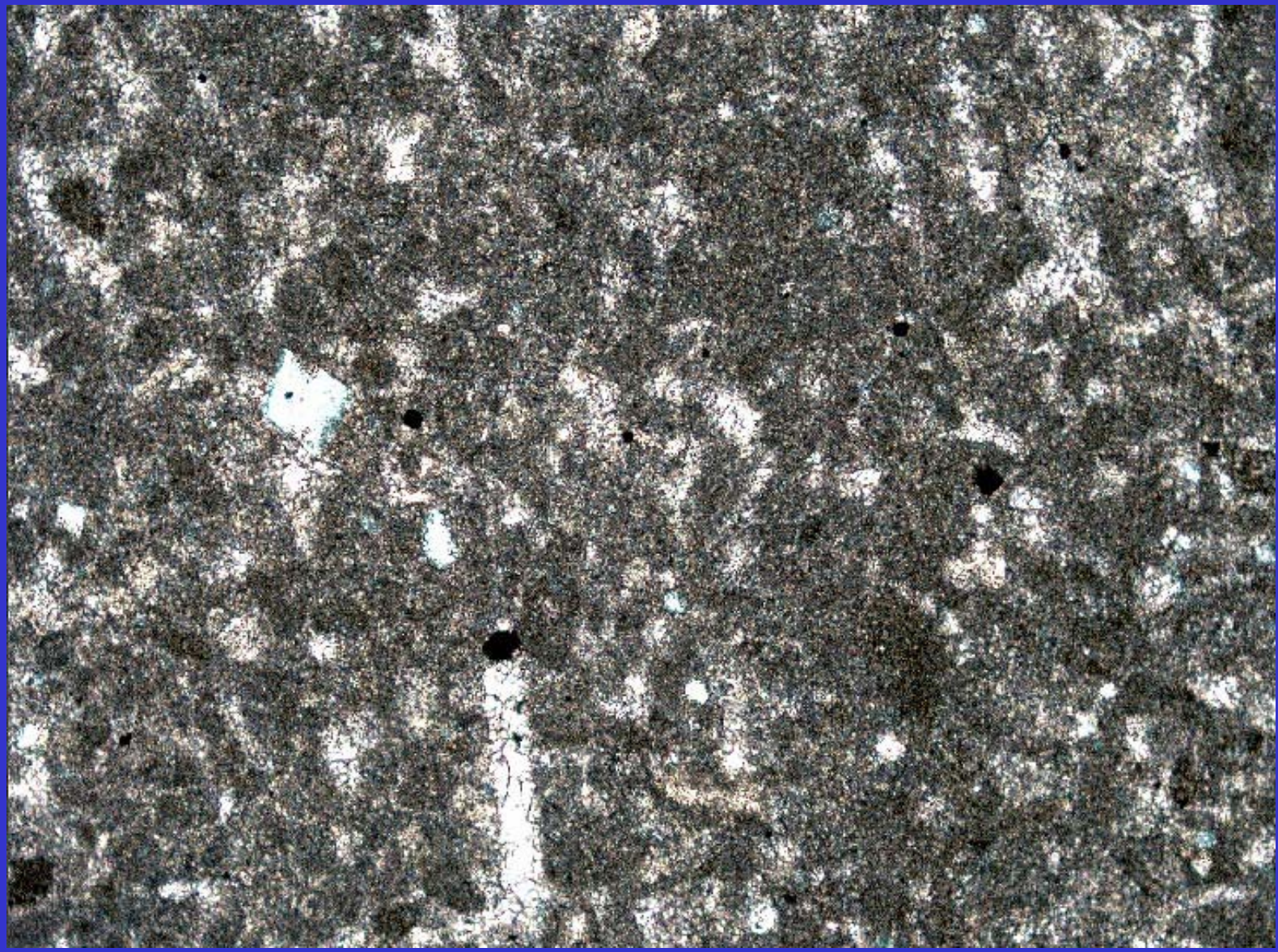


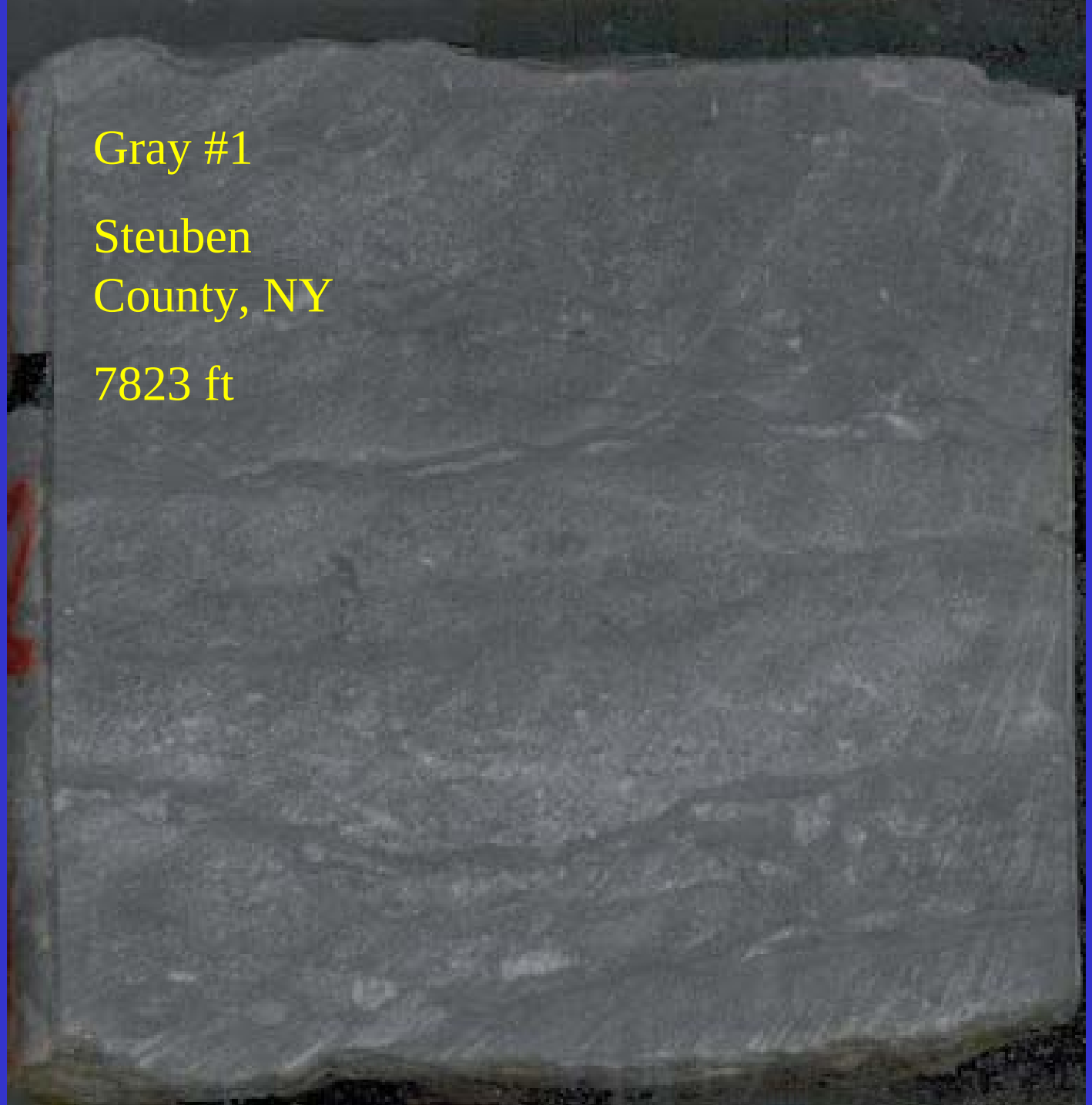


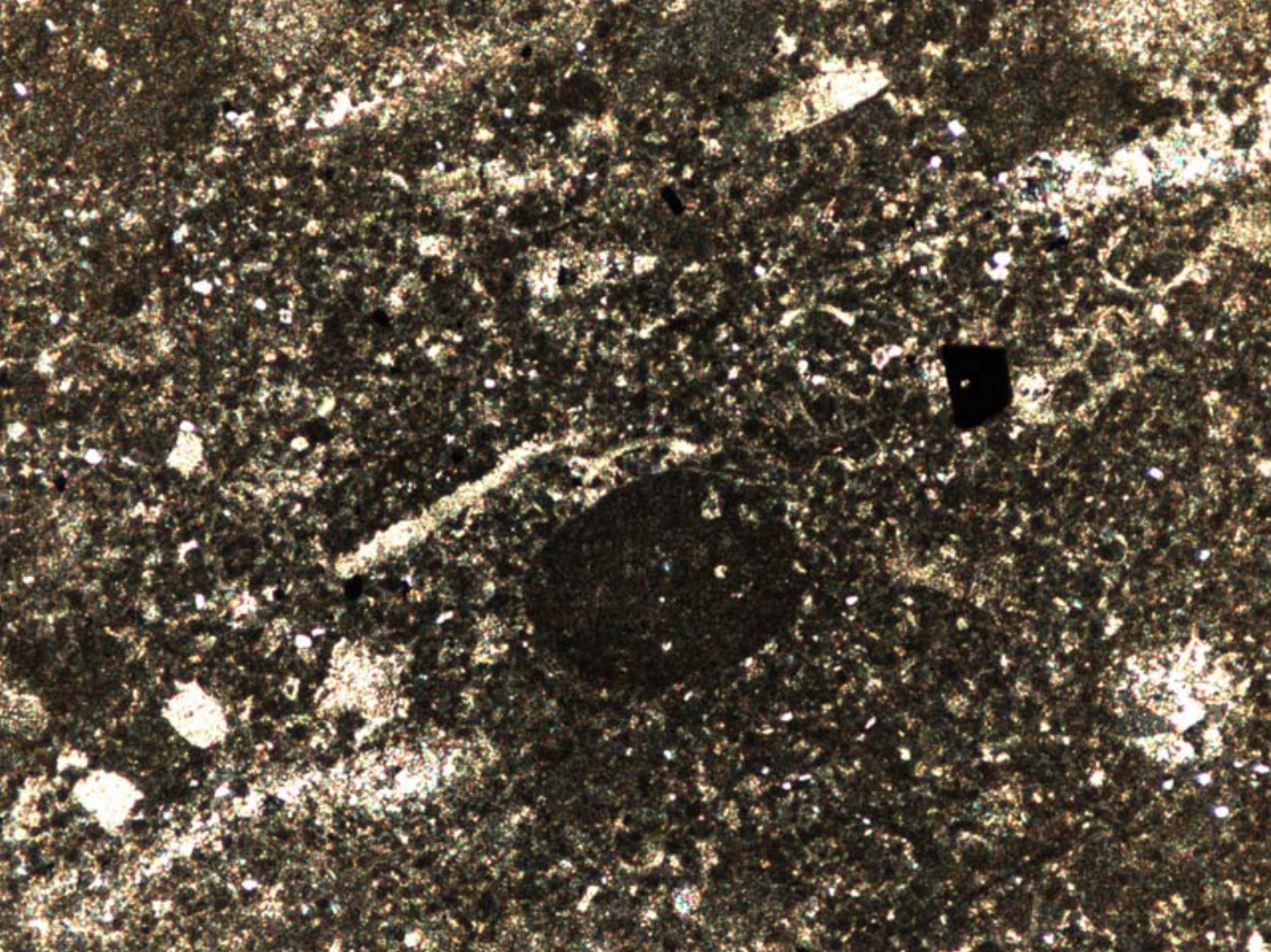




Peloidal Cement



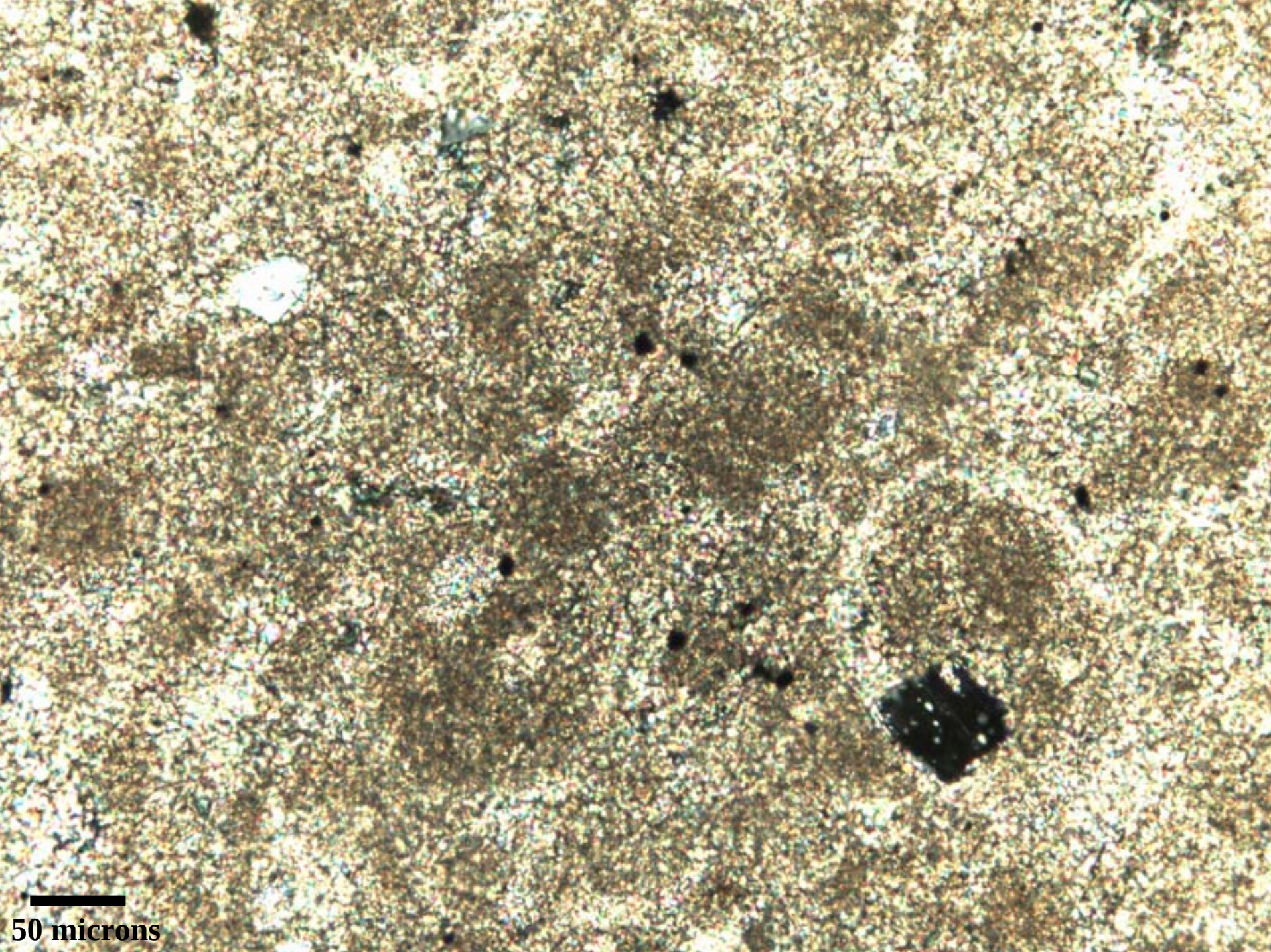

Gray #1
Steuben
County, NY
7823 ft



Name this rock…

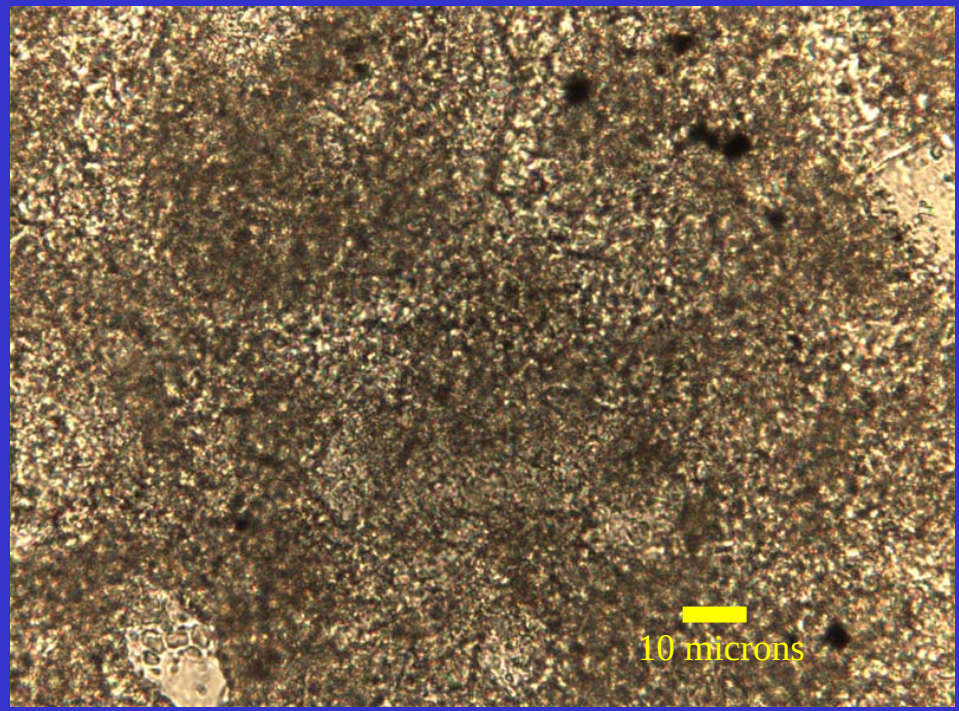
- 20% skeletal grains
  - Most altered by neomorphism
- 5.5% authigenic pyrite, quartz, feldspar, anhydrite, and dolomite
- **75% decimicron-size peloids**

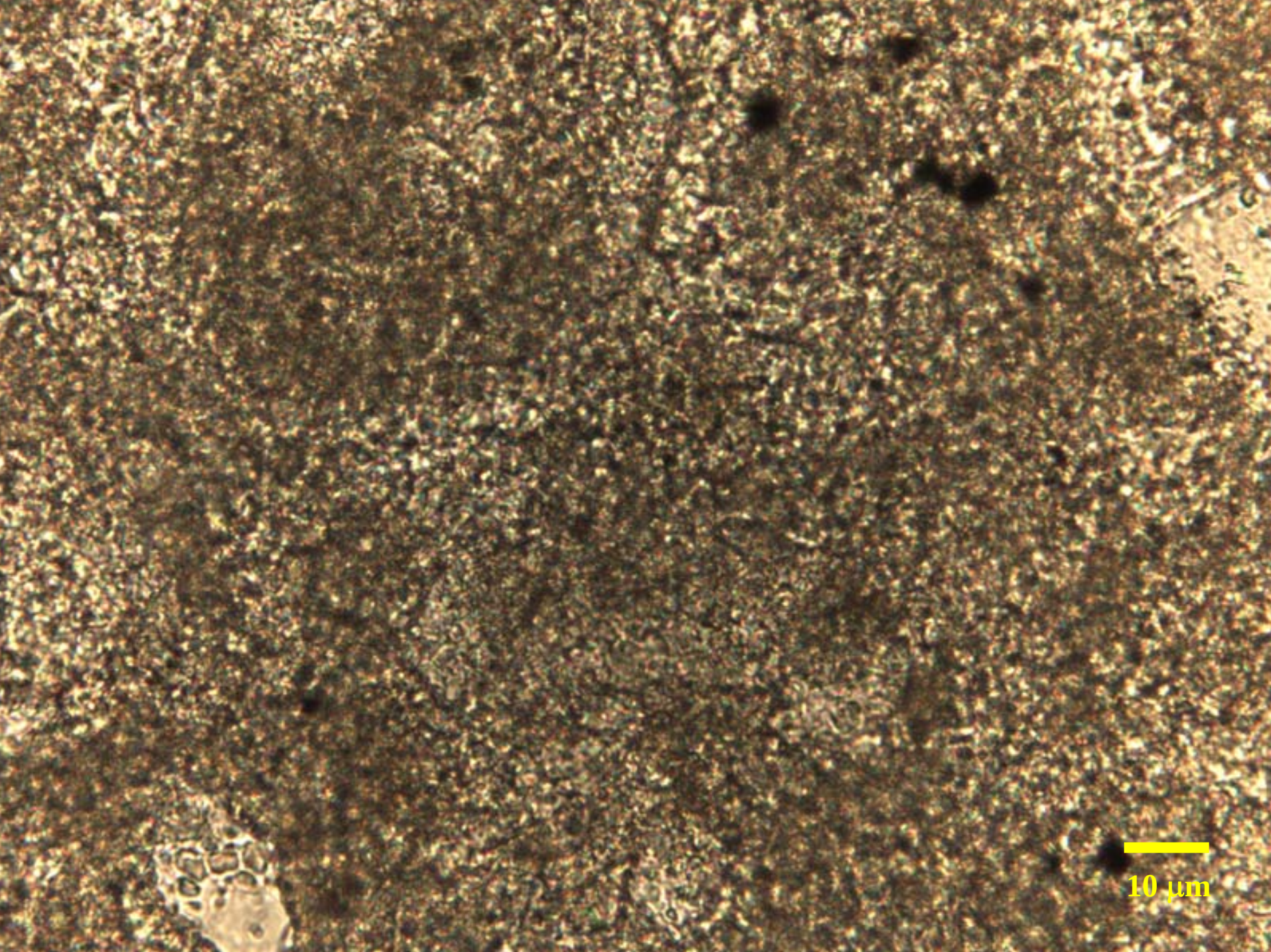
- Peloids: framework or cement?
  - If framework:
    - Algal material
    - Detritial sediment
    - Pellets
    - Replacement
  - If cement”
    - *in situ* precipitates

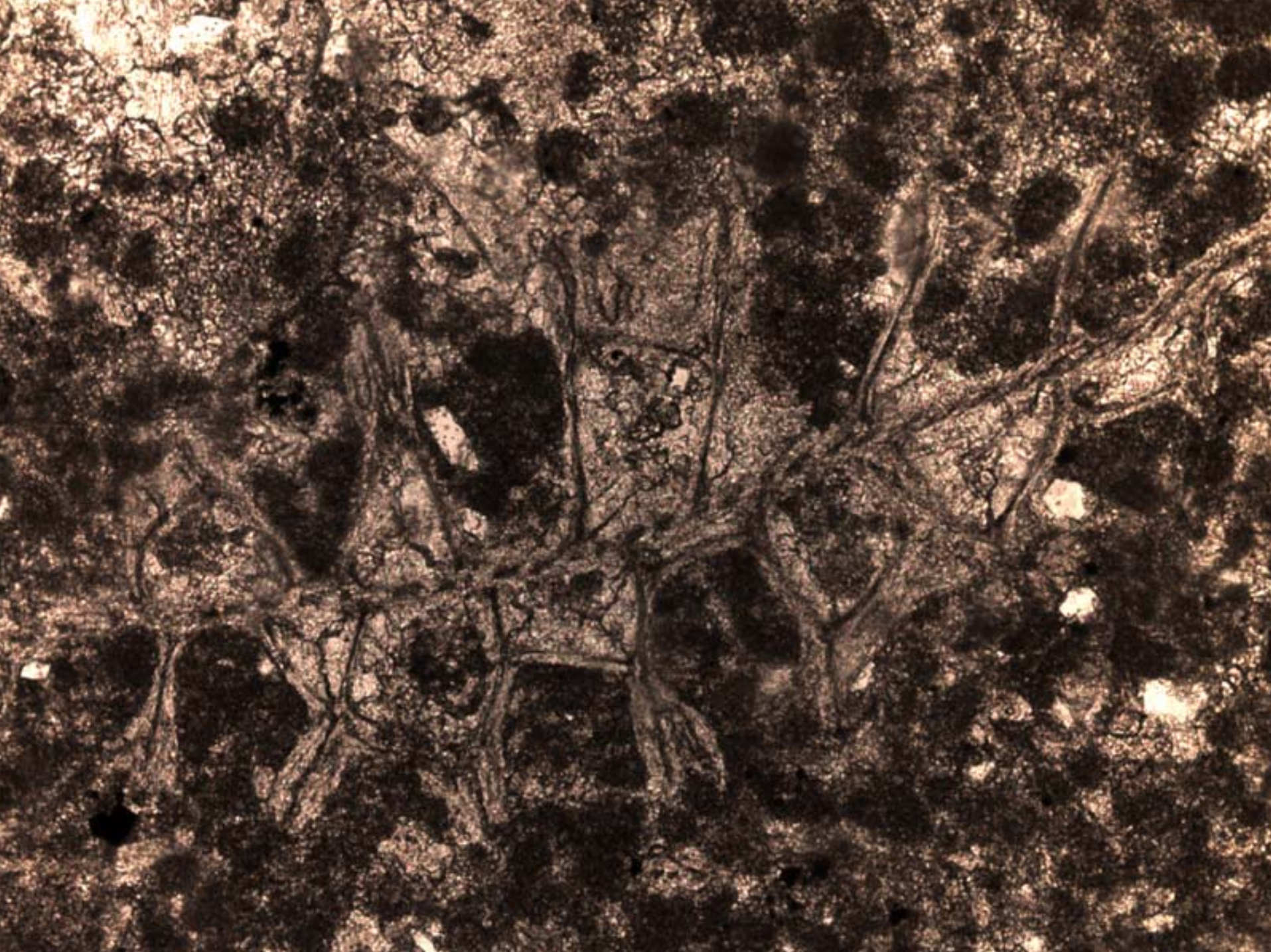

50 microns

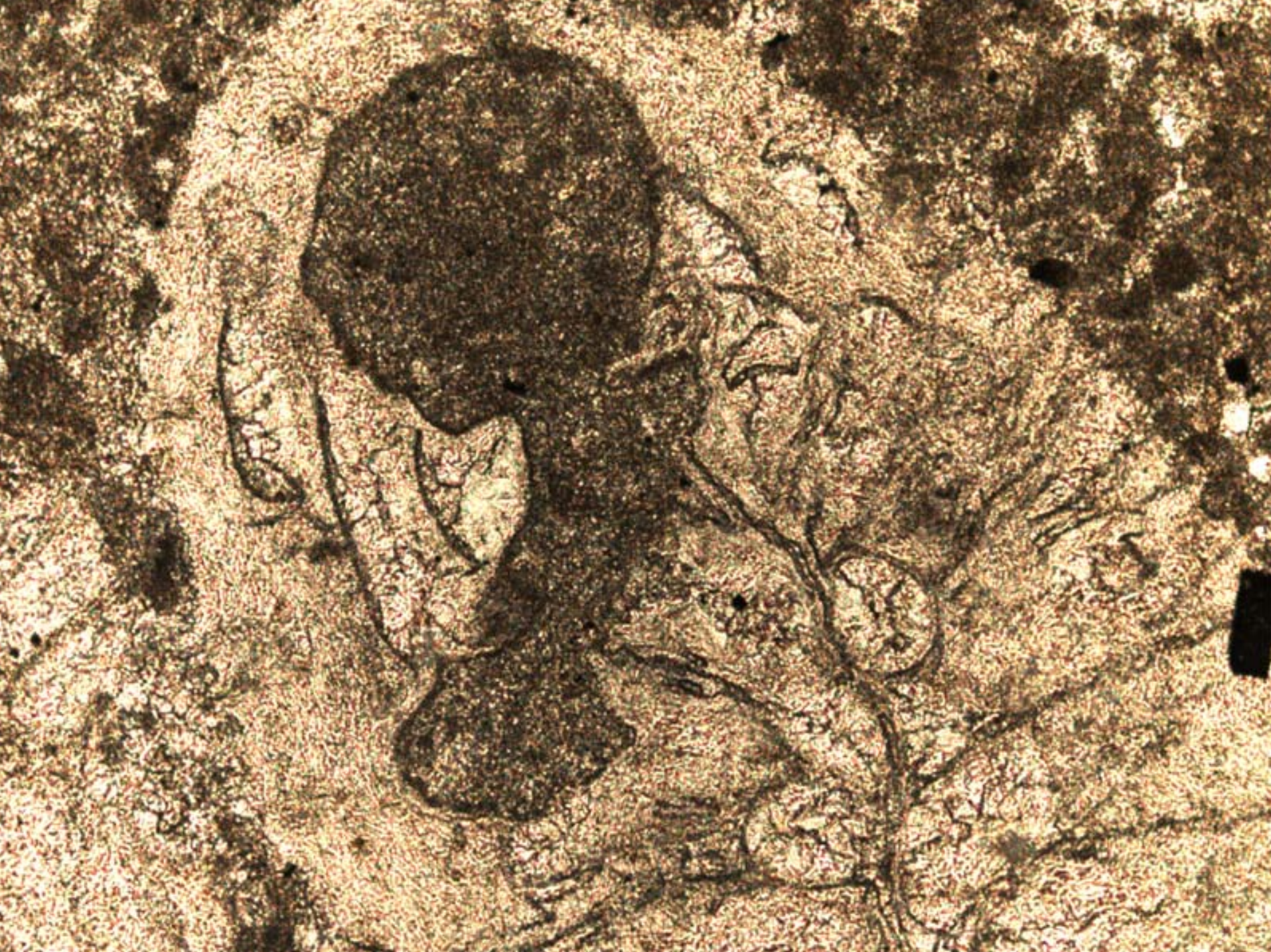
Peloids are cement, not grains

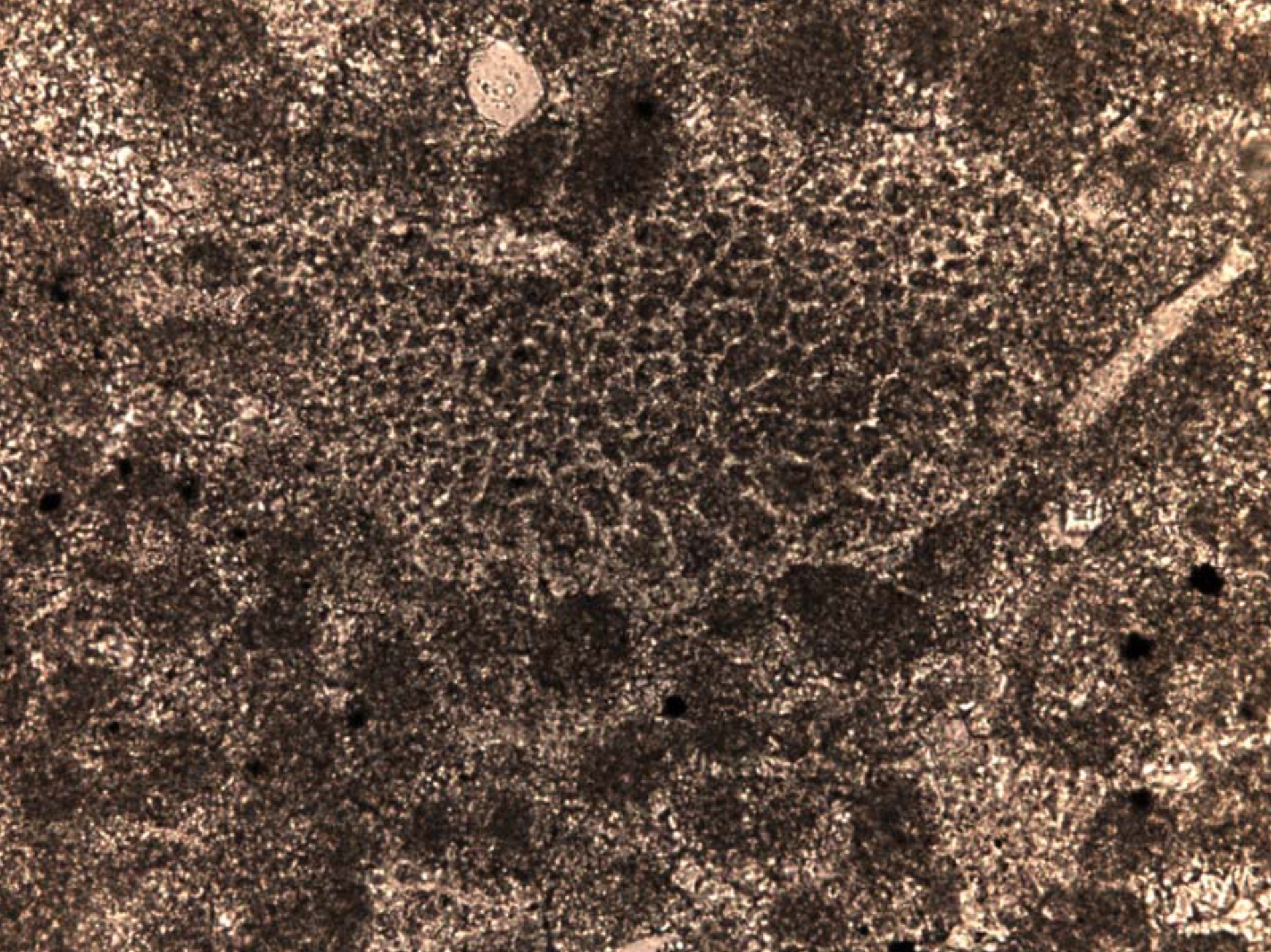
- Individual peloids – 50 to 100μm diameter
- Dark brown nucleus composed of micron-size calcite surrounded by a rim of euhedral dentate to blocky microspar
- Nuclei consist of clots of submicron-size opaque material:
  - Organic, microbial matter (Chafetz, 1986)
  - Submicrocrystalline calcite crystals that grew around a small number of nuclei (Bosak and others, 2004)

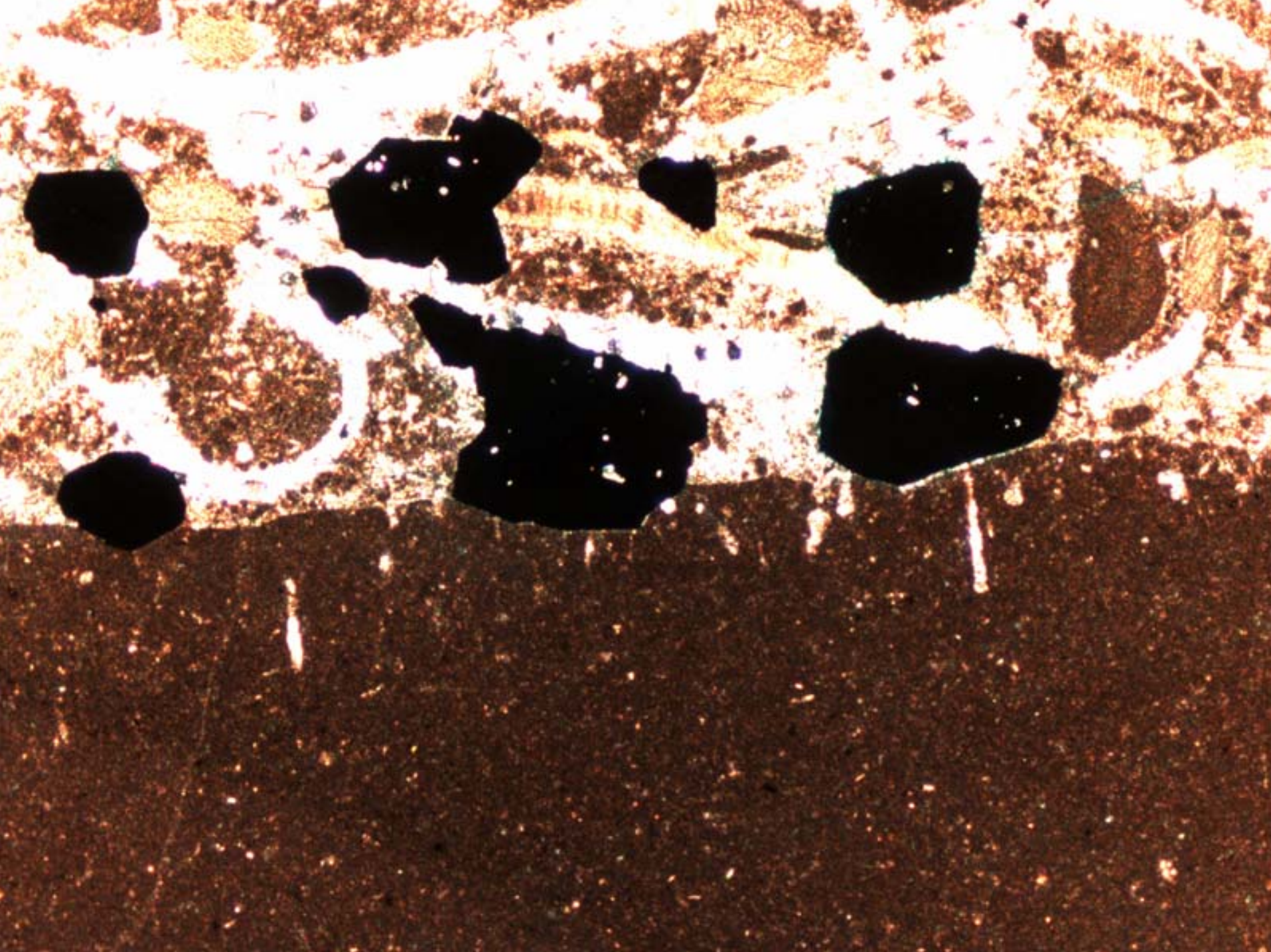


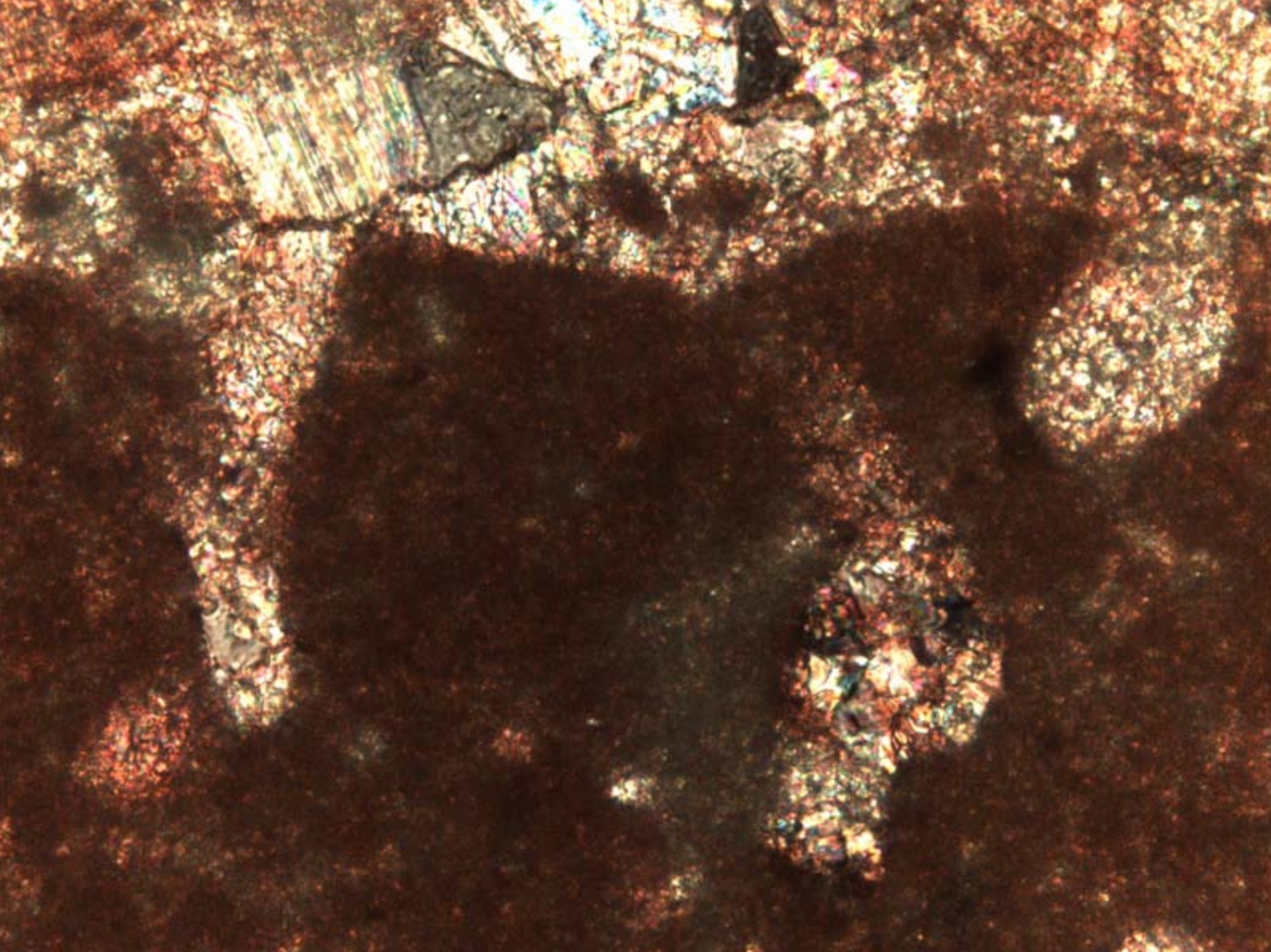

10 µm

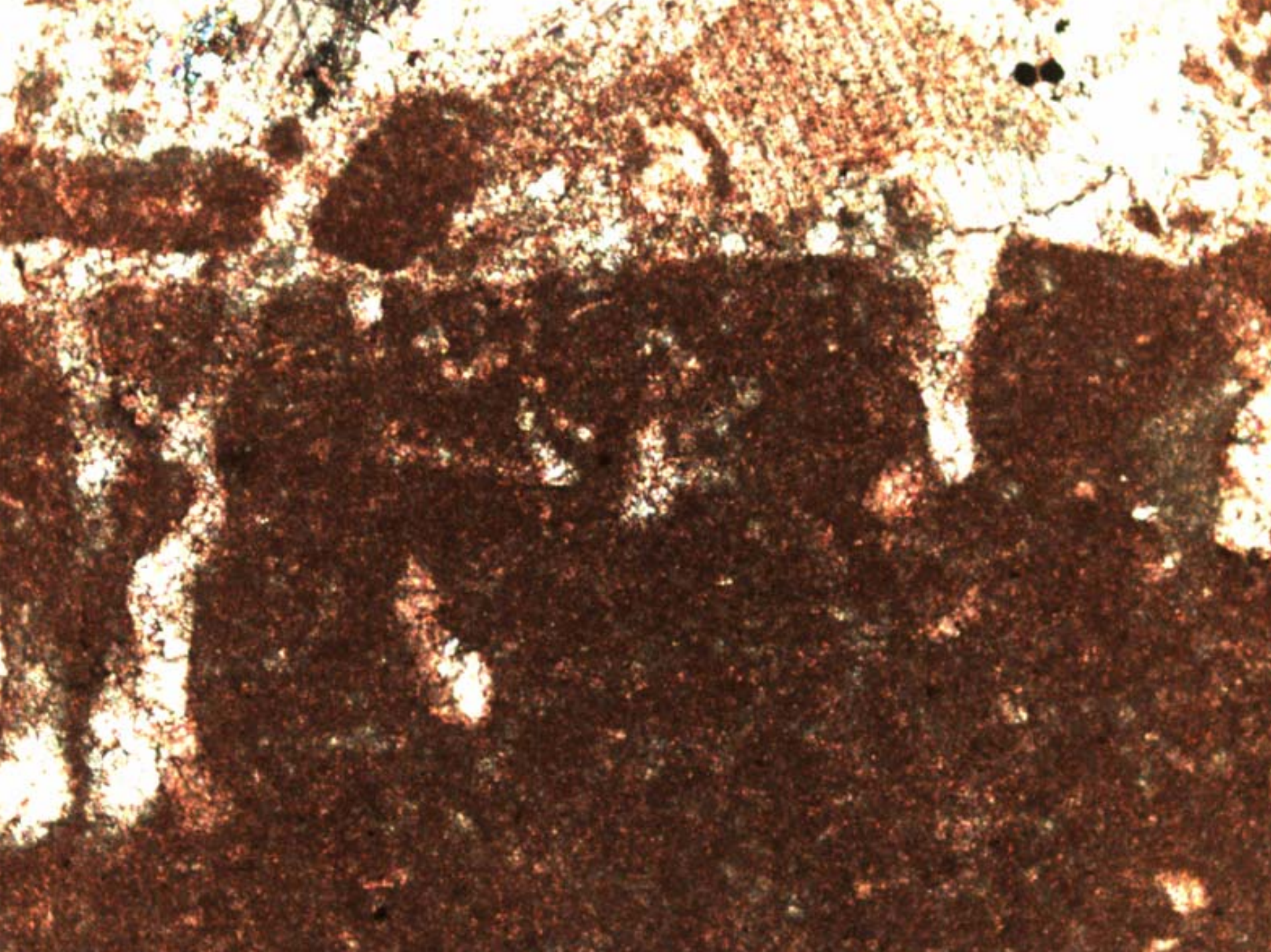


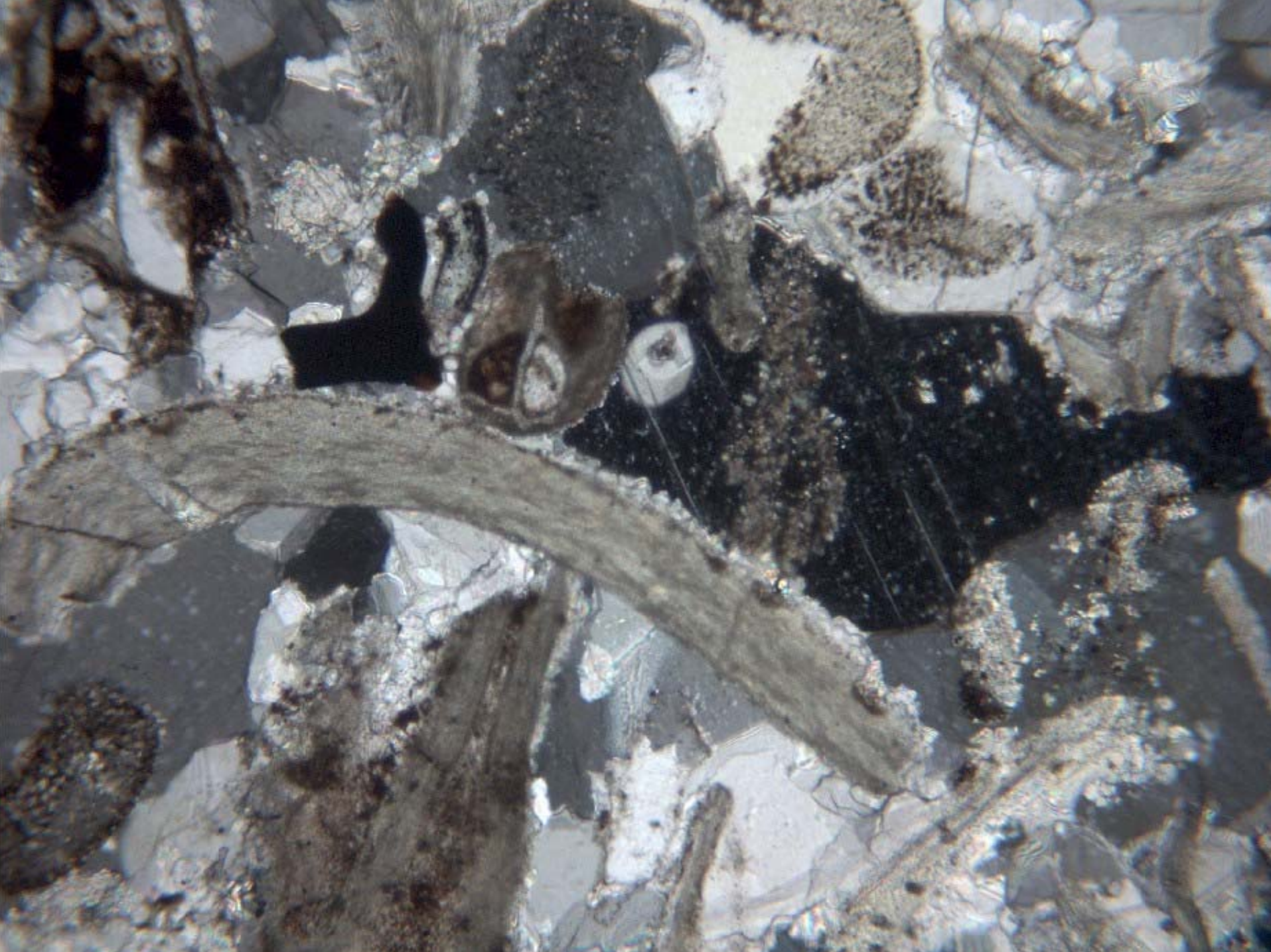


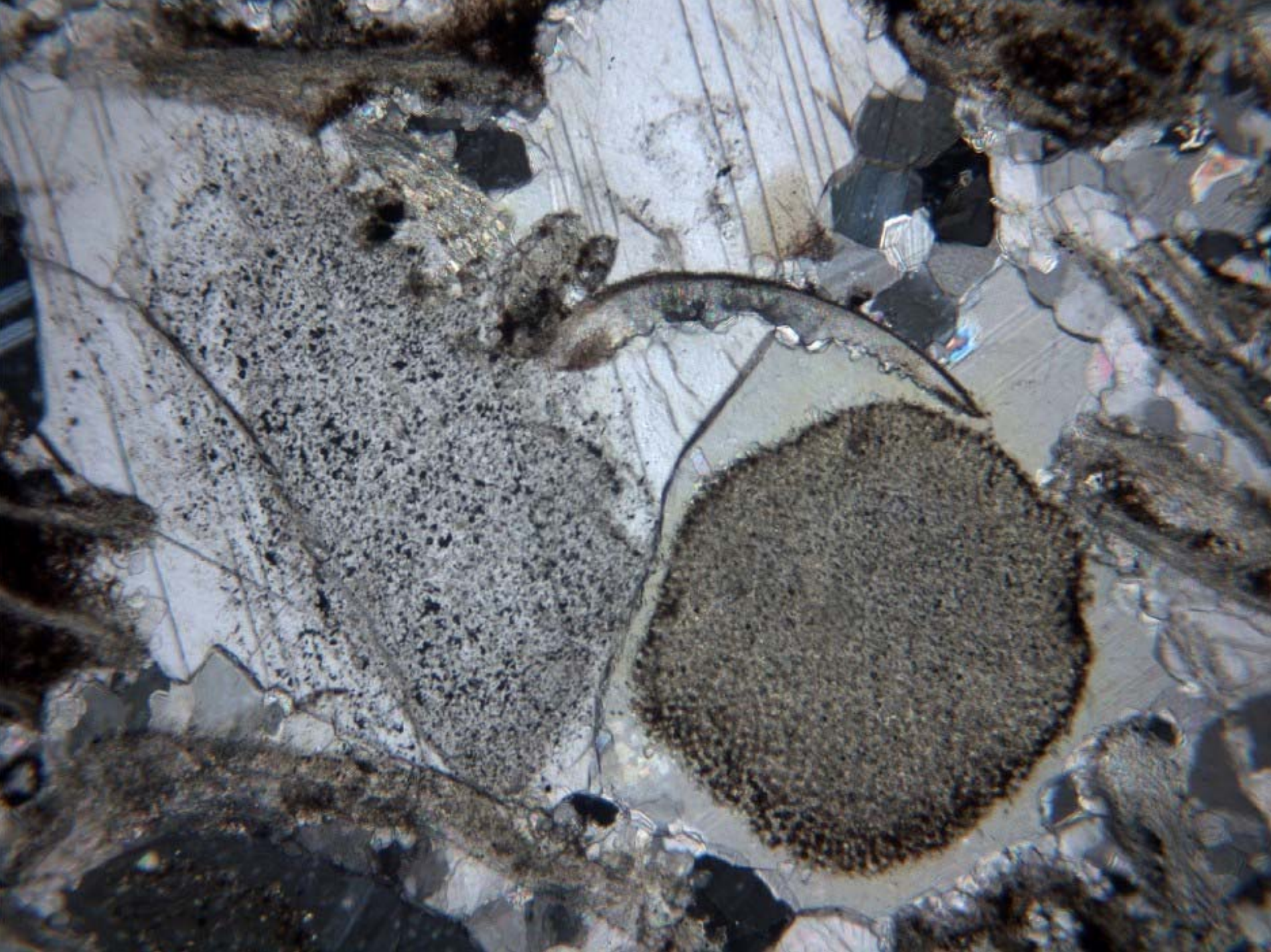


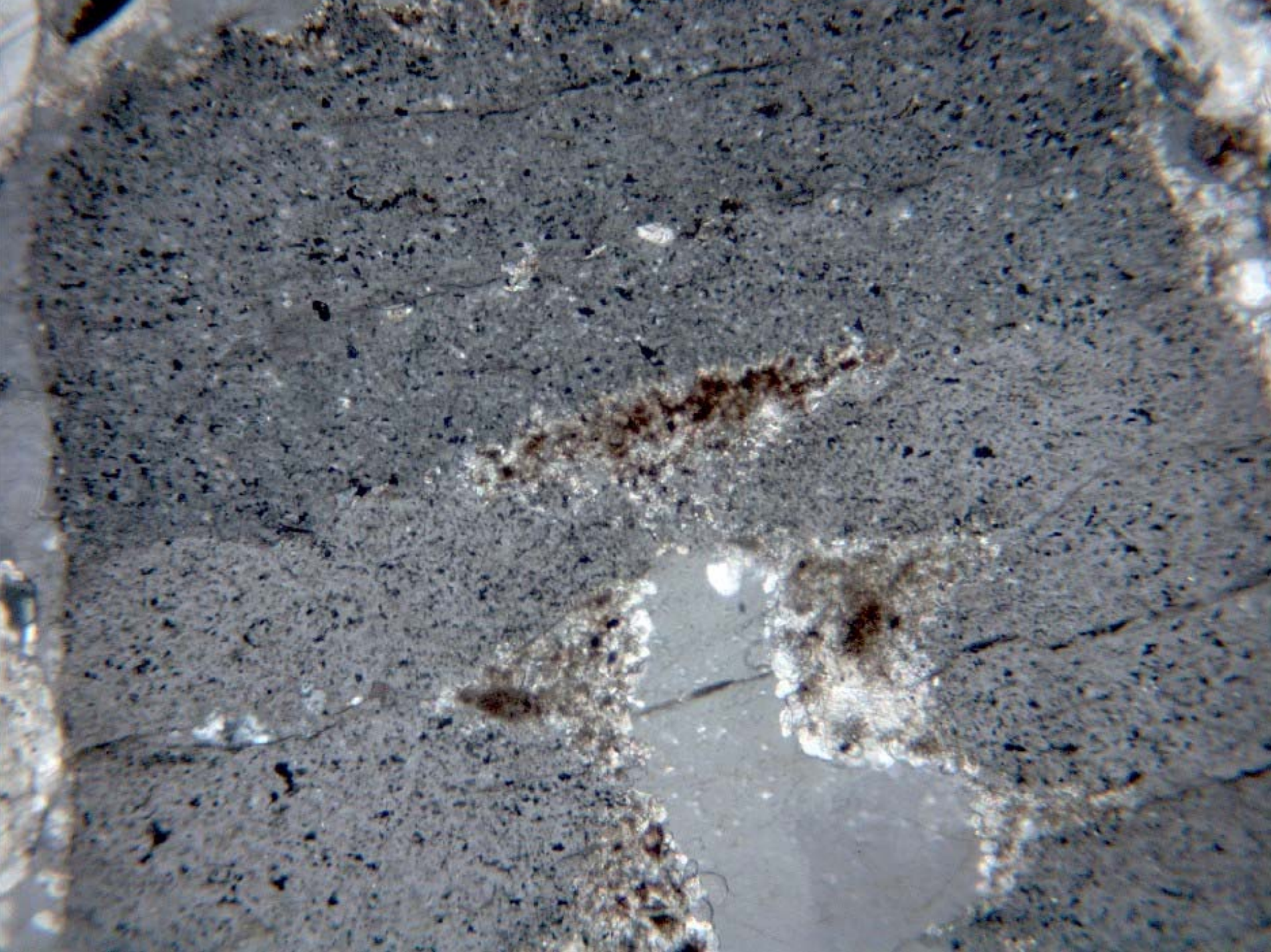


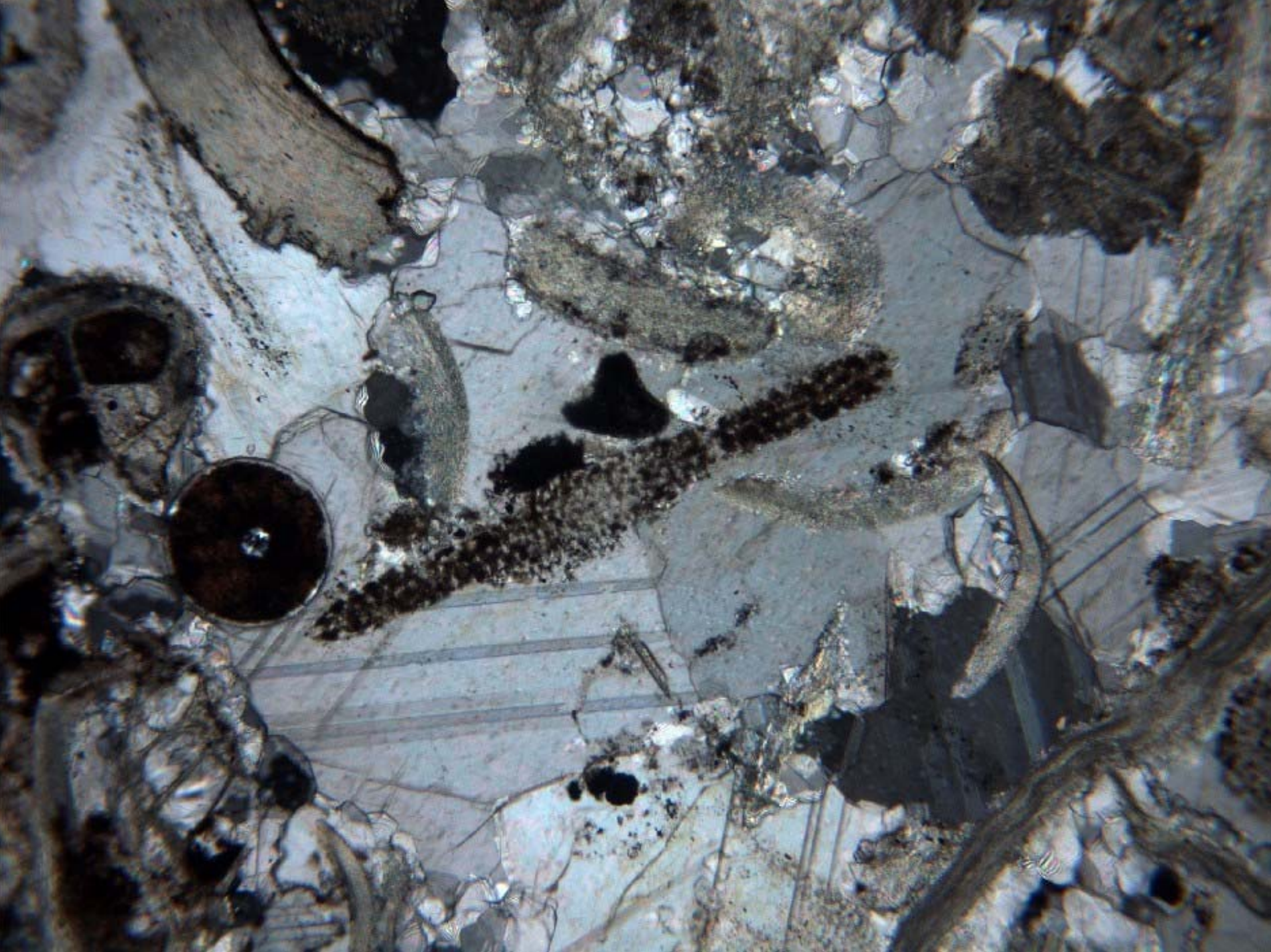




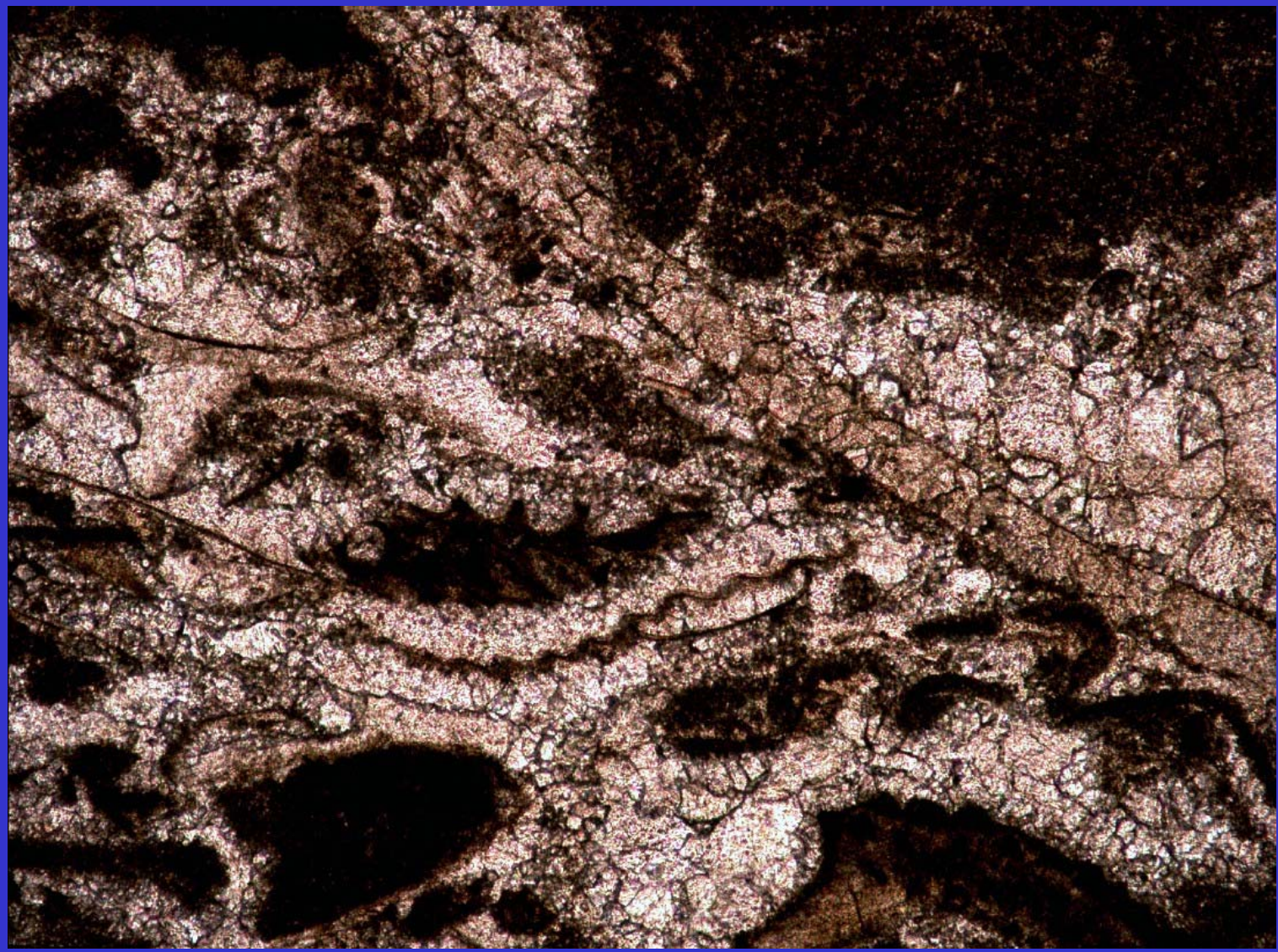




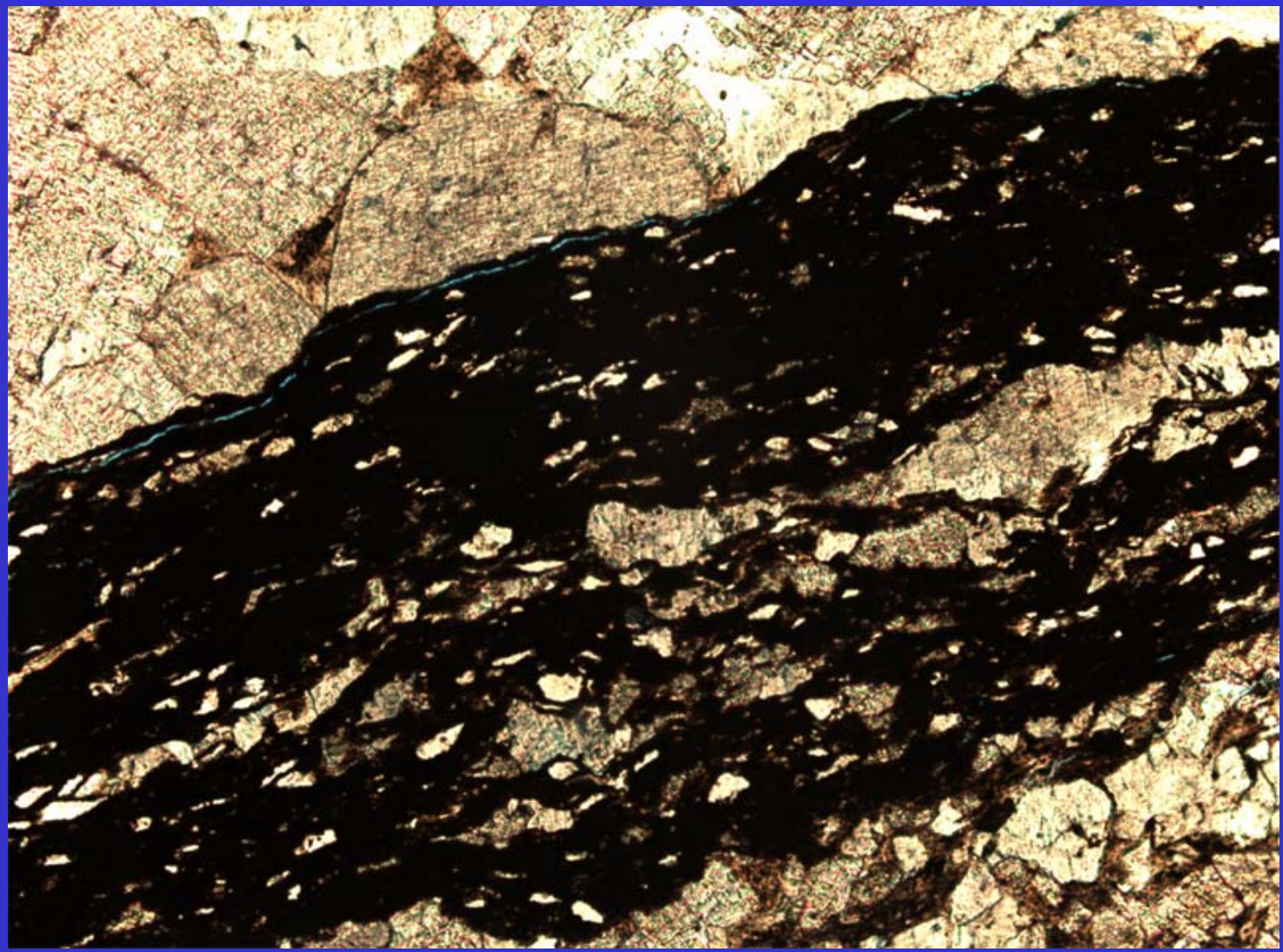


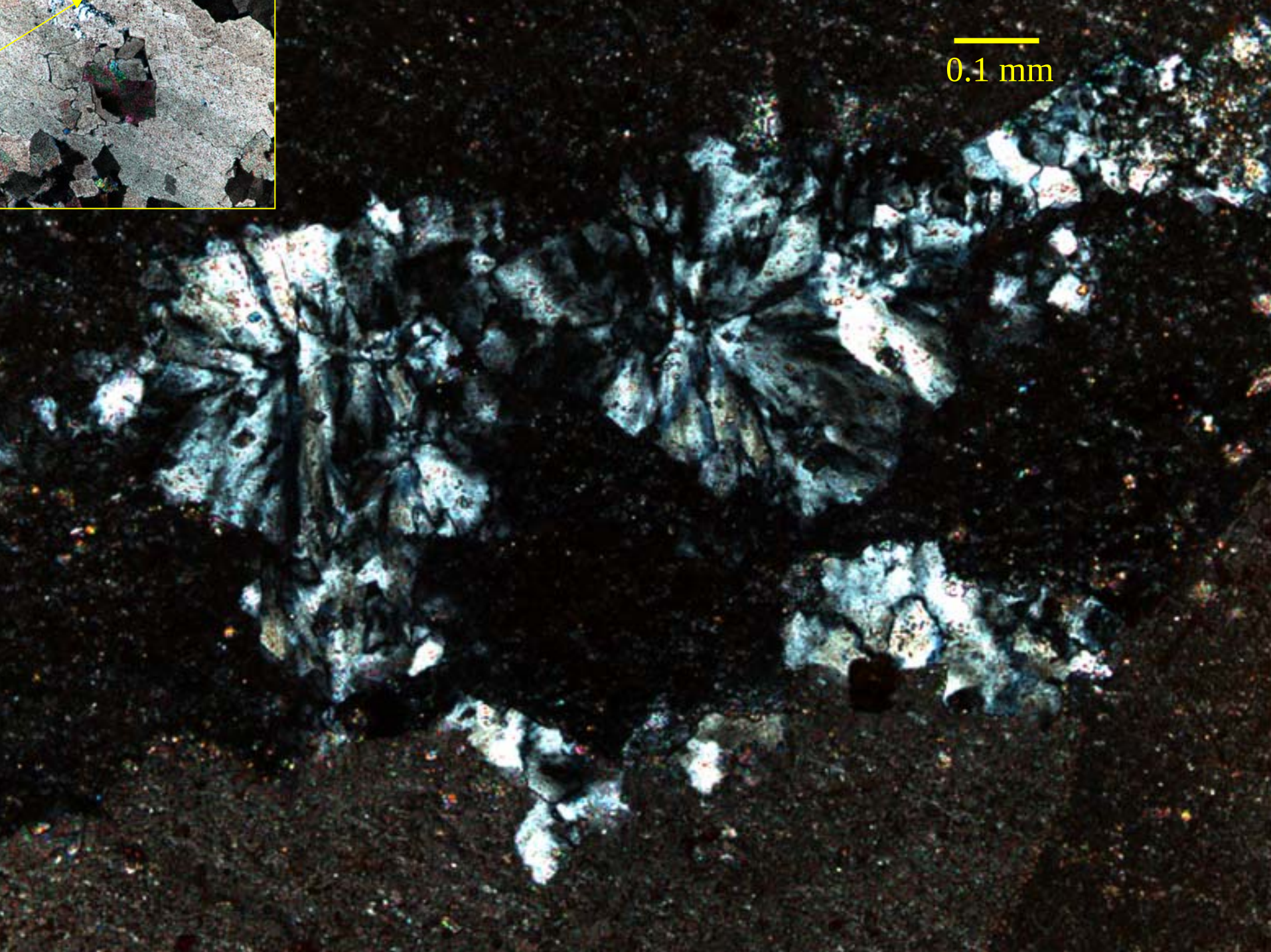


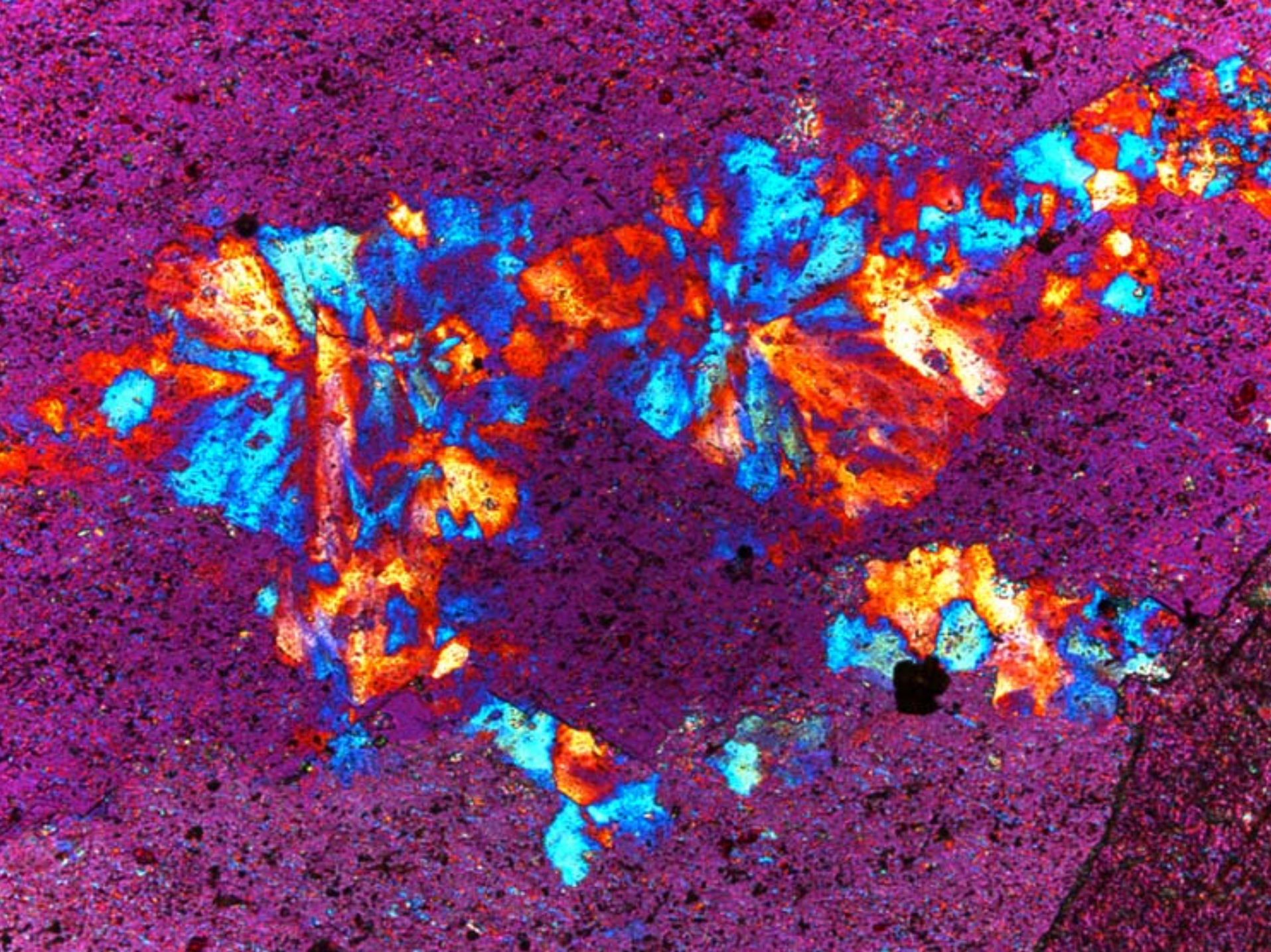
Neomorphism

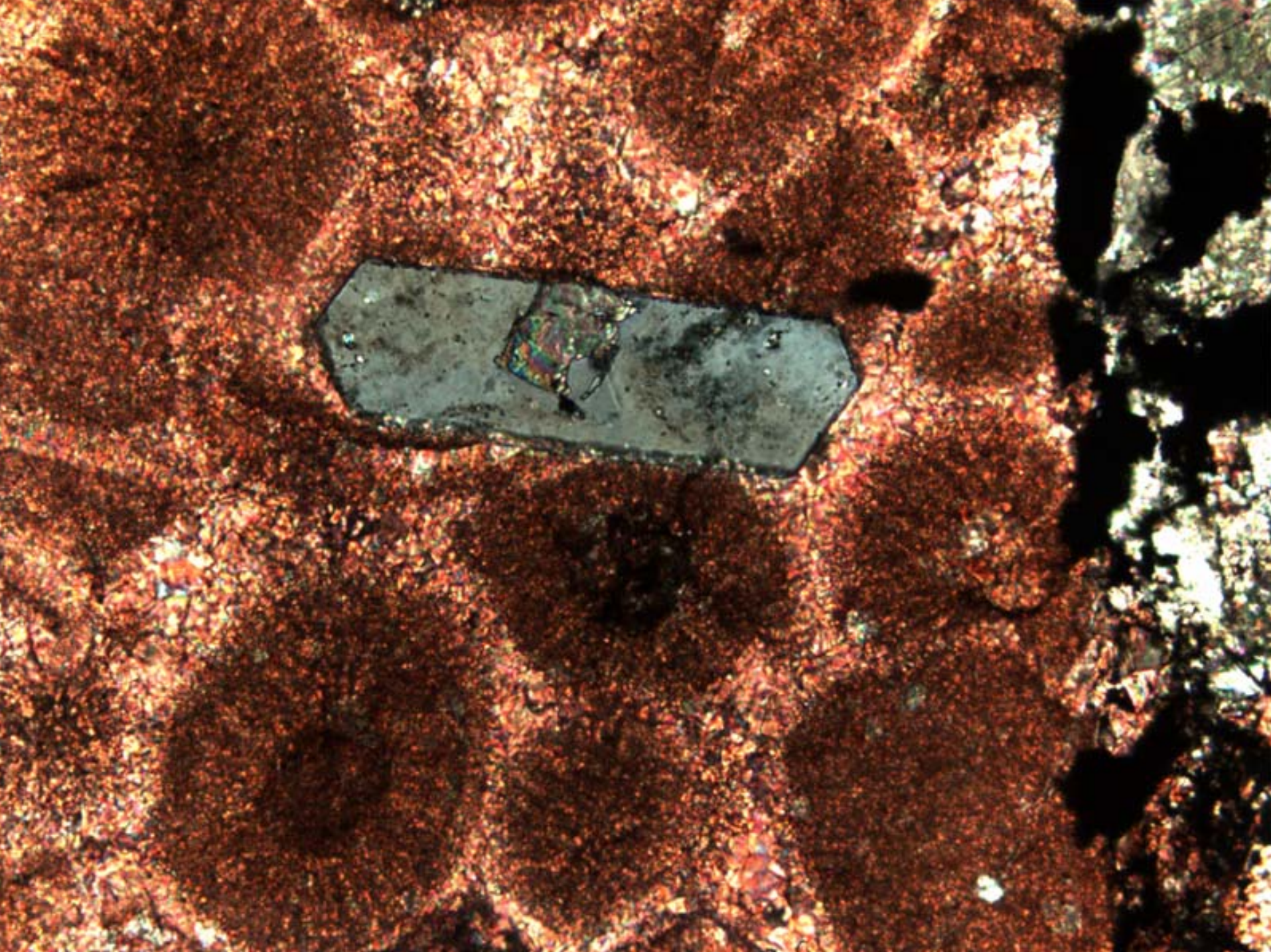


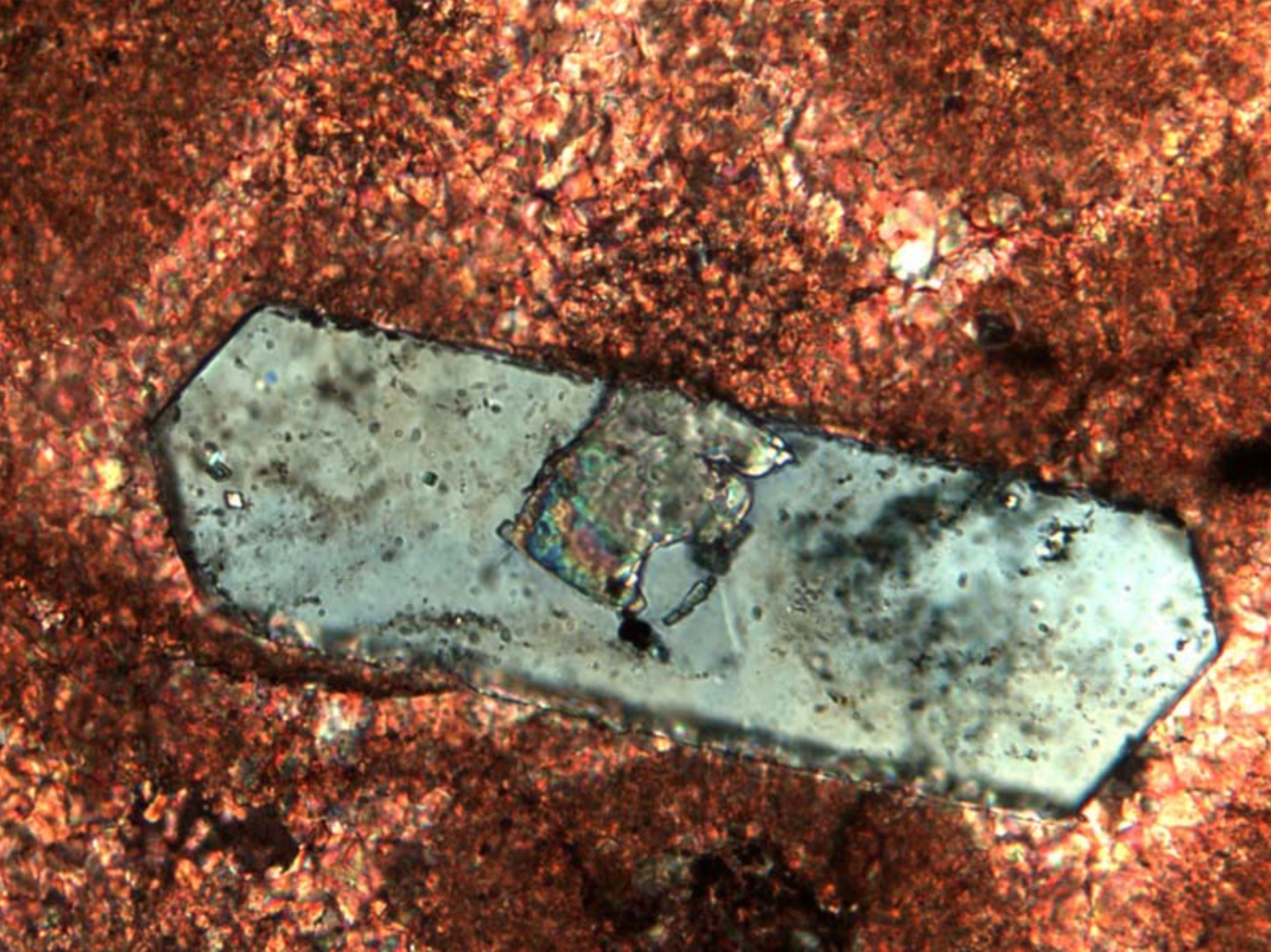
Compaction

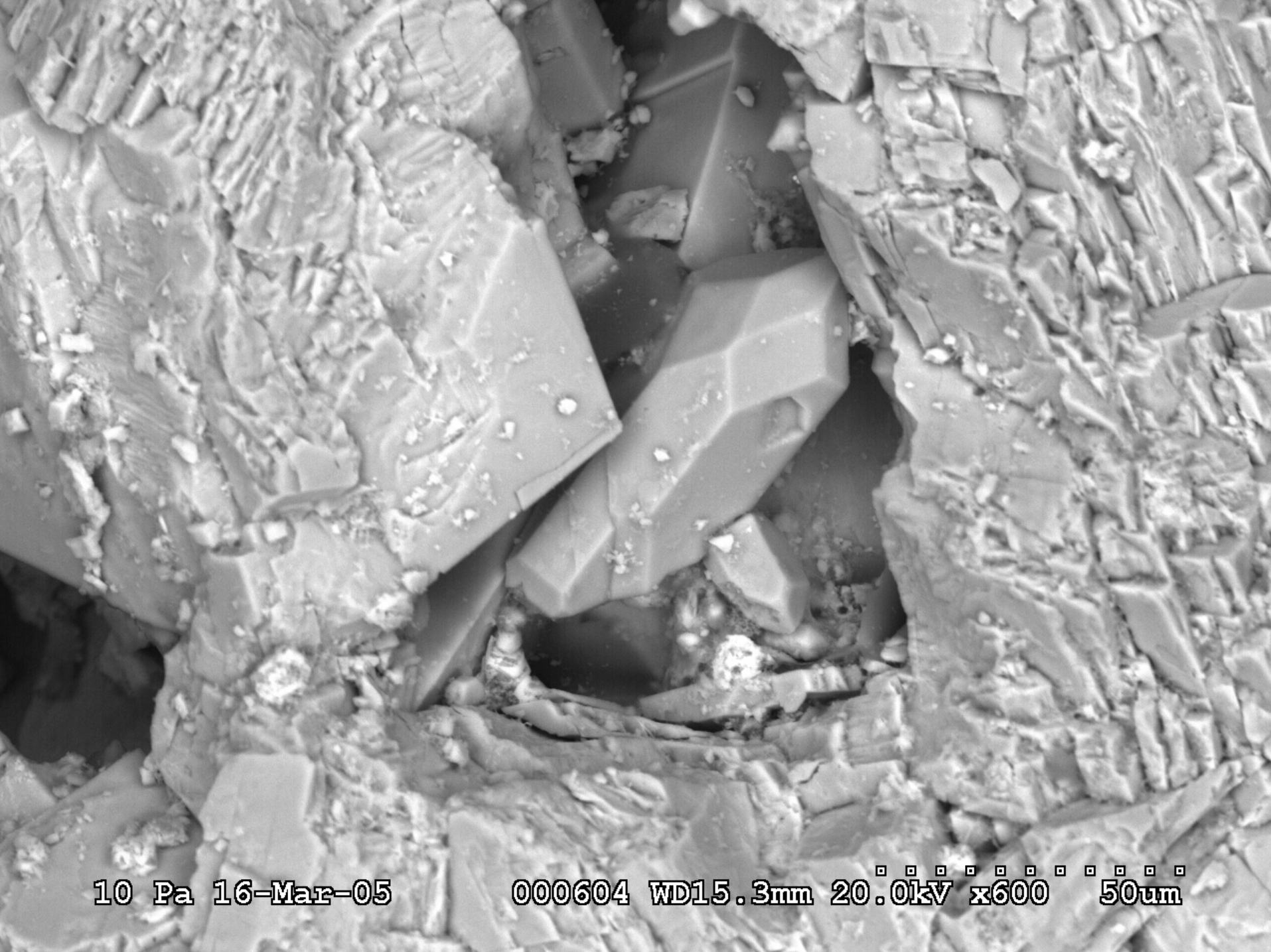



0.1 mm

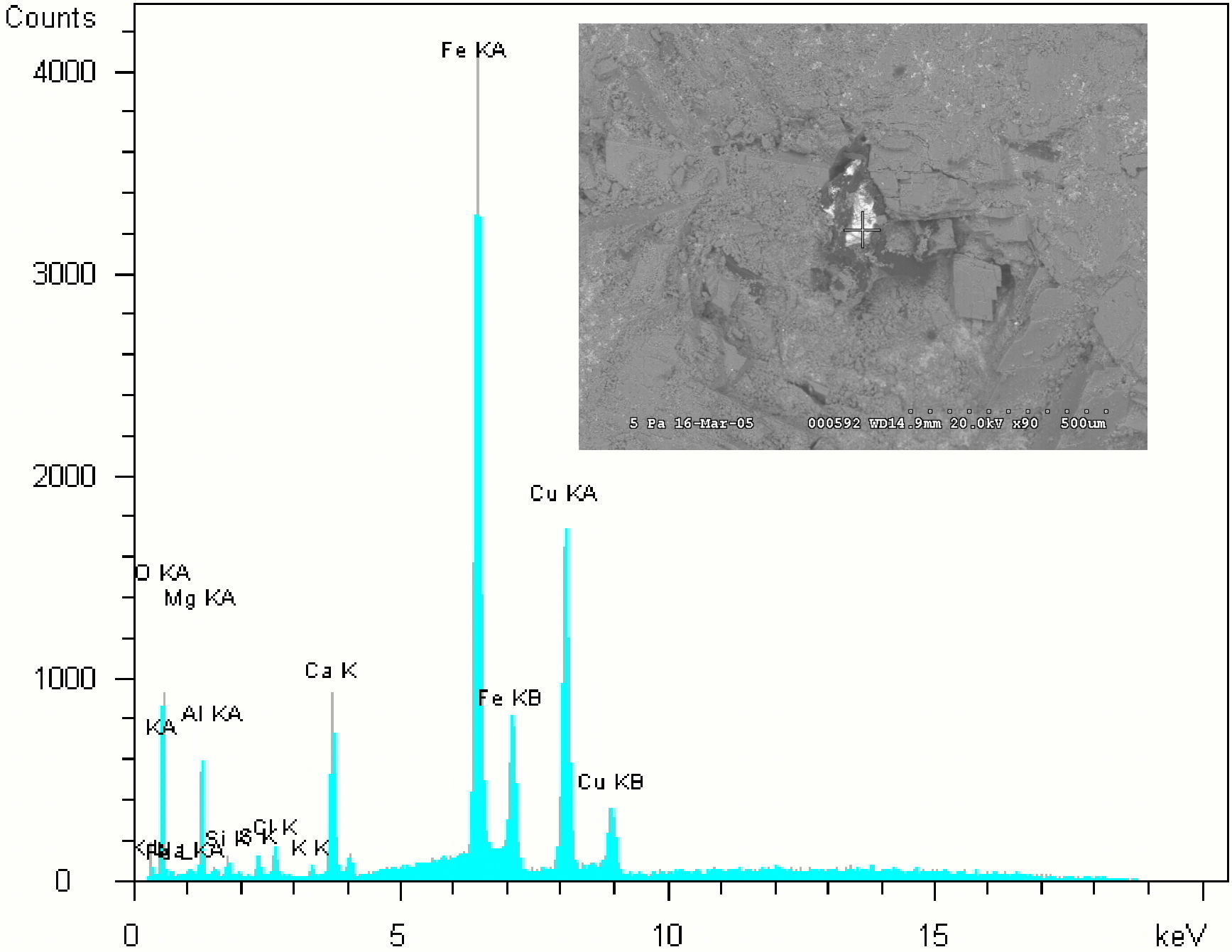


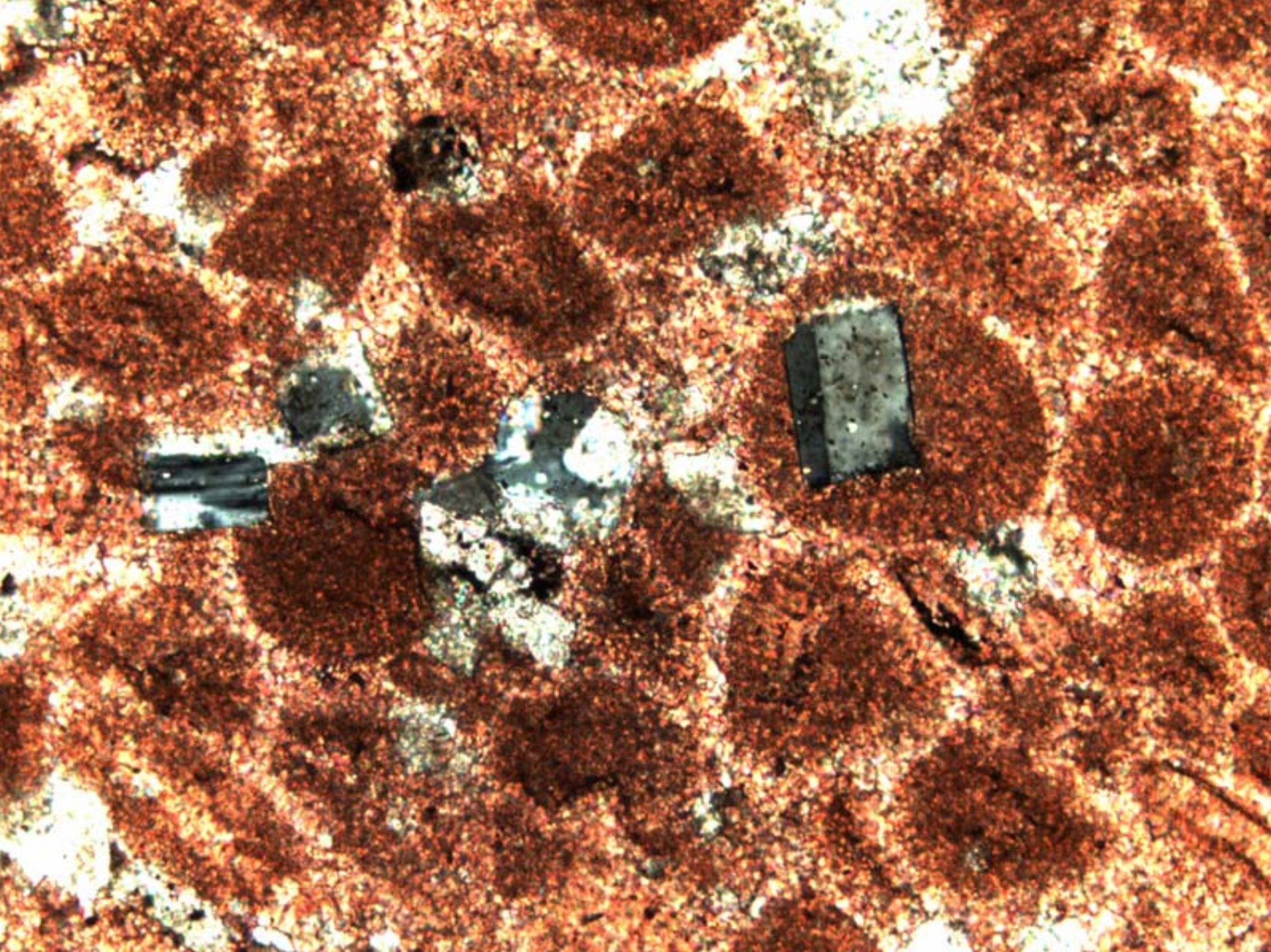


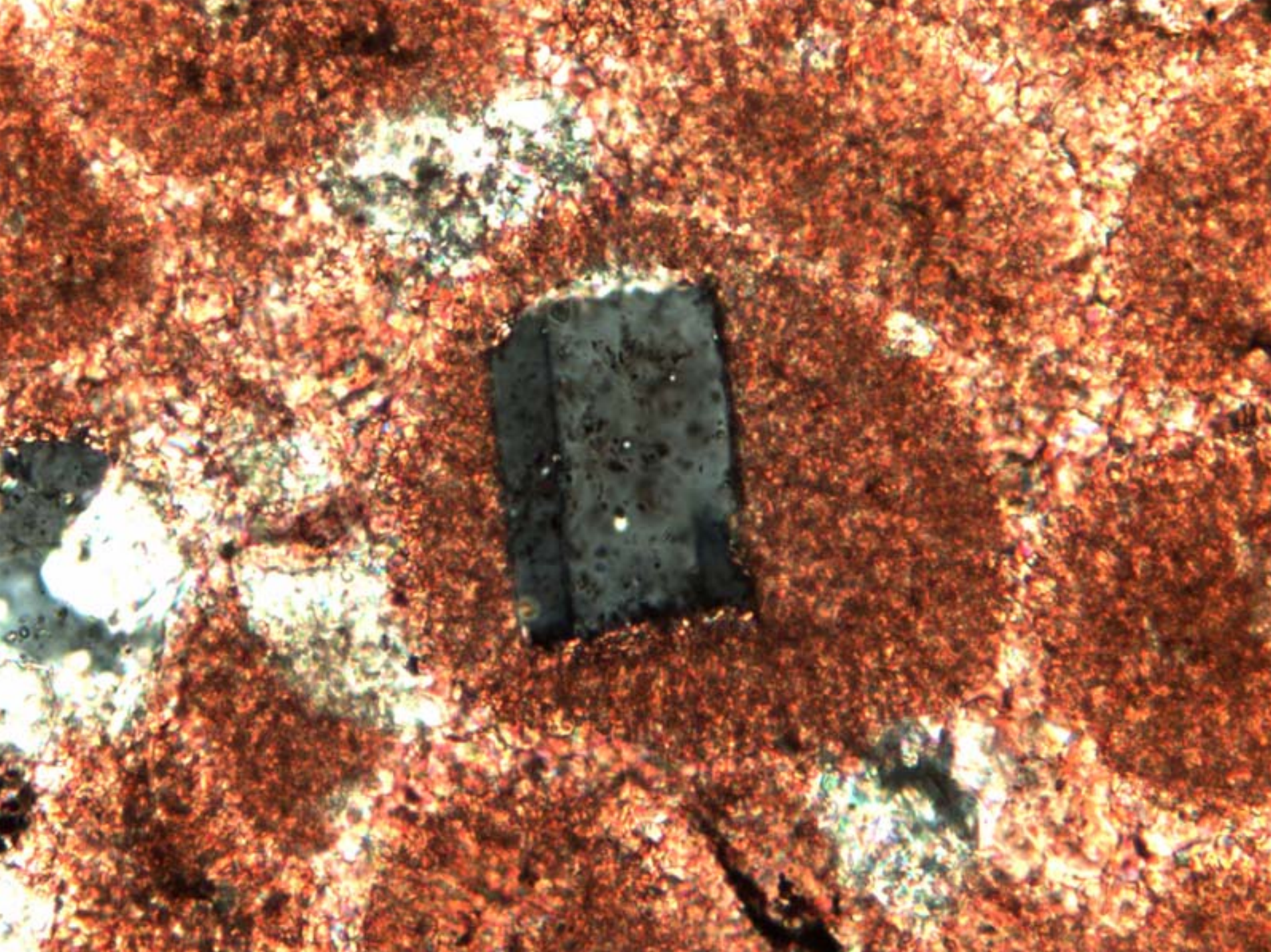



10 Pa 16-Mar-05
000604 WD15.3mm 20.0kV x600
50um

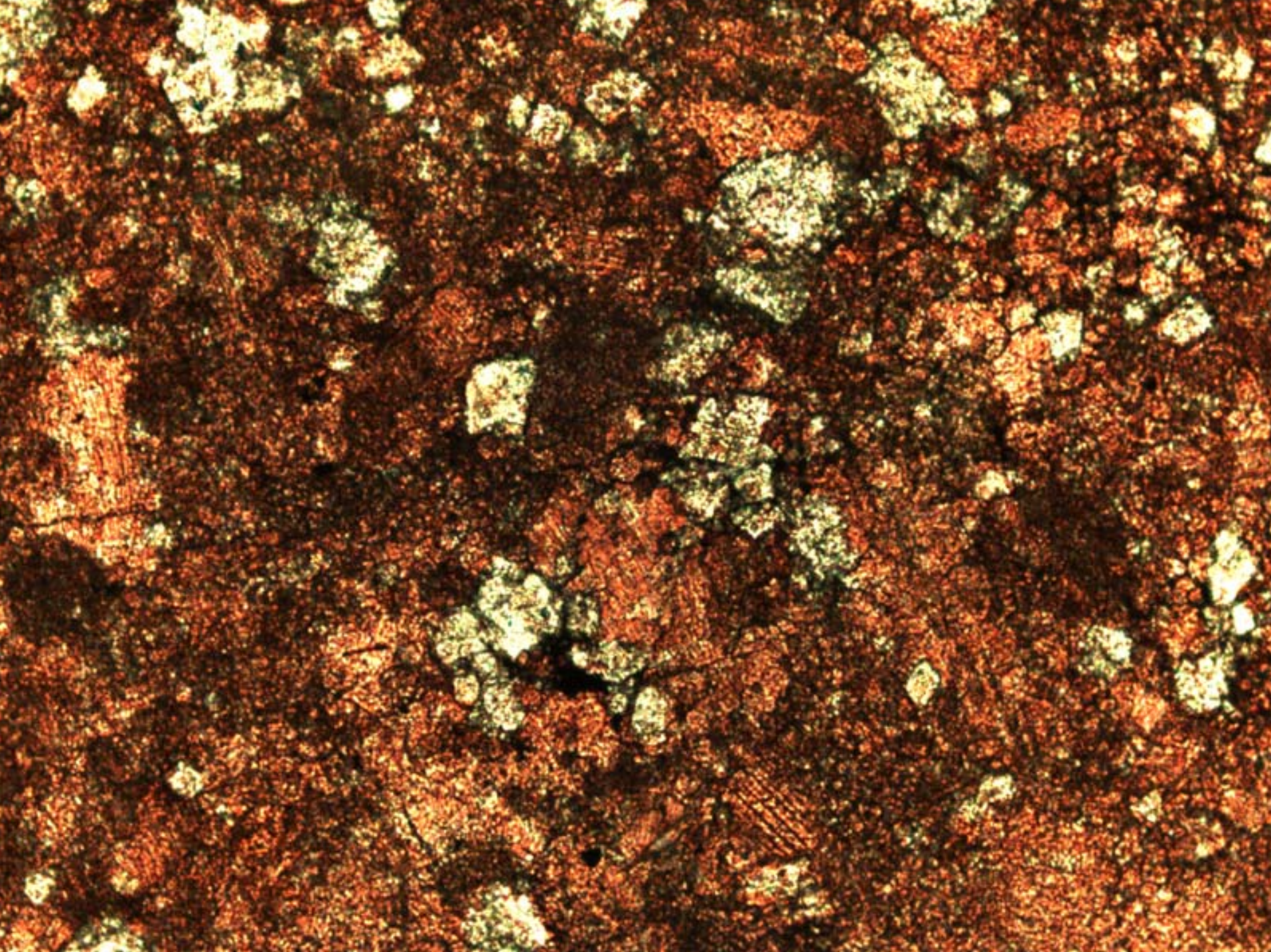

5 Pa 16-Mar-05 000592 WD14.9mm 20.0kV x180 250um

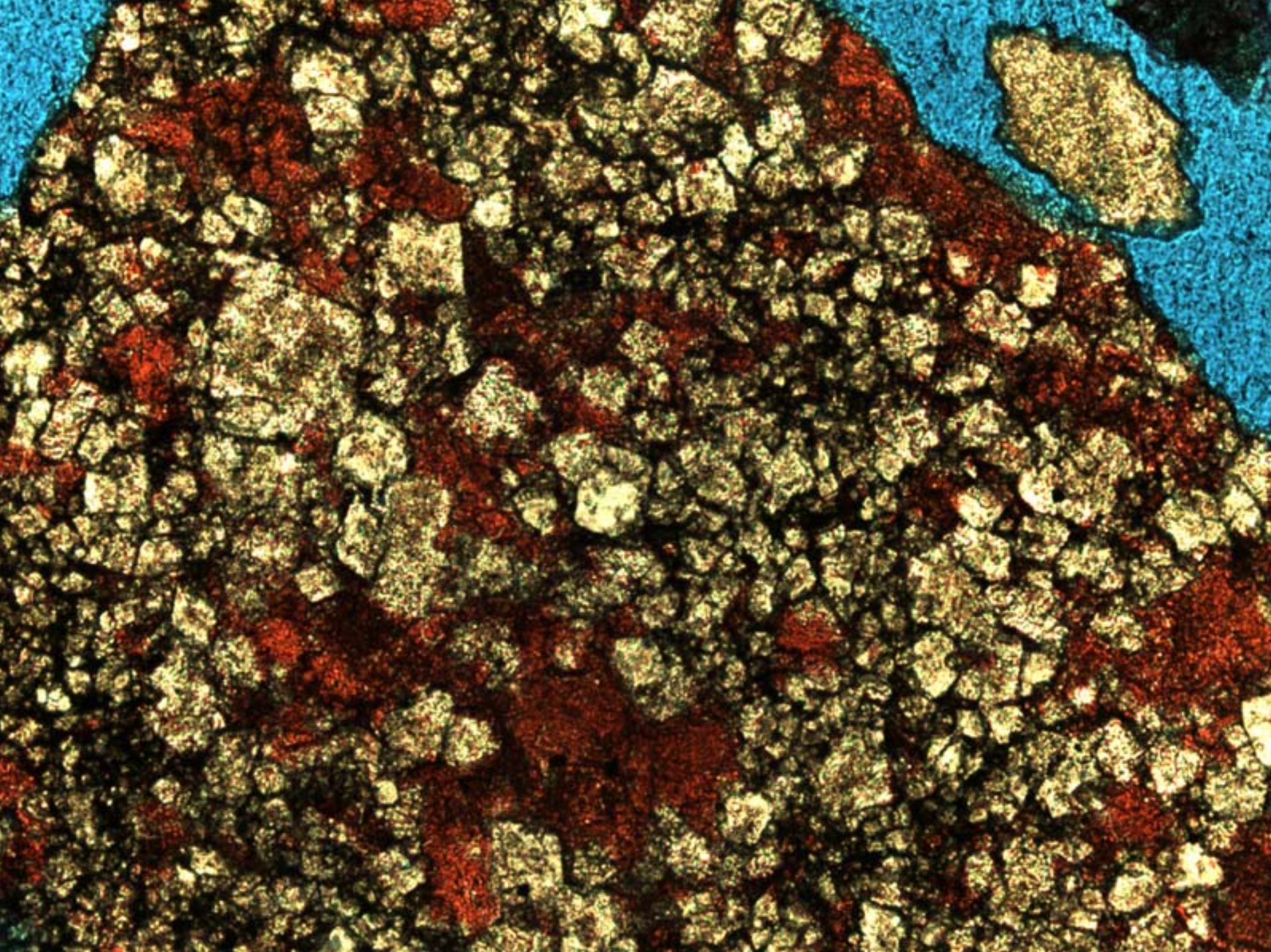

Counts
4000
3000
2000
1000
0
Fe KA
Cu KA
O KA
Mg KA
Ca K
Fe KB
Al KA
Cu KB
0
5
10
15
keV
5 Pa 16-Mar-05
000592 WD14.9mm 20.0kV x90
500um

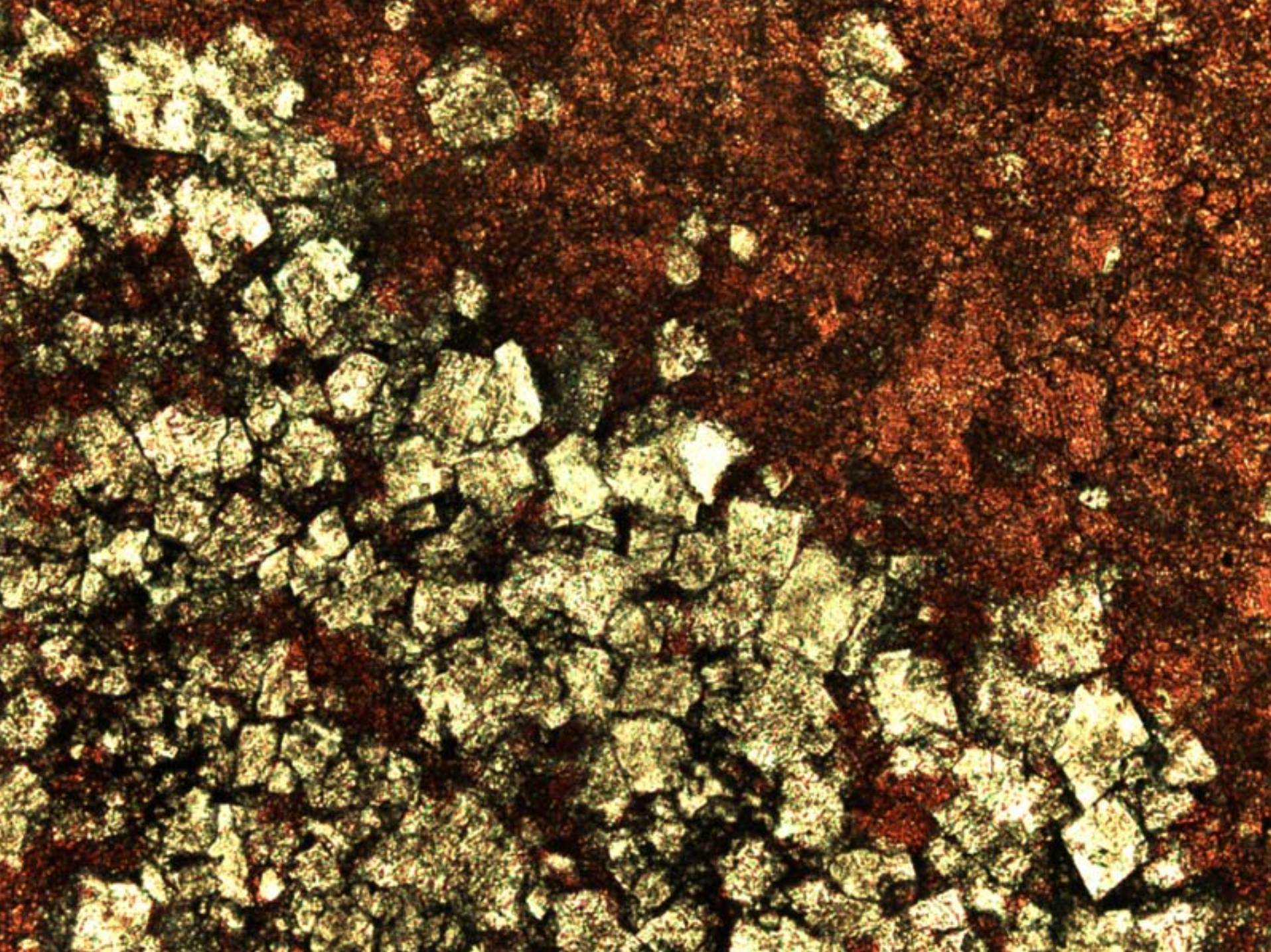


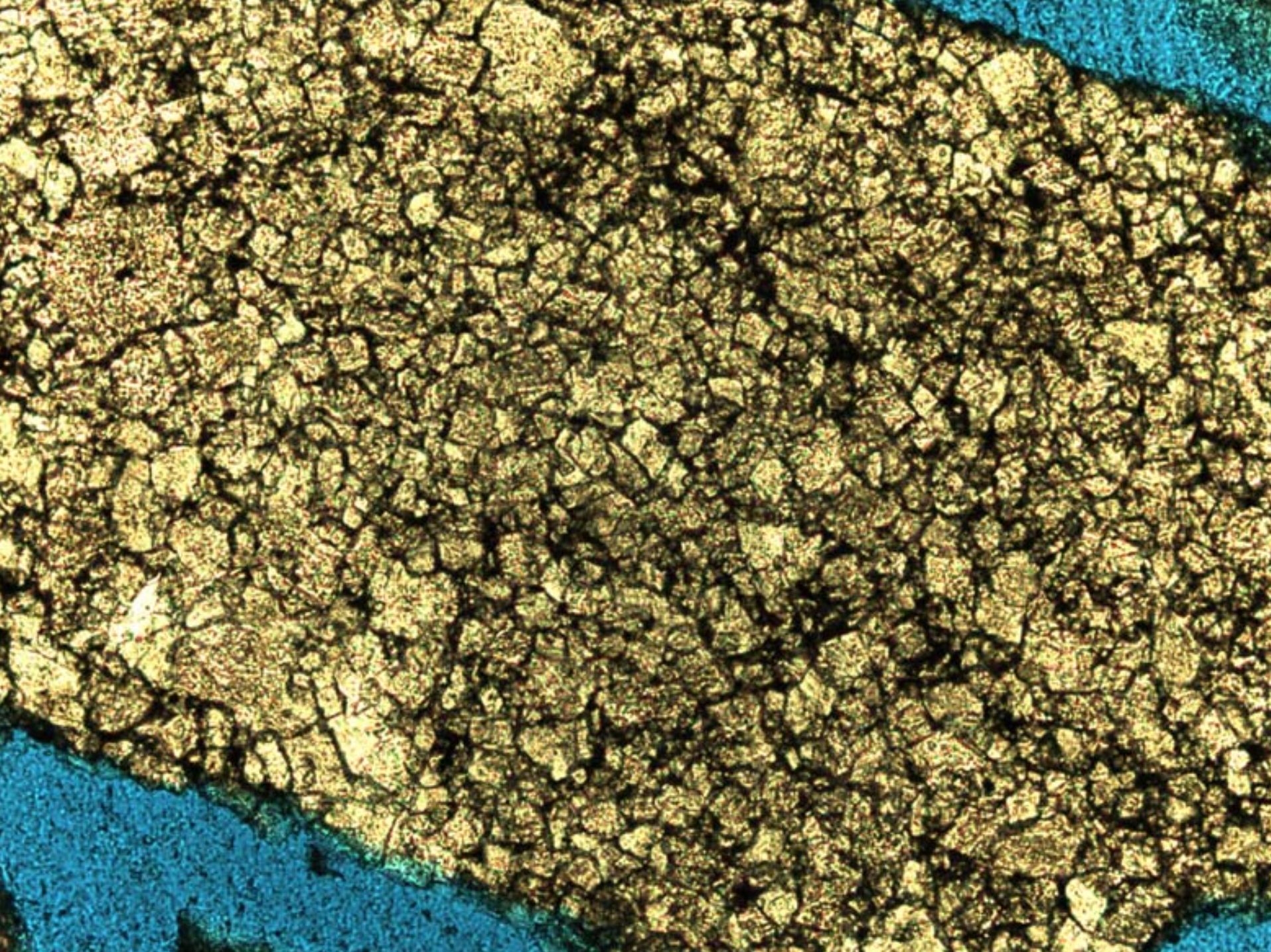


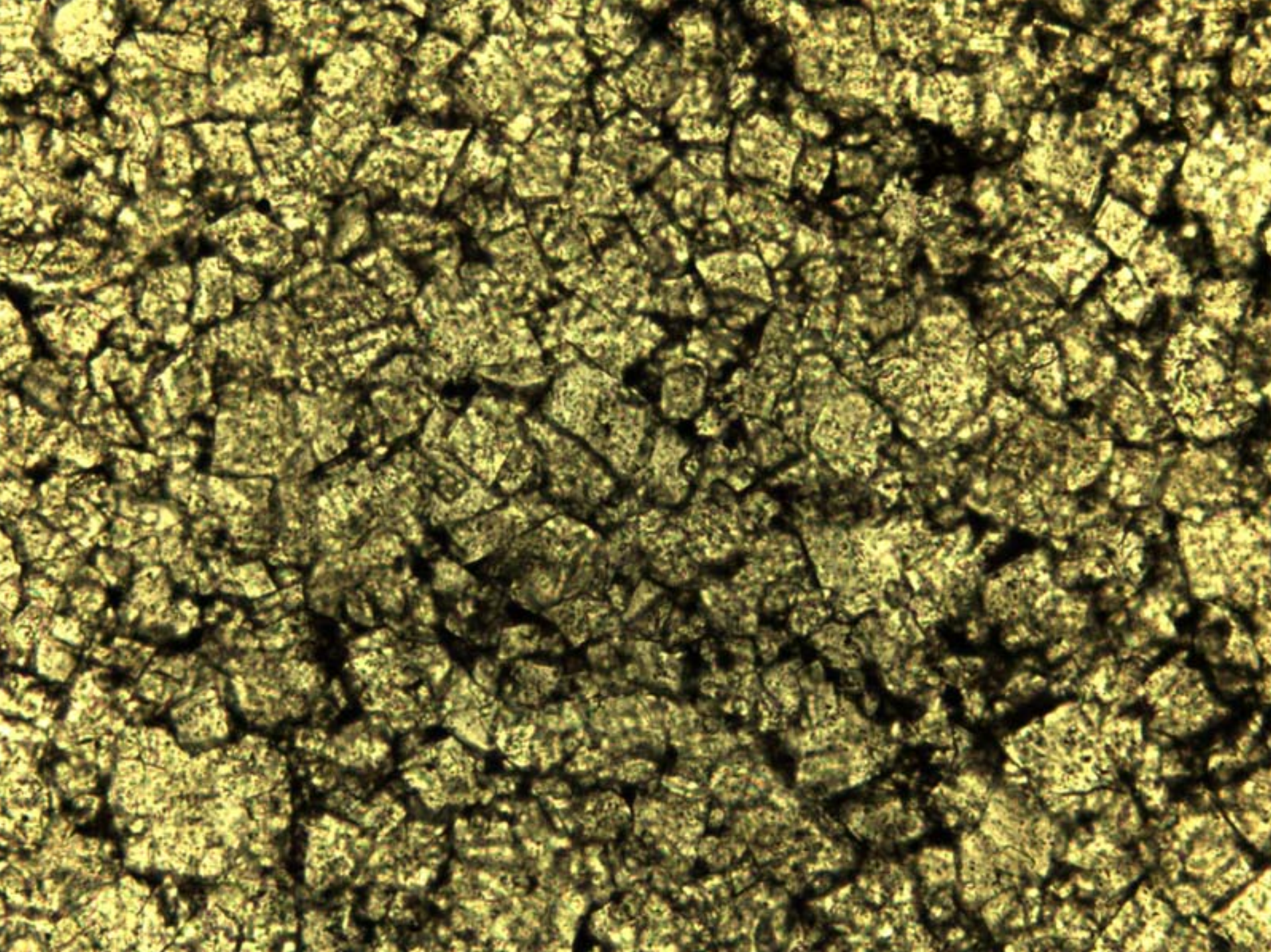
Dolomite Textures

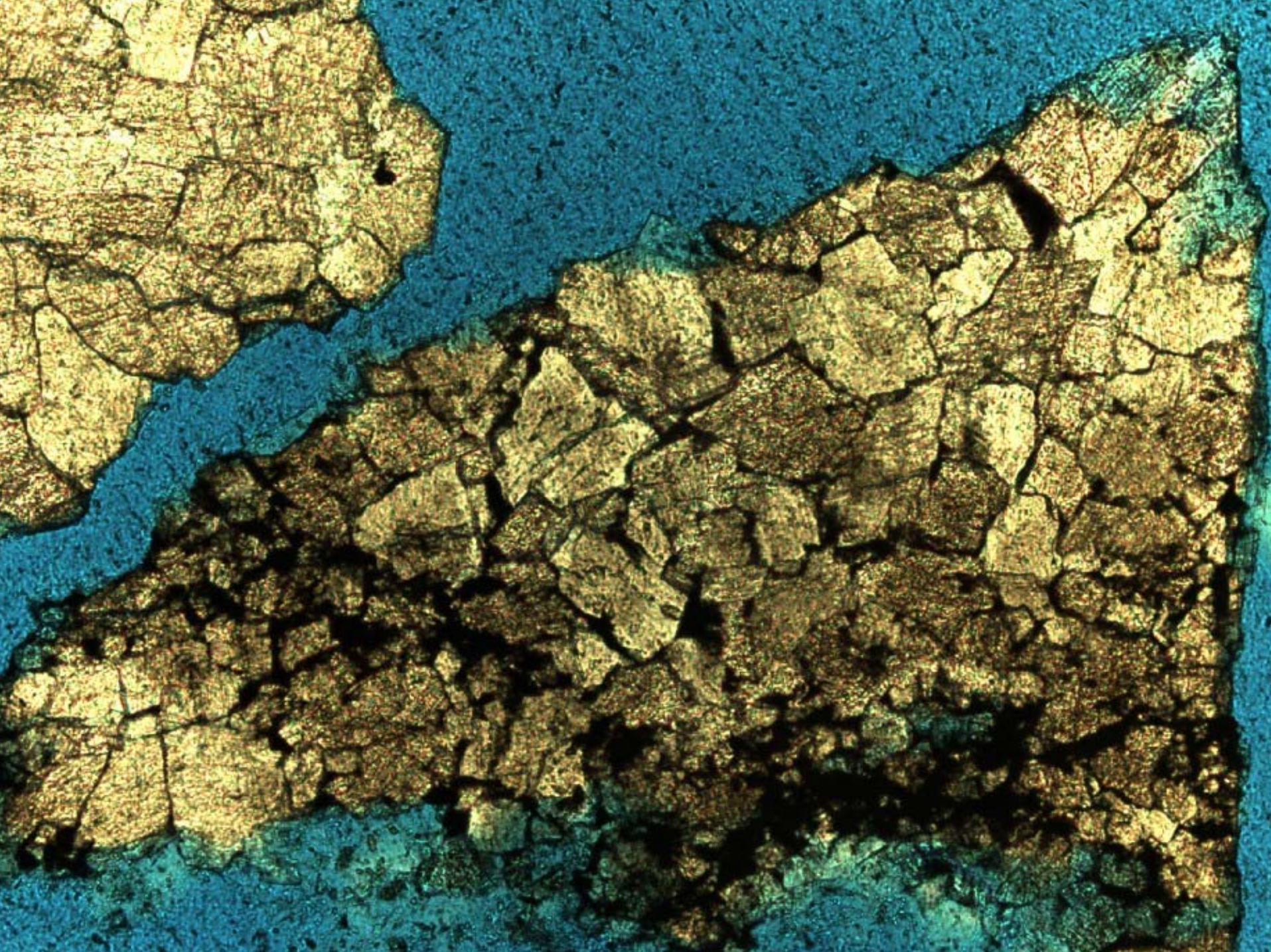


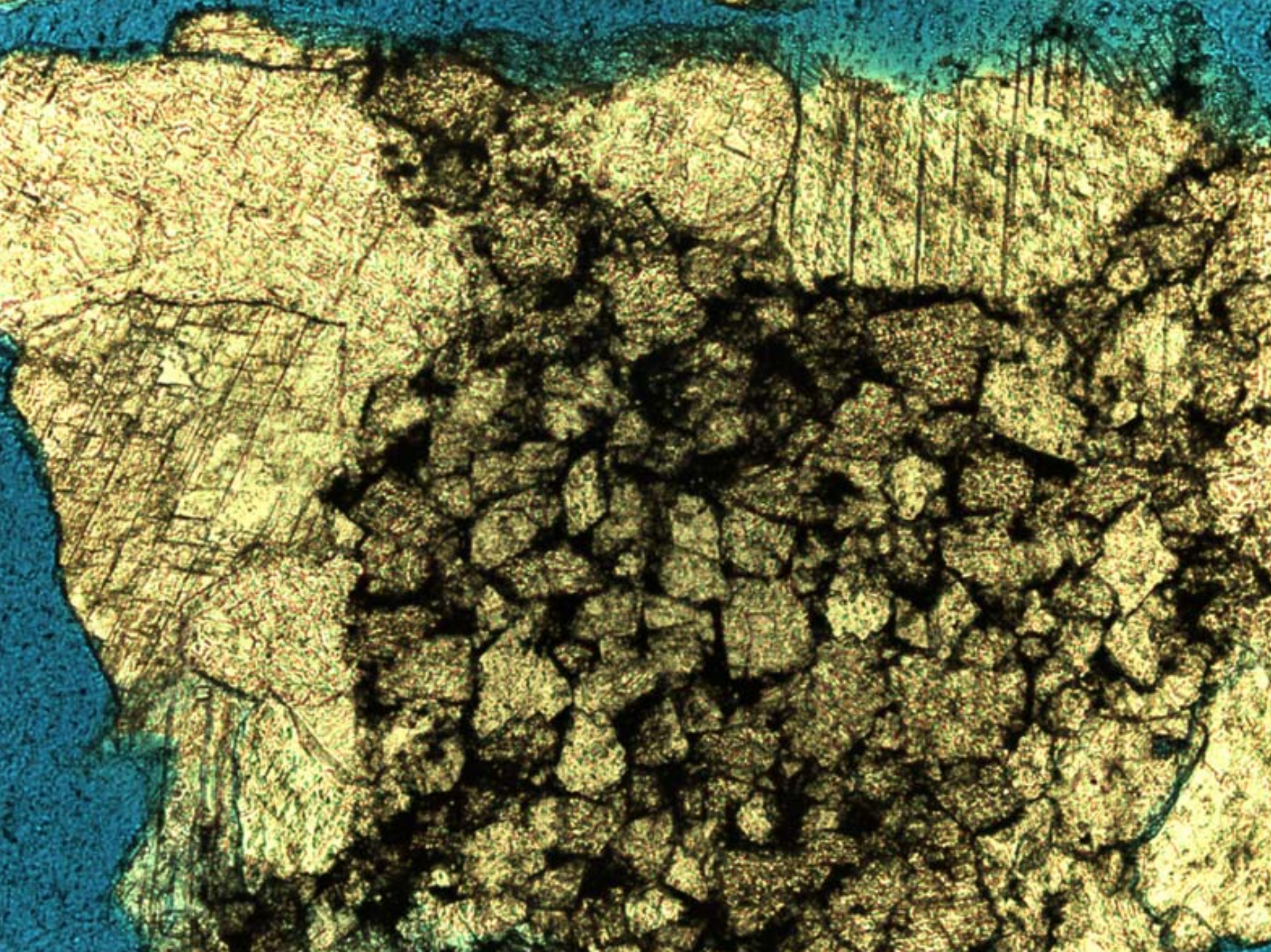


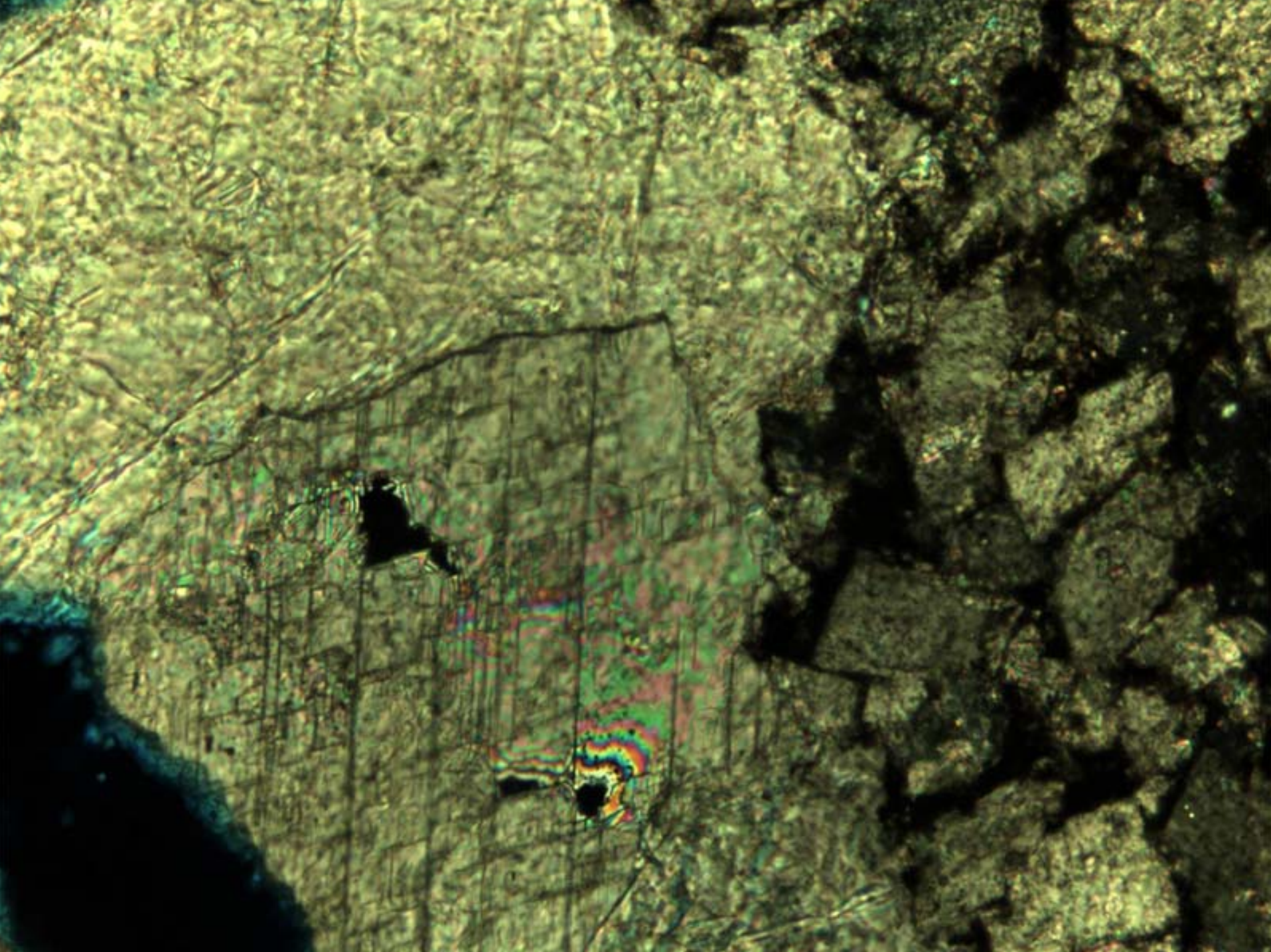


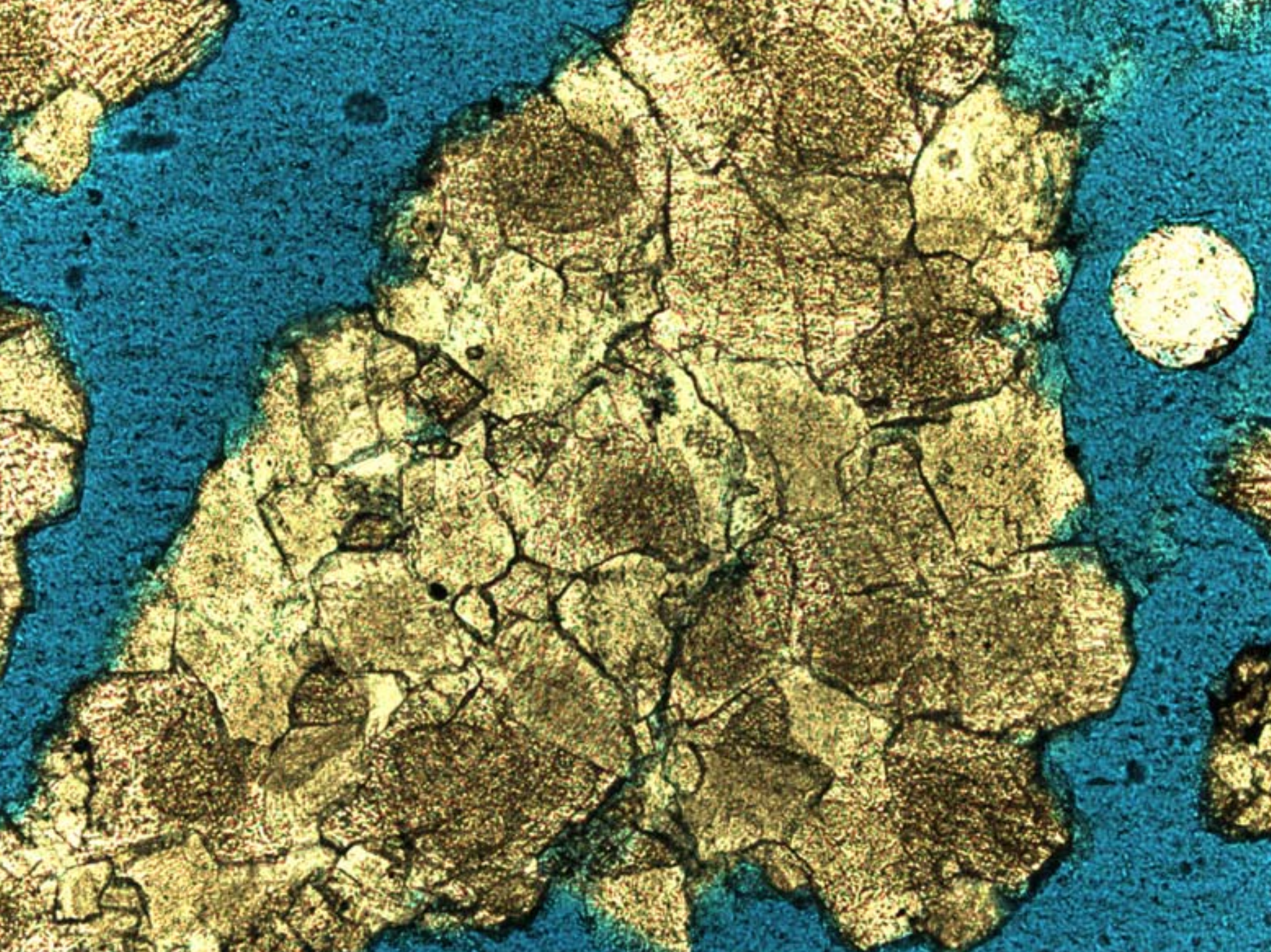


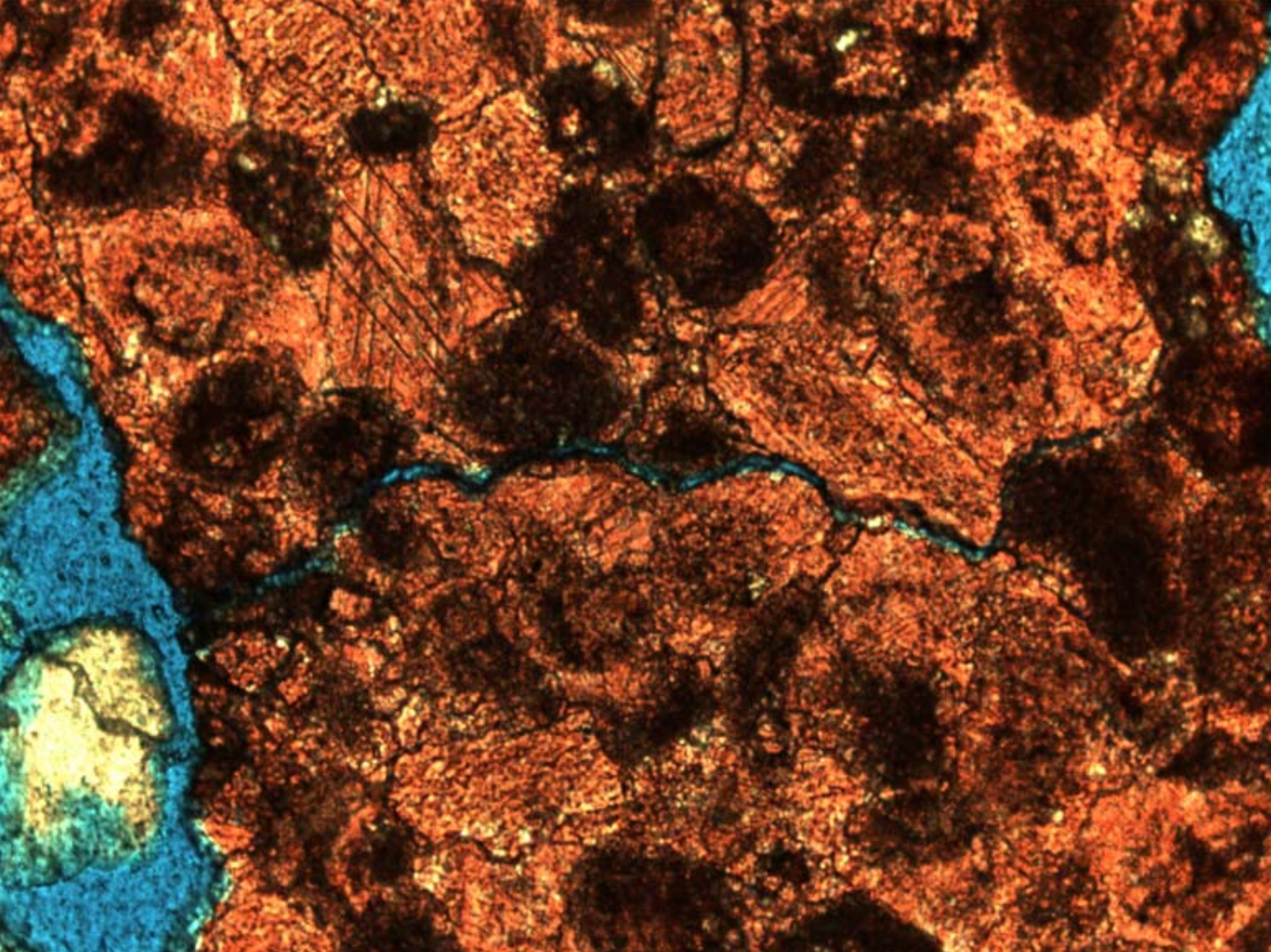




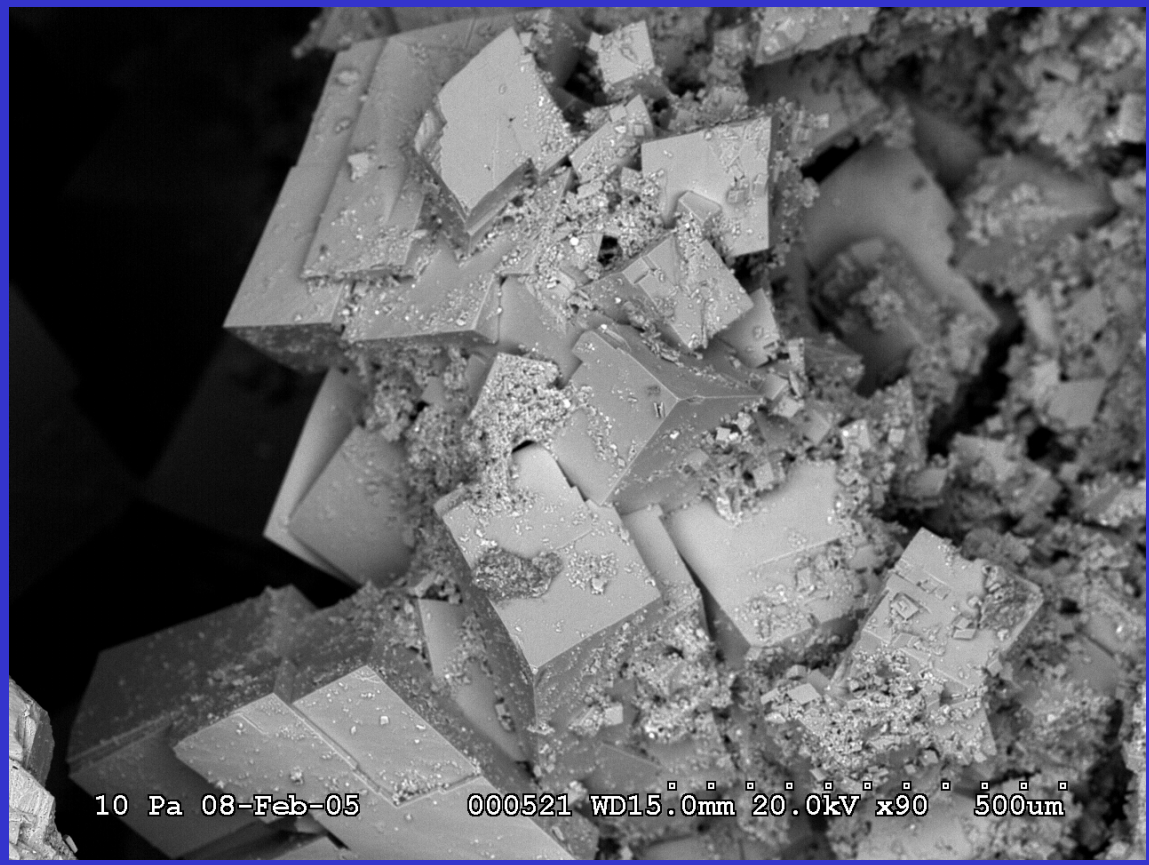






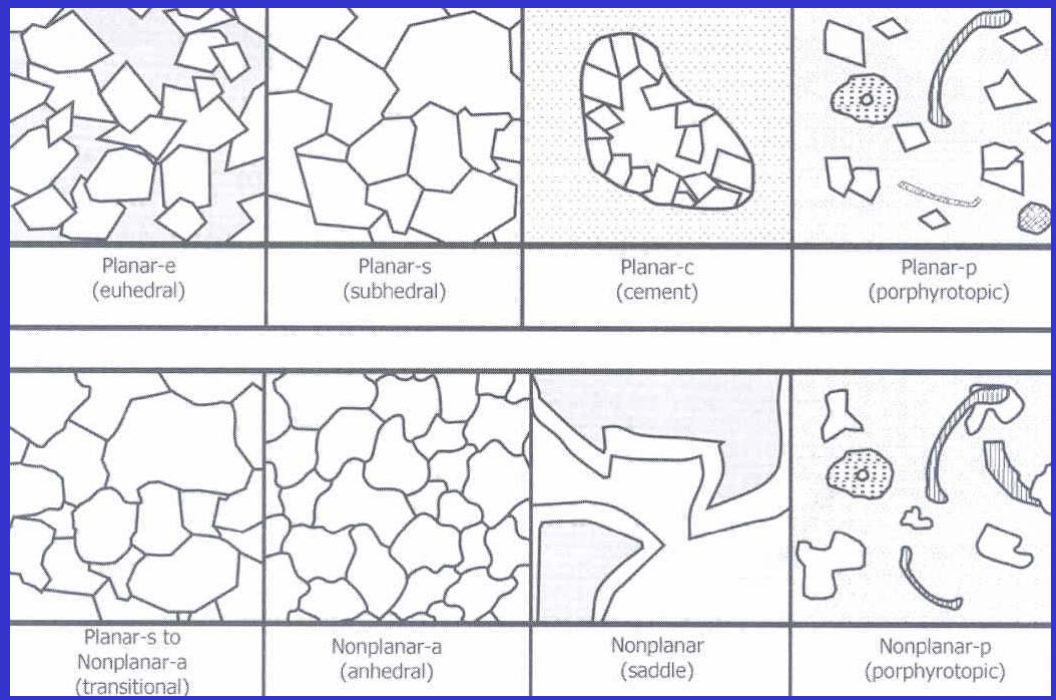


DOLOMITE TEXTURES IN TRENTON AND BLACK RIVER CARBONATE RESERVOIR ROCKS



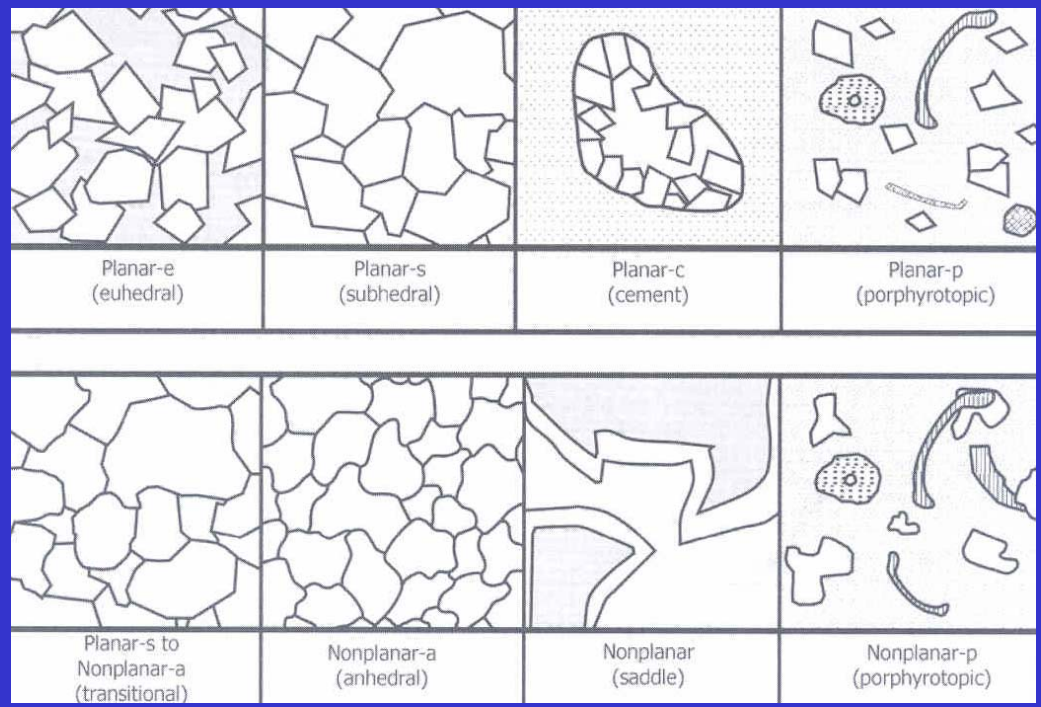
Dolostone Textural Classification

- Sibley and Gregg (1984; 1987; modified by Wright, 2001)
- Simple and mostly descriptive
- Carries some genetic implications, and restricted to microscope scale



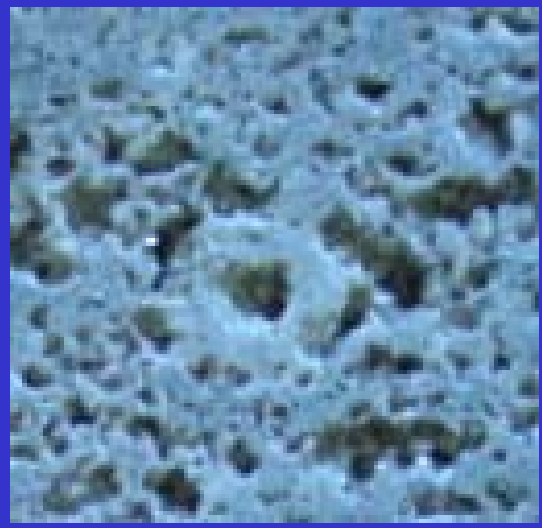
Dolostone Textural Classification

- **Crystal size distributions:**
  - Unimodal
  - Polymodal
- **Crystal Shapes:**
  - Planar-e
  - Planar-s
  - Nonplanar-a
  - Planar-c
  - Planar-p and nonplanar-p
  - Saddle dolomite: nonplanar or nonplanar-c
  - Transitional
- **Recognizable allochems, matrix, and void-filling**



Dolostone Textural Classification

- Particles and cement:
  - Unreplaced
  - Partially replaced:
    - Mimetic
    - Non-mimetic
  - Completely replaced
    - Mimetic
    - Non-mimetic

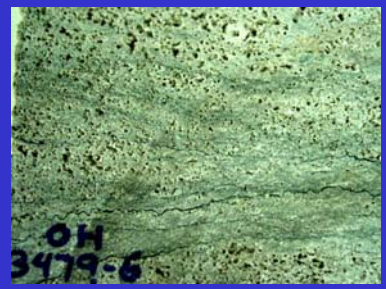


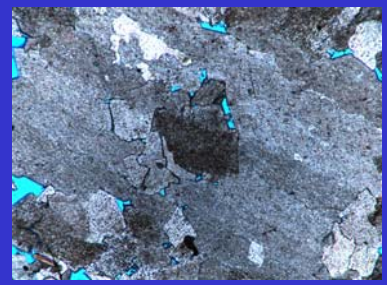
DOLOGRAINSTONES AND DOLOPACKSTONES

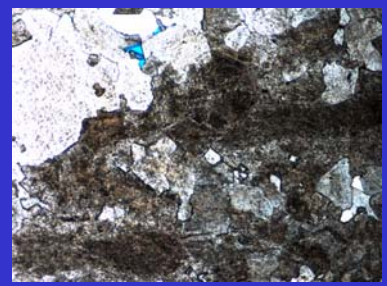
- Productive reservoir rocks in northwestern Ohio
- Depositional texture may or may not be recognizable to unaided eye
- Planar-s to nonplanar-a and saddle dolomites

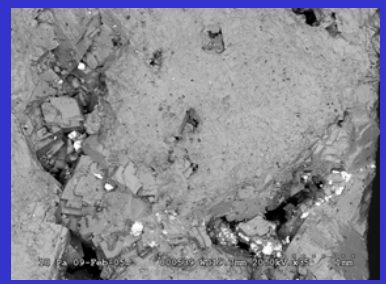
Porosity

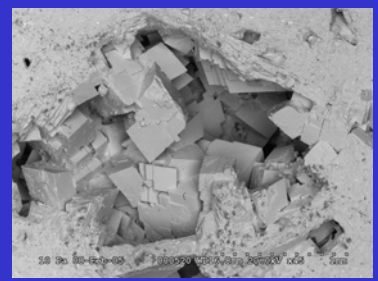
- Macroporosity:
  - Not fabric-selective:
    - Small to medium vugs
    - Fractures
- Mesoporosity
  - Fabric-selective:
    - Moldic
    - Intercrystalline
- Microporosity

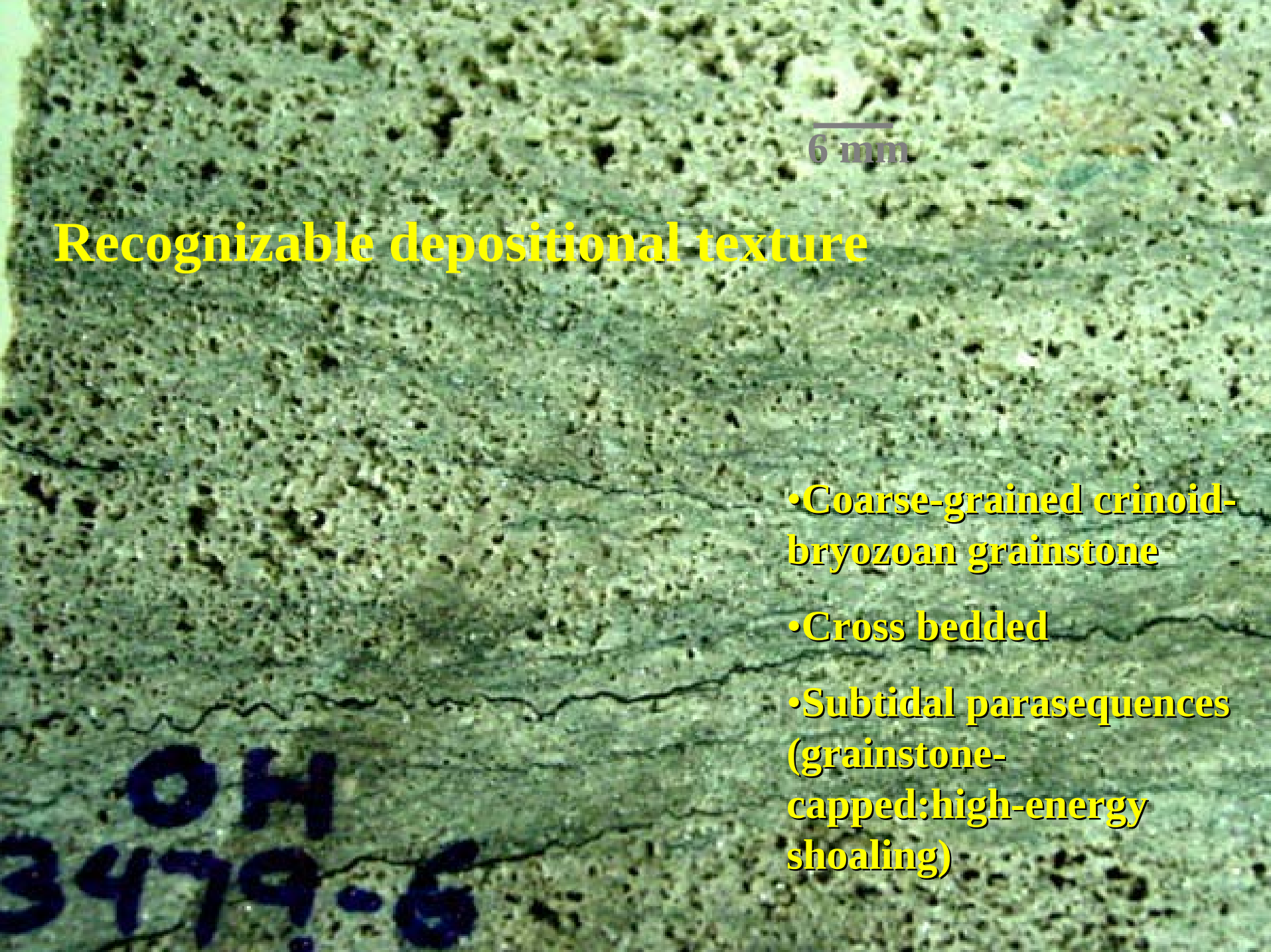






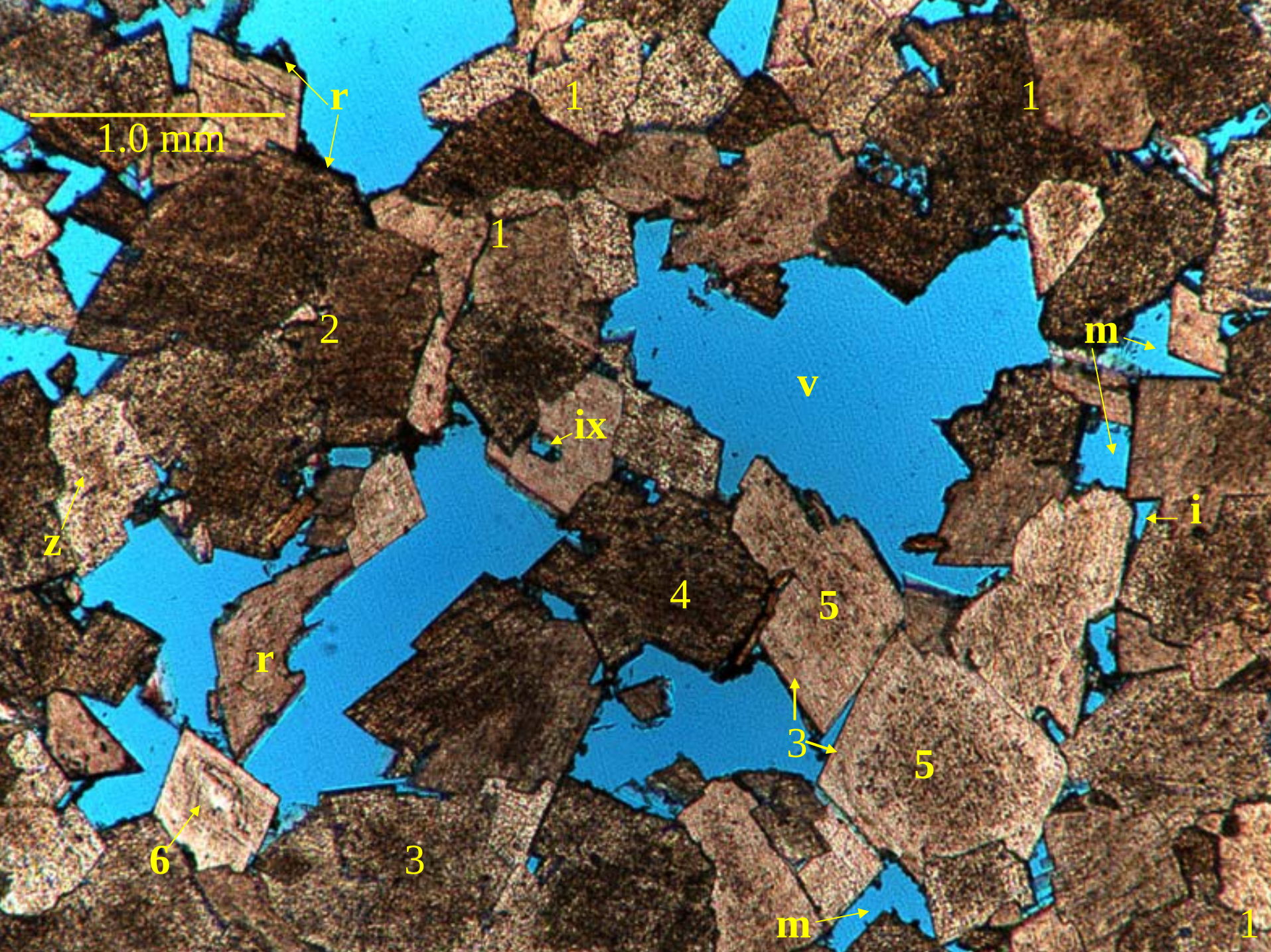


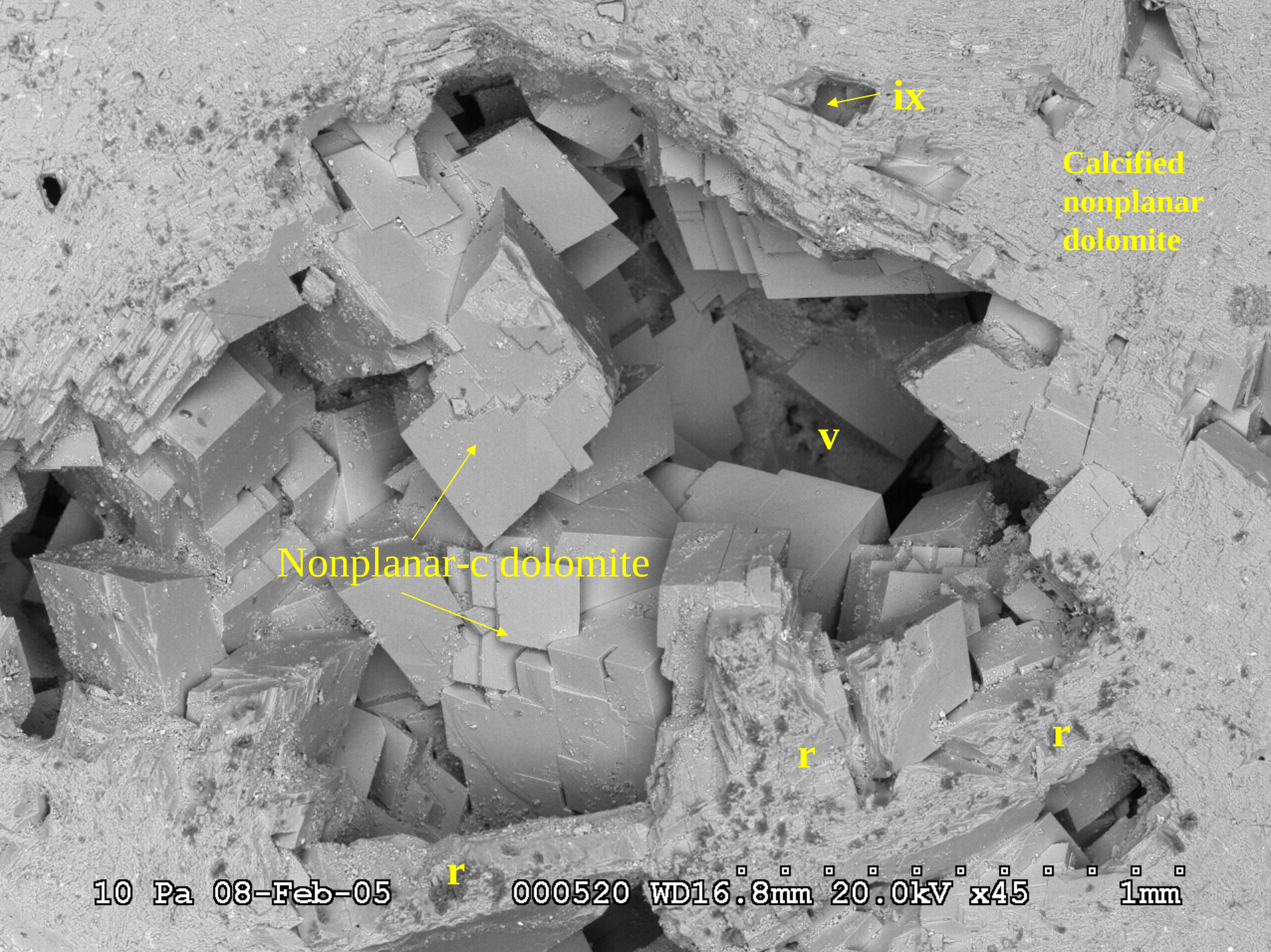


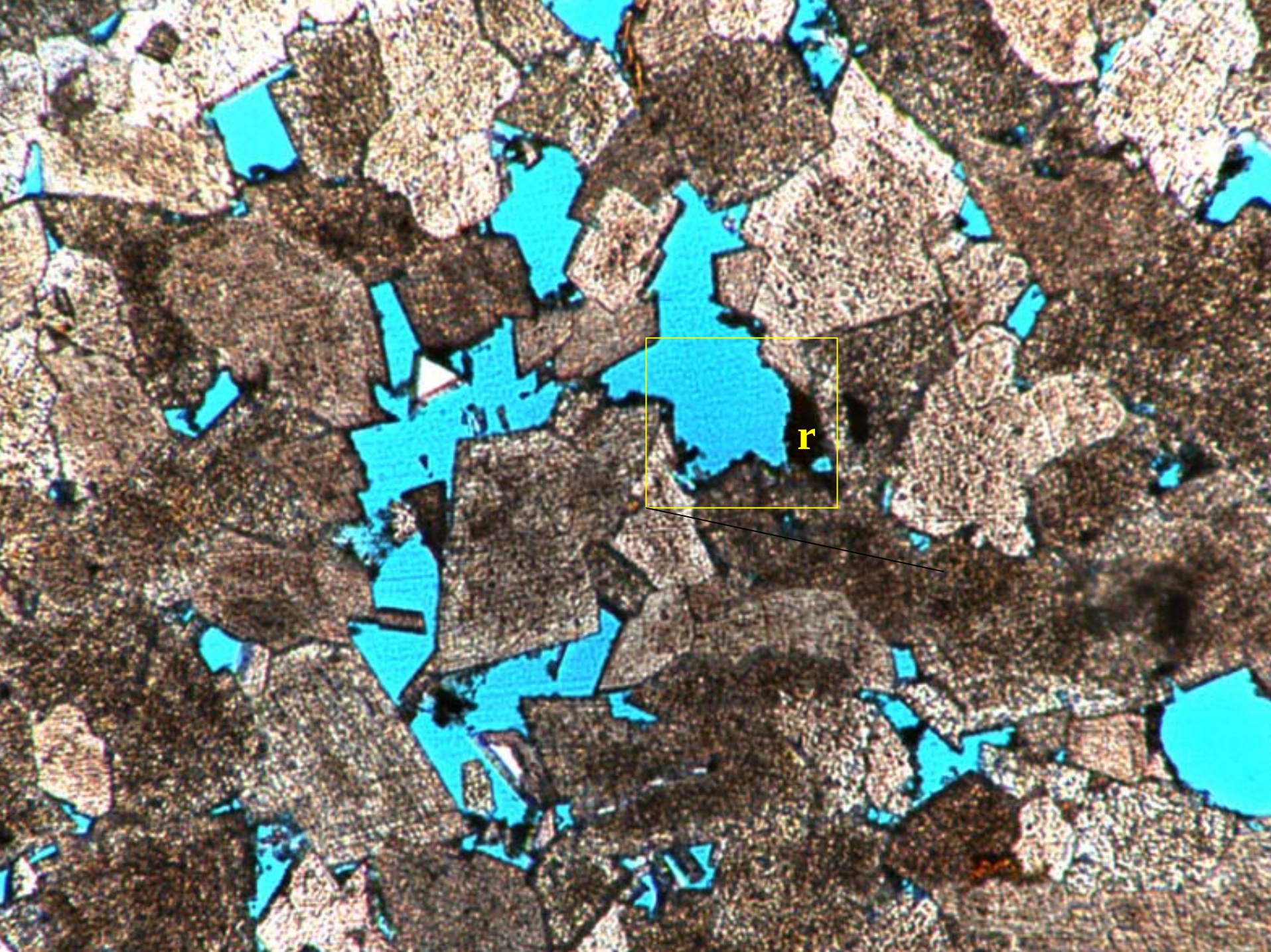


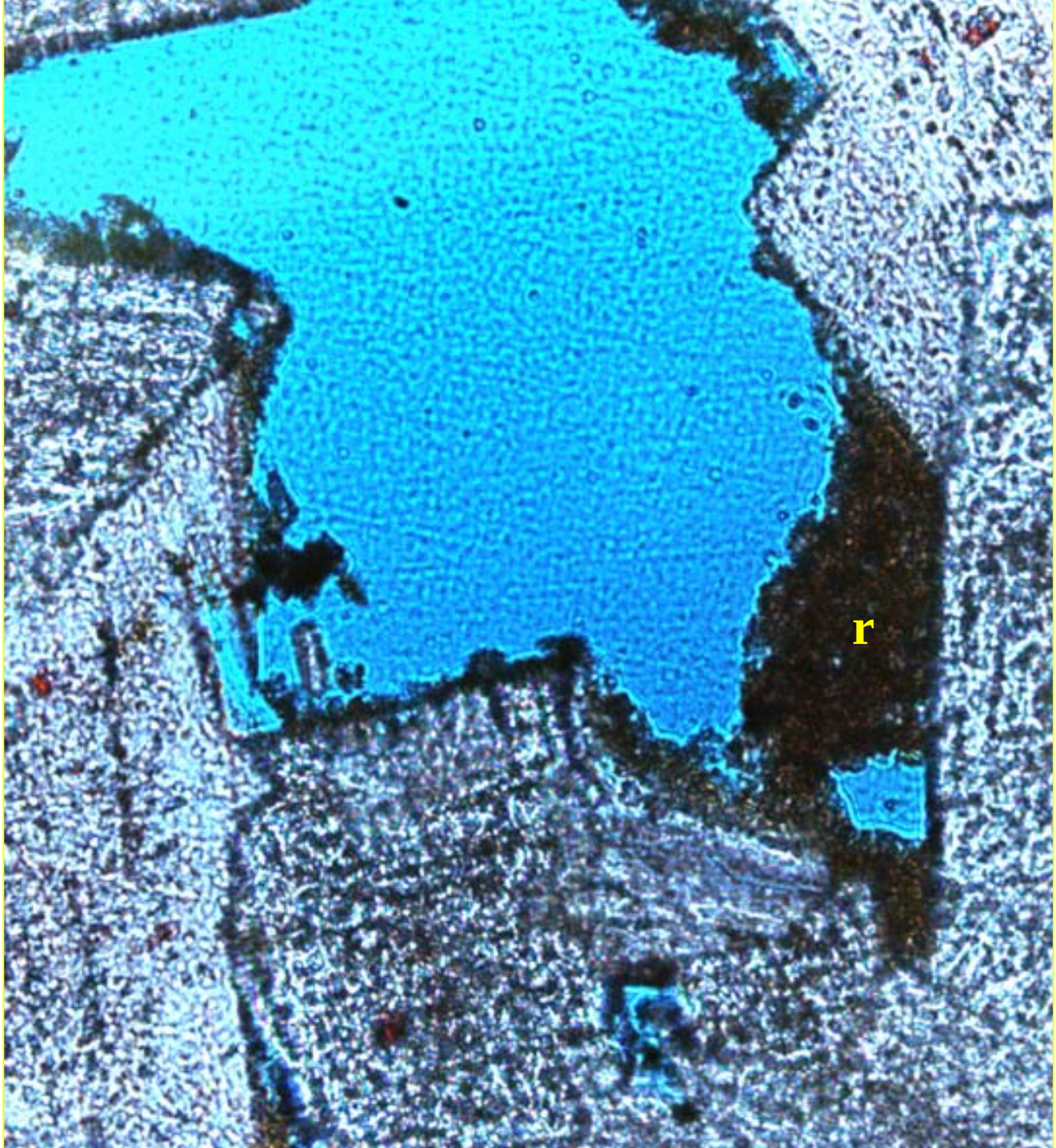
Recognizable depositional texture

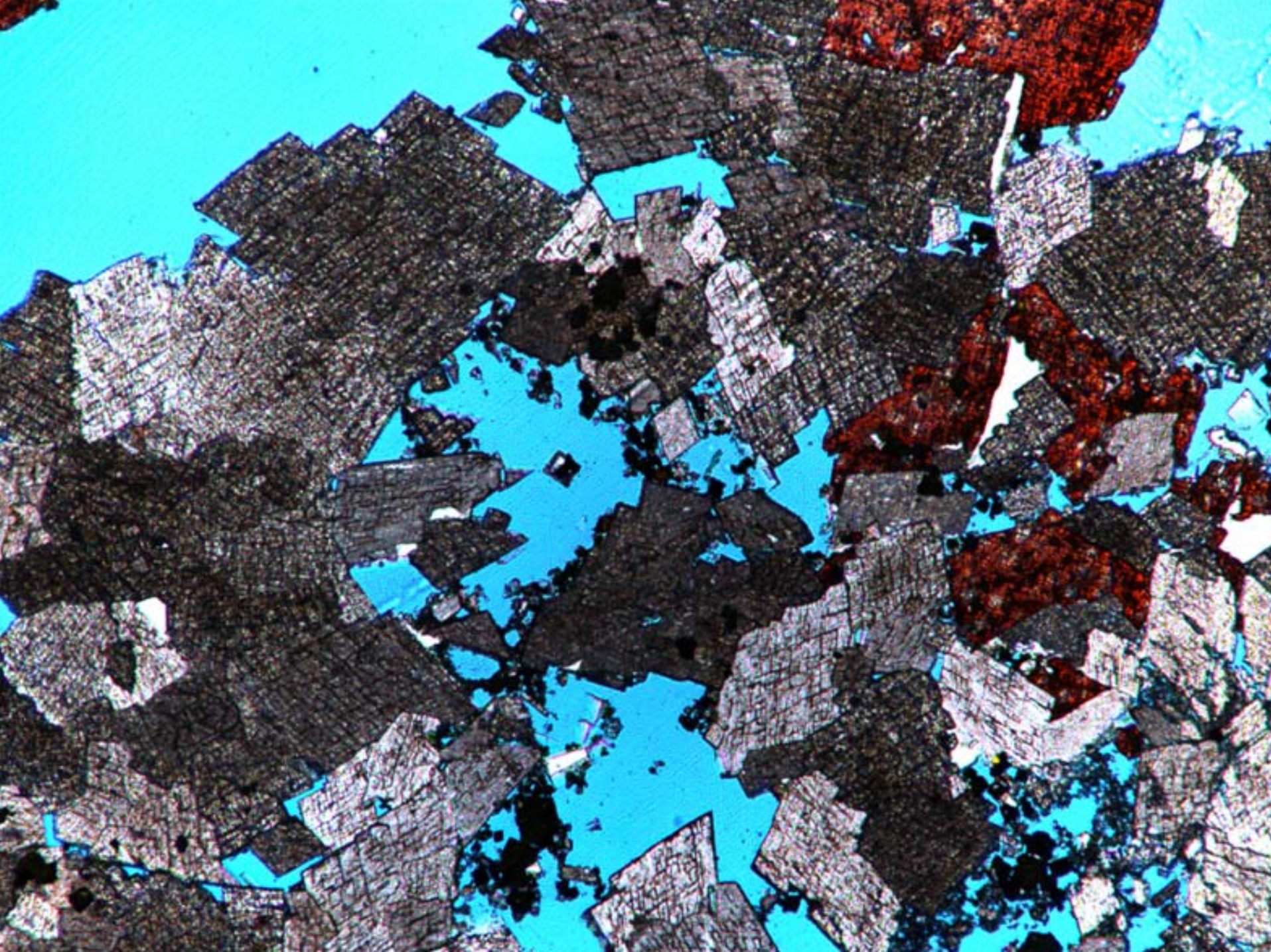
- Coarse-grained crinoid-bryozoan grainstone
- Cross bedded
- Subtidal parasequences (grainstone-capped:high-energy shoaling)

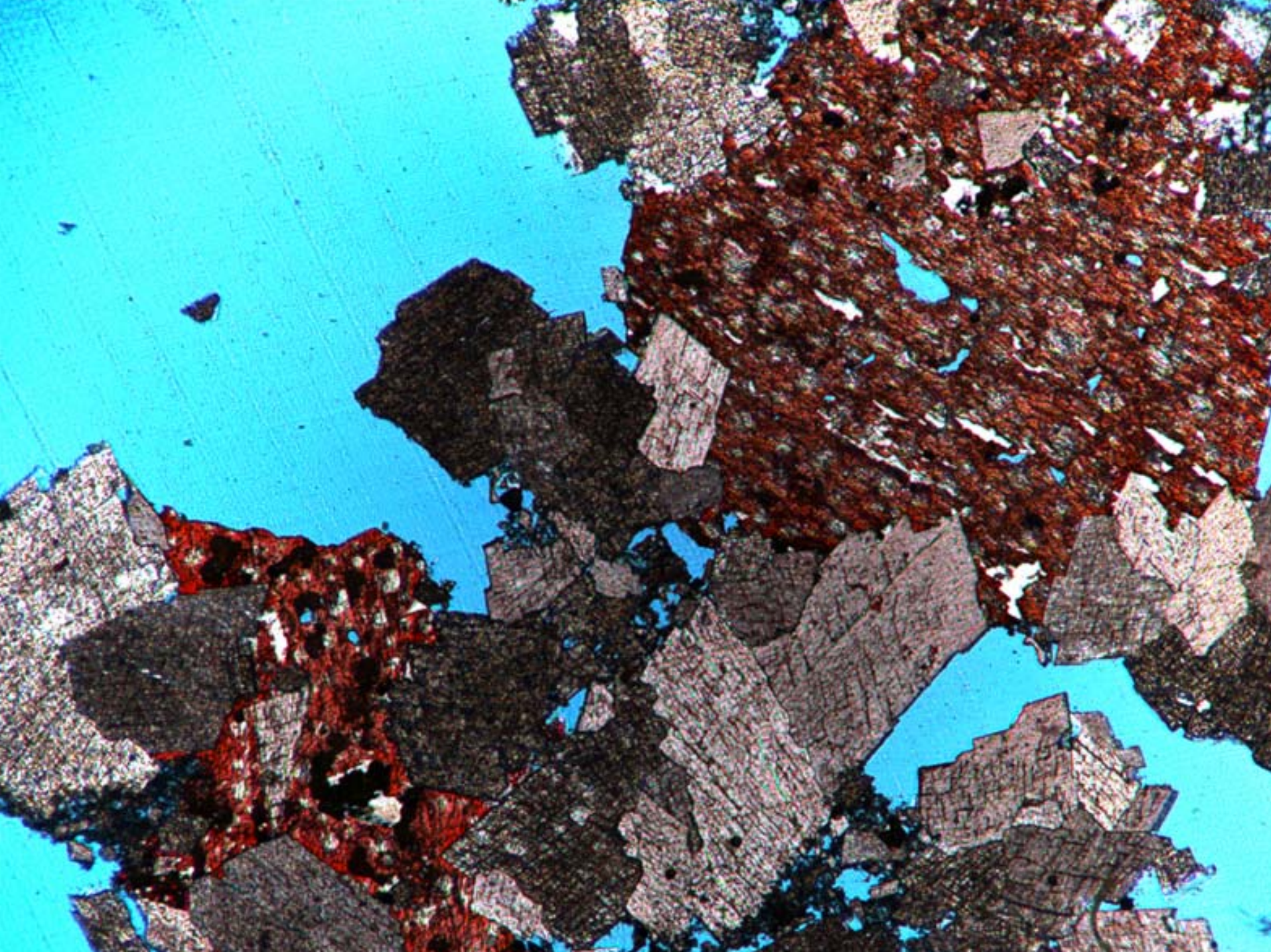

1.0 mm
r
1
1
1
2
m
v
ix
i
z
4
5
r
3
5
6
3
m
1


ix
Calcified
nonplanar
dolomite
v
Nonplanar-c dolomite
r
r
r
10 Pa 08-Feb-05 000520 WD16.8mm 20.0kV x45 1mm

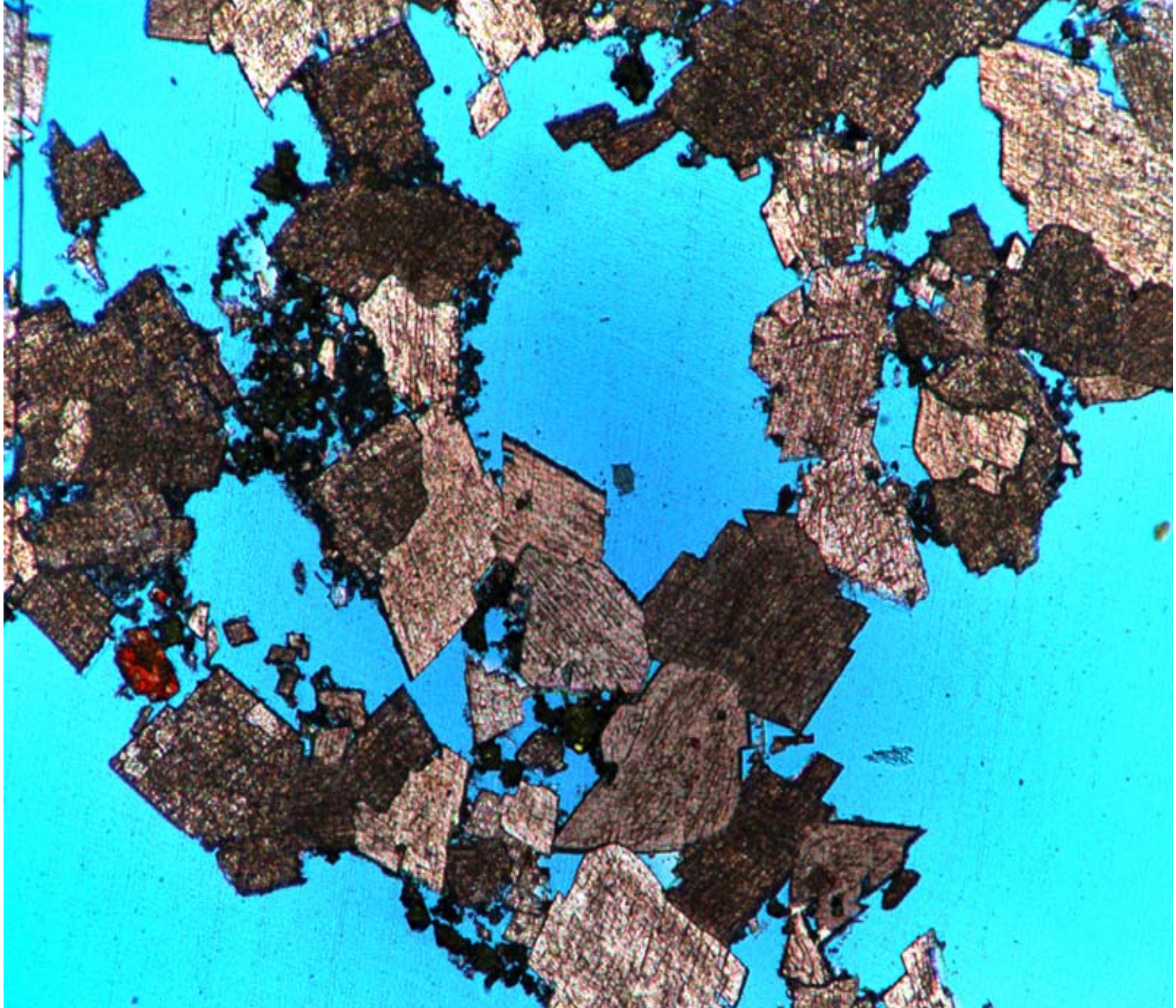

r

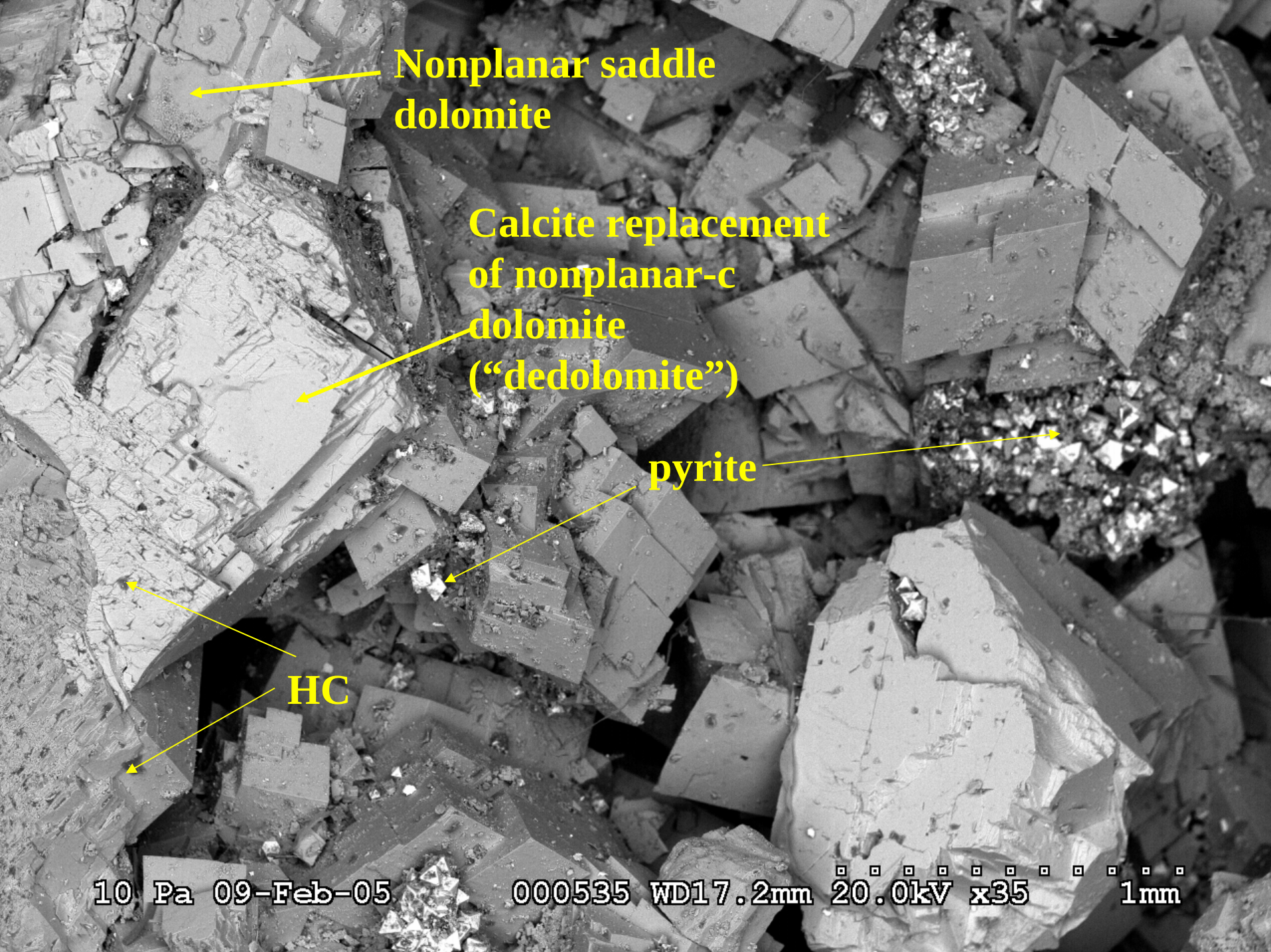

r






Nonplanar saddle dolomite partially replaced by calcite
Nonplanar saddle dolomite
Nonplanar saddle dolomite partially replaced by calcite
10 Pa 08-Feb-05
000522 WD15.0mm 20.0kV x80 500um



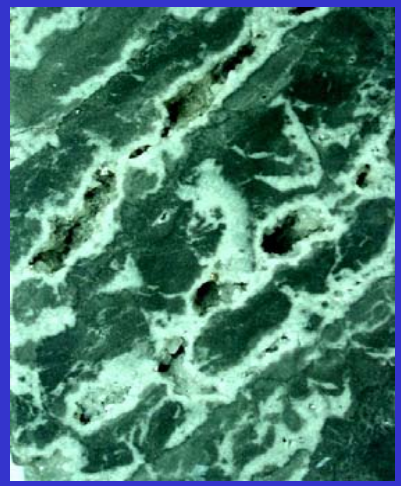

Nonplanar saddle dolomite
Calcite replacement of nonplanar-c dolomite ("dedolomite")
pyrite
HC
10 Pa 09-Feb-05 000535 WD17.2mm 20.0kV x35 1mm

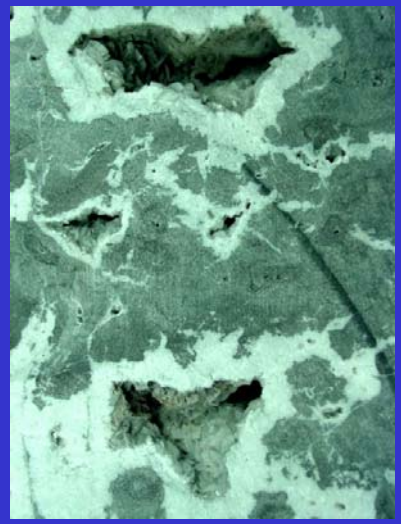
DOLOWACKESTONES AND DOLOMUDSTONES

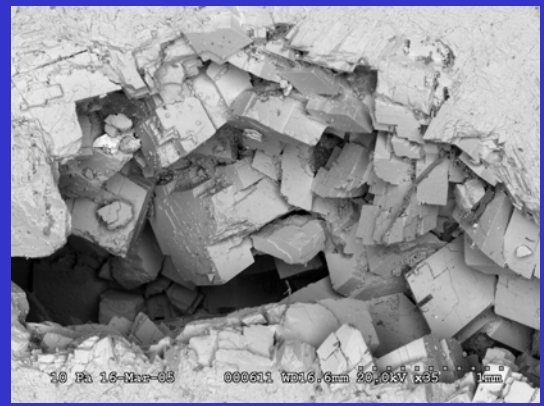
- Most productive reservoir rocks in the basin
- Recognizable depositional texture
- Planar-s to nonplanar-a and saddle dolomites

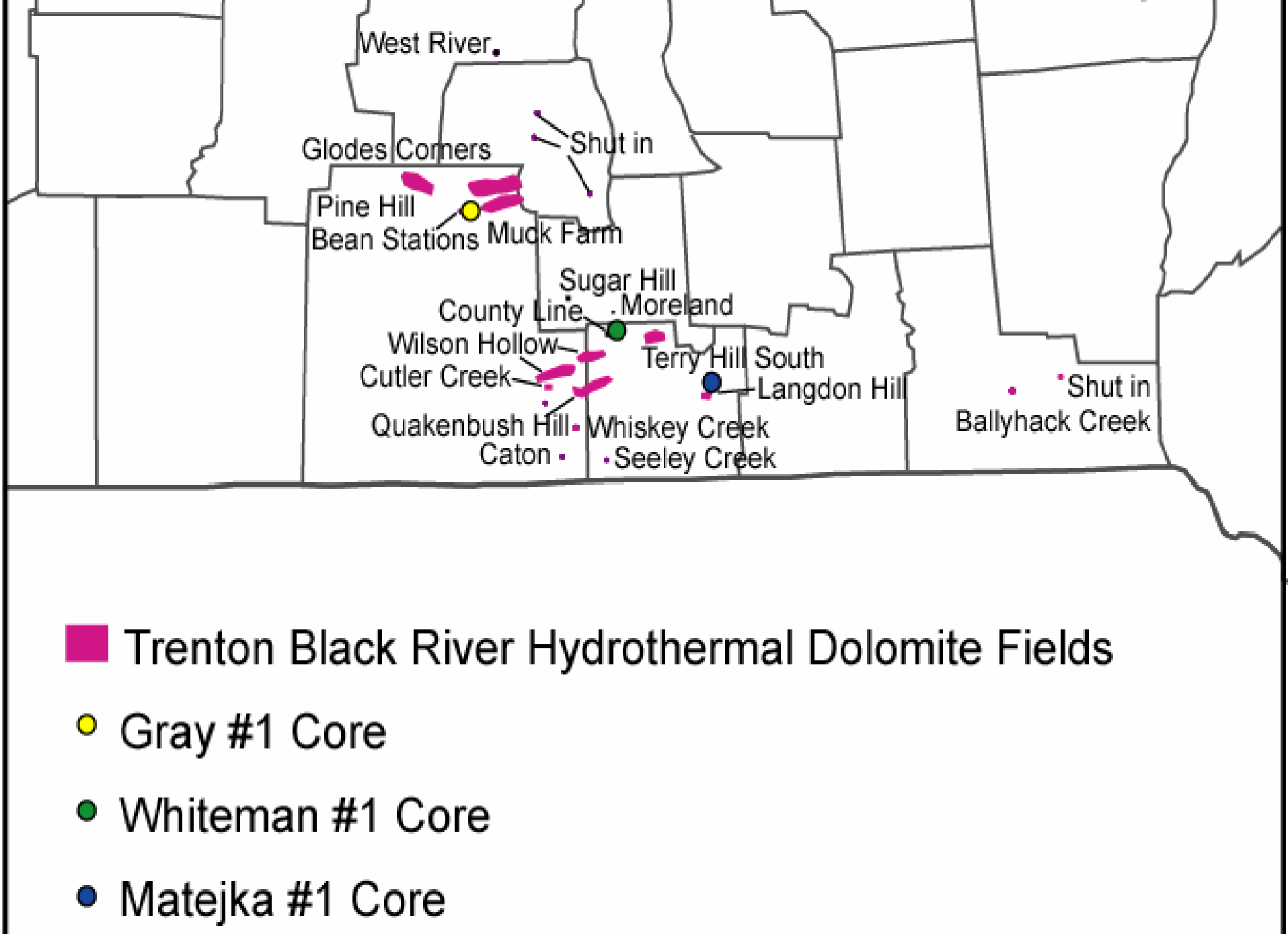
Porosity

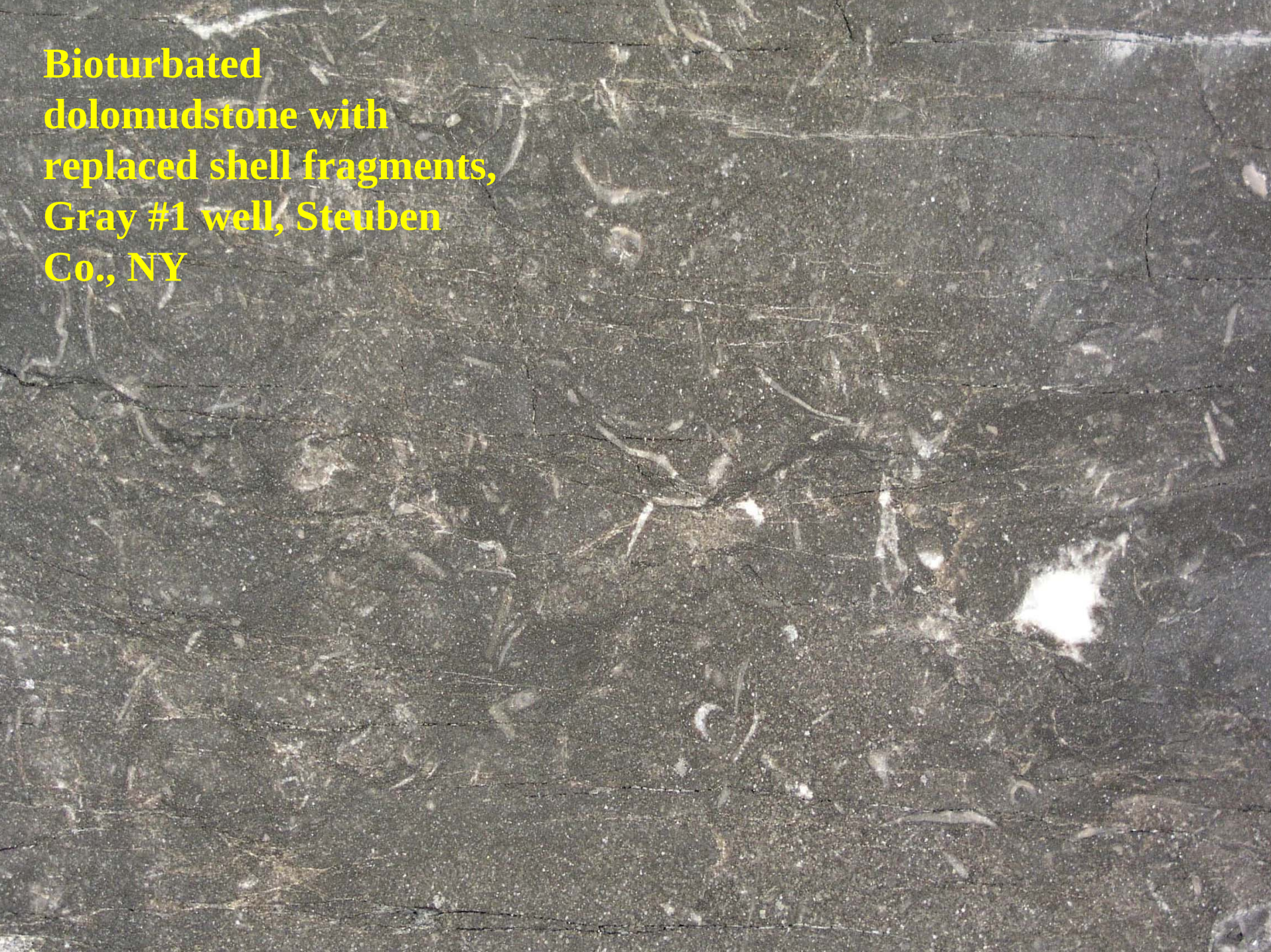
- Macroporosity:
  - Not fabric-selective:
    - Voids associated with zebra and breccia fabrics
    - Small to large vugs
    - Fractures
- Mesoporosity:
  - Fabric-selective:
    - Intercrystalline
    - Moldic
- Microporosity

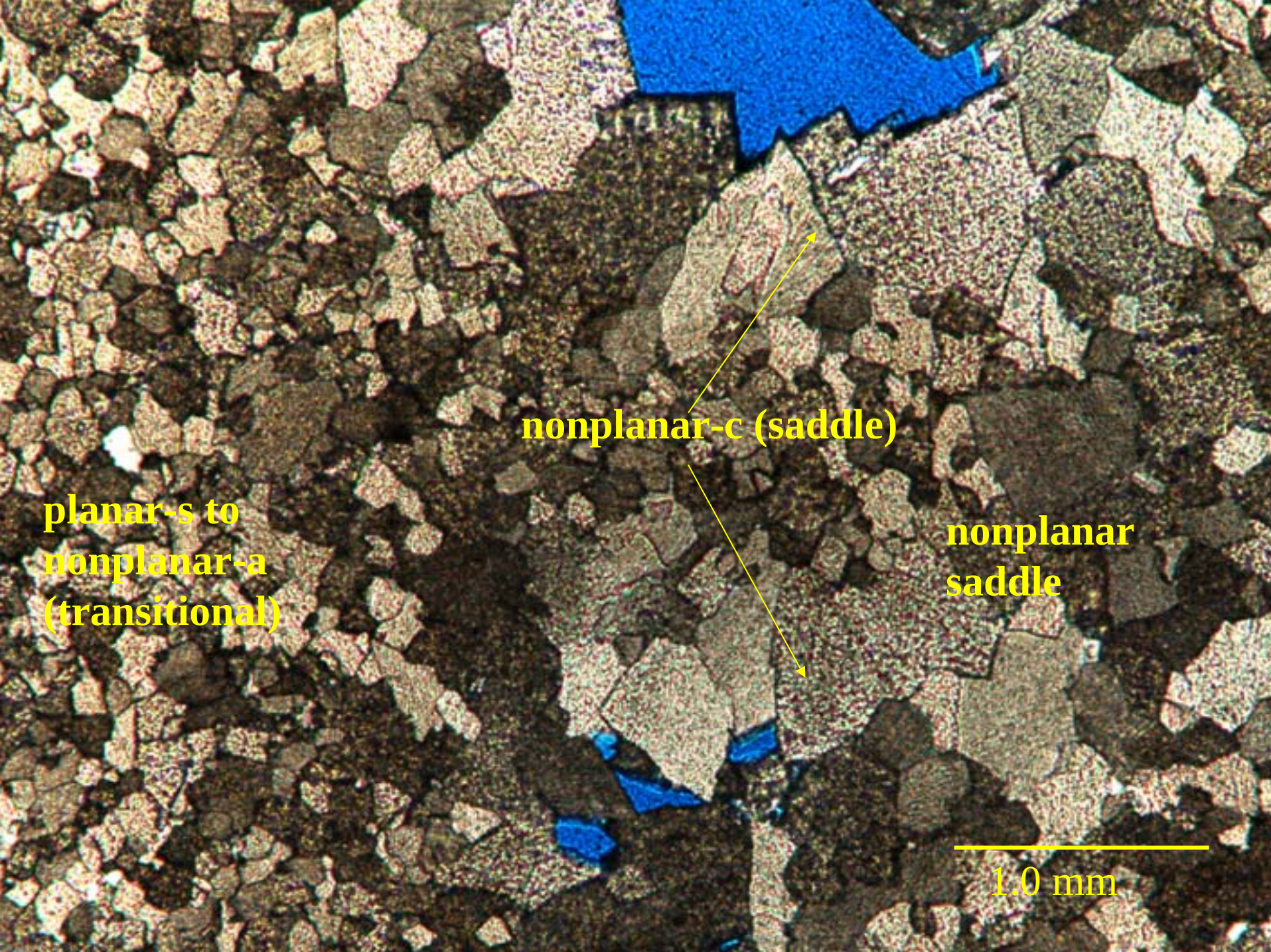


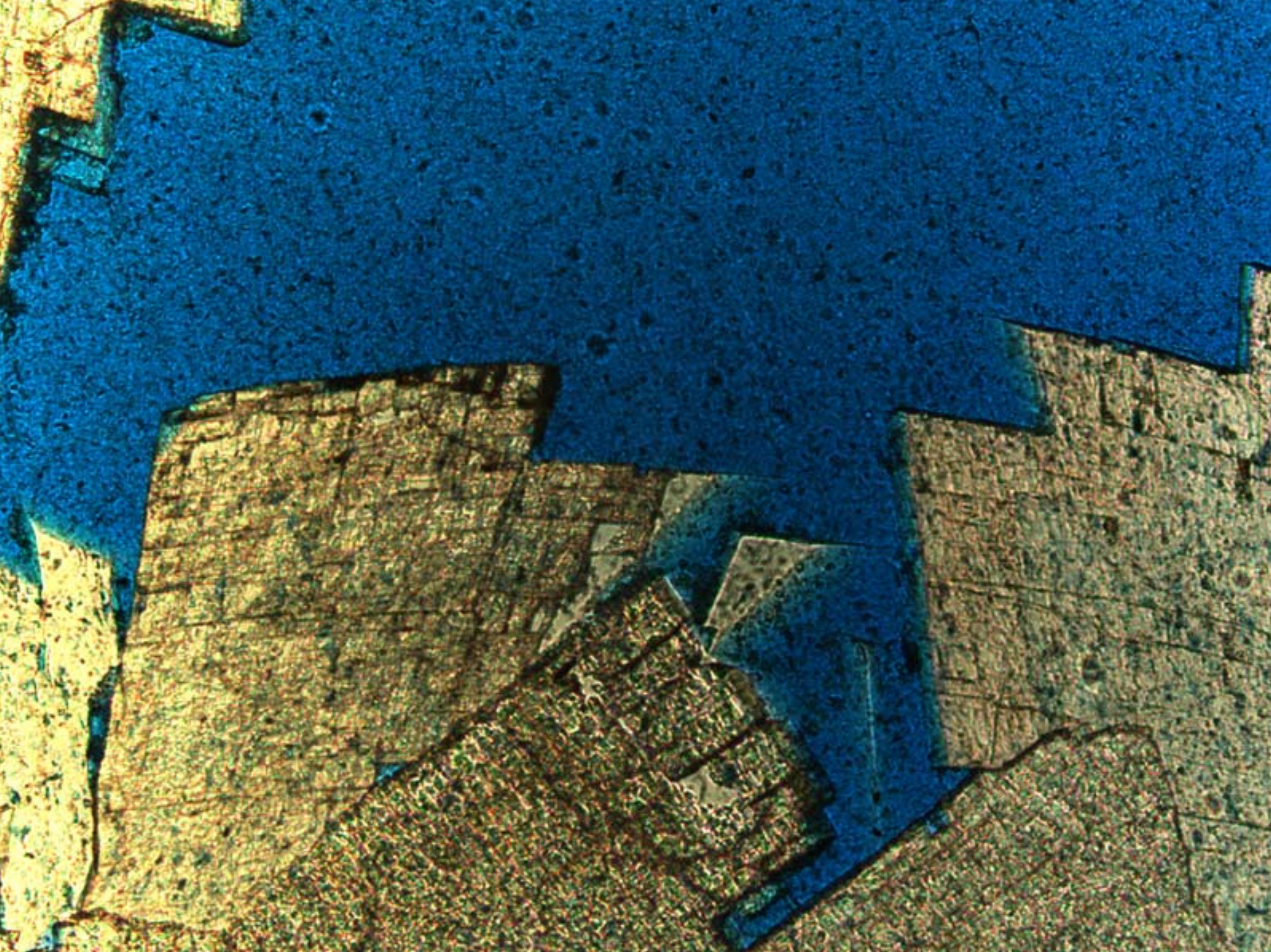


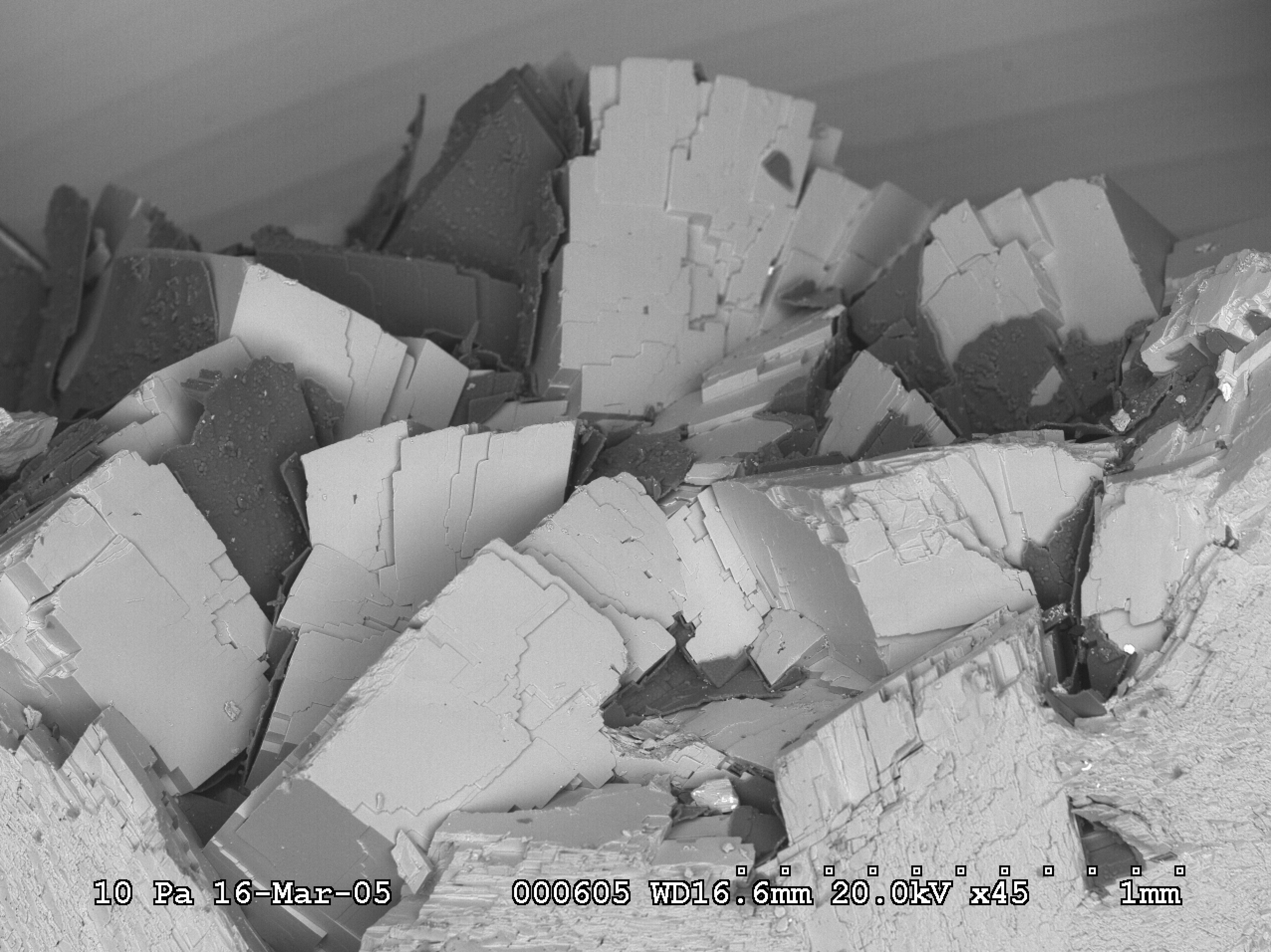


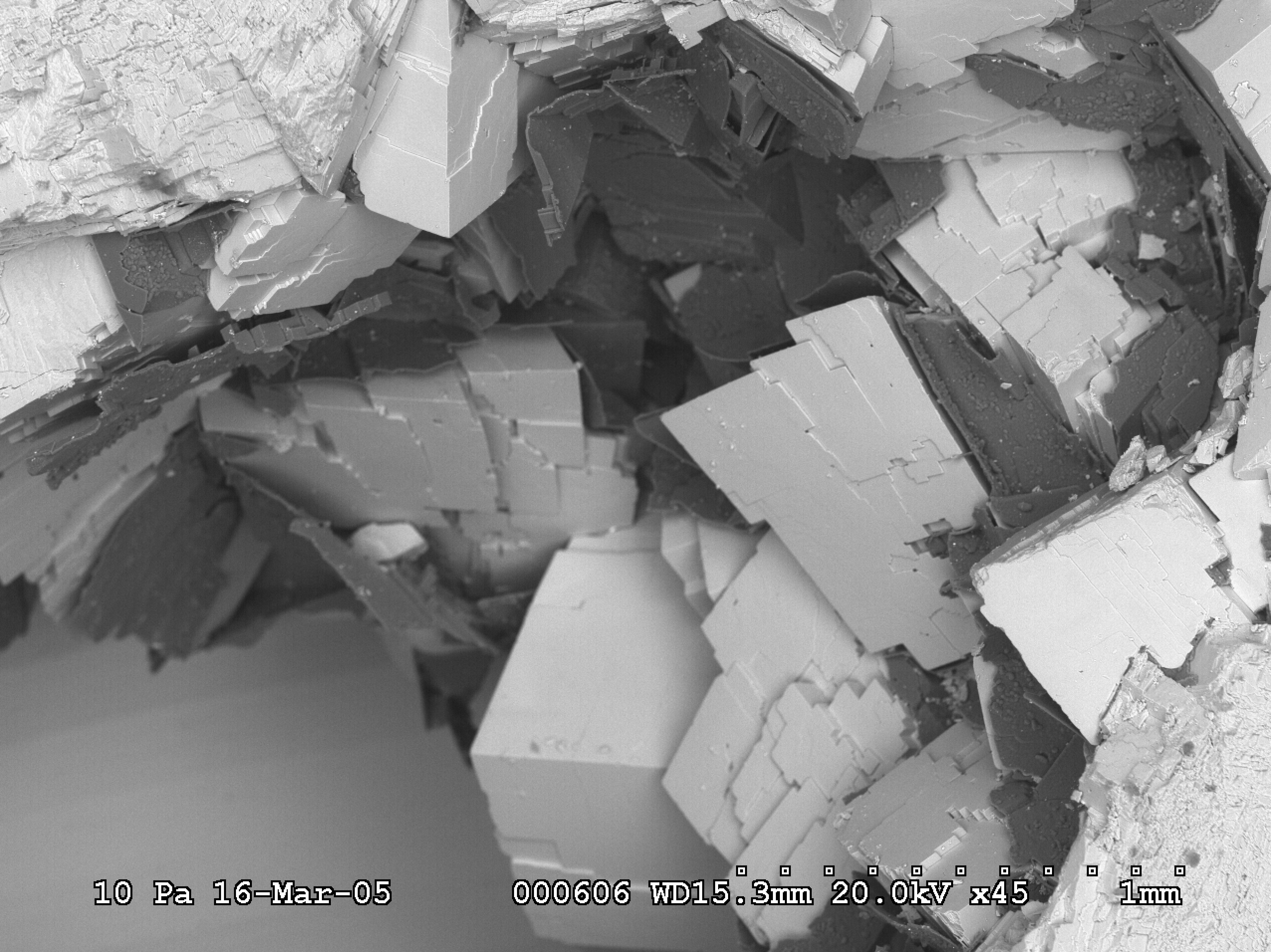

West River
Glodes Corners
Shut in
Pine Hill
Bean Stations
Muck Farm
Sugar Hill
County Line
Moreland
Wilson Hollow
Cutler Creek
Terry Hill South
Langdon Hill
Shut in
Ballyhack Creek
Quakenbush Hill
Whiskey Creek
Caton
Seeley Creek
Trenton Black River Hydrothermal Dolomite Fields
Gray #1 Core
Whiteman #1 Core
Matejka #1 Core

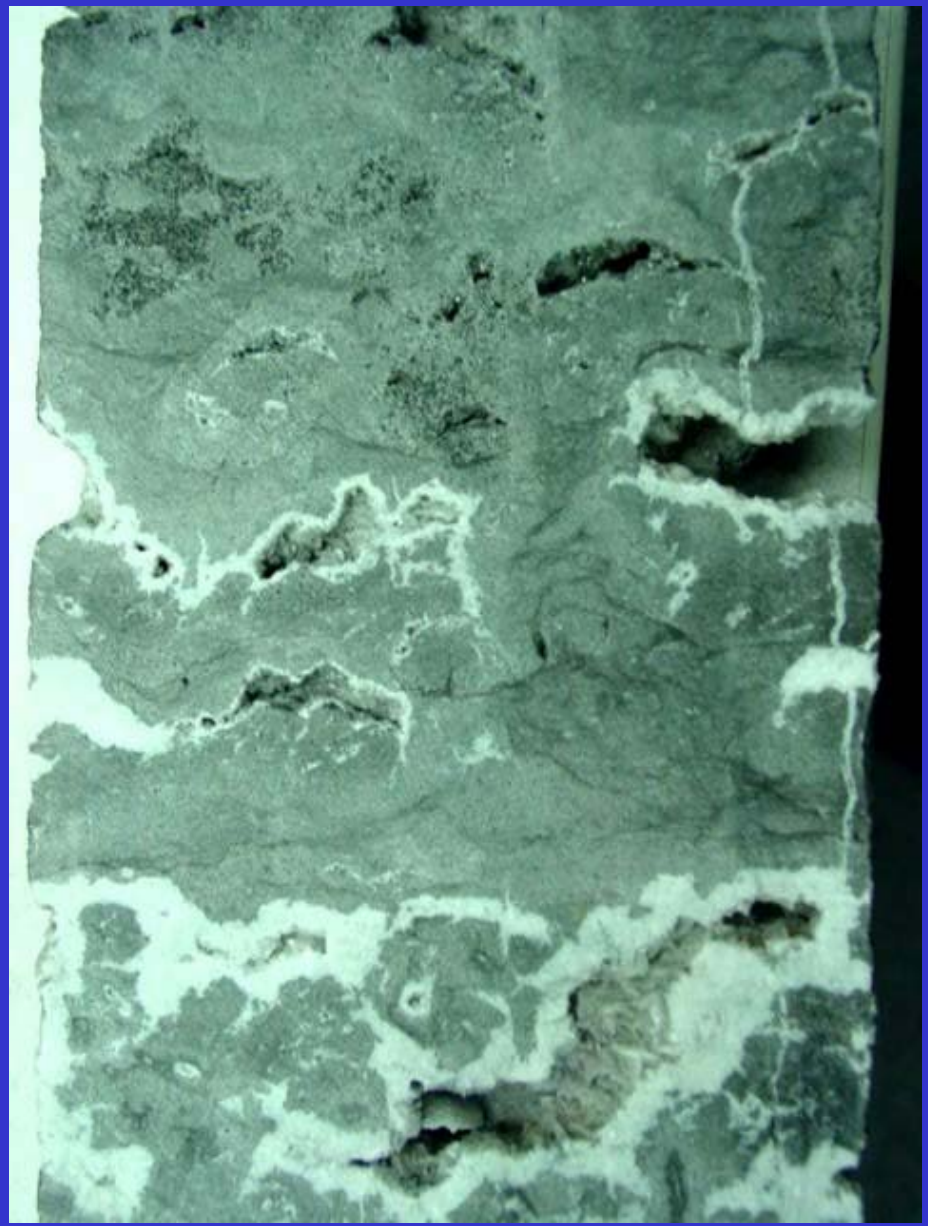

Bioturbated dolomudstone with replaced shell fragments, Gray #1 well, Steuben Co., NY

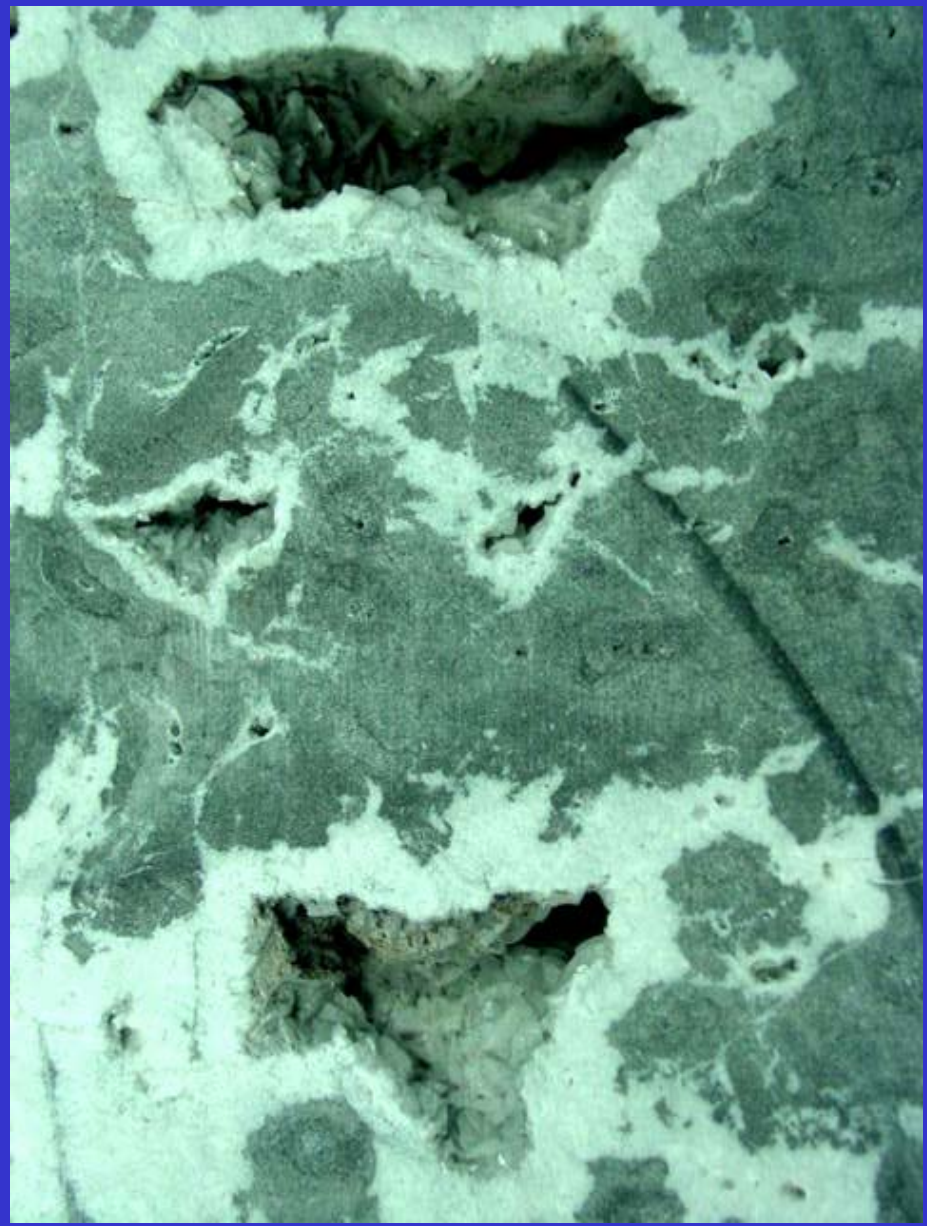

nonplanar-c (saddle)
planar-s to
nonplanar-a
(transitional)
nonplanar
saddle
1.0 mm

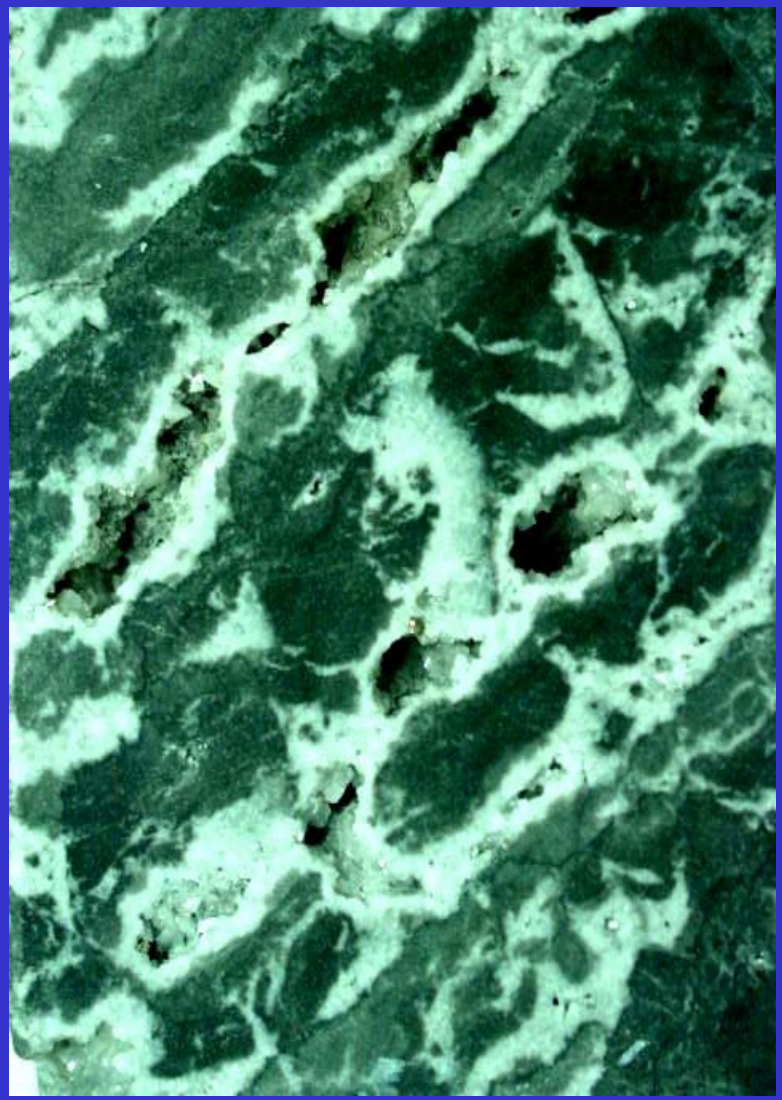


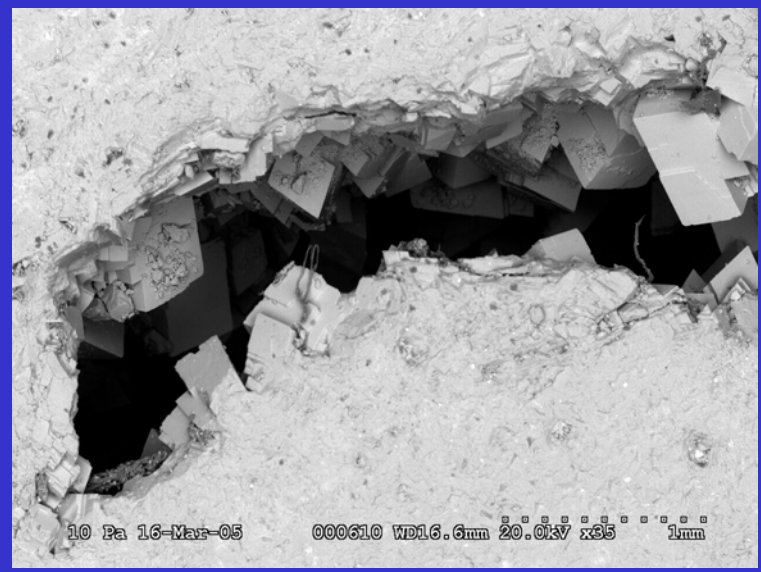

10 Pa 16-Mar-05
000605 WD16.6mm 20.0kV x45
1mm


10 Pa 16-Mar-05
000606 WD15.3mm 20.0kV x45
1mm



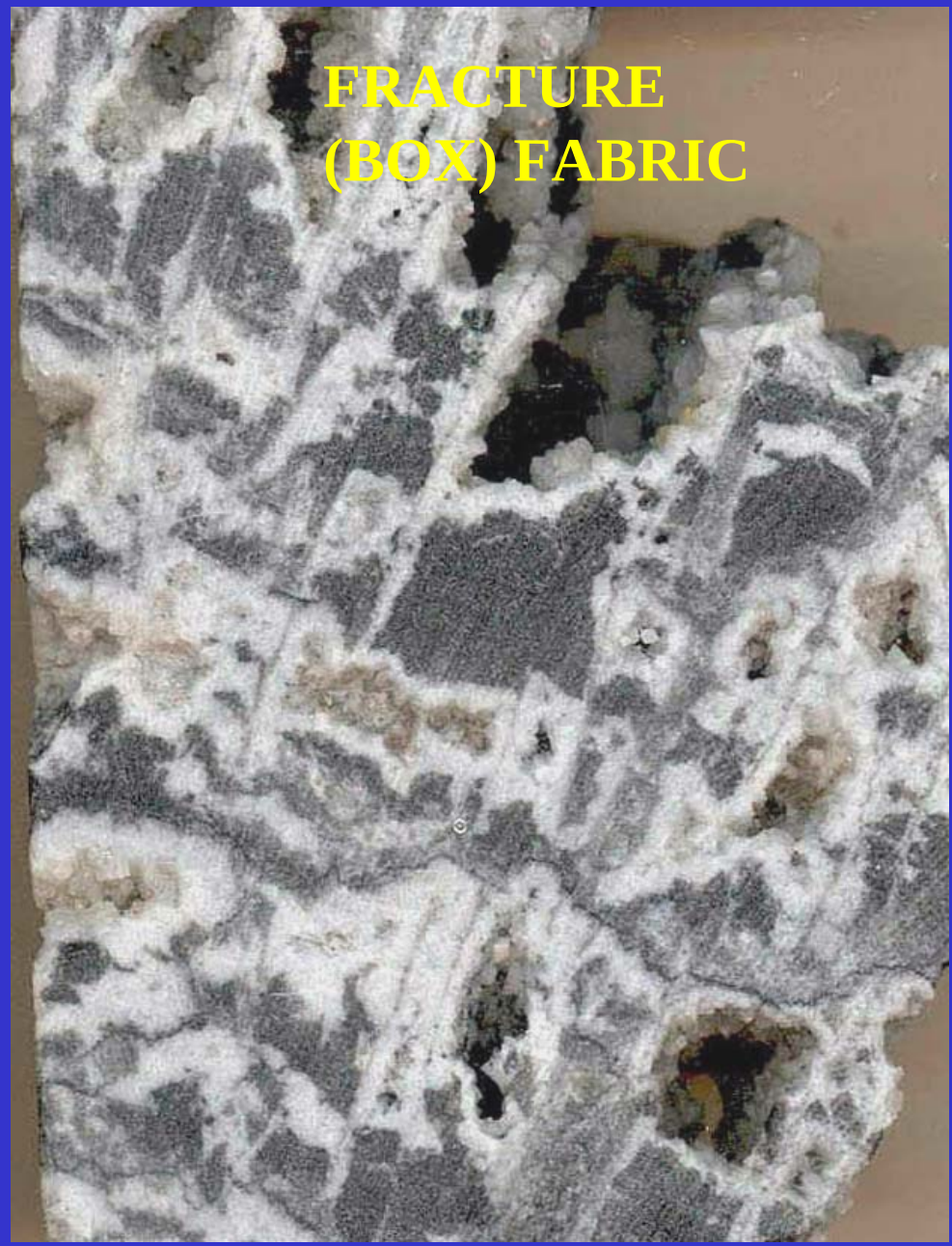


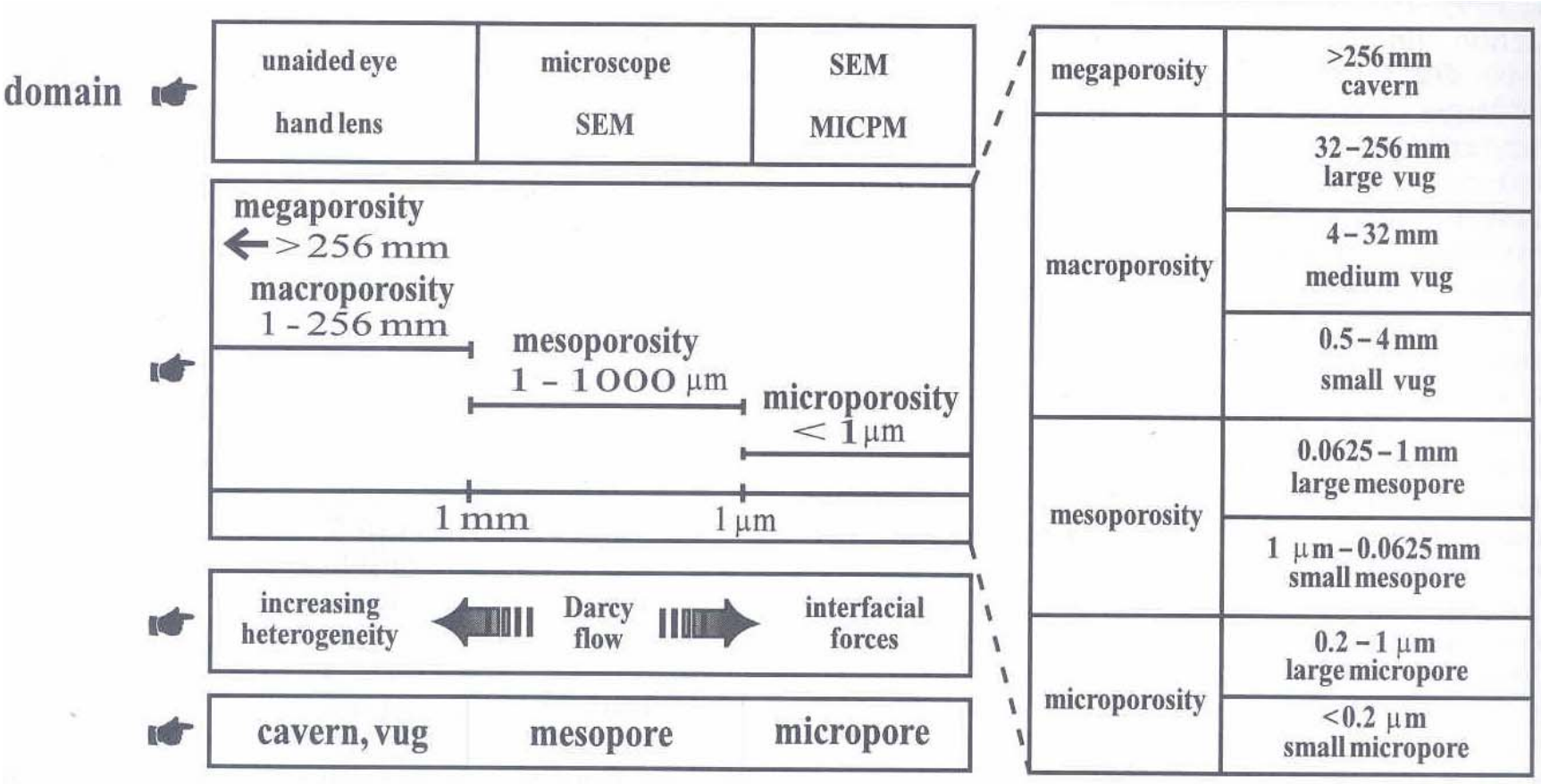




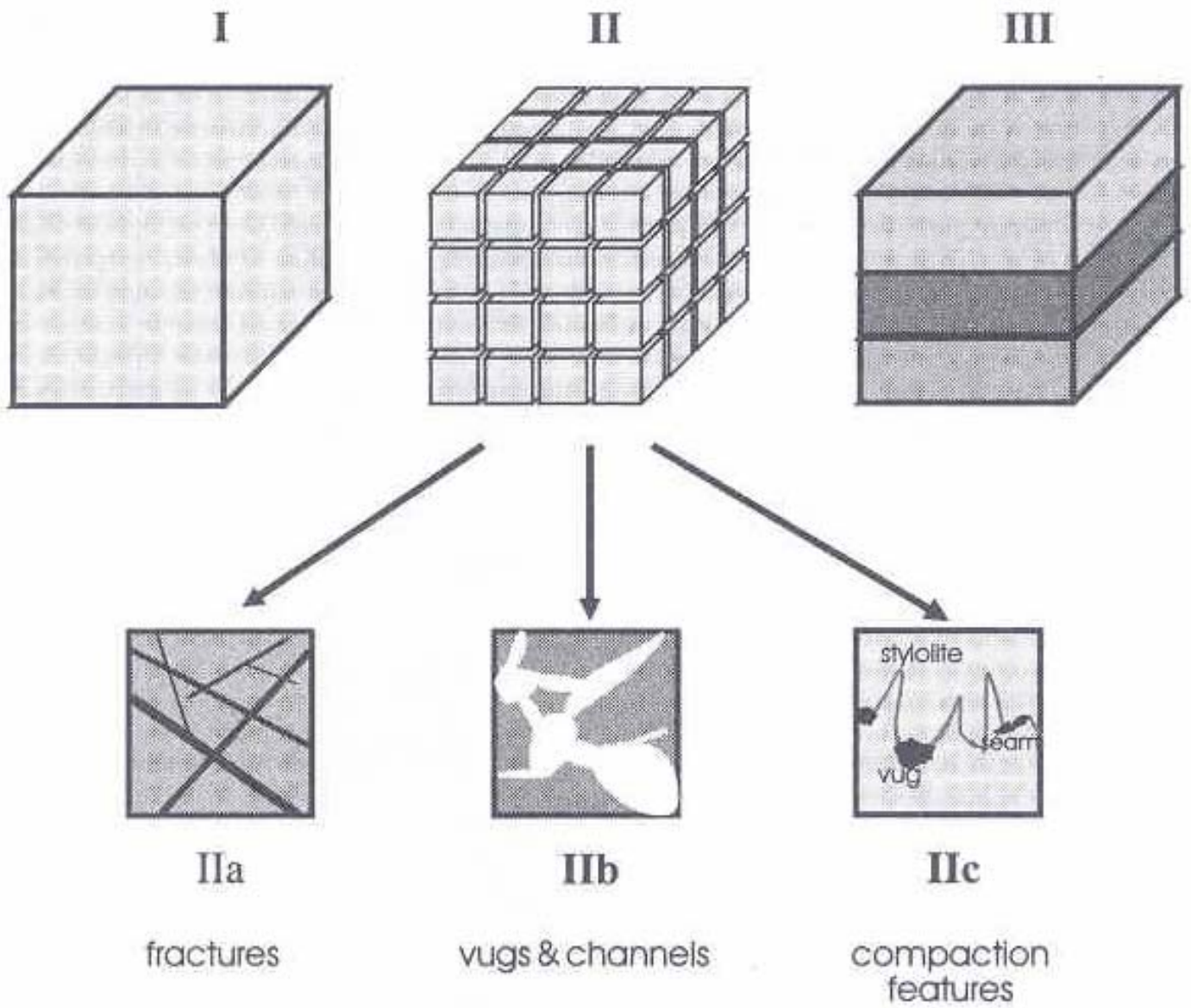
ZEBRA FABRIC


BRECCIA FABRIC


FRACTURE
(BOX) FABRIC



Lou and Machel (1995), AAPG Bulletin v.79, p.1698 – 1720)


I
II
III
stylolite
seam
vug
IIa
fractures
IIb
vugs & channels
IIc
compaction features

Conclusions

- Petrographic data support established depositional models.
- Regional diagenesis:
  - Early marine cementation
  - Burial diagenesis
  - HTD locally associated with structure

Conclusions

- Dolomitization of shallow water carbonates:
  - Distinctive textures formed in a sequential manner
  - Progressive degree of dolomitization
- Two distinct dolomite populations:
  - Initial metastable phase
  - Larger rhombs overgrow initial phase

Conclusions

- Two dolomite populations:
  - One dolomitization event?
  - Intracrystalline recrystallization?
- Textural differences in precursor limestone:
  - Heterogeneous lithification before dolomitization

Conclusions

- Dolomitization:
  - Burial
    - Local redistribution of older dolomite during stylolitization
  - Hydrothermal
    - Advection by hydrothermal fluids
    - By-product of thermochemical sulfate reduction
- Dolomitization reduced, even destroyed, porosity

Conclusions

- Porosity and permeability reduced by successive generations of dolomite, quartz, sulfides, and hydrocarbon alteration
- Porosity and permeability increased during sulfide mineralization concurrent with dolomite, calcite, and sulfate dissolution