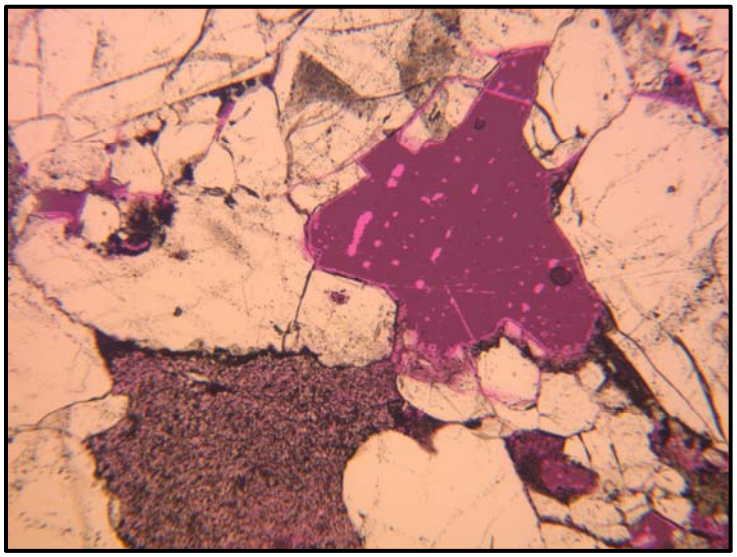
SAND2015-10961C

Exceptional service in the national interest

Sandia National Laboratories

Spatial Persistence of Macropores and Authigenic Clays in a Reservoir Sandstone: Implications for Enhanced Oil Recovery and CO_2 Storage



Thomas Dewers, Jason Heath, Jonathan Madison,
Sandia National Laboratories
Peter S. Mozley, New Mexico Tech

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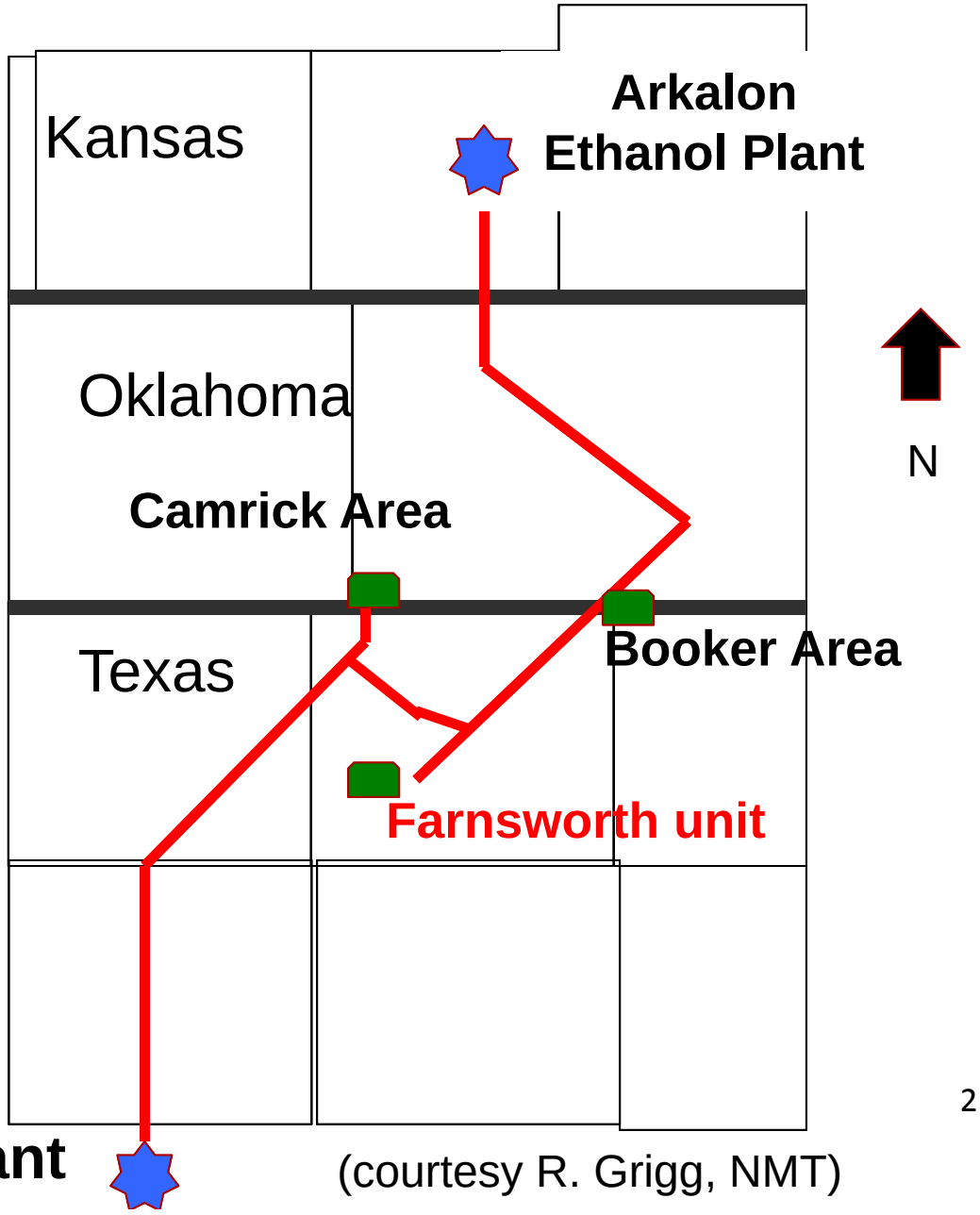
Southwest CO2 Partnership Phase III

Enhanced Oil Recovery & storage of anthropogenic CO_2 at Farnsworth Unit, TX

1 million tons total for 4-yr project

Legend

- Carbon Capture
- Transportation
- Utilization & Storage

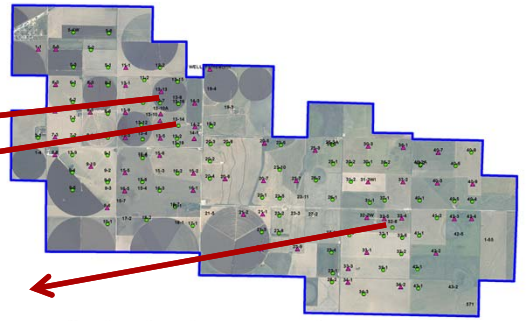


(courtesy R. Grigg, NMT)

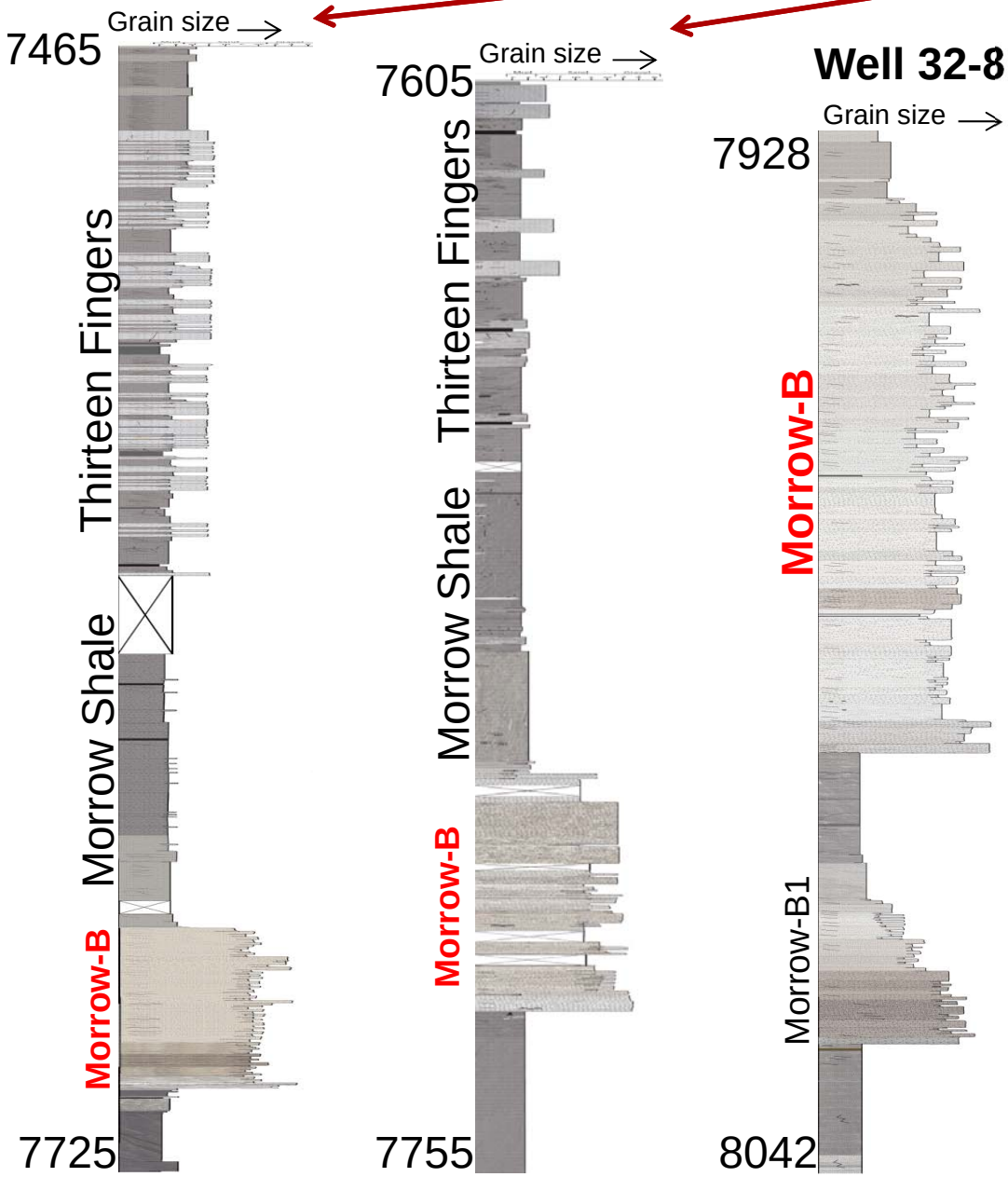
Well 13-10A

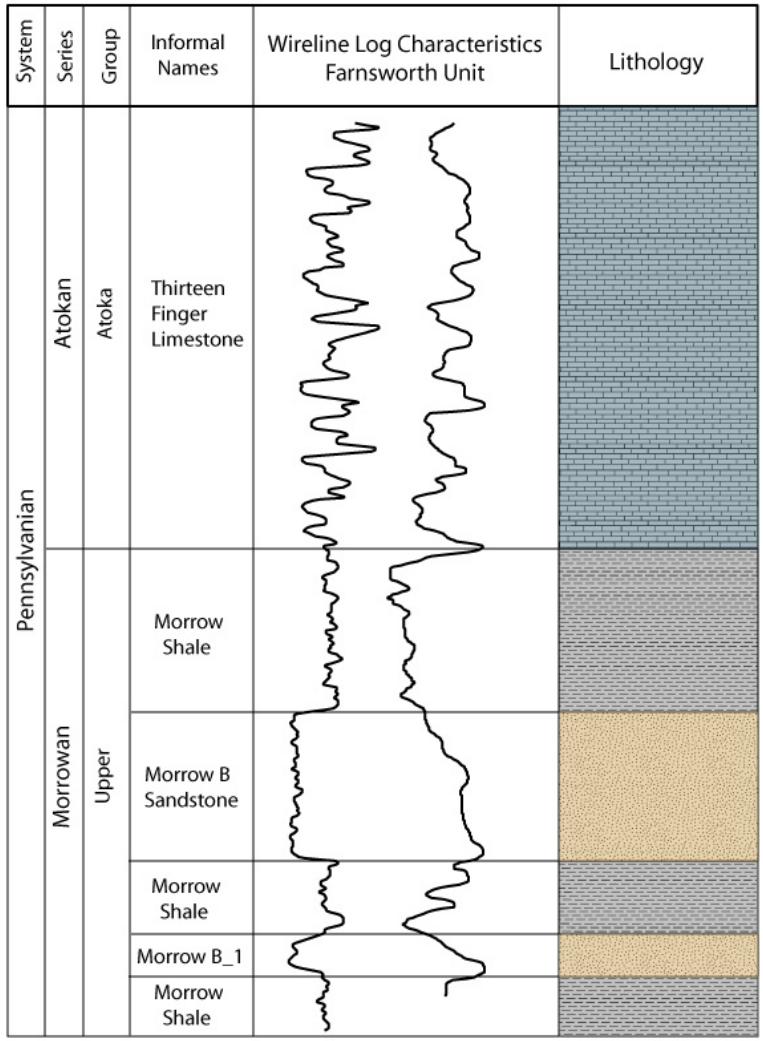
Well 13-14

Well 32-8



Farnsworth Unit, TX

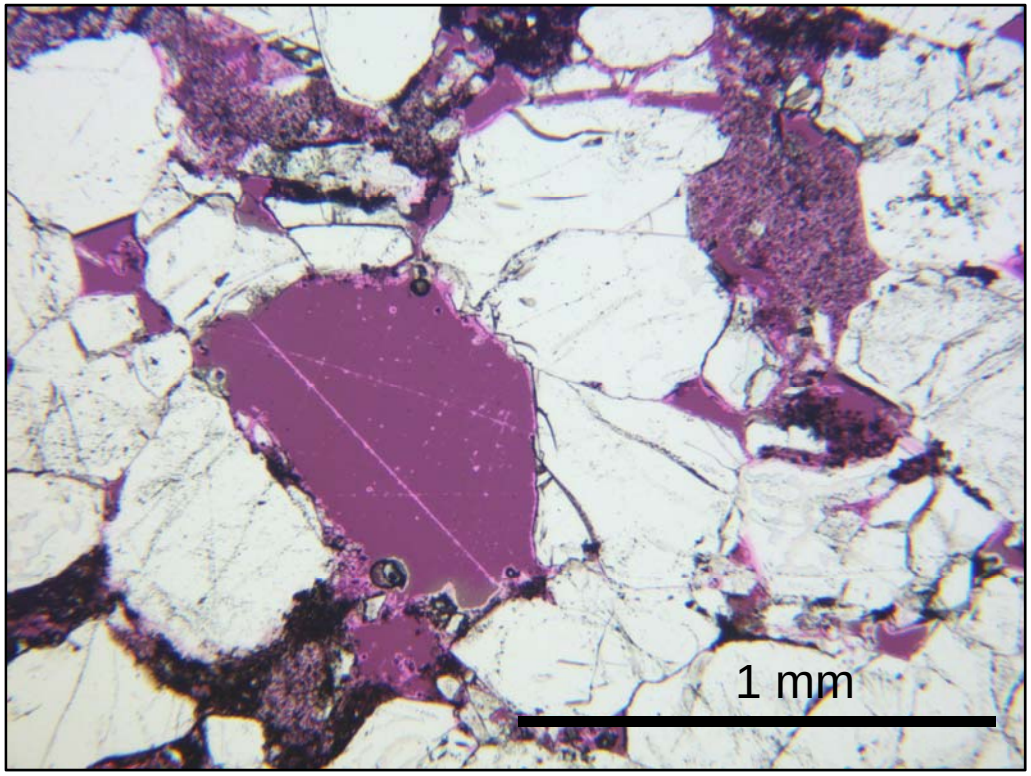




(courtesy D. Rose-Coss, NMT)

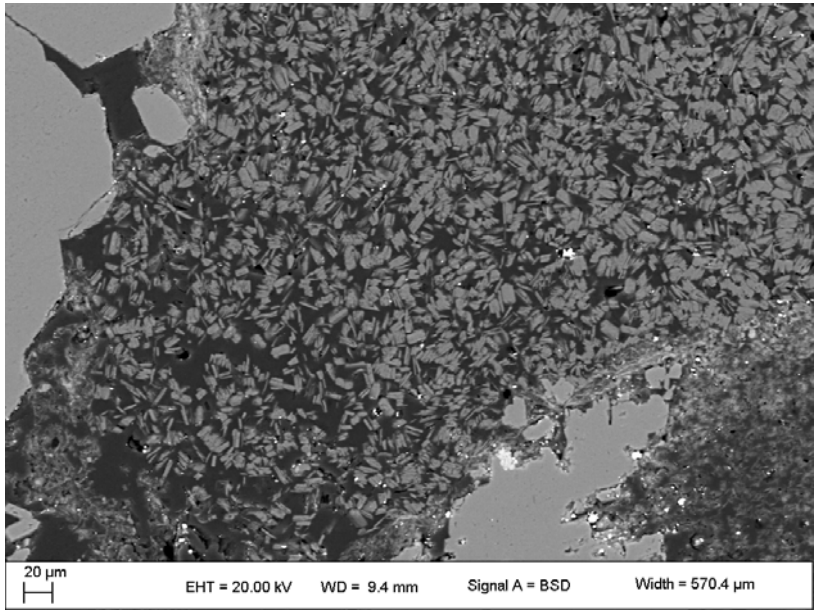
Previous pore-scale observations

Sara Gallagher (formerly of NMT) developed porosity facies using thin sections for Morrow sandstones– to map geologic controls on flow units



Common features:

- "clean" macro or oversized pores
- authigenic clays with microporosity



What is the "large-range" connectivity of the macropores and their intersection with clay micropores?

Methods

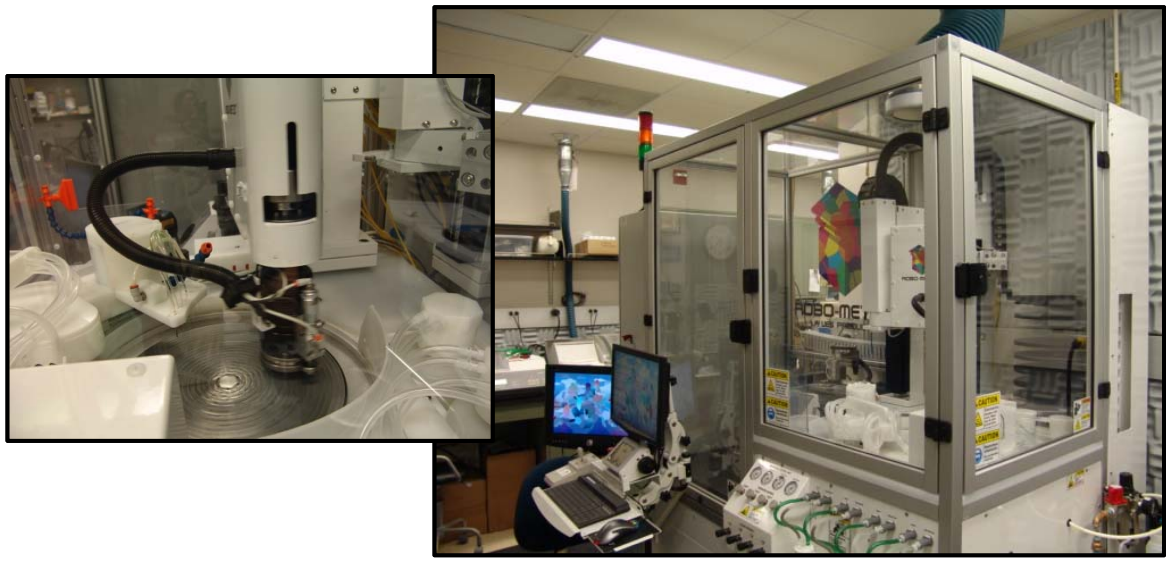
Goal: link mutliphase flow behavior to underlying pore structure

Multiscale 2D and 3D techniques:

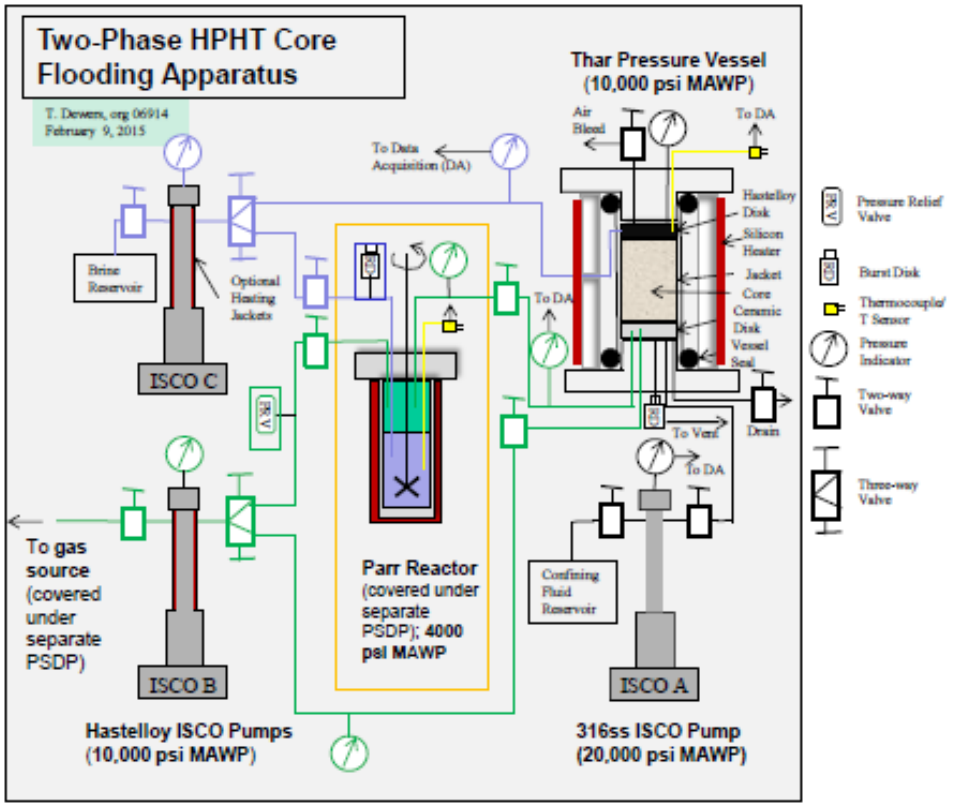
- Standard optical and electron petrography
- Mercury intrusion capillary pressure on clean/uncleaned samples
- Laser scanning confocal microscopy
- **Robotic serial sectioning and reflected light imaging**
- Relative permeability and capillary pressure

ROBO-MET.3D™
A UES PRODUCT

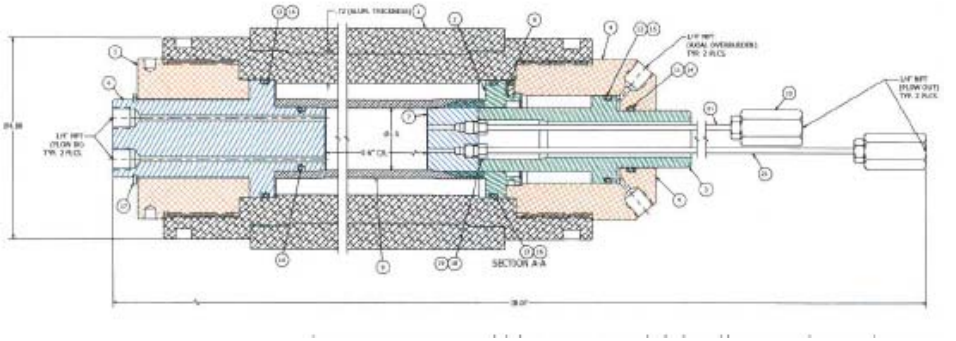
Imaging and Resolution
5 objectives
5X –- 2.10 um/pixel
10X –- 1.05 um/pixel
20X –- 0.53 um/pixel
50X –- 0.21 um/pixel



Capillary pressure and two-phase rel. perm



Schematic of Two-Phase Core Flooding System

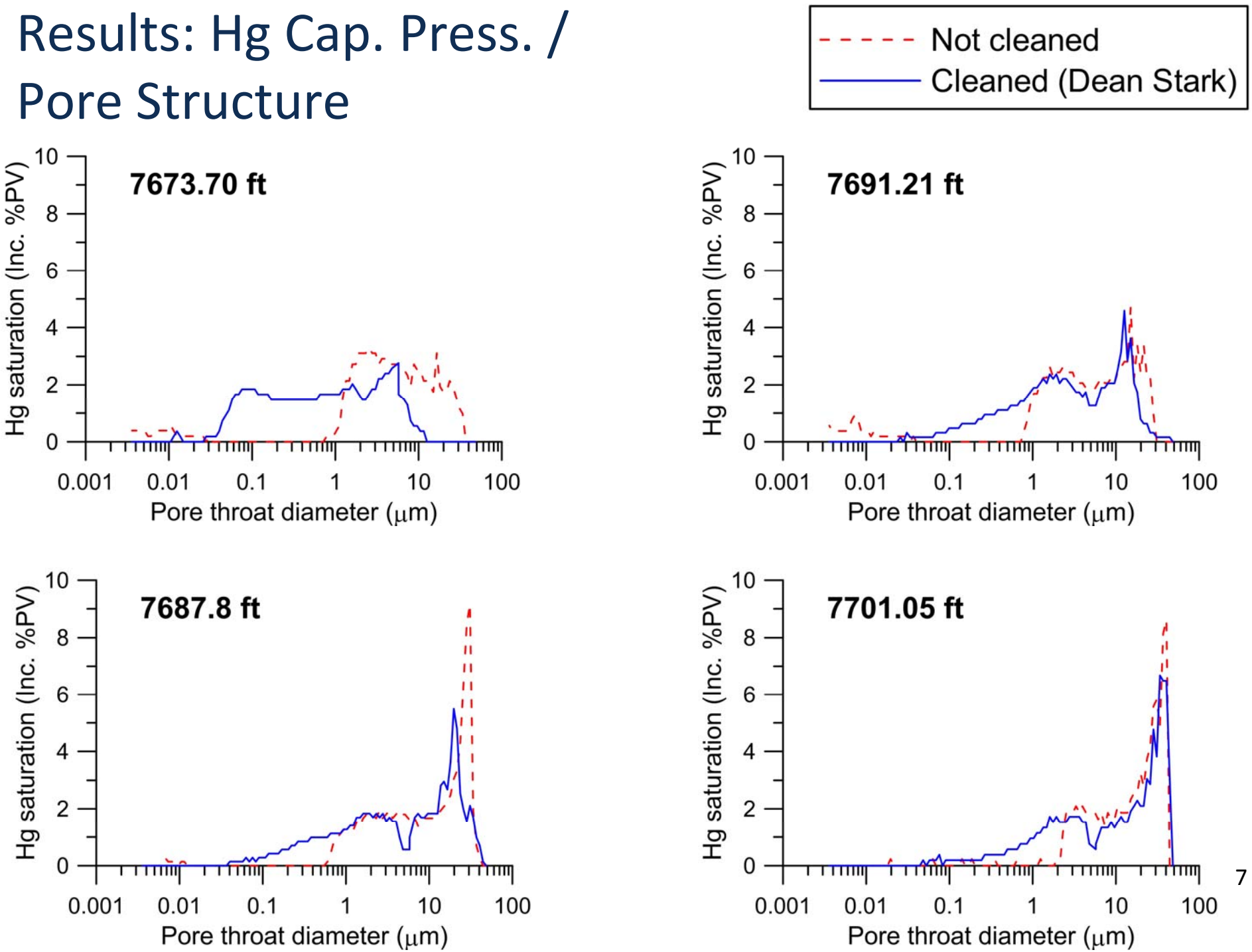


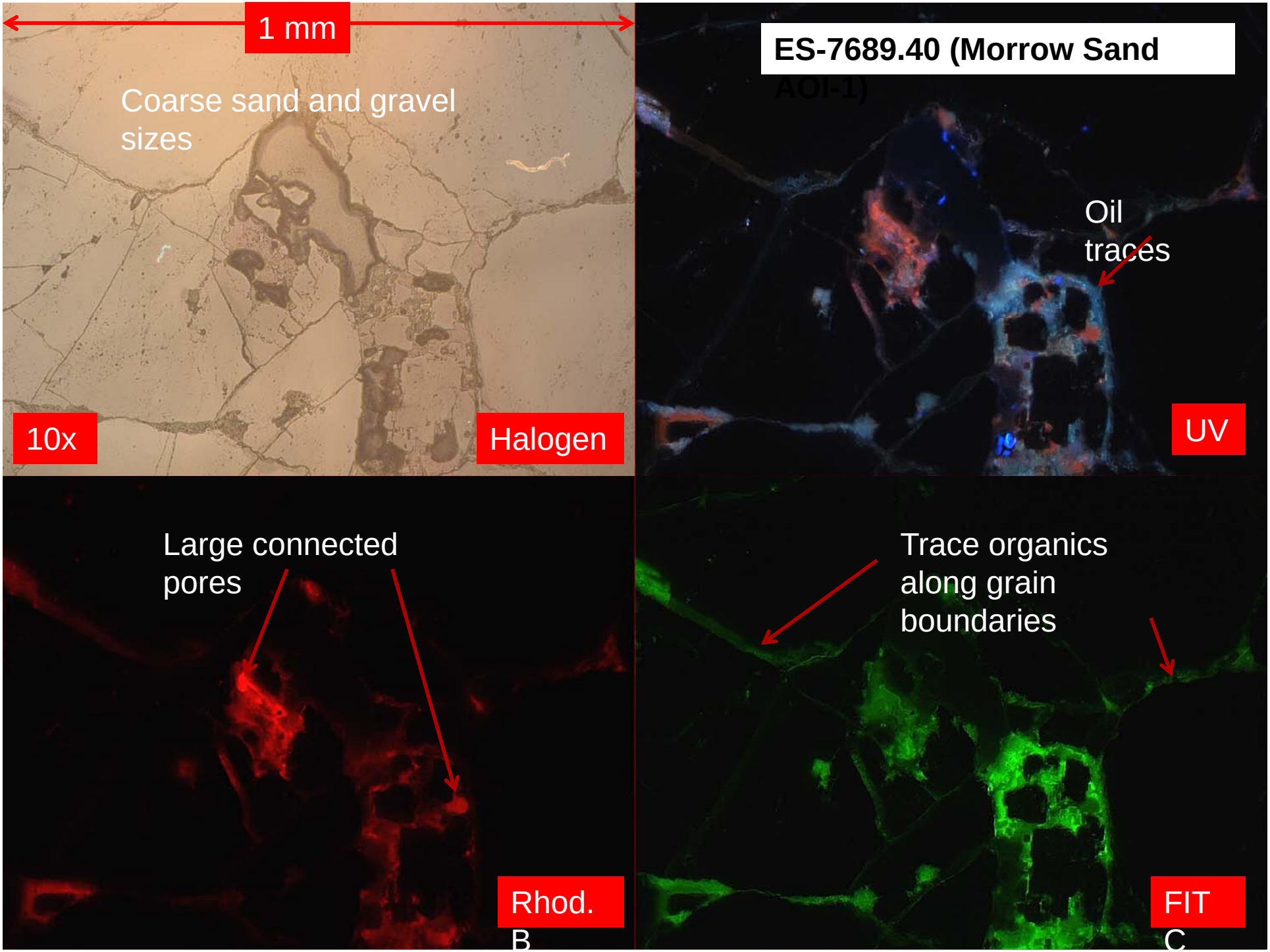
Schematic of Triaxial Coreholder

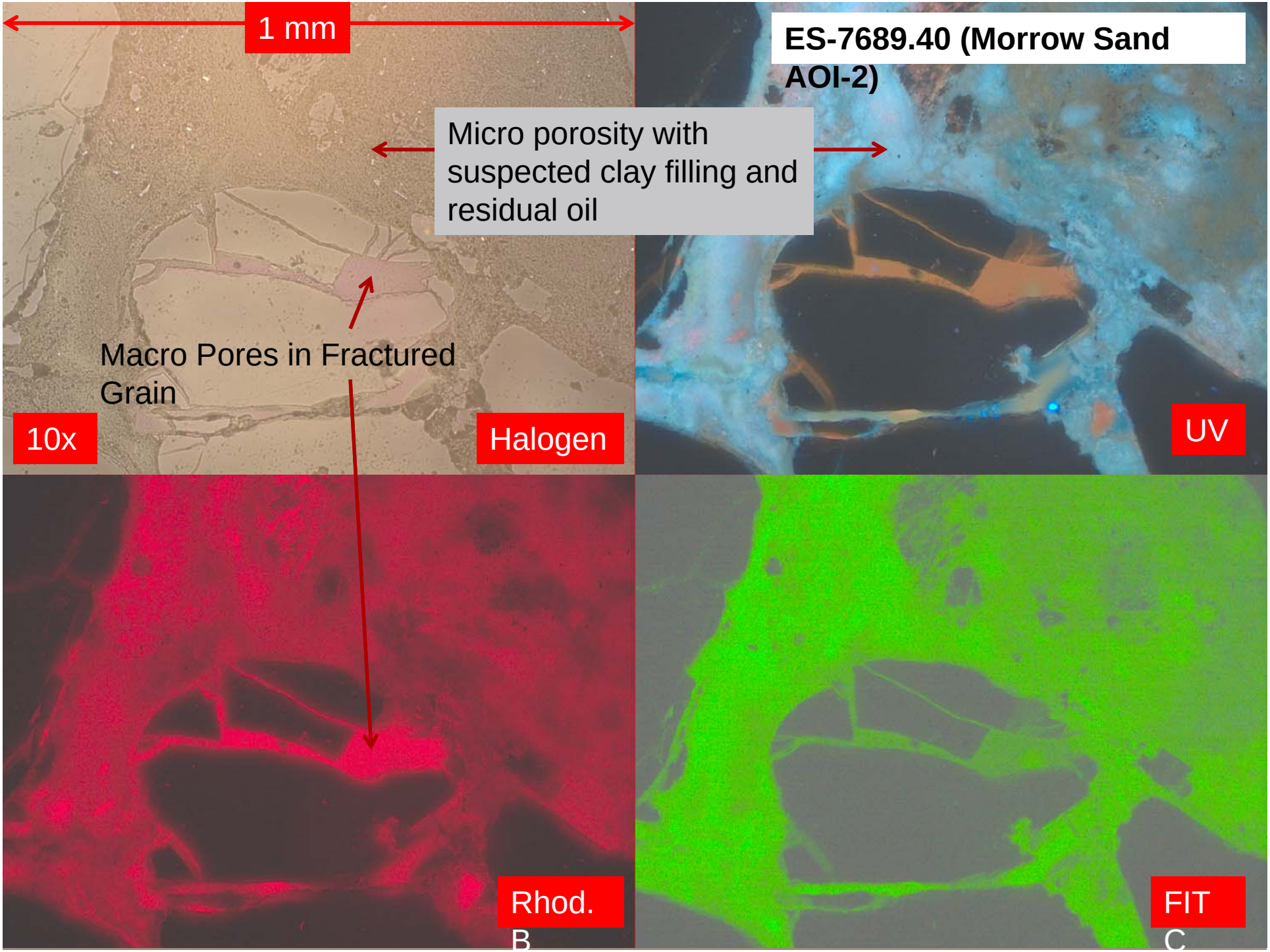
Aluminum-Carbon Fiber x-ray Transparent Triaxial Coreholder with Heating Sleeve

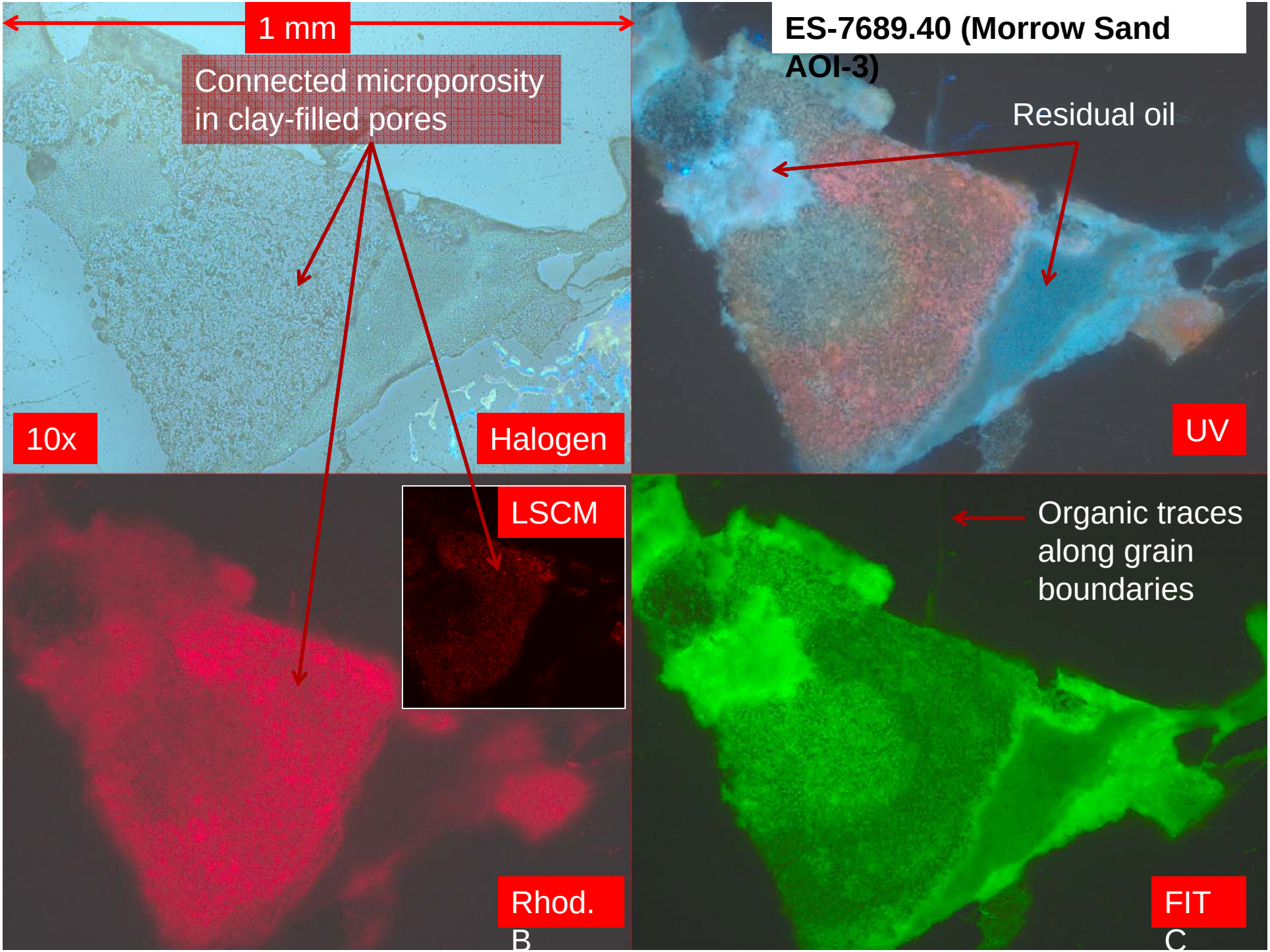
Teflon and EP-Jacketed Core

Results: Hg Cap. Press. / Pore Structure




1 mm
Coarse sand and gravel sizes
10x
Halogen
ES-7689.40 (Morrow Sand AOI-1)
Oil traces
UV
Large connected pores
Rhod. B
Trace organics along grain boundaries
FIT C


1 mm
ES-7689.40 (Morrow Sand AOI-2)
Micro porosity with suspected clay filling and residual oil
Macro Pores in Fractured Grain
10x
Halogen
UV
Rhod.
B
FIT
C


1 mm
Connected microporosity in clay-filled pores
10x
Halogen
ES-7689.40 (Morrow Sand AOI-3)
Residual oil
UV
LSCM
Rhod. B
Organic traces along grain boundaries
FIT C

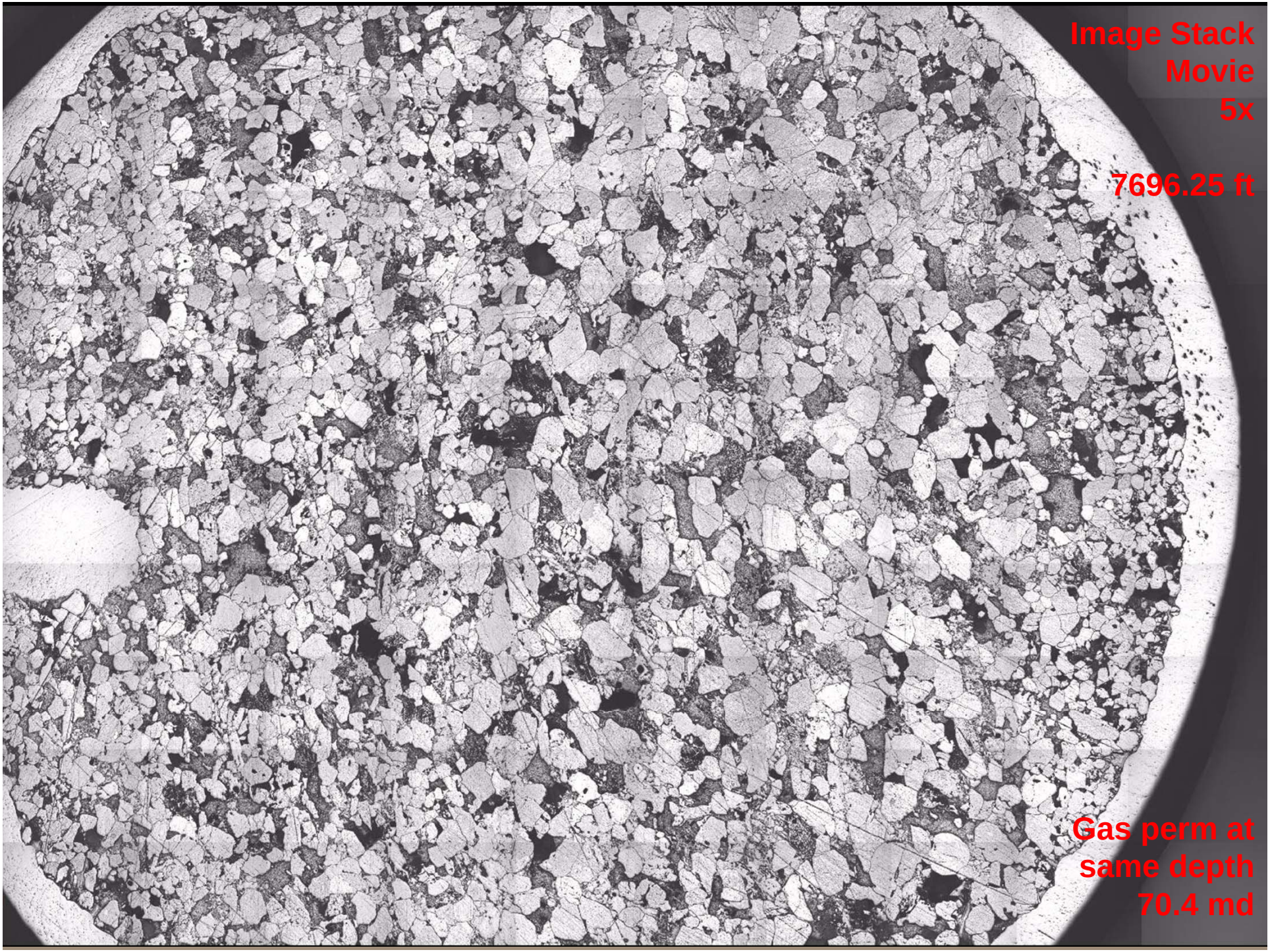
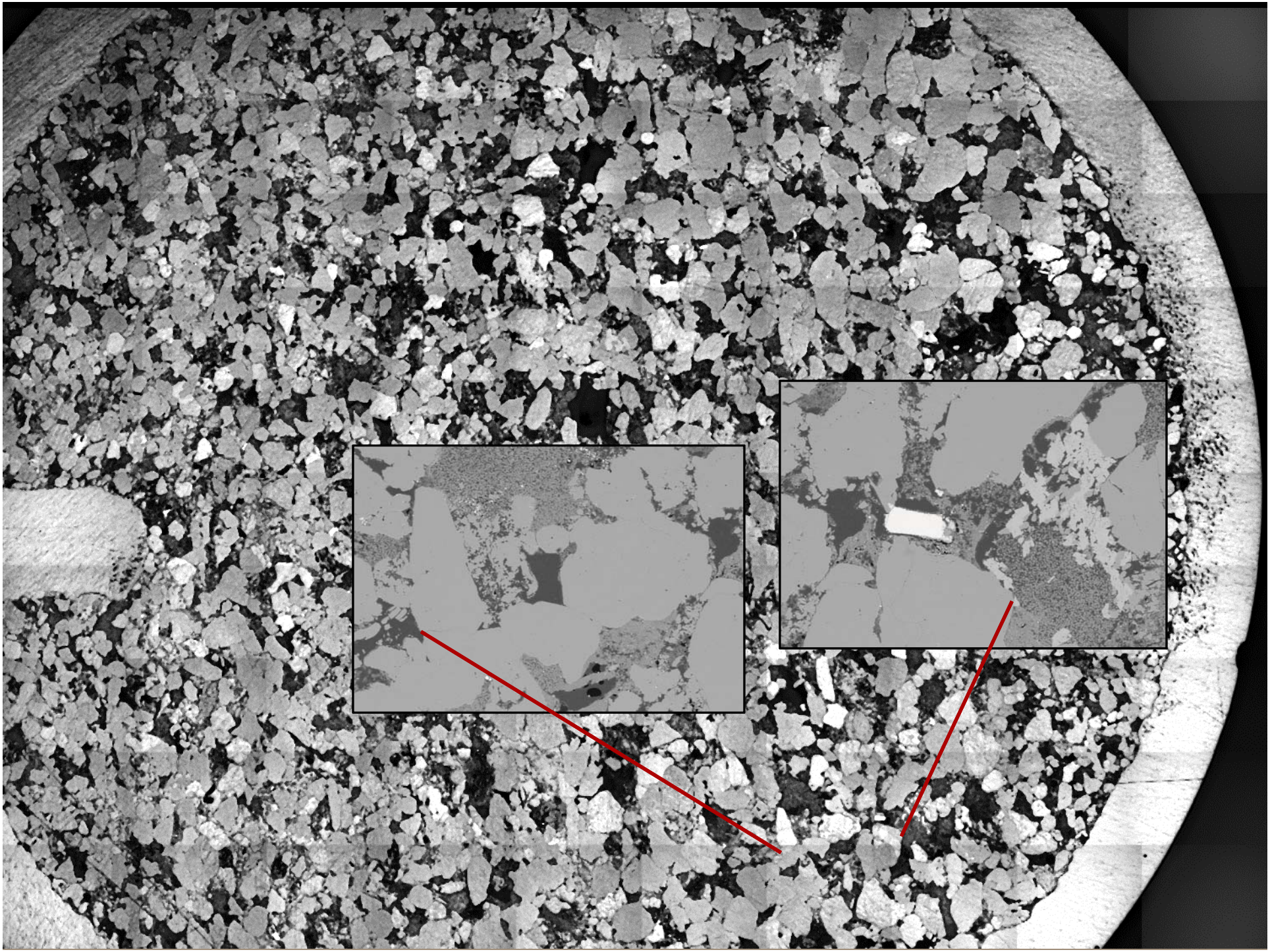
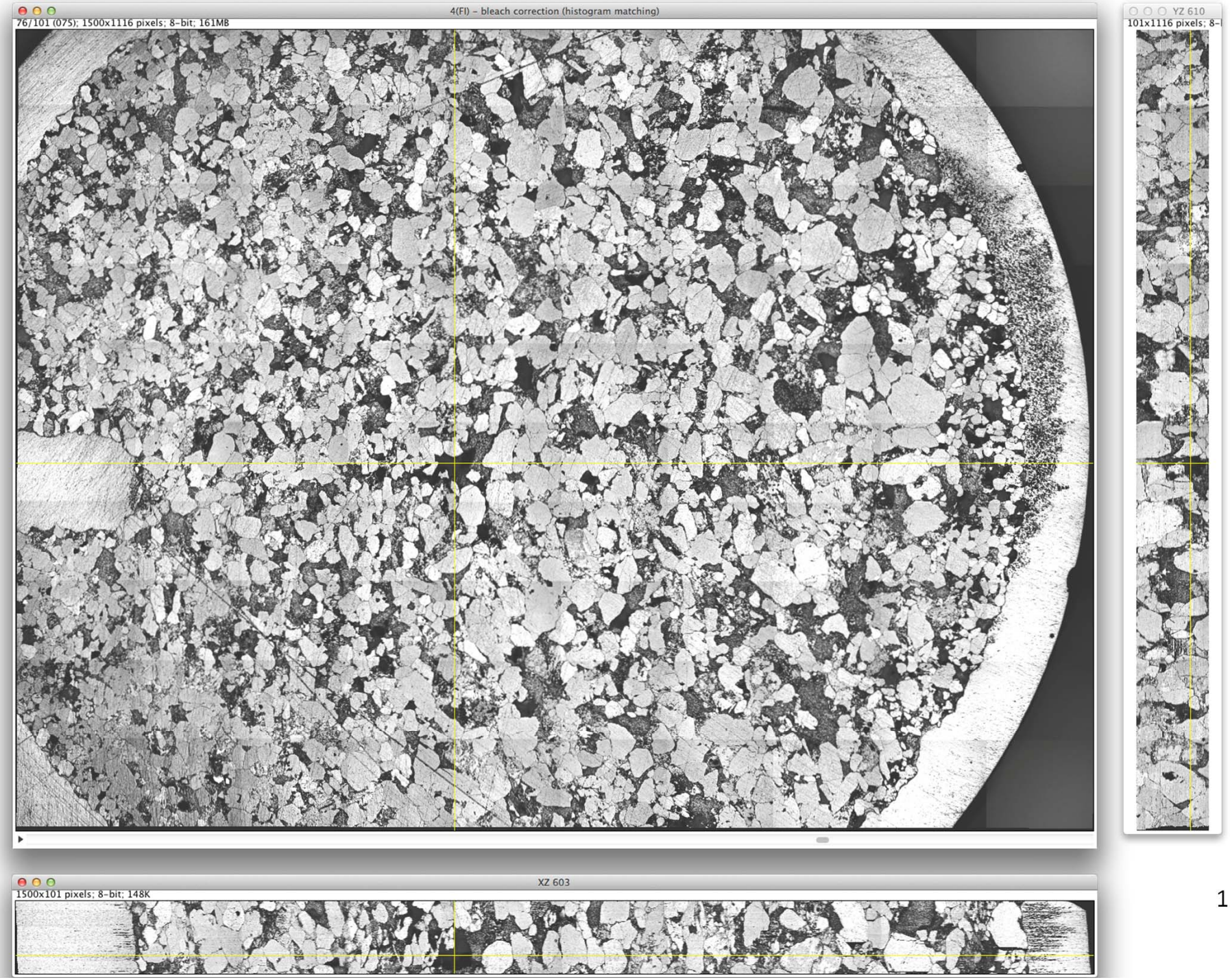
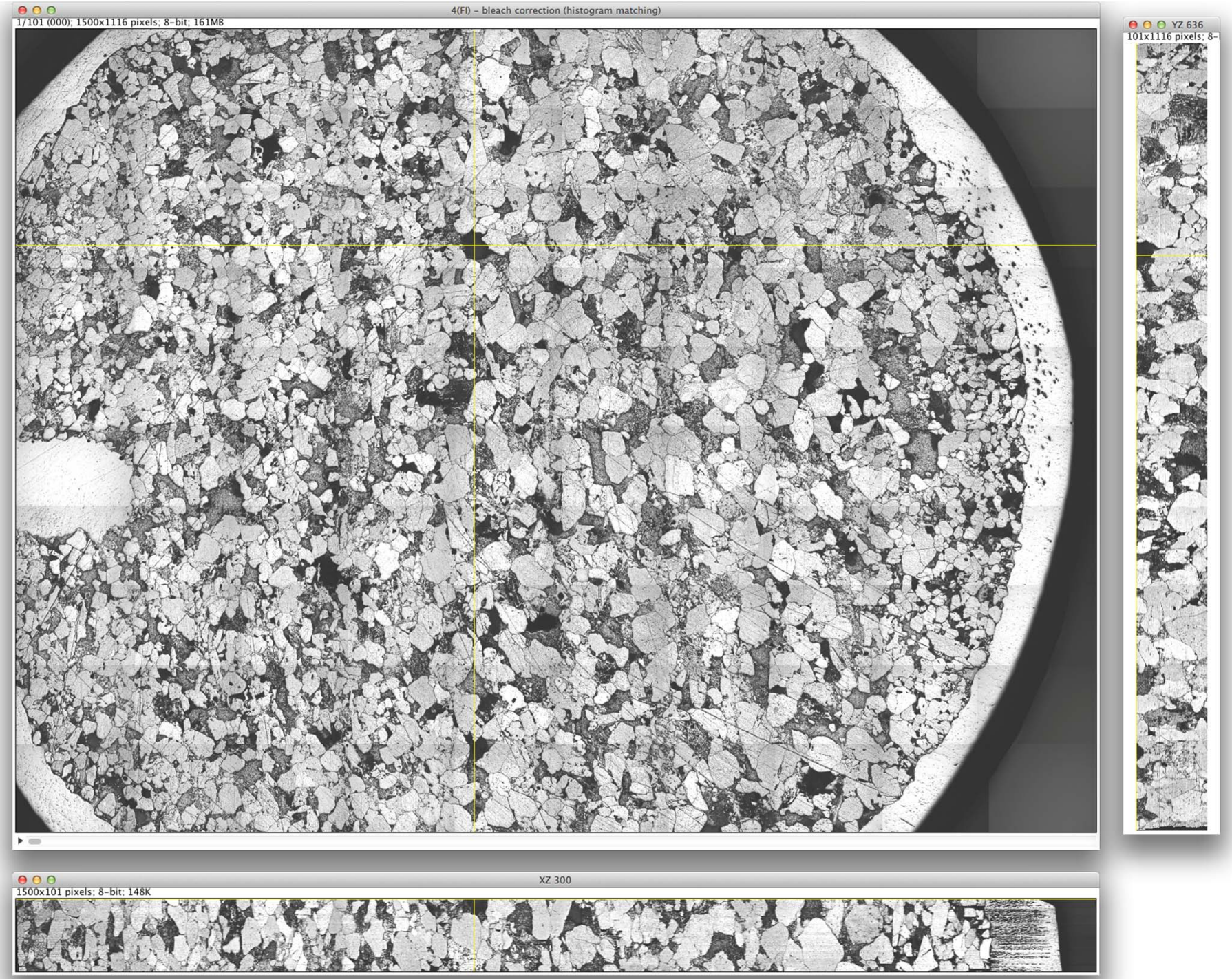
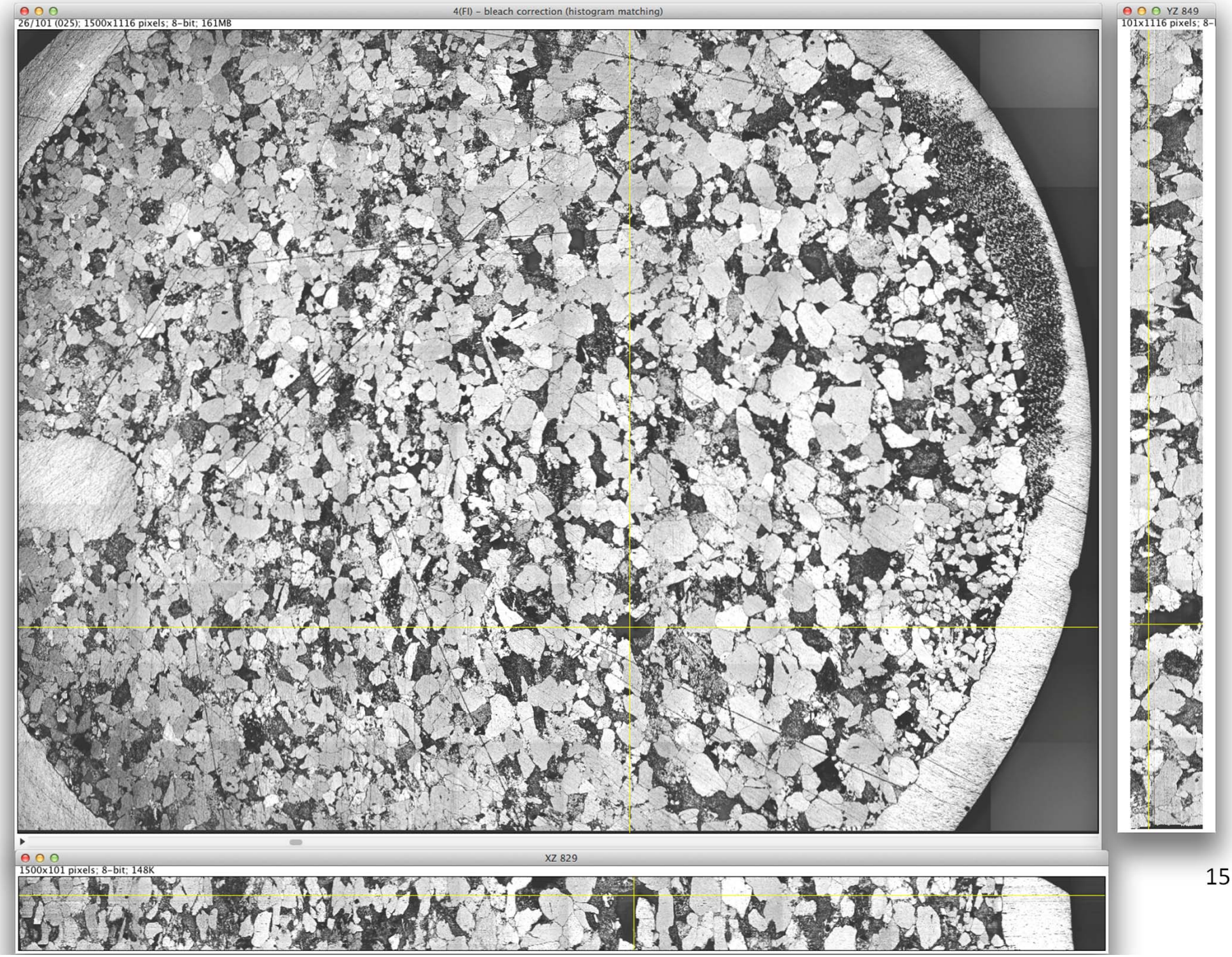


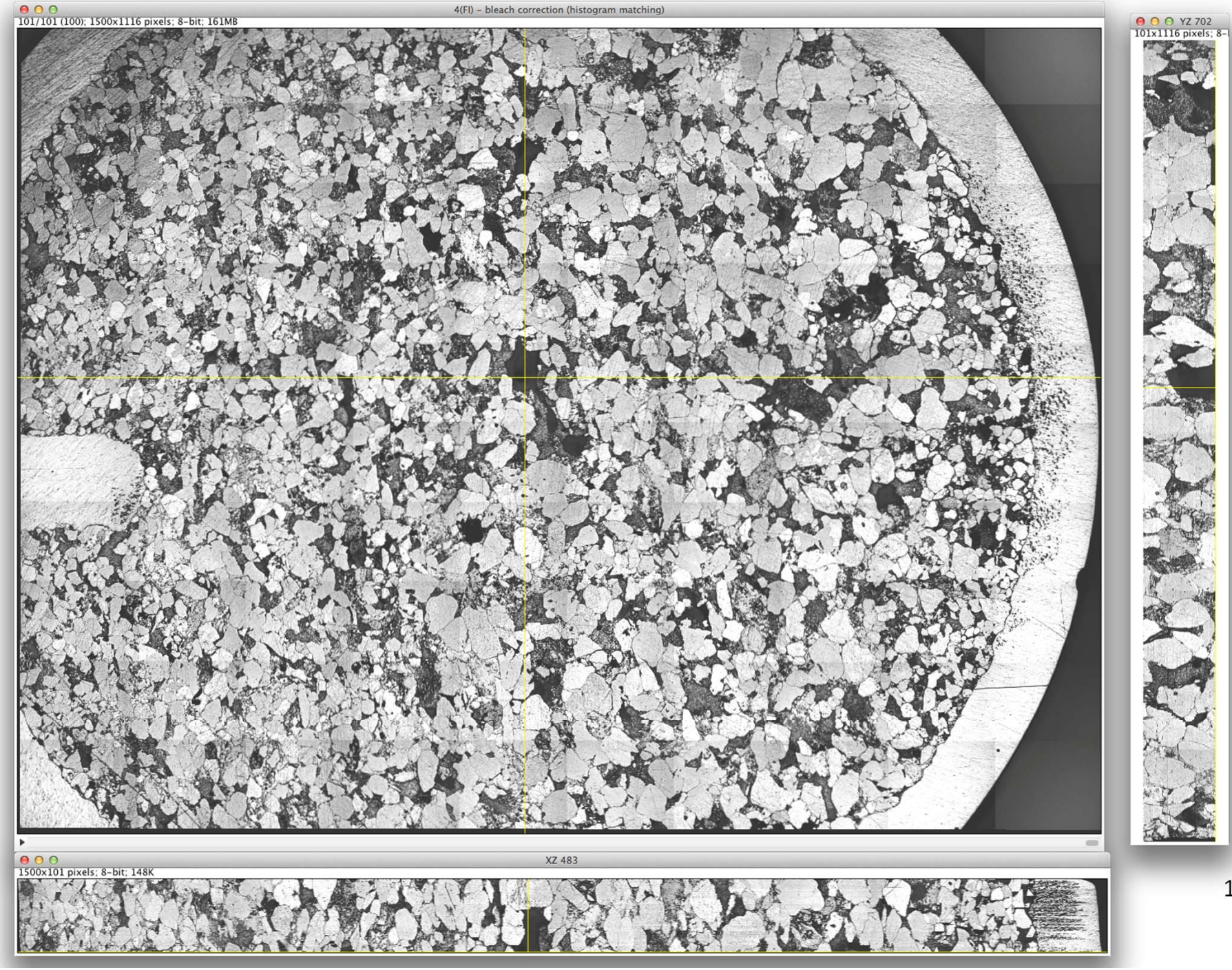
Image Stack
Movie
5x
7696.25 ft
Gas perm at
same depth
70.4 md




4(FI) – bleach correction (histogram matching)
76/101 (075); 1500x1116 pixels; 8-bit; 161MB
YZ 610
101x1116 pixels; 8-
XZ 603
1500x101 pixels; 8-bit; 148K


4(FI) – bleach correction (histogram matching)
1/101 (000); 1500x1116 pixels; 8-bit; 161MB
YZ 636
101x1116 pixels; 8-
XZ 300
1500x101 pixels; 8-bit; 148K


4(FI) – bleach correction (histogram matching)
26/101 (025); 1500x1116 pixels; 8-bit; 161MB
YZ 849
101x1116 pixels; 8-
XZ 829
1500x101 pixels; 8-bit; 148K


4(FI) – bleach correction (histogram matching)
101/101 (100); 1500x1116 pixels; 8-bit; 161MB
YZ 702
101x1116 pixels; 8-
XZ 483
1500x101 pixels; 8-bit; 148K

Segmentation: clays and pores together

montage: 10 x 10
magnification : 5X

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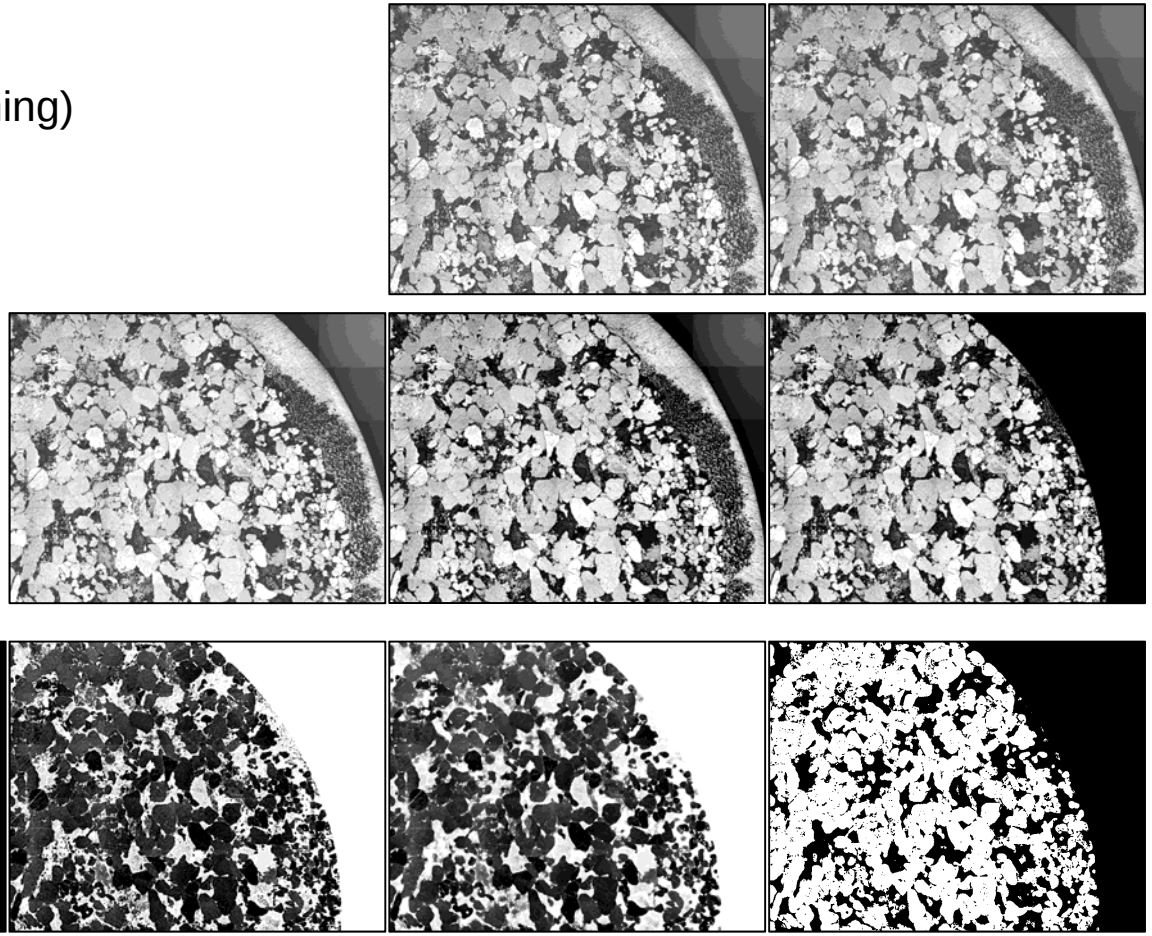
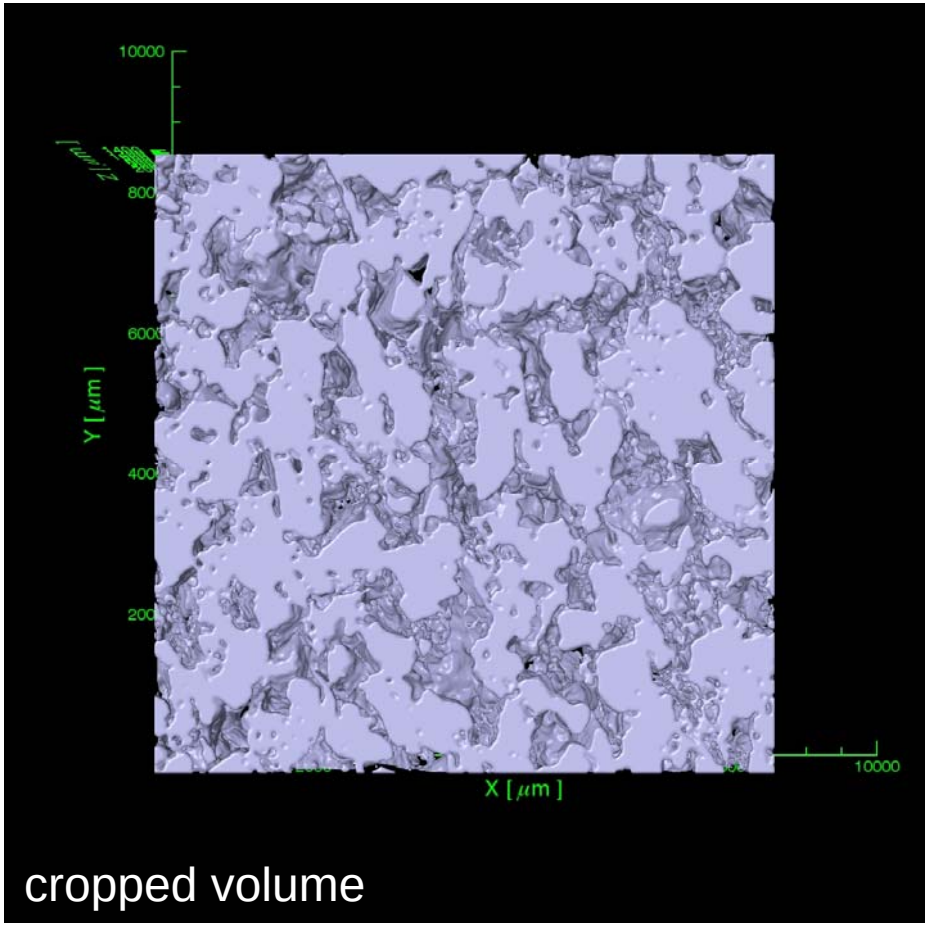
Segmentation approach, 11 steps:

1. Make grayscale
2. Sift align (rigid)
3. Bleach correction (histogram matching)
4. Autolevel stack
5. Remove mount from image
6. Upper right crop
7. Despeckle
8. Invert grayscale
9. Remove outliers & levels adjust
10. Stack local Bernsen threshold

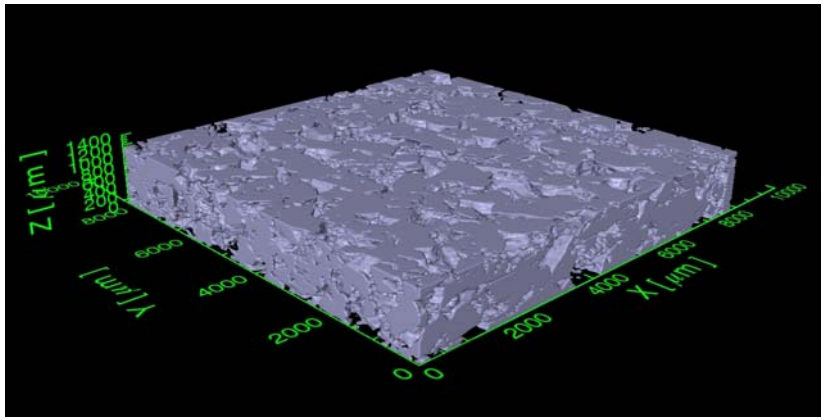


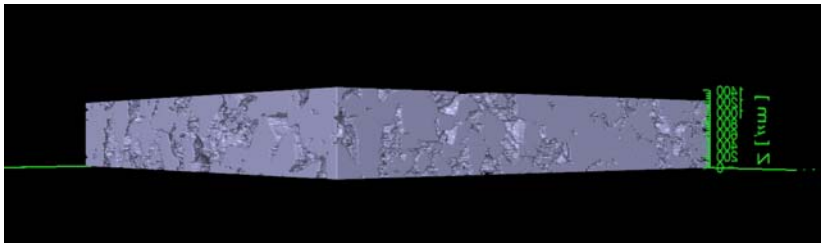
Segmentation: clays and pores together

montage: 10 x 10
magnification : 5X



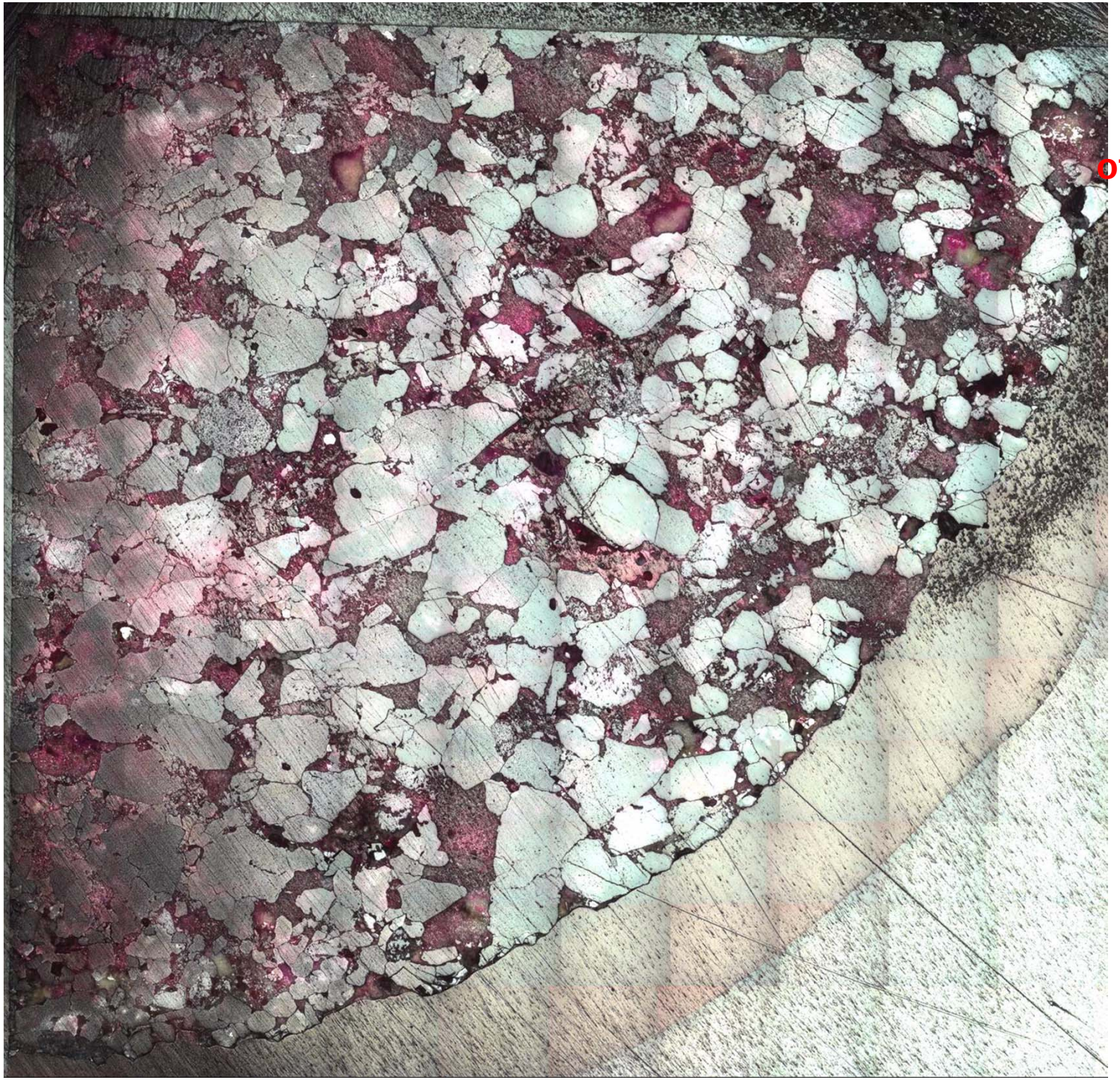
cropped volume





Quartz – FY 2015

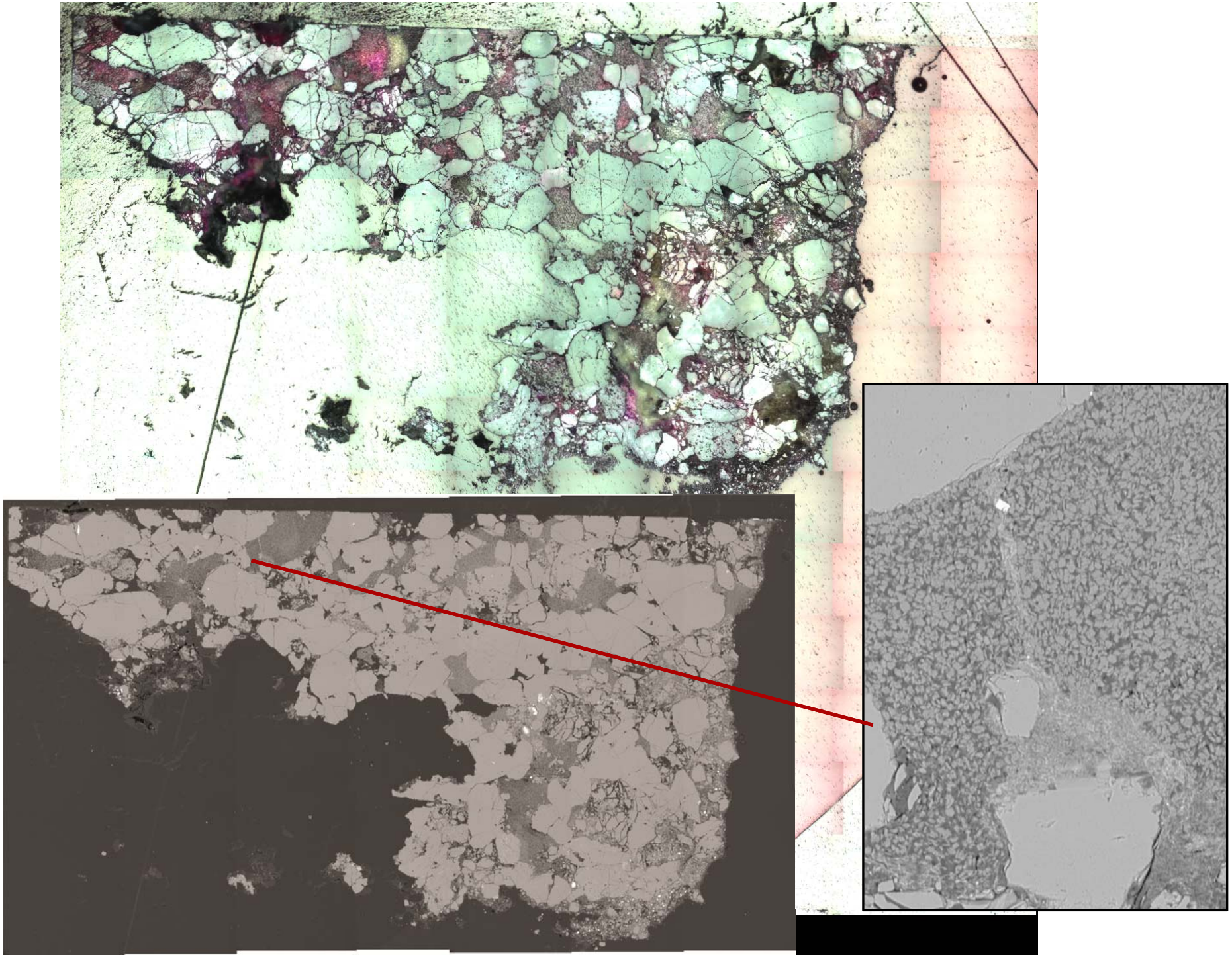
- Showing a cropped volume to show more detail.
- From the side-view it looks like we've sectioned through about 1-1.5 quartz grains in thickness



Next round:

Quartered
of same sample

Image Stack
Movie
10x



Conclusions and Future Work

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- Morrow B contains macro and micro pores
- Hydrocarbons are predominately associated with clays and micropores
- Visual inspection: macropores often are surrounded by clays from whole plug robo-grinding experiment
  - Quantitative analysis is underway with segmenting only pores and computing topology
  - Calculation of permeability on pore models will be performed

Acknowledgments

Funding for this project is provided by the U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL through the Southwest Regional Partnership on Carbon Sequestration (SWP) under Award No. DE-FC26-05NT42591. Additional support has been provided by site operator Chaparral Energy, L.L.C. and Schlumberger Carbon Services.

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