Image Processing and Analysis of Carbonate Rocks

STAR Fellowship Program

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Sandia National Laboratories

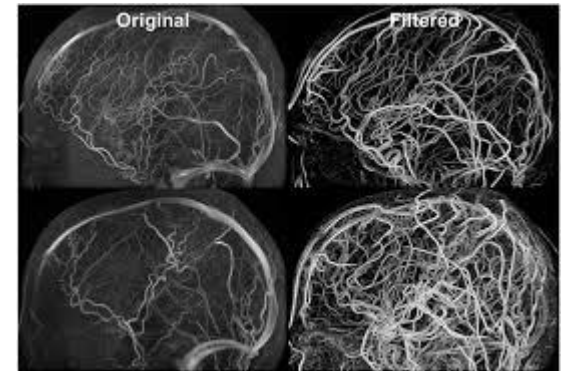*Exceptional service in the national interest*

Introduction to Image Processing

Image processing is the study of algorithms that take an image as input and returns an output.

- Image display and printing
- Image editing and manipulation
- Image enhancement

Major Fields that use Image Processing:

- Medical/Biological (x-rays, CT scans, etc.)
- Computerized Photography (Photoshop)
- Space image processing (probe and telescope images)

Hsu, Chih-Yang et al. *Brain Mesh Generation*. 2015. Web. 1 July 2016.

http://oredigger.net/2015/03/independent-researcher-finds-low-quality-living-conditions-for-instagram-filters/

Image Analysis

- One of the fields directly related to Image processing is image analysis.

- Image analysis involves extracting meaningful information from an image.
  - ➢Image segmentation
  - ➢Image matching and compression
 - ➢Medical diagnosis from an image

ImageJ

- ImageJ is a public domain, Java-based image processing program developed by the National Institute of Health (NIH).
- It has a wide variety of functions from segmentation to filtering and is really up to you on what you use it for.
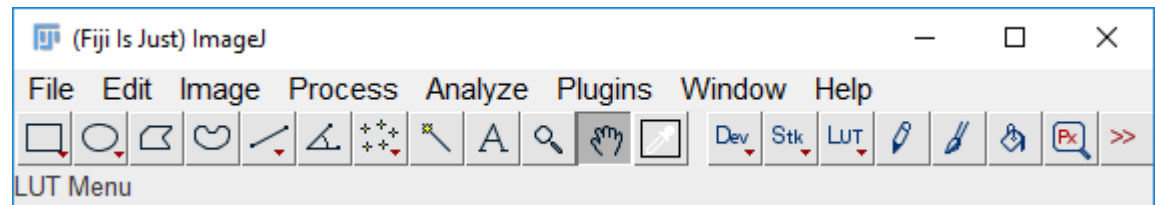
Basics of Digital Images

- A greyscale digital image is a matrix of numbers.

- Each number is called a pixel value.

- The numbers are on a 0-256 greyscale, where black is on the low end of the scale and white is on the high end.
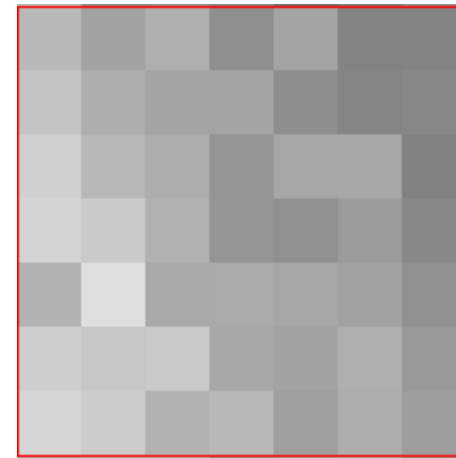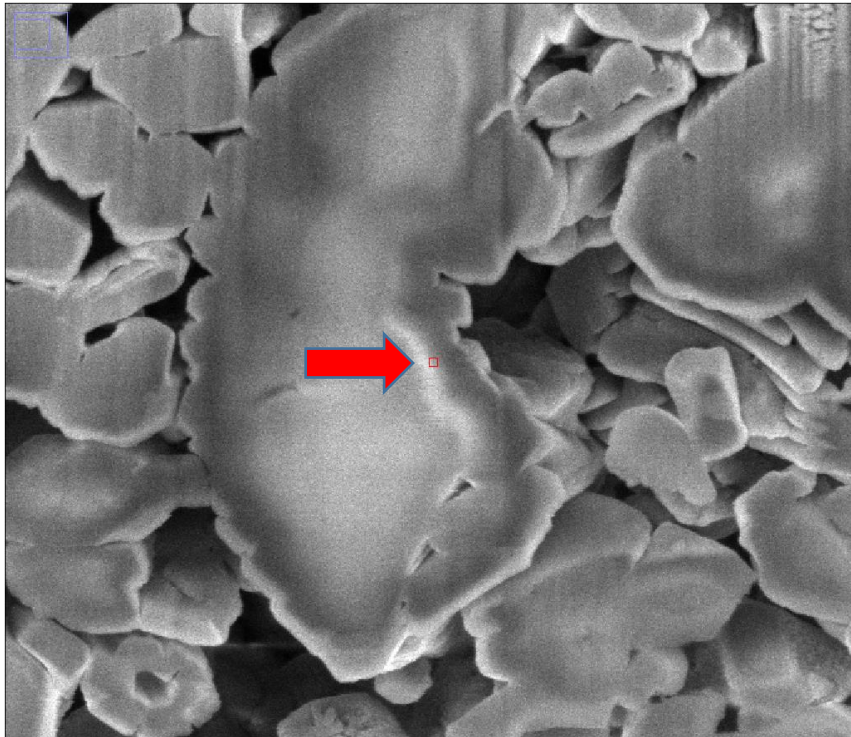

Zoom 3200%

185	162	175	143	164	131	132
195	174	164	164	142	133	136
208	183	173	149	166	167	129
212	202	177	149	144	155	136
178	223	169	170	166	161	144
207	199	202	168	163	163	175
214	203	178	185	159	173	157

# Dual focused ion beam-SEM (FIB-SEM) imaging of nano-scale pore structure

- Focused ion beam for cutting nanometer thin slices

- Scanning electron microscope for high resolution imaging

- Compositional analysis coupled with scanning transmission electron microscopy with energy dispersive X-ray spectroscopy

Nelson (2009)

1 Nanometer = 1 billionth of a meter
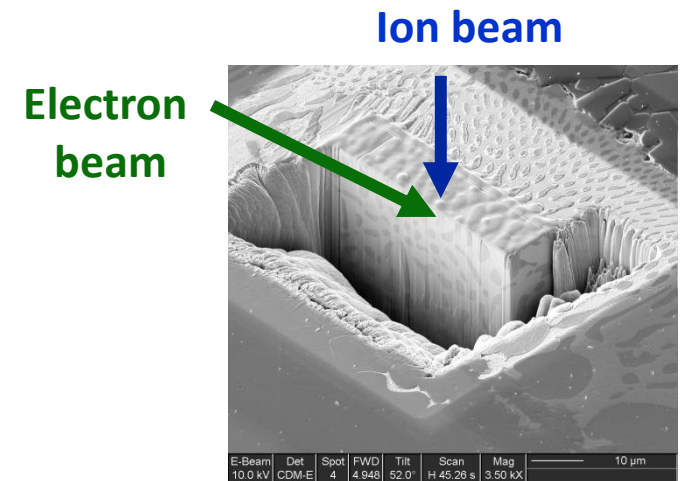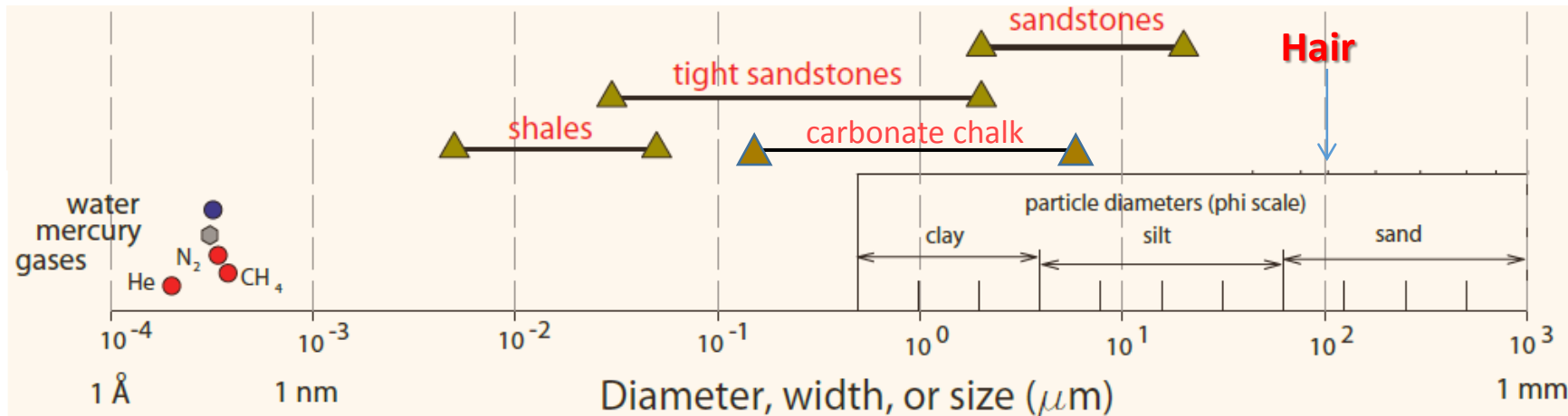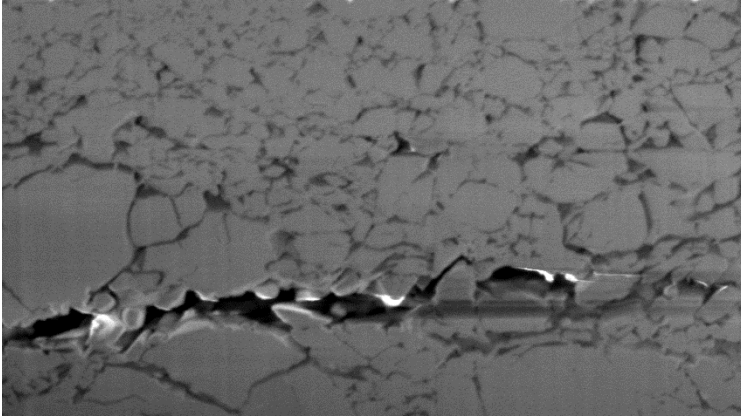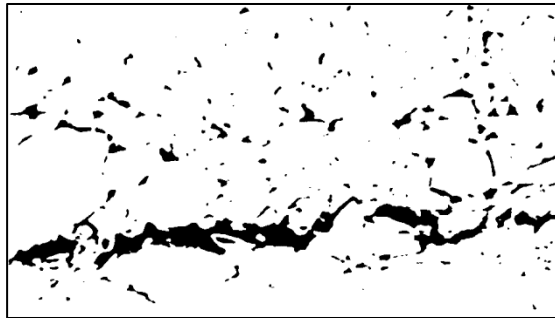
Filters

- Raw images have

- Uneven background

- Uneven illumination & horizontal scan lines

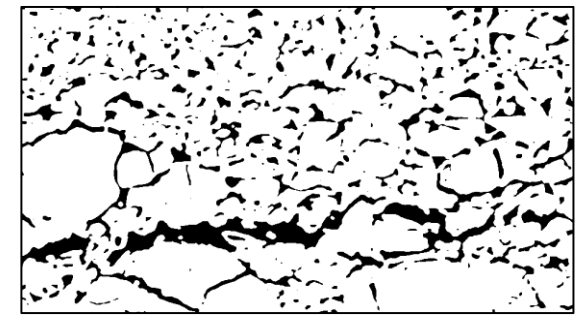- Charging effect (bright white spots)
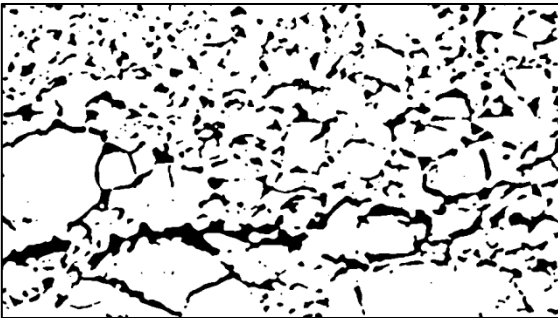
Small pores captured
- Background correction
- FFT bandpass filter
- Median filter
- Threshold

Large fractures captured
- Background correction
- Median filter
- Higher threshold value

Connectivity recovered
- Combine two binary images
- Dilate
- Erode (twice)

Yoon et al. (2013)

Image Segmentation

- Process of breaking a digital image into multiple segments.
  - ➢ Assigns a label to every pixel and groups the pixels with the same label which means the pixels have similar characteristics.
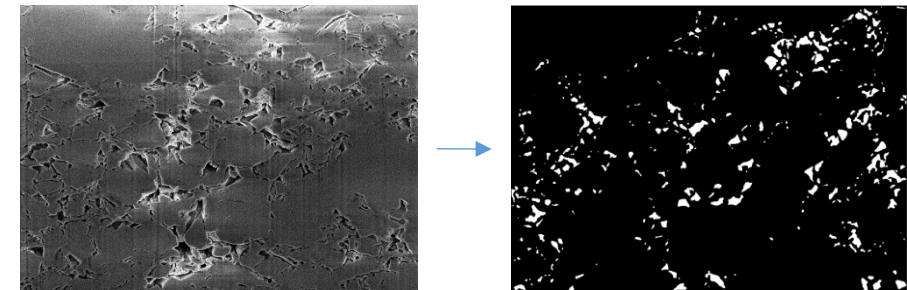 - ➢ Checks for discontinuities (edges)

Clustering Method
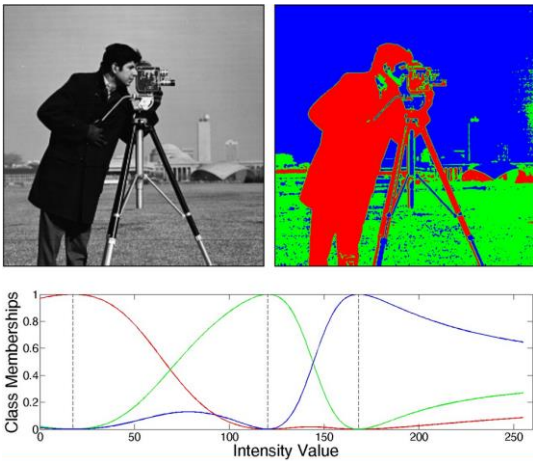
Semechko, Anton. *Fast Segmentation Of N-Dimensional Grayscale Images*. 1st ed. MATLAB, 2013. Web. 20 June 2016.

Edge Based Method
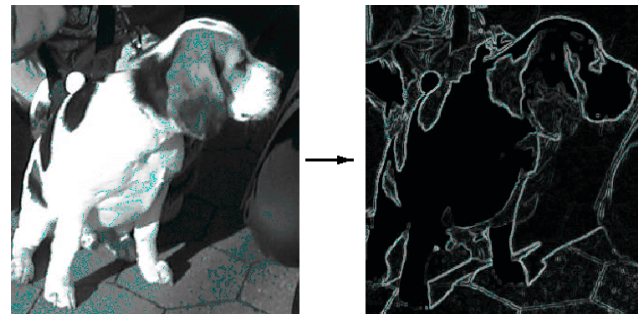
http://bestofpicture.com/edge-detection-image-segmentation.html: ed.ac.uk

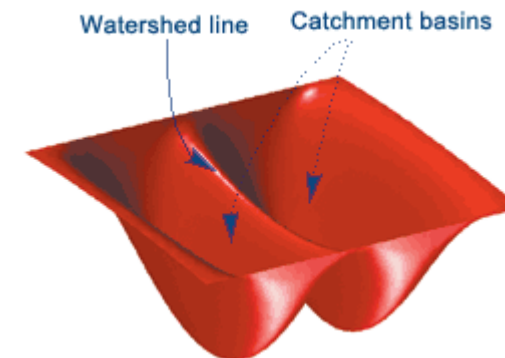### Threshold Method

0-256 scale
Otsu Method

Watershed Segmentation

- Watershed is a landform similar to a basin defined by its' highpoints and ridgelines that lead to lower elevations and stream valleys.

- Watershed segmentation floods the image to find catchment basins, low points, where the basins will merge.

- Watershed lines are then made to act as dams to separate the two catchment basins (CB).

| 32	64	128
16	0	1
8	4	2

Catchment Basin Values

8-direction Point Model: The number in each cell represents the direction water travels to enter the nearest downstream.

Watershed line   Catchment basins

Eddins, Steve. *The Watershed Transform: Strategies For Image Segmentation*. 1st ed. MathWorks, 2002. Web. 20 June 2016.
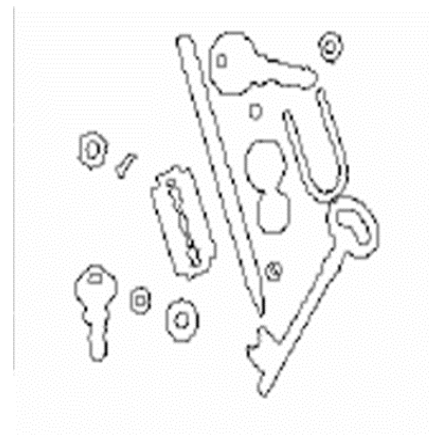
P-Algorithm

- This algorithm is relatively new; it was published in 2009.
- It was made to fix the shortcomings of the other algorithms.
- The P-Algorithm compares all the initial outlines at each hierarchical level to the hierarchical image.
- They had to find a way to reintroduce the maxima which in most cases correspond to highly contrasted regions (textures) in the original image.
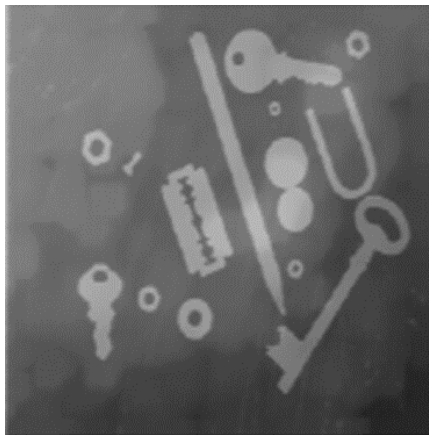
Original Image

Segmentation through the P-Algorithm

Segmentation through the Waterfall Algorithm

Morphological Segmentation

- This technique is applied to the gradient of an image.
- Three types of points trying to be identified:
  - ➢ Regional minimum
  - ➢ Catchment Basins
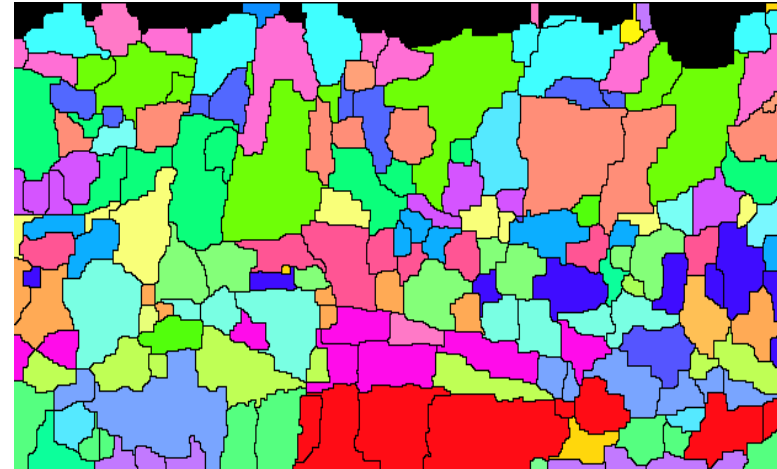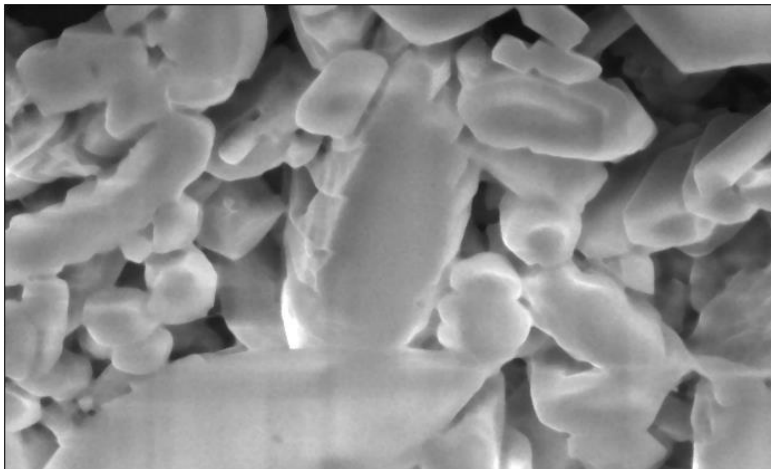 - ➢ Watershed Lines

A: Original Image
B: Gradient of image A
C: Watershed Lines
(Oversegmentation)
D: Watershed Lines obtained from
a smoothed image (applied
through a filter)

A	B
C	D

"Segmentation By Morphological Watersheds".
Math.tau.ac.il., Tel Aviv University, 2003. Web.
21 July 2016.
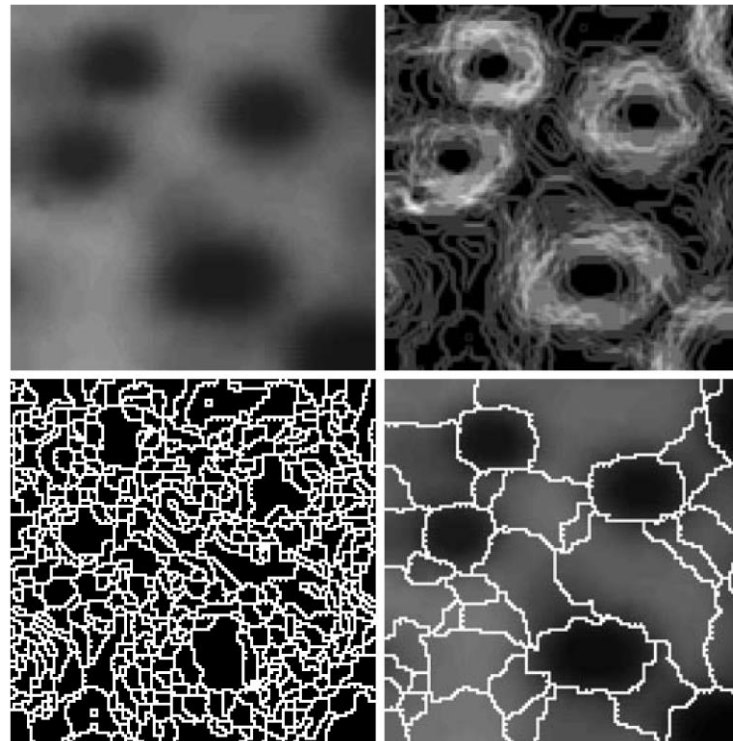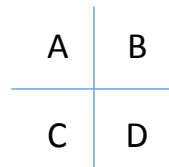
Parameters

- Radius (r), tolerance (t), and connectivity (c) are the parameters for this segmentation.

- The radius value is used in creating the gradient of the image.

- Tolerance: the intensity for the search of the regional minima. Increasing tolerance decreases the number of segments.

- Connectivity: voxel connectivity (6,26). 6 produces more rounded segments.

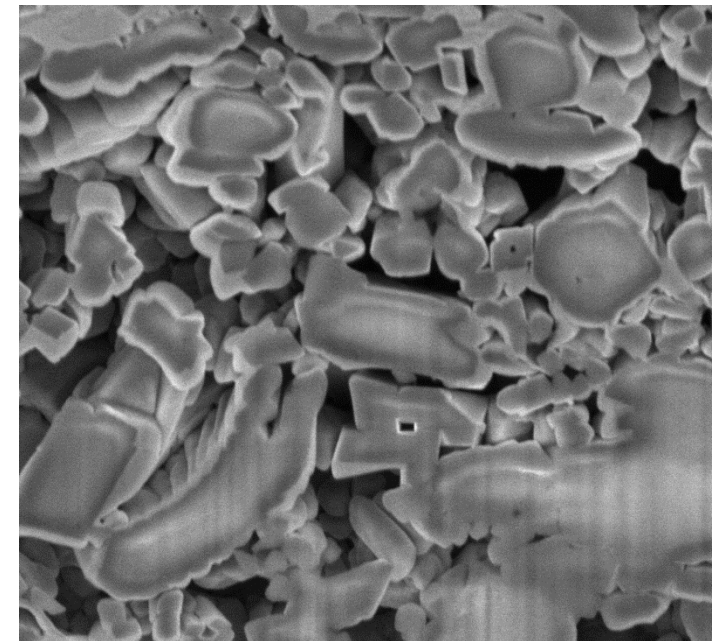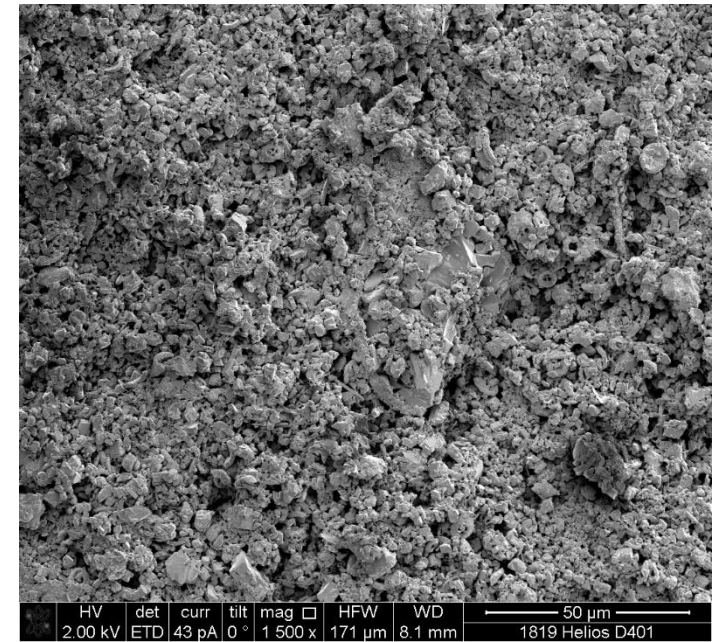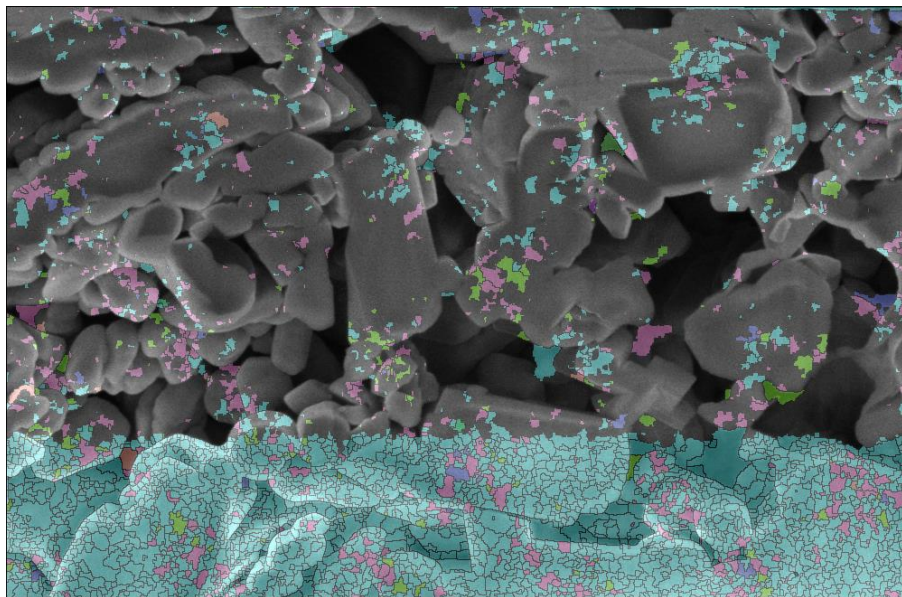- Main problem of watershed segmentation is over segmentation due to the presence of false minima.
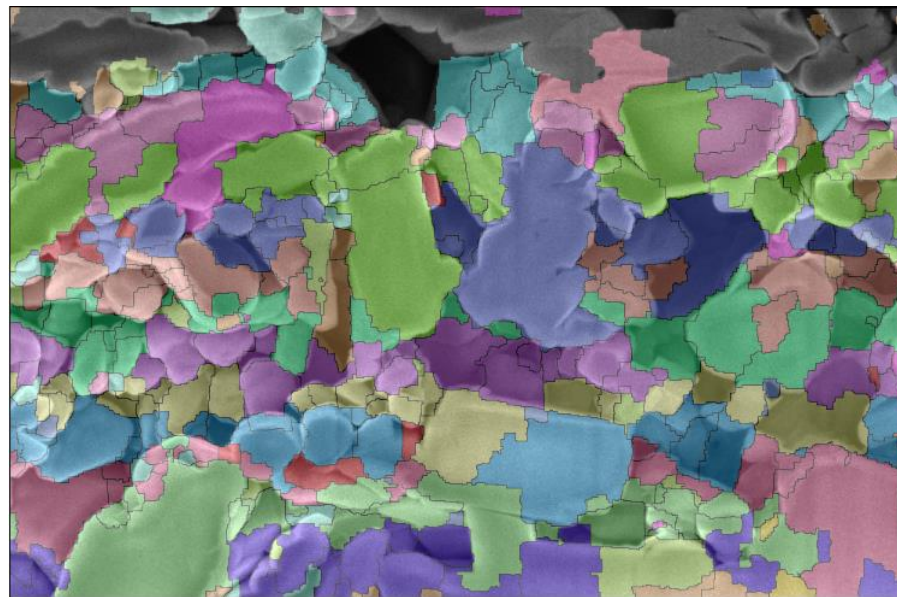
Liege_02

1.5cm
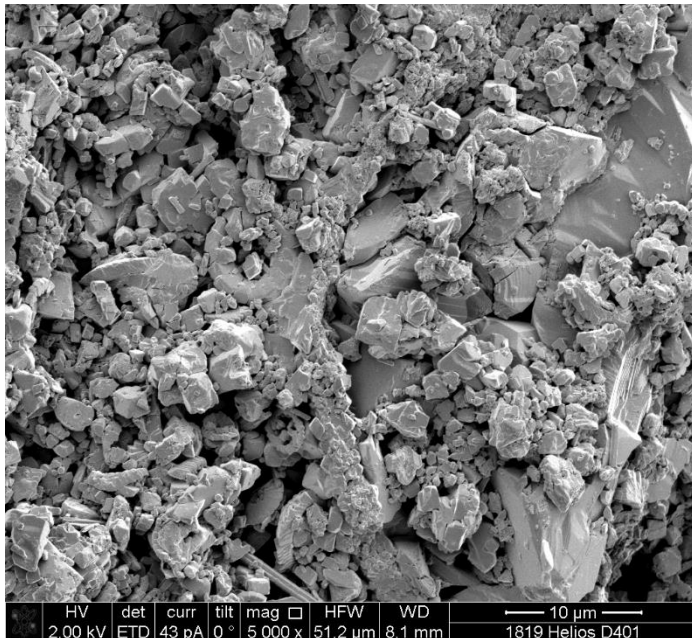
Liege_02 is sample of chalk carbonate from Norway.
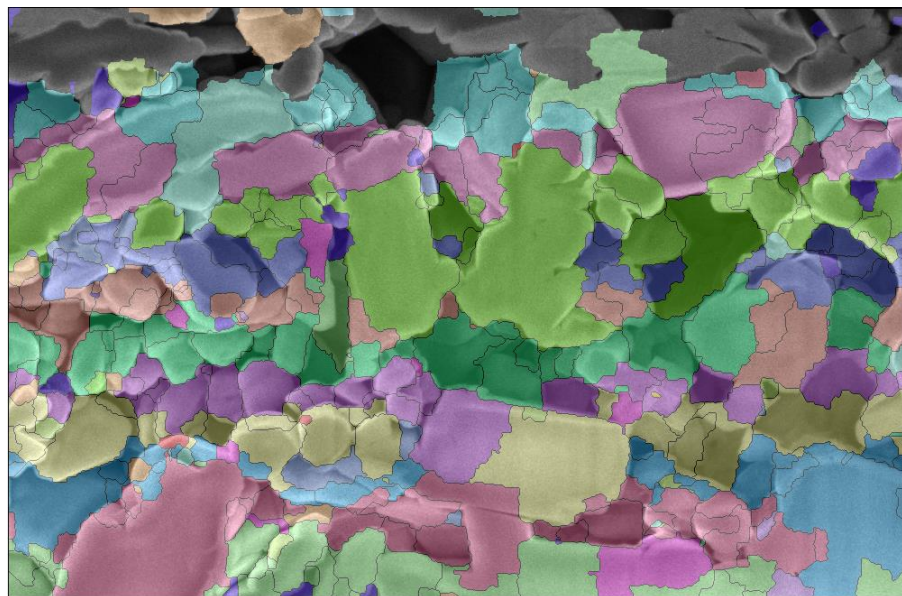

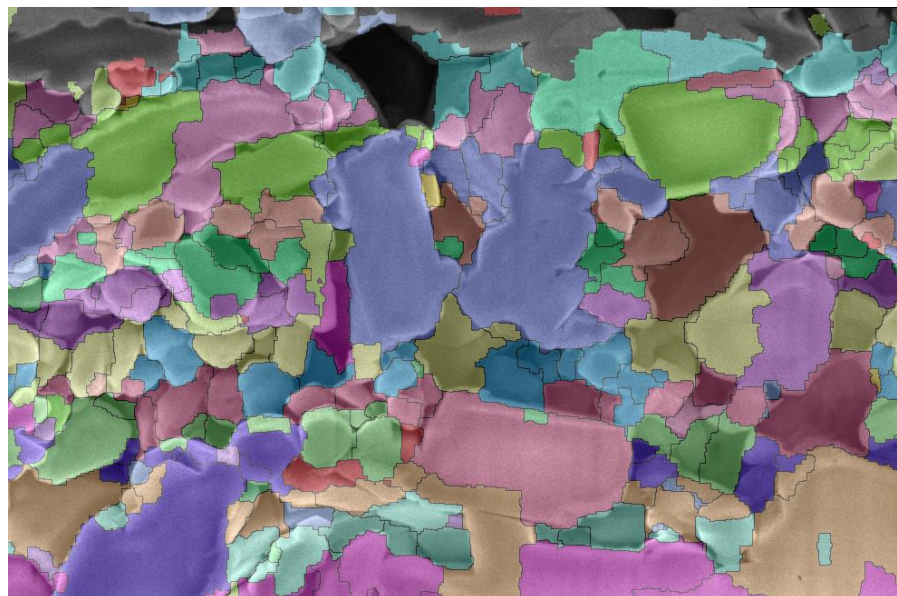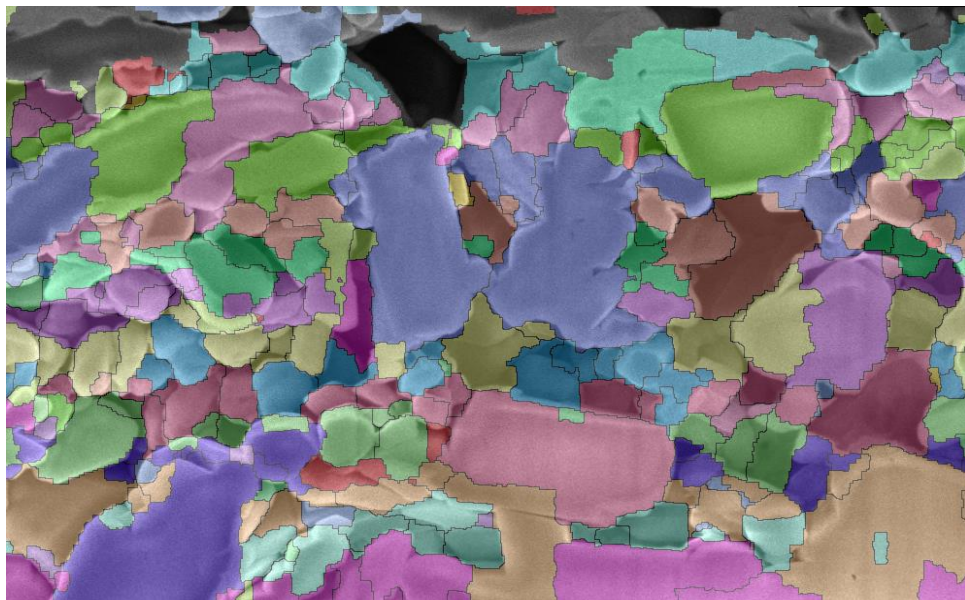10 µm

Parameters: r=1; t=5; c=26;

Parameters: r=7; t=10; c=26;

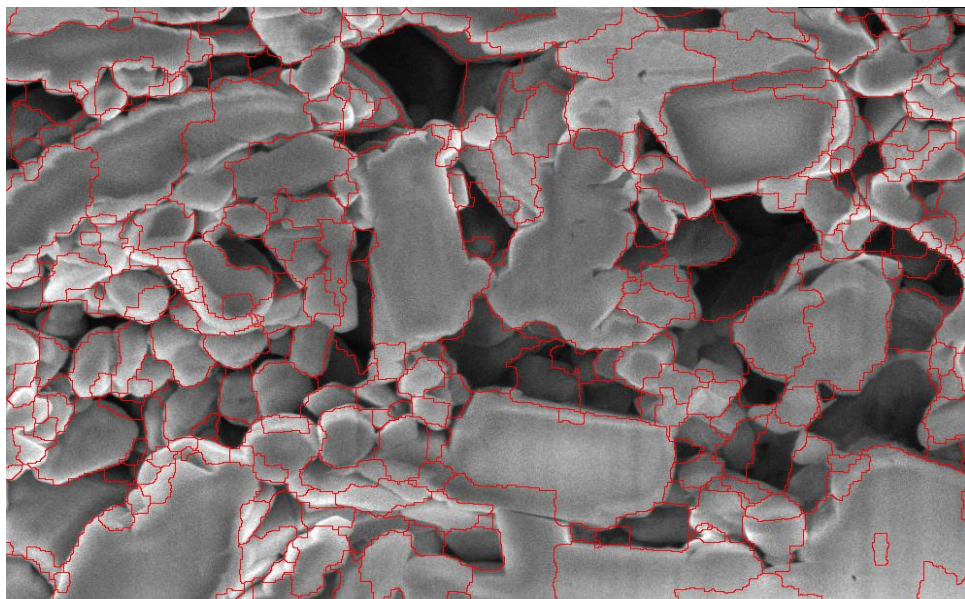Parameters: r=7; t=10; c=6;

Parameters: r=7; t=12; c=26;

Overlaid Basins

Parameters:
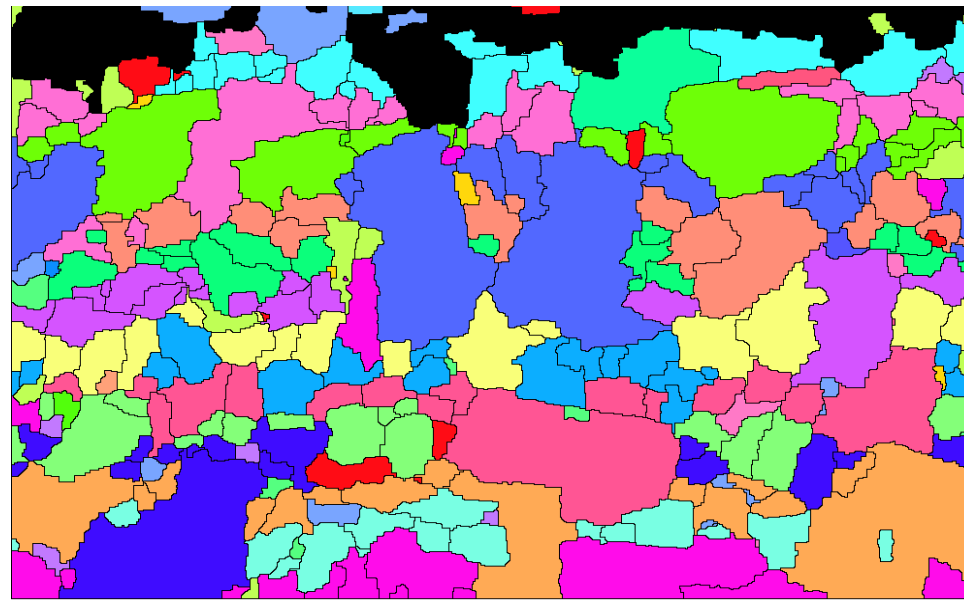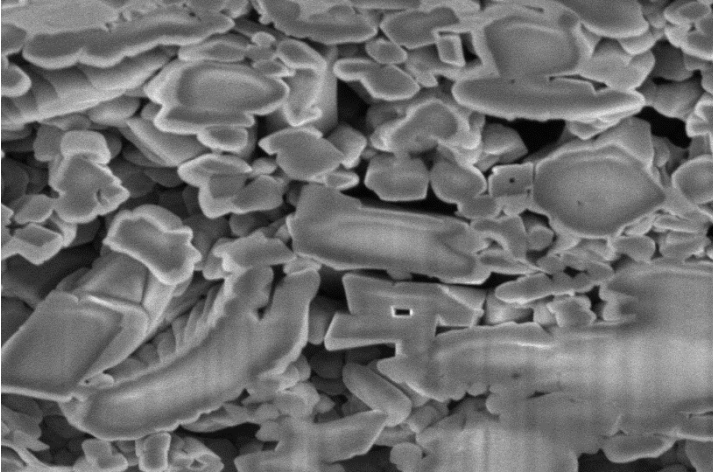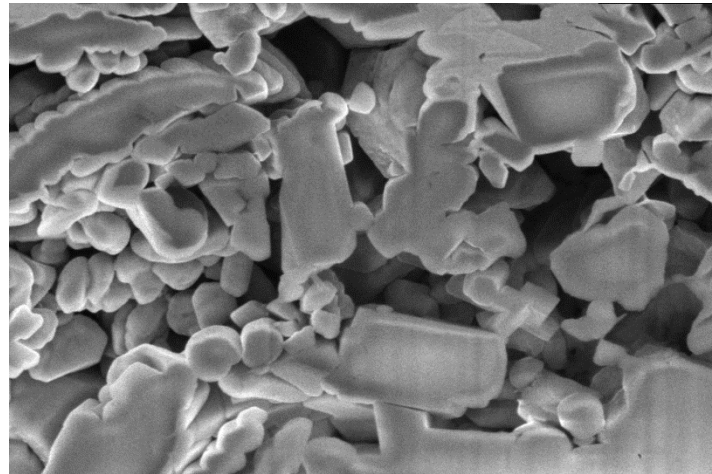r=7; t=12;
c=26;

Catchment Basins
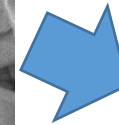
Overlaid Dams
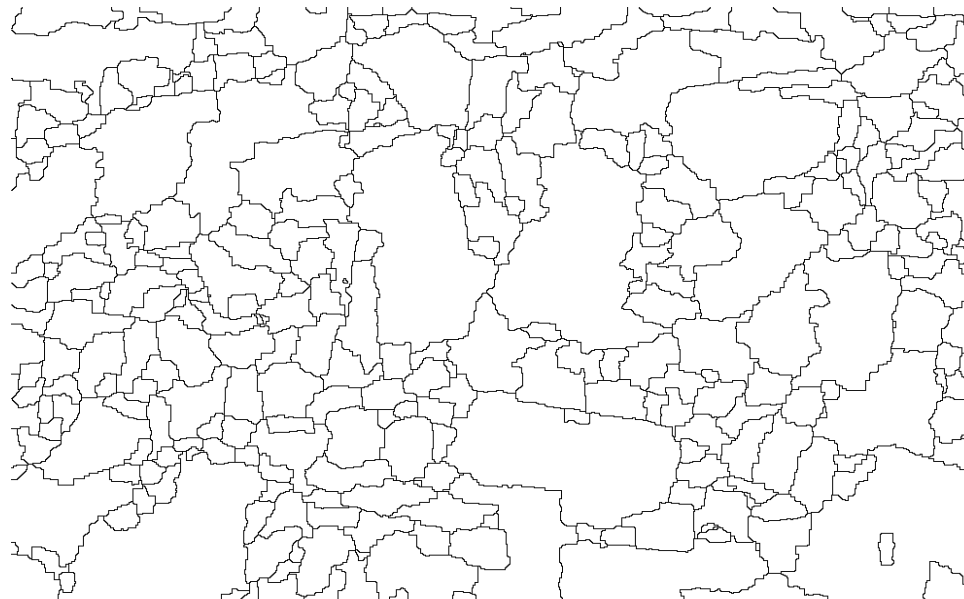
Watershed Lines

Results
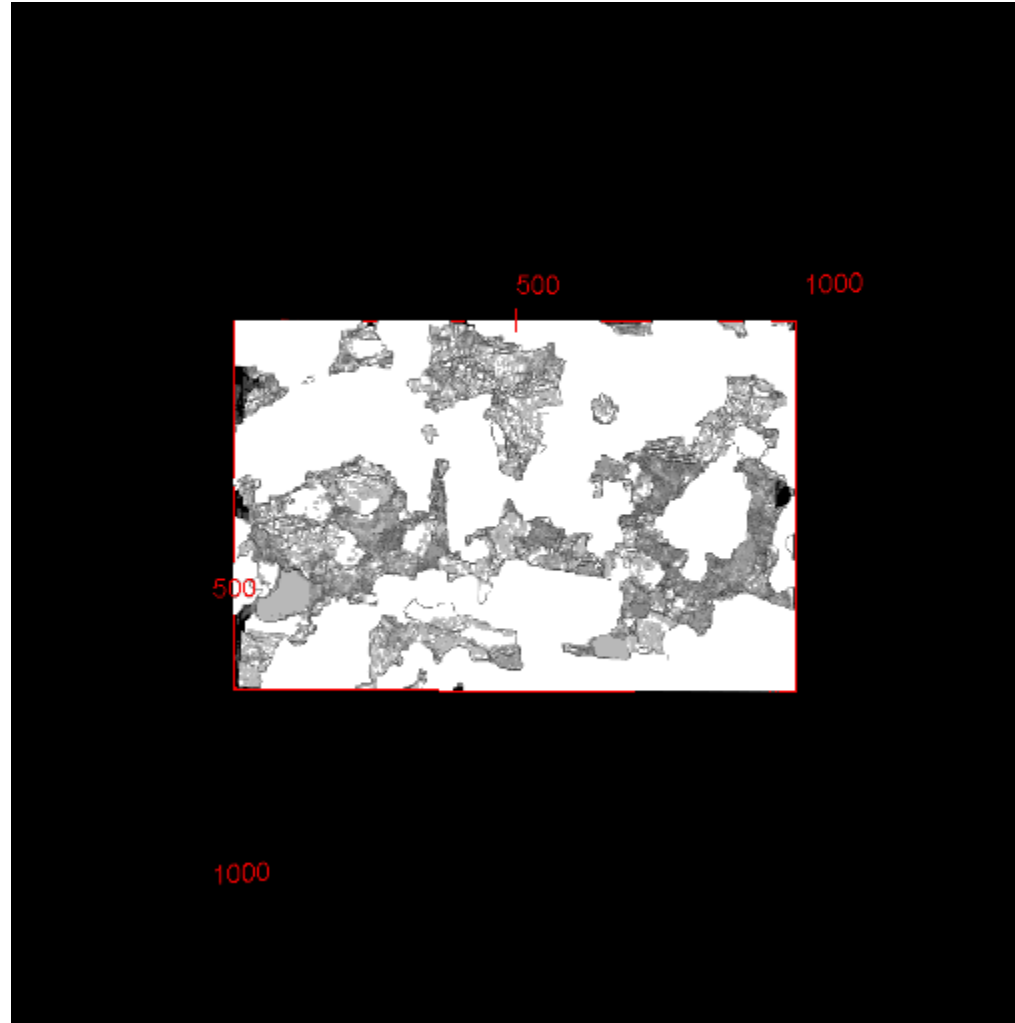

Original Image
Dimensions: 1024x884x1000 pixels

After alignment and 3D Median Filter
Dimensions: 993x654x700 pixels
(Image used in Segmentation)

Binary Image
(Black: Foreground and white: Pore Space)

3D Viewer

References

- F. Meyer, S. Beucher, and B. Marcotegui. *Advanced Morphological Segmentation*. 1st ed. Centre for Mathematical Morphology, 2005. Print.

- Beucher, S. and F. Meyer. *The Morphological Approach To Segmentation: The Watershed Transformation*. 1st ed. New York: Centre de Morphologie Mathematique, 1992. Print.

- Meyer, Fernand. *The Watershed Concept Andits Use In Segmentation: A Brief History*. 1st ed. Centre de Morphologie Mathematique, 2012. Print.

- Beucher, Serge and Beatriz, Marcotegui. P Algorithm, A Dramatic Enhancement of the Waterfall Transformation. 1st ed. MINES ParisTech, 2009. Print.

Questions?