

# High-Resolution Micro-CT for Petrophysical Properties

## Customer Need

High-resolution Micro-CT imaging is useful for investigating pore sizes, pore throat distributions, depositional anisotropy, and other factors affecting petrophysical properties in reservoir rock. In this example, high-resolution imaging of some sandstone samples was performed for the purpose of comparing conventional lab methods with image analysis. Imaging was done at different resolutions, 2 and 4 micron ( $\mu\text{m}$ ), to gauge the effect of voxel size on digital rock properties.

## Materials and Methods

Four 1"  $\varnothing$  sandstone core plugs with differing amounts of cementation and clays were supplied for this study. Before imaging, samples were dried in a vacuum oven for 3 days and porosity was measured with helium pycnometry. Although interior tomography at

these resolutions was possible with 1" plugs, cutting 5mm mini-plugs from the original sample allowed for faster, clearer data acquisition (Figure 1).

The 2 $\mu\text{m}$  resolution scan has a cylindrical region of interest 2mm L x 2mm  $\varnothing$ , the 4 $\mu\text{m}$  scan, 4mm L x 4mm  $\varnothing$ ; the same center point was used for both scans, i.e. the 2mm volume would be coaxially nested in the middle of the 4mm volume. The instrument used was a Carl Zeiss model 510 Versa outfitted with an autoloader. The scan acquisition parameters (Table 1) were designed to provide high quality images in a reasonable amount of time. It took 30 hours to scan four samples at both resolutions; 8 scans total.

The individual slices were automatically reconstructed using the 510's internal software. Some slight Gaussian filtering was applied during reconstruction and beam hardening was minimal. Images were processed with FEI's PerGeos software. Images were filtered using non-local means and grains were segmented from pores using watershed segmentation. The segmented images volumes were used to estimate total porosity and pore size distributions.

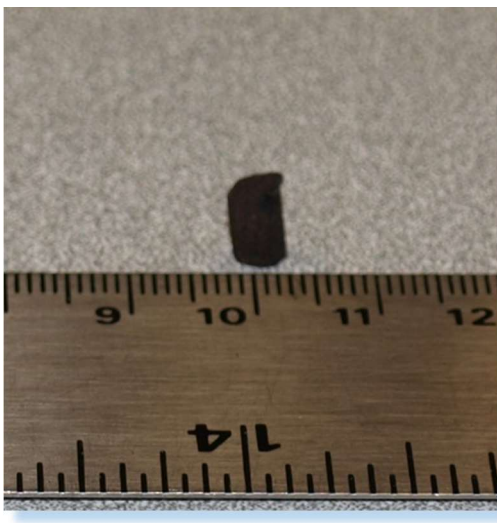


Figure 1: Example 5mm mini-plug used for high resolution Micro-CT imaging.

Table 1: Acquisition parameters for the different resolution Micro-CT scans.

Parameter	2 $\mu\text{m}$	4 $\mu\text{m}$
Power	40kV / 4W	40 kV / 4 W
Exposure	6 seconds	2 seconds
No. Slices	3201	3201
FOV	2mm L x 2mm $\varnothing$	4mm L x 4mm $\varnothing$

## Results of the Analysis

The quality of the scans were quite good. Image porosities were consistently less than those determined by helium pycnometry; this is well accepted in literature. Interestingly, all of the images acquired at 2 $\mu$ m resolution had segmented porosity values greater than their 4 $\mu$ m counterparts, even though the same volume of rock was being imaged. The reason for this is obvious (Figure 2), the 4 $\mu$ m scans failed to capture some of intragranular porosity clear in the 2 $\mu$ m scans. Comparisons of pore size distributions confirmed that high resolution scanning was able to capture finer pores. The difference in measured image porosity varied from 1.5-3.2%.

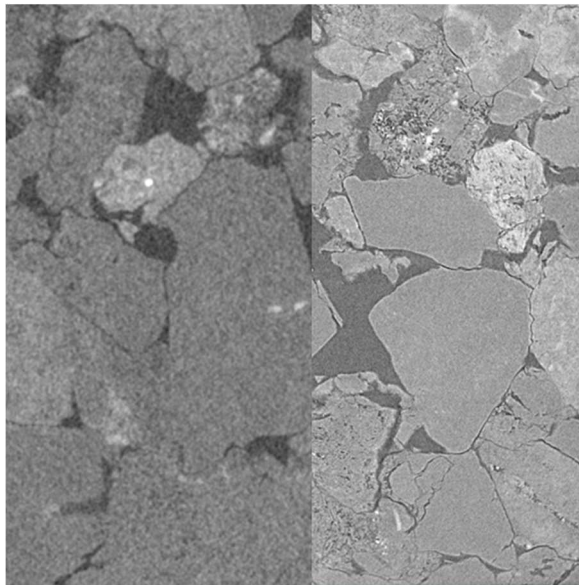


Figure 2: Un-filtered comparison of 4 $\mu$ m resolution (left) and 2 $\mu$ m resolution (right). The 2 $\mu$ m resolution scans captured more small intragranular porosity.

## Discussion

This is just one example using high resolution Micro-CT imaging for petrophysical properties. Finite element simulation of segmented volumes can also estimate permeability,

electrical properties, and capillary pressure curves.

Additionally there are pressure cells available allowing *in-situ* imaging of properties like contact angle.

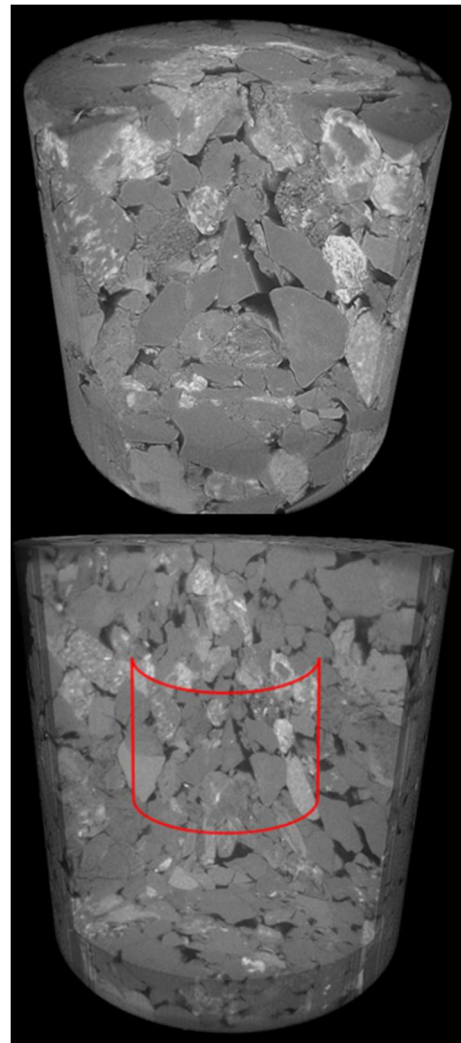


Figure 3: Volume renderings of the 2 $\mu$ m scan (top) and 4 $\mu$ m scan (bottom). The red outline shows where the 2 $\mu$ m scan nests in the 4 $\mu$ m scan.

Micro-CT imaging and Finite Element Analysis can be used for the determination of a variety of petrophysical properties like porosity, permeability, electrical properties, and capillary pressure.