# Investigation of the 3D Geometry of Low Permeability Rocks using Synchrotron X-Ray Computed Microtomography

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## Summary

Synchrotron X-Ray Computed microtomography (CMT) has been established as a powerful technique for imaging and characterization of low permeability rocks. CMT imaging provides information about internal pore distribution and geometry while retaining connectivity and spatial relationships, leading to a detailed understanding of the mechanisms controlling fluid flow (Ketcham et al., 2001). Pore scale flow mechanisms are of paramount importance for understanding subsurface oil and gas-phase migration.

## Introduction

Synchrotron X-ray Computed Microtomography (CMT) is a powerful 3D imaging technique that uses synchrotron light to produce high-resolution images based on differences in X-ray attenuation within a sample. Using high-flux, monochromatic light from a synchrotron for CMT imaging allows for better spatial resolution and enhanced image quality compared to conventional laboratory-based X-ray CMT. Synchrotron X-Ray CMT is a rapid, non-destructive technique that allows 3D, in-situ imaging of samples on the micron or submicron-scale. Of interest in this study is the value of Synchrotron X-Ray CMT for the imaging and petrophysical analysis of low permeability siltstone and shale. As the pores in these rocks are both small and relatively sparse, imaging at the submicron scale is needed to see the porosity that dictates permeability. This study also examines the potential for extracting petrophysical properties such as porosity, tortuosity and permeability from Synchrotron X-Ray CMT data.

## Method

Two samples were examined in this study; a silty marine shale from the Blackstone Formation, a member of the Upper Cretaceous Alberta Group in the Canadian Rockies, and a fine-grained red siltstone from the from the Mississippian-age Mabou Group in the Moncton Basin, New Brunswick. These samples were used to investigate the applicability of CMT for studying key petrophysical parameters (porosity, permeability and tortuosity) within very fine grained rock samples.

Cores 1.43 mm in diameter and 1.43 mm in length were imaged on July 1, 2007 at the European Synchrotron Radiation Facility, Beamline ID19. Data was collected at 20.5 keV, with a pixel size of 0.7 µm. Spatial reconstruction of the data and creation of three-dimensional pore space images was performed using AMIRA®, a voxel-based geometric reconstruction program (Figure 1). Total porosity, flow path tortuosity and permeability were determined using 3DMA_Rock, a software package for the quantification of pore space in reservoir rocks (Lindquist, 1999).

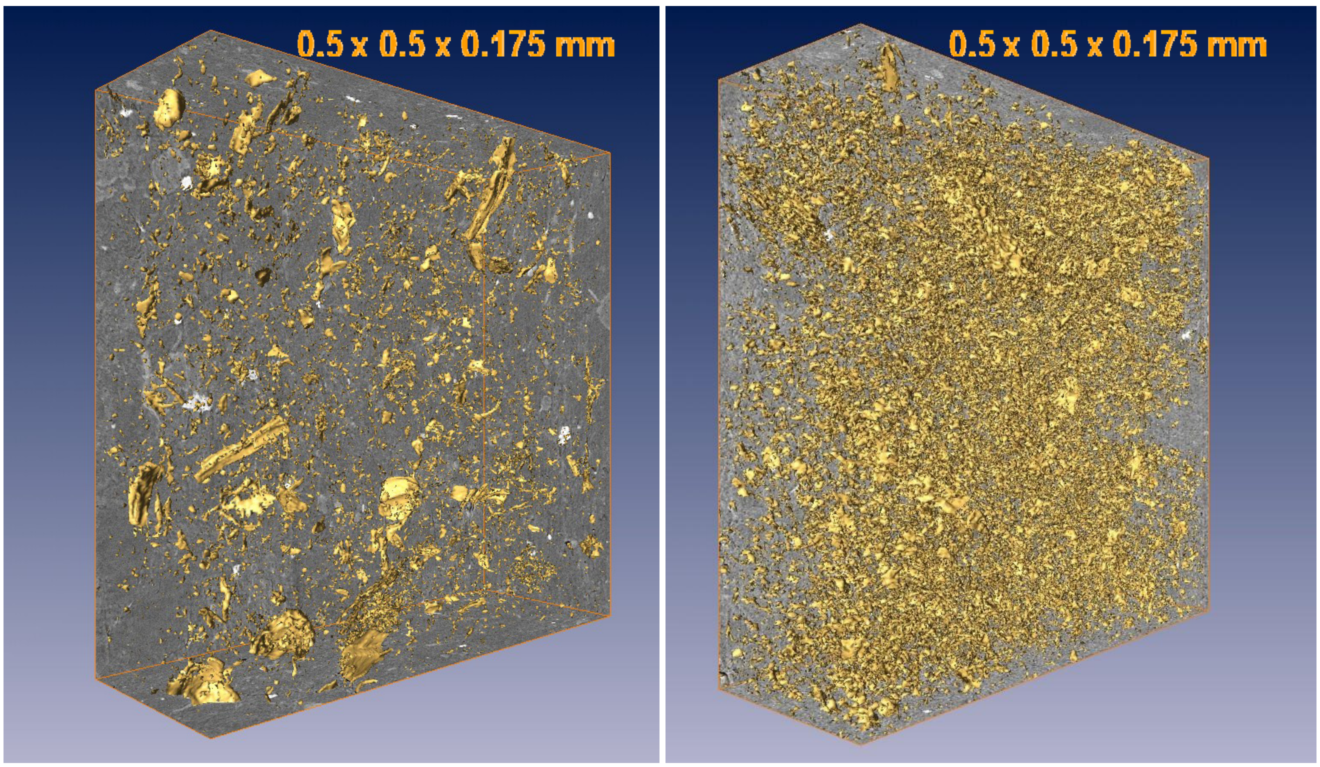


Figure1: Reconstructed 3D images of the CMT data for the shale (left) and siltstone (right) samples, with pore surfaces shown in gold.

## Conclusions

Synchrotron X-Ray CMT was successfully used to visualize the shale and siltstone samples in 3D, and values were extracted for porosity, tortuosity, and permeability. Agreement of the porosity value with preliminary measurements of effective porosity made on the samples using conventional petrophysical techniques indicate that CMT imaging is sufficient to see the pore space present in this type of rockl; any porosity below the 0.7 µm imaging resolution does not contribute significantly to the overall porosity of the sample. Experiments are currently underway to compare the permeability determined with CMT to conventional mercury porosimetry results, and to confirm the preliminary measurements of effective porosity.

This type of advanced high-resolution imaging could contribute to the understanding and development of enhanced oil recovery methods in unconventional oil reservoirs made up of low-permeability rocks like siltstone and shale, and may provide insight into the behaviour of these rocks as hydraulic seals overlying conventional hydrocarbon reservoirs, waste disposal zones, and ore deposits.

**References**


Ketcham, R.A., Carlson, W.D., 2001, Acquisition, optimization and interpretation of X-ray computed tomographic imagery: applications to the geosciences: Computers & Geosciences, **27**, 381-400.

Lindquist, W.B., 1999, 3DMA-Rock, a software package for automated analysis of pore rock structure in 3D computed microtomography images: http://www.ams.sunysb.edu/~lindquis/3dma/3dma_rock/3dma_rock.html.

Thompson, A.H., Katz, A. J., Krohn, C. E., 1987, The Microgeometry and Transport Properties of Sedimentary Rock: Advances in Physics, **36**, 625-694.

Glemser, C. T., 2007, Petrophysical and Geochemical Characterization of Midale Carbonates from the Weyburn Oilfield using Synchrotron X-Ray Computed Microtomography. Masters Thesis: Department of Geological Sciences, University of Saskatchewan, 2007.