

## Integration of Imaging Techniques Over Multiple Scales

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Many fundamental flow and transport properties in geologic materials are dictated by microstructural features that can be difficult to characterize at representative scales. For example, carbonate reservoir rocks may contain vuggy porosity on the order of centimeters, interparticle porosity on the order of 100 microns, and microporosity within micritized fossils on the order of a micron. Fractured, shaly sandstones may contain a similar range of pore sizes. In spite of the recent advances in high-resolution X-ray computed tomography (XCT) for imaging geological materials, the spatial scales (typically 5-10 microns on mm-scale diameter cores) are not always sufficient to capture relevant features. On the other hand, more traditional imaging techniques (e.g., optical microscopy, SEM) can provide resolutions down to tens of nanometers and therefore, are able to provide much finer details. However, these techniques are limited in their ability to capture representative length scales and 3D spatial correlations.

Another challenge with XCT images of natural rocks is how to interpret features that are visibly distinct due to differences in X-ray absorption contrast. These differences can be due to spatial variations in elemental composition such as calcite cement in feldspathic sandstones or because of density differences within grains (microporosity within fossil fragments or heterogenous rock fragments in lithic sandstones).

Here we present a multiscale methodology using two or more imaging techniques that provide complementary information and data. First, XCT is used to image volumes on the order of 10 mm<sup>3</sup>. Quantitative data, such as porosity and pore network structure, can be extracted from these images. In cases where the XCT images are of insufficient resolution or highlight features of interest, SEM and optical microscopy is used on thin-sections to obtain finer details such as clay morphology or interparticle porosity within rock fragments. Additional details such as microporosity and small pore/throat sizes are quantified. Finally, this information and data is integrated with the XCT image data and directly compare to typical laboratory bulk measurements such as porosity, permeability and capillary pressure curves.

The ultimate purpose of these analyses is to provide a 3 dimensional model of the pore network at all length scales to be used as a starting point for CFD models to simulate fluid flow and transport.