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Pore Network Reconstructions and Pore-Scale Characterization of Limestone and Carbonate-Based Rocks for Deep Geologic Carbon Sequestration

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High carbon dioxide (CO_2) emissions from concentrated sources, such as coal or natural gas combustion plants, have motivated research into CO_2 sequestration in deep underground geologic formations. While this approach has shown early promise as a viable method to reduce short- to medium-term carbon emissions [1], challenges remain in predicting the long-term security of injected CO_2 for a broad range of formation geologies, specifically carbonate structures. For a full understanding of the carbon trapping process, knowledge of the pore-scale microstructure is required to accurately model CO_2 reactive transport mechanisms. To address this issue, we present experimental characterizations of carbonate microstructures representative of the North Alberta basin in Canada, as well as numerical pore extractions to determine pore size distributions and transport properties.

In this work, we present a mineralogical and morphological characterization of Indiana Limestone and Pink Dolomite, which are both carbonates. A combination of imaging and analytical techniques were employed to fully characterize the rock structures, including x-ray micro-scale computed tomography (microCT), x-ray fluorescence (XRF), x-ray powder diffraction (XRD), and Electron Dispersion Spectroscopy Scanning Electron Microscopy (EDS-SEM). Of these, MicroCT provided the most complete three-dimensional structural information for use in detailed two-phase transport modeling studies. MicroCT has been used extensively to structurally characterize rock types such as sandstone [2]; however, this technique has seen limited application to carbonates and limestone for use in carbon sequestration studies. Reconstructions were completed using a custom image analysis algorithm which combined Fiji image analysis and Matlab [3].

Porosity, pore-size distribution and overall microstructure characterize the pore-space of a rock. In this study, we have employed a grain-based approach to reconstruct the pore space. This involved the generation of a 3D pore network from microCT images, which is a two-stage computational reconstruction process. First, 3D image voxels from the microCT scans are converted to a binarized pore space using Outsu's thresholding method. Second, the pore network and pore size distributions were determined using a network-extraction algorithm based on the watershed approach [4]. Finally, we present data on the sample mineralogy obtained from the XRF, XRD, and EDS-SEM measurements. This information, when combined with the 3D structural data, can be used to perform geochemical studies on the interaction between CO_2, the minerals, and saline brine. The three-dimensional (3D) reconstructions and characterization of carbonate rocks are essential for performing realistic pore-scale simulations to predict transport parameters that can be upscaled for use in reservoir-scale simulations and modeling of carbon sequestration projects. Future studies will include reactive transport to model the interaction of injected CO_2 with brine and the solid rock matrix.

References:
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