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Characterization of pore geometry of Indiana limestone in relation to mechanical compaction

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The mechanical and transport behaviors of a rock are sensitively dependent on its pore geometry. Hence it is of fundamental importance in rock physics to characterize the pore space and its geometric attributes, including pore size, shape, tortuosity and connectivity. Traditionally the pore structure is characterized using optical and scanning electron microscopes (SEM), but recent advances in 3-dimensional imaging techniques such as X-ray microcomputed tomography (microCT) have provided enhanced perspective on pore geometry complexity, which has contributed to useful insights into the preexisting pore space and how it influences rock physical properties, as well as damage evolution and its relation to the micromechanics of failure.

In a clastic rock, the void space is dominated by relatively equant pores connected by throats that are sufficiently large for direct imaging using microCT and the data have provided useful insights into the 3D geometric complexity and its control over permeability. In contrast, the use of X-ray microCT for 3D imaging of the pore space in carbonate rocks is not as straightforward. Carbonate rocks are generally recognized to have pore geometry that is significantly more complex than other sedimentary rocks such as siliciclastics. One of the reasons for the geometric complexity is that depositional environment and diagenesis exerts significant genetic influence over the development of texture and fabric of a carbonate rock, which can in turn modify both the size and connectivity of the pore space in a relatively rapid and drastic manner. The pore size in a carbonate rock may span over a very broad range, with a distribution that is often bimodal, including a significant subset of microporosity with submicron features that can only be resolved under a tool such as the SEM

We studied the pore structure in intact and inelastically compacted Indiana limestone using microCT imaging. Guided by detailed microstructural observations and using Otsu's global thresholding method, the 3D images acquired at voxel resolution of 4 microns were segmented into three domains: solid grains, macropores and an intermediate zone dominated by microporosity. The macropores were individually identified by morphological processing and their shape quantified by their sphericity and equivalent diameter. Our new data revealed a significant reduction of the number of macropores in hydrostatically and triaxially compressed samples with respect to the intact material, in agreement with previous microstructural analysis. The intermediate (microporosity) domains remained interconnected in compacted samples. Our data suggest that the inelastic compaction in Indiana limestone is manifested by not only a decrease in the volume fraction of the microporosity backbone, but also a corresponding decrease in its thickness.