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Heterogeneity Evaluation of Microstructures in a Sandstone Reservoir Using Micro-CT Imagery

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Heterogeneity of microstructures in clastic rocks is relevant to a wealth of subsurface properties (e.g., porosity, permeability, fracture orientations) and, yet, is challenging to effectively characterize because of the stochastic distribution of grain deposition, diagenesis, and texture deformation. At the pore to core scale, heterogeneity lies in the spatial variation of pore throat networks and complicates the fluid flow mechanisms associated with those networks. Therefore, it is essential to precisely comprehend the heterogeneity at the fine scale, which further facilitates understanding at a broader scale (well to basin). In this study, micro-CT (computed tomography) images of samples from a conventional sandstone reservoir were collected. The heterogeneity was evaluated in terms of the microstructure variation (pore size distribution, pore shape distribution, and porosity variation) in three dimensions spatially and the associated petrophysical property changes derived from images. Firstly, the representative elementary volume (REV) was determined by extracting the subvolumes at increasing sizes inside of CT image data sets. REV was set to 100 voxels ($20.7 \mu\text{m}/\text{voxel}$) to capture the representative area to assess heterogeneity. An ImageJ Macro algorithm was coded to automatically resample the subvolume from a 100-voxel size to a 600-voxel size for a cube-shaped region of interest. A machine learning-assisted thresholding method was developed to segment the grain matrix and pore structures. Further, microstructure variation was calculated by processing subvolumes, with the permeability derived by adopting the Kozeny–Carman equation. The statistics from the above parameters demonstrate both the size effect and spatial effect of the region of interest existing in the sandstone reservoir. Moreover, the fractal dimension, a mathematical parameter indicating the self-similarity and complexity of a subject, was utilized to quantify the heterogeneity of microstructures at increasing subvolume sizes, where the same trend was revealed as fractal dimension increasing from 2.6 to 2.95. The database obtained via quantitative evaluation of the microstructure variation within the sandstone samples provides for machine learning-informed image analysis and is an essential step toward heterogeneity characterization across various scales.

Time Block Preference

Time Block C (18:00-21:00 CET)

References

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