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Assessing the Representativeness and Precision of Three-Dimensional Digital Rock Modeling: A Case Study on Tight Sandstone

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Tight sandstones are characterized by low porosity and permeability, high clay content. Measuring the rock physics properties under low water saturation conditions using the displacement method poses significant challenges. Digital rock physics (DRP) has been emerged as a valueble method for studying of rock physics of unconventional reservoir. It should be noted that the resolution of X-ray Computer Tomography (CT) scans and sample size can impose mutual restrictions. In order to enhance the applicability of rock physics numerical simulation results, it is crucial to adequately assess the representativeness and accuracy of three-dimensional digital rocks. In this study,3 sandstone samples with porosities of 17.0%,10.8%, and 8.4%, and permeabilities of 339.7,13.2, and 0.94 mD, were selected to construct digital rocks. Seven sub-samples with diameters of 25.4,9,7,5,3,2, and 1mm were prepared for each sample. We utilized X-ray CT scanning to generate three-dimensional grayscale images of the samples, with resolutions ranging from 13.5μm to 1.1μm. These images were then segmented into five components- pores, clay, feldspathic, potassium feldspar, and high-density minerals- using a machine learning image segmentation algorithm. The volume content of the principal minerals in the multi-mineral component digital rocks was calculated and compared with the XRD measurement to assess the representativeness of the three-dimensional digital rocks with different size. The porosities of the digital rocks were determined and compared with the porosity measured in lab. This comparative analysis was conducted to evaluate the precision of the digital rocks. The outcomes of three-dimensional digital rock modeling for tight sandstones reveal that three-dimensional grayscale image acquire via CT scanning for the sample with the diameter of 25.4 mm exhibits difficulty in distinguishing between pore spaces and primary mineral types. By considering the composition of randomly distributed high-density minerals as a metric for assessing representativeness, it was found that the variability of this mineral component increases when the sample diameter is less than 5 mm. This suggests that samples smaller than this size may not adequately capture the macroscopic physical properties. As the sample size decreases, the porosity identified in the digital rock increases. However, it consistently remains lower than the experimentally measured porosity, even in the highest resolution 1 mm sample. When accounting for micropores that are smaller than the scanning resolution of CT, and incorporating them into the multi-mineral digital rocks, the computed porosities agree well with those measured in lab.

Keywords：Tight Sandstone, Machine Learning, Digital Rock Physics, Multi-mineral 3D Modeling, X-ray CT Scanning.

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