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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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Research Significance

Representativeness and precision

- Tight sandstone are characterized by low porosity and permeability, clay content.
- The resolution of X-ray Computer Tomography (CT) scans and sample size can impose mutual restriction.
- 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.

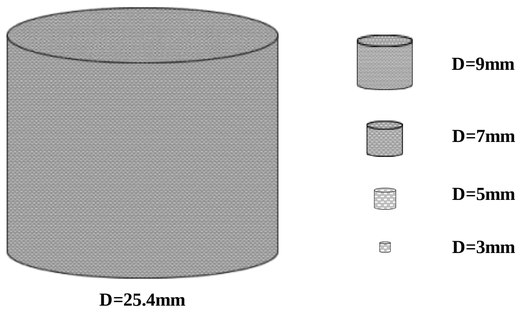

Fig.1 CT scan schematic diagram

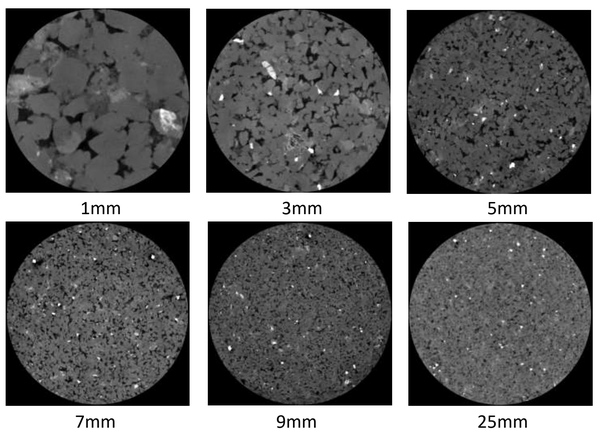

Fig.2 CT scan images of No.1 sample with different resolutions

Multi-scale 3-D Digital Rocks Modeling Method

Multi-resolution core CT image

- In the 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 sample ,with resolutions ranging from 13.5μm to 1.1μm。

Machine learning image segmentation

- These images were segmented into five components- pores, clay, quartz, 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 based on machine learning segmentation results.

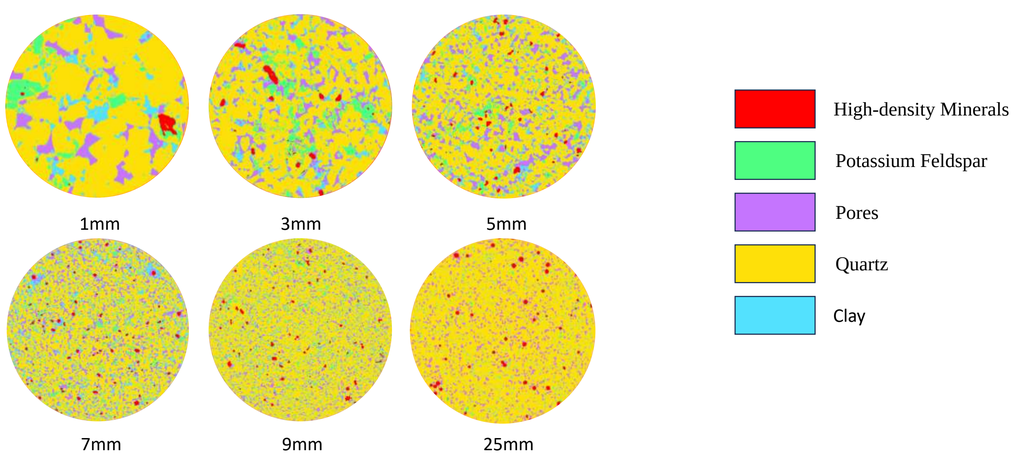

Fig.3 Machine learning segmentation of No.1 sample with different sizes

Representativeness and Precision of Three-Dimensional Digital Rock Modeling

Representativeness and precision

- The volume content of principal minerals in the multi-mineral component digital rocks was 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.

Three-dimensional Digital Rock Modeling

Analysis of machine learning segmentation

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 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.

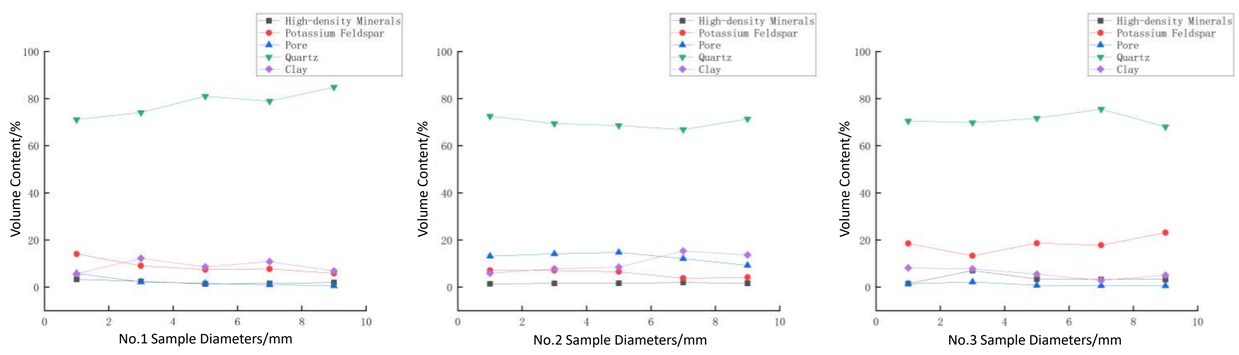

Fig.4 Segmentation results of subsamples of different sizes

Calculation result

- 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.
- The multi-scale and multi-component digital core model overcomes the difficulty of not being able to take into account the resolution and core size of the single-scale digital core model, and is able to characterize both the microscopic pore structure of the core and the macroscopic non-homogeneity of the core.

References:

[1] Cui Likai, Sun Jianmeng, Yan Weichao, et al. Construction of Multi-Scale and -Component Digital Cores Based on Fusionof Different Resolution Core Images, Journal of jilin University (Earth Science Edition), 2017,47(6): 1904-1912. doi: 10.13278/i.cnki. ijuese.201706307.

[2] Geophysical Prospecting for Petroleum,2023,62(5):806-819SUN jianmeng, SUN Xiaojuan,CHl Peng,et al,Digital cores and digital wellbore technology: Application and research progressl