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Characterization shale's pore structure of shale: Multi-experimental imaging technique with machine learning

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Shale oil and gas is becoming increasingly crucial for unconventional oil and gas exploration and development worldwide. The pore structure determines the transport properties in shale oil and gas reservoirs, which affects the assessment and development of shale oil and gas potential. Shale oil and gas reservoirs develop multi-scale and multi-type pore structures ranging from nanometers to millimeters, divided into micro-fracture, organic, and inorganic pore space. To wholly and precisely comprehend the pore structure of shale from the nano- to the micro-scale, this paper proposed a multi-experimental imaging technique, including X-ray computed tomography (XCT), large field of view scanning electron microscopy (SEM—Maps), and focused ion beam scanning electron microscopy (FIB—SEM), to establish a multi-experimental imaging workflow for shale. The combined imaging workflow was used to obtain two-dimensional (2D) and three-dimensional (3D) multi-resolution images of shale. Data fusion to combine different resolution XCT, SEM—Maps, and FIB—SEM images with machine learning methods to characterize the multi-scale pore structure of shale oil and gas reservoirs. The multi-dimensional and multi-resolution shale images were performed at single-scale and multi-scale simultaneously. The results showed that shale pores mainly consist of micro-fractures, inorganic pores, organic matter, and organic pores. All of them exhibit multi-scale characteristics. Organic matter shows strip and bulk distribution, and organic pores are not found in a large amount of organic matter. The multi-scale pore structure of shale was described quantitatively. The pore radius less than 10 nm accounts for 16%, 10-20 nm accounts for 18%, 20-50 nm accounts for 20%, 50-100 nm accounts for 23%, 100-500 nm accounts for 11%, and 500 nm-20 μm accounts for 6%, 20-50 μm accounts for 5%, 50-100 μm accounts for 1%. Inorganic matter pores are of various types, among which extensively produced dissolving pores. Finally, the connectivity of organic pores is poorer than inorganic pores. The connectivity between organic and inorganic pores plays a crucial role in oil and gas storage, while micro-fractures dominate the fluid flow channels. Organic pores dominate the Pore radius of shale <50nm, the pore radius of shale between 50~500nm are organic pores and inorganic pores, and the pore radius of shale >500nm is mainly contributed by micro-fractures. The method proposed in this paper can effectively obtain the multi-scale pore structure of shale.

Participation

In-Person

References

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