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Connectivity of multiscale porous structures of shale rocks based on multiscale imaging analysis

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Pore connectivity is a critical factor influencing the migration and production of shale gas (Sun et al., 2017). However, the inherent heterogeneity of shale, characterized by the development of various pore types (Loucks et al., 2012; Ma et al., 2017), renders the detailed and quantitative characterization of shale pore connectivity challenging (Zhao et al., 2020). The advancement of imaging technologies at different scales has facilitated the assessment of pore connectivity. In this study, we aim to investigate the pore structures and pore connectivity of the Longmaxi Formation shale in the Sichuan Basin. Imaging data include scanning electron microscope (SEM) and focused ion beam scanning electron microscopy (FIB-SEM). Machine learning algorithms were applied to shale image segmentation, revealing the development of distinct pore types. Additionally, high-pressure mercury intrusion and nitrogen adsorption experiments were employed to evaluate pore distributions and connectivity. The results demonstrate that machine learning-based image segmentation techniques effectively delineate various pore types on MAPS, including organic matter and clay ratios, as well as facial size characterization. The connectivity of organic matter pores is intricately linked to pore types, with honeycomb-like organic pores exhibiting the largest average pore diameter and good connectivity, followed by mixed organic pores. However, the latter lacks permeable channels at the FIB-SEM resolution. Sponge-like organic pores exhibit the poorest connectivity and porosity. Pores with a size smaller than 30 nm, which FIB-SEM cannot identify, significantly contribute to the connectivity of organic pores.

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