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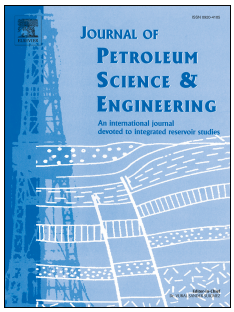

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Pore fractal model applicability and fractal characteristics of seepage and adsorption pores in middle rank tectonic deformed coals from the Huaibei Coal Field

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Abstract Middle rank tectonic deformed coal samples were screened from the Xutuan and Qinan coal mine in the Huaibei coal field, Anhui Province, North China. Based on mercury injection capillary pressure analysis and nitrogen sorption experiments using the Brunuaer-Emmett-Teller analysis, pore structure characteristics and applicability of the Sierpinski, Menger, Thermodynamics, and Frenkel-Halsey-Hill models for seepage and adsorption pore description were analyzed, as well as the fractal characteristics of the two types of pores. Several conclusions have been achieved. 1) The Sierpinski model can characterize the heterogeneity of seepage pores in tectonic deformed coals, and the thermodynamic model can be used for referencing and comparative analysis. The Frenkel-Halsey-Hill model can be used to describe the heterogeneity of adsorption pores, and the Sierpinski model can be a supplement. However, the Menger model is not suitable for characterizing the pore heterogeneity of coal because its fractal dimension exceeds three, and the standard deviation is larger than the others. 2) The fractal dimension of adsorption pores increases while seepage pores decreases, with the enhancement of tectonic deformation. The heterogeneity of adsorption pores in the cataclastic, schistose and scaly coals are weaker than that of seepage pores ($D_{s2}<D_{s1}$), the heterogeneity of the adsorption pores in wrinkle coal is similar to that of seepage pores ($D_{s2}\approx D_{s1}$), whereas the adsorption pores' heterogeneity in mylonitic coal is stronger than that of seepage pores ($D_{s2}>D_{s1}$).

Keywords: Tectonic deformed coal; Seepage pore; Adsorption pore; Fractal dimension; Fractal model applicability; Heterogeneity

1 Introduction

Coal, which is a porous media, is sensitive to stress and strain (Green et al., 2011; Mosher et al., 2013). Under different stress-strain environments, tectonic deformed coal of different texture characteristics and types will form (Ju et al., 2004; Qu et al., 2010; Li et al., 2011; Yuan et al., 2017). Tectonic deformed coals are widely found in coal bearing regions all over the world (Beamish and Crosdale, 1998; Cao et al., 2000; Busch et al., 2003). The special pore structure of tectonic deformed coal has an obvious effect on gas outburst hazards in coal mines and coalbed methane development (Ma et al., 1999; Jiang et al., 2010; Zou et al., 2013; Mark, 2018). Some researchers concluded that the adsorption (<100 nm) and seepage pores (>100 nm) in tectonic deformed coals are the main adsorption and migration spaces of coalbed methane respectively, and the study of their heterogeneity is the key to reveal the migration features of coalbed methane in coal reservoirs (Nishioka, 1992; Ju et al., 2009; Fu et al., 2009; Schmitt et al., 2013; Zhang et al., 2015; Wu et al., 2015).

Researchers primarily use fluid injection, gas adsorption and image analysis methods to carry out studies on the pore characteristics of unconventional oil and gas reservoirs (Zhang et al., 2015; Zou et al., 2016; Li et al., 2018). Ju et al. (2009) applied Brunuaer-Emmett-Teller (BET) analysis using nitrogen (N_2) sorption isotherm to investigate the nanopore classification and structural characteristics of various tectonic deformed coals. The results indicating that the adsorption and desorption mechanism of tectonic deformed coals are different from those of primary texture coal because of the differences in chemical compositions and pore structures. Using BET analysis, Fan et al. (2010) explored the characteristics of adsorption pores of coals under different metamorphic