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Experimental analysis on the effect of tectonically deformed coal types on fines generation characteristics

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ABSTRACT

Solid fines generation in coalbed methane (CBM) development can cause serious formation damage and production breakdown. The anisotropy of coal reservoirs makes fines issue more complicated. In this study, the experimental analysis of the correlation between tectonically deformed coal types and fines generation characteristics was implemented. Two samples with different coal structure types, undeformed coal and granulated coal, were collected from the same coal seam. Under single-phase fluid flow, two sets of core flooding experiments were conducted to generate fines from these samples. The yields of fines produced at varying experimental conditions were analyzed quantitatively. The characteristics of these fines were microscopically observed through the use of a laser particle size analyzer, a scanning electron microscope, and a polarizing microscope. The results indicated that tectonically deformed coal types significantly influenced the generating intensities, particle sizes and morphological features of fines. Because of the varying degrees of structural destruction, compared with undeformed coal, granulated coal contained more original tiny fines in the fractures and was more sensitive to variations of fluid flow rates and reservoir effective stress, which could intensify the generation of fines. Undeformed coal could generate fines with wider particle-size distribution ranges and larger mean particle sizes than granulated coal could. The micromorphology of fines produced from undeformed coal was mainly angular. However, for granulated coal, most of the fines were subangular and even subrounded. No appreciable impact of the development of tectonically deformed coal on the compositions of fines was found. Because of the water sensitivity of clay minerals and the stress sensitivity of vitrinite, the produced fines contained more clay minerals and vitrinite with increases of displacement velocities and confining pressures under laboratory conditions. Through well logging interpretation, the development intensity of tectonically deformed coal in three CBM wells was identified. After analysis of the concentration and mean particle size of fines collected from these wells, it was concluded that the more developed the tectonically deformed coal, the higher the fines concentrations and the smaller the fines mean particle sizes, which was consistent with the experimental results.

1. Introduction

During coalbed methane (CBM) production, the generation and migration of excessive fines can cause blockage of pores and flow paths, leading to reduced permeability of the coal reservoir, although the detachment of solid fines from the fracture surface might expand flow channels to some extent (Marcinew and Hinkel, 1990; Civan et al., 2000; Chen et al., 2009; Nunes et al., 2010; Zou et al., 2014; Yang et al., 2015a). Moreover, the retention of fines in the pumping equipment of CBM wells can cause downhole failures and production breakdown (Palmer et al., 2005; Magill et al., 2010; Liu et al., 2012; Yao et al., 2015a). In fines generation in reservoir development, various mechanisms of mechanical failures include formation water flow, external fluid invasion and reservoir stress fluctuation, and chemical reactions such as rock-fluid interactions also occur (Civan et al., 2007; Chen et al., 2009; Gentzis et al., 2009; Yuan and Shapiro, 2011; Zeinijahromi et al., 2011; Yao et al., 2015b). The characteristics of coal reservoirs influence fines generation fundamentally (Cao et al., 2012). The components of coal seams and interburden layers result in that fines mainly consist of coal macerals, clay minerals, pyrite, quartz and calcite

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(Wei et al., 2013b; Massarotto et al., 2014; Yang et al., 2015b). The anisotropy of coal reservoirs can make fines issue more complicated (Cao et al., 2012; Chen et al., 2013; Wei et al., 2013a; Xu et al., 2015).

With the rapid development of CBM comes an increasing importance of the study of solid fines. Theoretical analysis, experimental research and production practice have provided some knowledge of fines in coal reservoirs. Marcinew and Hinkel (1990) discussed possible sources of coal fines which showed that fracturing treatment, proppant embedment, dewatering, coal shrinkage and coal wettability variation could lead to fines production and also presented a chemical system to mitigate the associated damage. Palmer et al. (2005) summarized different coal failures during drilling, fracturing and CBM production, and concluded that failures in weak coal could cause fines generation. Chen et al. (2009) and Liu et al. (2012) analyzed the generation mechanisms and control measures of coal fines on the basis of laboratory tests and field monitoring in the southern Qinshui Basin and southeastern region of Ordos Basin, China. Magill et al. (2010) designed and applied a formed remedial treatment for displacing coal fines away from the CBM wellbore in the San Juan Basin. Synthetically considering the generation mechanisms, sources and impact on CBM production of coal fines, Cao et al. (2012) proposed a comprehensive classification system of coal fines. Chen et al. (2009) and Wei et al. (2013b) showed that the development of tectonically deformed coal was the key influence factor of coal fines generation. Zhang et al. (2013) concluded that the particle size and fill rate of coal fines in gas production channels affected reservoir permeability significantly. Liu et al. (2015) introduced a cleanout technology for coal fines by jet pump and Zhang et al. (2014a) suggested controlling bottom hole pressure to mitigate coal fines generation in CBM wells. Zou et al. (2014) experimentally studied the impact of fines on hydraulic fracture conductivity and developed a novel dispersant to improve fines suspension and dispersion in water-based fracturing fluid by changing their wettability and surface potential. Massarotto et al. (2014) contrastively analyzed differences of mineral content and skeletal density between field fines and core-derived lab fines by using novel comparative quantitative X-ray diffraction. Guo et al. (2015) conducted a laboratory investigation on fines production from anthracite coal and analyzed the permeability change caused by fines with water injection. This research suggested that the main compositions of produced fines were clay minerals.

Some experimental studies have analyzed fines generation from coal through the use of water injection or core flooding (Cao et al., 2013; Guo et al., 2015; Wei et al., 2015). A few researchers injected coal particles into proppant packs or fines suspension into coal to analyze the permeability damage caused by the migration and blockage of fines in fractures and cleats (Bai et al., 2011; Zou et al., 2012; Zou et al., 2014). It has been concluded that the generation and migration of fines is affected primarily by reservoir properties. Impact analyses of tectonically deformed coal types on reservoir development have covered the relationship between the deformation of coal and pore features, as well as reservoir permeability and CBM wells productivity (Cao et al., 2003; Li et al., 2012; Pan et al., 2012; Xue et al., 2012; Li et al., 2015; Xu et al., 2015). However, the correlation between coal properties and fines generation has rarely been investigated, especially the effect of tectonically deformed coal on fines issue. Because of the anisotropy of coal reservoirs, it is important to verify the influence of different reservoir properties on the characteristics of solid fines generation.

This paper investigated the correlation between tectonically deformed coal types and fines generation characteristics. First, coal samples of different structure types were collected from the same coal seam. Second, under single-phase fluid flow, two sets of core flooding experiments were conducted to generate fines from these samples, and the yields of fines produced at varying experimental conditions were analyzed quantitatively. Third, with the use of a laser particle size analyzer, a scanning electron microscope (SEM) and a polarizing microscope, the characteristics of these fines were microscopically observed. Finally, with production practice and through well logging interpretation, the development intensity of tectonically deformed coal in three CBM wells was identified, and the concentration and mean particle size of fines collected from these wells were analyzed, respectively.

2. Experiment of fines generation

2.1. Experimental apparatus

Two sets of core flooding experiments were implemented to quantitatively analyze the fines produced from artificial coal samples. This study focused on the impact of different tectonically deformed coal types on the generating intensity and microscopic features of fines. In this fines generation experiment, a modified API standard fracture conductivity instrument was chosen as the experimental apparatus (Fig. 1). This apparatus was applied in previous experimental studies in assessing the damage of hydraulic fractures conductivity caused by coal fines (Zou et al., 2012; Cao et al., 2013; Zou et al., 2014). Through the use of this

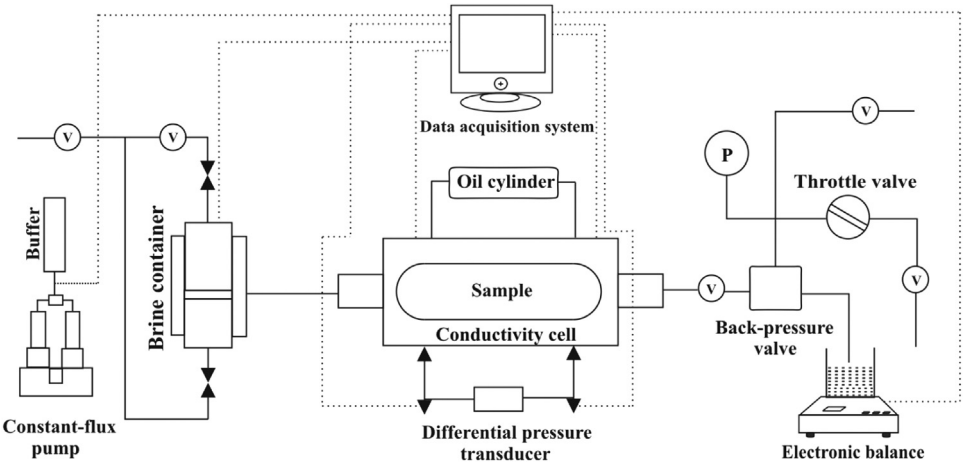

Fig. 1. Schematic of experimental apparatus for fines generation.