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Experiments on the effects of igneous sills on the physical properties of coal and gas occurrence

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ABSTRACT

The violent igneous intrusion produced two layers of igneous cover sills and an annular dike and led to several gas dynamic accidents and repeated phenomena of unusual gas emission in the Yangliu Coal Mine in Huaibei Coalfield, China. Six coal samples were collected at different distances from the igneous sills for the experiments to study the physical properties of coal and gas adsorption/desorption properties. The results indicate that the vitrinite reflectance and ash and moisture contents increase irregularly while the volatile content decreased irregularly with decreasing distance from the igneous sills. The coal mass being researched was divided into three zones based on the degree of thermal erosion: strong thermal erosion zone, weak thermal erosion zone and no thermal erosion zone. The metamorphism of the coal in two adjacent zones changes gradually rather than suddenly. The thermal erosion caused by the igneous intrusion volatilized the organic matters, left a large number of pyrolysis stomata, greatly increased the volume and surface area of pores, especially micropores, and improved the gas adsorption and preserved abilities of the coal. The thermal erosion, gas trapping and tectonic stress effects of the igneous intrusion on the underlying coal mass increased the outburst risk of coal covered by igneous sills to a greater extent than that of coal without the effect of igneous intrusion. The regions covered by igneous sills are sites where the gas resource is enriched, and the engineering applications show that the gas extraction technology via surface wells can ensure the safe and high-efficiency co-exploitation of coal and gas and be of significant commercial value.

1. Introduction

Intrusive igneous rocks are commonly associated with coal and are present in many coal mines throughout the world (Jiang et al., 2011b). Igneous intrusion provides a high-temperature and high-pressure environment for coal seams; so the shape, lithologic characteristics and occurrence of the igneous rocks play extremely important roles in coal quality, gas occurrence and outburst control. Many scholars worldwide have studied the physical and chemical properties of coal with the thermal erosion of igneous rocks from the perspective of petrographic and geochemical analyses, pore structures and gas adsorption/desorption properties (Beamish and Crosdale, 1998; Dai and Ren, 2007; Golab and Carr, 2004; Gurba and Weber, 2001; Rimmer et al., 2009; Stewart et al., 2005; Yao et al., 2011). The thermal erosion effects of igneous rocks on coal increase the vitrinite reflectance, decrease the volatile content and promote the metamorphism of coal (Wang et al., 2013a). After the organic matter in coal was volatilized, a large number of pyrolysis stomata remained, promoting the generation of pores, especially micropores, and thus improving the gas adsorption and desorption abilities of coal (Yao and Liu, 2012).

The thermal erosion of igneous rocks increases the rate of the secondary hydrocarbon generation of coal (Dias et al., 2014), and the igneous sills covering the coal seam trap and preserve the gas (Wang et al., 2013c), resulting in a rapid increase in the gas content and pressure of coal within the igneous intrusion regions. In addition, the igneous rocks intruded the coal and rock strata like wedges, transforming the existing geological structure to a certain extent and causing the localized concentration of tectonic stress (Cao et al., 2007). In short, the risk of coal and gas outburst within the igneous intrusion regions is greater than that outside the igneous intrusion regions (Chen et al., 2012; Wang et al., 2013b).

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Numerous coal and gas outburst accidents have occurred in coal mines in China, for example, in the Haizi Coal Mine, the Wolonghu Coal Mine and the Yangliu Coal Mine in Huaibei; the Daxing Coal Mine in Tiefa; and the Anlin Coal Mine in Anyang, due to igneous intrusion (Jiang et al., 2011a).

A violent igneous intrusion produced two layers of igneous cover sills and an annular dike in Yangliu Coal Mine in Huaibei Coalfield, China. Four gas-dynamic accidents and repeated phenomena of unusual gas emission, which were associated with igneous intrusion, occurred during the tunneling and mining of coal seam #10. By experimenting and analyzing the physical properties of coal samples at different distances from the igneous sills, we discuss the thermal erosion effects of igneous rocks on the physical properties of the coal and on the gas occurrence. The results may provide useful references for coal and gas control and high-efficiency co-exploitation of coal and gas under similar geological conditions.

2. Geological setting

2.1. Mine introduction

Yangliu Coal Mine, located in Suixi County of Anhui Province, China, is outburst-prone with a production of 1.8 Mt/a (Fig. 1). Yangliu Coal Mine contains nine coal seams, of which coal seams #8_2 and #10 are the most mineable. Coal seam #10, which is located at an intermediate height in the Shanxi Formation, has an average thickness of 3.19 m. Coal seam #8_2, which is 74 m above coal seam #10, is 1.87 m in average thickness.

2.2. Occurrence of igneous rock

Nearly all of the coal seams in Yangliu Coal Mine have experienced extensive igneous intrusion. Although mining area #107 did not undergo igneous intrusion, three layers of igneous sills intruded mining areas #104 and #106 (Fig. 1). Igneous sill #1, with an average thickness of 33.40 m, is located 58 m above coal seam #5_1. Igneous sill #2, with an average thickness of 40.24 m, is located 67 m below igneous sill #1, 29 m over coal seam #8_2 and 102 m above coal seam #10. Igneous sills #1 and #2 are called “cover sills”. Igneous sill #3, which possesses a widely varying thickness from 1.66 m to 66.50 m, intrudes coal seam #10 and the underlying rock mass, annularly surrounds the mining areas #104 and #106, and is called an “annular dike”. In addition, both Daniujia Fault and Daimiao Fault are closed normal faults. The cover sills, annular dike and closed normal faults comprise a natural “gas-preserving box” to preserve the gas in the coal seams.

3. Sampling and experimental methods

3.1. Sampling

Six coal samples were collected from coal seams #8_2 and #10 of mining area #104 and coal seam #10 of mining areas #106 and #107 (Fig. 1 and Table 1). Coal samples #1 and #2 were collected from coal seam #8_2 of mining area #104, which is located closer to igneous sill #2 than the other coal samples. Coal samples #3 and #4 were collected from coal seam #10 of mining areas #104 and #106 with a nearly equivalent distance from igneous sill #2. However,

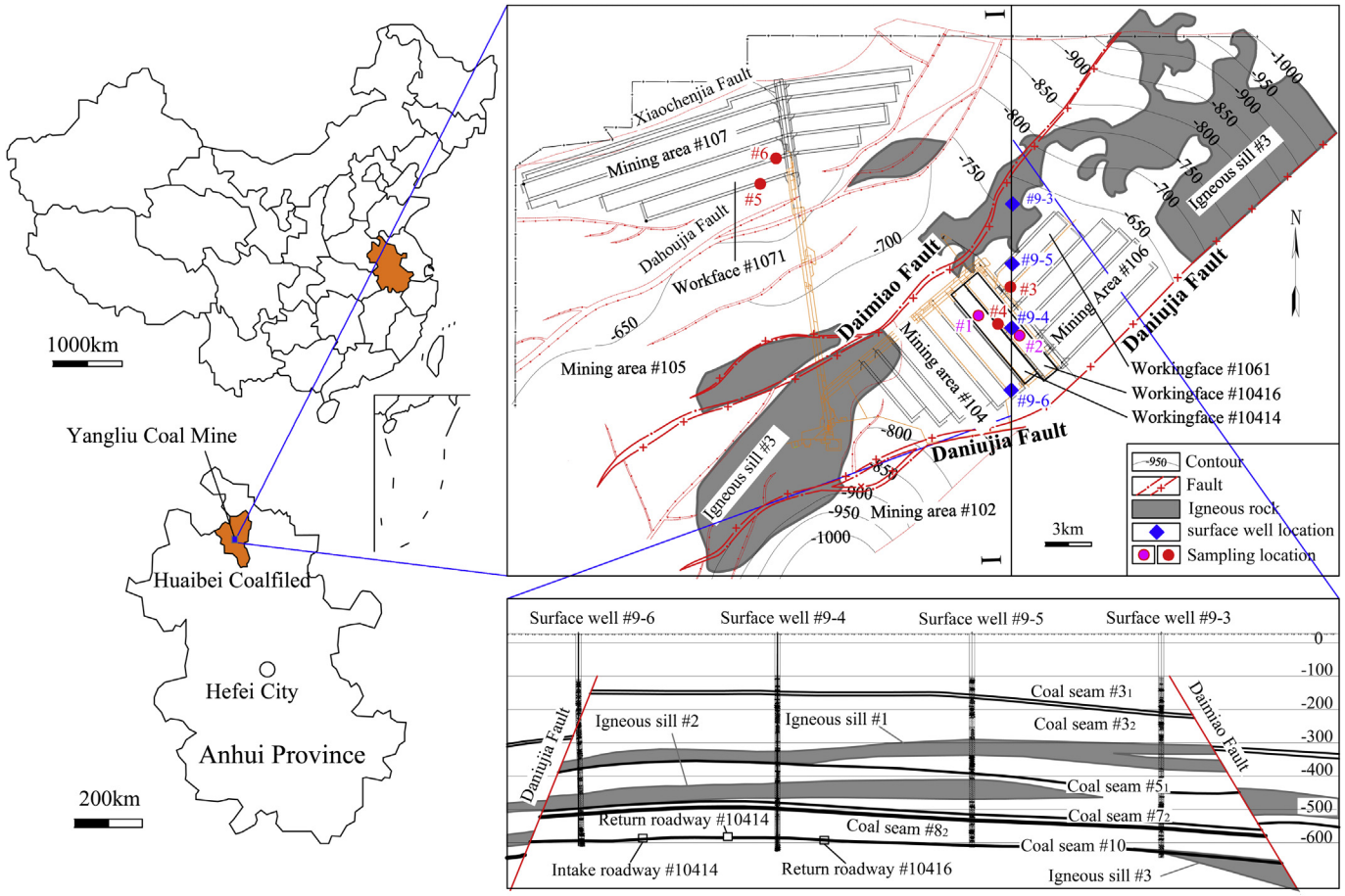

Fig. 1. Location and igneous rock occurrence of Yangliu Coal Mine.