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Generation and accumulation characteristics of mixed coalbed methane controlled by tectonic evolution in Liulin CBM field, eastern Ordos Basin, China

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ABSTRACT

Tectonic movement controlled the different basins evolutionary histories and affects the enrichment and accumulation of CBM of different genesis. The upliftment and depression are one of the important conditions for the generation of secondary biogenic CBM. The present study confirmed that mixed CBM are enriched in the Taiyuan formation at Liulin CBM field. The experimental results illustrated that the generation and accumulation of CBM in research area can be divided into three evolutionary stages. Diffusion, permeation and cap outburst dissipation were determined to be the main migration mechanisms of mixed-CBM. Secondary biogenic CBM can supplement the dissipation of thermogenic CBM.

1. Introduction

Based on a genetic mechanism, coalbed methane (CBM) is divided into biogenic CBM, thermogenic CBM (Rightmire, 1984), and a mixture of both types (Ayers, 2002; Moore, 2012). While biogenic CBM/gas can be existed as primary and secondary biogenic gases (Scott et al., 1994). Generally primary biogenic CBM is generated during the early stage of coalification, which is in the peat formation (Rice, 1992) or lignite to subbituminous coal rank (Moore, 2012). The generated quantites of primary biogenic CBM is lower and the burial depth is smaller (Rice, 1992). Thus presently the primary biogenic CBM is difficult or rare to preserved in the coal seam (Scott, 1993; Kotarba, 2001). However, there is also believed that the primary biogenic CBM retained by the coal in a absorbed or free state or dissolved in pore water becomes a part of the coal structure to survive (Rice, 1992).

Since the importance of secondary biogenic CBM generation to CBM production was early recognized in the San Juan basin (Kaiser et al., 1991; Scott et al., 1994), mixed CBM derived from secondary biogenic and thermogenic gases has been subsequently reported in many basins (Smith and Pallasser, 1996; Kotarba, 2001; Tao et al., 2007; Strapoc et al., 2011; Kedzior et al., 2013). For example, Smith and Pallasser (1996) and Ahmed and Smith, 2001 mentioned that the Permian CBM of the Sydney basin and Bowen basin in Australia contains partly secondary biogenic gas generated via microbial CO_2-reduction. Kotarba (2001) presented that the Upper Carboniferous CBM of the Upper Silesian and Lublin basins in Poland was generated probably after the Miocene during the microbial CO_2-reduction. Tao et al. (2007) discovered the secondary biogenic gas at the Permian formation of the Xinji area in Anhui province of China and quantitatively calculated the gas content of secondary biogenic gas. Tong et al. (2013) considered that the secondary biogenic gas at the Permian formation of Luling CBM field in China was generated via microbial CO_2-reduction and the coal bed water came from atmospheric rainfall based on the test results of carbon and hydrogen isotopic composition of CBM and the hydrogen and oxygen isotopic composition of the water produced from the coal bed.

Predecessors have done various work on the origin and geochemical characteristic of biogenic CBM (Zhang et al., 2005; Hu

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et al., 2010; Susilawati et al., 2013), and the evolutionary accumulation of thermogenic CBM (Wei et al., 2007, 2010). Bao et al. (2014) established the generation model of biogenic CBM, however, the quantity of biogenic CBM generation is based on the published data about methane and dioxide carbon. By 133 days experiment on the biodegradation for coal samples with different maturity and measured the yield of methane generated in the laboratory, we modified the yield parameters of primary and secondary biogenic CBM during simulated calculation. After two calculations and comparison of the accumulations of thermogenic CBM and mixed CBM, it can be revealed that their evolutionary process and the relative gas content of different genetic CBM occurred in the coal seam presently. Additionally, the factors influencing secondary biogenic CBM generation model and tectonic movement affecting the enrichment and accumulation of different genetic CBM were also discussed. Results of this study advance our understanding of the enriched process of secondary biogenic CBM and enrich the CBM accumulation theory for low- and middle-rank coal.

2. Geological background

Liulin CBM field, located central part of Jinxi fold belt and extend eastward into Lvliang uplift and westward into Shanbei slope (Wang et al., 2007; Liu, 2011). From the late Carboniferous to present, Liulin CBM field has been withstood weakly tectonic deformation and finally formed a westward monoclinal structure overall. The research area can be divided into several sub-tectonic units, such as the Jucaita fault, Qingshanheng fault, Nanliang fault, Lishi-Zhongyan syncline, and Shilou anticline (Fig. 1). Gas samples were collected from CBM tested wells S1 and S2, respectively (Fig. 1).

The Taiyuan formation of the Carboniferous and Permian, possessing good gas-bearing and higher permeability characteristics, is the main coal-bearing strata in Liulin CBM field (Tang et al., 2004). In addition, the Benxi formation of the Carboniferous, and Shanxi and Xiashihezi formations of the Permian distributes some thin coal seam discontinuously.

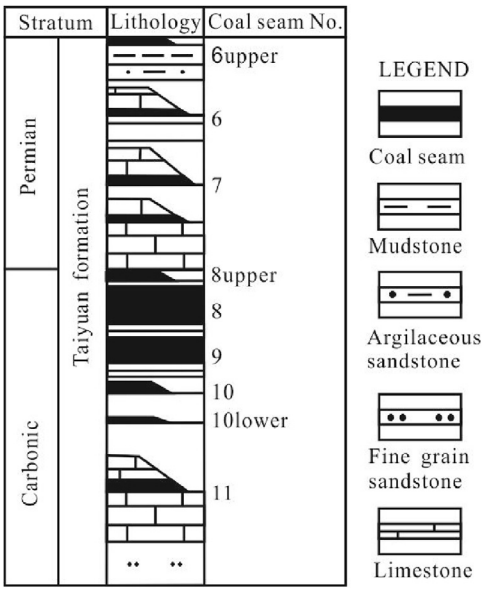

Fig. 2. Stratigraphic column of Liulin CBM field.

From bottom to top there are different numbers provided in the Coal seams of Taiyuan formation, such as, 11, 11 lower, 10, 9, 8, 8 upper, 7, 6, 6 upper (Fig. 2). Among them, the distribution of coal seam No. 8 is the most stable in this region, and its thickness is from 5.1 to 6.8 m. The values of vitrinite reflectance ranges from 1.31% to 1.48%. This study choose coal seam No. 8 as the target formation for numerical simulation of the CBM accumulation.

The average gas content of wells S1 and S2 is 6.37 m^3/t and 7.60 m^3/t based on measured value. Methane is the main gas composition, and its value is more than 97.90%, without heavy hydrocarbon gases. The dry gas ($C_1/C_{2+} > 10^3$) indicates a large

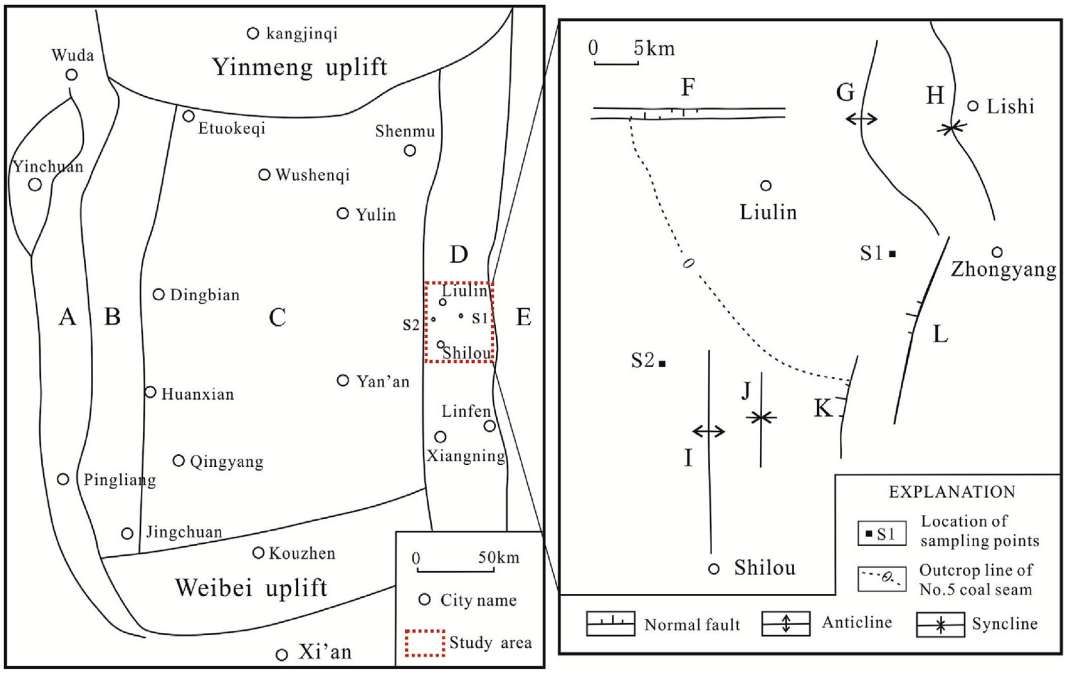

Fig. 1. Location and structure maps of Liulin CBM field at the Eastern Margin of Ordos Basin (after Wang et al., 2007; Huang and Jiang, 2009; Liu, 2011) (A. Fault-folded belts in Western Margin of Ordos Basin; B. Tianhuan syncline; C. Shanbei slope; D. Jinxi fold belt; E. Lvliang uplift; F. Jucaita fault; G. Wangjiahui anticline; H. Lishi-zhongyang syncline; I. Shilou anticline; J. Liuyu syncline; K. Nanliang fault; L. Qingshanheng fault.).