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Structural controls on coalbed methane accumulation and high production models in the eastern margin of Ordos Basin, China

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ABSTRACT

Significant progress has been made in coalbed methane (CBM) exploration and development in the eastern margin of the Ordos Basin where nearly 2000 CBM wells have been drilled, achieving a maximum gas production rate of 16000 m^3/d by 2013. The geological evolution of the eastern Ordos Basin plays an important role in the CBM formation. This study is focused on the interrelationship between structural geology, gas accumulation and production characteristics of the No. 4 + 5 coal in the Permian Shanxi Formation as well as the No. 8 + 9 coal in the Carboniferous Taiyuan Formation. This research is based on the data collected from CBM production wells and coal samples from coalmines and exploration wells. The results show that thermogenic gas is the dominant CBM source in the study area and there are two significant generation periods, the coalification in the Triassic and the magmatic thermometamorphism during the Yanshan movement. Combining the structure background and hydrogeological conditions, the monoclinic-hydraulic sealing model was proposed as the representative CBM enrichment model. Different types of structures are also classified, and their influence on the CBM accumulation is discussed. Compressional structures formed during the Yanshan movement are conducive to CBM enrichment and retention; however, the tensional structures formed during the Himalaya movement may have led to CBM dissipation. Combining the structural effect on the CBM production with CBM exploration and development practices in the study area, the following three types of high gas production models are summarized: updip of the monocline, the axial part of the anticline or nose structure, and the structural high far from the normal fault.

1. Introduction

Recently, the development of coalbed methane (CBM) from high-rank coals has achieved significant success in the southern Qinshui Basin in China (Su et al., 2005; Cai et al., 2011; Tao et al., 2012). CBM resources in medium-rank coal are abundant in China, especially in the Ordos Basin (Tang et al., 2004; Yao et al., 2008; Li and Zhang, 2013; Meng et al., 2014). The successful development of CBM in the San Juan and Black Warrior Basin in the United States (Murray, 1996; Ayers, 2002; Pashin, 2010; Tong et al., 2014) has shown that low to medium-rank coal reservoirs are of significant importance in CBM development. The eastern margin of the Ordos Basin CBM field occurs along the Yellow River, with a length of 560 km from north to south, a width of 50–200 km from east to west and an area of 25,000 km^2. The coal resources within this area occur at depths above 1500 m, with the gas resources estimated to be 9×10^{12} m^3 (Jie, 2010). It has become the second largest industrial development CBM field after the Qinshui Basin in China. By the end of 2013, the eastern margin of the Ordos Basin CBM field contained nearly 2000 drilled wells, among which the highest gas production rate of a single vertical well exceeded 6000 m^3/d and that a single horizontal well achieved16,000 m^3/d.

Gas contents and production from CBM wells in different regions show significant differences. Different structural characteristics in different regions not only control the shape, continuity and permeability of the coal seams but also have a direct influence on the CBM generation, migration, accumulation and production (Song et al., 2013). Different parts of the same structure may have different stress properties, positively or negatively influencing the CBM retention or even development (Ayers, 2002). Pashin and Groshong Jr. (1998) have stated the effects of extensional stress

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were benefited to improve permeability and compressive stress was favorable for CBM retention. Groshong Jr. et al. (2009) have reported the water production rate was high near normal faults but the trend was opposite close to fold-thrust belts. CBM composition and the methane isotopic variation have been reported by Li et al. (2014a), partly showing the CBM generation and evolution history. Other reports have primarily focused on a small part of the eastern Ordos Basin and are limited to the relationships between gas contents and structural properties, e.g., the Hancheng area (Yao et al., 2014) and the Liulin area (Li et al., 2014c, 2014e). However, the structural evolution and its influence on CBM generation, accumulation and production have not been studied in detail. The goal of this study was to reveal structural effects on CBM generation, accumulation and field development over the entire area of the eastern margin of the Ordos Basin, and to establish certain typical CBM accumulation and high gas production models controlled by structures.

2. Tectonic setting

The Ordos Basin, a stable polycyclic sedimentary basin formed on the North China Craton, is located in North China covering an area of 250,000 km^2 and contains the second largest accumulation of coal resources in China (Xu et al., 2012; Yang et al., 2013). The basin is divided into seven structural units (Xue et al., 2011; Tang et al., 2012) (Fig. 1). The eastern margin of the Ordos Basin is a N–S striking and west trending monocline within the following three tectonic units: the Yimeng uplift, Jinxi fold and Weibei uplift from north to south (Jiang et al., 2012; Wang et al., 2013; Fig. 2). A series of large-scale folds along the N–S and NE–SW trending and the less developed faults has been observed in the area, suggesting

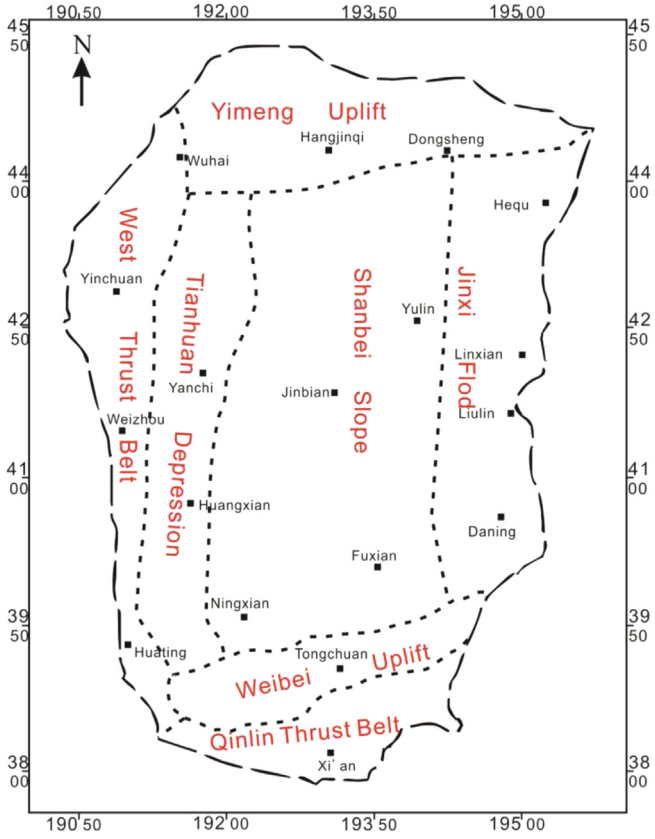

Fig. 1. The distribution of tectonic units in the Ordos Basin.

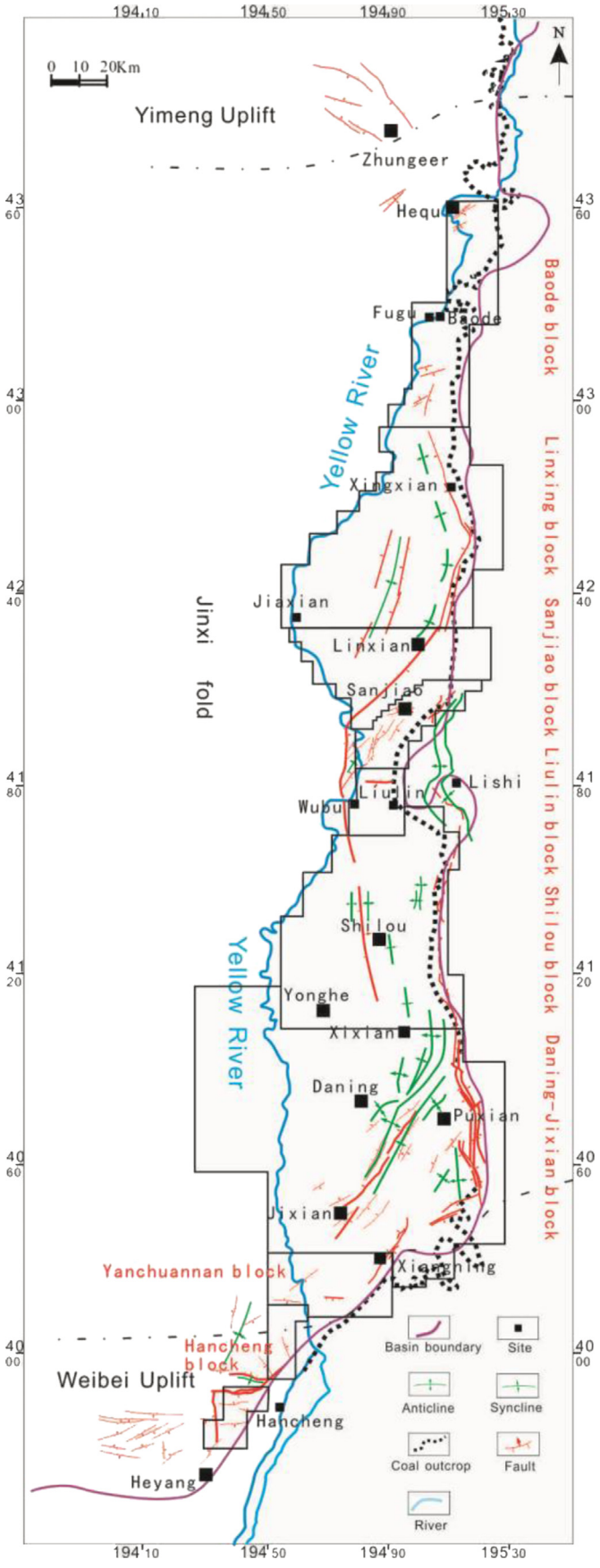

Fig. 2. The tectonic map of the eastern margin of the Ordos Basin.