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Research paper

Geological controls on gas saturation in the Yanchuannan Coalbed Methane Field, Southeastern Ordos Basin, China

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ABSTRACT

The paper investigates lateral variation of gas saturation and its geological controls of the No.2 coal seam in the Permian Shanxi Formation based on coal samples from 21 exploration wells in the Yanchuannan Coalbed Methane (CBM) Field, Southeastern Ordos Basin, China. The data set reveals that gas saturation of the No.2 coal seam shows a high lateral variation from 32.44% to 89.69%, and that there is an overall trend in gas saturation with depth overprinted by four other factors: 1) influence of faults, 2) secondary biogenic gas generation, 3) local top seal conditions and 4) variations in coal properties. The reverse faults F1 and F2 are effective barriers horizontally for the hydraulic communication and divide our study area into relatively closed and recharge zones. Gas saturation of the relatively closed zone is generally higher than that in the recharge zone. In the recharge, gas saturation increases generally along the flow pathway of groundwater with the exceptions of the areas affected by secondary biogenic gas. The stable isotope compositions suggest that late-stage biogenic methane was generated via CO_2 reduction associated with meteoric water recharge, which significantly contributes to higher gas saturation than expected. Meanwhile, the biogenic gas generation was/is restricted to shallow depths. The apparent variations in local areas of lithology of the overlying stratum next to the coal seam suggest that the top seal conditions are deteriorative, which can cause gas dissipation and reduce gas saturation remarkably. Integrally, for the variations in coal properties, gas saturation has a general positive relationship with coalification, and weak negative correlations with moisture content and ash yield but the relationships lacks statistical significances. Gas saturation is not associated with coal maceral in the study area.

1. Introduction

Gas saturation is an important index to evaluate production performance of coalbed methane (CBM) wells, including gas rate, dewatering process, pressure decline and ultimate gas recoverability (Bustin and Bustin, 2008; Moore, 2012; Pashin, 2010). Large quantities of gas can be generated during the coal formation process, especially in later stages of coalification (Gan et al., 1972; Karweil, 1955), and can markedly exceed gas adsorption capacity of the coal reservoir itself (Bustin and Clarkson, 1998; Zhang et al., 2008). In the actual CBM gas production operations, however, coal reservoirs in most cases remain undersaturated rather than oversaturated with respect to methane at present-day burial depths and temperatures (Bustin and Bustin, 2008; Scott, 2002). This can be attributed to basin uplift and cooling, which leads to an increase in gas adsorption capacity without augmentation by hydrocarbon migration or late-stage bacterial methanogenesis (Ayers Jr., 2002; Moore, 2012; Yang and Saunders, 1985) and/or the possible degassing of CBM to the surface (Scott, 2002; Yao et al., 2013). Gas saturation shows significant variations both vertically and laterally within a single coal seam (Strąpoć et al., 2008), which cannot be solely explained by basin uplift and cooling (Pashin, 2010; Scott, 2002). Therefore, more in-depth analysis is required to understand the controlling factors on gas saturation variation within a single coal seam and to establish a composite model on gas saturation variation.

The present study examines the gas saturation heterogeneity and its controlling factors in the No.2 coal seam exclusively, though there are 10 coal seams ranging in age from Carboniferous to

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Permian in the Yanchuannan CBM Field, Southeastern Ordos Basin, China. The coal seam is mined at shallower depths and is being developed as CBM resources in other areas of the studied area. This study will focus on the CBM areas. This paper begins with describing the lateral distribution of gas saturation, and then examines controlling factors, including depth, faults, secondary biogenic gas generation, sealing conditions and coal properties (coalification, coal quality and coal maceral). The paper concludes with proposing a model of lateral variation of gas saturation, which may serve as a theoretical basis for the next stage of CBM exploitation.

2. Geological setting

The Yanchuannan CBM Field is located in the southeastern Ordos Basin (Fig. 1) which is a stable polycyclic sedimentary basin formed on the North China Craton (Yang et al., 2008; Zhu et al., 2008). The field with a total area of 701.4 km^2 presents an irregular rectangle, which length and width are approximate 33.18 km and width 22.38 km, respectively. Four major faults are developed in the research area: Baihe reverse fault (F1) and Zhongduo reverse fault (F2) strike NE with the length of 20 km, and dip SE with the angle of 60° and the fault throw of 25–60 m. Jundiling normal fault

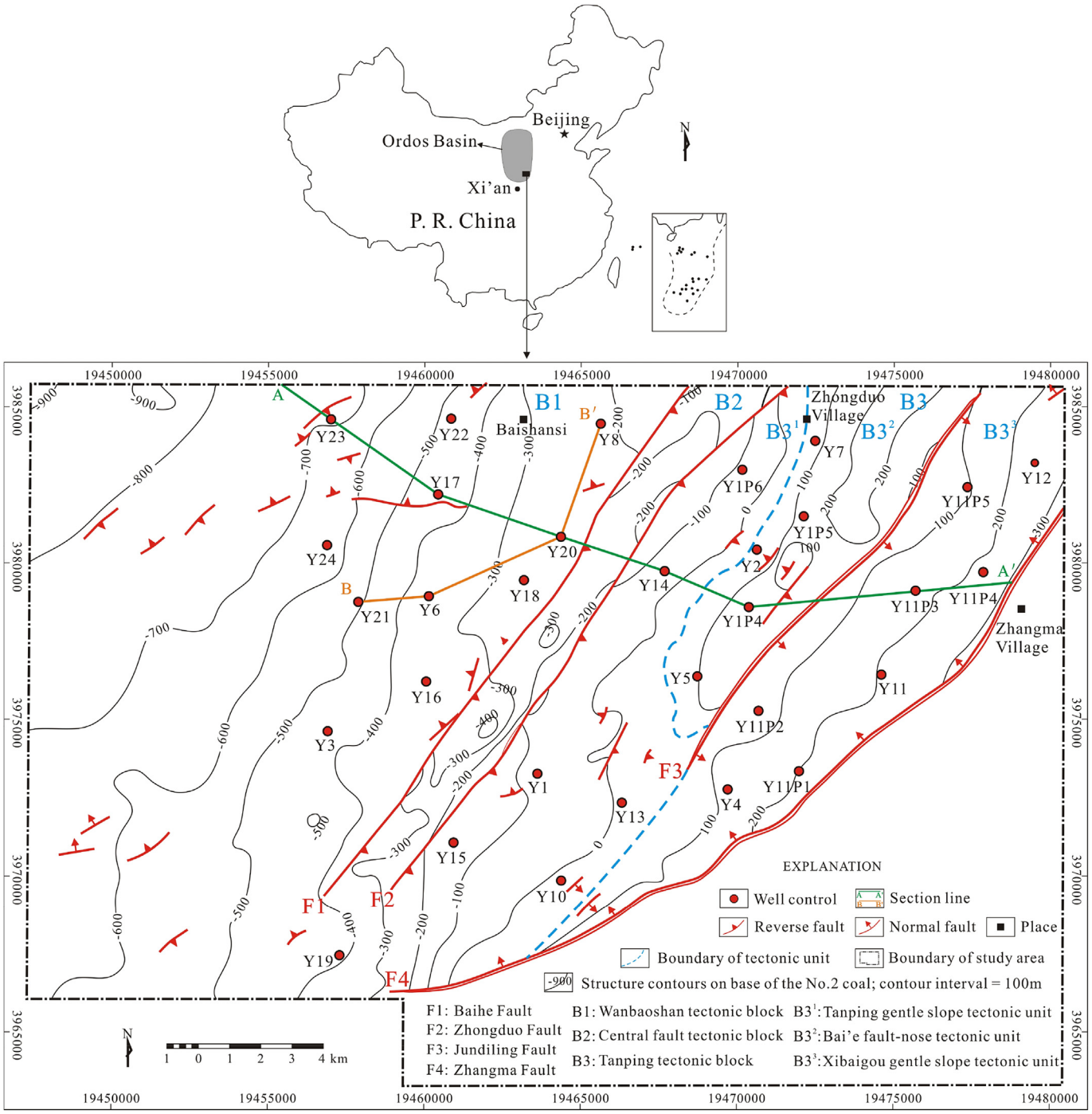

Fig. 1. The location of the Yanchuannan CBM Field as well as synoptic geological map of the study area showing the major tectonic blocks/units and the structural elevation on base of the No.2 coal seam.