International Journal of Mining Science and Technology xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

International Journal of Mining Science and Technology

journal homepage: www.elsevier.com/locate/ijmst

Coal reservoir characteristics and their controlling factors in the eastern Ordos basin in China

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ARTICLE INFO

Article history:
Received 12 July 2015
Received in revised form 15 October 2015
Accepted 6 March 2016
Available online xxxx

Keywords:
Coal reservoir
Coal rank
Controlling factors
Eastern Ordos basin

ABSTRACT

In the eastern Ordos basin, due to the diversity of the tectonic setting, coal rank, gas content and permeability, coal reservoirs have differing characteristics. In this paper, based on coal reservoir geometry, gas content, adsorption capacity, pores and fissures developments and permeability data, the coalbed methane (CBM) reservoir characteristics and their controlling factors in the eastern Ordos basin is discussed. The results show that, due to undergoing different paleo-temperatures in the geological history, coal rank has a higher trend from the north part to the south and from the shallow part to the inward basin, which determines CBM distribution and recoverability. In the north, although having large coal thickness and high permeability, Zhungeer-Xingxian coal rank is low, and gas content is small. In the central part, with medium rank, higher gas content and relatively high permeability, and the Wubao-Liulin area is the most favorable area in the eastern Ordos basin. In the southern part, medium and high metamorphism coal occurs, and although having the highest gas content, the permeability in the Hancheng area is low due to the development of sheared coal.

1. Introduction

The eastern Ordos basin is one of the most favorable CBM regions in China, with more than twenty-years of exploration history. From 1986 to 1991, Shanxi, Shaanxi and Inner Mongolia Coal Geology Bureau conducted coal prospect surveys, and assessed the coal-bearing strata sedimentary environment, tectonic characteristics, coal distribution, and coal properties.

The CBM exploration prospect has been studied since the 1990s [1,2], but, although some progress has been made during the past 20 years, no major breakthrough has been obtained in CBM development in the eastern Ordos basin. Until now, CBM production has been poor, mostly falling into several hundreds to 1000 m^3/d. Highly productive wells account for the minority; in the north, in Baode, the average CBM production of 14 horizontal wells is 1816 m^3/d; in the central part, the average production of 9 wells in Liulin is 4222 m^3/d, the highest is 15,195 m^3/d; and in the south the average production of 5 wells in Hancheng is 1470 m^3/d.

CBM geological condition is one of the main factors controlling CBM production. Due to the diversity in the tectonic setting, coal maturity, gas content and permeability, there are apparent reservoir compartments in the eastern Ordos basin. In this paper, by analyzing the above geological setting and reservoir characteristics, CBM recoverability and the controlling factors in the eastern Ordos basin is focused on.

2. Methods

CBM exploration data in this paper were acquired from 62 CBM exploration pilot wells in the eastern Ordos basin and laboratory measurements, e.g., gas content data are acquired from direct desorption tests, permeability from well testing, Langmuir volume and pressure from isothermal adsorption tests, pore features are measured by scanning electron microscope, vitrinite reflectance is tested by using an oil-immersed optical microscope, etc. Parameter correlative analysis is conducted by statistics, and contour maps are completed by interpolation point method.

3. Geological setting

The Ordos basin is located in the northwest of China, and its eastern part includes Zhungeer, Fugu-Wubao, Hedong and Hancheng mining areas, 400 km in length and 30–100 km in width. According to its tectonic features, with the border of Linxian and Shilou county, the eastern Ordos basin is divided into three parts-the north, the central and the south parts.

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http://dx.doi.org/10.1016/j.ijmst.2016.09.013
2095-2686/

Please cite this article in press as: Li G. Coal reservoir characteristics and their controlling factors in the eastern Ordos basin in China. Int J Min Sci Technol (2016), http://dx.doi.org/10.1016/j.ijmst.2016.09.013

3.1. Tectonic features

The eastern Ordos basin includes four 3rd grade tectonic units-the folded belt of west Shanxi, the eastern part of Yimeng uplift, the Weibei uplift and the slope of north Shaanxi (Fig. 1) [3].

In the shallow part of the eastern Ordos basin faults and deriving flexures occur, which are controlled by the dynamics from East China. Toward the west, structural features are substituted by broad and small dipping folds, and toward the Ordos basin are transformed into monoclinal structures.

In the north part of the eastern Ordos basin, the tectonic deformations of the folded belts are relatively weak, with sparse structures, predominantly flexings and folds [4]; in the central part, the Wubao-Liulin tectonic zone is a west-plunging nose-type structure; the deformation of the folded belts in the south part is strong, with intensive structures, and in the southeast of the basin, there is a typical nappe structure zone, the strata dip steeply or even become overturned, dipping west or northwest at an angle of 5°, which causes the well-developed sheered coal in Hancheng, with low permeability.

Hydrological conditions will have an influence on CBM conservation. In the Ordos basin, the Ordovician karst aquifer contains the most water-bearing strata, being separated by aluminum mudstone in the Benxi formation with coal-bearing strata, and is 5–48 m in thickness. Due to secondary faults and other structures, the aluminum mudstone may be lacking locally, which causes the karst water to be connected with sandstone fissure water in coal-bearing strata.

Controlled by the Lvliang mountain anticline and the drainage datum plane of the Yellow river in the east bare rock area, precipitation recharges then runoff occurs from the east to the west along the strata trend. With the degree of mineralization increasing in the west, where the seam depth is 1000 m, karst water circulation becomes slow and transforms into a stagnant zone.

3.2. Reservoir geometry

In the eastern Ordos basin, the seam dip is 1–10°, generally less than 5°, and the burial depth increases gradually from east to west. The depth of seam No. 5 increases to 2500 m in the western border, and that of seam No. 8 is 100 m deeper than No. 5. Considering CBM recoverability, the target depth should be between 300 m and 1500 m at present.

In the eastern Ordos basin, there are 12-layer coal seams in the Paleozoic coal-bearing strata (Fig. 2), of which seams Nos. 1–5 are located in the Shanxi formation, and seams Nos. 6–12 occur in the Taiyuan formation [5,6]. Seams Nos. 5 and 8 are the main targets, and seam No. 3, which is relatively continuous, is a secondary target.

The cumulative thickness of Paleozoic seams ranges from 5 m to 40 m. The thickness of the coal seams is greatest in the north (Fig. 3), with a border of Xingxian county, cumulative seam thickness is more than 20 m in the north, with local 40 m thickness; thickness ranges from 10 m to 20 m in the south.

Seams Nos. 3 and 5 are developed over the whole region and the thickness is 0.8–15 m (Fig. 3a). The thickest section is located in the northeast part, up to 15 m thick, and locally becomes less than 3.5 m thick in the central and south part. The thickness of seam No. 8 varies from 2 m to more than 20 m. South of latitude 38° north, the thickness is generally less than 5 m, whereas north of the line, the thickness is more than 5 m (Fig. 3b). Similar to seam No. 5, the coal accumulation zone of seam No. 8 is located in the northeastern part and is generally 8 m in thickness, though the thickest section is more than 20 m in thickness.

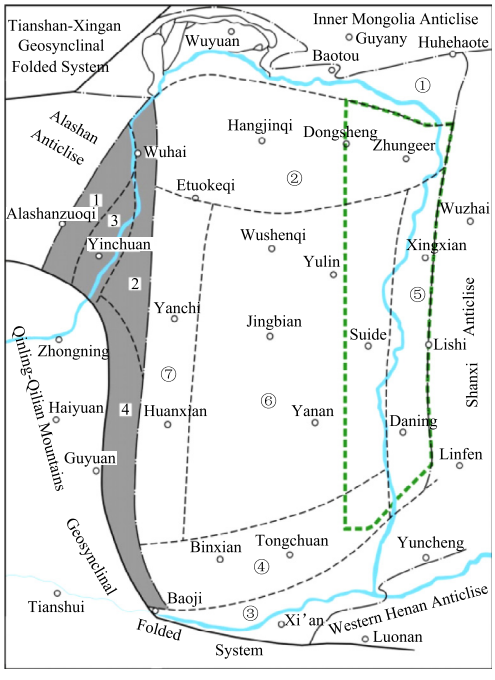

Fig. 1. Tectonic units in the Ordos basin (Ordos basin: ① Hetao rift; ② Yimeng uplift; ③ Weihe rift; ④ Weibei uplift; ⑤ Folded belt of west Shanxi; ⑥ Slope of north Shaanxi; ⑦ Tianhuan depression. Fold-thrust belt in the western Ordos basin: 1-Helan mountain fold-fault zone; 2-Zhuozi mountain-Hengshanbao fold-fault zone; 3-Yinchuan rift; 4-Qinglong-Yunwu mountain fold-fault zone; Dash line shows the scope involved in the paper).

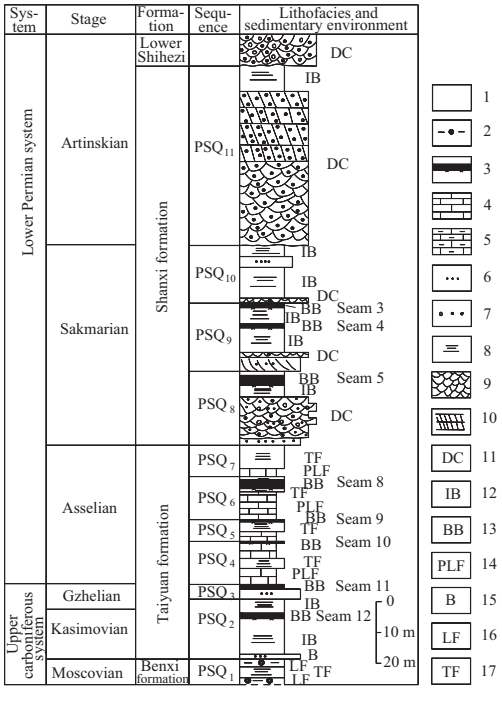

Fig. 2. Coal depositional system and stratigraphic sequence. (In case of borehole ZK17 in Wubao. 1-Argillaceous rock; 2-Aluminum mudstone; 3-Coal and root clay; 4-Limestone; 5-Argillaceous limestone; 6-Sandstone; 7-Pebbly sandstone; 8-Horizontal lamination; 9-Trough cross-bedding; 10-Plate cross bedding; 11-Distributary channel; 12-Distributary bay; 13-Peat mire; 14-Carbonate platform; 15-Sand bar; 16-Lagoon; and 17-Tidal flat.)

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