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The division and geologic controlling factors of a vertical superimposed coalbed methane system in the northern Gujiao blocks, China

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ABSTRACT

The Gujiao blocks are abundant in coalbed methane (CBM) resources. The reservoir pressure and pressure gradient in this area vary different for different mine fields. With increasing burial depth, the reservoir pressure increases. The reservoir pressure gradient ranges from 0.41 to 0.95 MPa/100 m; therefore, the reservoir can be classified as an under-pressurized reservoir. The southern region of the study area is a groundwater retention area, whereas the northern region is a runoff area. The gas content gradually increases from north to south. Taking the Miaogou limestone (L_1) and Xiedao limestone (L_4) as the boundary, three separate gas-bearing units can be divided vertically. The sequence stratigraphy structure is closely related to the quality of the CBM systems. The transgressive system formation provides a good sealing barrier that can be vertically divided into three CBM systems. In controlling the coal reservoir and the tectonic and hydrology conditions, components of the CBM system can communicate with each other in fracture development areas, which are suited for multi-layer drainage. However, we must design a method of development according to the law of diminishing fluid pressure of different CBM systems.

1. Introduction

Coalbed methane (CBM) resources are abundant in China. CBM recovery from coal seams will both benefit mining safety and reduce greenhouse gas emissions (Karacan et al., 2011). However, the CBM geology of China is complex. The country features many vertical coal seams, such as the south Qinshui basin and the west Guizhou basin group. By not considering the differences in properties between coal seams, the results of multilayer production may be poor, thus affecting the production ability of CBM wells (Guo et al., 2013; Fu et al., 2013; Vishal et al., 2013a, 2015a; Qin et al., 2014). Liu et al. (1998) proposed the concept of a "coalbed methane system," which refers to the concept of a "petroleum system" (Magoon and Dow, 1994). If fluid lacks the ability to be exchanged between different coal seams and the pressure system of the coal seam group or even a single coal seam and its controlled gas-bearing properties are relatively independent, an unattached multiple superposed CBM system will form (Qin et al., 2008). CBM systems with different "flow units" (Ebanks, 1987) vary in terms of reservoir pressure and physical conditions (Ayers, 2002) and require different methods if development (Guo et al., 2013). Therefore, the study of unattached multiple superposed CBM systems is important for the exploration and development of CBM accumulation theory (Su et al., 2005; Yang, 2011).

The Gujiao blocks are located in the Xishan coalfield, western Taiyuan City, Shanxi Province, one of the commercial development areas in northern China (Qin et al., 2012b). The CBM resources of the Gujiao blocks amount to approximately 82 billion m^3 (Mo et al., 2012). The abundant resources, shallow burial depth, high gas

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content, and high permeability are conductive to CBM recovery (Liu et al., 2005; Wang et al., 2007). The Xishan Lanyan CBM Corporation has drilled more than 700 wells in the aera. The gas production of a single well can reach more than 1200 m^3/d. The targets for CBM recovery are the No. 8 and 9 coal seams in the Taiyuan Formation and the No.2 coal seam in the Shanxi Formation. However, the results of multiple combination recovery attempts and the possible occurrence of an unattached multiple superposed CBM system require further discussion.

There are numerous methods for studying unattached multiple superposed CBM systems, such as the reservoir fluid pressure method (Powley, 1990; Zhang, 2002; Guo et al., 2014; Vishal et al., 2015b), the interwell flow capacity index method (Canas et al., 1994), the air content waving vertically method (Ye et al., 1999; Qin et al., 2005, 2008; Lei et al., 2012), the permeability method (Hearn et al., 1984; Rodrguez and Maraven, 1988; Hamlin et al., 1996; Vishal et al., 2013b; Fan et al., 2014), and the sedimentary sequence controlling method (Rodrguez and Maraven, 1988; Martin et al., 1997; Allen and Fielding, 2007; Qin et al., 2008; Yang, 2011; Shen et al., 2012). The first three methods quantitatively characterize unattached multiple superposed CBM systems. The sedimentary sequence controlling method explains the mechanism of formation of unattached multiple superposed CBM systems. Using basic geological data gathered from the Gujiao blocks and the above mentioned analysis methods, herein, we will systematically analyse the vertical superimposed CBM system of the northern Gujiao blocks.

2. Geological setting

2.1. Tectonic setting

The tectonics of the Gujiao blocks, which include five mine fields, are complex. A series of various scale NE–SW-strike faults develop in this area, such as the Gujiao fault, Duerping fault, and Wangfeng fault. The South-North axial strike fold develops in the western block in the Malan syncline, and the northeast axial strike folds develop in the eastern block in the Shiqianfeng syncline. The coal seam is substantially destroyed by the structure in the northwest block and less destroyed in the central and southern regions of the study area (Fig. 1).

2.2. Coal-bearing strata

The coal-bearing strata of the Gujiao blocks consist of the Upper Carboniferous series Benxi (C_{2b}) and Taiyuan formations (C_{2t}) as well as the Permian Shanxi (P_{1s}) and Xiashihezi formations (P_{1x}). The thickness of the Benxi formation is in the range of 13.77–45 m, with an average thickness of 30 m. The Benxi formation was deposited in a seashore environment. The contact relationship between the Benxi formation and the Ordovician Fengfeng formation is a parallel unconformity. The Taiyuan formation contains the main coal-bearing strata, which are 84–136 m thick, with an average thickness of 100 m. The formation was deposited in a seashore-delta environment and consists of sandstones, mudstone, siltstone, limestone and coal. The Dongdayao limestone (L_5), Xiedao limestone (L_4), Maoergou limestone (K_2), and Miaogou limestone (L_1) are stable. The No. 8 and 9 coal seams are the main mineable seams. The thickness of the Shanxi formation is in the range of 30–70 m, with an average thickness of 60 m. The formation formed in a delta-coastal plain environment. The No. 2, 3, and 4 coal seams are the main mineable coal seams (Pan and Cheng, 1987) (Fig. 2).

2.3. Hydrology

The Gujiao blocks are mainly controlled by the Malan syncline.

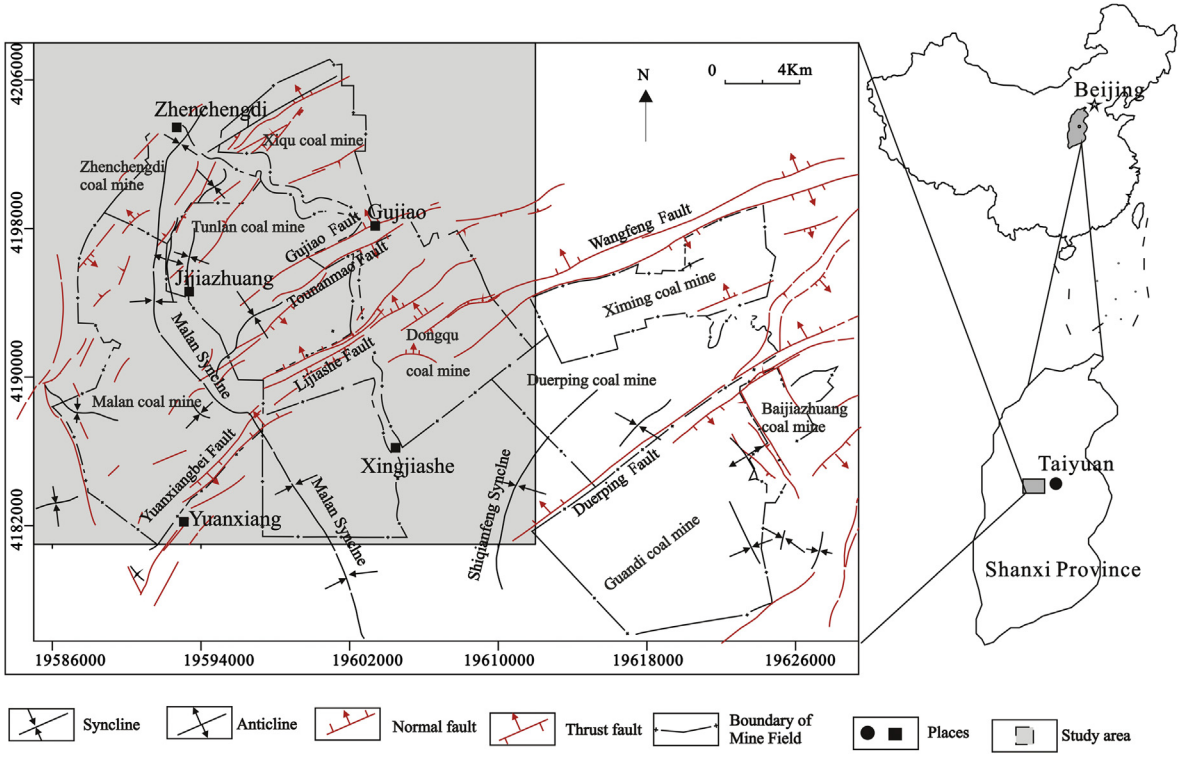

Fig. 1. Map of Gujiao blocks showing the major structures (modified from the hydrological map of the Xishan coalfield).