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Research Article

Engineering geological models for efficient development of high-rank coalbed methane and their application − Taking the Qinshui Basin for example☆,☆☆

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Abstract

Low average single-well production resulting in low economic benefit has become the main bottleneck of the CBM gas development in China. So it is significant to choose suitable efficient development technologies based on CBM geological factors for high rank CBM recovery enhancement. In view of this, CBM geological factors were analyzed, different geological models were established and the corresponding models of development engineering technologies were thus put forward. It was proposed that the four main factors affecting high rank CBM recovery from a lower degree to a higher degree respectively include coal texture, rank of coal metamorphism, in-situ stress, and the ratio of critical desorption pressure to initial reservoir pressure. On this basis, four engineering geological models were classified as follows: vertical well, open-hole multilateral horizontal well, U-shaped and roof tree-like horizontal wells, and fish-bone and L-shaped wells. It is concluded that the former two models are more adaptable in such areas with better coal texture and high degree of thermal maturity, while the latter two are commonly applied in a wide range of areas.

Keywords: Qinshui Basin; High-rank coalbed methane (CBM); Coal texture; Rank of coal metamorphism; In-situ stress; Ratio of critical desorption pressure to initial reservoir pressure; Engineering technology; Geological model; Optimization model; Development benefit

Commercial production of coalbed methane (CBM) has been successfully realized in the southern Qinshui Basin, the most important high rank coal reservoir development area in China [1−3]. However, affected by such geologic characteristics as low pressure, low porosity, low permeability, undersaturation and high heterogeneity, the development effect of vertical well development engineering technology dominated by active water fracturing is largely different in the blocks with different geologic conditions: the daily gas flow rate per well exceeds 3000 m^3 in some areas, or lower than 1000 m^3 in other areas, and lots of low yield and low efficiency wells even occur. Taking the Zhengzhuang−Fanzhuang block as an example, the daily gas flow rate of 1196 vertical wells is lower than 1000 m^3, accounting for 64.5% total vertical wells (1853 vertical wells); however, about 10000 m^3 daily gas flow rate is obtained in the vertical well low productivity area by roof tree-like horizontal wells. Therefore, the clarification, classification and evaluation of geologic factors that affect the development

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effect of high-rank coalbed methane and the selection of suitable and efficient development engineering technologies are of great significance strategically for enhancing the single well gas flow rate and the realization of large-scale efficient development of high-rank coalbed methane in China [4].

1. Geologic factors affecting development effect of high-rank coalbed methane

Numerous researches and practices have been implemented abroad on medium−low rank coalbed gas. Usually, appropriate development engineering technologies are selected based on such geologic factors as gas content, permeability, water saturation, in-situ stress, reservoir mechanical strength and thickness. For low rank coal reservoirs, coiled tubing drilling technology and high pumping rate nitrogen foam fracturing technology have been developed in Canada, and some drilling technologies like MRD, TRD and U-shaped horizontal well drilling as well as drilling along high angle coalbed have been developed in Australia. For medium rank coal reservoirs, open hole cavity completion technique has been developed in the San Juan Basin, and casing completion + fracturing technology has been developed in the Black Warrior Basin and the Raton Basin [5−9]. However, there are rare studies dealing with the geologic factors affecting the development effect of high-rank coalbed methane. In this paper, after reviewing the previous studies, and the development practices of high-rank coalbed methane in southern Qinshui Basin, the authors believe that the coal texture, rank of coal metamorphism, in-situ stress and ratio of critical desorption pressure to initial reservoir pressure are the major geologic factors affecting the development effect of high-rank coalbed methane.

1.1. Coal texture

Coal texture refers to the grain size, morphologic characteristics and interrelationship of coalbed components [10]. It reflects the damage level of in-situ stress to coalbed or coal seam in the course of geologic evolution. Coal is divided into 4 types according to its damage level: primary texture coal, cataclastic coal, flax seed coal and mylonitic coal [11,12]. Specifically, flax seed coal and mylonitic coal are severely damaged, with poor permeability and poor fracturability; during fracturing, the coal surrounding the wellbore is compacted, leading to the failure of normal fractures generation. When this type of reservoir is developed by horizontal well drilling, the wellbore is apt to collapse in the course of drilling or gas recovery by water drainage, bringing extreme challenges to operations. Meanwhile, very low permeability makes it impossible to obtain high production rates. Therefore, this type of reservoir can hardly be developed beneficially using the available engineering technologies. Cataclastic coal still contains endogenic fissures and also more exogenous fissures and inherited fissures. For high metamorphic coal without endogenic fissures, the permeability is much higher, but the fracturability is lower, with no fractures generated by fracturing; wellbore is also apt to collapse in the course of drilling or gas recovery by water drainage when this type of coal is developed by horizontal well, and instead the horizontal well with support is an effective technique to realize beneficial development of this type of reservoir. The development engineering technology suitable for this type of reservoir is still under consideration. Primary texture coal is preserved completely, which is favorable for creating long fractures by fracturing, and the success ratio of horizontal well drilling is high. Both vertical and horizontal wells are suitable for the development of this type of reservoirs. According to the statistics for the Zhengzhuang−Fanzhuang block, more than 90% of vertical wells with a daily gas flow rate higher than 1000 m^3 distribute in the area where the thickness of primary texture coal accounts for more than 2/3. Therefore, the primary texture coal development area is the preferred development target, and it is also the basic geologic factor for the efficient development of coalbed methane.

1.2. Rank of coal metamorphism

At the same effective confining pressure, the compressive strength of anthracite tends to drop with the increase of metamorphic rank, and the firm coefficient of coal sample decreases correspondingly [13]. Therefore, the fracturability of high rank coal reservoir strengthens with the increase of rank of coal metamorphism, and the fracturing stimulation effect also gets better.

The relation between gas flow effect and rank of coal metamorphism in vertical wells of the Zhengzhuang−Fanzhuang block in southern Qinshui Basin is shown in Fig. 1. It can be seen that the single well gas flow rate of high-rank coalbed methane vertical well increases with the increase of vitrinite reflectance (R_o). When R_o>3.8%, the daily gas flow rate exceeds 1800 m^3, efficient development is realized. When R_o<3.8%, the daily gas flow rate is lower than 1000 m^3, beneficial development is not realized. Therefore, R_o = 3.8% can act as a key criterion to judge whether vertical well development is suitable.

1.3. In-situ stress

The present in-situ stress field not only controls the openness of cleat, but also affects the morphology and length of

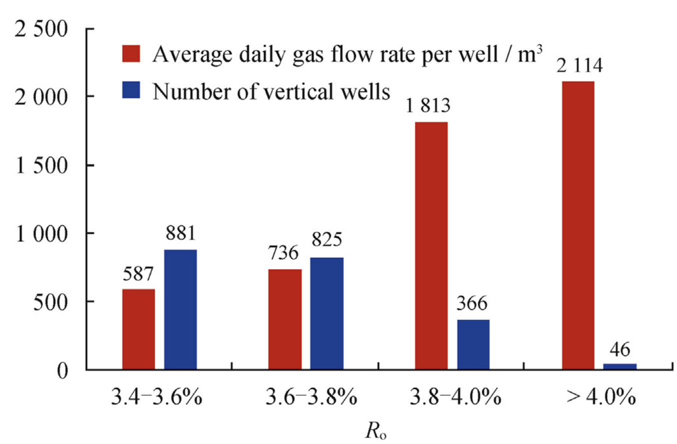

Fig. 1. Vitrinite reflectance vs. single well daily gas flow rate of vertical wells.