Analysis of main control factors of CBM productivity and optimization of sweet spot area in S block of Surat basin

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Abstract. S block is located in the eastern margin of Surat basin, with large area and great difference in geological conditions. How to optimize the sweet spot development zone is the key to achieve the economic and efficient development of the block. Based on the static and dynamic data, this paper conducts the sensitivity analysis for peak gas rate of well, Estimated ultimate recovery (EUR) of well and coal reservoir geological parameters. On the precondition of coal seam permeability higher than 100md, the coal seam thickness and gas content are the main factors affecting the development effect. According to the differences of key reservoir parameters, four types of reservoirs are divided: type 1 reservoir thickness ≥ 20m, dry-ash-free gas content ≥ 4m³/t; type 2 reservoir thickness ≥ 20m, dry-ash-free gas content between 3.6-4m³/t; type 3 reservoir thickness between 10-20m, dry-ash-free gas content between 3.2-3.6m³/t; type 4 reservoir thickness between 10-20m, dry-ash-free gas content between 2.8-3.2m³/t. Considering the reserve abundance and exploitable value, reservoirs of type 1 and 2 are considered as the development sweet spot area, which provides guidance for optimum selection of development area of coalbed methane (CBM) in S block of Surat basin.

1. Introduction

There are abundant CBM resources in the Middle Jurassic of Surat basin [1]. S block is located in the high structural part of the east wing of the basin syncline. At present, the development area of low rank CBM field in the block is only 200 km², less than 4% of the block area. Considering the large block area, many vertical strata and complex geological conditions of CBM, how to achieve high-quality development of the block is the key to economic and efficient development.

The target coal seam of S block is located in Walloon subgroup of Injune Creek group of Middle Jurassic, with a longitudinal span of 350-400m. It is divided into two sets of coal seam groups, Juandah and Taroom, from top to bottom (Figure 1). The upper Juandah coal seam group is consists of four sub coal seam groups (Kogan, Macalister, Wambo and Argyle), and the lower Taroom coal seam group is consists of two sub coal seam groups (Upper Taroom and Condamine). The sub coal seam group can be subdivided into several single coal seams.

The coal measures in S block are generally shallow, and the maximum depth of coal seam is no more than 850m. The coal seam in the block is a typical low rank with an average Ro of 0.6%, the cumulative net thickness of the coal seam is mainly between 5-35m, the permeability of the coal seam is mainly between 100-450mD, the dry-ash-free gas content of the coal seam is mainly between 2-6m³/t, the ash content and moisture of the coal seam are relatively homogeneous and stable with an average ash content of 28% and an average moisture of 6%.
2. Evaluation index of productivity of CBM
The peak gas rate of development wells reflects the productivity of a well [2-3], and the EUR of well reflects the estimated ultimate recovery of well. Therefore, the peak gas rate of well and the EUR of well are selected as important indicators to evaluate the productivity of CBM well.

2.1. Peak gas rate statistics
In order to avoid the abnormal high value of gas production due to abnormal production factors of development wells, the average value of gas production for 10 consecutive days is obtained from the gas production curve as the peak gas rate of well. According to statistics, the peak gas rate of 23 production wells in the production area is between 1100 and 3850Mscfd.

2.2. Prediction of EUR of well
The CBM in S block has been put into development since 2007, with a long production history and a good production law. Therefore, it has a good reliability to use the natural decline prediction method to calculate the EUR of well. Through the decline prediction, the EUR of well is predicted and calculated for a production well with a production period of more than 7 years in the gas field (Figure 2). The EUR of well of 23 production wells is between 0.9Bcf and 9.8Bcf.

2.3. Relationship between peak gas rate and EUR of well
Through peak gas rate statistics and EUR calculation, the peak gas rate of 23 production wells has a good consistent positive correlation with EUR of well (Figure 3), both of which can reflect the matching relationship between productivity of well.
3. Analysis of sensitive reservoir parameters of gas productivity evaluation index
For the development of CBM, the permeability, gas content and thickness of CBM are the main parameters that affect the productivity of CBM [4-6]. For the above 23 production wells, the sensitivity analysis was conducted on the peak gas rate of well, EUR of well and the above main parameters.

3.1. Sensitivity analysis of coal seam permeability on well productivity
The permeability range of the coal seams is between 100 and 420mD according to the 23 production wells. As shown in Figure 4, under the condition of high coal seam permeability, there is no obvious correlation between peak gas rate of well, EUR of well and coal seam permeability.

3.2. Sensitivity analysis of gas content on well productivity
According to the historical production data of 23 CBM wells, the correlations between peak gas rate, EUR and dry-ash-free gas content are established. As shown in Figure 5, with the increase of dry-ash-free gas content in coal seam, the peak gas rate of production of wells and EUR of wells show an obvious increase trend.
3.3. Sensitivity analysis of coal seam thickness on well productivity

Based on the coal seam logging interpretation results of 23 production wells, the coal seam thickness of them is between 24-38m. With the increase of the coal seam thickness, the peak gas rate of production wells and the EUR of well show an increasing trend (Figure 6). The coal seam thickness has a relatively obvious control over the gas productivity.

4. Coal reservoir division and optimization of sweet spot area

Based on the drilling data, coal reservoir core data and test data, a three-dimensional geological model is built to form the spatial distribution model of the structure, burial depth, coal seam thickness, gas content and permeability parameters of coal reservoir in block, which lays the foundation for the division of coal reservoir and the optimization of sweet spot area.

Based on the main parameters of productivity, the standard of reservoir division is established. Considering the shallow surface phreatic layer, low gas content and the limitation of surface casing, the shallow coal seam is not used as the development basis for the buried depth of 150m. Therefore, with the coal seam thickness (150-800m) as the preferred parameter, the coal reservoir is preliminarily divided into two categories: ① more than 20m; ② 10-20m; Based on the coal seam thickness, the coal reservoir is further divided into four categories according to the variation of the dry-ash-free gas content, as shown in Table 1.

According to the above classification of coal reservoirs, type 1-2 coal reservoirs are defined as dessert areas. The reserve abundance of sweet spot area is large, accounting for 81% of the block.
reserve, and the area only accounts for 55%. Under the condition of high permeability, the type 1 and type 2 coal reservoirs have the basis of block high-quality development reserve.

Table 1. Coal reservoir division and sweet spot optimization of S block in Surat basin.

| Classification of coal reservoir | Coal seam thickness (m) | Dry-ash-free gas content (m$^3$/t) |
|---------------------------------|------------------------|----------------------------------|
| Type 1                          | ≥20                    | ≥4.0                             |
| Type 2                          | ≥20                    | 3.6-4.0                          |
| Type 3                          | 10-20                  | 3.2-3.6                          |
| Type 4                          | 10-20                  | 2.8-3.2                          |

5. Conclusions
Based on the well productivity analysis of gas field in S block, it is clear that the thickness of coal seam and the dry-ash-free gas content of coal seam are the main geological factors affecting well productivity under the condition of high permeability of coal seam.

Based on the criteria for coal reservoir division, S block is divided into four types of coal reservoirs: type 1 coal reservoir thickness ≥20 m, dry-ash-free gas content ≥4 m$^3$/t; type 2 coal reservoir thickness ≥20 m, dry-ash-free gas content between 3.6-4 m$^3$/t; type 3 coal reservoir thickness between 10-20 m, dry-ash-free gas content The gas content is 3.2-3.6 m$^3$/t; type 4 reservoir thickness between 10-20m, dry-ash-free gas content between 2.8-3.2m$^3$/t.

Based on the division of 4 types of coal reservoirs, areas of type 1 and type 2 of coal reservoirs are considered as sweet spot area. The geological conditions of type 1 and type 2 coal reservoir are good, the coal reservoir is shallow, not only has good permeability, but also has high reserve abundance. The reserves in the sweet spot area account for 81% of the total reserves of the S block, and the area only accounts for 55%, which lays the foundation for high-quality development of the block.

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