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Study on Key Technologies of Coalbed Methane Development in Tiefa Coalfield

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Summary

The development of coalbed methane in Tiefa coalfield was begun in 1996 and it is one of the areas where the coalbed methane (CBM) was early extracted by the surface drilling in China. So far, there have been drilled 35 CBM wells with a cumulative production of 53×10^6m^3. Especially, the cumulative production of CBM in both wells No.DT3 and No.DT4 exceeded 15×10^6 m^3 and 20×10^6 m^3, respectively. It took the first place in the cumulative capacity of fracturing wells in China according to the statistical data. CBM development in coal mines is based on the surface drilling development and underground extraction for CBM. It brought the economic, environmental and safety benefits of new energy development and utilization, safety production of underground mine and atmospheric environmental protection and plays the model role in the development of CBM in China. This paper studied the key technologies of reservoir reconstruction used in developing CBM in Tiefa coalfield, in order to encourage the technical exchange for developing CBM of coalfields with similar conditions.

Keywords: coalbed methane (CBM); multiple coal seams; reservoir reconstruction; key technologies; research and application

1. Introduction

The Tiefa coalfield is a long–flame and fiery coalfield. The coalbed methane (CBM) resources in the zone are 10.7×10^8m^3 [1]. From 1996 to 2012, a total of 35 CBM wells were drilled, which is a typical CBM development and serves the needs of gas control in the coal mine. The key technologies for the reconstruction of CBM reservoirs are the combination of coal seam fracturing sublevels and the hydraulic fracturing completion. The Well No.DT3 drilled in 1996 has accumulated 15.4×10^6m^3 of CBM till February 2013. The Well No.DT4 drilled in 2004 has recorded the accumulated 20.16×10^6m^3 of CBM. The average production of these wells was over 2 000m^3/d and the amount of CBM supplied to the outside was 53×10^6 m^3.

2. Reservoir characteristics of CBM in Tiefa coalfield

2.1. Coal seam

The coal–bearing strata in the Tiefa coalfield exist in the Fuxin Formation of lower Cretaceous series. The lithology, facies combination and coal–bearing properties can be divided into upper and lower coal–bearing strata (sublayers), and their sedimentary characteristics are of braided stream flow and delta types. The multi–stage cyclic structures are obviously characterized by many coal seams, which have mainly medium–thick coal seams and the poor continuity. The spatial arrangement of lithofacies in the lower coal–bearing sublayer is alluvial fan–fan delta–delta plain or shallow lake sedimentary environment one by one from the basin edge into the basin. There are many thick coal seams, mainly composed of mudstone deposits, containing 10 coal seams. Here, coal seams of 12, 13, 14 and 15 are the main recoverable coal seams. The lithofacies composition of the upper coal–bearing section is similar to that of the lower coal–bearing sublayer. The delta plain is the main coal–rich environment with 10 coal seams, of which 4, 7, 8 and 9 coal seams are the main recoverable seams.

2.2. Structural features

The Tiefa Basin is recognized as a semi–fault graben or fault–breaking type, the main strike of which is elongated in north–northeast direction. Its formation and evolution were governed by various tectonic systems in a region, and the subsidence of the basin basement was affected by double factors such as the fracture of the basin edge and the subsidence in Songliao basin area. The strike of the fractures of the basin edge is north–northeast. It controls not only the distribution of the Tiefa basin but also the coal accumulation and displacement in the sedimentary environment inside the basin. Therefore, the sedimentary extent is always larger in the western part of the Tiefa coalfield and forms a zone of sedimentary center in the basin. The Daxing Mine field is the sedimentary center of the basin and forms the coal–accumulating center of the Tiefa coalfield. Also, it is the main area for the exploration and development of CBM.

2.3. Coal reservoir characteristics and coal–bearing properties

There are many coal–bearing seams within the Fuxin formation in the Tiefa coalfield. The coal seams in the mid–western coalfields were well developed and distributed along the north–northeast direction. The coal seams are relatively stable, and the tectonic structure of each coal seam in the western edge of the basin is complex with bifurcation, thinning and wedging out.

The joints of coal seam are moderately developed, the number of surface joint is about 4–15 sets/5cm and the end one 2–4 sets/5cm. The main joint system consisted of isolated net structures. The joint development is closely related to the coal type. Mainly, the coal seams No.7, 9, 12, 13 and 14 with bright coal had the relatively good joint development.

The gas contents of the coal seams tested by the desorption method for the coal samples obtained from geological drilling holes and the CBM wells in the coal field are as follows:

Table 1. Gas content of the coal seams by the desorption method.

Coal seam number	Gas content, m^3/t
4	3.01–14.19 8.43
7	2.29–17.20 7.24
12	3.91–23.30 8.85
15	2.17–26.28 8.34

The permeability of coal seams was tested by injection/depressurization method in test wells, and some reference data of coal reservoir are obtained. Especially, the permeability of coal seams is 0.01–1.507mD (millidarcy), and the difference is large.

2.4 Abundance of CBM resource

The CBM resources in the Tiefa coalfield are abundant, which is profitable to the exploration and development of CBM. Now, the coal reserves are of 1.4×10^8 t, the CBM resources about $10.7\times10^8 m^3$, and the resource per unit area is of $126\times10^6 m^3/km^2$. It belongs to the small and medium–sized CBM field with good development conditions. Because the CBM resources are thin but rich, it is suitable for exploration and development of CBM.

3. Application of key technology for the reservoir reconstruction

3.1. Multiple coal seam fracturing combination and technical principle

The main conditions for the gas extraction by surface drilling, are depressurization, desorption, diffusion and seepage in the coal reservoir. The purpose of hydraulic fracturing is to connect and expand the crack system in the coal seam by injecting the high–pressure water into the coal reservoir, and thereby to expand the crack channel [2, 3]. The fracturing sand supports the channel by carrying the fracturing sand with a large amount of fracturing fluid after the completion of fracturing. Then the artificial net system is formed in the coal reservoir so as to reduce the gas flow resistance and increase the productivity. However, in case of the large interval between multiple coal seams, this leads to excessive length of the fracturing section and to the large variation of liquid partial pressure difference. Also, there is a considerable limitation in liquid distribution and it limits the extension of the joint radius. Therefore, the key technology for developing CBM in the Tiefa coalfield is to reasonably combine the coal seams and conduct the fracturing by dividing sublayers.

3.2. Optimization of technical parameters

The principle of sublayer division is as follows: The combined sublayer thickness is about 35m depending on the coal seam condition. The sand filling thickness is generally larger than 15m to prevent the sand outflow. The perforating parameters of the coal seam are 102 bombs with a diameter of 89mm, phase 90° and 16 bombs/m. Top and bottom layers of the sandstone and the interlayer can be used for auxiliary perforation to create more effective and robust seepage channel of CBM. When the combination section of the coal seam exceeds 15m, it is possible to apply the artificial partial flow and overcome influence of the pressure gradient difference on the fracturing partial flow, by using the globe division pressure or sand filling with section plug. That is, the range of the reservoir reconstruction is maximized.

The basic parameters for fracturing are as follows:

(i). Pump discharge: $8m^3$–$10m^3$/min
(ii). Sand content: average 10% or more
(iii). Sanding method: using step sanding
(iv). Fracturing method: using casing fracturing
(v). Fracturing method with sublayer combination: using returning sand filling sublayer
(vi). Support selection: 20/40 mesh quartz sand (tailing sand 16/20 mesh)
(vii). Configuration of fracturing fluid: use clean water + 2% KLC + drainage promoter of 1 ‰.

The addition of KCL prevents ash swelling with water in the coal seam and acts to maintain the cracks. The addition of the drainage promoter can mainly reduce the backflow resistance of the fracturing fluid to a certain extent, and overcome the influence of the water tension on the resistance of the micro–channel.

3.3. Typical design for fracturing sublayer combination and perforation fracturing

In this paper, only the well No.DT3 of CBM in Tiefa coalfield is taken as an example to introduce the key technologies and design concepts related to coal reservoir reconstruction (Fig. 1).

Fracturing combination and perforation fracturing design for well No. DT3 are as follows (from bottom to up):

The first fracturing interval: 754.55–719.85m (15, 16, 17 coal), sublayer thickness 34.70 m, coal thickness 10.20m, perforation thickness 14.70m, total fracturing liquid volume 1000 m^3 (pre–liquid $400m^3$), sanding amount $60m^3$, globe division pressure, upper back sand filling sublayer thickness 38.00m.

The second fracturing interval: 681.36–640.60m (12, 13, 14 coal), sublayer thickness 40.75m, coal thickness 16.04m, perforation thickness 28.20 m, total fracturing volume 1 $000m^3$ (pre–liquid $400m^3$), sanding amount $60m^3$, globe division pressure, upper back sand filling sublayer thickness 109.00m.

The third fracturing interval: 531.85–501.65m (6, 7, 9 coal), sublayer thickness 20.30m, coal thickness 10.87m, perforation thickness 19.76m, total fracturing liquid volume 1 $000m^3$ (pre–liquid $400m^3$), sanding amount $60m^3$, globe division pressure, upper back sand filling sublayer thickness 21.98m.

The fourth fracturing interval: 479.67–461.60 (3, 4 coal), sublayer thickness 18.07m, coal thickness 8.22m, perforation thickness 12.86m, total fracturing liquid volume 1 $000m^3$ (proceeding fluid $400m^3$), sanding amount $60m^3$, globe division pressure.

3.4. Effectivity analysis of reservoir reconstruction

3.4.1. Sublayer fracturing combination of multiple coal seam can realize effective utilization of coal reservoirs.

The rational combination of fracturing intervals for the coal reservoir reconstruction can realize omnidirection and diversification, thereby to effectively repress the accidental distribution of fracturing fluid due to reservoir pressure difference, and cad create the fracturing direction artificially to maximize the reservoir reconstruction.

3.4.2. Fracturing scale determines the effect of reservoir reconstruction.

The fracturing scale determines the scope of reservoir reconstruction to a certain extent, and the scope of reservoir reconstruction determines the production capacity of CBM wells. In the design, the influence of coal seam on the leakage loss of fracturing fluid was considered, and the injection scale of proceeding fluid was increased to reinforce the connecting effect of the proceeding fluid, and the smooth sand transport was allowed to improve the formation of effective supporting cracks.

3.4.3 The productivity of gas wells was improved by carrying out perforated fracturing on top, bottom layers and interlayer of sandstone.

The fracturing of the coal reservoir after the perforation of the top and bottom plates has an important influence on the establishment of the fracture channel of the coal reservoir. The seepage direction of the coalbed methane has horizontal and/or vertical directions, and the sandstone layer can become a seepage channel or a reservoir of free gas.

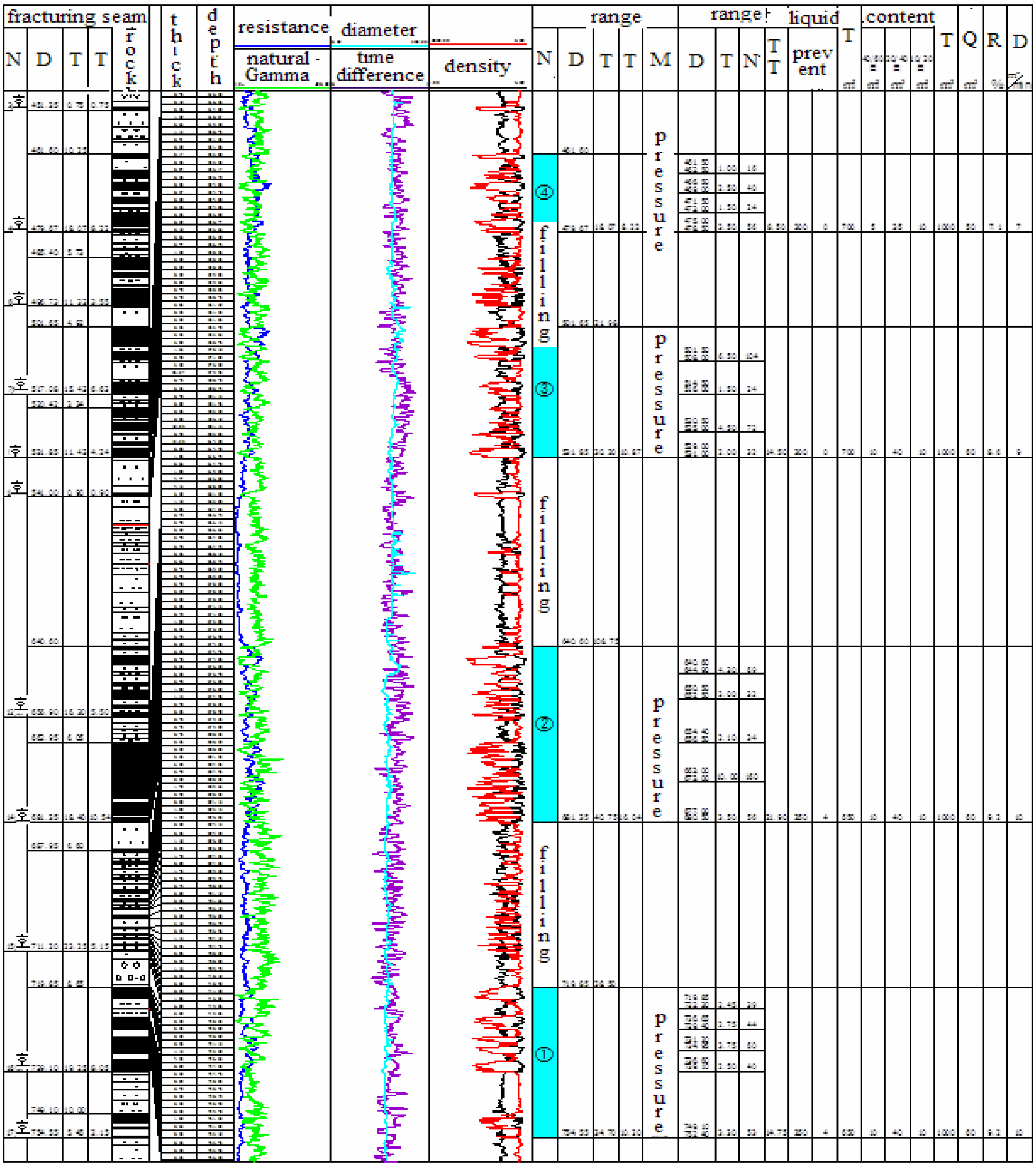

Figure. 1. Analysis diagram in borehole No.BLCX–1005 (the first fracturing range)

4. Comprehensive analysis of drainage and gas production and productivity prediction

The drilling of Well No.DT3 was started in 1996, and the drainage and gas production experiment began in May 1997 and ended in August 1998 (for 15 months). The cumulative gas production was $1.5\times10^6 m^3$, the water production 12 600m^3, the average daily gas production 3 300m^3/d, and the average daily production water was 28m^3/d. After the completion of the drainage and gas recovery test, the well was shut down, and then the well was reopened in April 2007 and ended in February 2013. The cumulative gas production was 15.4 million m^3. At present, the daily gas production of the well averaged over 3 500m^3/d and the final total gas production of one well was predicted more than $20\times10^6 m^3$.

The Well No.DT3 in Tiefa Coalfield is one of the earliest CBM wells in China, with the highest service life and the highest gas productivity in fracturing. The key technology of reservoir reconstruction introduced here plays the important role for high productivity.

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