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Evaluation on Coalbed Methane Favourable Zone of Jixi Basin

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Abstract

The stress field and seepage field are the important control factors of the CBM accumulation, preservation and effective exploitation. In order to effectively filter out the CBM favourable zone of a block in Jixi basin, the regional stress field and seepage field are studied. Firstly, the permeability sensitivity experiment under different effective stress and temperature are carried out with the JHCF intelligent core flow test instrument, the mathematical physics equations that reflect the relation between the coal permeability and the effective stress and temperature is established. Through analyzing the geological structure, reservoir and hydrogeological characteristics, a three-dimensional geological model is constructed. Applying the finite element numerical analysis method, the regional stress field, temperature field, permeability field and the seepage field are simulated. The result shows: the north central part has lower stress, higher permeability and lower velocity of seepage than other fields. It is conducive to the structural preservation; water power saving and efficient Exploitation for CBM, where can be the dessert zone for CBM exploration and development.

Key words: CBM; Jixi basin; Stress field; Seepage field; Permeability; The dessert zone

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INTRODUCTION

As the important foundation work of CBM exploration and development, the results of the evaluation and optimization on the dessert zone directly determines the success or failure of CBM development. In recent years, there are numerous studies on main controlling geological factors of CBM occurrence and CBM enrichment region optimization has been done by many scholars. According to the typical coal bearing basin, CBM enrichment patterns are summarized[1-2], and its developmental layer and characteristics in China are studied[3]. However, enrichment doesn't mean high permeability, which may not be the most dessert area for CBM development. So to screen out the target area, further evaluation and optimization is essential. Jixi coalfield is the important coal base in northeast China with rich coal-derived gas. The coal seam in Jixi basin belongs to medium metamorphic grade, and the coals are characterized by coking coal and gas coal, with a large amount of gas production. The buried depth of coal seam is relatively great, the joints are not developed, the sealing conditions of surrounding rock are better, and the gas content of coal seam is bigger. It has a broad prospect for CBM development[4]. Selecting a block of Jixi basin as the research object, Firstly, through determining the evaluation index of CBM enrichment and high yield, the primary CBM favourable development layer can be screen out. According to the datum of the drilled block provided by site such as regional tectonic feature, hydrogeologic feature, logging and fracturing, a three-dimensional geological model is established. Understand the coal reservoir physical property parameter and crustal stress condition. And applying the boundary conditions of three-dimensional geological model to simulate the distribution of regional stress field and seepage field, then the dessert zone for CBM development in Jixi basin are screened out and evaluated. Base on the study result, the cost of exploration and development can be reduced and the blindness development can be avoided. Besides, it can be timely used to conduct a more reasonable evaluation for the target area, which can provide a strategic decision for the CBM commercial exploitation.

1. DETERMINING EVALUATION INDICATORS

The distribution of CBM gas content is mainly controlled by gas generating and gas storage conditions, the effect factors including the geological structure, lithology of coal seam roof and floor, degree of coal metamorphism (namely coal rank), coal quality, coal seam buried depth and thickness, temperature, pressure and hydrological conditions and so on. Dividing CBM favourable zone is the basic work for the further CBM geological study. The "favourable development zone" for CBM consists essentially of two aspects including enrichment and high yield. The prerequisite of CBM enrichment is the favourable configuration of the conditions of some aspects such as generation, reservoir, capping, preservation and its dynamic development process, and it is a result of comprehensive action of many geological factors[5] controlled by the structural element, mainly including coal seam buried depth, structural characteristics, the stress field and the hydrological conditions. While high yield mainly depends on the permeability of coal seam, relating to the ease of enriched CBM desorbing from the coal surface and migrating into the wellbore, which represents the effective flowing capacity of CBM.

The above many effect factors are hard to quantify and are uncertainty, which makes the target area selection for CBM development extremely difficult. So it requires a scientific evaluation method for comprehensive assessment. Firstly, the evaluation indicators should be determined. The standard for selecting the indicators depends on the contribution degree to the evaluation target that refers to the optimization for the CBM favourable zone in the designated blocks. Aiming at this goal, two aspects including the CBM enrichment and recoverability should be mainly considered. Through summarizing and analyzing extensive related information about the CBM main control factors[6-7], the indicators that have greater associate degree with the CBM enrichment include: pressure, coal characteristics, coal thickness, buried depth, thickness of roof and floor, fracture density, original rock stress and velocity; and those associated with recoverability are: CBM pressure, permeability and original rock stress .

2. THE PERMEABILITY SENSITIVITY EXPERIMENT

Permeability is one of the key parameters affecting CBM recoverability, which is directly related to the recovery ratio and ultimate resource. In-situ stress has a great influence on the permeability of CBM reservoir, and many scholars such as Enever, Mckee and He Weigang conclude that coal reservoir permeability decreased with the increase of in-situ stress in index relationship[11-13]. Coring the coal sample of Jixi Basin and applying the JHCF intelligent core flow test instrument, under the constant temperature with different effective stress and the reverse condition the permeability sensitivity test is respectively conducted. Analyzing and processing the data obtained, the relationship curves are drawn and fitted as shown in Figure 1.

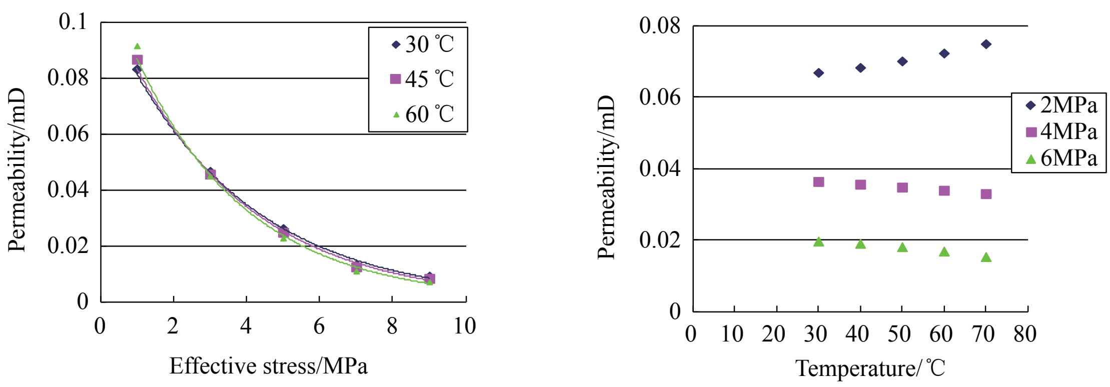


Figure 1
The Relationship Between Permeability and Effective Stress Temperature

It is concluded that the minimum principal stress and temperature affects the distribution of permeability at the same time. Through fitting the curve, its mathematical physics equation can be regressed as follows:

$$K = 0.1125e^{(-0.2293\sigma_f + 0.00026T)}. \qquad (1)$$

3. THE THREE-DIMENSIONAL STRESS AND TEMPERATURE FIELD SIMULATION

Combing with the real drilling data, stratigraphic hierarchical data and other relevant information, the regional geological structure model is established. The area of the region needed to build reaches 860 km^2. The overall buried depth of study regional strata is shallow with an average depth of about 300 m, of which the most shallow points is 100 m and the deepest depression reaches to 500 m distributing in some local areas. According to the T4-2 (the upper segment top surface of Chengzihe Group) reflector structure diagram of the southern Lishu Town Depression as shown in Figure 1, and based on a certain proportion, the outer outline profile of the region is drawn, and then its internal structure is added in. In the process of building model, due to the faults too complexity, some corresponding simplification and consolidation should be considered, of which the big fault controlling the tectonic movement is drawn and some local small faults is ignored. The final model built is shown as Figure 2.

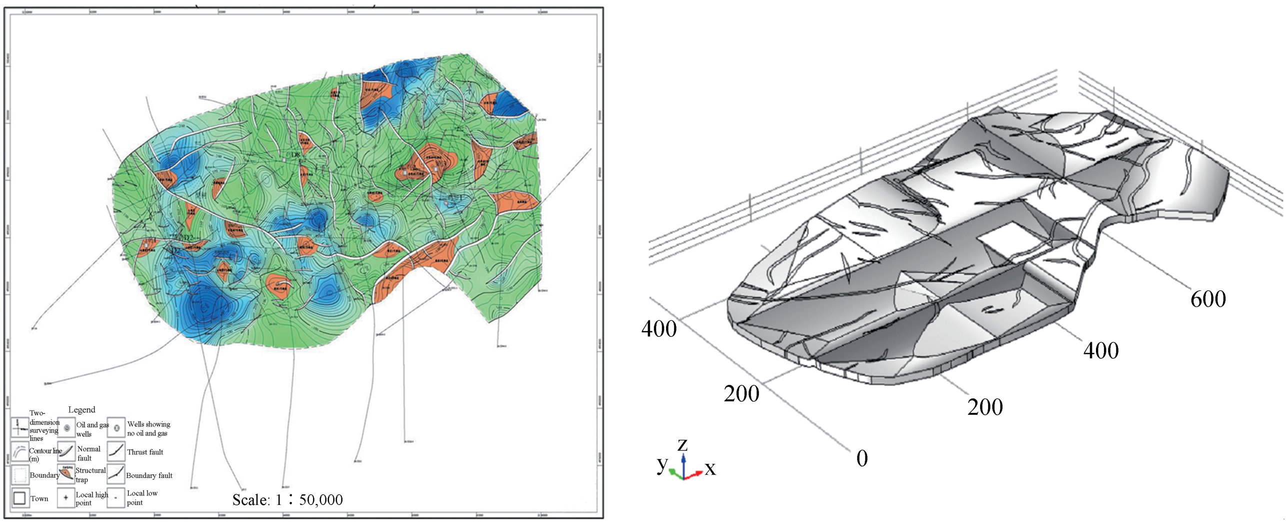


Figure 2
The Reflector Structure Diagram and the Three-Dimensional Geological Model

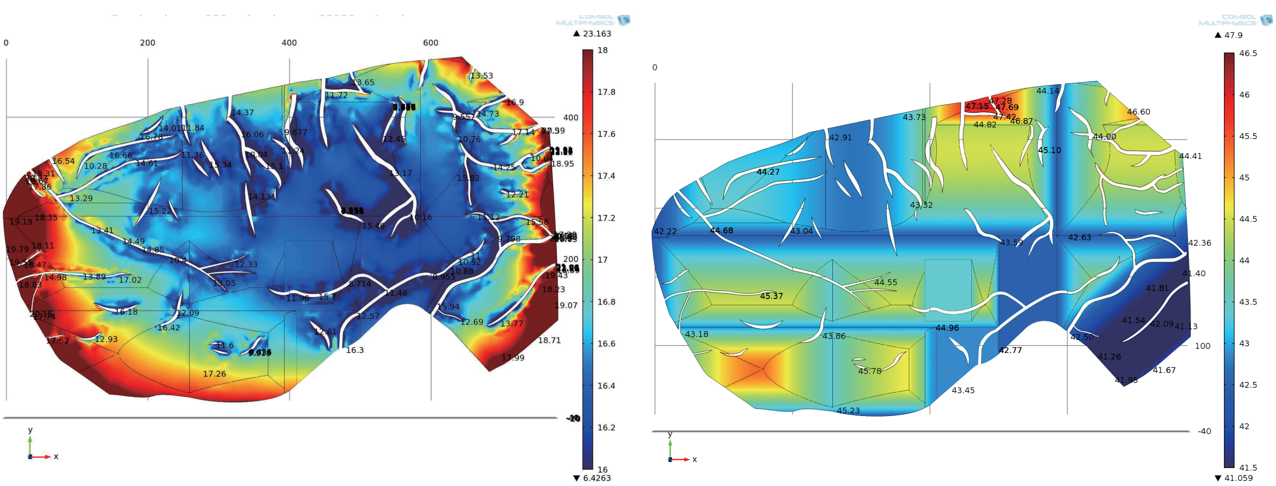
Based on the stress boundary condition of regional background and the stress state of measured points in study area, the rational loaded condition to the model can be determined, as well as the rock mechanics parameters are ensured. According to various indoor experiments and field data collection, all relevant parameters needed are gotten shown in Table 1 and 2. Then though calculating, the stress simulation results are displayed in Figure 3(a).

Table 1
The Boundary Loads of Model

Horizontal maximum principal stress /MPa	Horizontal minimum principal stress /MPa	Vertical stress / MPa	Pore pressure / MPa	Geothermal gradient/ ℃/100 m
20	15	18	5	3.2

Table 2
Basic Physical Parameters of Formation

Type	Elastic modulus E/Pa	Poisson ratio v	Density ρ/Kg·m^{-3}	Porosity ε_p	Permeability K/m^2
Coal seam	1.5×10^9	0.33	1.55×10^3	0.095	8×10^{-17}
Fault	8×10^9	0.22	2.22×10^3	0.05	1×10^{-17}



(a) (b)

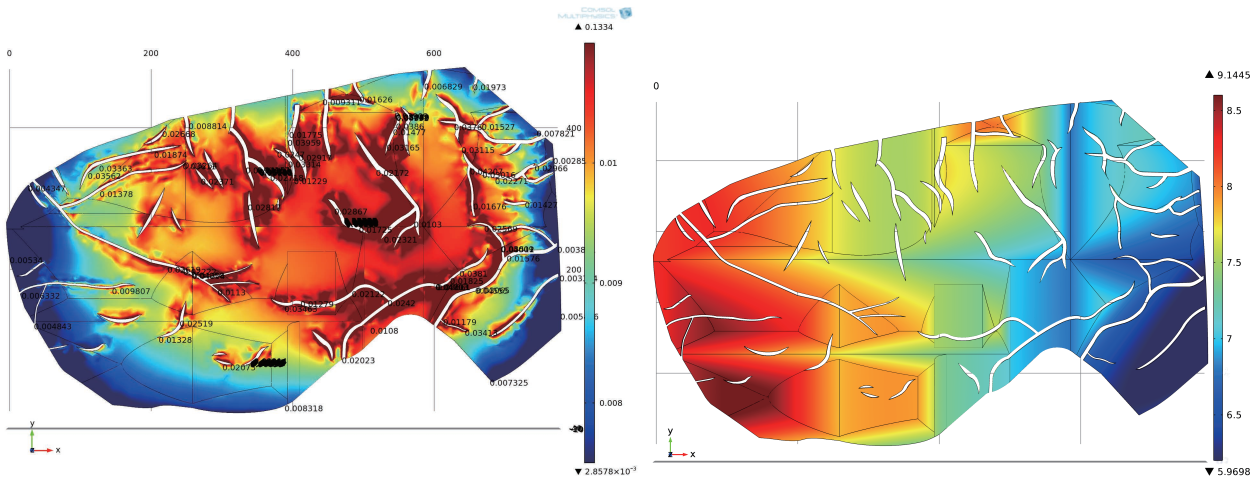
Figure 3
(a) The Minimum Principal Stress Field; (b) The Temperature Field

The minimum principal stress field and temperature field calculation results can be seen in Figure 3.

The regional minimum principal stress is in the range of 12 MPa and 18 MPa. The stress of the east and west edge is bigger and unevenly, and changes lower and smooth gradually towards the centre area. The stress of the centre area is mainly concentrated around 16.2 MPa, which can be the low stress zone. Additionally the stress is mostly compressive, in favour of the CBM preservation. The temperature is in the range of 41 ℃ and 46 ℃.

4. THE PERMEABILITY FIELD

According to the relationship of the stratigraphic minimum principal stress, temperature and the coal seam permeability obtained by the above study, the simulation on the permeability distribution of the target zone can be conducted, whose result is shown as Figure 4(a).



(a) (b)

Figure 4
(a) The Permeability Field; (b) Flow Pressure Distribution

The permeability of the centre area is relatively higher and smother than the others area, its average value is 0.0115 mD. Through the coal seam permeability distribution simulating, the central part as the high permeability zone can be effectively divided.

5. THE THREE-DIMENSIONAL SEEPAGE FIELD

On the basis of the stress field simulation boundary conditions, the seepage boundary pressure is added, that is the west side as 10 MPa and the east side as 8 MPa. In addition, the north and south both sides have no flow. Through calculating, the simulation result of the pressure distribution is obtained, that is shown as Figure 4(b). It shows that the regional flow field pressure gradually decreases from the west to the east. The seepage velocity field is shown as Figure 4(a).

The range of the velocity value is 1.85×10^{-7}~2.3×10^{-7} m/s, the central part's is relatively low and stable with the value of about 1.9×10^{-7} m/s. So the groundwater dynamic conditions of the centre area can be explained as weak and its activity is slow, which can be regarded as the retention zone. In addition, the direction of its streamline is from west to east and the regional normal faults are developed, thus the central part is conducive to the hydraulic seal.

Through the investigation and research[10], the reservoir pressure is one of the geological factors affecting CBM enrichment. Under a complete groundwater system, high reservoir pressure and high aquifer potential is beneficial to CBM enrichment.

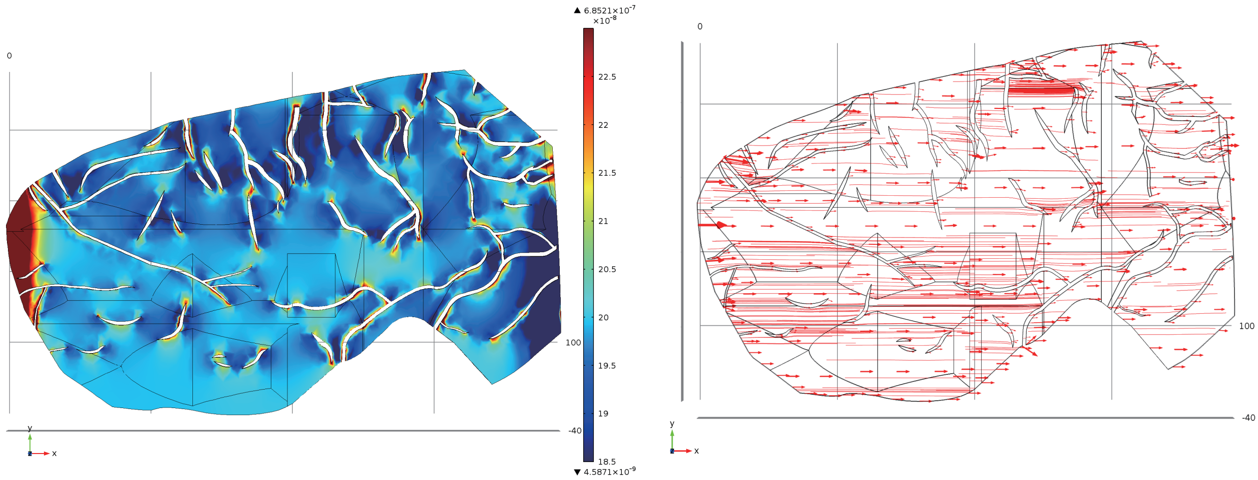


Figure 5
The Velocity Field Value and Direction Distribution

6. SCREENING OUT CBM FAVOURABLE ZONE

Through the simulation and analysis on the stress field and seepage field of Jixi basin, combined with the favourable conditions of CBM enrichment and high yield, the north central part as the favourable development zone in this layer is evaluated and selected, that is shown as Figure 6.

According to the above analysis and research, under the premise of selecting blocks, only to find out the specific reservoir tectonic stress characteristics, the hydrodynamic environment, as well as the permeability distribution, the CBM favourable zone can be screened out more effectively.

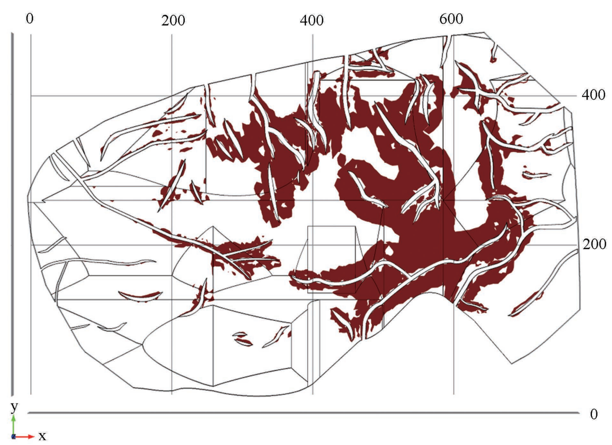


Figure 6
The Desert Zone of the Block in Jixi Basin

CONCLUSION

(a) Aiming at the favourable layer of Lishu town depression Chengzihe group in Jixi basin, three-dimensional geological model establishment and finite element numerical simulation analysis are conducted, achieving the regional distribution characteristics of the stress field and seepage field.

(b) Through testing the permeability under the constant temperature with different effective stress and the reverse condition, the mathematical physics equation of the index relationship of the minimum principal stress, temperature and the coal seam permeability is obtained.

(c) Low stress is in favour of CBM preservation and is conducive to the formation of high permeability, suitable reservoir pressure and low hydrodynamic conditions have advantages to CBM enrichment, high permeability means high yield. Based on the stress field and seepage field simulation analysis, combined with the comprehensive analysis on these beneficial evaluation standards, finally the central part of Lishu town as the CBM favourable development zone is determined.

(d) Applying the finite element numerical analysis method to study the regional stress field and seepage field, it can provide a certain reference value to improve the job level of CBM development constituency.

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