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Research on gas geological condition of Weifang mining area, Shandong Province, China

Pingli Wang a \*, Zengxue Li a, Dawei Lv a, Haiyan Liu a, Xinlong Pang a

a. Shandong Provincial Key Laboratory of Depositional Mineralization & Sedimentary Minerals, College of Geological Science & Engineering, Shandong University of Science and Technology, Qingdao 266510, China

Abstract

This article analyzed the geological conditions of the gas in Weifang mining area from aspects of the regional hydrogeology, the fault and the fold, the roof and the floor lithologic characteristic, the distribution of magmatic rock and the thickness of the coal seam roof. The study shows that the Zhuliu coal mine is of moderately complicated hydrogeology type; most of the faults in Wutu coal mine and all the faults in the other 5 coal mines are normal faults, belonging to open faults. The faults generally have water conductivity, which are beneficial to gas drainage; the roof and floor, most of which are mudstone, shale, claystone, and some sandstone and limestone with joint and bedding, have poor stability, which contributes to the overflow of the gas. The wide distribution of magmatic rocks in Wujing coal mine remarkably impacts the gas reservation, thus the gas emission is higher than the other 5 coal mines. The low thickness and lithology of coal seam roof are in favor of the emission of gas. For the reasons given above, the 6 coal mines of Weifang mining area are all low gas field. This article also predicted the gas content and the absolute gas emission of Weifang mining area.

Keywords: gas; geological condition; prediction; gas content; absolute gas emission; Weifang mining area

1. Introduction

In recent years, with the coal mining becoming further complex and the mining depth becoming deeper, the coal mine gas problems have been more and more serious; especially the coal and gas outburst causes severe casualties and damage. Hence the gas disaster has become one of the worst natural disasters of coal mines. Statistics show that the gas accidents occupy more than 40% of the whole casualties in coal...
mines. Gas is a kind of geological body in the gas form, its formation conditions, transport rules, occurrence and distribution are all controlled by extremely complex geological processes. Taken the Weifang mining area as an example in this article, the authors discuss the relationships between the mine gas and the main geological factors.

Weifang mining area is located in the middle and east of Shandong province, including 6 coal mines, with an area of about 594km². Luguang Coal Mine and Xinfang Coal Mine locate in the north of Yishu fault belt; Wutu Coal Mine, Wutu No.2 Coal Mine and Zhuliu Coal Mine are located nearly to the northwest of the fault belt; and Wujing Coal Mine is near the west of the fault belt (Fig. 1). The coal bed in the six coal mines of Weifang mining area mainly occurs in Carboniferous, Permian, Jurassic and Paleogene.

![Fig. 1 Location of Weifang Mining Area](image1)

![Fig. 2 The measured contour line of the absolute gas emission in Wujing Coal Mine](image2)

2. Regional Geology

2.1. The regional hydrogeology

The aquifer in Weifang mining area consists of the Quaternary pore water, bedrock fissure water, limestone fissure water, weathering basalt fissure water and sandstone fissure water. The water-resisting layer mainly consists of tuff, sandstone and claystone. Most of the tuff is compact and the fissures are undeveloped; the sandstone is tough; the claystone, which has strong expansion effect and water-resisting effect after absorbing, has high absorption capacity.

The fault-conducting water differs from each other in the coal series of this area, mainly relating to the lithological characters of the contacting part of the two faults, for instance, the fault belt wouldn’t conduct water when one water-resisting layer joints with another. Generally the fault-conducting water has no direct relationship with elevation, and some faults with several meters of elevation can also lead to the
water burst of the mine. Taken the factors above, the hydrogeology of Zhuliu Coal Mine is of moderately a complicated type.

2.2. The effect of fault and fold tectonics

Faults destroy the continuity of coal seams, which causes changes on the gas migration conditions. Some faults are benefit to the gas drainage, while others offer resistance and become the seepage barrier. The former is called the open fault, and the latter is called the sealed fault.

Most of the faults in Wutu Coal Mine and all the faults in the other 5 coal mines are normal open faults\(^5\), which have water conductivity and are benefit to the gas emission.

In regions of raised folds, the coal usually occurred in anticlines and synclines. As a fine gas-bearing structure, the anticline is not good for gas drainage when the roof of coal-bed has bad air permeability with the absence of structure damage. The gas at the axial part of the anticline, however, is gathered and the gas content is increased. The coal seams were generally preserved in syncline where the roof is sealed well. As a result, it is difficult for the gas to migrate along the vertical direction of the strata and most of the gas flow to the surface along the two limbs. However, it is easy to dissipate at the edge of the basin when the area of exposed coal-bearing strata is large. Generally there is higher gas content in the tightly folded zone because the strong tectonic concentrates stress; at the same time, the rock strata that were folded have strong plastic deformation and are easy to fold but uneasy to break, being well sealed, so, it goes against the dissipation of gas. Study shows that the folds of Weifang mining area have little effect on the gas occurrence.

2.3. The effect of roof and floor lithology

The rock existing on coal bed has sealing capacity; it can block and slow the loss of the coalbed methane in the form of percolation, spread, water and drain. When the roof is compact rock, such as shale and oil shale, the gas in the coal bed is easier to be conserved; when the roof is fracture rock such as conglomerate and sandstone, the gas is easier to loss. Argillaceous rock goes against the loss of the gas; its ability to prevent gas from emission will become weaker when the rock contains sandy and silty impurities. The content of silty impurities has effect on the size of the dominant pores in the pelite\(^6\).

Most of the roof and floor in the 6 minefield of Weifang mining area are mudstone, shale and claystone, there are also some sandstone and limestone with joint and bedding. They have poor stability, which contributes to the emission of gas.

2.4. The effect of magmatic rock distribution

Magma intrudes into coal-bearing strata and coal bed, leading to the expansion and compression of the coal and rock. The baking of the high temperature magma makes the rank of coal higher, which helps on the formation of gas. In addition, sometimes the magma makes the coal bed partially covered or closed. However, sometimes the weathering is strengthened for increase of fissure in the altered rock, which causes fissure channel gradually. So, the distribution of magmatic rock not only helps generating and saving gas but also helps spreading the gas. Take Wujing Coal Mine as an example, the magmatic rock of distributed along coal bed and interformational structure with the thickness of 0.3~1.8m, outputting as sill. The magmatic rock eroded and broke the coal bed extensively, making the coal bed becoming thinner or changing into natural coke or the mixture of coke and rock coke. The erosion of the magma was serious in the ninth coal seam and the eleventh coal seam. The ninth coal seam in the north and east of the field were almost changed into the mixture of coke and rock coke. At the west of the mine, the magma eroded into the eleventh coal seam seriously, accounting for 60% of the coal bed area, nearly making some sites
into no coal area. The distribution of magmatic rocks was wide, which had a big impact on the gas reservation. As a result, the gas emission in Wujing Coal Mine is higher than the other 5 coal mines (Fig. 2, Table 1).

2.5. The effect of thickness of the overlying basement

There is correlation between the depth of coal and the gas reservation in the same geological tectonic units. The increase of the depth not only increases the crustal stress, making the permeability of coal and rock becoming poorer, but also increases the migration distance to the surface of the gas, going against the emission of the gas. In the area that was not influenced by geological structure, the content of the coal bed gas increased with the increase of depth. The overlying basement is thin in most of the mines of Weifang mining area, together with the influence of lithology, they are all in favor of the emission of gas.

3. Prediction of the Gas Content and the Absolute Gas Emission

3.1. Prediction of the gas content

Taking the relationships between the absorption quantity of coal, the coal quality, the measured gas pressure and the measured gas content of Weifang mining area into consideration, the following empirical equations were obtained:

\[ W_c = W_a + W_s \]

\[ W_s = \frac{65.5(100 - A^f - W^f)}{(a + b)(V^v)^{0.146}e^{n(1 + 0.3W^f)100}} \]

\[ W_s = \frac{K_p p}{100K_r} \]

In the formula:

- \( W_a \) — absorption of coal, m³/min;
- \( W^f \), \( A^f \), \( V^v \) — the coal moisture, coal ash, coal volatile, 1.4%, 67.7%, 25.3%;
- \( P \) — the measured gas pressure, 2kg/cm²;
- \( e^a \) — temperature coefficient, 1/e^a = 0.609;
- \( e \) — Euler's constant;
- \( n \) — 0.02t / 0.993 + 0.007P;
- \( a \) — 2.4 + 0.21V^f;
- \( b \) — 1 - 0.004 V^f;
- \( W_s \) — separating gas content, m³/min;
- \( K_p \) — the porosity of coal, 6%;
- \( \gamma \) — the volume density of coal, 1.7 m³/min;
Kc——gas compression coefficient under the coal seam gas pressure,  1.098;
t——temperature,  25°C.

3.2. Prediction of the absolute gas emission

Basing on the mining depth, a linear regression of the gas emission was conducted and the following empirical equation was obtained:

\[ q = aH + b \]

In the formula:

q——the absolute gas emission quantity of the coal bed, \( m^3/min \);

a, b——regression coefficient, \( a=0.011, \ b=-4.67 \);

H——mining depth, \( m \).

The above formulas were operated for the max gas content and the max absolute gas emission, and then the table 1 was concluded.

<table>
<thead>
<tr>
<th>Coal Mines</th>
<th>Gas Content Prediction (( m^3/t ))</th>
<th>Gas Emission Prediction (( m^3/min ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wujing Coal Mine</td>
<td>4.230</td>
<td>2.760</td>
</tr>
<tr>
<td>Zhuliu Coal Mine</td>
<td>2.240</td>
<td>0.966</td>
</tr>
<tr>
<td>Wutu No.2 Coal Mine</td>
<td>3.650</td>
<td>0.460</td>
</tr>
<tr>
<td>Wutu Coal Mine</td>
<td>2.180</td>
<td>0.732</td>
</tr>
<tr>
<td>Luguang Coal Mine</td>
<td>1.188</td>
<td>0.220</td>
</tr>
<tr>
<td>Xinfang Coal Mine</td>
<td>1.400</td>
<td>0.320</td>
</tr>
</tbody>
</table>

4. Conclusions

1) The gas content and emission in coal mines are affected by complex factors such as the regional hydrogeology, the fault and the fold, the roof and the floor lithologic characteristic, the distribution of magmatic rock and the thickness of the coal seam roof. Study in this article shows that the 6 coal mines of Weifang mining area are all low gas fields.

2) The gas content and the absolute gas emission of the 6 coal mines were calculated by the empirical equations.

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