Coal Quality Characteristics and Distribution Regularity in Depth of Wangfenggang Minefield, Huainan Mining Area

Weihua Ao a,b*, Wenhui Huang a,b, Xiuyi Tang c, Ping Chen c

a School of Energy Resources, China University of Geosciences (Beijing), Beijing 100083, China
b State Key Laboratory of Coal Resources and Safe Exploitation CUMT, Beijing 100083, China
c Anhui University of Science and Technology, Huainan, Anhui 232001, China

Abstract

This paper studied the deep-seat coal seam in Wangfenggang mine Huainan area, and analyzed the characteristics of coal petrology and coal type distribution, then discussed the influences of regional geothermal history and tectonic subsidence history on regional coal metamorphism process. The results show that a series of bituminous coal band including gas coal, 1/3 coking coal, fat coal and lean coal vertically distributing in the deep seated seam (−600m ∼ −1200m). The metamorphism developing tend is same with coal seam structural shape. It presents that the tectonic stress on hydrostatic pressure state can affect coal metamorphism process. It was predicted that the metamorphic type of Wangfenggang minefield is superposition from the effect of energy transformation from tectonic stress on hydrostatic pressure state and katogenic metamorphism, which is long term regional extrusion has promoted and controlled coal metamorphism. The study on coal metamorphism on deep seated seam can be very important on coking coal’s development in China and also contribute to present metamorphism theory.

* Corresponding author. Tel.: +86-10-82322758
E-mail address: awh0223@cugb.edu.cn

Keywords: Huainan mining area, deep seated coal, coal quality, coal metamorphism;

© 2011 Published by Elsevier Ltd. Open access under CC BY-NC-ND license.
Selection and peer-review under responsibility of China Coal Society
1. Introduction

Traditional theory about coal metamorphism in China believe that, in most coal mines of North China, Jiyuan and Houma coal mining areas excluded, the rank of Permo-Carboniferous coals can merely reach flame coal, gas coal or fat gas coal, unless never been affected by the superposition of metamorphism [1]. In Wangfenggang mine, the deepest coal mine of Huainan mining area, coal quality of deep-seated seam is obviously different from that of the shallow-seated seam. A series of bituminous coal band distributes vertically in the deep seated seam from -600m to -1200m, which includes gas coal, 1/3 coking coal, fat coal and lean coal. Similar situation is also found in western area of Huainan mining area [2]. According to the drilling and geophysical data, there are no igneous rocks or insidious large rock mass, and the geothermal gradient is normal as well [3,4]. Thus, the change of coal quality cannot be explained by the principle of deep seated metamorphism merely. It is necessary to find out if there is a particular tectonic subsidence history and/or palaeo-geothermal history. Because the whole coal seams are under the huge nappe structure, and deformed-coal developed, the study about coal quality distribution and its metamorphic theory in Wangfenggang coal mine would be significant for the further development and utilization of coking coal in China [5].

Fig. 1. Structural outline map of Huainan mining area

Fig. 2. Structural section map of Huainan mining area
2. Geologic survey of research area

Huainan coal field lies in the Southeast margin of North China platform. It has a length of 180 km from east to west and a width of 15-25 km from north to south with an area of approximately 3200 km$^2$. There is a strong squeezing action in SN direction; a setup of thrust plate and nappe structure in a close EW direction (see Fig.1). In the mining area, the nappe constitutes imbricate structure, in the fault fixture block, stratigraphic dip angle rises steeply and overturns, then generate the fold belt (see Fig.2). The dip angle is gently in synclinore, which is 10°~20° in general, so there is a series of wide and gentle fold. In the area, there are two synclines and two anticlines across from south to north, named Xieqiao-Gugou syncline, Chenqiao-Panji anticline, Shangtang-Dicunji syncline and Zhuji-tangji anticline respectively. Wangfenggang minefield locates in the south of Xieqiao-Gugou syncline, which is made up of Xiejiaji monoclinal and the underpart of Lijingzi fold. It is a deep mine of Xiejiaji in old Huainan mining area. What’s more, it is the first kilometer deep mine that has the most complicated mining technical conditions in Huainan mining area. The coal-bearing strata in mine field consist of Carboniferous Taiyuan Formation, Permian Shanxi Formation, Upper and Lower Shihetang Formations. The coal seam in Taiyuan Formation is thin and unstable, for which it can’t be mined. Coal-bearing section of Permian has a thickness of 680 m in total, and there are 17 coal seams that can be mined (A1, A2, B4a, B4b, B6, B7, B8, B9b, B10, B11a-up, B11a-down, B11b, C12, C13, C14, C15), and the main coal seams are including C13, B11b, B4b, B6, B7, B10. Of which, B11 in third coal-bearing member and C13 in forth coal-bearing member are the main stable mining seams in minefield.

Table 1. Measurement results of maceral and vitrinite reflectance of coal seam in Wangfenggang mine

<table>
<thead>
<tr>
<th>Coal samples</th>
<th>W$_{0i}$/%</th>
<th>Vitrinite</th>
<th>Inertinite</th>
<th>exinite</th>
<th>R$_{max}$/%</th>
</tr>
</thead>
<tbody>
<tr>
<td>C13 (5)</td>
<td>83.3</td>
<td>15.7</td>
<td>0.9</td>
<td>0.87~1.31</td>
<td></td>
</tr>
<tr>
<td>B11b (8)</td>
<td>88.5</td>
<td>11.3</td>
<td>—</td>
<td>0.98~1.54</td>
<td></td>
</tr>
<tr>
<td>B10 (1)</td>
<td>83.7</td>
<td>16.3</td>
<td>—</td>
<td>1.26</td>
<td></td>
</tr>
<tr>
<td>B8 (2)</td>
<td>85.5</td>
<td>14.4</td>
<td>—</td>
<td>1.01~1.61</td>
<td></td>
</tr>
<tr>
<td>B4b (1)</td>
<td>76</td>
<td>22.9</td>
<td>—</td>
<td>1.23~1.68</td>
<td></td>
</tr>
</tbody>
</table>

3. Coal-petrological characteristic

The macroscopic petrographic characteristics of each coal seam in the research area are mainly semi-bright coal and semi-dull coal, with weak glassy luster, and the lower coal seam is mainly glassy. Coal seam above C13 presents dark brown, while B4 coal seam does light gray. In a single section, there is always a pattern, from top to bottom——cataclastic coal, crumbled coal, mylonitic coal, crumbled coal, cataclasitic coal, and it forms a multiplex structure in which the hard nips the soft. The coal in this mining area shares the same structure type with that in other mining areas of Huainan, and the whole coal seam suffers the superposition of multiple tectonic stresses. There is mostly powdery coal in the part where stress focused [6,7].

There are above 85% contents of organic part in microscopic component (see Table 1). On the basis of content, first is vitrinite, second are semivitrinite and semifusinite; fusinite is always below 2%, exinite is
little and the most cannot be picked out. It is seen from microscopic component, vitrinite and semi-vitrinite take the lead above 70\%, the contents of semifusinite and fusinite is higher (10\%~20\%). In B_{sh} semifusinite has even got to 21\%, which has an effect on the processing property of coal and reflecting the environment is dry in coal-forming period. In the lower coal seams, with the vitrinite reflection grow, exinite cannot be observed clear gradually, but the content of fusinite and semi-fusinite obviously grow. The fusinization of exinite in deep coal seams contributes a lot to coalbed methane directly, and it also can explain that powdery coal contains high amount coalbed methane.

The samples mined from C_{13} and B_{10} coal seam are both 1/3 coking coal (see Fig.3). Fig.3a shows the anisotropy in semifusinite. The holes of semifusinite are compacted, few of which still is circular pore, and these phenomenon present an asymmetric compactness. Fig.3b shows the main maceral of local coal is desmocollinite, and it is mixed up with macrinite. Fig.3c can explain that the degree of coal metamorphism is not high, because of the existence of generous sporinite, and the sporinite hasn’t been undergoing fusinization. The desmocollinite around the macrinite or semifusinite should be packed in late period. The contents of fusinite and semifusinite are quite high, 10\%-20\% in common, which has an effect on coal’s rank. It can be inferred that drought has played a role in the earlier coal forming period, which forms the more oxidized environment.

Table 2. The coal quality indicators from different main coal seams

<table>
<thead>
<tr>
<th>Coal seam</th>
<th>(w_{g})</th>
<th>1/3 (V_{daf})</th>
<th>(C_{daf})</th>
<th>(G_R)</th>
<th>(Y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C_{13}</td>
<td>13.72–31.25</td>
<td>20.18(18)</td>
<td>21.50–35.94</td>
<td>86.25–90.87</td>
<td>57.7–96.5</td>
</tr>
<tr>
<td>B_{11b}</td>
<td>13.61–30.99</td>
<td>23.40(21)</td>
<td>19.16–30.62</td>
<td>86.80–90.83</td>
<td>34.8–94.2</td>
</tr>
<tr>
<td>B_{10}</td>
<td>21.19–32.24</td>
<td>21.62(9)</td>
<td>22.06–30.53</td>
<td>86.81–89.13</td>
<td>60.0–89.2</td>
</tr>
<tr>
<td>B_{4b}</td>
<td>17.98–31.49</td>
<td>22.39(10)</td>
<td>18.74–31.34</td>
<td>87.38–90.00</td>
<td>27.7–85</td>
</tr>
<tr>
<td>A_{1}</td>
<td>13.05–18.40</td>
<td>21.16(6)</td>
<td>17.32–25.85</td>
<td>88.68–90.99</td>
<td>15.4–80</td>
</tr>
</tbody>
</table>

Table 2 showed the approximate analysis results of the main coal seams. It is found that all of the volatile matter of each coal seam reduces with the depth of coal seam (see Fig.4). However, it is in the same coal seam that the range of fugitive constituent changes a lot. Different contents of macerals in mined samples might account for it. According to the changed tendency chart, there should be soft coal of much higher level or even anthracite in the deep part, but coking coal mainly distributes within the depth of 1200m which is still the exploitable depth.

According to \(V_{daf}\) and G (binding exponent) or \(Y\) (thickness of gelatinous layer) as the sorting parameter, as \(V_{daf}\) being 28\% to be the dividing line between coking coal (JM) and 1/3 coking coal or fat gas coal (FQ), on the basis of the limits separating lean coal (SM) and coking coal (JM) by \(V_{daf}=20\%\), we can differentiate the type of coal in mining area. There are mainly three types of coal in whole area: 1/3 coking coal, coking coal and lean coal, fat coal and lean coal may appear in deeper seam. The analysis material to the coal from shallow production mine presents: C_{13} coal seam has got into zone JM at the depth of -660m and other coal seams have gone into the zone 1/3 JM.
It can be seen from the all types of coal in mining area, there are 1/3 coking coal from B\textsubscript{7} coal seam up to C\textsubscript{15} coal seam in mined ones and lean coal exists from B\textsubscript{11b} coal seam down to A\textsubscript{1} coal seam. 1/3 coking coal is distributed over western mining field while lean coal is distributed over eastern mining field and coking coal are widely distributed over the middle part. This characteristic of subsection can be showed in both -660\textendash-1200m and -1000\textendash-1200m. The quality of under part is better than that of headpiece in coal seam. Synthesizing various indexes from every coal seam, we found that the degree of coal metamorphism increases with the increase of depth which coal seam has been buried. On the strike, the degree of metamorphism in the same coal seam rises slightly from west to east.

### 4. The influence of regional geological factors on coalification

Huainan coal field is located in the foreland of Qinling-Dabieshan orogenic zone. There is an elongational structure opposite to the extruding structure under the Fufeng thrust nappe [8]. The structure is considered to be compressive under the neutral plane, where magmatic activity hardly exists [4, 7], because the bending elongational structure usually emerged merely in supracrust or on the surface of continental crust. The geothermal gradient in this field is at present normal and usually smaller than 2\degree C, between 0.74 \degree C and 2.1 \degree C. Former research indicated that the paleogeothermal gradient was even lower [9]. Thus abnormal magma hydrothermalism is not the reason for the generation of these high rank coals.

The Wangfenggang coal mine, which is located between Shungengshan and Fufeng thrust belts, has been in an extruding stress over time under the contribution of the south-north thrust nappe. The depth of the structural plane of this thrust nappe can be as deep as 934m. Coincidently, the coal metamorphic zone is consistent with the structural plane. There are still no adequate studies on the regional burial history and lithosphere-scale history of ancient thermal current in Huainan area. After the coal-forming period in Late Paleozoic, the northern part of Huainan coalfield went through three major tectonic thermal events before Neogene period (240Ma, 160Ma-120 Ma, 80Ma) [9]. In the later stage of Middle Triassic (240Ma BP), it went through another tectonic thermal events over a period of 120Ma\textendash60Ma when the geothermal temperature was supposed to be over 110\degree C. It coincides with the formation of the ultrahigh pressure and high pressure metamorphic rocks in Dabieshan structural belt which can be represented by the formation of coesite in Triassic (240 Ma\textendash210 Ma). The collision between North China and Yangzi cratonic blocks also emerged during this period [8]. The average palaeo-geotemperature is 85 \degree C during the tectonic thermal event in Late Jurassic (160 Ma \textendash 140Ma). The temperature in this event was supposed to be over 110\degree C and might last for a period of 10Ma. Since no known temperature was over 110\degree C by means of thermal analogy based on fission track technique, which is restricted by the sealing temperature of apatite, it is deducted that the temperature generated by this tectonic thermal event should
be higher. The high-ranked bituminous coal and anthracite coal could be formed when the duration of coalification was estimated to be 20 Ma~100 Ma under the high pressure and low geotemperature [10, 11]. As a result, the genesis of the high-ranked coal studied is supposed to be bounded with the long term tectonic thermal events.

Recently, it has been found in some studies that chemical activation can be enhanced by pressure in China [12-27], and many foreigner specialists has noticed the phenomena that pressure can impact the coal physical structure and chemical activities[28-35].

Chemical reactions indeed exist without thermal transformation, when high molecular polymers are affected by mechanical force directly [36]. Mechanical force, which includes the hydrostatic pressure caused by overburden rock and the shearing stress generated by tectonic disturbance, can make mechanical energy accumulated in the object that it acts on. This mechanical energy can be converted into other forms, like thermal energy, strain energy or surface energy. It can change the activity, texture and physicochemical property of the object and eventually, cause the coal metamorphism. The theory confirms that coal metamorphism can be effected by the later stage uplift and the energy generated by kinds of tectonic stress during the folding period. These energies include thermal energy generated by compression and deformation of coal rock, elastic deformation energy, surface energy, vibration energy as well as other energies in forms of acoustic wave, light, electricity and magnetism. Among all of them, the most significant ones would be the thermal energy created by kinetic energy and elastic deformation energy stored in coal rocks.

5. Conclusions

1. In Wangfenggang minefield of the Huainan mining area, a series of bituminous coal band include gas coal, 1/3 coking coal, fat coal and lean coal vertical distributing in the deep seated seam (−600m~−1200m). The metamorphism developing tend is same with coal seam structural shape, that is the metamorphic degree grow gradually with the coal seam burial depth. In strike, the same coal seam always has higher coal bank from west to east.

2. The geological structure has a great impact on the coal seams in Wangfenggang mine. Most of coals present powdery state. The results show that content of semi-fusinite and semi-vitrinite are very high, and nearly no exinite can be found in deeper coal seam. The volatile matter of coal is lower than normal. No phenomena of been heated directly has been found, but the anisotropy of vitrinite which could be caused by pressure can always be observed.

3. The metamorphic type of Wangfenggang mine is the superposition of two factors, one is the effect of energy transformation from tectonic stress on hydrostatic pressure state, and the other is katogenic metamorphism.

Acknowledgements

This paper is supported by the 973 Program of China (2006CB202202), the National Natural Science Foundation of China (No. 40972106、40772095), and the foundation from State Key Laboratory of Coal Resources and Safe Exploitation CUMT (SKLCRSM09KFB01).

References

Weihua Ao et al. / Procedia Earth and Planetary Science 3 (2011) 123 – 130


[34] Ross JV, Bustin RM. Vitrinite anisotropy resulting from simple shear experiments at high temperature and high confined pressure. *In J of Coal Geol* 1997;33:153-168.
