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# Gas Distribution and Geological Controlling Factors of Huainan Mining

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**Abstract:** The gas disasters of Huainan mining get more serious as the increase of mining depth. In order to the efficient mining of coalbed gas and adoption of reasonable measures to ensure mine safety in Huainan mining area, gas distribution characteristics were found out and the geological controlling factors of high gas content were analyzed in this study. Research on the law of gas distribution in the Huainan mining area shows that, the $CH_4$ content which extend in N-W direction and higher in NE area than SW area, $CO_2$ content in this mining area performances that south area is higher than north area while the $N_2$ content shows a inverse feature. $CO_2$ content is high in the hinge zone of PanJi anticline and low in the two wings, $N_2$ content is on the contrary. Main controlling factors for gas content in this mining area include coal bearing property, buried depth, coal thickness, geological structure and groundwater activity. In addition, gas content was positively correlated with coal bearing property, buried depth and coal thickness. Sealing fault structure is beneficial for gas accumulation while the open fault structure will reduce gas content. Gas content decreases with the lithologic particle coarsening. Retained groundwater is beneficial for methane's accumulation.

**Key words:** Huainan mining, gas, content, controlling factors

## INTRODUCTION

Coal is contained within about $2.1\times10^3$ km$^2$ in Huainan mining area, where rich coal resource and coalbed methane (CBM) can be found (Shuxun *et al*., 2001). However, because of the complex tectonic condition, the reservoir permeability of this mining area is low and absorption ability is high (Yuan, 2009). With the increase of mining depth, the gas disasters of Huainan mine get more serious (Yuan, 2006; Wei *et al*., 2009). Among the 11 coal producing mines, there are 7 gas outburst mines, 2 high gas mines and 2 low gas mines. The production of gas outburst and high gas mines accounted for 91.4% of the total output. Nearly 200 coal and gas outburst accidents had happened since the mines been built. According to the geological survey data and gas information of producing mines, the gas content is fairly high in each coal seam, average content is 6.23 m$^3$ t$^{-1}$ and the maximum content can reach 17.91 m$^3$ t$^{-1}$. The gas is mainly accumulation in the B and C groups of middle coal measure while in the lower A groups, upper D and E groups, the gas content is relatively low, gas emission quantity of producing mines are relatively high. By the end of 2009, there were 146 coal and gas outburst dynamic phenomena happened in the mines of Huainan Mining Group which includes 90 times in the South Huai River mining area and 56 times in PanXie mining area. There are 143 outburst phenomena occurred in the central of B and C group coal beds and 2 times belong to the lower A groups (one is in $A_1$ coal seam of Xinzhuang Zi mine and other is $A_3$ coal seam of PanEr mine), the upper D and E coal seams have one time ($D_{17}$ coal seam of PanEr mine) (Table 1). In South Huai River mining area, the gas content increase with burial depth first then begin to decrease with maximum is 28.33 m$^3$ t$^{-1}$ in $C_{13}$ coal seam. In PanXie mine the gas content has same trend with the increase of burial depth, however the peak is $B_4$ coal seam which is 33.01 m$^3$ t$^{-1}$ (Table 1). Deeply study about the geological controlling factors and characteristics of gas distribution for mining area has great significance for the gas control, mine construction and promotion of coal mining safely and efficiently (Tang, 2009).

Objective of the study is to find out gas composition and distribution characteristics and analyze the chief geological controlling factors of high gas content in Huainan mining area. The research results will provide support to efficient develop of coalbed gas and adoption of reasonable gas control measures to ensure mine safety.

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Table 1: Characteristics of gas content and outburst of coal and gas

| | South Huai River mining | | PanXie mining | | |
|---|---|---|---|---|---|
| Coal seam | Maximum gas content ($m^3\ t^{-1}$) | Times of outburst (time) | Maximum gas content ($m^3\ t^{-1}$) | Times of outburst (time) | Remarks |
| $D_{17}$ | | | | 1 | There are 90 times outburst happened in south Huai River mining (not list the 26 times outburst that occurred in the primary Xiesan mine). The types of outburst are extrusion, pouring out, outburst and eruption. Gas content of PanXie mining is obvious higher in east PanYi mining and happened 56 times outburst totally. |
| $C_{15}$ | 11.05 | | | | |
| $C_{13}$ | 28.33 | 15 | 21.37 | 34 | |
| $B_{11b}$ | 23.64 | 34 | 23.40 | 6 | |
| $B_{10}$ | 10.64 | | | | |
| $B_9$ | 16.46 | 2 | | | |
| $B_8$ | 15.54 | 2 | 24.26 | 4 | |
| $B_7$ | 11.77 | | 23.06 | | |
| $B_6$ | 9.39 | 4 | 24.14 | | |
| $B_4$ | 15.61 | 11 | 33.01 | 10 | |
| $A_3$ | | | 18.87 | 1 | |
| $A_1$ | | 1 | 12.78 | | |

## STATISTICAL CHARACTERISTICS OF GAS DISTRIBUTION

Among the gas composition of Huainan mining, the hydrocarbon accounted for 78% in average, $N_2$ is 18% and $CO_2$ is 4%. For the Xieyi mine, $CH_4$ of each coal seam ($C_{13}$, $B_{11b}$, $B_{10}$, $B_{9b}$, $B_7$, $B_6$, $B_{4b}$) accounted for 50.84~95.16% and the average is 75.74%, $N_2$ is 0.91~40.32% with 18.03% as average, $CO_2$ is 0.51~21.01% with 5.30% as average. In this mine, the gas content is between 0.08~21.71 $m^3\ t^{-1}$ and average is 8.71 $m^3\ t^{-1}$, $CO_2$ content is between 0.04~17.54 $m^3\ t^{-1}$ and average is 2.47 $m^3\ t^{-1}$. For the regional distribution, the $CH_4$ content extend in N-W direction and NE area is higher than SW. The $CO_2$ content in this mine performances that the south part is higher than north while the $N_2$ content shows a feature that south is lower than north.

Among the gas composition of PanXie mine, the hydrocarbon accounted for 50.14~97.92%, $N_2$ is 0~44.63% and $CO_2$ is 0~30.67%. Average percentage of gas composition, hydrocarbon is 77.58%, $N_2$ is 16.55%, $CO_2$ is 5.87%. For the regional distribution, $CH_4$ content (south wing of TaoWang syncline) extend in NW direction generally and NE is lower than SW, $CO_2$ content is high in the hinge zone of PanJi anticline and low in the two wings of anticline. $N_2$ content is on the contrary.

## GAS GEOLOGICAL CONTROLLING FACTORS

Factors which controlling gas distribution can be separated into two categories: One is original factors which include coal bearing property, coal thickness, surrounding rock lithology and so on, other is epigenetic factors, include geologic structure, burial depth of the coal bed, groundwater activity and so on.

**Control effect of coal bearing property to gas:** Coal bearing ratio of the Carboniferous Taiyuan formation in south Huai river mine is 3.98%. Maximum coal bearing ratio of Carboniferous coal measure is 14.91%, the average is 6.35%. Coal bearing ratio of XieJia Ji mine is the highest area, reaching 11.15% and its gas content is also high, coal and gas outburst is most serious. By contrast, Coal bearing ratio of LiZui Zi mine is relatively low, so coal and gas outburst has not happened up to now. Coal bearing ratio of PanXie mine is 8.70%, coal and gas outburst is also serious.

**Control effect of tectonic to gas:** In Huainan coal field the coal measures are Carboniferous and Permian. Main structural framework is an EW ramp fault-fold structural belt (Song *et al*., 2005). Influenced by Tan-Lu fault and Qinling Mountains latitudinal structural belt, the structure of south Huai River mining area is complicated and fracture structure is development. The coal and gas associated structure styles include fault, fold and combination of the two structures (Zhang *et al*., 2003). Among them, fault is the main controlling factor of gas distribution. Gas accumulation is primarily depended on the closure of fault and permeability of rock.

Open fault (tension, tension-torsion, water conductivity) or well permeability rock contacting with coal seam will lead to gas content declining in nearby area. Tension and tension-torsion fault are development in west and north of PanXie mine, west of DingJi GuQiao mine which helpful for gas emission and result in the low gas content. Although, the $F_1$ fault of LiZui Zi mine is compression and compresso-shear fault, coal seams of hanging side was raised and been denuded under the thrust nappe role, due to the layer's dip is vertical and is cut by fault, coal seam will be disconnected by the large drop fault and contact with the well permeability rock

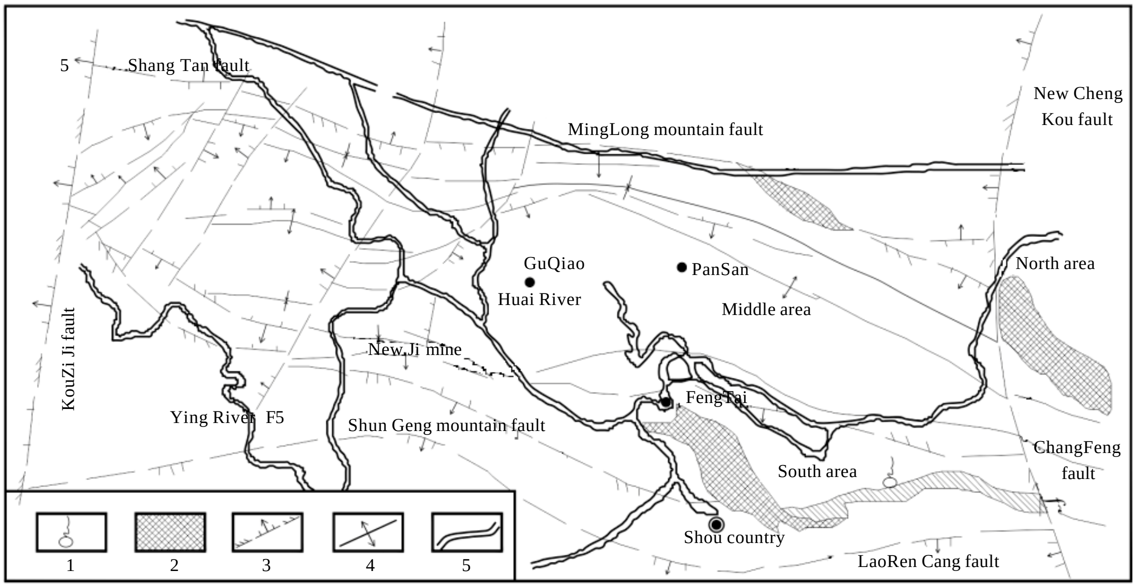


Fig. 1: Tectonic and hydrogeology map of Huainan mining area

formation on other side. In addition to groundwater activities, it is favor for gas emissions, so gas content of these areas are low (Fig. 1).

Sealing fault (compression, compresso-shear, aquiclude) and bad permeability rock formation that connect with coal seams can prevent the gas emission. So, it is probable that forming gassy area in these area. Such as the brush structure region ($F_{13-4}$~$F_{13-8}$ and $F_{12-8}$~$F_{12-13}$) of Xieyi mine, the coal body structure is destructed violently in the brush structure's convergence end where stress is concentration, this result in the gas concentration in the area. There are derived faults developed in or near the compresso-shear fault belts ($F_{13-5-1}$~$F_{13-5}$). So these mines are large gas content regions with in-situ stress concentration high methane pressure and content (Fig. 1).

**Control effect of groundwater activity to gas:** Ground water system controlled the absorption and aggregation of gas by the reservoir pressure (Ye *et al*., 2001; Zhang *et al*., 2005). The water-richness of Permian coal system in south Huai River mine is feeble. Units-inflow is ordinarily smaller than 0.1 L s.m$^{-1}$, permeability coefficient is smaller than 1.13 m day$^{-1}$. The water discharge of coal is about 1 m$^3$ t$^{-1}$. Water content of coal bed is about 1.5% and the salinity is above 750 mg L$^{-1}$. These figures illustrate that groundwater of coal series is retention and flow slowly. PanXie mine is the subject of synclinorium (eastern and middle). Owing to the resistivity water effects by the thrust fault located north and south wings (FuFeng fault and ShangYao-Minglong Shan fault), bedrock aquifers were cut off from the water supply of exposed areas and composes closed hydro-geological unit. Groundwater in this area is detention. Therefore, aquifers of coal measures in Huainan mine is relatively blocking and flow slowly. It is in favor of storage and enrichment of gas.

**Control effect of roof lithologic character to gas:** Gas occurrence in coal seams. The permeability of roof can influence the gas content directly (Lu, 2006). The statistics result of Fig. 2 shows that, gas content decreases with the lithologic particle coarsening. The direct roof of upper and lower main coal seam are shale and clay, account for 49.4%. Silty mudstone account for 32.8%, siltstone account for 11.5%, the other rock types only account for 6.3% (Table 2). Therefore, roof of this mining area is more compact and beneficial for gas enrichment. Statistics to the gas outburst point of PanJi No. 3 mine shows that, surrounding rock nearby the outburst point always have the characteristics of bad permeability, harder and denser (Zhu *et al*., 2008).

**Control effect of burial depth to gas:** Burial depth is a key factor that control gas content. It can influence the pressure and preservation conditions of reservoir (Xu *et al*., 2002). The statistic shows that, the gas weathering zone depth is located 100-200 m below

Table 2: Roof lithologic characters of each coal seam in south Huai River mining area

| Coal seam | Roof lithology | Floor lithology |
|---|---|---|
| $C_{15}$ | Mudstone, sandy mudstone, siltstone | Mudstone, sandy mudstone, siltstone |
| $C_{14}$ | Mudstone, sandy mudstone, siltstone | Mudstone, sandy mudstone, siltstone |
| $C_{13}$ | Sandy mudstone, mudstone, siltstone | Mudstone, sandy mudstone |
| $B_{11b}$ | Mudstone, sandy mudstone, fine siltstone, shale | Mudstone, sandy mudstone |
| $B_{10}$ | Mudstone, sandy mudstone | Sandy mudstone, mudstone |
| $B_{9b}$ | Siltstone, fine sandstone | Sandy mudstone, fine siltstone |
| $B_8$ | Sandstone, sandy shale | Mudstone, sandy mudstone |
| $B_7$ | Sandy mudstone, mudstone | Sandy mudstone, fine siltstone |
| $B_6$ | Sandy mudstone, fine siltstone | Sandy mudstone, mudstone, fine siltstone |
| $B_{4b}$ | Sandy mudstone, mudstone | Mudstone, sandy mudstone |
| $A_3$ | Sandstone, sandy mudstone | Sandy mudstone, siltstone |

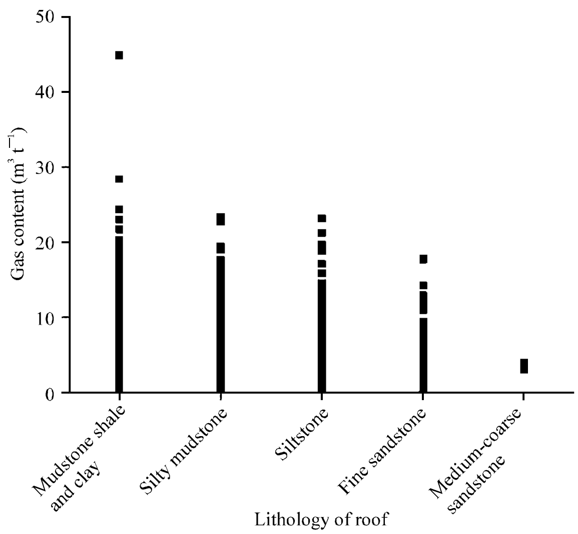


Fig. 2: Gas content different caused by the lithology of roof

bedrock. Thickness of Cenozoic is between 200-600 m (Liu *et al*., 1999). The occurrence of gas in Huainan mining area was notably controlled by burial depth (Fig. 3 and 4). In the level of above -1000 m, gas content increases with the buried depth. The gas content can increase from about 10-20 $m^3$ $t^{-1}$ when burial depth increases from 550-950 m in South Huai River mining area. In PanXie mining area, the gas content can increase from 2.5-20 $m^3$ $t^{-1}$ when burial depth increases from 350-820 m. On the same burial depth, the smaller dip angle of coal seam, the higher gas content.

**Control effect of coal thickness to gas:** Coal reservoir is a highly dense and low permeability rock formation itself. Middle stratification was sealed strongly by the upper and lower parts stratifications. The more thickness of coal reservoir, the longer travel that coalbed methane (CBM) diffusing from middle stratification to roof. Diffuse resistance is great and

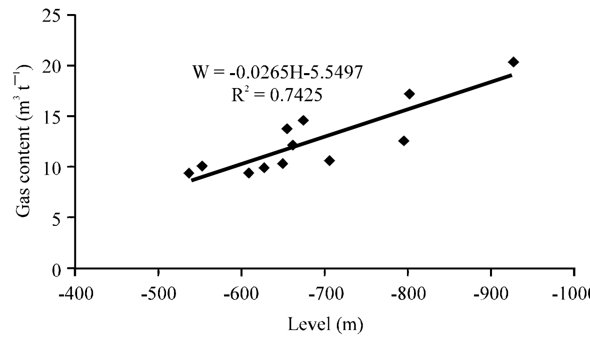


Fig. 3: Relationship between level and gas content of $C_{13}$ coal seam which located from $F_{4-5}(F_{17})$ to $F_{13-5}$ in south Huai River mining area

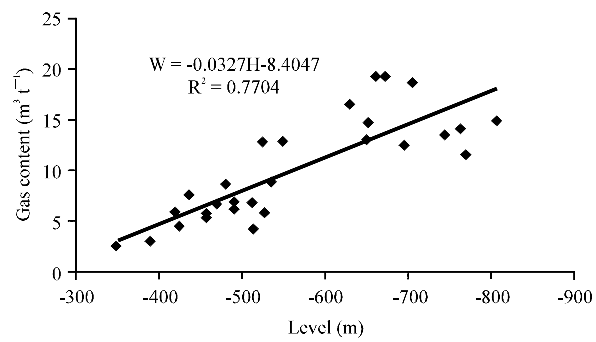


Fig. 4: Relationship between level and gas content of $13_{-1}$ coal seam which located from the footwall of $F_5$ fault to the wall of $F_2$ fault in south PanXie mining area

it is helpful to storage of CBM (Wei, 1999; Qin *et al*., 2000). The gas content of south Huai River mining area and PanXie mining area correlate positively with the thickness of coal seams. When the thickness of coal seam further increasing, the gas storage ability will be expressed to the maximum and the influence from thickness to gas content will decrease gradually (Fig. 5 and 6).

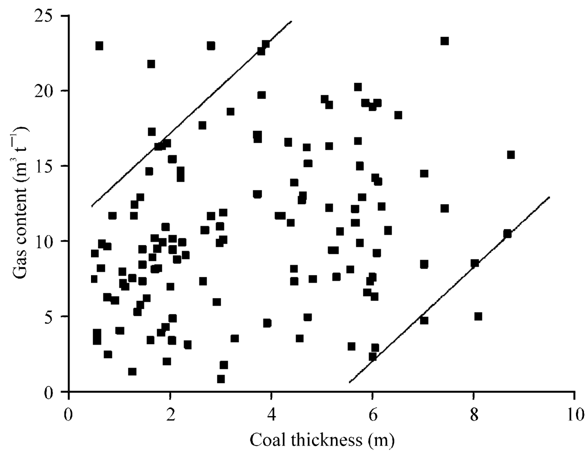


Fig. 5: Relationship between coal thickness and gas content of south Huai River mining area

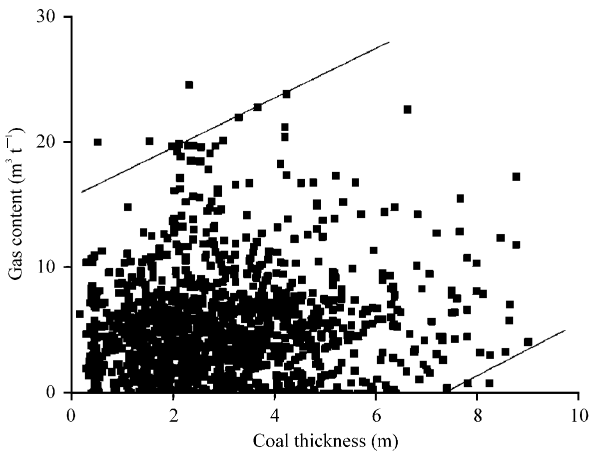


Fig. 6: Relationship between coal thickness and gas content of PanXie mining area

## CONCLUSION

$CH_4$ content of south Huai River mining area extend in N-W direction and NE area is higher than SW. $CO_2$ content in this area performances that south area is higher than north while the $N_2$ content is on the contrary. $CH_4$ content of PanXie mining area extend in NW direction totality and NE is lower than SW. $CO_2$ content is high in the hinge zone of PanJi anticline and low in the two wings of anticline. $N_2$ content is on the contrary.

Gas content of south Huai River mining area is controlled by coal bearing property, buried depth, coal thickness, geological structure and groundwater activity. Gas content was positively correlated with coal bearing property, buried depth and coal thickness. Open fault or well permeability rock connected with coal seam will lead to gas content declining in nearby area. While the fault connected with coal seam is sealing and bad permeability will result in gas enrichment. Gas content decreases with the lithologic particle coarsening. It will beneficial for accumulation of methane when the groundwater keeps retention state totally.

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