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CBM geology conditions study of Gemudi syncline, Western Guizhou Province *

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Abstract Through the analysis of the surrounding rock, coal seam burial depth, coal quality and hydrologic geological condition, the methane-bearing property characteristics of the coal reservoir in the Gemudi syncline were elucidated. Most of the wall rock of the coal reservoir is mudstone and silt, which is a favourable enclosing terrane. Burial depth of the main excavating coal seam is moderate. The groundwater activity is thin, and there are absolute groundwater systems between each coal seam, which make poor interconnections to accelerate CBM enrichment. In our research, the area coal reservoir metamorphosis is high, CBM content is high, hole-cranny system development degree is high, and permeability of the great mass of the main coal seam exceeds 0.1×10^{-3} μm^2. The result demonstrates that the southeast of the Gemudi syncline has the best conditions for prospecting and exploiting CBM.

Keywords Gemudi syncline, CBM, geological condition, coal reservoir characteristics, permeability

1 Geological overview

The Gemudi syncline lies to the north of the Pan county basin. It belongs to the Upper Yangtze area, bounded to the north by the Waterside town (Ya) Ziyun fault, and to the south by the Mount Cock anticline. It runs from northwest to north-northwest, exhibiting a ribbon-like shape. The traps were formed by the coal measures of the upper permian, above which are the late and middle Triassic coasts. The cores of the syncline in the east and west were formed by the upper Triassic series and Jurassic. The northern alar was incised by northwestern and northeastern faults. The basin of Gemudi has an area of 523 km^2 of coal; the coal formation is 35 201 m thick, 413 m on average. Commercial beds are buried less than 2 000 m deep, generally less than 1 500 m. The main commercial beds are the Longtan formation and Changxing formation (Fig.1). A lagoon, peat marsh, distributary channel, tide flat, tidal channel, delta front, sand bank and marsh make up the transition environment. They are in an unconformable contact with the underlying upper permian basalts and in conformable contact with the overlying lower Triassic Feixianguan formation.

2 Coalbed methane occurrence conditions in studying areas

2.1 Structural feature of the study area

The Gemudi syncline lies to the north of the Pan county basin, which is bounded to the north by the Waterside town (Ya) Ziyun fault, to the south by the Mount Cock anticline, exhibiting a ribbon-like shape. The coal measures of upper permian form the enclo-

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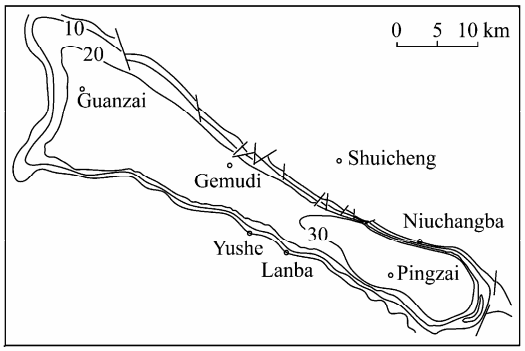

Fig.1 The isopachous map of workable seam of Gemudi syncline

sure. The western and eastern cores of the Gemudi syncline are made up of the upper Triassic series and Jurassic, above which are the late and middle Triassic coasts. The northern alar was incised by northwestern and northeastern faults. The whole structure is complex and belongs to medium-sized type (Huang, 1991).

2.2 Country rock conditions

Coalbed methane reservoirs need appropriate conditions for generating, storing and capping. A gas-bearing formation is good at generating and storing coalbed methane. Cap rock, specifically country rock condition, has a direct influence on the coalbed methane reserve, and the properties of the country rock are decided by lithological characteristics and ventilative power of the bed roof and floor.

The Gemudi syncline coal-bearing formation (including Longtan and Changxing formations) is located in the paralic district, to the east of which is a shallow marine district, while to the west is a continental deposit area (Ao, 2006). Mudstone and siltite make up the primary part of lithology, occupying 41%~62% of the coal-bearing formation. The lesser in this district is made of limestone, pack sand, and sandstone inserted conglomerate. Mudstone, yakatagite and argillaceous sandstone make up the main part of the lithology of the bed roof and floor. A single layer of mudstone, argillaceous flour sand in this district is 4 to 12 m in thickness. It is a better cap rock in the gas-bearing reservoir group that can transform the reserve layer into a good enclosure. The lower Triassic series Feixianguan formation or Yelang formation, belongs to the shallow bank marine deposit, having purple mudstone, argillaceous flour sand rock inserted pack rock widespread; the thickness is constant, reaches 43 580 m thick, and is a good regional cap rock. Because of the very low carrying of permeability at the Gemudi baseplate and good traps that can prevent the longitudinal dissipation of coalbed methane, its country rock condition is very good for storing coalbed methane.

2.3 Buried condition

Generally speaking, it is more difficult for coalbed methane to escape outward with the increase of stratum pressure influenced by the depth of the coal-bearing formation. Most coalbed methane exists in sorption state and it is not easy for deep formations to form crannies, making the coalbed methane well stored.

According to wildcat materials outside the area, the content of coalbed methane in the Gemudi syncline increases with increase of depth. It is greater than 15 m^3/t of the content of the main working seam which is buried less than 500 m deep. The contents of formations buried 800~1 000 m deep is constant, and for formations that are about 200~1 500 m deep, the coal seam area can reach 403 km^2, coalbed methane resource is about 2 063×10^8 m^3, and resource abundance degree is 5.20×10^8 m^3/km^2. All these help store coalbed methane in the aspects that the stratum coal seam is continuous and coal seam seldom appears.

2.4 Geohydrologic conditions

The siltstone and pack stone of the Longtan formations in the Gemudi synclinal keep the pressure-bearing crevice water, limestone stores the karst crevice water; limestone has stronger permeability than sandstone. Watery sandstone and limestone present intermediate layers lying in mudstone, sandy mudstone and coal bearing formations, which are as thick as 45~65 m in total. Therefore, the Longtan coal bearing formation shows weak watery characteristics. The Changxing coal bearing formation where erosion crannies exist develops into a medium-sized rich watery layer. A weak watery layer, and also the regional water barrier present are Emeishan basalts at the bottom of the Longtan formations.

The amount and velocity of groundwater have a certain influence on the storage, exploitation and utilization of coalbed methane. In the area where groundwater flows fast, coalbed methane relatively reduces. The upside of the Feixianguan formation, which deposits on the Changxing formation, also shows weak watery characteristics, so the whole area is very suitable for cap rock superposition, forming multi-layer traps longitudinally. There are close negative structural traps and possible sealing faults in the lateral direction. Water power of the basin has a system of its own, enabling coalbed methane storage in coal bearing formations.

3 The physical property of coal reservoir

3.1 Content of coalbed methane

New Star of the Chinese Petroleum Company has implemented a shallow natural gas (including coalbed methane) evaluation and investigation project in the western region of Guizhou Province, constructing 5 test pits, and has tried to drain water and product gas. After conducting sand fracturing in 5 strata in Qianhong No.1 and No.2 well and Guimei No.1 well, the company started to drain water and product gas for 7 months starting March 2000. The daily gas production of a single well was dozens of cubic meters (Jiang, 2008). The gas production rate of Qianhong No.1well was 29 to 38 m^3/d, the cumulative gas production was 7 258.5 m^3. Meanwhile, the fluid production rate was 0 to 30.40 m^3/d and the cumulative fluid production was 294.48 m^3. The gas production rate of Qianhong No.2 well was 2.10 to 10.20 m^3/d, the cumulative gas production was 663.60 m^3, the fluid production rate was 0 to 9.05 m^3/d and the cumulative fluid production was 67.86 m^3. The gas production rate of Guimei No.1 well was 29.40 to 33.00 m^3/d, the cumulative gas production was 5 311.23 m^3, the fluid production rate was 8.65 to 26.95 m^3/d and the cumulative fluid production was 5 234.41 m^3. Total production of the 3 wells was 13 253.33 m^3; total liquid production was 5 596.75 m^3.

According to existing data, the maximum gas content in Gemudi Basin is 37.66 cm^3/g, the average content is 12.84 cm^3/g, which has the tendency of high in the south and low in the north; 19.03 cm^3/g in the south wing and 14.11 to 16.90 cm^3/g in the north wing(Fig.2).

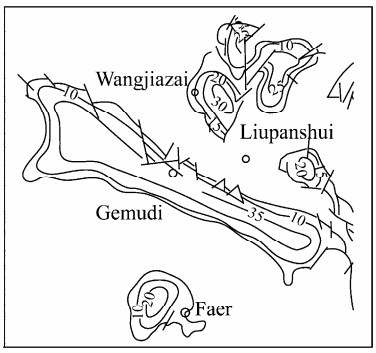

Fig.2 Equivalence line chart of the content of synclinal coalbed methane of Gemudi Basin

3.2 Characteristic of coal property

The rank of coal metamorphism's impact on the content of coalbed methane are mainly shown in two aspects: First, with the increasing of the degree of coalification, the amount of coalbed methane increases gradually, reaching a maximum by anthracite stage. Studies have suggested that the total production of coalbed methane can reach 4 000 m^3/t as the coal turns into anthracite. Second, the absorbing amount of coalbed methane of the coal seam increases constantly as the degree of coalification rises by anthracite stage. Inside the coal seam, it produces a large number of pores, joints and microcracks, which lead to the adsorbtion surface area reaching the maximum. The gas content of the coal seam can reach 40 m^3/t. Therefore, the high degree of coal metamorphism created conditions for the formation and accumulation of coalbed methane. The higher the rank of coal metamorphism is, the bigger the gas content of the coal seam is.

The coal lithotype of Longtan group in the Gemudi coal Basin includes half clarain, bright coal mixed with semidull coal; the group of Changxing consists of semidull-half bright coal. Coal luster strengthens from east to west in the Gemudi Basin Shuicheng area, half clarain and clarain increase; the coal lithotype of Liuzhi Basin is mainly half clarain. Coal macerals are mainly vitrinite (38.4%~98.6%); the content of vitrinite is greater than 50%, except for parts of the Gemudi Basin and Liuzhi Basin. The intertinite takes up 1.4% to 59.3%, except for some parts of the Gemudi Basin and Liuzhi Basin which are greater than 45%, the others are smaller than 10%. The content of exinite and inertinite in the Qianxi coal Basin is very high, the content of inertinite is 21.0% to 44.8%, among which fusinite and half fusinite have comparative advantage, the content of exinite is 6.0% to 8.5%. The ash content of the coal rock is 14.63% to 38.21%, belonging to ash coal and is partly bone coal. The northeast is slightly low, while the southwest is relatively high, general ash content is 20% to 30%.

3.3 Coal seam porosity and permeabilities

(1) Porosity

The microstructure determination of the Gemudi coal sample by mercury intrusion porosimetry indicated that there is a spike of mercury intrusion when the pressure is under 0.1 MPa, another peak appeared when the pressure transited to 10 MPa. This proves that the coal rock has a double pore structural characteristic. We determined 16 samples, with 6 samples having macropore as the core; the others are with fine pore and micropore. Coal rock cryogenic nitrogen adsorption and desorption test proved that it contains storage pore and open space in the coal; the open

space is favorable to interconnection and flow of gas in the coal rock pore. The cryogenic nitrogen adsorption determined pore volume and average pore diameter and proved that the pore volume and average pore diameter distribution rewidespread, and have a strong randomness. The specific surface area of the coal sample is determined to be 0.1 m^2/g.

The northwest area of the Gemudi Basin is like a long band, and the development of cleat is quite different as the direction and intensity of stress in every part is different. According to the macroscopic and microscopic statistical analysis of the coal seam (Table 1), the direction of the main cleat and outstanding tectonic direction are roughly the same, though with a slight offset; the direction of cleat development still varies with structural trend. The direction of secondary cleats is basically identical with secondary structure line. Thus, the porosity in this area is comparatively good, and is favorable to adsorption and deposition of coalbed methane.

Table 1 Statistical form of cleats in Gemudi synclinal colliery

The average density of cleat(strip/cm)	Cleat type	Cleat length(mm)	Cleat width(mm)	Cleat spacing(mm)
4~11.3	Face cleat	0.12~720.00	0.008 7~0.5	0.1~5.0
	Side cleat	0.14~720.00	0.007 5~0.2	0.1~3.0

(2) Permeability.

The key parameter that influences air output during the development of coalbed methane is the permeability of the coal beam. In the area where the structure stress is close, it is relatively low, while in the area where the structure stress is lax the permeability is high.

The coefficient of permeability of coal seam in Shuicheng, Gemudi is 0.17 $m^2/(MPa^2 \cdot d)$. The coal seam permeability in this district is relatively low, generally smaller than 0.1×10^{-3} μm and not exceeding 0.61×10^{-3} μm. As the coefficient of permeability of the coal seam is 0.69×10^{-3} μm^2 in the neighboring area Qianxi Mopanshan No.4 well, where the coal deposit condition is similar and the coefficient of permeability of coal seam is 0.81×10^{-3} μm^2 on the 9th coal seam, with developing cracks and high porosity in this district, we can conclude that the coefficient of permeability of coal seam in Gemudi is relatively high too.

4 Conclusions

(1) The coalbed methane occurrence conditions at the Gemudi syncline is good. The adjacent rock is mainly mudstone and siltstone in the study area with a good capped ability. It will be difficult for the coalbed methane in the coal reservoir to escape; the buried depth of minable seam and main minable seam is generally smaller than 1 000 m, the depth is moderate. The activity of ground water is weak, and every coal seam has independent ground water regime and the connectivity is not very good, which promotes coalbed methane accumulation.

(2) The physical property of the coal reservoir of the Gemudi syncline is good. The gas content of the coal reservoir in the study area is high, the maximum is 37.66 cm^3/g, the average is 12.84 cm^3/g. The coal is mainly meager coal and lean coal, the rank of coal metamorphism is relatively high; pore sand crack abundance is relatively high, the permeability of most main mineral seam exceeds 0.1×10^{-3} μm^2.

(3) In sum, the coal reservoir in the Gemudi syncline in the west of Guizhou Province has good coalbed methane hosting feature and physical property. The most suitable place for coalbed methane exploration and exploitation lies in the southeast of the study area.

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