Potential Analysis of Coal-bed Methane in Sanjiang Basins of Eastern Heilongjiang Province

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Abstract: Sanjiang basins of eastern Heilongjiang Province are important coal production bases with abundant coal resource. In recent years, multiple gas accidents in coal mines have done serious harm to people's lives and property; therefore, there is an urgent need to find out the accumulation of CBM (gas) so as to effectively manage the treatment of the gas disaster and the comprehensive utilization of CBM. Studies suggest that Sanjiang basins contain thick coal seam and good preservation conditions for CBM, which is beneficial for the accumulation of CBM. The major coal-bearing seam in Sanjiang basins is Cretaceous Chengzihe group, with over 20-70 coal layers, coal bed thickness up to 10-90m and single-layer thickness reaching more than 15m. By the thermal metamorphism of the regional magma, coals have different degrees of degeneration, but the main coal ranks have gas coal, fat coal and coking coal. Comprehensive analysis suggest that the Nanshan-Xinyi mine in Hegang basin and Muling depression in Jixi basin are of high content, rich resource and great exploration potential of CBM, which are favorable exploration target areas for CBM. This study has some guidance for the further management of coal mine gas and exploration of CBM in Sanjiang basins of eastern Heilongjiang province

Keywords: Sanjiang Basins; Coal-bed Methane (CBM); Coal quality; Coal resource; Favorable target area

Heilongjiang province has rich coal resources, including 11 major coal basins, namely Horla, Xigangzi, Heibaoshan in the west; Yilan in the central part; Hegang, Jixi, Boli, Suibing, Hulin, Shuanyashan and Dongning etc. in the east.， 92% of the coal resources is distributed in Sanjiang Basin Group, Jixi Basin, Hegang Basin, Boli Basin and Suibin Depression which are major coal-bearing areas with an area of nearly 22000km2 [1].

Coal-bed methane is a kind of high efficiency and clean new energy which can ease the problem of oil and gas supply shortage; in addition, coal-bed methane is the culprit that causes gas explosion in coal mines, which seriously threats safe production, life and property in coal mines. In 2009, a gigantic gas explosion accident occurred in Hegang Xinyi Coal Mine. It caused extensive damage to people's lives and property and coal production. Therefore, in order to guarantee the effective use of new energy resources and safe and high efficiency coal production, we should predict coal-bed methane enrichment laws to reduce gas content in coal beds quickly and effectively before coal mining, realizing coal mine safe production, development and utilization of new energy.

1 Geological Settings

Sanjiang Basin Group in the east of Heilongjiang Province crosses Mudanjiang, Suifenhe, Jixi, Boli, Shuangyashan, Jiamusi, Hegang and other cities. Its width, from east to west, is 140~220km and the length,from south to north ,is 460km, mainly including five coal bed gas-bearing areas of Jixi basin, Boli Basin, Hegang basin, Hulin Basin and Suibin Depression, with gas-bearing area nearly 15000km2. They have abundant coal-bed methane resources [2].

Strata from old to new include Upper Archean, Proterozoic, Paleozoic, Mesozoic and Neozoic etc. The strata of Cretaceous of Mesozoic Group is mainly exposed in Boli, Jixi and Hegang basin and other regions, while strata of Tertiary and Quaternary is mainly exposed in Suibin Depression, the south of Hulin Basin and the west of Boli Basin (Fig.1) [3].

Sanjiang Basin Group regional structure is located in the joint region between the Central Asia-Mongolia structural domain and the Pacific Coast structural domain. There are four large-scale deep faults: Mudanjiang fault, Yishu Fault, Dunmi Fault and Dahezhen Fault (Fig.1). These faults affect local structural features and sedimentary environments [4-5]. The structural evolution in the region of interest has experienced three stages: (1)

Early and Late Jurassic was the initial rifting stage of the fault basin. Coal-bearing features are thin coal beds, poor coal bed continuity, small distribution and coal bed can be extracted locally; (2) Early Cretaceous was the extension stage of the basin rift. Coal-bearing features are multiple coal beds, large thickness, strong coal bed continuity, rich reserves, complete coal types. They form many large coal fields with commercial value; (3) Tertiary was the lake basin contraction stage. Features of its space extension are as follows: Yishu and Dunmi fault zones have better coal bearing condition and coal bearing condition in Hulin Basin is better than which in other basins [6-7]. The total thickness of coal beds in Well Hucan 1 in Hulin Basin reaches to 117m.

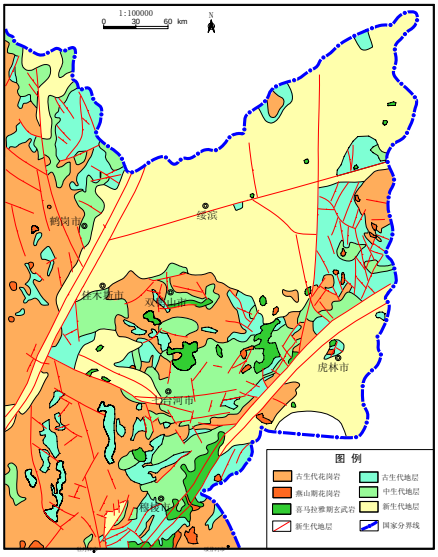

Fig. 1 Geological Structural Map of East Heilongjiang

2 Geological Features of Coal-bed Methane

2.1 Coal-bearing Strata

Coal-bearing strata of Sanjiang Basin Group include Chengzihe Formation and Muleng Formation of Early Cretaceous, and Chengzihe Formation is the main coal bearing strata [9].

Strata of Chengzihe Formation has thickness of 600m to 1400m, containing 20 to 70 coal-bearing layers with total thickness of over 80m, consisting of thin coal beds with monolayer thickness of <1.5m; but in Hegang and Suibin, there are medium thickness coal beds with recoverable thickness of 1.85～20.75m. Jixi region has over 40 coal-bearing layers, 3 to 17 recoverable and locally recoverable layers; Boli Region has over 40 recoverable and locally recoverable coal-bearing layers; Suibin Region has 63 coal-bearing layers, 15 recoverable and locally recoverable coal-bearing layers, mainly instable coal beds; Hegang Region has over 40 coal-bearing layers, 30 recoverable and locally recoverable coal-bearing layers with stable distribution [9].

Strata of Muling Formation has thickness of 150～1000m. Coal beds in Boli Region developed

well, including 9 layers of recoverable coal beds with thickness of 3.7～7.8m; There are 2 to 7 thin layers of coal beds in Jixi Basin; Hegang Basin has 1 to 5 layers of coal beds, but only partially recoverable.

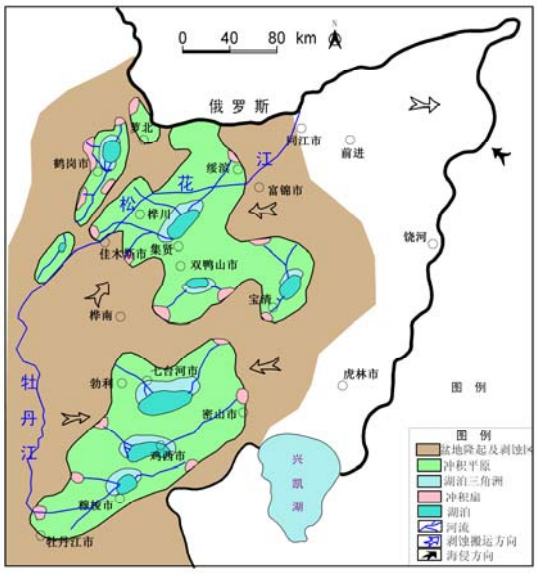

Figure 2 paleogeography map of Sanjiang Basin in the late stage of Early Cretaceous

2.2 Sedimentary Environment Of The Coal-forming Period

Sanjiang Basin belongs to an offshore depression basin. After the largest transgression in Late Jurassic, the coal-bearing strata of Chengzihai Formation in early stage of Early Cretaceous deposited in the regression stage. In the north and east parts of the basin, from the edge to the inside of the basin, there are sedimentary systems of bay, delta, lake, stream and alluvial fan etc. The delta depositional system developed in Jixi Region; stream and lacustrine systems developed in the zone of Qitaihe and Shuanyashan; the peaty moor developed above depleted delta, stream systems and beneaped lakes. In the late stage of Early Cretaceous, sea water receded from the basin to form a continental basin with sedimentation of Muleng Formation coal-bearing strata. The sedimentary environment mainly consists of alluvial fan, stream, Lake Delta and lacustrine systems and the depleted lake delta system is a favorable location for coal bearing (Fig.2) [8].

Chengzihe Formation is the offspring of regression. It is the major coal-bearing formation with widely distributed coal and good coal bearing conditions. Muling Formation is land source clastic rock deposition which has poorer coal bearing conditions than Chengzihe Formation.

2.3 Characteristics of Coal-bearing Rocks

Macerals in coal-bearing rocks are mainly vitrinite with content of 77.2%- 90.2%; the content of exinite is generally less than 10% and 21.5% individually; ash content in coal is high, generally between 20% and 30%. The coal has very low sulfur content, mostly less than 5% [2], belonging to high ash and low sulfur coal.

The macrolithotype of coal is mainly semilustrous coal, followed by semidull coal, mostly with thinly laminated and irregular strips and endokinetic fissure [9].

2.4 Coal Metamorphism

Vitrinite reflectivity Ro is 0.65%- 2.74%, featuring long-flame coal and anthracite coal, but mainly gas coal, fat coal and coke. Vertically, vitrinite reflectance values of various coal beds get higher upward. Horizontally, as affected by regional magmatic thermal metamorphic action, coal from various regions has experienced different degrees of metamorphic changes and coal rank has partially increased [9]. For instance, anthracite, lean coal,

coke, fat coal and gas coal have ring shape occurrence surrounding rock bodies of Yanshanian orogeny in Lingxi Mine and Lingdong Mine of Shuangyashan Coal Field [2]; coal metamorphic grades of rocks of Yanshanian orogeny in the north of Hegang Coal Field are gradually increased from south to north.

2.5 Cap Rock Conditions

Stable mudstone and tuff developed in the overlying strata of Chengzihe Formation in Hegang Basin. It has favorable preservation function for coal beds. The upper part of main coal-bearing section of Meleng Formation in the west of the south depression of Jixi Basin has 50-80m thick mudstone, intercalated with tuff between layers. In the upper part of the mudstone, there are multilayer tuff marker beds, playing the role of a good cap rock [5].

2.6 Geohydrologic Conditions

Except for Jixi and Hegang which have low mountains, hills and terrain slops, other coal fields belong to plain environment. Coal measure strata mainly consists of clastic rocks and aquifers are mainly in weathering zone and fracture water-bearing zone, interlayer fractured aquifers come the next. Groundwater movement is mainly located in shallow weathering fractured zones and in closed position exists in microcracks and structural fractures below the weathering fractured zone. The specific water capacity in a weathering fractured zone is 0.24- 2.73l / (s·m). The permeability coefficient is 1.22 - 3.03m / d and salinity is 0.249g / L [2].

The general trend in this area is that with the increment of depth, aquosity in strata is gradually decreased. Ground water is in the closed condition in which runoffs are slow. It can form hydrostatic pressure trap coal-bed methane reservoirs.

2.7 Coalbed Gas Conditions

Coal bed gas potential mainly include: basic elements of gas content, methane concentration and gas saturation etc. It is an important basis for coal-bed methane resource evaluation. It is observed from Table 1 that coal-bed methane content in Sanjiang Basin Group is 2.47- 30m3 / t. Methane concentration is high and the average concentration is 80%; gas saturation is relatively low, 37 - 51%.

The research is based on coal bed gas potential, getting reference from previous research results. Sanjiang coal province can be divided into four gas-bearing areas: the area with coal bed methane content of smaller than 4m3 /t is called gas barren area; the area with coal bed methane content of 4-7m3/t is called gas-bearing area; the area with coal bed methane content of 7-10m3/t is call relatively rich gas area; the area with coal bed methane content of larger than 10m3/t is called fat gas area. The average methane content in Hegang Basin is 7.7m3/t and the highest methane content is 23.26m3 / t. The area is evaluated as a relatively fat-fat gas area; the average methane content in Jixi Basin is 8.4m3 /t and the highest methane content is 30m3 /t, the area is evaluated as relatively fat-fat gas area. Whereas, methane contents in Suibin and Boli are relatively lower, or 6.89 m3 /t, 6.7 m3/t respectively, the area is evaluated as a gas-bearing area.

Table 1 average gas potential of coal beds in various basin in eastern Heilongjiang Province

Basin	Geological setting			Coal bed gas potential		
	Coal bearing strata	No. of main coal bed	Coal rank	Methane content m^3/t	methane concentration%	Gas saturation%
Hegang	K1	3-30	CY-QM	2.47-23.26 7.7	<78	50
Jixi	K1	1-10, 20-50	QM-JM	2.86-30 8.4	89	51
Leibin	K1	5-30	CY-QM	3.8-10.8 6.89	87	47

Boli	K1	45-71, 87-99	QM-WY	3.2-10.2 6.7	90	37

Note：CY- flame coal，QM- gas coal，JM-coke，WY-anthracite coal

3 Target Area Of Coal-bed Methane Exploration

It is suggested that Nanshan ~ Xinyi Mine in Hegang Basin and Muleng depression in Jixi Basin are favorable target areas for recent coal-bed methane exploration according to comprehensive analysis on factors of geological setting of coal-bed methane, thickness of coal bed, methane content and resource abundance et and evaluation on favorable exploration targets of coal-bed methane.

3.1 Evaluation On The Target Area Of Hegang Basin

Hegang Basin has 10 coal production mines, including Nanshan ~ Xinyi Mine with area of 34.08km2 [10] bearing over 40 layers of coal beds, 36 layers of recoverable and locally recoverable coal beds, the total thickness of coal beds of over 90 meters (Fig.3), maximum monolayer thickness of 24.87m and buried depth of less than 1500m. Complete coal types developed, including gas coal, coke, fat coal, lean coal etc. [9]. Hegang Coal Field structure is a monoclinal structure tilting east. Pit Hecan 3 has preferable coal-bed methane indication.

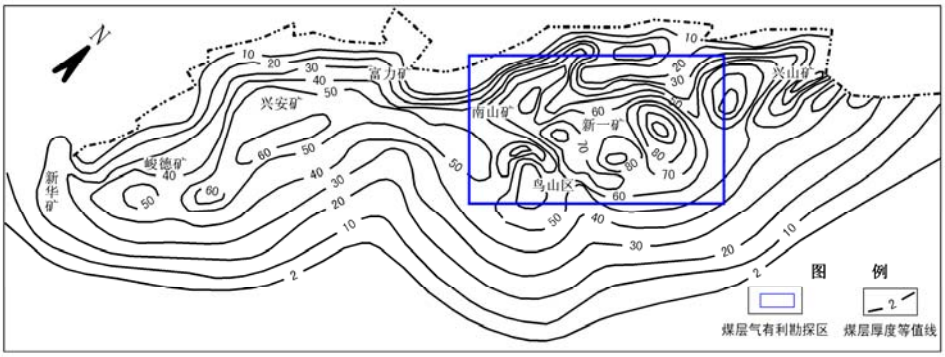

Fig. 3 Isogram chart of total thickness of coal bed in Hegang Basin

Therefore , Hegang Basin Nanshan～Xinyi Mine of Hegang Basin is a favorable block for CBM exploration.

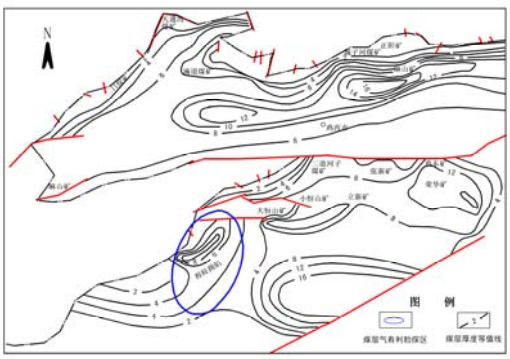

Fig. 4 contour map of total depth of Chengzihe coal beds in Jixi Basin

3.2 Jixi Basin Target Area Evaluation

Jixi Basin has abundant coal reserves, except Hengshan Mine, others are highly gassy mines. As controlled by Hengshan uplift, Jixi Basin can be divided into two structural zones: southern depression and northern depression, and Muleng depression is located in the west of the southern depression. The local geological structure is an uplift in sag structure, including 7-40 layers of coal, 3-17 layers of recoverable coal bed and the total thickness of coal bed is over 20 meters (Fig.4). The types of coal are mainly coke and fat coal, which are in favor of gas generation. There is a thick mudstone layer intercalated with multiple tuff layers that have favorable sealing function to coal-bed methane and for the enrichment of coal-bed methane [11].

Therefore, Muleng Depression is a favorable area for CBM exploration.

4 Conclusion ；

(1) The east of Heilongjiang Province is controlled by four deep faults that has established today's tectonic framework；

(2) The coal-bearing strata include Chengzihe Formation and Muling Formation. Coal beds are well developed in Chengzihe Formation with 20-70 layers of coal bed and total thickness of over 90m; in Hegang Basin the medium thickness seam has monolayer thickness over 20m. As controlled by regional magmatic thermal metamorphism, coal is under different degrees of metamorphic changes, but with coal ranks of mainly gas coal, fat coal and coke.

(3) Mudstone and tuff distributed in overlying strata of coal-bearing rocks has favorable sealing function; whereas aquifers in coal-bearing rocks are in closed position with slow flow-off, which plays the function of hydrostatic pressure plugging to coal-bed methane.

(4) The region of interest has good coal-bed methane exploration prospects. Muleng Depression in Nanshan ~ Xinyi Ore and Jixi Basin is a potential target area for next step coal-bed methane exploration.

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