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Coalbed Gas and Shale Gas Resource Prospect of Heyang-Hancheng Area

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Abstract. As an important coal production area, Heyang-Hancheng has already reached coalbed gas exploration stage. However past study had been focused on coal resources survey; systematic oil gas resources assessment had never been conducted. Based on sediment environment research, this paper using field coal survey data combined with source rock organic geochemistry analysis, argillaceous shale and coalbed aero field absorption and resolve tests, isothermy absorption tests, coalbed gas well logging and gas well logging methods etc. to assess the coalbed gas and shale gas exploration prospects. Resource rock of this area is widely distributed and rich in organic matters, has plenty of type II kerogen, and its organic maturity reaches post mature dry gas stage; thus, has sound hydrocarbon production potential. Both coalbed gas well-logging and isothermy absorption indicated gas content has reached resource evaluation criteria; both shale gas in-situ desorption and gas well-logging show existence of gas, and the natural gas is mainly methane (CH₄) with heavy hydrocarbon component. Introduction. Locates at the intersection of Hancheng and Chenghe Mining Area in Weibei Coalfield in Hancheng City and Heyang County, the study area has a width of 20.14km from east to west, length of 22.58km from north to south, with an irregular shape and has a total area of 300km². The area, rich in coal resources, is an important coal resource producing area with widely distributed coal-bearing construction and good continuity. The loess covers a large part of area, and the bedrock is intermittently exposed along the valley. The structural position is in the turning position of the anti-"S" type head in the Weibei coalfield, which is not conform to the monoclinic structure of the NW or NNW, and the dip angle of the stratum is 3°~7°. The faults are all normal faults, with strike of NE or NEE, usually less than 10 km, the section dips NW, and the fault scale is generally tens of meters to more than 100 meters. The northern fault is mostly southward, and the southern fault is mostly northward, which together forms the NEE direction asymmetric garben structure.

1. Sediment Environment

The Upper Paleozoic Taiyuan and Shanxi Formations in the area experienced a sedimentary evolution process from the coastal shallow sea to the offshore terrigenous clastic lake basin [1], and the Taiyuan



and Shanxi Formations are important coal-bearing construction [2]. Microfacies such as mud flats, lagoons, peat swamps, subaqueous diversion bays, shallow lake marshes and lake muds are important sites for source rock and coal rock development [3], which is beneficial to the formation of source rocks and the accumulation of shale gas and coalbed methane.

1.1. Taiyuan Formation

The Taiyuan period is a set of clastic tidal flat deposits with a thickness of 25 to 35 meters. Niping microfacies, which is composed of mudstone, silty mudstone and shale and contain lens of silt and fine-grained sandstone, is dominant in the period. Niping microfacie has horizontal bedding, lenticular tidal bedding, contains plant fossil fragments, and muddy matter (where the phenomenon of bio-disturbance is strong, footprint and wormhole structure is common). Stratum transits upward to coal seam, which is an important source rocks deposit of argillaceous hydrocarbon; The Niping microfacies is the most favorable facies belt for the development of argillaceous source rocks, while the peat bog environment is beneficial to the formation and preservation of coal seams, which also provides important material conditions for oil and gas formation in this area.

1.2. Shanxi Group

The delta front and shallow lake deposits are developed in Shanxi Period, with a thickness of 65~85m. The bay marshes are generally formed in humid climates with low-water stagnant water plants grow lush and gradually accumulate environment; or formed in floodplain lake in a humid climate [4]. Organic-rich marsh deposit formed by this occlusion environment is a good coal-forming environment; the diversion bay is between the underwater diversion channel and the lake in the connected low-lying areas, the environment is relatively enclosed and the hydrodynamics are weak [5]. The sediments are composed of grayish, dark grayish, blackish fine clastic materials and mud, and the development of horizontal bedding, sand layering, etc., witness tems and fossils. The shallow lake mud microfacies are dominated by argillaceous sediments, and their sediments are fine grain size and thick mudstone; shallow lake marshes microfacies is rich in organic matter formed by the occlusion environment. Due to poor drainage conditions, the stagnant water body predominates, the organic matter accumulates rapidly and the sediment surface is continuously covered by water, and oxidation rarely occurs. By the effect of anaerobic bacteria, sediment can be reduced to coal seams or carbonaceous mudstone.

2. Characteristics of coal and argillaceous source rocks

2.1. Lithology and distribution traits

The coal and mudstones in this area are widely distributed, the thickness of the eastern has been increasing, the thickness of the central sediment is stable, and the thickness of the south is comparatively thin. Due to the difference in sedimentary environment, the development of source rocks in different strata is different. The drilling core shows that the dark mudstones of the Taiyuan Formation in this area are developed, which can be further categorized as silty mudstone, mudstone, carbonaceous mudstone, and 3-4 layers of coal seams. The source rocks of the Shanxi Formation are mainly composed of coal seams and dark mudstones: The upper part is grayish mudstone with low organic matter content; The middle and lower parts are dark mudstone, carbonaceous mudstone and coal seam with high organic matter content. The cumulative thickness of coal and mudstone is mainly 35~55m, but the thickness and number of layers of single-layer mudstone vary greatly (Fig. 1). The section of single-layer mudstone with thickness less than 5m accounts for 61.79%, 5~10m thicked sections accounts for 20.28%, while thickness greater than 10m (which qualify the layer thickness requirement for shale gas development) reaches 17.92%. The mudstone strata are mostly separated by siltstone. Some of the wells are separated by coal seams, and the lithological grain size changes little, all of which are fine-grained deposits. This is mainly because the area is in the environment of sedimentary interaction from the sea-land interaction phase to the offshore continental lake basin; where phases changes frequently, and the silty and

argillaceous deposits frequently intersect with each other, leading to results of thinner thickness of the mudstone and a faster change.

The Taiyuan Formation and the Shanxi Formation contain 3 layers of coal seams (No. 4, 5, 11). The No. 4 coal seam is mainly medium-thick coal seam with an average of 1.85 m. Majority of area can be mined; No. 5 coal seam is mainly medium thick~ Thick coal with an average thickness of 3.89m, thus whole No. 5 area can be mined; No. 11 coal seam is mainly medium-thick coal seam with an average thickness of 1.82m, and most of the whole area can be mined. The macro coal types of each layer of coal are mainly semi-bright coal type, brittle, mainly powdered coal with a small amount of granular coal and lump coal, which belongs to extra low moisture, medium ash coal with high degree of coal metamorphism. Coal in this area all belong to poor grade coal.

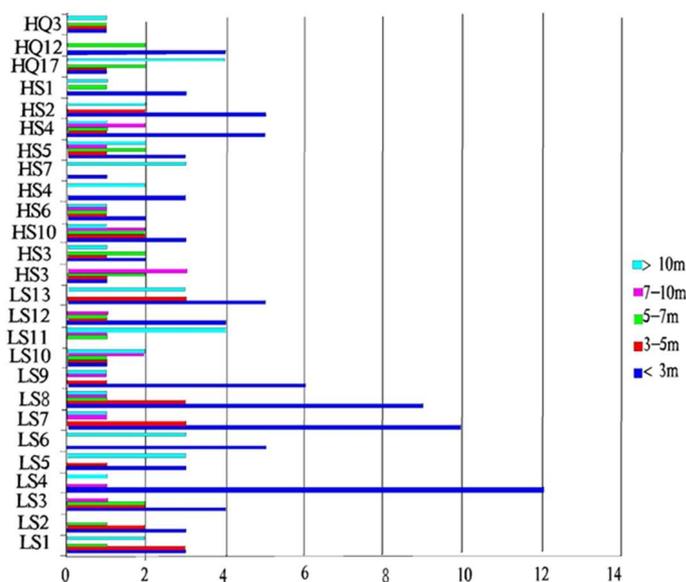


Figure 1. Taiyuan, Shanxi Group Mudstone Single Stratum Depth Distribution Frequency for Each Well

2.2. Organic Geochemical Characteristics

Organic earth characteristics of source rocks in the region were evaluated from three aspects: organic matter abundance, type, and maturity. The coal seam continuity was good, the organic matter abundance was high with average TOC as high as 72.36%. The type of organic matter is mainly type III, with high sulfur content and strong reduction. The micro-components of coal rock are mainly vitrinite group, with an average of 67.22%, the average inertia group is 19.74%, and the chitin group is 12.92%. The vitrinite group is the main gas-producing components in coal and rock belong to the dip-type coal source rock [6].

Dark mudstone has broad-distribution characteristics, medium abundance of organic matter, and certain hydrocarbon generation capacity. The average TOC of the Shanxi group is 8%, the average hydrocarbon generation potential is 1.29, and the medium and good grade source rock samples account for 75%. The organic matter abundance of the Taiyuan Formation was higher than that of the Shanxi Formation, with an average 12.6% TOC and an average hydrocarbon generation potential of 1.41. The type of organic matter is mainly type II, and some samples reach type I. The average composition of the argillaceous source rocks in the Shanxi group is 58% in the saprolite group, 17.78% in the inert group, 0.29% in the chitin group, and 24.21% average in the vitrinite group; Taiyuan group's kerogen type pass that of Shanxi group with average slime group composition of 67.5%, inertia group of 7.67%, vitrinite group of 24.83%, no shell group is found, and the organic matter type is mainly type I (also type III is evident but there's no type II). The organic matter has high maturity, and the average R_o is 1.88. Among

them, the sample with R_o is 1.0~2.0 accounts for 73.68%, and the sample with $R_o > 2.0$ accounts for 26.32%, which indicates source rock in this area reaches the high mature condensate moisture - over mature and dry gas stage.

3. Evaluation of gas content of coalbed methane and shale gas

Coalbed gas desorption, coalbed methane logging, isothermal adsorption experiments and other means are used to analyze the gas-bearing characteristics of coal seams. By shale field desorption and gas logging work gas shale gas-bearing characteristics were understood, which provides gas content parameters for evaluating the potential of coalbed methane and shale gas.

3.1. Coalbed methane gas evaluation

The coal seam was taken in the coal seams of each coal hole. The average content of natural methane in No. 4 coal seam is 4.39ml/g.daf, the average content of natural methane in No. 5 coal seam is 3.84ml/g.daf, and the average content of natural methane in No.11 coal seam is 5.05ml/g.daf. The gas content of coalbed methane logging is obviously higher than that of gas desorption, with average content of methane in No. 4 coal reaches 15.46ml/g.daf, average content of methane in No.5 coal reaches 18.76ml/g.daf, and the average content of methane in No.11 coal reaches 19.12. ml/g.daf, the methane content of all coal seams is higher than the lower limit of coalbed methane evaluation in this area. According to the adsorption isotherm test curve (Fig.2) the amount of adsorbed gas in each recoverable coal seam is large with average volume of Lange 25 cm³/g. At low pressure, the adsorption amount increases rapidly as pressure increase. When the pressure reaches a certain point, as the pressure increases, the adsorption amount per unit pressure gradually becomes smaller, and the slope of the curve gradually becomes smaller. The development process of coalbed methane is in a state of depressurization. Generally, the unit pressure-drop obtained during initial discharge is low, but high in the middle and late stages. However, in the later stage of mining, it is more difficult to reduce the pressure of coal seam drainage. From the point of seepage, the development of such coalbed methane requires a certain permeability of the coal seam.

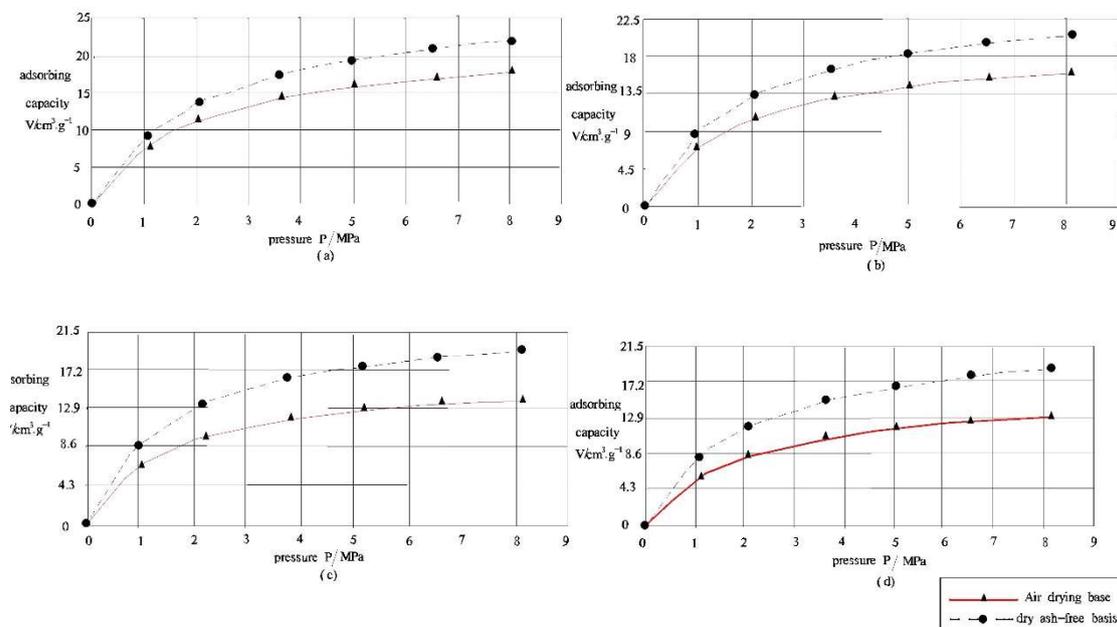


Figure 2. Coal bed Isotherm Absorption Curve
(a.coal 4, Longshi 1 well b. coal 5, longshi 1 well c. coal 4, Longshi 13 well d. coal 5, Longshi 13 well)

3.2. shale gas gas content evaluation

1. shale gas field analysis

The gas content of the shale gas desorption sample consists of three parts: the amount of lost gas, the amount of desorption on site, and the secondary desorption of the laboratory. A total of 10 samples were collected, all of which were released during the site desorption phase; among which siltstone has the highest gas content. The gas content of the shale gas sample desorbed in this area is satisfactory; however, the methane content in the gas component is not high (Table 1), which resulting in a lower final calculation of the methane content of the shale. Among samples, the methane content in the siltstone and coal seam roof mudstone is higher, while the methane content in the carbonaceous mudstone is slightly worse. It is assumed that the gas mainly comes from coal seam gas, which has the characteristics of local migration and accumulation, while the siltstone seepage condition is better than mudstone, so it has better gas content. The natural gas component is mainly methane (CH₄), with an average of 54.2%. Existence of heavy hydrocarbon components indicates that the natural gas supplier is mainly composed of high methane content coalbed methane and mixed source gas supply. Coal rock is affected by many factors such as high degree of coalification, depth of coal seam and desorption time. The coal seam is the main source of parent rock, but the hydrocarbon generation capacity of mud shale cannot be ignored [7]. The area shale is mainly type II kerogen, also witnessed type I; the presence of mashed kerogen is also an important factor in the production of heavy hydrocarbon gases.

Table 1 Shale Gas Sample Desorption Results

| Sample | Lithology | Desorption(ml) | Gas Content (daf) | | | Total Gas |
|--------|----------------------|----------------|-------------------|-----------------|--------------------------------|-----------|
| | | | CH ₄ | CO ₂ | C ₂ ~C ₈ | |
| F2-1 | Carbon Mudstone | 201 | 0.26 | 0.01 | 0 | 0.27 |
| F2-2 | Blackish Mudstone | 740 | 0.57 | 0.01 | 0 | 0.58 |
| F2-3 | Blackish Mudstone | 234 | 0.40 | 0.01 | 0 | 0.41 |
| F2-4 | siltstone | 416 | 0.60 | 0.01 | 0 | 0.61 |
| F2-5 | Blackish Mudstone | 282 | 0.44 | 0.03 | 0 | 0.47 |
| F2-6 | Mudy- siltstone | 1048 | 1.33 | 0.08 | 0 | 1.41 |
| F2-7 | Blackish Mudstone | 427 | 0.36 | 0.02 | 0 | 0.38 |
| F4-1 | siltstone | 32 | 0.29 | 0 | 0 | 0.29 |
| F4-2 | Carbon Mudstone | 86 | 0.18 | 0 | 0 | 0.18 |
| F4-3 | Blackish Mudstone | 31 | 1.7 | 0.01 | 0 | 1.71 |

2. shale gas gas logging

The gas logging work was carried out in Benxi, Taiyuan, Shanxi and Shihezi Formations. The hydrocarbon content of the gas carried in the mud filtrate returned during the drilling process was monitored real time to fully grasp the alteration of hydrocarbon content in the formation. There are 18 gas logging anomaly sections, of which the Shihezi Formation witness 9 gas anomaly sections, which corresponds to the middle sandstone and fine sandstone sections developed by the fractures; the Shanxi group sees 5 gas anomaly sections, and the upper part corresponds to the fracture development. The fine sandstone section in the middle and lower part corresponds to the carbonaceous mudstone and coal seam section; the Taiyuan Formation witness the gas-measured anomaly section 3, corresponding to the

carbonaceous mudstone, coal seam and limestone section; the Benxi Formation sees the gas-measured anomaly section, corresponding to Gravel thick sandstone section. In addition, the light hydrocarbons in the hydrocarbon gas component are not the only contributors to the total hydrocarbon content, obviously heavy hydrocarbons also contribute to the hydrocarbon content of the formation.

4. Conclusion

The coalbed methane, which is abundant in this area, has entered the stage of exploration. The spatial distribution of coal seams is sound and gas content of coalbed methane logging and isothermal adsorption has reached the resource evaluation standard. The Niping microfacies developed in the Upper Paleozoic Taiyuan are the most favorable facies belt for the development of argillaceous source rocks, while the mud-carbon swamp environment is conducive to the formation and preservation of coal seams. Bay swamp, the underwater diversion bay, Shallow lake mud and shallow lake marsh microfacies of Shanxi group are important concieve places for hydrocarbon source rock deposition. The coal-bearing mudstone has a wide distribution, large cumulative thickness, sound organic abundance, and type II kerogen prevails. The microfacies has certain hydrocarbon generation potential, which not only provides a material basis for the accumulation of conventional oil and gas, but also beneficial to oil and gas resources deposit. Both shale gas desorption and gas logging show the existence of gas; in which natural gas components are mainly methane (CH₄) with heavy hydrocarbon components.

Acknowledgments

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