Study on the Control Effect of Sedimentation on Coalbed Methane in Daning-Jixian Area, Ordos Basin

Haiqing Niu 1, *, Xiaofeng Han 2, Shiyue Chen 3
1 Xianyang vocational Technical College, Xianyang, 712000, China
2 Xi’an center of Geological Survey, CGS, Xi’an 710054, China
3 School of Geosciences in China University of Petroleum, Qingdao 266580, China

*Corresponding author e-mail: upc_nhq@163.com

Abstract. Daning-jixian area is the main distribution area of Carboniferous-Permian coal-bearing rock series in eastern Ordos basin. the enrichment of coalbed methane in the study area is not only controlled by the modern characteristics of the structure, but also closely related to the buried-palaeogeothermal-hydrocarbon history of coal reservoirs under the control of tectonic evolution, which is an important kinetic factor for coalbed methane enrichment. The characteristics, lithology, lithofacies and spatial assemblages of coal-bearing rocks are controlled by the sedimentary environment, and the multigenerational reservoir-cap assemblage increases the thickness and sealing property of the caprock, so the depositional action is very large It controls the coal reservoir gas material base, reservoir cover combination characteristic and reservoir property, and affects the coal bed methane preservation through the combination relation between coal seam and surrounding rock.

1. Introduction
The Daning-Ji county area of Ordos basin is a gas-bearing area of high saturated coal seam discovered by CNPC in the exploration of coalbed methane. Industrial gas flow has been obtained in well 1,5 and 13. According to the literature, the previous studies in the study area mainly focus on the description of coalbed methane distribution characteristics and influencing factors, and the system of gas control factors There is a lack of research. The purpose of this paper is to systematically analyze the influence of sedimentary action on coalbed methane in the study area, and to provide theoretical basis for further study of the basic geological theory of coalbed methane in Daning-Jixian and the next exploration and deployment [1].

The Daning-Jixian area is located in the southeast margin of Ordos basin. It is located in the south of Shanxi flexor fold belt and the north of Weibei uplift [2]. The Carboniferous-Permian system is rich in coal reserves and coalbed methane resources. At present, there are many schemes to divide the coal system. There are more than 10 layers of coal seams in the Benxi Formation of Middle Carboniferous and Taiyuan Formation of Lower Permian (previously divided into Middle Carboniferous) and Shanxi Formation. Among them, Benxi formation contains 2~3 layers of coal, the main recoverable coal seam is No .8 coal seam; Taiyuan formation contains 2~4 layers of coal, the thickness is relatively small, mostly non-mining coal seam; Shanxi formation generally contains 3~5 layers of coal, mining coal seam 2~3 layers, the main recoverable coal seam is No .5 coal seam .
2. Analysis on the Burial History and Hydrocarbon History of Coal System

From the analysis of coal measure sedimentary burial history (Fig. 1), it can be seen that the coal measure is basically in the state of continuous deep burial from the Carboniferous-Permian coal measure deposition to the late Triassic in the study area. During this period, the paleotemperature of coal measure continues to increase and the thermal evolution of coal is deepening. The Carboniferous-Permian coal series was in continuous subsidence during the Triassic period, and the coal evolved into deep metamorphism. The sediment thickness of the study area was about 1661~3057 m. According to the analysis, the geothermal gradient from early Permian to late Triassic was about 2. The relationship between temperature and coal metamorphism established in the late Triassic Carboniferous-Permian coal series \( \text{℃} 80\sim110 \), according to Левенщтейн(1969). The coal metamorphism reached the stage of gas coal and fat coal in the study area.

![Figure 1. Burial and Thermal Evolution Patterns of Carboniferous-Permian Coal in Daning-Ji County (Modified from Changqing Oilfield Data)](image)

At the end of the late Triassic, the Indosinian movement, the crust uplift, the previous deposition of the upper strata were denuded, the coal cover layer became thinner, the coal seam temperature appeared to decrease in a small range, the first deep metamorphism of coal was terminated, and the gas was temporarily stopped. Because of the low degree of denudation, tectonic movement has little effect on the preservation of coalbed methane.

After the Indosinian movement at the end of the late Triassic, the crust of the study area was basically in the state of subsidence. During the continuous buried depth, the ground temperature of the coal system increased, and finally it was larger than the temperature of the first deep metamorphism, and the secondary deep metamorphism occurred and continued to be angry. At the study area, the Jurassic sediment thickness is about 700 m; The late Jurassic to the early Cretaceous, Yanshanian movement caused the crust to rise and the depositional action was stopped at one time, but because of the relatively weak tectonic intensity, it can be regarded as a continuous process with the Jurassic deposition. By the end of the early Cretaceous, the Carboniferous-Permian coal seam reached the maximum burial depth, about 3370~4840 m, Permian coal layer temperature was about 100~135 \( \text{℃} \), coal metamorphism reached the stage of fertilizer and coking coal, secondary deep metamorphism to the stage of fertilizer and coking coal. At the end of early Cretaceous, Yanshanian movement was strong again, tectonic activity intensified, and the earth heat flux increased, which further increased the degree of coal metamorphism. On the basis of deep metamorphism, the Carboniferous-Permian coal seam was superimposed with
magmatic thermal metamorphism. Tectonic and sedimentary evolution analysis shows that at the end of Jurassic-early Cretaceous, the coalbed methane preservation conditions in the study area have been relatively good. Yanshan movement occurred in the early and late Cretaceous period, which caused the crust of the study area to uplift and uplift.

3. Characteristics of controlling gas by sedimentation

3.1. Sedimentation affects the development of coal reservoirs

No.5 main coal is formed in terrestrial environment, Single layer thickness 1~7 m, A thick belt with more than 4 m of coal is located in Xueguan-Caojing, Xiangning-Mingzhu and Puxian East Belt. A coal-rich center with a single layer of No.5 main coal more than 5 m is mainly distributed in the north-south line of the mountain-kiln canal. The main characteristics of No.5 main coal gathering in this area are as follows: the thick belt of coal is banded, The coal-rich center is attached to both sides of Xue Guan fault. No.8 main coal formed in marine sedimentary environment, Single layer thickness 1~9 m, A coal-rich center with a thickness of more than 5 m is located in Daning-Yaoqu, east of Pu County and southeast of Ji County. A thick belt with a single layer of No.8 main coal more than 7 m is mainly distributed in the middle of the mountain, Wu Cheng and the east of Puxian. The main advantage of No.8 main coal distribution is that the thick coal belt extends north and south to the periphery of the block, The east is on the west side of Luliangshan, And the thickness of the single layer of coal seam, characteristics of stable distribution and concentration. Two layers of main coal, The thickness of No.5 main coal and the stability of flat distribution are less than that of No.8 coal, This is related to the superiority of marine coal-forming environment over terrestrial factors.

3.2. Substance base for sediment environment control of coalbed methane production

The mineral content of No.5 coal and No.8 coal is relatively low, generally less than 10%, an average of 3.5% in the north and a higher average of 8% in the south. moisture content is generally low, 0.26%~3.10%, the lateral change is not obvious, but the water of low mature sample is slightly higher.

ash content in coal changed greatly, which was 7.58%~25.04%. the mean value of volatile content of No.5 coal is 14.7%, No.8 coal is 16.4%, and the volatile content is low, which shows the characteristics of medium and high metamorphic coal (Table 1). In general, the coal ash yield of Shanxi group on the plane has little change, and the coal ash yield of Benxi group on the longitudinal direction is higher than that of Shanxi group. It is generally considered that the coal system deposit is thin, the center deposit is thick, the ash content of the corresponding depression is high and the middle part is low; the closer the denudation area is, the higher the ash content is, the lower the ash content is.

It is proved that the coal-rock vitrinite content is proportional to the gas content and reservoir performance of coal seam The higher the vitrinite content, the better the coal reservoir performance and the higher the gas and gas content[4, 5]. the influence of ash content on gas content is very prominent in Gushan area of Ordos Basin. If the base value of ash content in coal seam is set at 15%, the ash content decreases by 2.5~3 m3/t, and the ash content in coal seam is inversely proportional to gas content. The composition and microstructure of coal and rock are controlled by the depositional environment, which is based on the causal relationship.

| Coal seam number | Ash content(%) | Volatile content (%) | Water content(%) | Remarks |
|------------------|----------------|---------------------|-----------------|--------|
| Number 5         | 5.3~13.3       | 14.7                | <5              | All values are the average of each sample |
| Number 5         | 10.8~15.4      | 16.4                | <3              |        |
3.3. Control of reservoir physical properties by sedimentary environment

To study the main controlling environmental factors of pore system differential development in the eastern margin of Ordos basin, the main factors were analyzed by seven parameters: ash content (%), mineral content (%), gelation index (GI), plant preservation coefficient (TPI), mirror inertia ratio (V/I), flow index (MI) and forest index (WI)[6-8].

In high-grade coal-phase areas like Daning, the cumulative percentage of variance $f_1$, $f_2$ and $f_3$ of the first three factors is 84.958%, This suggests that the first three factors already reflect the vast majority of the raw data. Although the main factor $f_1$, $f_2$, $f_3$ more comprehensive expression of raw data information, Except for the principal factor $f_1$, The geological significance of each principal factor is not well known. As a result, the original data are still taken in the R cluster analysis, As you can see from the diagram, A ad %, M%, WI these three parameters have a strong correlation, At the same place as inertinite group%, TPI% and pore%; GI, V/I, vitrinite has a similar relationship, Characterized the amount of gelation in the reservoir, thus controlling the development of micropores; and MI was correlated with macroporous content (Fig.2).

![Figure 2. Clustering analysis of R clusters in the southern eastern margin, Ordos Basin](image)

It is generally believed that the adsorption capacity of coal to gas increases with the increase of coal grade. According to this rule, the specific surface area of coal should also increase with the increase of coal grade, but the results of low temperature nitrogen test on the eastern edge of Ordos basin are not completely so. When the total clay mineral content is less than 10%, its influence on coal seam surface area is still superimposed on the background of coal metamorphism degree. When the clay mineral content exceeds 10%, its influence will often exceed the influence of coal metamorphism degree, and the specific surface area of coal reservoir constitutes a substantial influence (Fig.3 a, b). Zhang Songhang analyzed the pore distribution characteristics of the eastern margin of Ordos basin and pointed out that the pore contribution of clay minerals in the coal sample stage in the central and southern part is mainly "ink bottle" pore size of 3-4 nm, but there are such "ink bottle" pore size even if the mineral content is small in the northern part[9]. However, for the dim coal seam with high mineral content, its hardness is relatively high, and the influence of deposition compaction is relatively small, and the change of inert components, which are dominated by silk and semi-silk bodies, is relatively small, so that most of its internal pores can be preserved, so that the influence of minerals on coal reservoir will increase
with the increase of metamorphism and the evolution of coal and rock microporosity system will be differentiated.

![Graph](image1)

**Figure 3.** Relationship between BET surface area and coal grade and mineral content

3.4. Distribution of surrounding rock and gas control characteristics of coal reservoir

Due to the influence of rock composition and pore structure, the sealing property of different lithology is quite different. The mudstone area is the most favorable area for coalbed methane accumulation. The sealing property of elastic rocks is related to the thickness of lithology. Generally, with the increase of particle size, the effective porosity increases, the drainage pressure decreases, the permeability increases, and the sealing property becomes worse (Figure 4); the sealing property of carbonate rocks is affected by the composition of carbonate rocks and the degree of fissures and karst development, and the sealing performance of karst and fractured carbonate rocks is poor. The roof of No. 8 coal seam in the area is limestone, although the lithology is dense, but the sealing property is slightly inferior to that of mudstone, so the gas content is lower overall than that of No. 5 coal seam.

![Graph](image2)

**Figure 4.** Region Characteristics of Roof Pore Structure in No. 5 Coal Seam in Daning Area, Southeast margin of Ordos Basin

The conditions of coal cover in Daning area are superior [5]. The Lower Shibiao Formation is mainly composed of mudstone with a small amount of siltstone and fine sandstone; the Upper Shibiao Formation is mainly mudstone, siltstone and fine sandstone; the Shqianfeng Formation is dominated by fine sandstone and siltstone with mudstone and marl; and the Triassic is interbedded with mudstone and
fine clastic rock. Multi-layer mudstone is developed from Xiashibiao formation to Yanchang formation, which becomes a good regional cover layer of Carboniferous-Permian coal seam, especially Xiashibiao formation.

4. Conclusion
Through the above analysis, it can be concluded that the Daning area has been in the continental sedimentary state since the western period of the mountains, and the crust is stable and in the continuous sedimentary state after the Carboniferous-Permian coal series deposition, which creates a good environment for coal evolution, gas generation and coal bed methane preservation. The formation of coal reservoirs is closely related to the distribution, the composition of coal and rock, the lithofacies and their spatial composition, which are all controlled by the sedimentary environment[9]. Based on this causal relationship, the depositional effect determines to a large extent the material basis of coal bed methane formation and the geometric characteristics and physical properties of coal reservoir and cap rock, and affects the preservation conditions of coal bed methane through the combination relationship between coal seam and surrounding rock.

Sedimentary action is one of the important controlling factors of coalbed methane enrichment in Daning-Ji county. The study of coalbed methane enrichment in this area should also take into account the geological factors such as structure and hydrogeology and their configuration relationship.

Acknowledgments
We gratefully acknowledge the financial support for this study from the Doctoral Fund of Xianyang Vocational and Technical College [Grant nos 2019BK002] and the Research Fund Project of Xianyang Vocational and Technical College [Grant nos 2020KJB01].

Main References
[1] JIANG Bo, XU Jinpeng, ZHU Kui, et al. Structural and Hydrogeological Controls of Coalbed Methane Preservation in the Eastern Ordos Basin[J]. Geological Journal of China Universitie, 2012, 18(3): 438-446.
[2] TIAN Wenguang, XIAO Jianxin, ZHANG Jidong, et al. CBM reservoir-cap formation type and its gas controlling function in the eastern margin of Ordos basin[J]. COAL GEOLOGY & EXPLORATION, 2015, 43(4): 31-35.
[3] SOBCZYK J. The influence of sorption processes on gas stresses leading to the coal and gas outburst in the laboratory condition[J]. Fuel, 2011, 90(3): 1018 - 1023.
[4] Ju Yiwen. Wei Mingming. Xue Chuandong. Control of bamm mountain evolution on the occurrence of deep coal and coalbed methane in North China[J]. Journal of China University of Mining & Technology, 2011, 40(3) , 390-398.
[5] Ma Xingzhi,Song Yan,Liu Shaobo,et al. Origins and geochemical characteristics of coalbed methane in Hancheng. eastern Ordos Basin[J]. Natural Gas Industry, 2011, 31(4)(17-20.
[6] CHEN Yue, MA Dongmin, XIA Yucheng, et al. Study on wettability and influencing factors of different macroscopic components in low rank coal[J]. Coal Science and Technology, 2019, 47 (9): 97 - 104.
[7] LIU Dameng, LI Junqian. Main geological controls on distributionand occurrence and enrichment patterns of coalbed methane in China[J]. Coal Science and Technology, 2014, 42(6): 19-24.
[8] LU Xiaoxia, ZHANG Bing,WU Jian, et al. Analysis on production features and influence factors of coalbed methane in deep section of north Shizhuang Block[J]. Coal Science and Technology, 2018, 46(6): 92-100.
[9] YANG Heng, LUO Xian, SUN Changyan. Research on law of coalbed methane enrichment and main controlling factors in Jiaozuo Machang exploration area [J]. Coal Science and Technology, 2020, 48 (3): 180 - 187.