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The influence of tectonic characteristics on the accumulation of Coalbed Methane in H area

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There are several geological factors affecting the accumulation of CBM, including tectonic condition, burial depth, coal thickness, coal rank, gas content, permeability, reservoir pressure, desorption pressure and hydrological condition, etc. This article analyzes the influence of tectonic characteristics on the accumulation of CBM in H area, combining the tectonic characteristics and the actual production data, finally conclusions can be drawn that the uplifting movement of crust after coal- forming period could break the original adsorption equilibrium, then CBM would escape under unfavorable preservation condition; different scales of fractures and folds formed by tectonic movements play an important role in the preservation and dissipation as well as in the enrichment and accumulation.

[**Key words:** CBM; gas content; folds, faults, tectonic characteristics]

Introduction

Coalbed methane has won numerous scholars' attention, as the replacement of conventional natural gas. CBM is a kind of unconventional natural gas, self-generated and self-stored, whose accumulation process is controlled by CBM-bearing system making up of coal seam and its upper and lower layers, together with different geological factors. As is demonstrated, there are several geological factors affecting the accumulation of CBM, including tectonic condition, burial depth, coal thickness, coal rank, gas content, permeability, reservoir pressure, desorption pressure and hydrological condition, etc.[1] Various tectonic styles directly determine the CBM occurrence, the fractures development of coal reservoir, CBM reservoir type and preservation condition and so on. Thus the analysis of tectonic characteristics is one of the important contents of CBM occurrence law, as it controls not only the formation and evolution of coal-bearing basins and strata, but also the formation, enrichment and output of CBM. This article discusses the influence of tectonic characteristics on CBM enrichment and accumulation, combining the actual geological condition in the study area and the previous research.

Geologic setting

As is shown in Fig.1-1, the study area locates in H county of Weinan city in Shaanxi Province, in the southeastern part of Ordos basin, next to the east margin of coal field in the Carboniferous-Permian of Weibei, Shaanxi, that in the north lies the main block of Ordos basin, that in the south is next to Weihe graben and joins the east-west belts of Qinling, that in the east is Fenhe graben and joins the Lvliang belts, that in the west locates at the joint of Helanshan belts and Liupanshan belts. The study area went through several tectonic changes in different properties and direction since the sedimentation of coal measures in the Carboniferous-Permian, at the same time, these structures around, affected a lot by tectonic effects, controls the formation and evolution in the study area. The mining area is divided into two geomorphic units, the loess tableland and loess ridge [2], whose topography general trend is northwest high and southeast low. On the monoclinic structure, a serious of S-N and E-W secondary belts, open and flat, as well as some nearly E-W normal faults on a large scale.

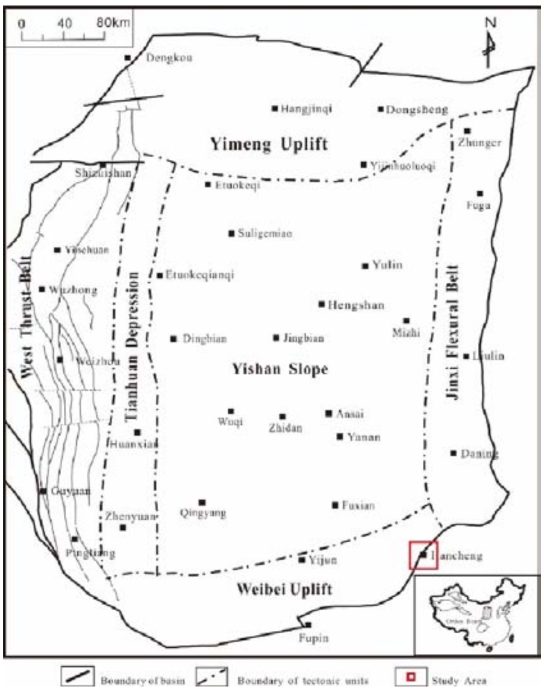

Fig.1-1 The tectonic map of Ordos basin

The coal strata in the study area include Benxi formation in Middle Carboniferous, Taiyuan and Shanxi formation in Low Permian from the top to the bottom, among which Benxi formation usually doesn't bear coal while Taiyuan and Shanxi formation are the main coal-bearing strata.

The number of coal seam in the study area is up to 13, from top to bottom, the number of which is $1^{\#}$, $2^{\#}$, $3^{\#}$, $4^{\#}$ of Shanxi formation, and $5^{\#}$, $6^{\#}$, $7^{\#}$, $8^{\#}$, $9^{\#}$, $10^{\#}$, $11^{\#}$ of Taiyuan formation, etc. The distribution of coal seam $3^{\#}$, $5^{\#}$, $11^{\#}$ is relatively common, as are the main mining coal seam in the study area.

The influence of different tectonic forms on CBM enrichment and preservation

The enrichment of CBM depends on the following three geological factors, regional tectonic evolution, hydrodynamic force and sealing condition[3], this section will focus on the influence of various tectonic forms on the enrichment and preservation of CBM in the tectonic evolution.

Geological structures are one of the important factors affecting the enrichment of CBM, as it not only affects the gas content of CBM, but also obviously controls the variation of coal seam, the stability of coal roof and floor, and many kinds of geological conditions, including the magmatic intrusion, karst collapse, ground temperature and pressure, and hydrogeological condition.

The coal seam structures are divided into two basic types, folds and fractures[4]. Fold structure refers to the wave-shaped bend of coal seam and rock stratum under stress, keeping the continuity and integrity of the stratum, making up of two tectonic forms, anticline and syncline. Fracture structure consists of all kinds of faults, cracks, and stratum fractures. Faults will be mainly discussed in this section, which can be divided into extensional type and compressive type. Various kinds of geological structures result in different tectonic stress field characteristics and different internal stress distribution, thus the occurrence, structure, physical property, cracks development and groundwater flow condition of coal reservoirs and sealing stratum differ, hence, the gas content of coal seam is affected.

The influence of folds on the enrichment and accumulation of CBM

The fold structure is one of the most widely existed in nature. In material mechanics, when a beam of internal uniform structure bends under the horizontal extrusion, the distribution of stress in the beam differs obviously, there is a surface of no strain, which is called the neutral plane, neither extended nor shortened, however, the upper of which extends because of tension, while the lower of which shortens because of compression[5]. (Fig.2-1) According to the previous research, the neutral plane in the study area lies at the bottom of the sandstone of Shanxi formation[6].

1） Anticlinal structure

The anticline is under compressive stress as a whole, whose distribution of stress both wings is relatively uniform. When the coal seam is above the neutral plane, the upper coal seam suffers the tensile stress, which is the strongest an the core, making the ductile strata at the core become thinner, the porosity of which gets bigger as well, consequently, the gas permeability of coal seam increases, providing access to the escape of CBM, at the same time, a lot of CBM turns to the free state from the absorption state along with the formation of folds because of the plasticity of coal seam, escaping from the pores, causing the reduction of CBM content at the core. However, when the coal seam lies beneath the neutral plane, the stress suffered is just on the contrary, the extrusion stress at the axial part is the strongest, making the ductile strata at the axial part become thicker, and the desorption of CBM accelerates with the flow of coal seam from the wings to the core, at this time, the anticline is under high pressure because of the sealing of overlying strata, which is favorable for the enrichment and accumulation of CBM. The wings of anticline are usually under tensile stress, which is favorable for the storage of CBM, hence, the relative position between the coal seam and the neutral plane will determine whether to form the CBM reservoir, as far as the anticline structure concerned[7] （Fig.2-2）.

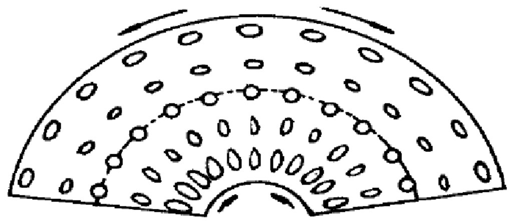

Fig.2-1The stress distribution in the neutral plane

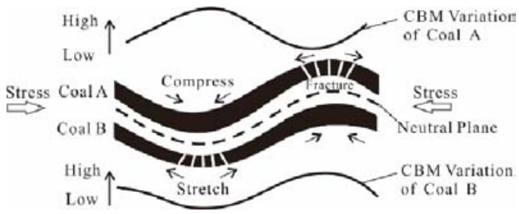

Fig.2-2 Sketch map of relationship between folds and CBM contents

2） The synclinal structure

The strata are under strong extrusion stress as a whole. When the coal seam is above the neutral plane, the coal seam suffers the extrusion stress, making the ductile strata at the core of syncline become thicker and CBM desorb on a large scale, which is favorable for the enrichment and accumulation of CBM reservoirs, however, the permeability of coal seam decreases significantly as a result of stress concentration . When the coal seam is beneath the neutral plane, the coal seam suffers the tensile stress, resulting in the thinning of ductile strata at the core of syncline, as the burial depth of coal seam is relatively big, there exerts small amounts of open fractures, the relative low area is formed[8] because of the releasing of some stress, CBM content will reduce relatively, whereas it could become the enrichment area of CBM. Hence, in terms of synclinal structure, whether the coal seam lies above or beneath the neutral plane, or at the wings or the core, it is favorable for the preservation of CBM, and eventually become the enrichment and accumulation area.

The influence of fractures on the enrichment and accumulation of CBM

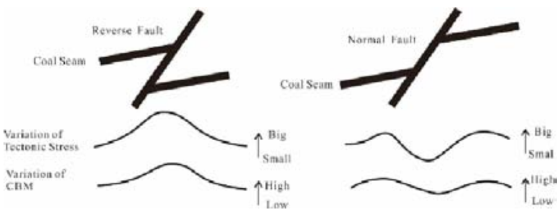

Fig.2-3 Sketch map of relationshiop between faults and CBM contents

The influence of fractures on the accumulation of CBM reservoirs is multifaceted; it affects not only the integrity of coal seam and the sealing condition of CBM, but also the coal body structure, the microscopic characteristics, and the permeability to different degrees[9]. The impact of faults on the CBM reservoirs has something to do with its properties and scales.

The compressive faults usually include reverse faults, compressive faults or reversed normal faults, fault planes of which are usually enclosed, making it difficult for CBM to escape from the fault planes, as the tectonic stress concentration zone is near the fault plane[10], the pressure of CBM increases, resulting in the increase of adsorption of CBM, thus to increase the CBM content.

The tension faults usually include normal faults, extensional strike-slip faults or reversed reverse faults[11], fault planes of which are usually are usually open, making it adverse for the preservation of CBM. Because of the release of tectonic stress, it becomes the low pressure area where is near the fault plane, resulting in the increase of adsorption of CBM, and CBM escapes through the fault plane, making the CBM content decrease drastically.

Example of H area

The strata in H area emerge a NE trending tectonic slope[12], southeast shallow and northwest deep, across which exist a couple of low-amplitude structures, alternating with anticlines and synclines. The faults in the south and north are of highly complexity degree and the strata

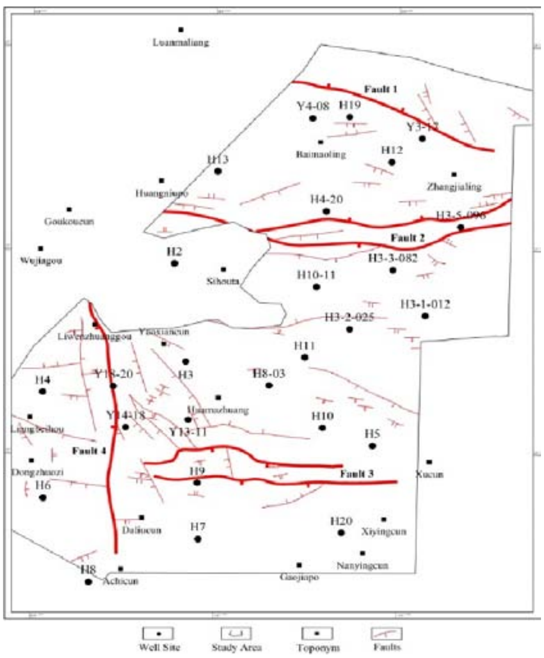

Fig. 3-1 The distribution map of faults in H area

occurrence changes greatly[13]; while the middle area suffers little by the faults and the strata occurrence is rather stable. The fracture system in the study area is very complex, a group of EW trending normal faults and another group of nearly SN trending reverse faults were developed, and two faults, nearly EW trending, are of strike-slip property.

Fault 1, located in the further north of study area, is a north dipping fault, nearly EW trending, whose general trend is NE 30°~40°, being the marginal fracture of Fenhe graben. It has the characteristics of multi-period activities, and now presents the extensional normal fault[9], obvious property of strike-slip. The biggest fault displacement in the study area is 280m.

Fault 2 lies in the middle of study area, the fault plane of which appears like slow waves, almost parallel to Fault 1. It is a south dipping fault, nearly EW trending, extending as long as 16km, whose general trend is NE50 °, obvious property of strike-slip. The biggest fault displacement in the study area is 240m.

Fault 3, located in the further south of study area, is a south dipping normal fault, nearly EW trending. The biggest fault displacement in the study area is 460m, whose lateral changes are great.

Fault 4, located in the further south of study area, is a dipping west reverse fault, nearly SN trending, whose strata occurrence of upthrow and downthrow side vary a lot. The biggest fault displacement in the study area is 300m.

In order to illustrate the influence of faults and folds on the enrichment and accumulation of CBM, I choose 4 cross sections in the study area this time, among which there are 2 sections trending EW, another two trending SN, then the comprehensive comparison maps of relationship between structure and gas content are drawn, via comparing the chosen sections, the influence of faults and folds on the gas content can be reflected basically.

For the section H6-H9-H10-H5, the structure increased higher and higher gradually from the west to the east. In the east of well H9, there exists a normal fault, dipping south, EW trending, and well H9 lies at the downthrow side of the fault. The gas content data are 11.73m^3/t, 6.3m^3/t, 8.94m^3/t and 8.91m^3/t respectively, reflecting that the gas content of lower structure is better than that of the higher (Fig.3.2). The low gas content of well H9 may have something to do with the fault activities. On account of the existence of tensional normal faults, the fissures around well developed, at the same time, well H9 lies at the anticline, affected by the tensile stress at the core, the increase of porosity also adds the channel for the escape of CBM, resulting in the decrease of gas content.

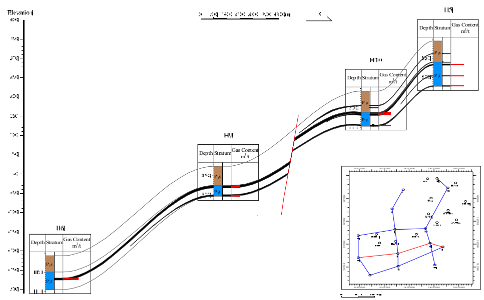

Fig. 3-2 Comparison map of gas content of section H6-H9-H10-H5

For the section H4-H3-H11, from the west to the east, it appears a tectonic framework of east high and west low, as is shown in Fig.3-3. The gas content data are 15.47m^3/t, 9.99m^3/t and 14.55m^3/t successively from the west to the east, reflecting the character of low-side among high. In the gas-generation stage, as the burial depth of well H4 is relatively big, its gas content is relatively big correspondingly, afterwards the strata characteristics complicate as a result of the reverse fault in the east, the upthrow side suffers the uplift of strata. The well H11 lies at the core of anticline, the coal seam beneath which is under the neutral plane, and CBM desorb on a large scale on account of the compressive stress, however, by reason of the sealing of the overlying strata, CBM is under closed circumstance of high pressure, thus to increase the gas content.

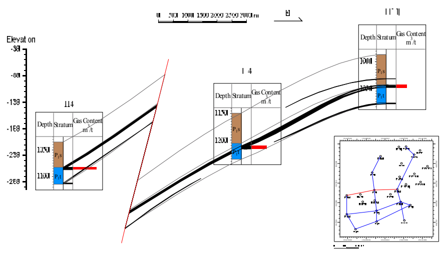

Fig. 3-3 Comparison map of gas content of section H4-H3-H11

In terms of the section H7-H9-H3-H2-H13, the strata occurrence appears the monocline dipping north from the south to the north, and the strata is incised into several fault blocks by faults, as is shown in Fig.3-4. The gas content data are 9.56m^3/t, 6.3m^3/t, 9.99m^3/t, 7.71m^3/t and 15.07m^3/t respectively from the south to the north. Generally, the gas content of coal seam increases with the increase of its burial depth, i.e. the bigger the burial depth is, the higher the gas content will be. In the north of well H9, as there exists extensional normal fault, places near the fault plane become the low pressure area because of the release of tectonic stress, CBM desorbs in large quantities, and escapes from the fault plane, thus to decrease the gas content of coal seam. In the north of well H3, insomuch as the sealing of the compressive reverse fault, CBM get well preserved, nonetheless, in the north of well H2, the gas content of coal seam decreases drastically, as a result of the extensional normal fault.

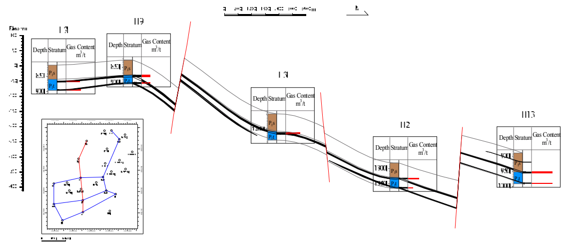

Fig.3-4 Comparison map of gas content of section H7-H9-H3-H2-H13

In terms of the section H10-H11-H12-H19, the structure gets lower and lower from the south to the north, presenting the structural feature alternating with anticline and syncline, and the strata characteristics get complicated because of faults, as is shown in Fig.3-5. The gas content data are 8.94m^3/t, 14.55m^3/t, 6.31m^3/t and 9.28m^3/t successively from the south to the north, and the gas content decreases with the reduction of burial depth. The well H10, H12 and H19, all locate at the core of anticline, and the coal seam lies above the neutral plane, which is adverse for the preservation of CBM, thus to decrease the gas content; however, the well H11 lies at the core of syncline, maintaining the biggest effective thickness of overlying strata and the stable strata pressure, even though there exists the extensional normal fault in the north, CBM get well preserved because of the stress concentration, hence, the gas content is relatively big.

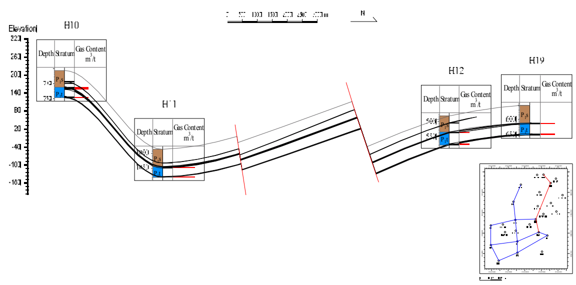

Fig.3-5 Comparison map of gas content of section H10-H11-H12-H19.

Conclusions

The structures in the study area are very complex, and the faults distribute densely where concentrated in the middle and southern part of study area, while in the north of study area, the structures are relatively simple, and there are fewer faults.

(1) The uplifting movement of crust after coal- forming period could break the original adsorption equilibrium, resulting in the mutual transformation between adsorption gas and free gas, then CBM would escape under unfavorable preservation condition[14];

(2) Different scales of fractures formed by tectonic movements play an important role in the preservation and dissipation as well as in the enrichment and accumulation. Reverse faults or compressive strike-slip faults usually belong to the compressive faults of good sealing condition, planes of which are closed, at the same time, it becomes the tectonic stress concentration area near the fault planes, making it good for the increase of adsorbed CBM. Normal faults or extensional strike-slip faults are usually extensional faults, planes of which are normally open, and the fault plane can become the channels for the migration of CBM, meanwhile, it becomes the low pressure area near the fault plane, resulting in the mass desorption of CBM, thus to decrease the gas content.

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