Gas content prediction and gas cascade control based on gas geological unit

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Abstract: The division of gas geological units in coal mine is the basis of studying the occurrence law of gas geology in coal mine field, which is of great significance to the prediction of regional gas content and gas emission. Taking Weijiadi coalfield in Jingyuan mining area of Gansu Province as an object, this paper divides the coalfield into gas geological units, according to the gas content of coal seams in different regions, targeted gas extraction measures are implemented, gas cascade control is implemented, regional gas abnormal emission is strictly prevented, and mine safety production is ensured.

1. Introduction
The division of gas geological units in coal mine field is helpful to study the law of gas geology in coal mine, the division of outburst dangerous areas and gas prevention, and is of great significance to the safety management of coal mine. At present, the division of gas geological units in coal mine field is mainly carried out from the angle of coal mine safety production, that is, by dividing gas geological units from the own geological conditions, gas geological conditions and gas dynamic phenomena, so as to carry out safety management differently for these gas geological units.

Wang Yuhuai [1] used the theory of gas geology, combining with the gas geology data revealed by geological exploration and mine production, the 13 mine fields are divided into two gas geology units. In order to reveal the law of gas occurrence and distribution in coal seam 11-2 of Dingji Mine, Huainan Coalfield, according to the distribution characteristics of mine geological structure, it is divided into six gas geological units, and the gas occurrence characteristics of each unit are analyzed by using the theory of progressive control of gas occurrence structure[2]. Wu Fahong [3] uses the geological structure, gas occurrence characteristics and the development of tectonic coal in the mine field, divides the mine field into three geological units: Nanping syncline and its F33 fault, NF26 fault and -720m horizontal roadway, and predicts the gas distribution geological units.

In order to predict regional gas emission more accurately and implement gas precise extraction measures, this paper divides Weijiadi Coal Mine minefield into gas geological units, implements corresponding gas extraction measures according to gas content in different regions, prevents regional gas abnormal emission, and ensures mine safety production.
2. General Situation of Weijiadi Coal Mine

Weijiadi Coal Mine is a part of Baojishan Coalfield in Jingyuan mining area. The Mesozoic strata in the coalfield are well developed. There are Cretaceous and Jurassic strata. The Jurassic strata are divided into upper and lower Jurassic strata, which mainly occur in the north flank of Baojishan syncline and the southwestern wall of F_{1-2} fault group. The middle and lower Jurassic strata are coal-bearing strata, and the base of the coal measures is the Upper Triassic. From West to east, the mine field consists of Baojishan syncline (and its secondary No. 1, No. 2, No. 3 and No. 4 synclines). The south side of the minefield is affected by the F_{1-2} fault group, which makes the coal seam in the southwest wing more seriously damaged, resulting in a more complex structural belt in the shallow part of the southwest wing. The coal seam destroyed is characterized by powder, mylonitic and scaly, and micro-folds and faults can also be seen. The middle part of the minefield is mainly affected by F_{3} and F_{48} faults, in which F_{3} fault is a compressive-torsional fault thrust from NE to SW with a fault spacing of 28-65m; F_{48} fault is south of F_{3}, roughly parallel to F_{3}, and the fault is a high angle thrust from SW to NE and thrust against F_{3} with a fault spacing of less than 40m. The north side of the northern minefield is affected by deep fault F_{46}, which is a fully concealed high-angle thrust fault. Because of the strong compressive and torsional stress during the formation process, the fault fracture zone reaches more than 100 m.

The coal-bearing strata in the minefield are Middle-Lower Jurassic, which contain five seams of coal. From top to bottom, there are no one coal seam, one coal seam, two coal seams, no two coal seam and three coal seams. The mineable coal seam is one coal seam, the second coal seam and the third coal seam, and the main coal seam is one or three coal seams. The average total thickness of the main coal-bearing strata is 88.28m and the coal-bearing coefficient is 27.5. The mineable coal seams are concentrated in the middle and lower Jurassic, with a total thickness of 22.5m.

3. Division of Gas Geological Units

3.1. Principles for dividing gas geological units

The division of gas geological units was originally developed from the "gas geological zoning theory" put forward by the Institute of gas geology of Jiaozuo Institute of Technology on the topic of "geological structural characteristics of coal and gas outburst zones in Hunan, Jiangxi, Henan Province". The main viewpoint is that the distribution of gas and outburst zones are not balanced and have the characteristics of zoning, which is closely related to geological conditions and the location of the area. It is pointed out that the division of gas geology research is to compare various geological factors affecting gas occurrence and gas outburst, to find out their differences and connections in time and space, to synthesize according to certain signs, to divide different levels of regions or areas, and to divide gas geological units. Gas geological unit is to divide the minefield into several areas according to the geological conditions of different coal seams and gas occurrence characteristics by applying the viewpoint of gas geological regionalization theory. The gas geological characteristics of coal seams in each area are similar, which is more conducive to the implementation of different technical measures.

At present, there are no unified standards and norms for the division of gas geological units, and there are no fixed models and zoning indicators for the division of gas geological units. In the process of the division of gas geological units in specific wellfields, there may be situations that vary from person to person, resulting in differences in the division of gas geological units, which hinders the establishment of guiding principles for the division of gas geological units to a certain extent.

According to the development of gas geology, the division principles of specific gas geological units are as follows:

- (1) To define the classification of gas geological units. According to the scope of the study area and the law of regional gas geology, the division level of gas geologic units is determined. Generally speaking, the division of gas geologic units is determined by two levels. First, the division of first-level gas geologic units is carried out, and then the second-level gas geologic units are further precisely divided on the basis of the division of first-level gas geologic units.
(2) The boundary of gas geological unit is delineated by the regional boundary which controls gas distribution.

(3) Unified dividing index should be adopted to divide gas geological units in the same area. When dividing gas geological units in the same mining area or mine field, uniform dividing indexes, or gas, or geology, or single index, or comprehensive index should be adopted.

(4) The division of gas geological units should be combined with the compilation of gas geological maps. The results of the division should be reflected in the gas geological maps so as to guide production practice.

3.2. Division of Gas Geological Units in Weijiadi Coal Mine

The occurrence and distribution of coal seam gas are influenced and controlled by many geological factors. The occurrence and distribution of coal seam gas in a certain area of coal seam occurrence space presents certain regularity. Within this area, gas content and gas pressure are controlled by several main geological factors respectively. Such a spatial range is called gas geological unit. Different gas geological units have different gas geological characteristics, and gas geological units have hierarchical nature. According to research needs, a large coal-bearing basin can be divided into regional gas geological units, mine-level gas geological units can be divided into regional gas geological units, mining-level gas geological units can be divided into mine-level gas geological units, and higher-level gas geological units can outline the overall attributes of lower-level gas geological units. Lower gas units are more detailed in local details of higher-level gas geological units. Scientific and rational division of gas geological units is conducive to clarifying the law of gas occurrence within each gas geological unit, which is not only conducive to the safe and efficient exploitation of coal resources, but also conducive to the exploration and development of gas resources. According to the research needs, Weijiadi Coal Mine is divided into three levels of gas geological units.

The degree of coal metamorphism in the whole mine field does not change obviously along the direction of coal seam, and basically does not change along the trend of coal seam within the scope of study; the coal seam distributes evenly and its thickness does not change much; the sedimentary environment of regional coal seam is basically the same, the roof and floor of coal seam are relatively dense, which has a good sealing effect on coal seam gas; the whole area is in a hydrogeological unit and the hydrodynamic system has a good sealing effect on the whole area. The key factor to distinguish different geological units is geological structure, and large faults are developed in the whole area. According to the theory of gas geology, these large faults can be used as the boundary of gas geological units. By collecting and sorting out relevant data of geological exploration and actual production of gas in the whole area, using gas geology theory, the distribution law of gas content and gas pressure in the whole area is analyzed, and the boundary of each gas geological unit is initially determined. Then the occurrence law of gas in each unit is studied, and the similarities and differences of gas geological law in each geological unit are analyzed. The whole area is initially divided into four gas geological units.
The specific geological units are divided as follows:

(1) Unit I: Unit I consists of the part between the F$_{1-2}$ fault group and the F$_3$ fault group. F$_{1-2}$ is an external nappe at the southern edge of the well field. It consists of F$_1$, F$_2$ and many faults in the middle of the nappe. It runs through the whole well field in a direction consistent with the direction of the well field. It pushes the vertical direction of the well field to a distance of 500-2000 m (horizontal fault distance) in the middle and deep part of the well field at a gentle angle. It almost covers most of the well fields. It has nothing to do with the main structure of the well field and is a floating surface structure. However, it destroyed the lower coal seam seriously, resulting in the southern flank of the minefield becoming a complex structural influence zone of the F$_{1-2}$ fault group. F$_3$ Fault: Located between No. 1 anticline and No. 2 Syncline in the middle of minefield, it is a concealed reverse fault covered by F$_{1-2}$ fault group. It starts to the east of line X in the West and cuts No. 1 anticline in the west of 55 degrees. It disappears between line X V and supply line X V, with a total length of 4100m. The gas content in this area ranges from 6.10 m$^3$/t to 8.37 m$^3$/t.

(2) Unit II: Unit II is the part between fault F$_{46}$ and fault F$_5$. F$_{46}$ is located in the northeast of the minefield, which is the Northeast boundary of the whole minefield. It enters the field from hole 179 of line X IX to the east, extends to NW with N50 W, and slightly turns to N55 W between supply line X III-2 and line X IV, which passes through the whole field. Fault plane inclines SW with dip angle of 70°~75°. It is a compressive-torsional reverse fault with SW plate rising and NE plate falling. Fault F48: Located in the south of Fault F$_3$, which is roughly parallel to Fault F$_3$, is a thrusting fault thrusted from SW to NE and thrusted against Fault F$_3$. The dip angle of the cross section is 60°~70° and the fault distance is less than 40 m. As the two faults rise from their opposite sides, the middle coal seam decreases in an inverted wedge-shaped belt. The gas content in this area ranges from 8.65 m$^3$/t to 9.28 m$^3$/t.

(3) Unit III, Unit III is the part between F$_{1-2}$ and F$_{49}$ faults. F$_{1-2}$ is an external nappe at the southern edge of the well field. It consists of F$_1$, F$_2$ and many faults in the middle of the nappe. It runs through the whole well field in a direction consistent with the direction of the well field. It pushes the vertical direction of the well field to a distance of 500-2000 m (horizontal fault distance) in the middle and deep...
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coal seam seriously, resulting in the southern flank of the minefield becoming a complex structural
influence zone of the F_{1-2} fault group. F_{49} is located in the shallow part of the south-west wing of the
minefield. It is a compressive-torsional reverse fault with a length of 700 m and a N60 degree E syncline
spanning the line X V and V. The fault spacing is 40 m in hole No. 195. It tends to increase in the shallow
part and decrease in the deep part. The gas content in this area ranges from 9.25 m$^3$/t to 10.57 m$^3$/t,
which is the highest relative to other units.

(4) Unit IV, Unit IV is the part between F_{3} fault and F_{50} fault. F_{50} is a thrust fault west of fault F_{49},
which is a compressive-torsional reverse fault thrust thrust from NE to SW. The section inclines to NE
with an inclination of 55°~65°and the fault distance is less than F_{49}. Its property is the same as that of
F_{49} and its length is about 150 m. F_{3} Fault: Located between No. 1 anticline and No. 2 Syncline in the
middle of minefield, it is a concealed reverse fault covered by F_{1-2} fault group. It starts to the east of
line in the West and cuts No. 1 anticline in the west of 55 degrees. It disappears between supply line X
V and line X V, with a total length of 4100m. The gas content in this area ranges from 7.24 m$^3$/t to
8.68 m$^3$/t.

4. Gas Classification Control
Through dividing the gas geological unit of Weijiadi Coal Mine into four units, according to the gas
occurrence situation of different units, according to the concept of "one area, one policy, grading
management", and through comprehensive consideration of regional gas emission quantity and
geological factors, the regional gas grading control is determined, and the measures of gas extraction
are implemented pertinently to ensure the precise gas extraction.

According to the gas content of geological unit and considering the special structure such as
geological structure, the measures of mine gas control are divided into four levels:
The first level is the working face with gas content less than 2m$^3$/t in the regional coal seam (the
three-seam coal mined in the protected seam), which is controlled by conventional measures such as
reasonable ventilation, borehole extraction along the seam \[4,5\], leakage plugging in the upper and lower
corners, gas drainage in the buried pipe in the upper corner, etc.
The second level is the working face where the gas content in the regional coal seam is between 2
and 5 m$^3$/t. On the basis of the first level measures, the measures of buried pipe extraction in the upper
corner and short-high drilling hole extraction in the low-level drilling field at the upper exit are added.
Level 3: The regional coal seam gas content is in the working face of 5-10m$^3$/t. On the basis of the
second level measures, the roof rock is added to the large diameter and high position borehole extraction
measures \[8\], and equipped with separate source gas extraction system.
Level 4: On the basis of the second level measures, the working face with gas content above 10 m$^3$/t
in regional coal seam is equipped with ground drilling and roof gas extraction roadways and separate
gas extraction system.

5. Conclusion
(1) According to the theory of gas geology, Weijiadi coal mine is divided into four gas geological units.
(2) According to the division of gas geological units in the mine field, the gas prevention and control
mode of "one area, one policy and cascade control" has been established in the mine, which lays a
foundation for the implementation of precise extraction, the prevention and control of abnormal gas
emission and the guarantee of mine safety production.

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