Reseach on Controlling of Rock Mass Structure on Water Inrush From Coal Seam Floor in Huaibei Mining Area

WU Jiwen\textsuperscript{a}, JIANG Zhenquan\textsuperscript{b}, ZHAI Xiaorong\textsuperscript{a,} \textsuperscript{a}\textsuperscript{*}

\textsuperscript{a}Anhui University of Science and Technology, Huainan 232001, China
\textsuperscript{b}China University of Mining and Technology, Xuzhou 221008, China

Abstract

Huaibei Mining Area is located in the south of the North China Coal-bearing Region. Its hydrogeological condition has basic features of the North China Coalfield. The hydrogeological condition is complex. The mining in the coal seam of Shanxi Formation where water inrush from coal seam floor happened mang times is generally seriously threatened by the limestone water from floor. The paper systematically analyzes typical cases about water inrush from coal seam floor in the researched area, and uncovered the different features of water inrush caused by different geological structure condition and water-inrush passage, which is of typical meaning to study controlling of rock mass structure on water inrush from coal seam floor.

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1. Overview

Huaibei Coalfield is located in the south of the North China Coal-bearing Region, two large enterprises of Wanbei Coal-electricity Group Co., LTD. and Huaibei Coal Mining Group Co., LTD. are in the district, has been 50 years of mining history, existing more than 20 pairs of large and medium-sized mines, it has formed annual production of about 30 million tons of coal production scale, it is an important coal base in Anhui Province and east China.

* Corresponding author. Tel.: +86-0554-6668761.
E-mail address: jwwu@aust.edu.cn
HuaiBei Coal Seam group contains mainly Permian Shanxi and Xiashihezi Formation, Shanxi coal layer contains one mining coal seam (which called No.6 coal seam by Zhahe Mine, and No.10 by Suxian, Linhuan coal mining), Xiashihezi Formation contains three minable seams, numbering 3,4,5. Coalfield hydrological engineering geological environment is similar to basic characteristics of North China Coalfield, and hydro-geological conditions are complicated, the lower seams 6 (10) are universally threatened by the underlying coal seam Taiyuan Ordovician limestone water and major flooded Wells accidents caused by water inrush from coal seam floor happened many times.

2. Hydrological engineering geological environments of coal-bearing strata

2.1. The background of regional geological structure

HuaiBei Coal is an entire concealed coal field covering with loose layer. The basic structure of the coal formed in yanshanian periods. HuaiBei mining area located in the front of Xu-Huai nappe tectonics nearby, west of North-China subsidence area. Regional tectonic framework, first restricted by the east-west structural, then controlled by NNE structural, and subsequently subjected to Xu-Su arcuate nappe structure which causing the torsion stress and damaged to the new tectonic movement, formed a regional multi-trending folds, faults and more structural pattern of activity, so that coal stratum subjected to different degrees of transformation.

2.2. Stratigraphic structure

According to the revealed information of the drilling and mine workings, the strata of mining area are: the Ordovician, Carboniferous,Permian, Tertiary and Quaternary, the main coal-bearing strata are Shanxi and Shihezi Formation of Permian.From the old to new are summarized as follows:

Ordovician: in the mining area for the burial type, according to regional data the total thickness is about 600m, can be divided into seven-segments or five groups, composed by the thick layer of limestone, dolomite, local mingled with chert bands, conventionally called, "Ordovician", is the base of the coal. The karst channel is highly developed in this formation, and with high water bearing properties, the karst fissure water constitutes the main source of water of the regional groundwater system.

Benxi Formation of Middle Carboniferous series: the thickness of 30 ~ 40m, light gray, gray and white oolitic aluminum mudstones, part in violet red color, and is relatively impermeable layer.

Upper Carboniferous Taiyuan Formation: a thickness of about 130 m, mainly composed of limestone, siltstone, sandy mudstone, fine sandstone, mudstone and coal line, in which formation 12 to 14 thin layers of limestone developed, the cumulative thickness is 60 m, the thickness of the third and fourth layers of limestone are thick, karst developed, water content is rich, often called "limestone in Taiyuan formation ". The first limestone layer called "marker bed (K1)".

Lower Permian Shanxi Formation: thickness of 85 ~ 135 m, mainly composed of sandstone, siltstone, mudstone and coal seam. This group has one primary mineable coal bed (which called No. 6 coal seam by Sui Xiao Mine, and No. 10 by Suxian, Linhaitong coal mining), that is, the lower group.

Lower Permian Xiashihezi Formation: This group has a thickness of 300 m, mainly composed of sandstone, mudstone, al mudstones (K2) and coal seam. With five coal (group), and 3, 4, 5 seam of which are locally mining coal seam in the mining area.

Upper Permian Shangshihezi Formation: has a thickness of about 730 m, lithology is based of fine clastic rocks, mainly with two unworkable coal seams.

Tertiary and Quaternary (unconsolidated): Cenozoic ca. 40 ~ 400m thick, mainly composed by lacustrine sand layer, clay, some formation containing a small amount of lime concretion. Part of the
bottom where pluvial facies (debris flow) sedimentary sequences develops, composed by clay and sand mixture. Unconsolidated cover the top of Permian, making the entire coalfield to be a concealed coal field.

2.3. The main aquifer groups

(1) Cenozoic thick unconsolidated aquifer and aquifuge(group)

Cenozoic ca. 40~400 m thick, and the thickness is controlled by the ancient landform. Composed by clay and sand interaction, is a lake - river facies. According to the property of water-bearing and water-resisting, Cenozoic can be divided into three aquifers and three impermeable layers, as missing or wedging out phenomenon of the second and third aquifuge, the second and third aquifer combined in local section, resulting in complementary relationship. The third aquifer comes into contacting with fractured sandstone aquifers of coal measure, which cause a hydraulic connection.

(2) Fractured sandstone aquifer of coal measures

Take the aquosity of the Permian (coal measures) for example, the aquifer composed by sandstone where fracture develops, and aquifuge composed by the mudstone and siltstone, there are aquifuges between each aquifer, the water abundance of interlayer fractured aquifer under pressure depends on the degree of fracture, connectivity and supply conditions. There are four more stable distribution of the aquifer in the region, number five, six, seven, eight.

Number five and six aquifer are mainly composed by sandstone, 120m and 70m away from the NO. four coal below, though fracture develops, for far from the primary mineable coal bed, and separated by impermeable layers, fissure water is difficult to inrush into the pit directly. NO. seven and eight aquifer are the roof and floor of NO.four and six coal seam, the two aquifers are about 100m apart. Because of the tectonic movement in many different periods, the cracks of sandstone roof and floor are well developed, which becomes the main water source of mine water-filling.

(3) Karst fissure water of Taiyuan limestone

Taiyuan Formation underlying has a total thickness of 130m in average, composed by mudstone, siltstone and 13 layers of limestone. From top to bottom, L1 and L2 are the thin layers of limestone, thickness of 2 ~ 3 m, and weak aquosity; the L3, L4 limestone, have a thickness of 8 and 12 m in average. Karst fissure cave develops abundant supply of water. There is an aquifuge of sand-shale of 50 ~ 60 m from 6 (10) coal seam, which is the effective impervious layer under normal circumstances, making Taiyuan limestone Aquifer will not have a direct impact on Water Filling. However, affected by mining or construction damage, Karst fissure water of Taiyuan limestone under pressure may cause water-bursting in mine, so Taiyuan limestone Aquifer is the main water source of mine water-filling which threaten the mining.

(4) Karst fissure water of Ordovician limestone

Ordovician limestone has a total thickness of about 600 m, is the strong regional aquifer. Majiagou Formation in the Ordovician limestone is the main aquifer, water bearing space is mainly composed of karst cave and corrosion fissure, in the mine area is buried type. The layer is more than 180m from 6 (10) coal, and the NO. six coal mining is not directly affected. However, the district where karst collapse column, water-conducting fracture develops, resulting in the Ordovician limestone water have a hydraulic connection with Taiyuan Formation water to a certain extent, meanwhile recharge Taiyuan Formation aquifer through the strata outcrop. Therefore, the Ordovician limestone aquifer is a indirect aquifer which cause water-filled underground mining.

2.4. Characteristics of the floor of the lower group

The lower group in Huaibei Coalfield NO.6 (10) coal seam lies to the lower part of Shanxi Formation, of a thickness in the North (Suixi-Xiaoxian) and Western (Woyang) is relatively thin, generally 1.57 ~ 2.0 m; in central district (Linhuan-Haizi-Tongting) and eastern (Suxian) is relatively thick, usually 2.2 ~ 2.52 m, maximum thickness of 12.3 m.

NO.6 (10) coal seam is one of the primary mineable coal bed of the region, the mining of the coal seam threatened by the Taiyuan Formation limestone and Ordovician limestone water, major water inrush has occurred many times so far.

2.4.1 Lithology and thickness of the floor

The floor of NO.6 coal seam denotes the strata between NO.6 coal seam and the first limestone of Taiyuan Formation belonging to Huaibei coal field, the distribution of the floor of NO.6 coal seam is relatively stable, with a thickness of 40 ~ 60 m.

Lithology of the floor is mainly a delta phase clastic sedimentary, stable in the whole region, and can be broadly divided into three sedimentary layers: the upper section of interbedded sandstone and clay, mainly composed of mudstone, fine sandstone, sandy mudstone, shale sand and siltstone; the middle section is sandstone, mainly composed of fine-grained sandstone, siltstone or mudstone locally; the lower section is mudstone, mainly composed by black mudstone, sandy mudstone.

2.4.2 Rock structure

According to the drilling conditions of NO.6 coal seam floor having been exposed in the district, tectonism has an obvious influence on rock structure of the floor. In the non-structural parts, the upper sandstone - mudstone layers and the middle section of sandstone are generally good, the structure of the rock is mainly the layered and block structure. Mudstone of the bottom where bedding develops, layered is the main rock structure; joint fissure develops in the fold axle Ministry crankshaft fractured joints, or associated sliding between layers, always form the layered joint structure; in the fault zone of a poor integrity, mostly fractured or granular structure.

3. Typical case of water inrush when mining lower coal group

(1) water inrush of working face III 622 in Zhuzhuang coal mine

Working face III 622 began mining in October 2004, when the working face push-gathered 185m away from the cut-hole on January 25th, 2005, exit of machine Lane of working face started inflowing water, the initial water inflow quantity was about 5m³/h, with the mining of working face, water inflow quantity increased to 30m³/h on 26th, at about 10:30 that night, with the roof suddenly weighting, water inflow quantity suddenly increased to about 200m³/h, with tympanites of floor, at 18 o’clock on 27th, the water inflow quantity rapidly increased to 1400m³/h, leading to the working face locally flooded. After a period of time, water inflow quantity had declined.

(2) Water inrush of mining area II 61 in Yangzhuang coal mine

Mining area II 61 is located in the middle of minefield, the structure of mining area is simple, no large fault distribute, in addition to the broad, gentle small anticline in direction of N40°W, the major faults disclosed were some small broken-tension normal faults in NW. Water bursting point mostly distributed in three working face of II 611, II 613, and II

Fig.1 Sketch map of water-inrush positions in the II 61 mining area of Yangzhuang coal mine
617, and focused on turning of the end of the west wing of small anticline (as figure 1 shows), the pressure of limestone water in Taiyuan formation in the area was 3.11 MPa. Mechanized mining working face Ⅱ 617 output coal when transferred on September 1st, 1988, when the working face normally advanced 42 m on October 2nd, water inrush was found in the direction of goaf water in mechanical roadway, the measured water inflow quantity was 59.87 m$^3$/h, because the elevating conveyor was flooded, working face shutdown, it put back on production on October 15th, when the working face advanced to 60m on Oct. 24th, that the amount of water of working face suddenly increased, the measured maximum water inrush was 3153 m$^3$/h, leading to flooding of the working face and the second level.

(3) Water inrush of mining area Ⅱ 62 in Liuqiao No. 1 coal mine

The mining area is the first mining area in north wing of the second level in Liuqiao No.1 coal mine, which is located in the west wing of Chan syncline. The thickness of floor of coal NO.6 in the working face was 55 m, fine sandstone and siltstone mainly in the upper, marine mud layer with the thickness of 17m distributed in the bottom, its lower was Taiyuan formation with the thickness of 130 m, with the interlayer of 13 thin limestone layers, rich in water, water inrush from floor occurred in the working face Ⅱ 623, Ⅱ 626 in the mining area when mining.

water inrush occurred in working face Ⅱ 623 after mining when first weighting, stable water inflow quantity was about 200 m$^3$/h; water inrush from floor of working face Ⅱ 626 occurred when periodic weighting, the maximum of water inflow quantity was 220 m$^3$/h.

(4) Water inrush of working face 7222 in Renlou coal mine

Water inrush occurred in 7222 working face in March 1996 when mining. A few drops of water spray from the roof of the working face early in period of mining, and then gradually disappeared. A normal faults with the drop of 1.0 ~ 1.5 m was encountered when the working face push-gathered to 120m, water inflow quantity was 3.0 m$^3$/h, water inflow quantity increased to 50 m$^3$/h when push-gathered to 220m. Production was immediately stopped to transform for safety reform, working face would be moved 60m from north to south, and the cut-hole was re-opened to avoid the part of water inrush. During the process of transfixion of the new cut-hole from top to bottom at 11:00 on March 4th about, a small amount of dripping water only occurred in roof of the upper roadway, but a lot of water gushed from the north wall of the cut-hole at about 15 o’clock in that afternoon, initial water inflow quantity was 50 m$^3$/h, it increased rapidly at a later time. Water inflow quantity increased to 1980m$^3$/h at 19:40; water inflow quantity had reached as much as 11854 m$^3$/h at 21 o’clock, finally because of constraint of drainage capacity (1200 m$^3$/h) that couldn’t stand against it, the pumping station was flooded because water came in and the power failed at 21 o’clock. Flooded water level of shaft had risen to -297 m at 5:30 on March 6th, total mine water quantity had been up to 31.0×10$^4$ m$^3$; With the water level rising, flooded rate also decreased, at last the water level rose to about ± 0 on March 21st, then it was basically stable when rose to + 15.59 m on May 21th.

4. Rock mass structure control mechanism of water inrush

Taiyuan limestone water and Ordovician limestone water are source water of floor water filling of lower coal group during mining. Its water inrush quantity mainly depends on the contract level between Taiyuan limestone water and Ordovician limestone water, while high water pressure and water-filled channel is the necessary condition of water inrush. Head pressure is the dynamic condition of rising of floor water, under weaker barrier condition, high water head pressure more easily leads to the formation of the channel with connectivity and water inrush.

Water inrush channels include three types: central channels posed by faulted structure and paleo -sinkholes, planar channels posed by extension of fissure existing in rock floor and point-like channels
posed by not closed or closed non-performing drills. Among these channels, faulted structure channels and rock fissure channels are most likely to form.

The four cases of floor water inrush incidents mentioned above reflect the different geological conditions in floor and water bursting channels which is very meaningful for understanding the nature of rock floor water inrush control.

(1) Water inrush caused by floor mining deformation conducting crack channels

There is no fault in lots of water inrush working face II622 of Zhuzhuang coal mine. Fault F1 is 20m away outside the haulage way, leaning to the working face, dip angle is 65°, seam drop of 8m. The inside sloping haulage way is 180M setting along Fault F1 (as figure 2 shows). Affected by the fault, the coal seam strike has changed, as a small widely slow, the crustal stress is relative concentrate. Exposed by drilling, existing a pinnate fissure zone 25M away from the fault plane and the width of which is 15 ~ 20M and altitude is fitting with F1. In the pinnate fissure zone limestone L1 ~ L2 is very fragment and easy form hollow in local.

![Diagram](https://example.com/diagram1.png)

**Fig.2** Sectional sketch map of structure of floor rock mass on the water inrush positions in the 3622 working face of Zhuzhuang coal mine

a- Floor Plan; b- Profile

The floor sickness of the 6 coal is 55M in water inrush position of II622 working face and the floor mainly consists of medium hard sandstone, siltstone and soft clayey rocks and the Limestone water pressure in Taiyuan under floor is 2.70 MPa. Because of the existence of the fissure zone, the integrity of floor water-resisting layer has been broken, waterproof performance has greatly reduced. Once the rocks above the floor was mined and broken, the position that fissure existing will be the weak point of stopping water blocking and it is very easy to be conducted forming the water inrush channel. This shows that the connectivity between above mining broken zone and pinnate fissure zone is the main reason why the water inrush happened meanwhile forming the water inrush channel.

(2) Floor mining activated the fissure structure leads to water inrush

The water inrush position in II61 mining area Yangzhuang coal mine is very similar to that of II62 mining area in Liuqiao coal mine, as figure 3 and 4 show.

Mining area II61 anticline of Yangzhuang coal mine shows a very apparent thinning zone. It’s the thinnest water-resisting of 6 coal floor in the whole coal mine. The water inrush position is in anticline

![Diagram](https://example.com/diagram2.png)

**Fig.3** Sectional sketch map of structure of floor rock mass on the water inrush positions in the II617 fully mechanized coal mining face of Yangzhuang coal mine
shaft where the thickness of rock is only 33.95m (Ⅱ617 drilling 3-4) contrasting with the normal thickness 59.01m (drilling 85-1) a difference about 25 m.

The open-off cut of Ⅱ617 fully mechanized coal face was digging along the fault 2F29 (fault with seam drop 1.3 to 3.5m). The small anticline where fissure fully developed in fault up rock was the drag structure of fault F29 (as figure 3 shows). Under mining condition, affected by water pressure and mine pressure; fissure became further expansion and leaded to water inrush.

The water inrush position of Ⅱ623 mining face in Liuqiao coal mine is at the shaft of small syncline. It is exposed fissure fully exist by drilling before mining showing there is fissure water 6M at the bottom of coal floor when it came 7 ~ 9m the maximum out of water was 20m³/h. Exposed to the seam floor under the 14 m, 31 m, 48 m, 58 m, 70 m, 15 drillings have water, and water in excess of 40 m³/h, which indicated that the considerable development of coal seam floor fracture, and has conducted with the under Taiyuan limestone water.

(3) Exposing centralized water conducted zone leads to water inrush

Water inrush incident at 7222 working face of Renlou coal mine is due to expose centralized conducted zone. By water analysis and post-treatment exploration confirmed that the water inrush channel of this incident is collapsed pole. This collapsed pole is located in the north of open-off cut in 7222 working face and lower side the wind roadway of 7222 working face. The collapsed pole is oval in plane and its long axis along NNW, length is 25 to 30m while short axis along NFF, width is 20 to 25m. Accumulation in the collapsed pole is cracked and unfirm. From the view of profile point, the shape of this collapsed pole was basically vertical. The top boundary is to the fourth aquifer of Cenozoic Erathem and the height is about 300M conducting the hydraulic connection between Cenozoic Erathem, coal rocks and other limestone water.

5. Conclusions

(1) Huaibei Coalfield is part of North China Coalfield, its hydro-geological environment features have a basic similarity. Complicated hydrogeological conditions, with four major aquifers (group), the mining of lower group coal mainly threaten by the floor gray aquifer, site of structure or collapse column also easily connecte Ordovician aquifer.

(2) floor strata of Huaibei Mining Area mainly composed of three sections: the upper layer is sand and mud interstratification; the middle layer is the sandstone; the lower layer is the mudstone. Its main types of lithology are middle hard rock mass and soft rock mass, soft rock fold the hard rock, which is the strata assemblage type with strong water-resisting ability. More complete and blocky rock mass structures are in normal section.

(3) Information of water invasion from floor in Huaibei mining area indicates that the water inrush from floor is controlled significantly by the structure of floor rock mass, That the minng damage conduct the lower tectonic fracture zone to form water burst is the most important reason, therefore, the failure depth of mining deformation is a critical factor to water inrush.
References


