Analysis on the main controlling factors of water-flowing fracture evolution in deep-buried and thick bedrock

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Abstract. The study on the evolution and development law of mining disturbed overlying rock fissures is the basic theory for mine water prevention and gas drainage. In order to reveal the evolution law of water conducting cracks in bedrock after deep burial, through the in-situ measurement of mining cracks in overlying strata in Huanglong mining area, the structural characteristics of overlying strata are calculated and analyzed by using key layer theory. It is found that the development height and shape of mining fissures are controlled by 8 direct influencing factors such as mining thickness and 10 indirect influencing factors such as subsidence space, in which mining size and roof overburden structure are the main control indexes. The development pattern of mining fracture is "trapezoid". For the structural characteristics of roof overlying strata, this paper puts forward the ratio of soft rock proportion coefficient and permeability coefficient in the key layer load layer based on the key layer theory, which plays an important role in the actual development height of mining fissures and the incidence of water inrush.

1. Introduction
The study on the evolution and development law of mining disturbed overlying rock fissures is the basic theory for mine water prevention and gas drainage. "rules for coal pillar setting and pressing coal mining in buildings, water bodies, railways and main shafts and lanes" (abbreviated as "regulations") is based on the idea of mathematical homogenization. An empirical formula for the development height of water-conducting cracks with different lithology[1-3]. Xu Jialin[4] proposed a method for calculating the development of water diversion fracture zone based on the location of the main key layer. Miao Xiexing [5] puts forward the concept of waterproof key layer, and thinks that the unbroken structural key layer is the waterproof key layer, and if the structural key layer is broken, it will form a compound key layer with the soft rock layer above it. Xu Yanchun[6] collected the measured data of the "two zones" height of more than 40 fully mechanized top coal caving faces, obtained the empirical formula for calculating the "two zones" height suitable for fully mechanized top coal caving mining, and revised it accordingly. Although there are many research achievements on the development of law and influencing factors of water diversion fissures, each theory and method has certain regions and limitations. Based on the comprehensive arrangement of the existing research results, this paper comprehensively analyzes all the factors that affect the development of water diversion fissures, and analyzes the key indicators to control the development of water diversion fissures, in order to provide theoretical support for mine safety production.
2. Evolution law and shape of mining fissures

2.1. Affecting factors of mining fractures
Generally speaking, the key to the analysis of mining fissures is the development height and distribution shape of mining fissures, the spatial size of mining influence reflected by the development height, and the spatial range of mining influence reflected by the distribution pattern. The factors restricting the development height of mining fissures are generally divided into geological factors and mining factors, such as coal seam buried depth, overburden lithology and combination characteristics, coal seam dip angle, geological structure and so on. Mining factors are divided into coal mining method, mining thickness, working face width, working face advancing length, mining speed and roof management method and so on. From the controllable analysis of the influencing factors, the geological factor is the uncontrollable factor and the mining factor is the controlling factor. Geological factors and mining factors interact and influence each other to form coupling factors, such as the breaking angle of rock strata, which influence the development height and distribution pattern of mining fissures. The key factors for the development of mining fissures in overlying strata are shown in Figure 1.

![Figure 1. Key factors for the development of mining fractures in overlying strata](image-url)

2.2. Development morphology of mining fissures
The theoretical analysis shows that the state of the coal body or the distribution law of the leading abutment pressure in front of the coal wall affect the shape of the mining fracture (the relationship between the boundary of the water-conducting fracture zone of the overlying rock and the boundary of the goaf). The physical and mechanical properties of coal and overlying rock determine the lateral expansion range of water-conducting fracture zone of overlying rock. The boundary of the water conducting fracture zone of the upper soft and lower hard lithologic structure in Yangcun Coal Mine
extends from bottom to top to the goaf [7]. Zuo Jianping puts forward the "quasi-hyperbolic" failure movement form of mining overburden, and thinks that the deep bedrock is broken in "inverted funnel type", forming caving zone and fracture zone[8]. By means of similar material simulation and numerical simulation, it is proved that the overall shape of mining water diversion fracture in Jurassic coal-bearing strata is "inverted hopper" [9-10]. In this paper, the 3DEC simulation software is used to analyze the development shape of mining fracture in the first mining face of Hetaoyu 1802 in Ningzheng mining area. It is found that the development height of water diversion fracture zone is "trapezoid". Due to the re-compaction of overlying rock, the plane bends downward, the two upper angles of trapezoid are the highest by rock lateral extrusion crack height, and the water diversion area of mining fracture is open-cut and inclined fracture zone.

![Figure 2. Mining fracture block and roof displacement in 350m working face](image)

3. Analysis of main controlling factors of mining fracture

It is found that there are obvious differences in the influence of different factors on the evolution of mining fissures. the sensitivity of the main factors affecting the height of mining fissures from large to small are mining thickness, face size, overburden structure characteristics, mining depth and coal seam inclination angle [11]. Therefore, the analysis of mining thickness, face size and overlying rock structure characteristics play a high guiding role in the study of mining fracture evolution.

3.1. Mining thickness

The empirical formula of the development height of the water diversion fracture zone recommended in the regulations for Coal Pillar setting and pressing Coal Mining of buildings, Water bodies, Railways and main Shaft roadways in China takes the mining thickness as the only quantifiable parameter. The greater the mining thickness and the larger the goaf, the thicker the roof strata filled with the goaf, the lower strata are prone to structural instability, the mining fissures gradually develop upward and the fissures height increases. Fully mechanized mining, large mining height and the development height of water diversion fracture zone in working face of top coal caving increase with the increase of mining thickness, in which the development height of water diversion fracture zone in top coal caving face increases in a fractional function [12]. Generally speaking, the mining thickness is positively related to the development height of the water diversion fracture zone in the working face [13]. Based on the analysis of the relationship between mining height and mining fracture, it is found that the height of caving zone is directly controlled by mining height. The increase of mining height leads to the increase of effective direct roof thickness, the rotary instability of the key strata of the lower main roof, which changes from fracture zone to caving zone, and the rock swelling property is not obvious after roof hard rock instability, resulting in a significant increase in mining fractures.

3.2. Analysis of mining size factors.

The results of field measurement and numerical simulation show that the parameter that determines the final development height of mining fracture is the minimum size of the working face [7], that is,
the width of the working face or the pushing progress of the working face. The width (oblique length) of the working face in the modern mine is generally less than the pushing progress of the working face, so the length of the working face is the minimum size that determines the development of mining fractures. As for the nature of the size effect of the working face is the sufficient degree of mining, Guo Wenbing put forward the definition of the sufficient mining degree of overburden failure when analyzing the development law of the water diversion fracture zone, and considered that the development height of the water diversion fracture zone reached the maximum under the geological conditions. And the stage that does not increase with the increase of face size is the full mining of overlying rock [14]. The numerical analysis shows that the development height of the water-conducting fracture zone increases with the increase of the mining width of the working face, and the longitudinal fracture height of the overlying rock does not increase linearly, but increases piecewise linearly [15], which shows that there are retardation and jump phenomena with the breaking movement of the key strata [16-17].

4. Characteristics of rock assemblage based on the location of key strata
The coal measures strata have the combination characteristics of soft and hard interbeds formed by the sedimentary environment, and the overlying rock structures are obviously different in different regions and different coal-forming periods, but the thick and hard key layers must exist objectively in the strata, so the position of the key layers is first determined in the analysis. The overlying strata are divided into different parts through the key layer, and the load layer of the lower key layer will be the cushion or filling layer of the upper key layer. For the key layer of the old roof, the load layer of the lower key layer will be the cushion or filling layer of the upper key layer. The enrichment degree of the direct roof determines the stability of the key layer of the old roof, so for the key layer of the old roof, the thin soft layer above or the thick soft layer below is better for the stability of the key layer and restraining the development of mining fissures. It can be summarized as "thin soft high position-small load, thick soft low position-filling". For the key layer above the fracture zone and the load layer, after the key layer is broken, the soft rock load layer with coordinated deformation is not conducive to the development of mining fractures because of its strong anti-plastic ability. Therefore, the analysis of the ratio of soft rock proportion coefficient and permeability coefficient in the key layer load layer is of certain significance to the development of mining fractures.

The soft rock ratio of the key layer load layer refers to the ratio of the soft rock thickness to the hard rock thickness in the load layer of the key layer, expressed by R>1 or R<1. Due to the filling effect of the direct roof, the space above the key stratum of the old roof is getting smaller and smaller, the fracture of hard rock remains in the original state, and the fragmentation and expansion of soft rock has a certain filling effect on the key strata above, so the ratio of soft rock can reflect the anti-plastic deformation ability and filling ability of overlying rock. The ratio of permeability coefficient of soft rock refers to the sum of permeability coefficient and thickness of soft rock in the load layer of key layer than the sum of permeability coefficient and thickness of hard rock. This parameter can better reflect the ability of rock to resist roof water permeability after fracture.

5. Conclusion.
(1) The study on the evolution and development law of cracks in mining disturbed overlying strata is the basic theory for mine water prevention and gas drainage. The development height and shape of mining fissures are controlled by 8 direct influencing factors such as mining thickness and 10 indirect influencing factors such as subsidence space, among which mining size and roof overburden structure characteristics are the main control indexes. The development pattern of mining fissures is "trapezoid".
(2) For the structural characteristics of roof overlying strata, the ratio of soft rock proportion coefficient and permeability coefficient in the key layer load layer based on the key layer theory plays an important role in the actual development height of mining fractures and the incidence of water inrush.
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