

# Study on the Height of Water-Conducting Fracture Zone of Overburden Rock in Filling Mining of Gold Mine

Xin Shi

School of Energy Science and Engineering, Henan Polytechnic University, Jiaozuo, China  
Email: 1414461687@qq.com

**How to cite this paper:** Shi, X. (2025) Study on the Height of Water-Conducting Fracture Zone of Overburden Rock in Filling Mining of Gold Mine. *Open Journal of Applied Sciences*, 15, 1073-1084.  
<https://doi.org/10.4236/ojapps.2025.154075>

**Received:** March 12, 2025

**Accepted:** April 20, 2025

**Published:** April 23, 2025

Copyright © 2025 by author(s) and Scientific Research Publishing Inc.

This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

## Abstract

It is the premise of preventing water inrush accident and ensuring mine safety to make clear the development height of water-conducting fracture zone. Based on rock mechanics and hydrogeological parameters of Songxian Gold mine, the height of water-conducting fissure is 8.38 m according to empirical formula method. By using discrete element software UDEC, numerical simulation method and Mohr-Coulomb constitutive model as the plastic yield criterion of rock and soil mass, it is determined that the development height of water fracture zone in stope 050001-07 filling mining of gold mine is about 9 m. Field measurement shows that the development height of the water-conducting fracture zone is 8.12 m. In summary, the height of the water-conducting fracture zone obtained by the three methods is 8.38 m, 9 m and 8.5 m, respectively. It can be seen that the height difference between the numerical simulation and the measured one is 9.78%.

## Keywords

Water-Conducting Fracture Zone, UDEC, Filling Mining, Field Measurement

## 1. Introduction

Mineral resources are the foundation of human civilization and progress, national economic development and scientific and technological revolution. According to statistics, at present, more than 92% of China's primary energy and more than 80% of industrial raw materials come from mineral resources, and the development and utilization of mineral resources has become an important pillar of China's social and economic development [1]. After more than 60 years of efforts,

China has become a major mining country in the world, there are more than 160,000 non-coal mines, the total industrial output value of more than 100 billion yuan, accounting for 1.12% of GDP, of which the content of gold mines in 2023 has reached 3203.77 gold tons. China's gold reserves are the fifth largest in the world, and its mining volume is the first in the world [2].

The occurrence areas of metal deposits often experience strong tectonic activities and metamorphism, resulting in prominent ground stress, complex rock mass structure, joint fissure development, and common fault fracture zones. These geological characteristics aggravate the geological disasters caused by underground mining activities, such as ground pressure appearance, rock movement, and surface subsidence, which seriously affect the safety production of mines [3]-[6]. If the water-conducting fissure develops into the upper water-bearing body, the surface and upper groundwater may collapse into the well. There are two possible reasons for the water-carrying body: on the one hand, the natural geological fissure existing in the surrounding rock may play a role in conducting water; on the other hand, the disturbance of the surrounding rock and roof of the upper and lower wall caused by the mining of the deposit will result in the rapidly developing water-conducting fissure [7] [8]. Therefore, it is necessary to first study the geological characteristics of surrounding rock to find out whether there is a possibility of natural spring, and then study the deformation of backfill and surrounding rock and the possibility and development height of water-conducting fractures under the condition of incomplete roof connection in late filling [9] [10]. The accurate prediction of the fissure zone is not only related to the life and property safety of the underground workers, but also to the national energy security. Understanding the development law of overlying rock failure can clarify the probability of water inrush accident in mine, which is an important basis for predicting water inrush and making preventive measures in advance. Therefore, it is of great significance to study the development law of water-conducting fracture zone of overlying rock in gold filling mining for underground safety production.

The caving and falling of the rock mass of metal ore is mostly in the state of "arch". Under some special geological and mining conditions, the caving and falling of overlying rock will also show other different forms, such as "collapse pit", "barrel", "pipe" or "funnel". At present, domestic and foreign experts have carried out a large number of studies on the height change of water-conducting fracture zone, and explored the law of the development height change of fracture zone through laboratory experiments, field tests, numerical simulation and other methods. For example, scholar Geng Xinsheng [11] studied the influence of different filling rates on the movement rule of overburden rock, and analyzed the stability and movement characteristics of overburden rock in gangue filling mining by combining mechanical analysis, physical simulation and numerical simulation. With Macheng Iron Mine as the engineering background, scholar Ma Yingge [12] used numerical simulation methods to study the effects of multi-section superimposed mining, different filling rates, different filling strength and mining sequence

on surface movement and deformation of steep inclined ore bodies.

## 2. Theoretical Calculation of the Height of Water Conduction Fracture Zone

### 2.1. Mining Area Profile

Songxiashan Gold mining area is located in Dazhang Town, Songxian County, Luoyang City, Henan Province. At present, it mainly mines the 100-middle, 140-middle and 160-middle orebodies of M1-II orebodies. The control length of M1-II orebodies along the strike is 380 m, the ore-body along the dip is in a soothing wave shape, the control vertical depth is 594 m, and the occurrence elevation of orebodies is  $-20$  to  $+574$  m. The ore body strikes about  $20^\circ - 25^\circ$ , dips to the northwest, and dips  $53^\circ - 68^\circ$ . The maximum thickness of the ore body is 19.99 m, the minimum thickness is 0.7 m, and the average thickness is 3.69 m. The gold grade is generally 1.32 - 17.44 g/t, and the average gold grade is 4.33 g/t. The ore body in the whole mining area is a gold deposit of tectonic-altered rock type, which mainly occurs in the M1 tectonic-altered fracture zone and is strictly controlled by the M1 tectonic-altered fracture zone. The surrounding rock is mainly dacite and rhyolite. As the M1 tectonic-altered fracture zone is both a ore-conducting structure and a water-bearing structure, the integrity and stability of ore and rock are poor, and the structural cracks are prone to collapse. It has a great impact on the mining of ore deposits.

### 2.2. Calculation of the Height of Fracture Zone with Equivalent Production Height

Equivalent mining height represents the value of mining height that is equivalent to the actual participation in the development of water-conducting fissure zone after the overlying rock layer of the mining zone is supported by the filling body during the moving process. By determining the equivalent mining height, the relationship model between the traditional mining height and the height of the hydraulic fracture zone can be effectively applied to the filling mining scenario. Subsequently, the concept of equivalent mining height is proposed in order to predict the height of hydraulic fracture zone development in the overlying rock layer in infill mining. Equivalent mining height is the space (height) where the top and bottom plates of infill mining are allowed to move closer, *i.e.*, it is equivalent to directly mining the ore body with the thickness of the equivalent mining height. Equivalent mining height is calculated as:

$$M_c = H - (1 - B)h \quad (1)$$

In its formula:  $B$  is the compression rate of the filling body;  $H$  is the height of the mining face stage,  $m$ ;  $h$  is the height of the filling body,  $m$ ;  $M_c$  is the equivalent mining height,  $m$ .

In this equivalent mining height concept, only three parameters are included, and the mining height and the height of the filling body can be obtained directly

by measuring tools, and the compression rate of the filling body is measured. It can be seen from the measurement: the mining height is 4 m, the filling height is 3.2 m, the compression rate of the filling body is 3.65%, according to the formula (1) to get the equivalent mining height  $M_c$  is 0.92 m. The empirical formula for the maximum height of the water-conducting fissure zone is shown in **Table 1**. after the measurement, the compressive strength of the rock in the Songxian Shan-jin gold mine filling mining area is less than 40 MPa, and the inclination angle of the ore body is  $60^\circ$ , so according to **Table 1**, we can get the formula for the height of the water-conducting fissure zone.

Belt height calculation formula:

$$H_{ii} = \frac{100M_c h}{7.5h + 293} + 7.3 \quad (2)$$

where:  $H_{ii}$  —height of water conduction fracture zone (m).

$M_c$  —is the equivalent mining height (m), which adopts 0.92 m.

$h$  —refers to the stage height of the mining face (m), and adopts the elevation  $+168 - (+164.0) = 4$  m.

Substituting into Equation (2) shows that the calculation results are as follows:

$$H_{ii} = \frac{100M_c h}{7.5h + 293} + 7.3 = \frac{100 \times 0.92 \times 4}{7.5 \times 4 + 293} + 7.3 = 8.44m$$

It is concluded that the maximum height of water conduction fracture zone under surrounding rock filling mining of gold mine is 8.44 m.

**Table 1.** Empirical formula of maximum height of water-conducting fracture zone.

Orebody dip ( $^\circ$ )	Compressive strength of rock (MPa)	Rock name	Empirical formula
0 - 54	40 - 60	Diabase, limestone, siliceous rock, conglomerate, sand conglomerate, sandy shale, etc.	$H_{ii} = \frac{100M_c}{2.4n + 2.1} + 11.2$
	20 - 40	Sandy shale, argillaceous sandstone, shale, etc.	$H_{ii} = \frac{100M_c}{3.3n + 3.8} + 5.1$
	<20	Weathered rock, shale, argillaceous sandstone, clay rock, Quaternary and Tertiary loose, etc.	$H_{ii} = \frac{100M_c}{5.1n + 5.2} + 5.1$
55 - 85	40 - 60	Diabase, limestone, siliceous rock, conglomerate, sand conglomerate, sandy sheet, etc.	$H_{ii} = \frac{100M_c h}{4.1n + 133} + 8.4$
	<40	Sandy shale, argillaceous sandstone, shale, weathered rock, argillaceous sandstone, clay rock, Quaternary and Tertiary unconsolidated strata, etc.	$H_{ii} = \frac{100M_c h}{7.5h + 293} + 7.3$

### 3. Numerical Simulation

The collapsing process of the overlying rock layer caused by the mining of gold ore body belongs to the damage process of discontinuous solid medium, and UDEC software has more obvious advantages in dealing with discontinuous medium, especially suitable for the study of the damage process of solid medium un-

der the action of loading. According to the mechanical properties of rocks in Songxiashan gold mine and the actual geological mining conditions on site, the numerical simulation makes the following settings:

- 1) The block intrinsic model adopts elastic model, which satisfies the Mohr-Coulomb yield criterion.
- 2) The distribution of the surface and ore body shows a hierarchical distribution, and the rock body is homogeneous and isotropic.
- 3) The tensile strength of the surrounding rock body is zero.

### 3.1. Abbreviations and Acronyms

According to the actual mining condition of Songxian mountain gold ore body can be seen, the size of the mining field is generally 40 - 60 m in length, the size of the simulation design mining field is 40 m, the average inclination angle of the ore body is 60°, the height of the ore body is taken as 40 m, the width of the ore body is 4 m in thickness, the height of the middle section is 40 m in height, and 4 m in each sublayer, there are a total of five mining rooms, the size of each mining room is 6 m × 4 m, and the ore pillars are 4 m × 4 m, and the next step in the ore rooms mined in the previous step have been filled before mining back. Using UDEC numerical simulation software, a numerical calculation model was established, and the model was moderately streamlined, with a size of 80 m × 40 m (length × width).

Boundary conditions: fixed displacement constraints are applied around and at the bottom of the model, and stress constraints are applied at the top of the model. In order to simplify the study model, a vertical stress load is applied to the top of the model without affecting the area of the study ore body, calculated as:

$$\sigma_z = \gamma H \quad (3)$$

where:  $\gamma$  is the volumetric force of the overlying rock layer (KN/m<sup>3</sup>);  $H$  is the burial depth at the top of the model (m).

The model only applies the self-gravitating stress pick of the upper rock mass, the upper rock mass is probably the height is 460 m rock gravity, the density of the ore is taken as the density of the ore is 2700 Kg/m<sup>3</sup>. So applying a uniform load on the top of the model, substituting into Equation (3) shows that

$\sigma_z = \gamma H = 2700 \times 9.8 \times 460 = 12171600 \text{ pa} \approx 12 \text{ Mpa}$ . Therefore a stress boundary condition of 12 MPa is applied at the top of the model.

The model is divided into the upper disk and lower disk, the middle part of the ore body, the ore body according to the height of 10 m for a stratification, divided into the ore body 1, 2, 3 and 4, the ore body studied in this paper is located in the first stratification of the ore body 2, from the upper disk to the lower disk mining, according to the order of the mining room in order to mine a total of five mining rooms, the left and right sides of the addition of pillars to prevent the boundary effect, as shown in **Figure 1** numerical simulation grouping diagrams.

According to the geological report of Songxiashan Gold mine and related rock mechanics test results, the reduction coefficient method is used to determine the

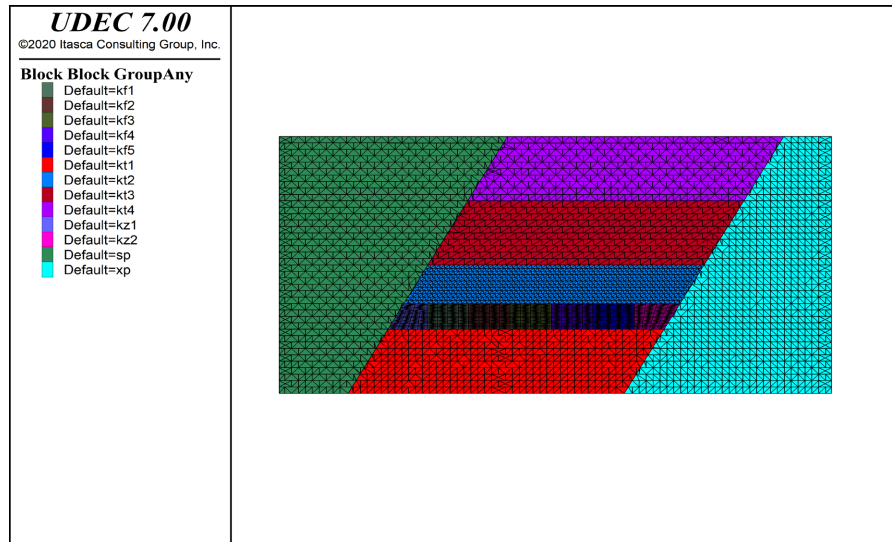


Figure 1. Value simulation grouping diagram.

engineering mechanics parameters of rock mass by referring to the Engineering rock mass classification Standard (GB50218-92) and the geotechnical engineering investigation Code. In the simulation process, the mechanical parameters of each rock layer in the model mainly include density, volume modulus, shear modulus, cohesion force, tensile strength, internal friction Angle, etc. The detailed parameter values are shown in Table 2.

Table 2. Rock mechanics parameter.

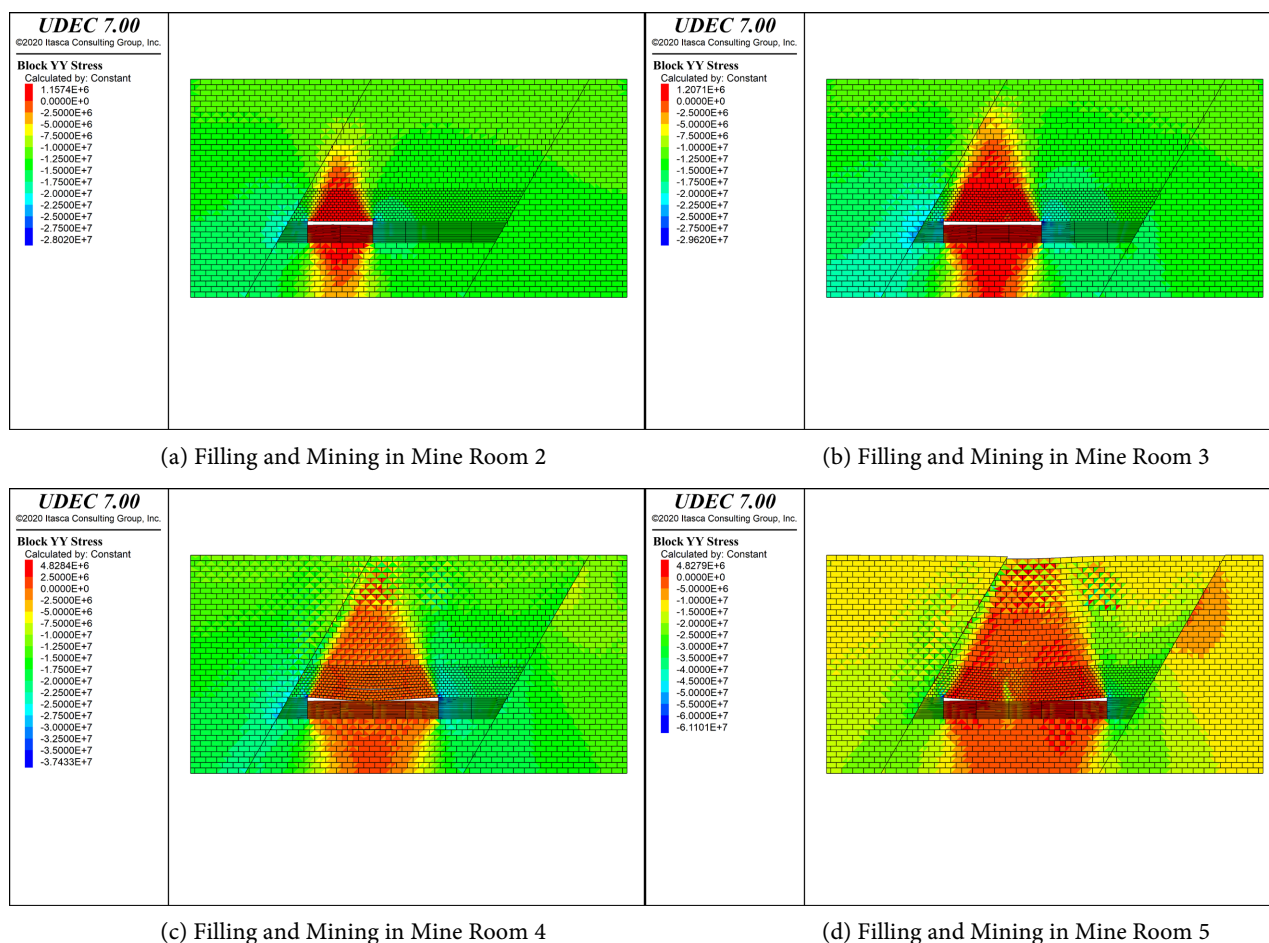
Rock mass	Density (kg/m <sup>3</sup> )	Modulus of elasticity (GPa)	Poisson's ratio	cohesion (MPa)	Friction Angle (°)	Tensile strength (MPa)
Hanging wall	2650	25.0	0.21	5.5	42	7.6
Ore body	2700	27.8	0.19	5.0	46	8.2
footwall	2650	21.0	0.22	5.3	53	7.5
obturator	2020	1.2	0.28	0.7	27	0.9

### 3.2. Numerical Result Analysis

#### 3.2.1. Vertical Stress Analysis

The vertical stress distribution diagram of the filling mining method can be seen as shown in Figure 2. From Figure 2(a), it can be seen that the overlying rock layer has not been disturbed, the stress is concentrated on one side of the pillar and the mine wall, the peak vertical stress is 28.0 Mpa; from Figure 2(b), it can be seen that the peak vertical stress is 29.6 Mpa; from Figure 2(c), it can be seen that the top plate bends and sinks to produce the phenomenon of separation of the layer, the rock body collapses into the mining airspace, and at this time, the peak vertical stress is 37.4 Mpa; from Figure 2(d), it can be seen that after filling the mine, the filling body forms a more stable bearing arch structure to the overlying rock layer, which plays a certain role in supporting. Figure 2(d) can be seen, after

the quarry filling back to mining, the filling body to the overlying rock layer to form a more stable bearing arch structure, play a certain support role, the maximum vertical stress distribution is irregular, irregular, at this time the peak vertical stress is 61.1 Mpa. From the overall can be seen, filling mining, both sides of the pillar in the filling of the corresponding stress concentration phenomenon, the majority of the stress concentration in both sides of the pillar. Most of the stresses are concentrated in the two sides of the pillar.

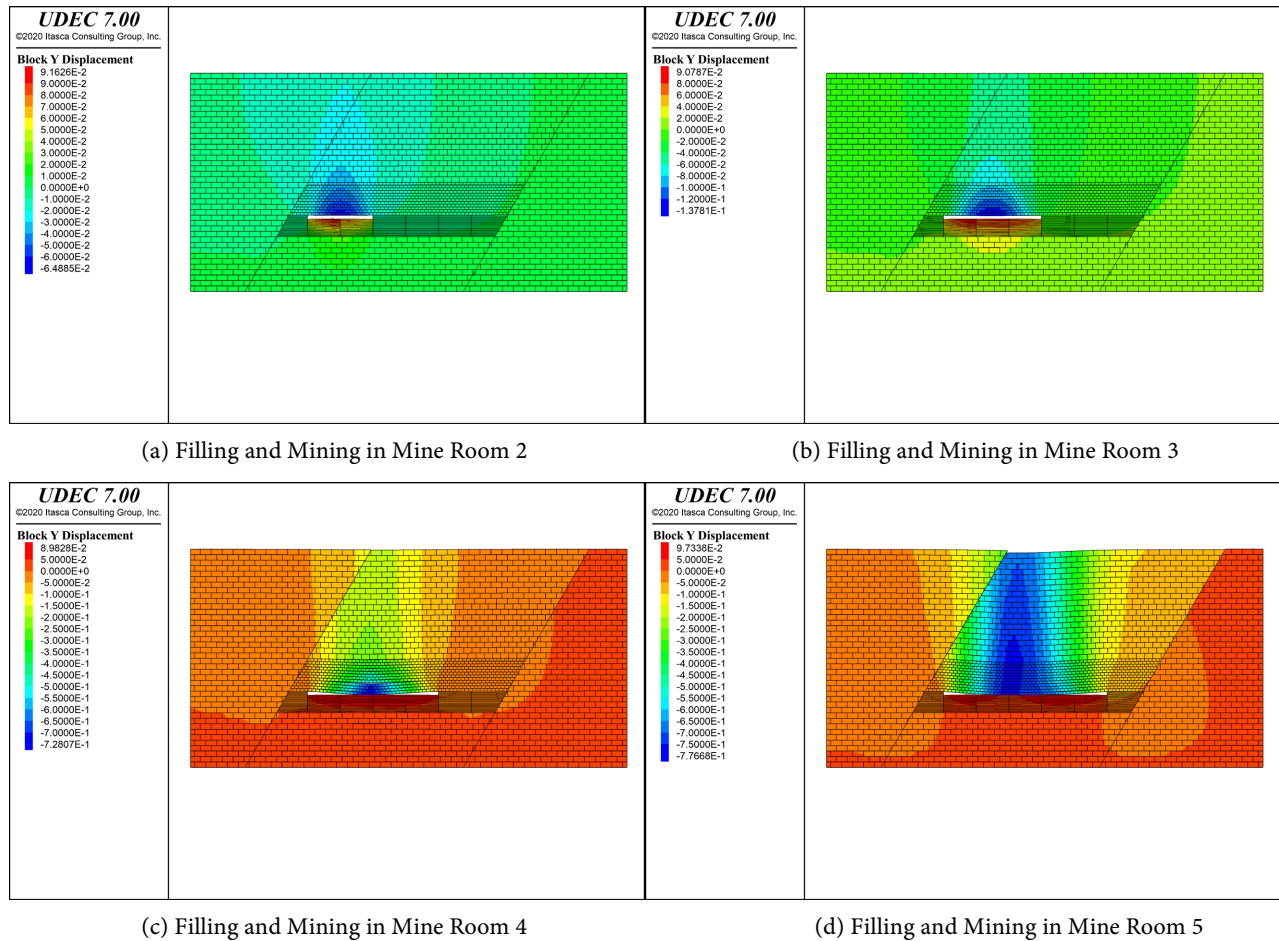


**Figure 2.** Vertical stress distribution diagram of filling mining method.

### 3.2.2. Vertical Displacement Analysis

The vertical displacement represents the displacement in the vertical direction of the rock mass. In the calculation results, the negative value of the vertical displacement represents the downward displacement and the positive value represents the upward position. The vertical displacement distribution diagram of open stope mining method is shown in **Figure 3**. It can be seen from **Figure 3(a)** that the stope roof has no sinking trend, and the maximum vertical displacement of the stope is 0.65 cm. As can be seen from **Figure 3(b)**, the stope roof does not sink, and the maximum vertical displacement is 1.38 cm. As can be seen from **Figure 3(c)**, the stope roof has a weak subsidence, and the maximum vertical displacement is 1.38 cm.

ment is 7.28 cm. As can be seen from **Figure 3(d)**, after filling the stope, the filling body forms a relatively stable bearing arch structure to the overlying rock. Its main function is to transfer the weight of the overlying rock to the surrounding rock and play a certain supporting role, so there is no subsidence trend, and the maximum vertical displacement of the stope at this time is 7.76 cm.

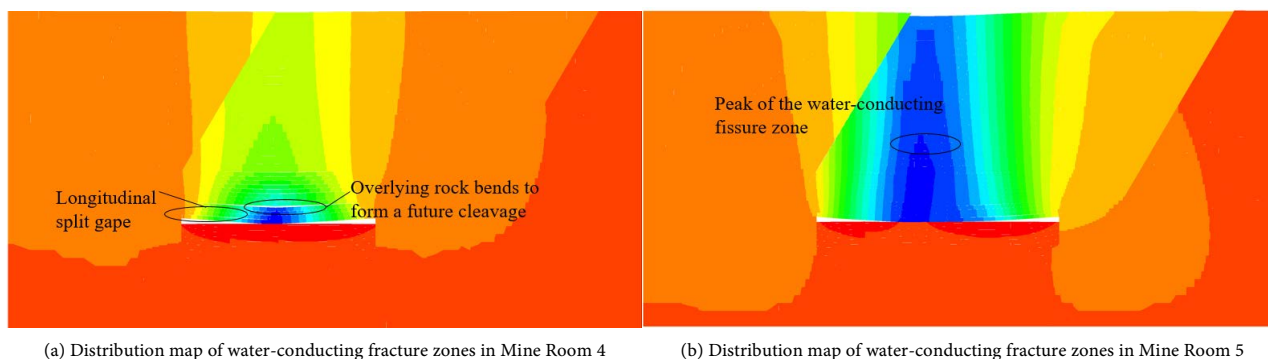


**Figure 3.** Vertical displacement distribution diagram of filling mining method.

### 3.2.3. Height Analysis of Water Conduction Fracture Zone

The distribution diagram of the crack guide zone of filling mining method is shown in **Figure 4**. As can be seen from **Figure 4(a)**, the supporting force of the goaf backfill on the overlying rock leads to weak bending and subsidence, and the overlying rock sinks to form a small separation layer without collapsing. As can be seen from **Figure 4(b)**, there is no longitudinal pull fracture in overlying rock of the filling goaf, the longitudinal development of the fracture zone stops, there is no re-compaction zone in the goaf, and there is no phenomenon of separation subsidence. At this time, the height of the guided fracture zone is about 9 m.

The overlying strata in the mined-out area of filling mining in gold mine is stable, and there is no stretching failure zone or large moving deformation, so

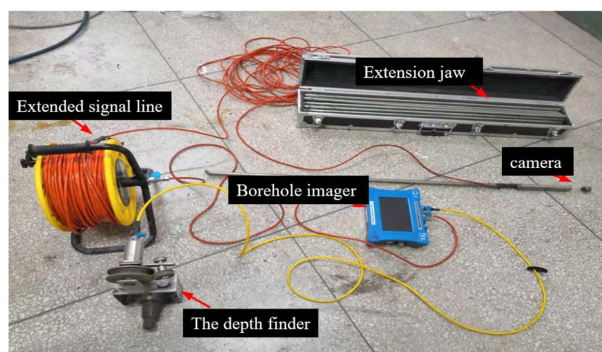


**Figure 4.** Distribution map of crack guide zone by filling mining method.

there is no fall zone and fracture zone. Combined with the actual mining practice of metal mines, the height of the fracture zone guided by the numerical simulation filling mining method is about 9 m, which is 6.22% different from the height of the water-conducting fracture zone calculated by the empirical formula.

#### 4. Field Measurement

The orebody studied in this study is the actual observation face of the height of the water-conducting fracture zone in stope 050001-07, and the observation method is borehole TV method. Borehole TV detection instruments mainly include imager, camera, depth detector, extended connector (signal line), as shown in **Figure 5** for borehole TV observation system.



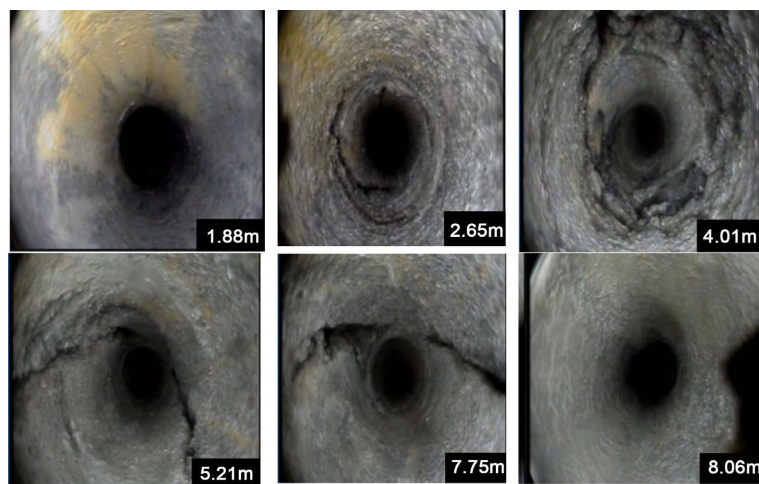
**Figure 5.** For borehole TV observation system.

#### Analysis of Detection Results

Considering the length of the article, this chapter mainly introduces the rock formation images of the borehole in approach 2# and joint lane 2#.

The image information of each section of the rock formation obtained during the process of drilling route 2# is shown in **Figure 6**. It can be seen that the integrity of the rock formation is good from the opening hole upward to the hole depth of 0 - 2 m, that is, the drilling has just entered, and no obvious mining-induced fractures have been found. From the hole depth of 2 - 4.2 m, the cracks are relatively developed. The analysis is that the rock layer has a large uneven movement,

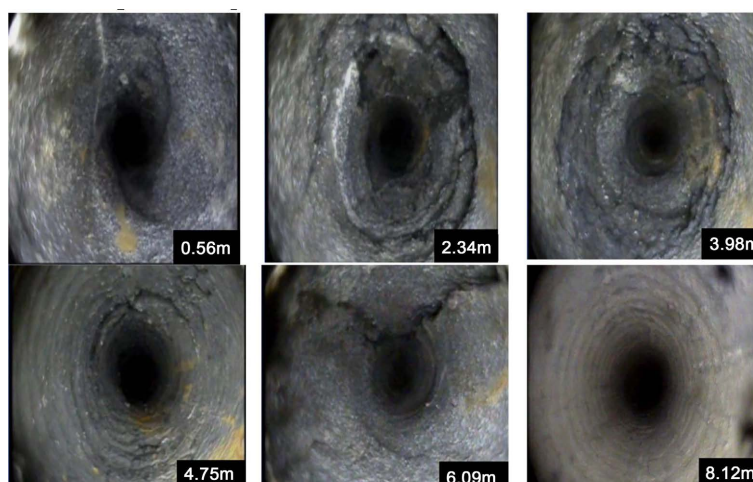
and the rock layer is seriously damaged. The hole depth of 2.65 m is just entering the crack zone, and there are cracks around the rock layer at the beginning, and the rock layer is broken more seriously when we drill up to 4.01 m. From the opening hole upward to the hole depth of 4.2 - 8 m, the transverse and vertical fractures in the overlying rock show cross-distribution characteristics, and the fracture distribution is relatively uniform, and obvious longitudinal and transverse fractures can be seen at the hole depth of 5.21 m and 7.75 m. From the hole depth of 8 m up to the bottom of the hole, from the hole depth of 8.60 m, it can be seen that the rock mass integrity of the hole wall is good, only some rock mass has small primary cracks, the development degree of primary cracks is low, the fine cracks are not connected, the water conductivity is poor, and the rock permeability is small. without a hyphen.



**Figure 6.** Peeking shot of borehole at route measurement point 2#.

As shown in **Figure 7** the image information of each section of the rock layer obtained during the process of advancing the borehole 2# can be seen: the integrity of the rock layer is good from the opening hole upward to the depth of the hole 0 - 2 m, that is, the drilling has just entered, and no obvious mining-induced fractures have been found. From the hole depth of 2 - 4.2 m, the cracks are relatively developed. The analysis is that the rock layer has a large uneven movement, and the rock layer is seriously damaged. The hole depth of 2.65 m is just entering the crack zone, and there are cracks around the rock layer at the beginning, and the rock layer is broken more seriously when we drill up to 4.01 m. From the opening hole upward to the hole depth of 4.2 - 8 m, the transverse and vertical fractures in the overlying rock show cross-distribution characteristics, and the fracture distribution is relatively uniform, and obvious longitudinal and transverse fractures can be seen at the hole depth of 5.21 m and 7.75 m. From the hole depth of 8 m up to the bottom of the hole, from the hole depth of 8.60 m, it can be seen that the rock mass integrity of the hole wall is good, only some rock mass has small primary cracks, the development degree of primary cracks is low, the

fine cracks are not connected, the water conductivity is poor, and the rock permeability is small.



**Figure 7.** Peeking screen shot of hole 2# in Lianxiang.

It shows that the basic characteristics of the deformation and failure of the ground borehole after mining are roughly the same, which mainly goes through the evolution process of fracture generation, fracture expansion, dislocation, separation of layers and collapse. After the working face pushed through the borehole, the borehole collapsed, and then under the influence of the rock strata breaking movement, the evolution process of the borehole produced cracks crack expansion horizontal dislocation separation compaction and closure showed the characteristics of group movement, and gradually developed from the bottom up, and finally stopped when it reached a certain height. Based on the above simple hydrological observation and borehole TV detection results, the development height of roof water-conducting fracture in Shanjin 050001-07 stope in Songxian County ranges from 2.0 to 8.5 m, and it can be seen that the maximum development height of water-conducting fracture zone is 8.5 m.

## 5. Conclusions

1) Through theoretical analysis, it is known that the mining height and filling compression rate of the mining area, according to the equivalent mining height empirical formula method, the height of the water-conducting fissure zone of Songxian Gold Mine 050007-01 filling and mining is calculated to be 8.44 m.

2) Through numerical simulation, it can be seen that the maximum vertical stress of the ore body when filling and mining show the “arch” shape with high sides and low middle, the maximum height of the arch stress area damage is 9 m, the maximum value of vertical displacement is 7.76 cm, and the height of water-conducting fissure zone development after the stabilization of gold mine filling and mining is 9 m.

3) Through on-site test, it can be seen that, when using drill hole TV method to

050001-07 quarry when on-site drill hole peeping, measured Songxian mountain gold 050001-07 quarry roof water-conducting fissure development height range of 2.0 - 8.5 m, it can be seen that the maximum height of the water-conducting fissure zone development is 8.5 m.

In summary, this paper through theoretical analysis, numerical simulation, field test and other comprehensive research methods, for gold mine filling mining water-conducting fissure zone height research, concluded that the height of water-conducting fissure zone of gold mine filling mining is 8.5 m, which can be used as a reference for the filling mining program of other similar gold mines.

### Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

### References

- [1] Diao, X.H., Yuan, Y. and Zhang, C.X. (2006) Geological Hazards of Metal Mines and Their Research and Development Trend. *Metal Mine*, No. 6, 1-4+26.
- [2] Zhang, H.F., Peng, S. and Ma, X.L. (2019) Discussion on Mining Methods and Safety Measures of Complex Gently Inclined Ore Bodies. *World Nonferrous Metals*, No. 14, 35+37.
- [3] Song, X.G., Chen, X.X., Pang, H.L., *et al.* (2018) Study on the Relationship between Mining Advancement and Surface Deformation in Metal Mines. *Rock and Soil Mechanics*, **39**, 425-436.
- [4] Liu, X.M., Wang, Y., Chen, X.X., *et al.* (2022) Study on the Mechanism of Ground Pressure Development in Metal Mines under the Influence of Geological Structure. *Chinese Journal of Rock Mechanics and Engineering*, **41**, 2451-2459.
- [5] Yang, K.-Y., Chen, X.X., Xia, K.Z., *et al.* (2019) Fault Effect on Failure Mechanism of Roadway Surrounding Rock in Metal Mine by Caving Method. *Rock and Soil Mechanics*, **41**, 279-289.
- [6] Fu, H., Chen, X.X., Xia, K.Z., *et al.* (2015) Analysis of Rock Mass Deformation Induced by Underground Mining in Metal Mines. *Chinese Journal of Rock Mechanics and Engineering*, **34**, 1859-1868.
- [7] Xu, G.Y. and Zhong, S.Y. (1990) Numerical Simulation Study on the Expansion Law of Water-Conductive Fracture Zone of Surrounding Rock of Roof Mining with Underwater Filling Method. *Nonferrous Metals*, No. 4, 18-24+12.
- [8] Zou, H., Gui, H.R., Wang, G.L., *et al.* (1998) Prediction Method for the Height of Water-Conducting Fracture Zones in Fully Mechanized Caving Mining. *Coal Geology and Exploration*, No. 6, 44-47.
- [9] Gui, H.R., Zhou, Q.-F., Liao, D.-S., *et al.* (1997) Prediction of Maximum Water Conductivity Fracture Zone Height by Stress Method in Fully Mechanized Caving. *Journal of China Coal Society*, No. 4, 41-45.
- [10] Wang, X.M., Xiao, W.G. and Zhang, Q.L. (2005) Theory and Technology of Filling in Deep Mine. Central South University Press, 128-235.
- [11] Geng, X.S. (2022) Research on Overburden Movement Rule in Filling Mining with Different Filling Rate. Master's Thesis, University of Science and Technology Liaoning.
- [12] Ma, Y.G. (2019) Research on the Law of Surface Movement and Deformation Induced by Multi-Section Superimposed Mining. Master's Thesis, North China University of Technology.