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& Gas Hazards Control in Coal Mines

## Comprehensive Exploration Technology of Water Disaster Prevention and Control in Coal Mining Roof

Lijuan Zhai\*

*Hydro geological Team of China National Administration of Coal Geology, Handan 056004, China*

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### Abstract

Top roof water is the direct water disaster troubling the coal mine. With the modernization of exploitation method and the increasing of exploitation, the threat of top roof water to coal mine is also increasing, damaging more and more the rock mass in coal seam roof. Therefore, it is important to study deeply into the exploration technology of top roof water disaster prevention and control. We take the NO.3 mine shaft in Pingshuo as an example, introducing comprehensively main content and methods of exploration of coal mine top roof water, demonstrating the application of remote sensing hydro - geological survey, geophysical prospecting, hydrochemistry and environment isotope, etc advanced exploration methods in coal deposits hydro-geology and “tri figure-double prediction method” of water disaster treatment.

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**Keywords:** top roof water disaster; comprehensive exploration; remote sensing hydro geological survey; geophysical exploration; water chemistry and environment isotope; “tri figure-double prediction method”

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\* \* Corresponding author. Tel: +86-310-8128935  
E-mail address: [zhailijuan1965@sina.com](mailto:zhailijuan1965@sina.com)

## **1. Preface**

After coal production, the roof falling collapse fissure communicates with the upper aquifer that changed from the groundwater to the mine water, result the increase of the mine water inflow, even happen water inrush disaster. Presently in our country top roof water disaster prevention and control measure is direct water-filled aquifer in water flowing fractured zone range must stoutly drain in advance. The ample recharge water source should primarily carry out curtain grouting or embankment interception and other project then proceed drain in advance after blocking water source.

In order to proceed effective drain in advance, content as follows should be studied and ascertained: i recharge source, boundary condition and water abundance of water-filled aquifer; ii whether developing height of water flowing fractured zone communicates with main water-filled aquifer; iii partition and assessment of danger of sudden water inrush; iv the mine water inflow and drain water yield of forecast. The above content that the main task is top roof water hydro- geological exploration, exploration means and exploration method of top roof water disaster must complete the above task tightly round to selection and establishment.

### **1. Selection of exploration method**

Exploration method once upon a time is too single and basically drilling and pumping dewatering test first, lack quantitative evaluation mean of sudden water inrush condition, the mine water inflow of forecast just also adopt analytic method. This traditional exploration method already haven't satisfied with the complex changeable mine hydrogeology condition and the modern mining method. According to the new research achievement of the exploration technology of hydrogeology and the evaluation technology of hydrogeology in our country as well as Author's aged working experience a set of comprehensive exploration technology of water disaster prevention and control in coal mining roof is summed up, that's adopted remote sensing hydro geological survey, geophysical exploration, drilling exploration, hydrogeology well logging, pumping test, water chemistry, "tri figure-double prediction method" and others to proceed comprehensive exploration, gain good prospecting effectiveness in the mine area of Pingshuo in coal base in the north region of Shanxi.

### **2. Remote sensing hydro geological survey**

Difficult and easy level of dewater of top roof water-filled aquifer mainly depend on profusion of recharge water source. Atmospheric precipitation that can't accept of aquifer and recharge by surface water or minor recharge rate of aquifer, is easy to dewater generally, but aquifer that communicates with surface water is difficult to dewater. The size of atmospheric precipitation and surface water recharge rate depend on the location of concealed outcrop aquifer, landform and surface rock property, for example outcrop landform low-lying, mine area landform flat, outcrop upper rock property that give priority to good permeability grave, then atmospheric precipitation and surface water of infiltration recharge is more plentiful: if the greater slope of outcrop landform, cutting of the mine area landform crushing, surface rock property is loess, atmospheric precipitation discharge in the form of surface runoff, ground water of infiltration recharge is less.

The purpose of remote sensing hydro geological survey understands supply condition and ascertains recharge water source. The task is: i discover aquifer outcrop of position, area and upper rock property; ii enclose surface valley of the range in the exploration area nearby, surface runoff amount, ascertain the hydraulic connection of surface water and ground water; iii understand rugged surface, the extent of gully cutting and parent rock property. The adoption of remote explain technique, visual field broad, great

system property, image intuition, then match up field validation and investigation, can obtain effect getting twice the result with half the effort.

The NO.3 mine shaft in Pingshuo in tunnel recurrent top roof of the water inrush disaster during the excavation course, water inrush quantity reaches up to  $4000 \sim 7200 \text{m}^3/\text{d}$ , is a rare top roof sandstone fracture water disaster. During hydro geological exploration course, disaster is discovered through remote sensing hydro geological survey course. Coal seam of top roof sandstone aquifer exposed in the northwestern state of the well, concealed outcrop range immediately is situated the area of low-lying big sand-groove river valley, outcrop upper rock property is incompact sand gravel stone. The whole river basin of surface runoff all discharge and confluence in this range, flow sandstone aquifer to mass infiltration recharge by outcrop (Fig. 1), this is the main reason of the mass water inrush in tunnel.

### 3. Geophysical exploration

Although drilling exposure is accurate, drilling exposure barely control on the point.. Complicated hydro-geological condition must carry out geophysical exploration; fully systematically understand the water yield property of water-filled aquifer. Transient electromagnetic is sensitive to low resistivity reaction, is good geophysical method of ground water exploration. Growth aquifer simultaneously on the coal seam draws firstly contour map of top roof aquifer, according to coal exploration borehole data, then explains according to control of aquifer, thus avoids better multiplicity that cause low resistivity rock property, improve precision of explanation.

The NO.3 mine shaft in Pingshuo grows three main mineable coal seam, divides 4、9、11 from top to bottom, is located at Taiyuan Formation of Carboniferous, on the top roof of coal seam is grown five Carboniferous- Permian sandstone aquifer that is  $K_4$ 、 $K_3$ 、 $T_4$ 、 $T_3$ 、 $T_2$ , locate on No. 4 coal seam among  $K_4$ 、 $K_3$ 、 $T_4$ 、 $T_3$  is located between No. 4 coal seam and No.9 coal seam.  $T_2$  is located between No. 9 coal seam and No.11 coal seams. According to Transient electromagnetic exploration investigate, along the area of sand groove in the northwestern state of the well, sandstone aquifer have great

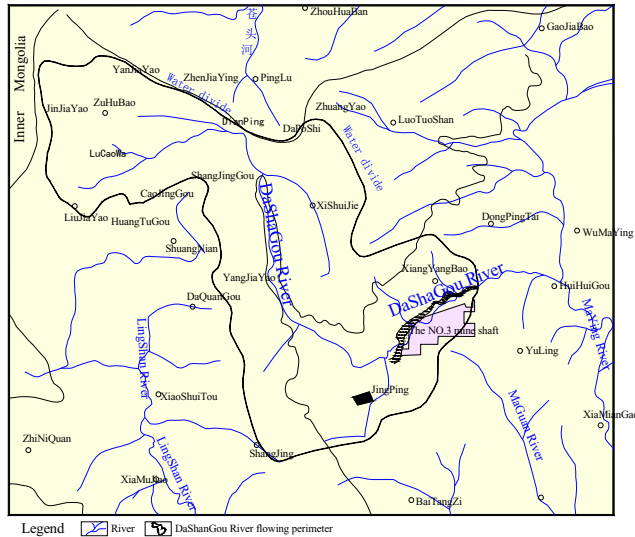


Fig.1 Flowing perimeter of Dashagou

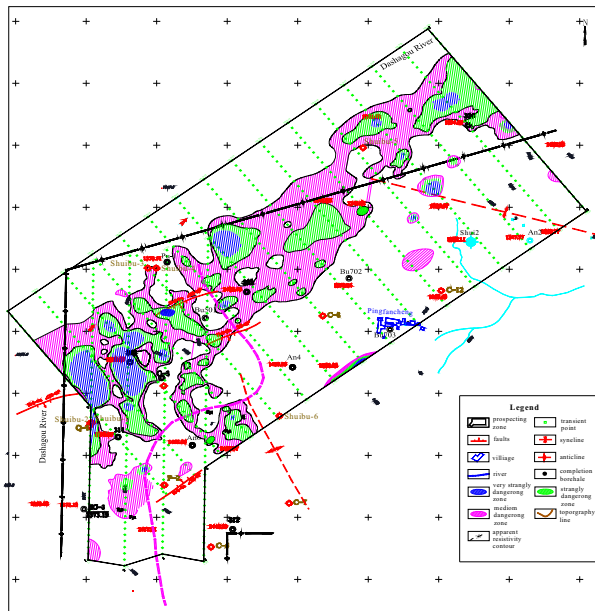


Fig.2 Diagram of T3 sand mass water-richness anomalies

water yield property (picture 2~4),  $T_1$ 、 $T_3$  on the vertical direction have good water yield property, declare that water flow of No. 9 coal seam is more than No. 4 coal seam, along the area of sand groove is key sections of draining in advance, this conclusion gains drilling confirmation, has decisive function at the prevention of mine water.

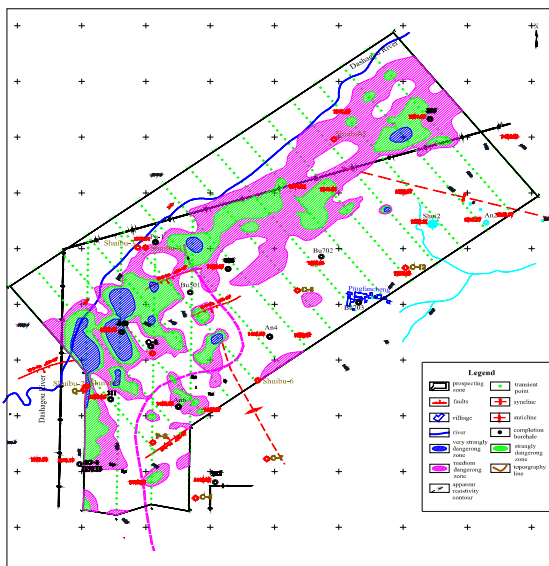


Fig.3 Diagram of T4 sand mass water-richness anomalies

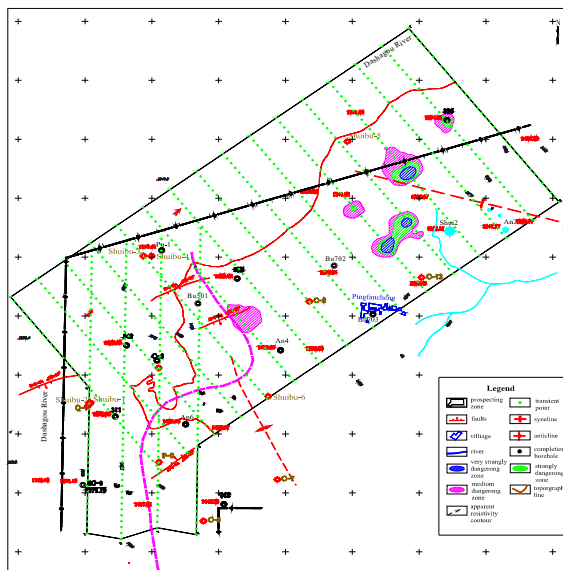


Fig.4 Diagram of K4 sand mass water-richness anomalies

#### 4 .Drilling and hydro geological well logging

The lithologic and facies feature is one of main factors that affected the water yield property of water-filled aquifer include mainly aquifer thickness, ratio of brittle rock and plastic rock. The more aquifer thickness is, the more ratio of brittle rock, the more the water yield property of aquifer is. Lithologic and facies feature of top roof water-filled aquifer confirm mainly through core drilling and hydro -geological well logging. According to core identification and hydro geological well logging investigation, grit sandstone of aquifer thickness is about 13.68~55.95m in the top roof in the NO.3 mine shaft in Pingshuo, shows the character of synclinal shaft thick, two wings thin, the aquifer thickness of the northwestern state of the Well 311 syncline and east slope synclinal shaft is 40~50, other section is 20~30m ( Fig. 5 ) . The roof of coal seam of water-filled aquifer composes grit sandstone、

Medium fine grained sandstone, belongs to brittle rock, produces easily structural fissure and weathering fissure to water-filled. Top roof of coal seam of plastic rock composes mainly mudstone, sandy mudstone, coal seam and siltstone, produces difficult fissure and fissure that filled, aquifer feature weak. The ratio of brittle rock and plastic rock situated between 0.20 and 2.30, the ratio of the southwestern state of the well is high, about 1.50~2.03; The ratio of brittle rock and plastic rock in the eastern state of the well is low, is mostly between 1.0 (Fig. 6).

Drilling of simple hydro geological observation can primarily understand growth condition of aquifer fissure; research the water yield property of aquifer of important means. Consumption of drilling fluid in

the southwestern state of the well in the NO.3 mine shaft in Pingshuo is larger, about  $10\sim 15\text{m}^3/\text{h}$ , some drilling is eat out; Consumption in the northeast state is reduce, most of drilling is  $3\sim 5\text{m}^3/\text{h}$ , specific is  $1\text{m}^3/\text{h}$ . Structural fissure and weathering fissure in the southwestern state of the well explain growing, the water yield property of aquifer is strong. This result is the same with the result of transient electromagnetic and pumping test.

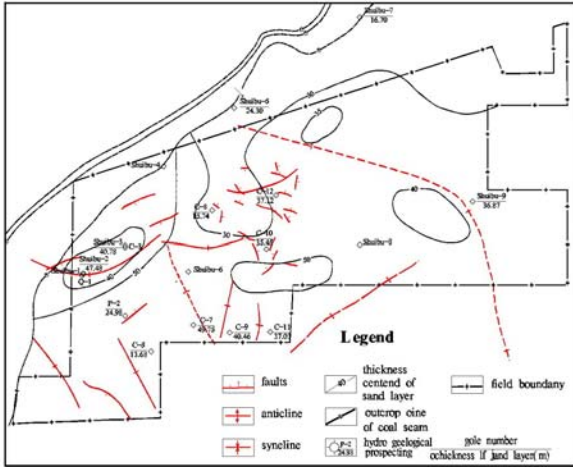


Fig.5 Contour map of sand thickness

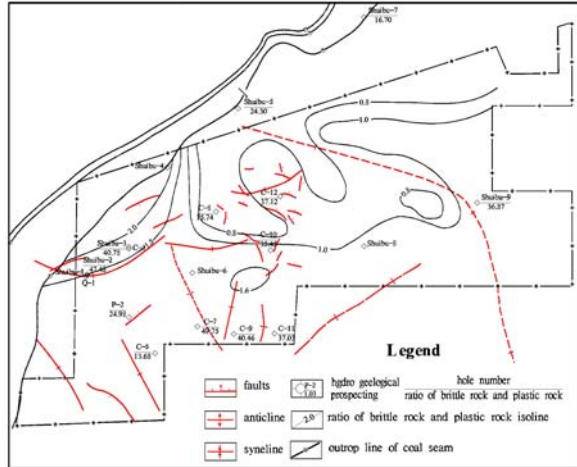


Fig.6 Contour map of ratio between brittle rock and plastic rock

### 5. Pumping test

Pumping test is the most direct and the most accurate method of understanding the water yield property of water-filled aquifer. Because pumping drilling quantity is limited, drilling must lay out watery sector, according to occurrence regularity of bedrock fissure water, most of this region is the supply source plentiful fracture development, fault, back oblique axis, dip angle  $30\sim 60^\circ$  gently inclined rock stratum, large thickness of brittle rock, low-lying terrain collected region and so on. Pumping hole should lay out the above-mentioned region and explore physically round watery sector to check achievement of physical exploration.

According to the result of single borehole pumping test, near concealed outcrop in the southwestern state of the well in the NO.3 mine shaft in Pingshuo, as a result of grown of weathering cracks and structural fissure, the supply source plentiful, the water yield property strong or most strong, drilling unit

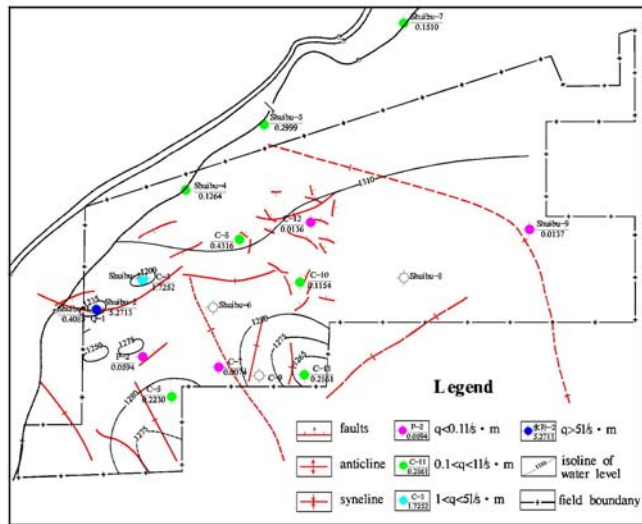


Fig.7 Distribution Map of pumping hole

water flow is 1.73~5.27l/s·m; in the northeast state of the well , the water yield property is weak, drilling unit water flow is 0.13l/s·m; vast region in the east state of the well, because aquifer of buried depth increase, grown degree of weathering cracks and structural fissure is weak, distance far from concealed outcrop surface water of supply boundary, the water yield property turn bad, drilling unit water flow is just 0.0074l/s·m (picture 7) .The result of pumping test is same with the result of ground transient electromagnetic.

Group drilling pumping can expose adequately hydro geological condition, understand main method of water-filled aquifer of watered out direction and permeability, and provide proof for numerical simulation and prediction of mine water flow, drainage quantity and arrangement of drainage hole. The NO.3 mine shaft in Pingshuo composes 6 large diameter pumping hole to hole group, exploration borehole around observes proceeds group drilling pumping test. Result declare that drainage flow field form each independent depression cone as the center of drainage main hole, show oval on the plane ( Fig 9), show “V- type” on the vertical, horizontal influence scope is small, can’t form unified depression cone, bad reflection of sandstone aquifer of hydraulic connectivity, in-home. Result provides a basis for layout of succeeding dispersed advance dewater drill hole.

**6. Water chemistry and environment isotope**

The feature of water chemistry ground water and feature of environment isotope relations with groundwater discharge recharge condition, runoff strength, the more unobstructed groundwater discharge recharge, the more strong runoff strength, the less low ion content in the ground water, the more high environment isotope. In weathered oxidized zone in the western of the NO.3 mine shaft in Pingshuo due to sandstone weathering cracks, grown of structural fissure, accept high strength recharge surface water of concealed outcrop, great runoff condition, positive water exchange, each ion content in the water is relatively small; Far away from concealed outcrop recharge zone, is weathering cracks weak gradually in the eastern of well and in the northeast of well, runoff condition getting worse, delayed water exchange, then each ion content in the water is relatively raise. From west to east, Carboniferous-Permian sandstone fracture water of type of water chemistry transits  $HCO_3-Na \cdot Mg$  type from  $HCO_3-Ca \cdot Mg$  type,  $HCO_3-Cl \cdot SO_4-Mg \cdot Ca \cdot Na$  type water (picture 8~9) .

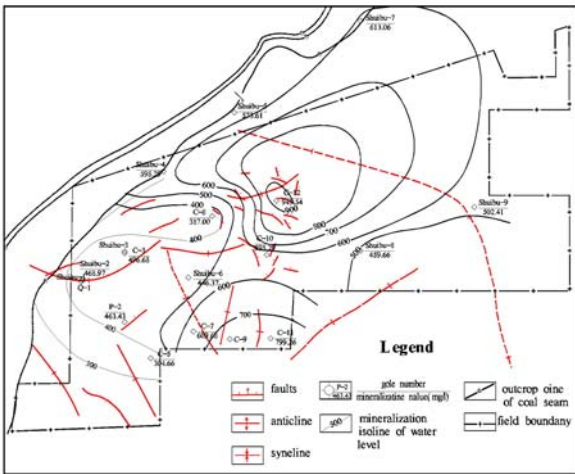


Fig.8 contour map of sandstone fissure water mineralization

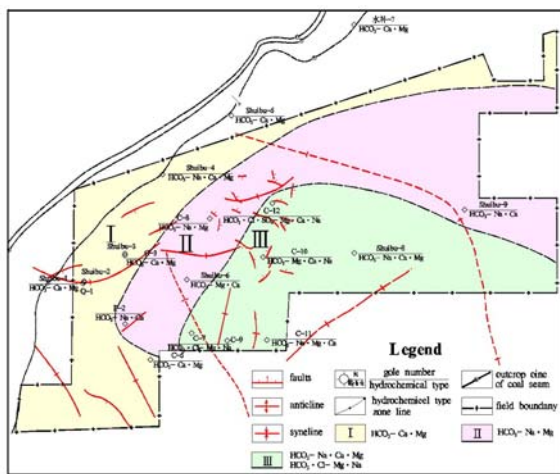


Fig.9 Distribution map of water chemistry type

## 7. Forecasting evaluation technology

Danger of top roof of sudden water inrush lacks quantitative evaluation method formerly. In recent years, China University of Mining and Technology, Professor Wuqiang proposes solving top roof water disaster of quantitative evaluation method “tri figure-double prediction method”, is top roof direct water-filled aquifer of water yield property distribution map, top roof falling safety distribution map, top roof sudden water inrush condition distribution map, mine water flow prediction, top roof direct water-filled aquifer of before-Harvest drain in advance plan prediction.

Many kinds of top roof direct water-filled aquifer of water yield property of influencing factor and information response, superimposition of many factors and information can appraise water-filled aquifer of water yield property exactly, the NO.3 mine shaft in Pingshuo, reflection of aquifer of structural feature of aquifer thickness, ratio on brittle and plastic rock, ground geophysical feature, reflection of water chemistry feature of ion content, distribution map of water chemistry type, pumping test feature, structural feature, simple hydrological feature, water inrush region and so on, 7 aspects of factors and information stacked compound can work out distribution map of top roof

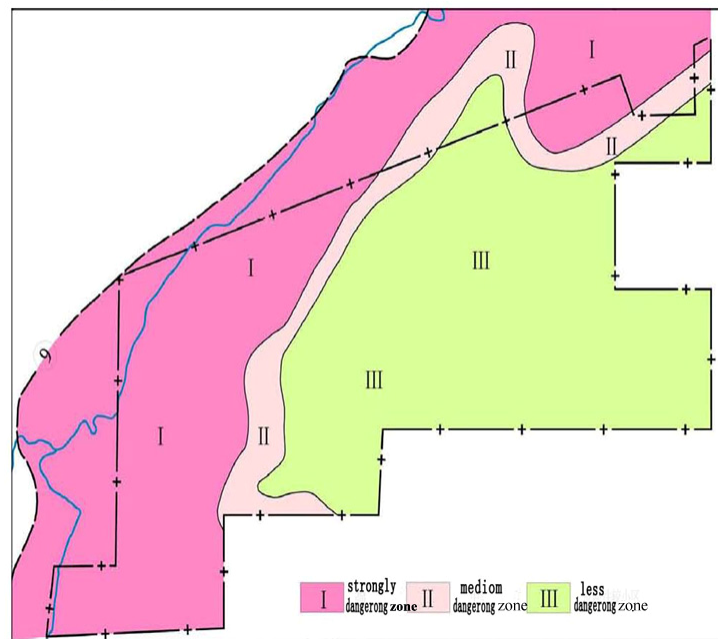


Fig.10 Section map of coal seam top roof aquifer water richness

water-filled aquifer of water yield property (Fig. 10). According to distance from calm to aquifer, falling safety distribution map is exacted by adopting experience formula and theoretical formula to count height of water flowing fracture zone (Fig 11). It should be put forward, because height of water flowing fracture zone reflected have many factors, experience formula have minor considered factor, calculation method of proper practical situation of height of water flowing fracture zone should adopt rock and soil body of numerical simulation methods. Water yield property distribution map and falling safety distribution map stacks compound, work out danger of sudden water inrush distribution evaluation map (Fig 12.). The evaluation result is that the south and west of well near concealed outcrop part is danger of top roof sudden water inrush, transit along the east and north of well, buried depth of aquifer gradually increase, danger of top roof sudden water inrush gradually reduce.

According to hydrogeology conceptual model in mine area of Pingshuo, the popular Visual Modflow Software in the world is adopted, and established 3-D numerical simulation model of groundwater flow, proceed working face water surging quantity of mining prediction. Because of difference of water yield property, change of each working face water surging quantity is greater, between  $744\text{m}^3/\text{h}$  and  $1902\text{m}^3/\text{h}$ .

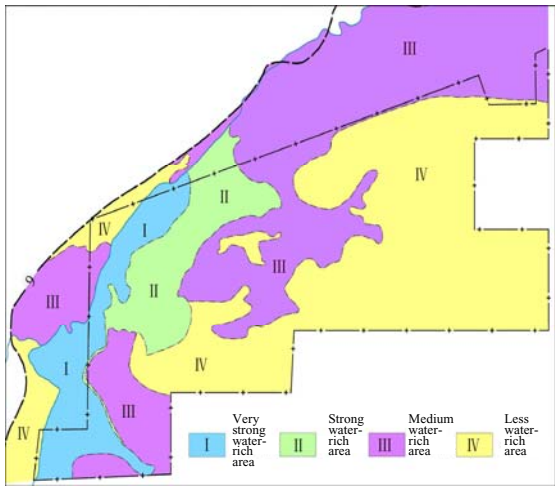


Fig.11 section map of NO.9 coal seam top roof safety

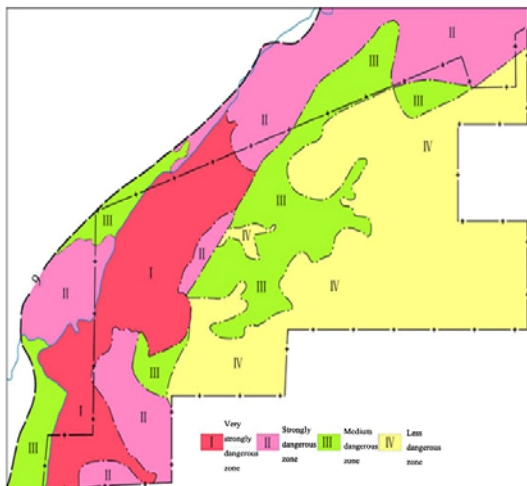


Fig.12 Evaluation map of coal seam top roof water surging condition

**8. Exploration achievements application**

According to exploration achievement, exploration enterprise suggests the NO.3 mine shaft in Pingshuo take the way of combination of waterproofing and drainage, is combination of the surface flood control project and above-below well advance dredging draining project. The surface flood control project is outside Carboniferous- Permian sandstone of concealed outcrop part, dug and drained flood channel to make up cut-protection ring, intercepted flood, make rainy season of flood in big sand-ditch basin flow along floodwater draining channel, reduce ground water of sandstone that water flowing fracture infiltration supplies flowed along concealed outcrop part and strata movement damage zone. On the premise of building the surface flood control project, construction use heavy caliber of surface advance dredging draining in the area of strength water abundance to bore a hole, proceed hard intensity of drain, decrease sudden water surging disaster. But in common area, take method of advance water exploration and discharging below the well to dredge and drain, take unite dredging draining method above the well and below the well.

**References**

[1]Wu qiang, Huang xiaoling, Dong donglin. Primary study on a method of “three maps—two predictions” for quantitative assessments of water bursting conditions on roof of coal seams . Journal of China coal society, 2000 (1) .  
 [2]Wu qiang, Li zhuyao. Mine flood disaster prevention and cure. China University of mining and technology press, 2002.