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# Advanced prediction for multiple disaster sources of laneway under complicated geological conditions

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ABSTRACT

The driving safety in the laneway is often controlled by multiple disaster sources which include fault fracture zone, water-bearing body, goaf and collapse column. The advanced prediction of them has become a hotspot. Based on analysis of physical characteristics of the disaster sources and comparative evaluation of accuracy of the main advanced geophysical detection methods, we proposed a comprehensive judging criterion that tectonic interface can be judged by the elastic wave energy anomaly, strata water abundance can be discriminated by apparent resistivity response difference and establish a reasonable advanced prediction system. The results show that the concealed disaster sources are detected effectively with the accuracy rate of 80% if we use advanced prediction methods of integrated geophysics combined with correction of seismic and electromagnetic parameters, moreover, applying geological data, we may then distinguish types of the disaster sources and fulfill the qualitative forecast. Therefore, the advanced prediction system pays an important referential and instructive role in laneway driving project.



## 1. Introduction

There are many kinds of multiple disaster sources which influence the driving safety in the laneway, and the most important anomalous bodies include fracture zone, water-bearing body, goaf and collapse column. Therefore, it is important to perform the advanced detection and prediction for them in order to provide reliable technical support for the excavation [1]. In the process of advanced detection, while the effect of using a single method is limited, multiple technical means should be adopted comprehensively to improve the accuracy of detection. At present, many scholars have done a lot of work on integrated prediction and forecast in tunnels. Qi and Wang [2] and Qu et al. [3] established a comprehensive advanced prediction method while Wang et al. [4] constructed a complete set of geological forecast technique. Based on the study of comprehensive geological prediction method, Li et al. optimized the process of comprehensive geological prediction, proposed the four-color warning mechanism of tunnel geological disasters and developed corresponding contingency plans [5]. Li et al. established the system and organization of comprehensive geological prediction in tunnels, and according to results of relevant geological and geophysical parameters, they obtained effective prediction results using Fuzzy Neural Network (FNN) method [6]. However, due to the special working environment of coal mine, the advanced detection techniques in sinking and driving engineering are backward compared with tunnel engineering. Shao et al. united the prospecting technique of seismic and ground penetrating radar to detect karst, but didn't discuss the integrated interpretation principle and the prediction system [7]. Liu proposed comprehensive geophysical exploration technology system of water inrush from coal seam floor, but did not mention comprehensive advanced detection technology for driving face [8]. Therefore, in this paper, we considered the special working environment of coal mine, the comprehensive technical means which include Mine Seismic Prediction method (MSP), Mine Resistivity Prediction method (MRP), Mine Transient Electromagnetic method (MTEM) and geological analysis were used to predict the anterior concealed geological disasters in the laneway of full space. And according to the characteristic of technical means, the corresponding forecast criterion and system was built, which can guide the safety production of driving.

## 2. Advanced prediction methods and evaluation

### 2.1. Physical characteristics analysis on multiple disaster sources

In the laneway, the main media are coal seam, terrane, water and air. Due to the different metamorphic grade of coal seam, the resistivity difference is great, and the resistivity range is from

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100 to 1000 Ω·m; the P-wave velocity is quite different, it ranges from 800 to 2500 m/s. For the diverse lithology of terrane, there is a great difference of resistivity which varies between 10 and $n \times 10^3$ Ω m, 1 < $n$ < 10; the P-wave velocity of which ranges from 1000 to 6100 m/s is also quite disparate. One of the physical properties of water is low resistivity which generally changes between 1 and 10 Ω m; the P-wave velocity is low, its range usually varies from 1430 to 1590 m/s. Extra-high resistivity is a principal character of air whose resistivity is $10^{10}$ Ω m, whereas seismic wave speed is rock-bottom, and the P-wave velocity is 340 m/s [9–17].

Combined with the above analysis on characteristics of diverse media, the geophysical basis of detecting multiple disaster sources can be obtained that: the tectonic interfaces of fracture zone, goaf and collapse column possess wave impedance differences, and electrical difference characteristics exist among the tectonic interfaces, moreover water-bearing body have the low-resistivity feature.

### 2.2. Advanced prediction method in the laneway

At present, in the laneway there are plenty of advanced geophysical detection methods which include mine seismic reflected wave method, channel wave exploration, Rayleigh wave exploration, direct current method, transient electromagnetic method, geological radar, infrared detection, radioactivity prospecting, electromagnetic radiation method, etc. Under complex conditions, MSP, MRP and MTEM are mainly adopted in times of detecting concealed geological anomalies ahead of driving face [18–20].

#### 2.2.1. Mine seismic prediction

MSP is an advanced detection technology which is exploited on the basis of other advanced detection methods such as TSP, HSP and TRT. MSP applies reflected wave exploration principle that the seismic wave which encounters the uneven geological body can produce reflection. Combined with the feature of laneway, the sources and the sensors which arrange along the rear laneway are designed to detect advanced geological conditions. In data processing, the prestack migration method is used to obtain the anterior geological interface information. Furthermore, MSP is the joint seismic exploration technique of the multi-wave and multi-component. The depth migration profiles of the P and S waves ahead of the laneway can be gained.

#### 2.2.2. Mine resistivity prediction

On the base of the triple-pole DC electrical sounding principle, combining with network parallel electrical technique, and set driving face as the center, 64 electrodes are arranged regularly during advanced detection in the laneway, thereby MRP forms tridimensional DC electrical method system. Source electrode A slides backwards one after another from driving face, whereas electrode B parks infinite distance. The system makes disposable electrode arrangement in the laneway, both source electrodes and measured electrodes can dispose discretionarily. Owing to the large data gained from the system, the anterior abnormity can be calculated by superposition operation, which enhances greatly the accuracy rate of the results.

#### 2.2.3. Mine transient electromagnetic method

Around the driving face, by measuring characteristics of induced electromotive force of secondary turbulence field with time-variation, MTEM can ascertain the scale of the electromagnetic anomalous body and the distance of the body to driving face, etc. In the routine data processing, by computing apparent resistivity of time-domain electromagnetic induction, anomalous body ahead of laneway can be judged rapidly.

### 2.3. Evaluation methodology

Analysing the veracity of the above three advanced geophysical exploration methods which are the detected fracture zone, the water-bearing body, goaf and collapse column, comparative evaluation situation is shown in Table 1. For example, for the detection of water-bearing body, the evaluation result of MSP is III which is low accuracy, so MSP is not considered. The evaluation result of MRP is I which is high precision, hence MRP is mainly considered for adoption. The evaluation of MTEM is the same as MRP. Therefore, at the time of detecting water-bearing body, MRP and MTEM are requisite means. However, in the process of predicting fracture zone, goaf and collapse column which all don't contain water, it is necessary to put emphasis on considering MSP and advise to select MRP, although MRP is not taken into consideration. Otherwise, those anomalous body all have the character of water abundance, it is important to adopt the combination of MSP + MRP or MSP + MTEM, even MTEM + MRP + MTEM.

According to Table 1, one or several geophysical methods can be pertinently chosen to synthesis detection.

### 2.4. Comprehensive evaluation criteria and prediction system

Each method has its own applied condition and characteristic, and it is difficult to forecast effectively geological anomalies for a single approach, yet synthesis detection technology may complement on each other's advantages so as to realize precise prediction.

In the process of comprehensive forecast, fracture zone, water-bearing body, goaf and collapse column usually present two geological features which include tectonic interface and strata water abundance. When exist structure interface and abnormal condition of water abundance, wave impedance and electrical conductivity change dramatically, the reflected wave energy and resistivity are abnormal accordingly. So, in times of synthetical interpretation, a comprehensive judging criterion should be followed. The criterion is that the tectonic interface can be judged by elastic wave energy anomaly and the strata water abundance can be discriminated by apparent resistivity response difference.

In the light of a comprehensive judging criterion, and in the process of advanced prediction for multiple disaster sources,

**Table 1**
Accuracy evaluation of three geophysical methods for detecting.

| Advanced prediction method | Accuracy evaluation | | | | | | |
|---|---|---|---|---|---|---|---|
| | Fault fracture zone | | Water-bearing body | Goaf | | Collapse column | |
| | Conducting water | No conducting water | | Accumulating water | No accumulating water | Conducting water | No conducting water |
| MSP | I | I | III | I | I | I | I |
| MRP | I | II | I | I | II | I | II |
| MTEM | I | III | I | I | III | I | III |

*Note:* I, II, III is the accuracy of one method corresponding to one disaster source compared with the others, respectively.