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Research on Environmental Geophysical Methods in Geological Hazards Monitoring

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Abstract: Geological hazard monitoring can predict geological hazard to a certain extent, so that relevant measures can be taken to reduce the damage of human and financial resources. Therefore, the quality of geological hazard monitoring is particularly important. In order to effectively improve the quality of geological hazard monitoring, the environmental geophysical methods in geological hazard monitoring are deeply explored in this paper. Firstly, the characteristics of environmental geophysical methods in geological hazard monitoring are described in detail. Secondly, this paper also introduces the environmental geophysical methods commonly used in geological hazard monitoring, such as electric exploration, seismic method, magnetic method and other methods, and provides relevant suggestions and suggestions for these methods, so as to provide certain help for geological hazard monitoring. This paper introduces the main applications of electrical prospecting, seismic method, gravitational method, radioactive prospecting, magnetic method and geophysical well logging. Some examples include the application scope and application results of DC resistivity method, magnetotelluric method and wide-field electromagnetic method, the method layout and application results of seismic survey methods in seismic method, Radon measurement results in radioactive exploration, and the application scope and application results of imaging method in geophysical well logging. Finally, this paper expects the development form and future development trend of geological hazards monitoring, and expects that the geophysical exploration methods can be more widely used in geological hazards monitoring.

Keywords: Geological Hazard, Hazard Monitoring, Environmental Geophysical Methods

1. Introduction

Geological hazard, is a catastrophic event that causes the gradual deterioration of geological environment due to natural and man-made geological processes, and causes loss of human life and property, and destroys the resources and environment on which human beings depend for survival. Geological hazard is a kind of common natural hazard [1-3]. The common address hazard includes geotechnical geological hazard, special rock engineering hazard and surface deformation geological hazard. China is a country which located in the intersection of the Pacific rim tectonic belt and the Eurasian tectonic belt, with complex topography, strong crustal activity and changeable climate. With the rapid development of national economy in recent years, more and more irrational behaviors of human have beings lead to the increasing incidence of geological hazards. We need to strengthen the monitoring and forecasting of geological hazards for effectively preventing and mitigating hazard. According to relevant literature reports, China's annual direct economic loss caused by geological hazards is as high as 50.2 billion yuan, accounting for more than half of the total economic loss caused by natural hazards. In addition, geological hazards will also trigger other natural hazards, which will also cause greater material and financial losses. Therefore, the use of scientific and effective methods to prevent and control hazards is imperative, now technology through multidisciplinary, cross-department cooperation, rely on the combination of multiple means to strengthen the detection and prediction of geological hazards [4-6].

With the continuous development of science and technology, geophysical methods are constantly improved and expanded, and show outstanding advantages in geological hazard survey, such as accurate monitoring, rapid response, comprehensive data, simple and economical. In many special areas of our country can there be a method to carry out geological hazard monitoring, and achieved relatively excellent results, effectively improving the detection level of geological hazard [7-10].

However, the application degree of geophysical method in geological hazards monitoring is still relatively low, and the effective early warning mechanism and method combination are still in the process of further exploration. This paper aims to optimize the favorable combination of methods in hazards monitoring by investigating and analyzing the existing geophysical exploration methods. Through the analysis of the method application results, it provides a reliable thinking basis for the specific hazards monitoring work.

2. Characteristics of Environmental Geophysical Methods in Geological Hazard Monitoring

In principle, environmental geophysical method is to determine geological hazards by monitoring some characteristic parameters of geological media. Therefore, in geological hazard monitoring, environmental geophysical method has obvious advantages. First, compared with other monitoring methods, its work efficiency is high and the cost is low, which is very suitable for the use of geological hazard monitoring [11, 12].

In practice, the environmental geodynamic method can be used to telemetry the three-dimensional variation of the characteristics of underground media from the ground surface without a lot of drilling and exploration grooving [13, 14]. Secondly, the environmental geodynamic method has a wide range of application. Compared with other hazard monitoring methods, the environmental geo-physical method has the same application field; And it has unique advantages in all kinds of hazard research. Thirdly, the environmental geo-physical method has a wide coverage. Drilling and sampling methods can only analyze the situation of point and line, but using environmental geophysical methods can study the space of the whole study area. Fourthly, the environmental geophysical method has the function of nondestructive testing. Environmental geophysics can be applied to environmental investigation under conditions where drilling sampling is impossible to achieve non-destructive testing [15, 16]. Fifthly, Environmental geophysical methods have very fast monitoring speed. In practical work, the using of high-speed computers can process a large number of environmental geophysical survey data, which can effectively shorten the data processing time, from that person to improve the monitoring efficiency [17, 18].

3. Environmental Geophysical Methods Commonly Used in Geological Hazard Monitoring

3.1. Electrical Prospecting

Electrical prospecting method is mainly used to solve geological problems by observing and studying the spatial and temporal distribution of electromagnetic fields created artificially or in nature through the difference between electromagnetic properties and electrochemical properties between rocks (Figure 1). Basically, electrical exploration technology can be applied in the investigation and monitoring of different geological hazards, such as high-density resistivity method and geological radar method [19]. Electrical prospecting is widely used in geological inquiry, ore, water and geotechnical engineering. In the high-density resistivity method, resistivity method is mostly used in ground crack investigation, goaf detection, coal collapse column detection and so on. Three-dimensional resistivity is mostly used in revealing the distribution of water damage in coal mining area, determining the water accumulation area and water access, and has good results. High-density electrical method is a new exploration method, which is mostly used in the investigation and monitoring of geological hazards, especially in the investigation of hazards in karst areas and the exploration of ground cracks [20]. In addition, the high-density electrical method has good application effect in the detection of mined-out area and the study of landslide. Excitation polarization method is mostly used in advanced detection of groundwater in mining area, water accumulation in goaf of coal seam, diagnosis of earth dam disease, detection of landslide surface and so on. Ground penetrating radar (GPR) belongs to electromagnetic wave detection technology, which is mostly used in karst collapse investigation, landslide prediction, ground fissure investigation, etc. differential radar measurement technology is mostly used in monitoring mine ground subsidence monitoring and regional ground subsidence. Electromagnetic method technology is mostly applied to detect goaf and karst subsidence areas [21]. Electrical method is the most widely used method in geological hazard monitoring. Table 1 lists the application of this method in geological hazard in detail.

Table 1. *Application of electrical method in geological hazard monitoring.*

No.	Method	Application
1	DC resistivity method	1. Survey lava collapse, karst cave, submerged river and fault; 2. Understand the development zone of underground concealed karst gap; 3. Survey hidden cracks, karst caves, hidden rivers and faults; 4. Understand the distribution of geology.
2	Mise-a-la-masse method	1. Survey distribution of underground rivers and underground karst caves; 2. Survey groundwater dynamics in coal fields and mining areas; 3. Identify ground cracks caused by earthquake and bottom subsidence; 4. Explore landslides and survey collapses.

No.	Method	Application
3	Natural electric field method	1. Survey the distribution of underground water system in karst areas; 2. Survey coal fire areas; 3. Survey of collapse.
4	Induced polarization method	1. To solve the problem of disease prevention and water improvement; 2. to detect landslide surface; 3. to detect the shallow water in dangerous rock mass and cracks; 4. Advance investigation of groundwater in underground mining area;
5	Electromagnetic method	1. Geological detection of landslide; 2. Determine the width of the fracture affected zone; 3. Investigate the hidden cracks, hidden caves and hidden rivers of dangerous rock mass; 4. Predict mine water inrush.

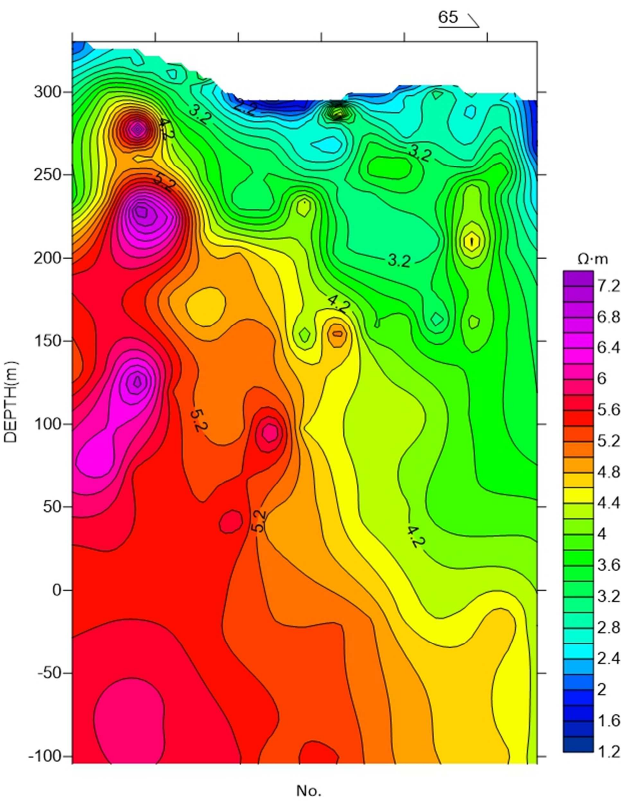

Figure 1. *Utilization of DC resistivity in fault detection.*

3.1.1. Magnetotelluric Method

Magnetotelluric method (MT) is a geophysical exploration method using natural alternating electromagnetic field to study the electrical structure of the Earth (Figure 2). Magnetotelluric method has the following advantages:

(1) The natural field source is adopted to meet the requirements of plane electromagnetic wave field source, and the near field effect problem of unattended factory source is solved.

(2) No artificial field source, low cost, flexible construction, adapt to more responsible terrain conditions, green environmental protection.

(3) It is not affected by shielding of high resistance layer and sensitive to low resistance layer.

(4) Large exploration depth, up to 10km deep at medium and high frequency. Maximum exploration capacity of long period observation is over 100km.

(5) Compared with artificial field-source electromagnetic method, the tensor observation method can obtain more detailed geoelectric information. In the case of two-dimensional or even three-dimensional geological structure, it has the advantage that artificial scalar source electromagnetic method doesn't possess.

Magnetotelluric method is widely used in large scale geological structure and plate activity monitoring. It can provide better data support for the analysis and prevention of geological hazards.

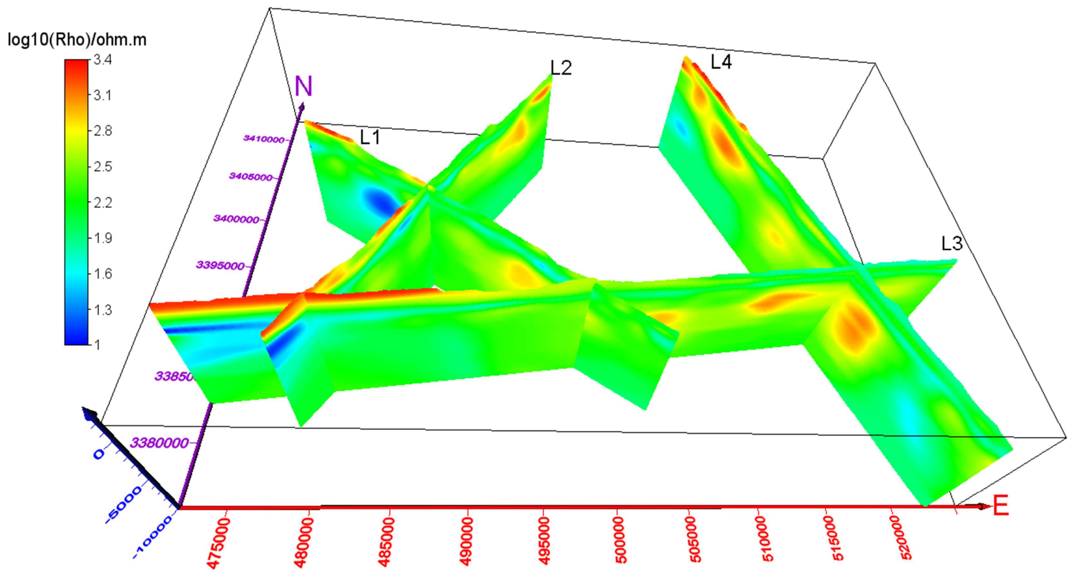

Figure 2. *3D visualization of shallow structures and strata using MT.*

3.1.2. Wide Field Electromagnetic Method

Wide field electromagnetic method is a new artificial source electromagnetic method proposed by academician He of Central South University. Through artificial ground source or unground source, the alternating current of 0.0117Hz-8192Hz is sent down, and only one electromagnetic field component is observed in the vast area not limited to the traditional far area, and the wide-area apparent resistivity is calculated, so as to achieve the frequency domain electromagnetic sounding method for detecting geological targets with different buried depths.

This method inherits CSAMT's human field source and overcomes the shortcomings of large randomness and weak signal of natural field source. Wide-area electromagnetic method need not through the ratios of electric and magnetic field cagniard resistivity, but directly use of the measured electric field or magnetic field and electric current to calculate apparent resistivity, the district (near and transition field) far into the measurable area, must overcome the CSAMT far area measurement and the shortcoming of weak signal, also greatly expanded the scope of observation of artificial source electromagnetic method.

Wide-field electromagnetic method is not limited to the far area observation, expand the observation range, increase the exploration depth; It avoids the influence of traditional electromagnetic field interference on the measured data and improves the anti-interference ability of the instrument. Multi-frequency could carry out multi-receiving while simultaneously sending and receiving. After years of field construction, the results are remarkable.

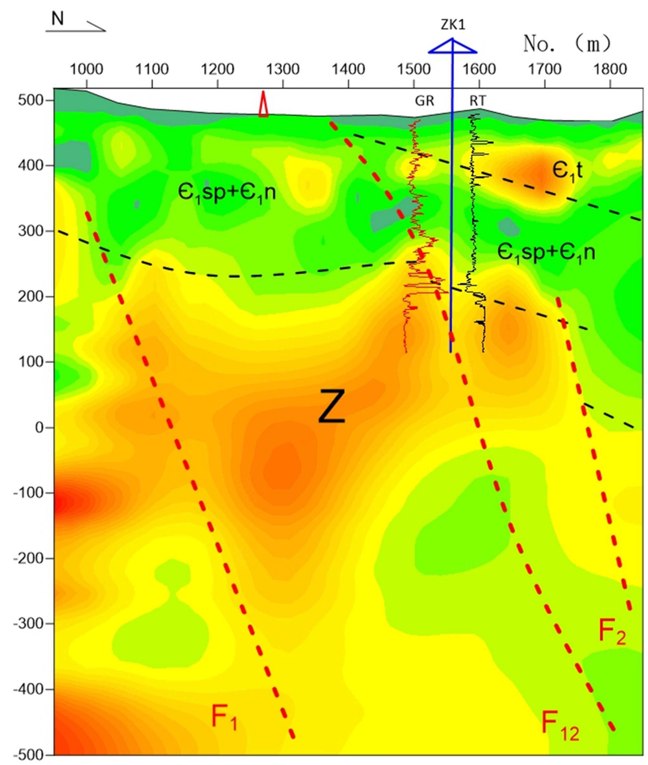

Figure 3. *Inversion section of wide-field electromagnetic method reveals high resolution subsurface structures.*

Wide-filed electromagnetic method, a new method, has great advantages in precision and anti-interference. It can accurately explore the distribution of cracks and faults, and regular monitoring can play an observation and warning role (Figure 3).

3.2. Seismic Method

Seismic exploration is based on the law of seismic wave propagation in rock, which is caused by the elastic property of rock itself. In geological hazards, this method is mostly applied in detecting karst and cave, and also in monitoring and preventing sudden geological hazards, such as landslide, ground collapse and ground fissure, high-resolution shallow seismic exploration is mainly applied in the investigation of karst collapse, landslide, ground fissure, detection of coal mine collapse column and coal seam goaf, etc. [22, 23]. Additionally, transient Rayleigh wave exploration technology is mainly used in the investigation of landslide, debris flow and other environmental geological hazards.

In recent years, seismic survey methods are applied more and more, which can be divided into shallow seismic survey, surface wave survey and so on. The depth of shallow seismic survey is usually not more than 200 m, and most of the shallow seismic survey is small scale and the rock mass varies greatly in vertical and horizontal direction. This method has high resolution in the application process and can carry out effective detection. At present, this method is widely used in coal mining cities, and it can be used to survey hidden faults, damaged zones, karst caves, soil caves and hidden rivers. Especially in the exploration of coal seam goaf, it can predict the gas enrichment area, so as to effectively reduce the occurrence of hazard [24-26].

Surface wave survey is a new survey technology, which has the function of surface wave compared with the traditional survey method. This method can be divided into steady state method and transient method. It can overcome its own shortcomings through a large number of superposition, so as to make the monitoring results more reliable. Surface wave survey is mainly used in frozen soil survey, debris flow monitoring and detection of landslides, with good detection results [27].

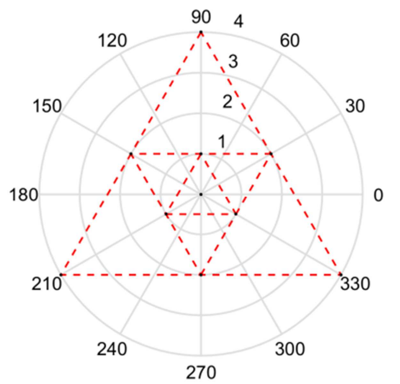

Figure 4. *Sketch shows stations deployment of the micromotion seismic method.*

Fretting exploration method is frequently used in the field of natural field seismic observation in recent years. The distributed station layout has the characteristics of convenient layout, timely monitoring and strong anti-interference. In the field of hazard monitoring, the can be deployed in the field monitoring area for a long time in the form of wireless connection, and the data can be sent back in real time for analysis and evaluation (Figure 4). External equipment can replace the battery of the equipment regularly, so that real-time monitoring and early warning can be achieved (Figure 5).

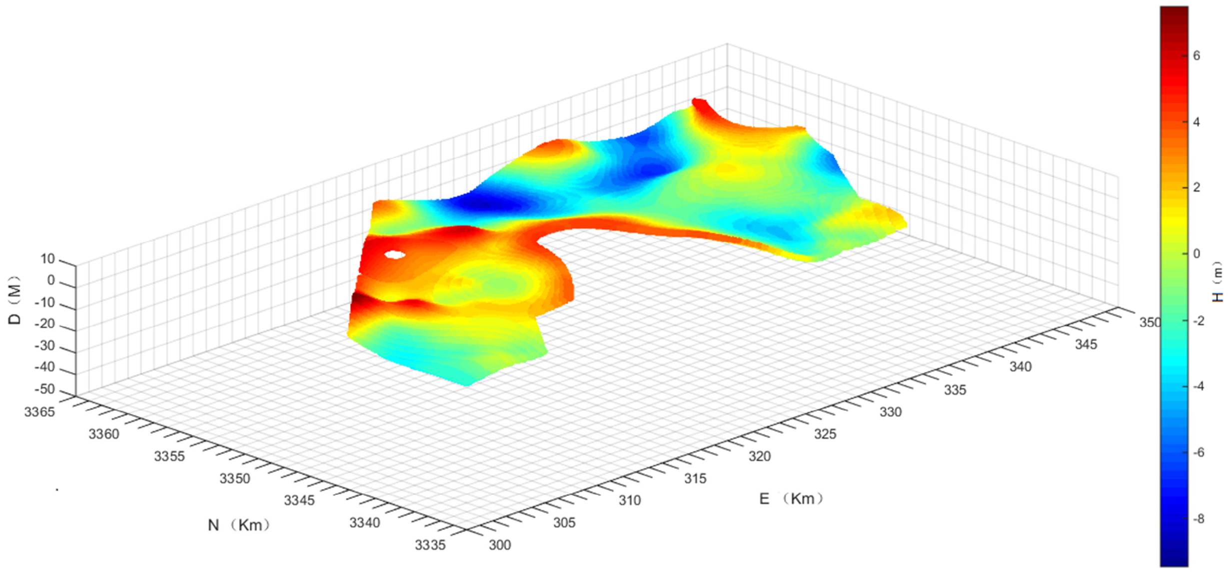

Figure 5. *3D inversion results using the micromotion station method, which shows high-resolution structures subsurface.*

3.3. Gravitational Method

Gravity method is based on the density difference of underground objects. This method is mainly based on outdoor survey, so as to obtain the abnormal phenomenon of gravity of geological structure, so as to study the change rule of these gravity anomalies through analysis, so as to understand and solve geological problems. Since the emergence of gravimeters, this medium monitoring method has been gradually applied to shallow exploration fields [28-31]. At present, gravity method is mainly used in short leg earthquake prone zone, monitoring earthquake precursor, exploring karst and cave, detecting landslide, monitoring ground subsidence hazard, etc. In addition, in the production of mining area, the prevention and control of coal mine water damage is a difficult problem, with the continuous improvement of the precision of gravity method exploration, effectively solve this difficult problem.

3.4. Magnetic Method

Magnetic method is to solve geological problems through magnetic field changes caused by magnetic differences between underground rocks and ores or rock-soil media [32-34]. In recent years, high-precision magnetic measurement has been gradually applied in geological hazard monitoring, which has high observation accuracy, simple operation, high efficiency and can obtain more information. In the field of geological hazards, magnetic method is mostly used in earthquake prediction, detection of coalfield fire area, detection of coalfield collapse column and other aspects [35-40]. In the process of detecting spontaneous combustion area in coal field, the characteristic electric method and downward continuation method of magnetic method are used to explain the boundary of single-layer fire area more accurately. According to geological conditions and magnetic characteristics, multi-layer fire is analyzed and compared, which has good application effect.

3.5. Radioactive Prospecting

Surface radioactive prospecting is a surface exploration method with both construction efficiency and economic benefits, and it responds well to special geological phenomena in hydrology and geothermal. Radon gas survey is a common ground radioactive exploration method (Figure 6).

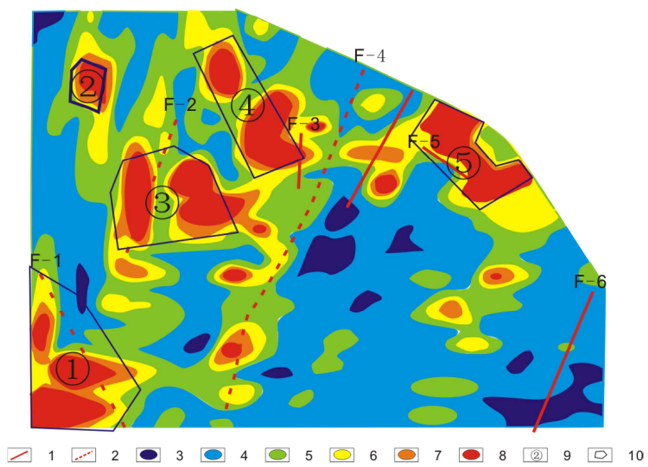

Figure 6. *Structures unraveled by Radon measurement.*

Radon measurement is a kind of nuclear geophysical prospecting, which is very popular in coal fire detection in recent years [41-45]. Liu et al from Shanxi Institute of Mining and Technology studied the mechanism of detecting the location and range of spontaneous combustion in coal seams by radon measurement method in the mid-1990s, and established a radon measurement test bed for natural radioactive media, studied the relationship between radon precipitation and temperature, and developed CDTH (radon detection and fire detection) special software. And in Shandong Zao' Group Co., LTD. Chaili mine and other 15 mining bureau to promote the application. Taiyuan university of science and Technology, former Changchun university of science and technology wait for colleges and universities and Hebei Xingtai mining bureau Gequan coal mine, Shi et al coal mine and other production units also measure radon law (α cup measure radon) delimit underground coal seam fire range did many research, and achieved very good effect in actual production. Radon emission is easily affected by meteorological conditions and other factors. In order to reduce the interference, RTM2100 radon thorium detector produced by Germany SARAD Company was selected for this study. The RTM2100 is equipped with a special sensor to measure temperature, humidity and pressure at the measuring point, and automatically calibrate the three effects. The instrument has two modes of measuring radon and thorium, and in the mode of measuring radon, the influence of thorium emission can be eliminated as interference factor, and vice versa.

3.6. Geophysical Well Logging

As an exploration method in drilling, geophysical logging has the characteristics of high precision, rich parameters and wide application. Conventional geophysical logging methods include SP, GR, caliper CAL, inclination DEV, acoustic time difference AC, resistivity RT, neutron porosity CNL, volume density DEN, etc. Unconventional special logging methods include imaging logging, energy spectrum logging, array acoustic logging, nuclear magnetic resonance, etc. Geophysical logging equipment is closer to the formation and can accurately monitor the stratigraphic sequence (Figure 7). Conventional logging resolution can be up to sub-meter, and special logging such as imaging logging can identify millimeter-scale fractures and monitor their status to identify their occurrence. As the depth of geological exploration deepens, the surface method often receives the interference and shielding of the surface strata, and makes full use of the geophysical logging method of drilling, which plays a great role in the establishment of geological model, the collection of background data, fine observation and so on.

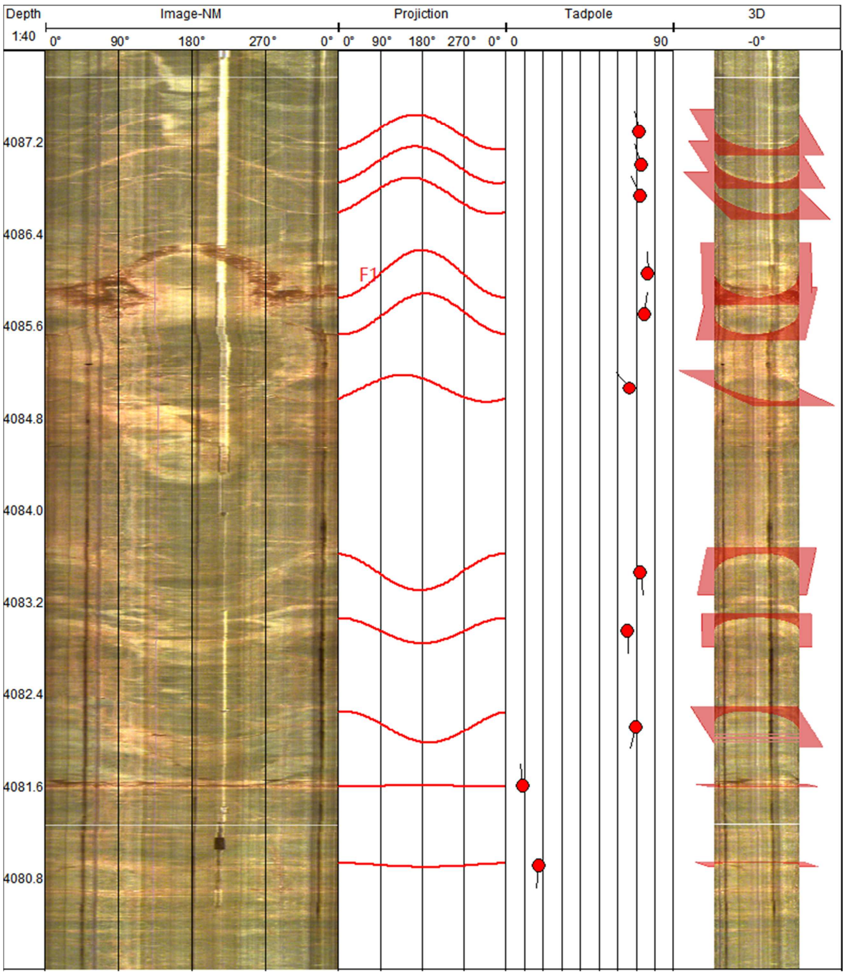

Figure 7. *Image logging results shows the micro-fratures of subsurface.*

Table 2. *Main applications of geophysical logging methods.*

No.	Method	Main application
1	Natural gamma, natural potential	Stratigraphic sequence division
2	Acoustic time difference, neutron porosity, volume density	Pore, fissure identification and evaluation
3	Hole diameter and inclination	Collapse, broken section monitoring, formation structure evaluation
4	Resistivity, double lateral resistivity, etc.	Fracture evaluation and formation identification
5	Imaging logging	Stratum and fissure identification, occurrence and width reading.

4. Unresolved Issues

At present, the environmental geophysical methods of geological hazards still have some problems to be further improved and solved.

Geological hazard survey and research are mostly passive studies, mostly for prevention and emergency measures, so it is difficult to accurately and comprehensively survey the occurrence of geological hazards. Therefore, we should further study the geological characteristics and development rules of Our country, and provide different detection methods for each type of geology so as to achieve accurate and effective prevention effect, and effectively suppress the loss and damage caused by geological hazards.

Geological hazard survey should take the initiative to find the leading factors of the occurrence of the hazard, and analyze the factors, so as to get the main causes of the geological hazard, and specific plans to prevent the recurrence of geological hazard.

The environmental geophysical methods used in mining areas are universal and can be used in other geological hazards. However, the causes of geological hazards are generally more complex, and may be related to the topography of the area, or may be related to the weather. Therefore, researchers should design different detection methods for different geological hazards and put forward different technical parameters. In view of different geological hazard sites, researchers should develop environmental geophysical methods suitable to them, and at the same time, further improve the resolution of geophysical methods, so as to eliminate the influence of topography and make the obtained data more comprehensive and objective.

China has a vast territory, complex terrain, geological hazards occur in different situations, involving a wide range of technical fields. In the actual geological hazard survey process, it is often difficult to deal with problems by single detection method, and it is difficult to play a good effect. Therefore, researchers must comprehensively use environmental geophysical methods to solve geological problems. Different environmental geophysical methods have their own characteristics and advantages, which can solve the shallow and deep surface geological problems. Comprehensive utilization of environmental geophysical methods can make the methods and techniques more scientific and reliable. For different geological hazards, researchers should adopt a combination of various methods from the aspects of safety, economy, efficiency and accuracy to improve the efficiency of geological hazard survey.

The application of environmental geophysical method is relatively limited. At present, the application of this method is limited to the monitoring and prediction of geological hazards. We should think about the expansion of the function of this method, and turn more to the limitation and management of geological hazards, so as to fundamentally limit the occurrence of geological hazards.

5. Conclusion

On the whole, with the continuous progress of social science and technology, human interference to the geological environment has become more and more obvious. It is necessary to detect and prevent geological hazard, and the geological hazard monitoring method represented by environmental geophysical method is particularly important. The accuracy, extensiveness, reliability and high efficiency of detection are important criteria for judging geological hazard monitoring methods. Environmental geophysical methods have many advantages in application, and are also widely used in the actual geological hazard survey. In practical work, relevant survey departments need to grasp the principles and characteristics of environmental geophysical methods accurately, and flexibly select and use environmental geophysical methods according to the actual geological conditions, so as to find out the environmental geophysical methods suitable for local geology. This is conducive to the efficient development of geological hazard monitoring, and constantly improve the level of geological hazard prediction, prevention and control, so as to better serve the environmental governance and protection.

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