

Application of Transmission Slot Wave Exploration Technology in Structural Exploration

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Abstract

The geological conditions of coal mining in my country are complex, and the difficulty of coal mining is becoming more and more difficult. Among them, the problem of coal mine structure also appears frequently. The existence of structures will not only greatly increase the cost of coal mining, but also pose a great threat to the safe production of coal mines. Conventional exploration methods cannot accurately predict structural development areas. At present, trough wave seismic exploration technology has become a mine geophysical method to detect coal seam structure. Because trough wave seismic exploration technology has the advantages of large exploration distance, high precision, strong anti-interference ability, easy identification of waveform characteristics and intuitive results, it is widely used in engineering widely used in practice. This time, the transmission slot wave exploration method was used to detect the structural abnormal area of the working face. The results show that the attenuation coefficient inversion results can intuitively reflect the abnormal area with structural development, and the interpretation accuracy of the structure is greatly improved, which provides a guarantee for the safe production of coal mines.

Keywords

Coal Mine; Structure; Transmission Channel Wave Exploration.

1. Introduction

With the steady, rapid and healthy development of my country's national economy, there is a large demand space in the domestic coal market, which leads to the continuous increase in the depth of coal mining. Due to the increase in the complexity of the geological terrain in the deeper depths, the difficulty of coal mining is also increasing, and the problem of coal mine structure has also frequently appeared [1]. In recent years, due to the lack of understanding of underground geological information and structural development by coal mine personnel, huge economic losses and even coal mine accidents have been caused in the process of coal mining. The existence of structures will not only greatly increase the cost of coal mining, but may also pose a great threat to the safe and efficient production of coal mines. Therefore, clarifying the internal geological structure of the working face is crucial to the safe production of coal mines. In recent years, with the continuous improvement of coal exploration accuracy, the previous detection methods such as ground 3D seismic exploration and downhole radio perspective

technology have been unable to meet the actual detection work [2]. The inversion results are mainly used to detect the overall distribution of coal seams and the overall distribution of structural development in coal mines. However, in the structural detection of small-scale mining face areas, there will be problems of low detection accuracy and inaccurate detection. It is difficult to meet the needs of structural detection in the mining face [3]; the downhole radio wave perspective technology is relatively mature in both development and application, but the propagation distance of this technology is limited, the longitudinal resolution of the detection face is low, and the anti-electrical interference ability is weak and has obvious response to collapse column structure, but it is still very difficult to detect faults [4]. At present, trough wave seismic exploration technology has become a mine geophysical method to detect coal seam structure [5]. In 1955, FFE vision excited and recorded trough waves in coal seams for the first time, revealed the dispersion characteristics of trough waves, and predicted trough waves. The possibility of being used for exploration [6]; in 1963, TCK rey proposed the theory of the propagation mode of trough waves in coal seams. Channel waves identify structures in coal seams and lay the foundation for channel wave exploration [7]. After decades of development, the channel wave exploration technology has developed into an exploration technology with a high success rate and strong practicability [8]. Because the channel wave seismic exploration technology has the advantages of large exploration distance, high precision, strong anti-interference ability, and easy waveform characteristics. The advantages of recognition and intuitive results have been widely used in engineering practice [9-11]. This time, the transmission slot wave exploration method was used to detect the structural abnormal area of the working face. The results show that the attenuation coefficient inversion results can intuitively reflect the abnormal area with structural development, and the interpretation accuracy of the structure is greatly improved, which provides a guarantee for the safe production of coal mines.

2. Slot Wave Detection Principle

Slot wave is a kind of seismic wave. In the geological section, the upper and lower interfaces of the roof and floor rock layers constitute a high wave impedance interface, and the coal seam is a low velocity zone. According to Snell's law, when a wave propagates from a low-speed medium to a high-speed medium, when the incident angle reaches the critical angle, the seismic wave is totally reflected at the wave impedance interface, and then a refracted seismic wave is generated, which interferes with the reflected wave and superimposes to form a strong interference wave, namely the slot wave, as shown in Fig. 1. Since the channel wave only propagates in the coal seam, the energy of the seismic wave is attenuated during the propagation process, and the propagation distance is long, and the waveform of the channel wave is easy to be picked up and identified, and the geological information it carries is rich and real. The structural distribution can be judged by analyzing the presence or absence of groove waves, their strength and their related kinematics and dynamic characteristics.

The formation process of the trough wave described in Fig. 1 is: the seismic wave generated by the shot point in the coal seam propagates to the top and bottom plate: in area A, since the incident angle of the seismic wave is less than the critical angle, a part of the energy leaks into the surrounding rock through the top and bottom plate, The other part of the energy is reflected back into the coal seam, and the A area is called the leakage area. When the incident angle in zone B is greater than the critical angle, the seismic waves are totally reflected and refracted back into the coal seam at the interface of the roof and floor. Since the slot wave is composed of seismic waves of different frequencies, the propagation velocity of the slot wave is a function of the frequency, and the slot wave is a dispersive wave. Since the trough wave is confined in the coal seam, it can travel far in the coal seam, but the trough wave is related to the thickness of

the coal seam. The thinner the coal seam, the higher the trough wave frequency and the shorter the propagation distance.

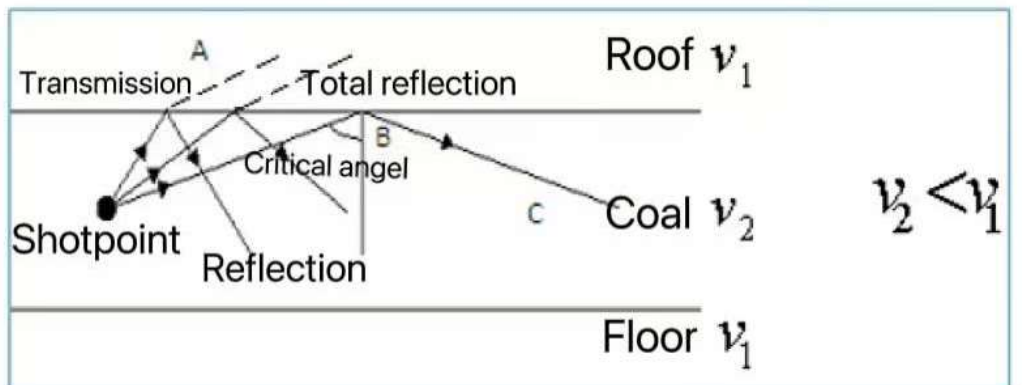


Fig. 1 Schematic diagram of groove wave formation

2.1. Types of Slot Waves

According to the different polarization characteristics and physical composition, the types of groove waves can be divided into Love-type groove waves and Rayleigh-type groove waves. Love-type groove waves are formed by the mutual interference of horizontal shear waves. Linearly polarized vibration in a plane and a plane perpendicular to the propagation direction; Rayleigh-type groove waves are formed by the superposition and interference of vertical shear waves (SV) and longitudinal waves (P), and their particle points are perpendicular to the coal seam and contain rays. Elliptical retrograde polarization is made inside.

The Love-type trough wave is used in this trough wave detection, and the Love-type trough wave is more advantageous in downhole detection because:

- (1) Compared with the Rayleigh-type slot wave, the physical composition of the Love-type slot wave is simpler, which makes its interpretation easier.
- (2) Compared with Rayleigh-type groove waves, Love-type groove waves can be recorded with less recording components; therefore, the use of Love-type groove waves can reduce costs when the number of measurement tracks is limited. At the same time, the reduction of the recording component brings convenience to the construction. Therefore, the arrangement of the detectors for the Love-type slot wave is easy to implement and the construction efficiency is high.
- (3) In the coal seam with symmetrical surrounding rock, the basic mode of Love-type trough wave is symmetrical. Even if the potentially excited higher-order modes are converted to lower-order modes near the fault, a stable fundamental mode will eventually be reached, which produces a maximum amplitude in the deep central plane, which makes Love-type groove waves easy to record. In order to receive the Love-type slot wave to the greatest extent, the geophone should be installed in the center of the coal seam as far as possible during construction.

2.2. Method of Trough Wave Seismic Exploration

Channel wave seismic exploration is a geophysical method to detect the discontinuity of coal seams by using the guided waves excited and propagated in the coal seam, and it is a branch of seismic exploration. There are two main methods of channel wave seismic detection: transmission method and reflection method. When the excitation source in the coal seam is completely blocked, the transmission slot wave cannot be formed, but the reflection slot wave

can be formed; when it is partially blocked, the weak transmission slot wave can be observed, and some reflection slot waves can be observed.

(1) Detection by transmission method

The transmission method detection means that the source and the detector are arranged in different roadways, the excitation source is arranged in one roadway in the detection area, and the detector is arranged in another roadway to receive the slot wave. The schematic diagram of the transmission method is shown in Fig. 2. The channel wave transmission method is the most reliable and important method in the channel wave seismic method. The effective wave used in the channel wave transmission method is the direct channel wave signal transmitted from the seismic source through the coal seam to the receiving point. When the thickness of the coal seam is less than the thickness of the abnormal structure, the channel wave signal is completely blocked, and the channel wave signal cannot be collected; when half of the thickness of the coal seam is equal to the thickness of the abnormal structure, the channel wave signal is partially blocked, and the signal energy is weakened to different degrees. The transmission channel wave energy is strong, the detection depth is large, and the interpretation accuracy is high. The channel wave seismic transmission method has a good response to the collapsed column in the mining face. Therefore, the transmission method is used as the main detection method [12].

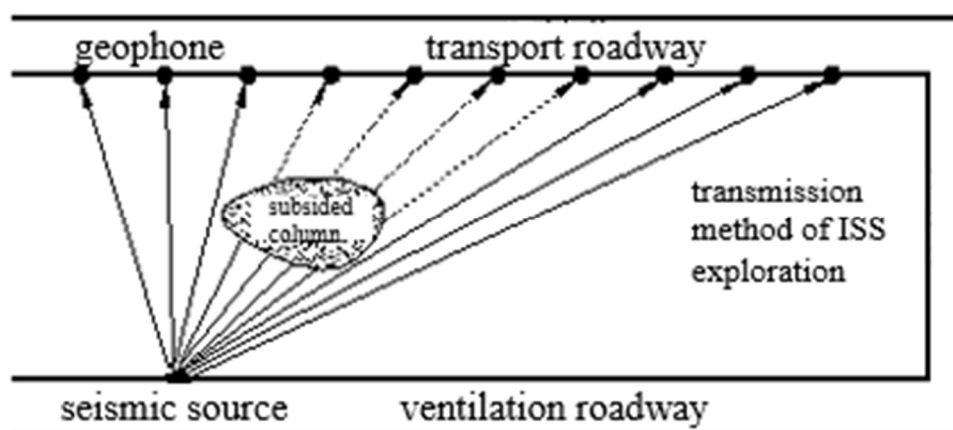


Fig. 2 Schematic diagram of detection by slot wave transmission method

(2) Detection by reflection method

The effective wave of the slot wave reflection method is the reflected slot wave signal. If the channel wave propagates in the coal seam and encounters the discontinuity in the coal seam, that is, it encounters the interface of the wave impedance of the seismic wave, a reflection channel wave will be generated. The channel wave reflection method is based on the measured channel wave velocity and reflection groove. The position of the structure is determined by the time of the wave, and the advantage of the reflection method is that the source and the detector are arranged in the same roadway. Compared with the transmission method, the energy of the reflected channel wave is generally weaker. The channel wave seismic reflection method has a good response to the strike-type fault in the mining face. The schematic layout of the reflection method is shown in Fig. 3 [13,14].

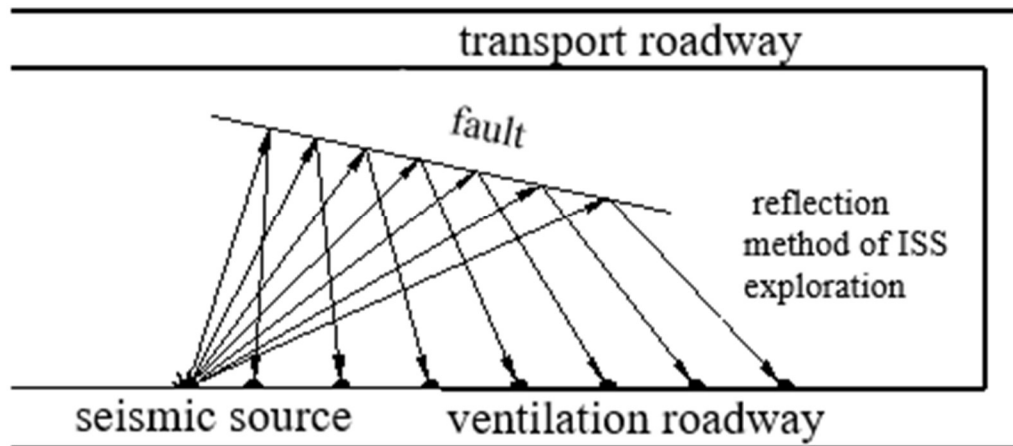


Fig. 3 Schematic diagram of the layout of the slot wave reflection method

3. Applications

3.1. Data Processing Flow

This time, taking the Hexi coal mine in Shanxi as an example, the application of transmission channel wave exploration technology in structural exploration is analyzed. This data processing is mainly carried out by KDZ2002 and SCT3.0 mine seismic CT processing software developed by ourselves. The software is easy to use and the results are analyzed intuitively. Firstly, the internal data of the multi-channel digital seismograph is transmitted to the computer through the communication module, and the data format is converted on the KDZ2002 workstation. And with the support of the preprocessing module of the SCT3.0 mine shock wave CT processing software system, each single shot record was extracted and rearranged, so that the downhole record was converted into a common shot point record (CSP) and a common receiver point record (CGP). Data preprocessing, establishment of observation system, first arrival correction, channel wave energy compensation, broadband filter dispersion analysis and other processes are carried out to process and analyze the data.

(1) Data preprocessing: A large number of abnormal traces will affect the subsequent processing effect, especially abnormal traces with strong energy, which will affect the attenuation law of amplitude, making it difficult to obtain the compensation coefficient accurately. First, the abnormal traces must be checked and eliminated. Bad sectors, empty sectors, rearrange the data to make it easier to process and improve the accuracy of the data.

(2) Establish an observation system: The observation system refers to the geometrical arrangement relationship between the source excitation point and the receiving point. The accuracy of the observation system will have a direct impact on data processing, so it must be ensured that an accurate observation system is established. According to the geological task of channel wave detection, carefully study the layout of the roadway in the detection area, the placement of mining equipment, noise interference, etc., to determine the best observation system method.

(3) First arrival correction: There is a certain time difference between the detonation of the detonator and the actual explosion, and the detonation delay of each detonator also has a time difference. This difference affects the first arrival time of the slot wave, which in turn affects the imaging quality of the slot wave velocity imaging. Therefore, it is necessary to correct the first arrival time of each trace according to the seismic wave propagation theory.

(4) Energy compensation: With the increase of propagation distance, the seismic wave from the shot point shows spherical diffusion, and the energy decreases. It is necessary to perform

diffusion compensation correction on the original single shot, so that the long-distance recording energy can be strengthened, and the energy between tracks can be balanced.

(5) Broadband filtering: The characteristic of the groove wave recording is that the frequency of the Elliott phase of the groove wave is much higher than the refracted longitudinal wave in the first arrival area and the refracted transverse wave in the continuous arrival area. The seismic phase corresponding to the minimum point in the dispersion curve (that is, the stagnation point of the curve) is called the Airy phase, which generally has the characteristics of strong amplitude, high frequency and low velocity. The Airy phase is the presence or absence of the channel wave signal. Weak sign. Through broadband filter, the longitudinal wave and transverse wave can be suppressed obviously, and the signal-to-noise ratio of the slot wave can be improved.

(6) Dispersion analysis: Slot wave is a typical dispersive wave, that is, the speed of the slot wave changes with the change of frequency. After estimating parameters such as the surrounding rock and coal seam longitudinal and shear wave velocities, the calculated single-shot trough wave dispersion curve is shown in Fig. 4. It can be seen from the figure that the Airy phase is around 140 Hz, most of the energy distribution of the channel wave is concentrated near the Airy phase, and the channel wave velocity is concentrated around 900 m/s.

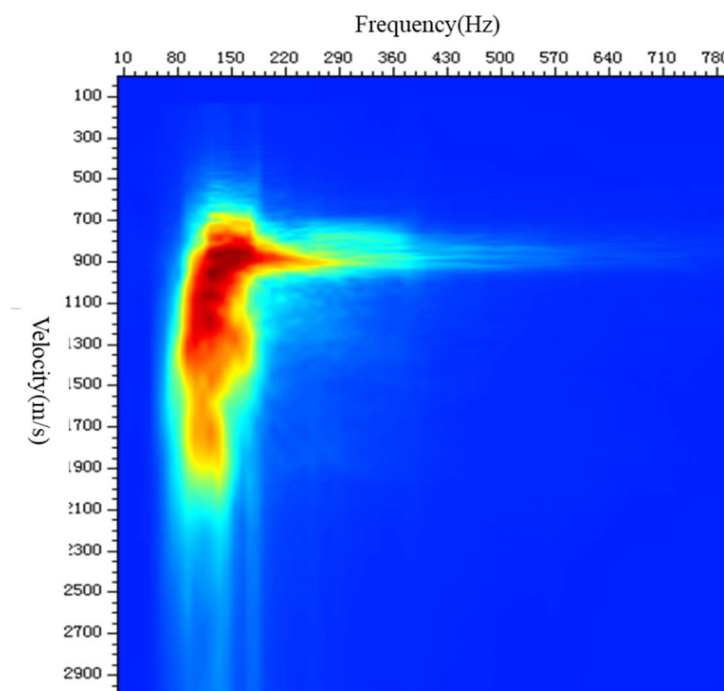


Fig. 4 Single shot trough wave dispersion curve

3.2. Data Analysis

Similar to the propagation of light waves in optical fibers, the propagation of slot waves in coal seams has good penetration. When the lithology of the coal seam in the working face is single and stable, the trough wave can penetrate most of the working face, and the energy attenuation is slow. When the channel wave encounters abnormal geological structures such as faults, collapse columns, and goafs during the propagation process, the energy of the channel waves will change. As shown in Fig. 5, the channel wave cannot be transmitted when it encounters a large fault block, and the detector cannot receive the channel wave signal; as shown in Fig. 6, when the channel wave encounters a small fault block, part of the energy can be transmitted, and the energy is weakened, and the detector Part of the slot wave can be received.

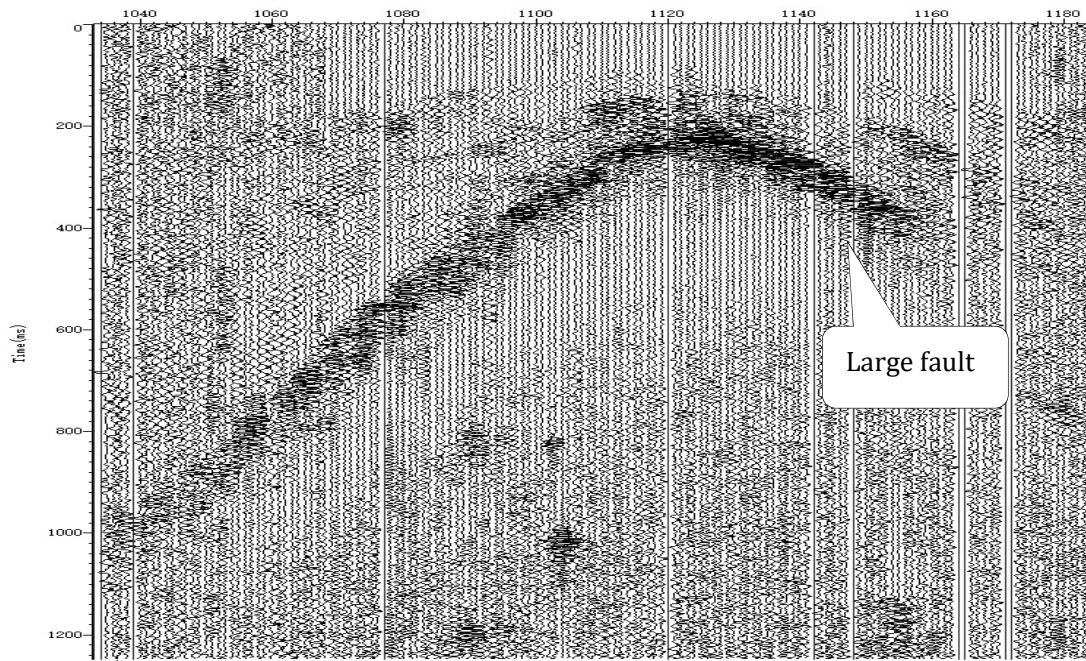


Fig. 5 S1055 shot groove wave record

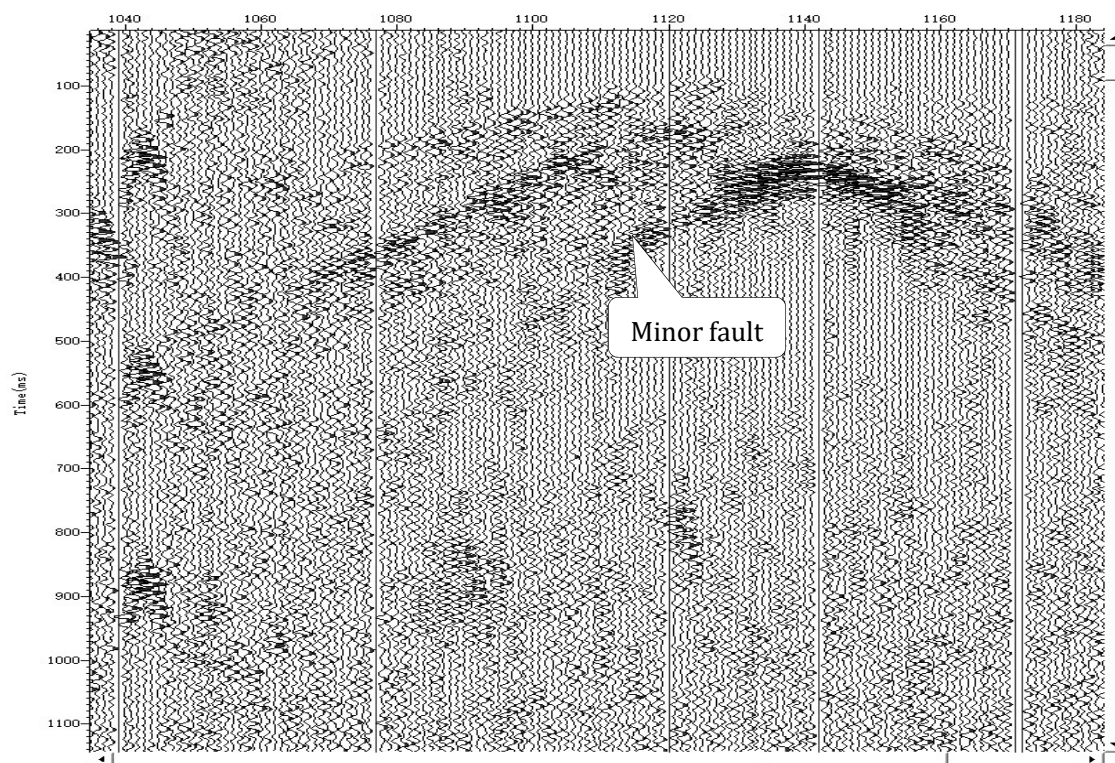


Fig. 6 S1064 shot groove wave record

3.3. Attenuation Coefficient Inversion Results

The interpretation of the detection results of the transmission channel wave exploration method mainly judges the geological anomalies in the detection area according to the existence, strength and weakness of the channel wave and other related kinematic and dynamic characteristics. The influence of the structure on the energy attenuation of the transmitted channel wave can be equivalent to the absorption effect of the medium. The attenuation coefficient inversion is the main part of the channel wave processing. The development of the structure in the working face affects the propagation of the channel wave. When the energy of

the channel wave weakens sharply, and the coal seam structure is reflected by calculating the energy attenuation coefficient of the channel wave, and the area with a large attenuation coefficient represents the abnormal influence of the geological structure. The figure below shows the attenuation coefficient inversion structure of a coal mine in Anhui by transmission exploration method.

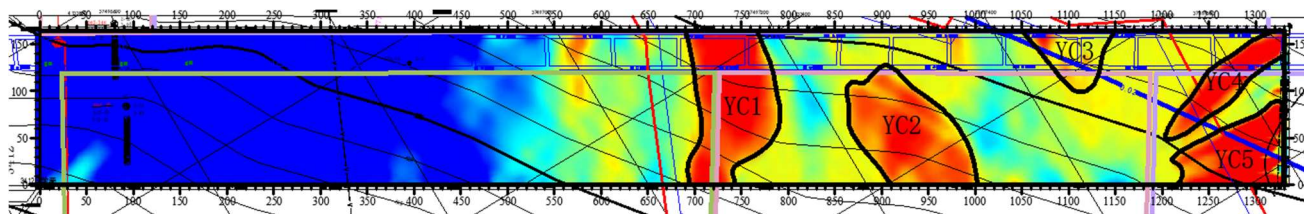


Fig. 7 Imaging image of channel wave attenuation coefficient of a coal mine in Anhui

In Fig. 7, blue represents the area with relatively strong trough wave energy, the trough wave normally passes through, which is a normal area, and yellow represents the area with weak trough wave energy. is the structural anomaly area. The red area on the figure represents the largest anomaly area in the working face, indicating that there is a large fault and other structural anomalies. The five red box areas delineated in the figure: YC1~YC5, are the five areas where large-scale structures of the working face develop.

To sum up, there is a large difference in physical properties between the structural area in the coal seam and the surrounding coal seam, which has a strong blocking effect on the channel wave energy. Using the received transmission channel wave exploration data to invert the attenuation coefficient, the inversion results can directly reflect the abnormal area of structural development, and the interpretation accuracy is greatly improved. Therefore, using the transmission channel wave exploration method is very suitable for the detection of structural anomalies in the working face.

4. Summary

(1) When the channel wave in the coal seam passes through structures such as collapsed columns and faults, the energy will change. Through the analysis of the inversion results of the channel wave attenuation coefficient, the blue color represents the area where the channel wave energy is relatively strong, and the channel wave passes through normally. Normal area; red and yellow are areas where penetration energy is sharply weakened, and trough waves encounter structural blockages such as faults and broken zones, which are structural anomalous areas, and five areas that may be large-scale structural development of the working face are delineated: YC1~ YC5.

(2) When the channel wave in the coal seam passes through structures such as collapsed columns and faults, it has a strong blocking effect on the energy of the channel wave. Using the received transmission channel wave exploration data to invert the attenuation coefficient, the inversion results can directly reflect the abnormal area of structural development, and the interpretation accuracy is greatly improved. Therefore, using the transmission channel wave exploration method has a good application prospect for the detection of structural anomalies in the working face.

Acknowledgments

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