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Application Practice of Transient Electromagnetic Advanced Water Detection Technology in Underground Metal Mines

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Abstract: By carrying out transient electromagnetic advanced geophysical water detection in metal mines and verifying the geophysical detection results with tunnel excavation, the results show that the transient electromagnetic method can well detect underground aquifers and water-rich areas, predict risks such as water inrush and gushing, and provide guiding significance for mine water exploration and drainage design, drainage system design and optimization, so as to reduce the adverse impact of water hazards on mines and ensure safe mine production.

Keywords: Transient Electromagnetic Method; Advanced Water Detection; Underground Metal Mines.

1. Introduction

With the continuous increase of mine mining depth, the hydrogeological conditions have become increasingly complex, and tunnel excavation often faces the risk of water inrush. In recent years, several underground mine water seepage accidents have occurred in China, which have seriously affected people's life safety and mine production safety. Therefore, adopting effective technical means to find out the occurrence state of groundwater in key mine operation areas is of great practical significance for preventing and curbing water hazard accidents. Due to its advantages of low cost, good portability, high lateral resolution and good coupling with detection targets, the transient electromagnetic method is regarded as one of the best geophysical methods for advanced water detection in underground mines [1].

Due to the unique occurrence conditions of coal mines, the prevention and control of groundwater hazards is the top priority of safe production work. Transient electromagnetic advanced detection technology is often used to study the occurrence of groundwater in tunnels and working face areas [2]-[7]. However, there are few application examples of transient electromagnetic advanced detection technology in metal mines. This paper carries out transient electromagnetic advanced detection technology in metal mines and verifies the detection results with tunnel excavation, so as to provide reference for the application of this technology in similar mines.

2. Principle of Transient Electromagnetic Technology

The Transient Electromagnetic Method (TEM) is a geophysical exploration method based on the principle of electromagnetic induction [8]-[10]. It uses an ungrounded loop or a grounded line source to send a primary pulse magnetic field to the underground. After the primary field disappears, a coil or a receiving monopole is used to measure the time-varying response of the secondary eddy current field excited by the underground medium (Figure 1). By processing and analyzing the response data, the electrical distribution, structural characteristics and water-bearing status of the underground medium are inferred. In water-bearing rock formations, since water is a low-resistivity body with low-resistivity anomalies, the secondary eddy current field decays slowly and the induced electromotive force generated is high. Therefore, it shows high-voltage anomalies on the transient electromagnetic multi-channel voltage induction profile and low-resistivity anomalies on the transient electromagnetic pseudo-apparent resistivity section. The location and size of the water-bearing rock formation are judged according to this electrical difference.

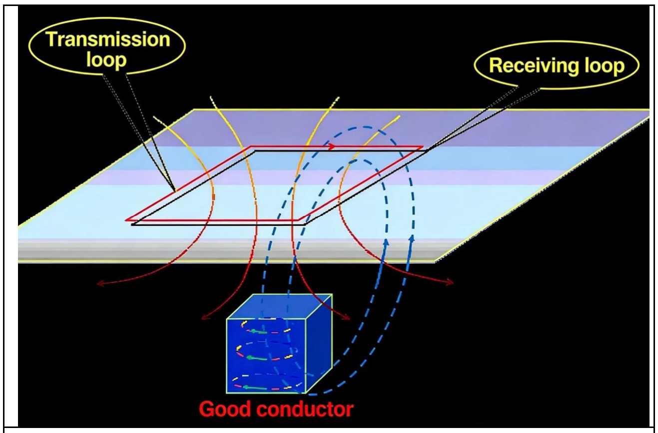


Figure 1. Principle of Transient Electromagnetic Technology

3. Practical Application

3.1. Project Overview

Tongkuangyu Mine is a large-scale underground copper mine. During the excavation of a certain tunnel, water gushing and dripping phenomena were encountered. Combined with the mine geological data and on-site investigation, it is considered that the lithology of the excavation area is sericite quartzite, and there are no pore water-filling and karst water-filling types. The water-filling type in this area is fissure aquifer water-filling. The main water-filling channels include: primary joints and fissures of rocks, and faults with a width of about 0.3-0.5m. It is estimated that the on-site water gushing volume is about 10-15m³/h. To prevent water seepage accidents, the mine adopted the transient electromagnetic method for advanced geophysical water detection in the excavated tunnel to predict the hydrogeological conditions within 80m in front of and around the tunnel.

3.2. On-site Data Collection

3.2.1. Observation System Layout

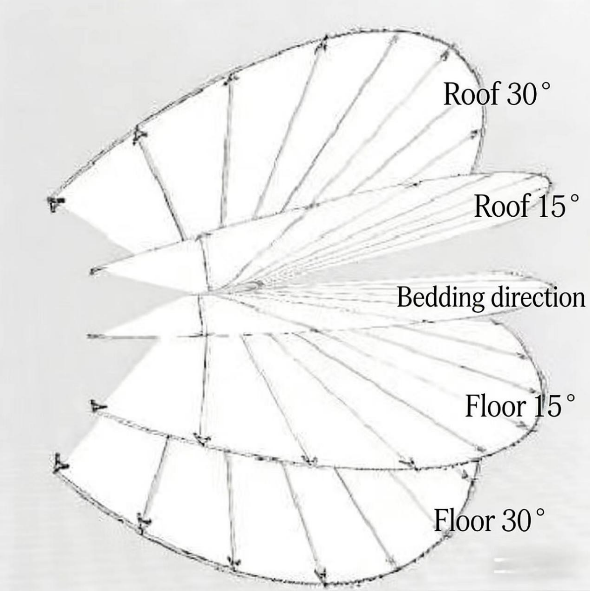


Figure 2. Schematic Diagram of Observation System Layout

Taking the horizontal direction directly in front of tunnel excavation as the benchmark, 5 transverse scanning sections are arranged on the working face with an upper and lower range angle of 60° (Figure 2):

1）30° obliquely upward to the roof direction;

2）15° obliquely upward to the roof direction;

3）Horizontal bedding direction (parallel to the tunnel excavation direction);

4）15° obliquely downward to the floor direction;

5）30° obliquely downward to the floor direction.

3.2.2. Observation Scanning Range

Taking the direction directly in front of the excavated tunnel as the benchmark, it is 60° to the left and right. Each scanning section has 9 measuring points, and each measuring point has 20 data in total (Figure 3).

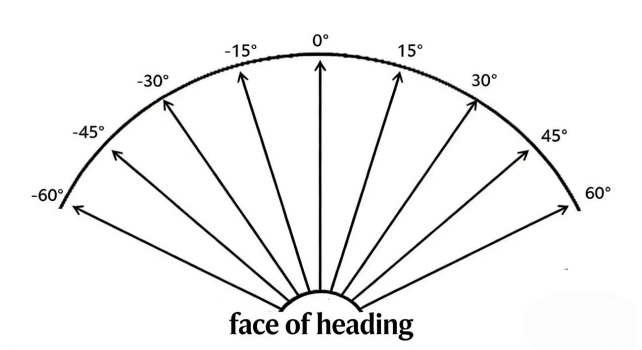
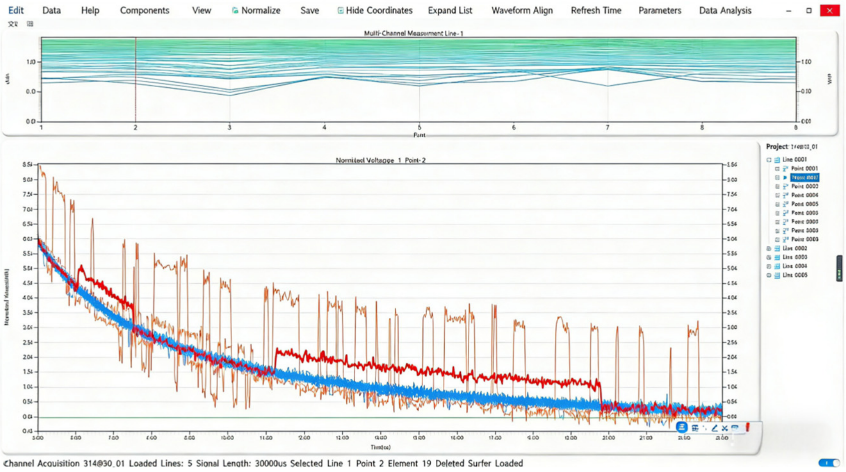


Figure 3. Observation Scanning Range

3.3. Data Analysis

After data collection, the transient electromagnetic professional software is used to process the data and filter out the interference waves (Figure 4). After data analysis, the fan-shaped map and 3D observation map of the detection results are drawn. Different colors in the fan-shaped map represent the relative changes of apparent resistivity at different positions, which means the trend of resistance value from low to high from cool color to warm color, that is, cool color indicates low-resistivity anomaly, which may be a groundwater occurrence area; the 3D observation map can more intuitively reflect the horizontal and vertical changes of lithology resistivity.

Waveform Time Window Field Survey Line Time Window Parameters Data Analysis



Channel Acquisition 314@30_01 Loaded Lines: 5 Signal Length: 30000us Selected Line 1 Point 2 Element 19 Deleted Surfer Loaded

Figure 4. Filtering Processing

3.3.1. Fan-shaped Map of Detection Results

The detection results show that 2 low-resistivity anomaly areas are found in the direction of 30° obliquely upward to the roof. (Figure 5)

1# Anomaly (YC1): The area 35-50m away from the working face in the direction of 30°-45° to the left of the front;

2# Anomaly (YC2): The area 60-80m away from the working face in the direction of 30°-45° to the left of the front. There are signs that the low-resistivity channel of the low-resistivity anomaly area invades the working face.

(2) Analysis of detection results in the direction of 15° obliquely upward to the roof (Figure 6)

The detection results show that 1 low-resistivity anomaly area is found in the direction of 15° obliquely upward to the roof.

3# Anomaly (YC3): The area 55-75m away from the working face in the direction of 30° to the left of the front. There are signs that the low-resistivity channel of the low-resistivity anomaly area invades the working face.

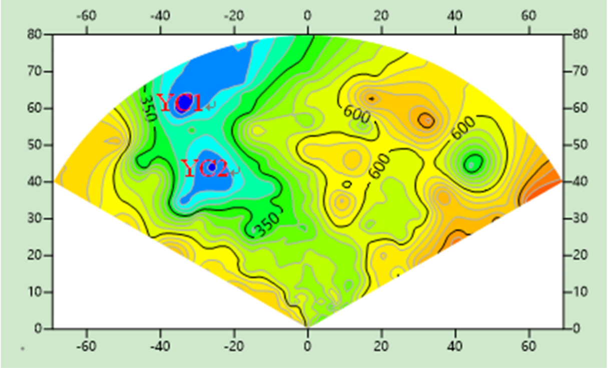


Figure 5. Fan-shaped Map of Detection Results in the Direction of 30° Obliquely Upward to the Roof

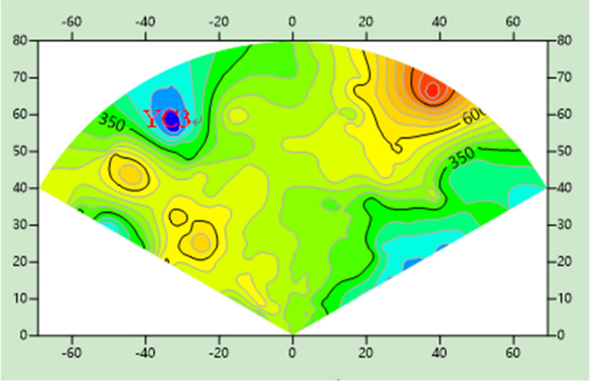


Figure 6. Fan-shaped Map of Detection Results in the Direction of 15° Obliquely Upward to the Roof

(3) Analysis of detection results in the bedding direction (Figure 7)

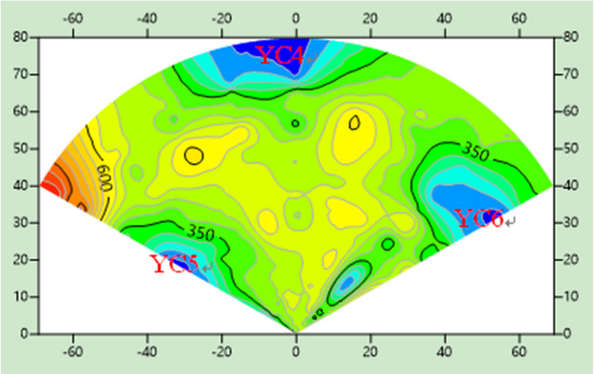


Figure 7. Fan-shaped Map of Detection Results in the Bedding Direction

The detection results show that 3 low-resistivity anomaly areas are found in the bedding direction.

4# Anomaly (YC4): The area 7080m away from the working face in the direction of 0°15° to the left of the front;

5# Anomaly (YC5): The area 15~25m away from the working face in the direction of 60° to the left of the front;

6# Anomaly (YC6): The area 2540m away from the working face in the direction of 45°60° to the right of the front. There are signs that the low-resistivity channel of the low-resistivity anomaly area invades the working face.

(4) Analysis of detection results in the direction of 15° obliquely downward to the floor (Figure 8)

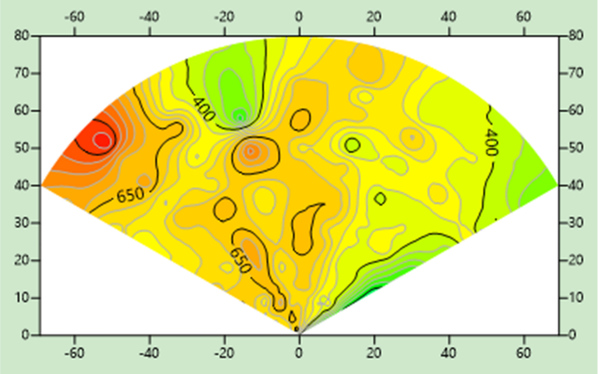


Figure 8. Fan-shaped Map of Detection Results in the Direction of 15° Obliquely Downward to the Floor

The detection results show that there is no low-resistivity anomaly area in the direction of 15° obliquely downward to the floor.

(5) Analysis of detection results in the direction of 30° obliquely downward to the floor (Figure 9)

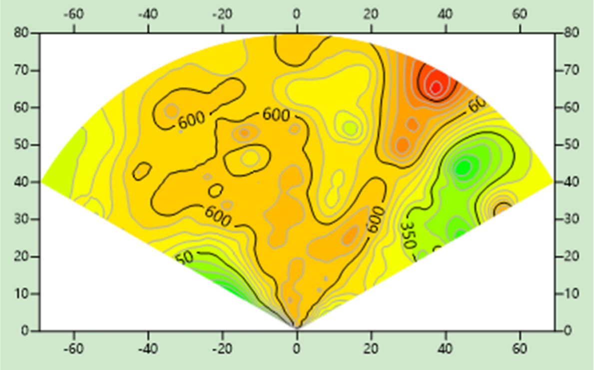


Figure 9. Fan-shaped Map of Detection Results in the Direction of 30° Obliquely Downward to the Floor

The detection results show that there is no low-resistivity anomaly area in the direction of 30° obliquely downward to the floor.

3.3.2. 3D Observation Map of Advanced Prediction

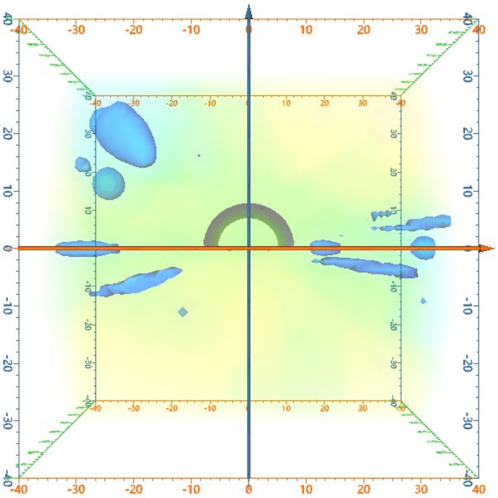


Figure 10. Front View

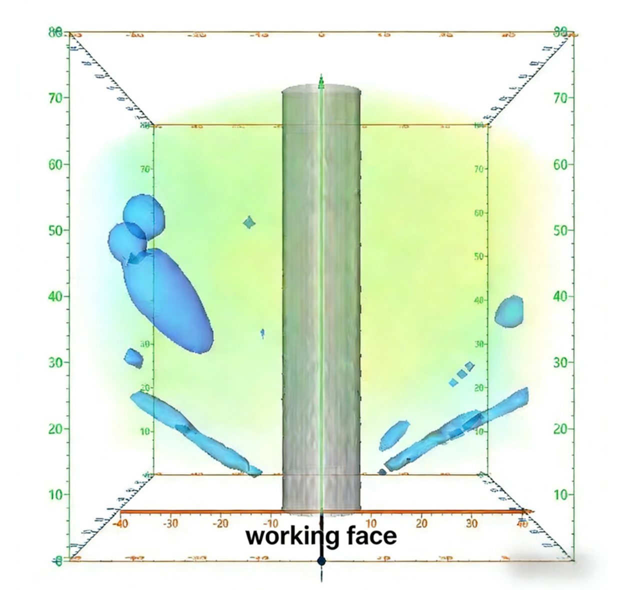


Figure 11. Top View

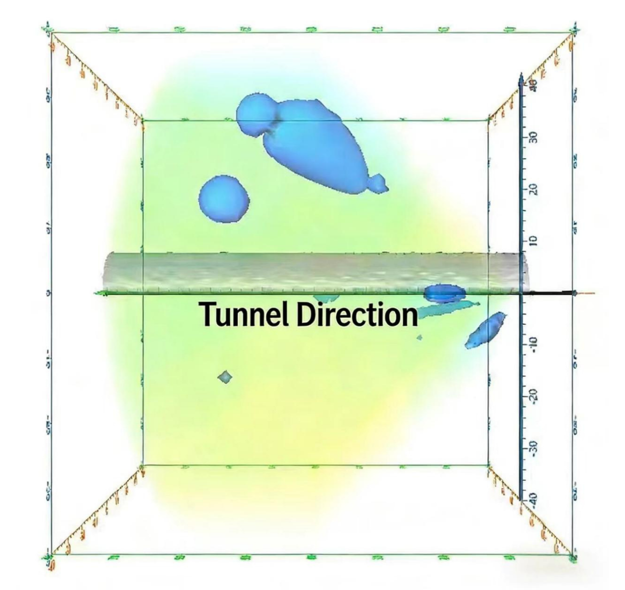


Figure 12. Left View

Combined with the fan-shaped detection result map, the analysis from the 3D observation maps of advanced prediction [11] (Figure 10, Figure 11, Figure 12) shows that the main water-bearing area is about 30-60 meters away from the working face and within the range of about 40°-50° above the left side of the tunnel, and the occurrence state is bedrock fissure water. It can be clearly seen in the figure that the bedrock fissure water invades the working face through the water-conducting structure.

3.4. Result Verification

Technical personnel have conducted long-term observation on the water gushing during the excavation of the tunnel. Taking the working face detected by geophysics as the starting point, fissure water at the working face gushes out from structural fissures and excavation blast holes; after excavating 25 meters, fissure water gushes out from the roof joints. During the construction of the shunting chamber on the left side of the tunnel (Figure 13), a large amount of water gushing occurred (Figure 14), which is in good agreement with the geophysical interpretation results. On the whole, the transient electromagnetic advanced water detection results in this study well reflect the occurrence state of underground fissure water and provide guiding significance for the safety guarantee work during the excavation operation.

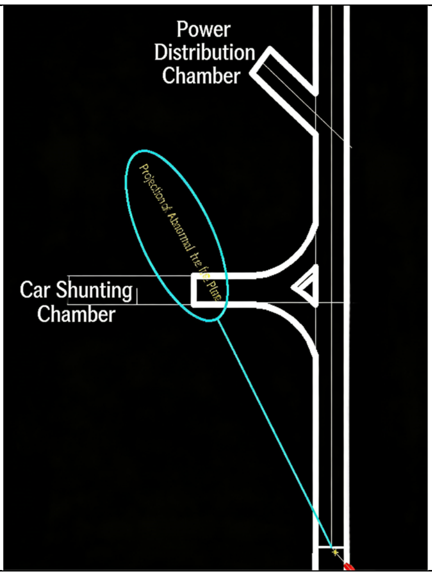


Figure 13. Location of the Shunting Chamber of the Tunnel

Figure 14. On-site Water Gushing in the Shunting Chamber of the Tunnel

4. Conclusion

By carrying out transient electromagnetic advanced geophysical water detection in metal mines and verifying the geophysical detection results with tunnel excavation, the results show that the transient electromagnetic method can well detect underground aquifers and water-rich areas, predict risks such as water inrush and gushing, and provide guiding significance for mine water exploration and drainage design, drainage system design and optimization, so as to reduce the adverse impact of water hazards on mines and ensure safe mine production.

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