ISSN 2663-1563 Vol. 6, Issue 4: 49-53, DOI: 10.25236/AJAGE.2024.060408

Exploration and 3D visualization application of controllable source audio magnetotelluric method for water rich coal mine faults

Zhang Dabin

Third Exploration Team of Shandong Coalfield Geological Bureau, Tai'an, Shandong, China
644484185@qq.com

Abstract: *The development of faults and other structures poses significant safety hazards in coal mining. With the increasing depth and accuracy of fault exploration, three-dimensional visualization applications based on two-dimensional data volumes have become the main development direction for fine exploration of water rich coal mine faults. In terms of fault exploration, controllable source audio magnetotelluric method is currently the main geophysical method for fault exploration. Through detection and comparative analysis, the controllable source audio magnetotelluric method can effectively identify differences in physical properties such as apparent resistivity. 3D visualization utilizes 3D visualization software to display the spatial distribution of apparent resistivity and analyze the differences in physical properties in 3D space.*

Keywords: *Fault rich water, controllable source audio magnetotelluric method, 3D visualization*

1. Introduction

Controllable source audio magnetotelluric method is a frequency domain resistivity sounding method developed in the 1970s based on natural source magnetotelluric sounding. This technology uses artificial field sources and has advantages such as high signal-to-noise ratio, high resolution, high efficiency, and low cost. This method is widely used in fields such as geological survey, engineering exploration, environmental governance, disaster geological survey, and mineral exploration. And it has a wide range of applications in the study of structures and sedimentary environments. The application of 3D visualization based on 2D data volume has become the main development direction for fine exploration of water rich properties in coal mine faults. This article takes the exploration and 3D visualization application of controllable source audio magnetotelluric method in a coal mine in Shandong Province as an example. The controllable source audio magnetotelluric method is used for geophysical exploration of faults, and 3D visualization is used for visual resistivity analysis. The spatial distribution and water abundance of faults are comprehensively analyzed and studied.

1) Geology of the research area

The research area is located in the southeastern part of the Ningyang coalfield, with the main coal bearing strata being the Shanxi Formation and Taiyuan Formation of the Carboniferous Permian Yuemengou Group. The coal measures and coal seams are stable in sedimentation and belong to the North China type coal bearing rock series. The strata in the well field develop from old to new, including Ordovician (O), Carboniferous (C), Permian (P), Jurassic (J), and Quaternary (Q).

The aquifers that have an impact on coal mining production in the research area from top to bottom mainly include the Quaternary alluvial pore aquifer rock group, the Permian sandstone fracture aquifer rock group, the Carboniferous interlayer karst fracture aquifer rock group, and the Ordovician karst fracture aquifer rock group [1-2].

2. Electrical characteristics

There are many factors that affect the electrical resistivity of rocks, and different rocks have different electrical resistivity. Based on the electrical resistivity of different rock layers in previous regions, under normal geological combination conditions, the physical properties of the electrical resistivity values of different rock layers in both horizontal and vertical directions have regular patterns to follow.

ISSN 2663-1563 Vol. 6, Issue 4: 49-53, DOI: 10.25236/AJAGE.2024.060408

The coal bearing strata in the research area are the Carboniferous Permian strata. After the coal seam roof and floor or the Ordovician limestone become rich in water, the resistivity of the water rich area and the water conducting channel significantly decreases. At the same time, there is also a significant difference in resistivity between the limestone and the coal seam, which provides good geological conditions for mid to deep electromagnetic exploration. However, the structure of this area is complex, and the geological conditions for mid to deep electromagnetic exploration are generally average[3-4].

3. Research situation

In this study, the controllable source audio magnetotelluric method was used, and 30 controllable source audio magnetotelluric measurement lines were arranged in a network of 40m (line spacing) × 20m (point spacing) in the research area, with a total of 990 physical points in the north-south direction. The data was collected using the V8 electrical workstation produced by Phoenix Corporation in Canada, with a magnetic probe of AMTC-30. The Ex and Hy components were measured, and 48 frequency points were collected. The working frequency range used for measurement is preliminarily determined based on the maximum depth to be detected by the exploration task target and the background value of the earth resistivity in the survey area.

4. Processing interpretation and 3D visualization analysis

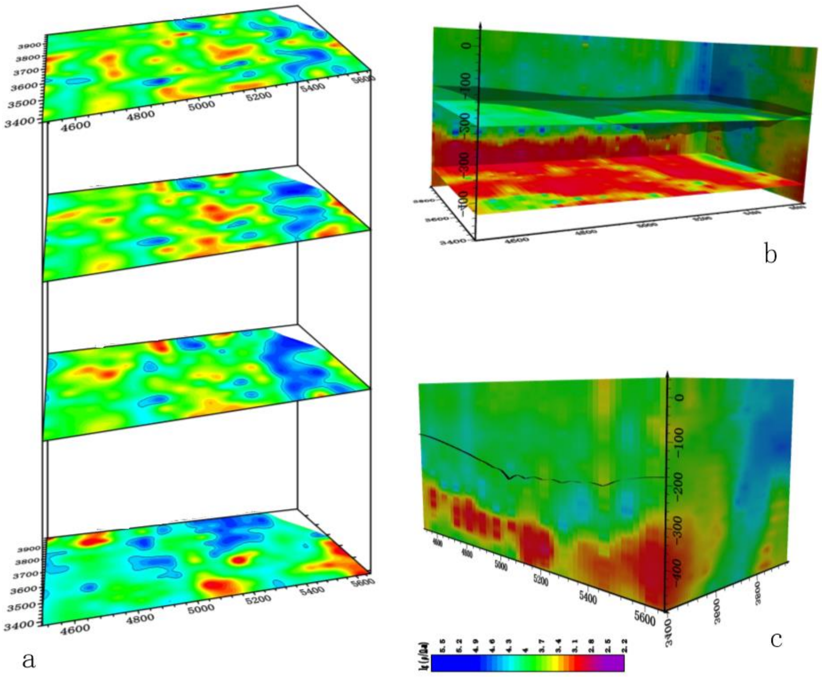
The data processing of controllable source audio magnetotelluric method mainly uses CMTPro provided by Phoenix Company and MTsoft2D software developed by Chengdu University of Technology for post-processing, forward modeling, and inversion interpretation. After performing near-field correction, terrain correction, data smoothing, static correction, and two-dimensional spatial filtering in the later stage, two-dimensional inversion and imaging interpretation under undulating terrain are carried out. The 3D visualization analysis is conducted using Voxler software.

The water rich property of a fault should be determined based on the variation law of apparent resistivity, and the water rich property of a fault is an important factor affecting its electrical properties. For water rich faults, their apparent resistivity values are lower compared to those of non water rich faults and surrounding non water rich formations; The hydraulic conductivity of a fault also depends on the lithology of the two sides and the mechanical properties of the fault. It is a tensile fault developed in brittle rock layers, with loose structural breccia in the center and fractured zones with relatively high fracture rates on both sides. It often has good hydraulic conductivity, and the apparent resistivity values on both sides of the fault do not change significantly; Tensile fractures developed in plastic rock layers with high water content, with a large amount of mud interbedded in the structural rock. The strengthening of cracks on both sides is not as obvious as in brittle rock layers, often resulting in poor water conductivity or even water isolation. The apparent resistivity values on both sides of the fault will undergo significant changes.

Based on the collected raw data, data processing and interpretation were performed to obtain cross-sectional diagrams of apparent resistivity for each measuring line, as well as layer wise slice diagrams of apparent resistivity for coal seam 3 and each aquifer. The three-dimensional data volume obtained from the resistivity cross-section diagram is visualized using three-dimensional visualization software. Obtain the three-dimensional contour maps of resistivity slices in the research area (Figure 1a), three-dimensional slice maps (Figure 1b), and three-dimensional electrical structure maps (Figure 1c). The horizontal axis in the figure represents dots, the vertical axis represents elevation, and the transition from blue to cyan to yellow to red indicates the change in apparent resistivity from low to high. The black thin line shown in the figure represents the stratigraphic boundary, the black thick line represents the location of the mineable coal seam, and the red diagonal line represents the fault.

From a vertical perspective, the apparent resistivity from shallow to deep shows an electrical characteristic of high to low and then increasing again. The shallow part (below 180m) in the figure reflects the uneven low to medium resistivity, and the apparent resistivity gradually decreases from shallow to deep, reflecting the electrical changes in the Quaternary strata. The resistivity of the middle part (elevation -140m to -280m) is moderate, reflecting the electrical properties of mudstone, sandy mudstone, siltstone, and medium fine sandstone in the upper and middle Permian strata. The resistivity increases sharply near the elevation of -300m, due to the high resistivity of limestone, which is a normal electrical reflection of limestone formations[5-7].

ISSN 2663-1563 Vol. 6, Issue 4: 49-53, DOI: 10.25236/AJAGE.2024.060408



a - Three dimensional map of resistivity slice contour lines in the study area; b - Three dimensional slice map of resistivity in the study area; c - Three dimensional electrical resistivity map of the study area.

Figure 1: Three dimensional electrical structure of the research area

By extracting three-dimensional data from data with low apparent resistivity values, a three-dimensional visualization of low resistivity anomalies was obtained (Figure 2), which provides a clear view of the spatial distribution of low resistivity anomalies in three-dimensional space from different angles.

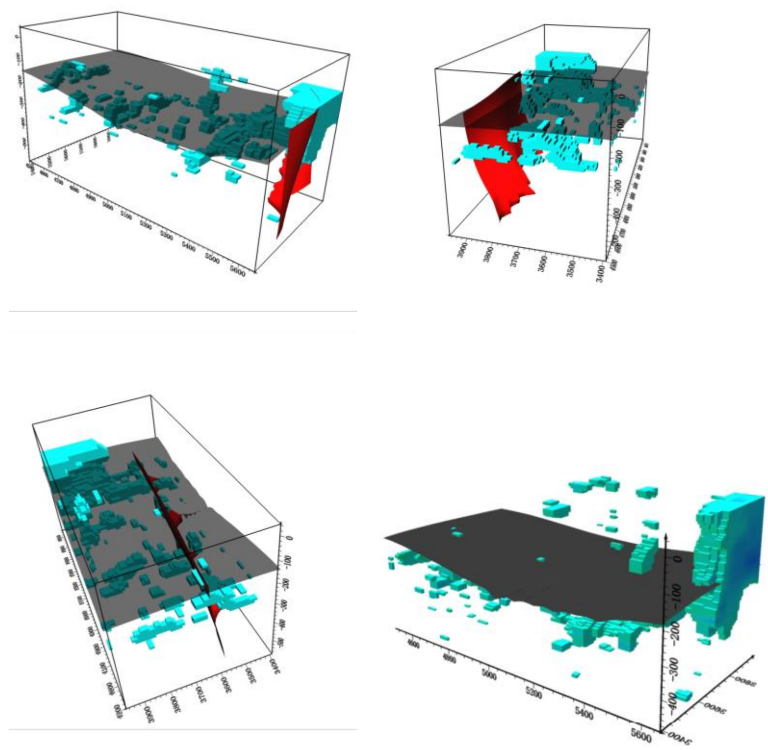


Figure 2: Three dimensional visualization of low impedance anomalies from different angles

ISSN 2663-1563 Vol. 6, Issue 4: 49-53, DOI: 10.25236/AJAGE.2024.060408

Table 1: Evaluation of Fault Conductivity and Water Content

name	nature	Abnormal layer	Containing (conductive) water
FD98	Normal fault	Bottom sandstone, 3 gray	Containing (conducting) water
FD113	Normal fault	Bottom sandstone, 3 gray	Locally containing (conducting) water
FD114	Normal fault	3 Grey	Localized water content
FD115	Normal fault	Bottom sandstone, 3 gray	Locally containing (conducting) water
FD116	Normal fault	---	Relatively free of (conductive) water
FD119	Normal fault	Bottom sandstone, 3 gray	Locally containing (conducting) water

According to known information, there are many faults in the exploration area. Through the analysis of 3D slice maps and 3D visualization maps, it is known that there are obvious continuous low resistance bodies near the FD98 fault, indicating that FD98 has strong water bearing (conductivity) properties; All abnormal areas of aquifers near the FD113, FD114, FD115, and FD119 faults do not completely overlap, only a few adjacent aquifers have local overlapping anomalies. Analysis suggests that the overall hydraulic conductivity of the controlled faults in the study area is poor, with localized small-scale hydraulic conductivity; Poor water content, locally broken rocks with water content, and mainly static storage capacity. The fault conductivity and water content are shown in Table 1 above.

In order to better analyze the distribution of faults and low resistance areas in three-dimensional space, low resistance abnormal areas and fault development areas were extracted from three-dimensional space through three-dimensional visualization software, and a three-dimensional visualization map of faults and low resistance areas was obtained (Figure 3). It can present the distribution of faults in three-dimensional space more intuitively, and better analyze the impact of fault development on changes in formation resistivity, thereby analyzing the water rich properties of faults[8].

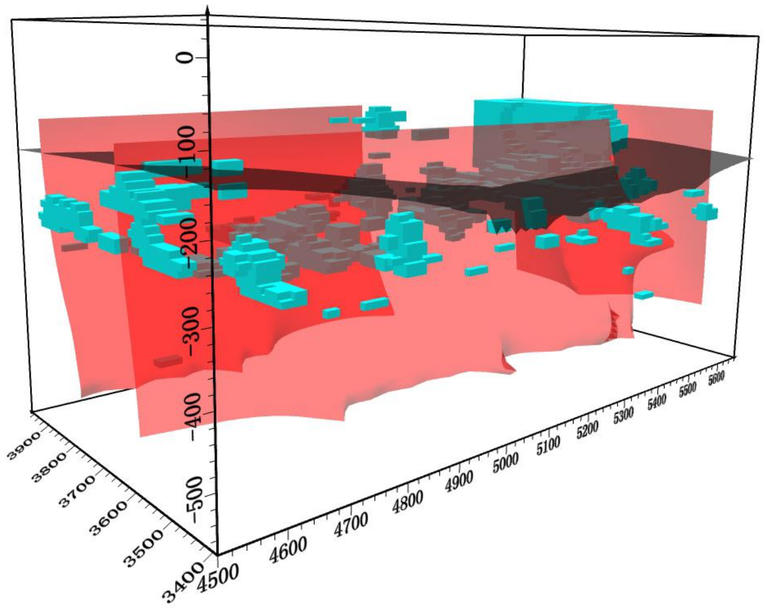


Figure 3: Three dimensional visualization of faults and low resistance areas

5. Conclusion

1) The controllable source audio magnetotelluric method has a good effect on exploring the water rich properties of coal mine faults.

2) By using 3D visualization software for 3D visualization analysis, this article effectively identified the water rich nature and spatial distribution of faults in the study area.

3) The use of 3D visualization software for 3D visualization analysis can effectively enhance the exploration, interpretation, and identification technology of coal mine fault water richness.

References

[1] He Jishan. Controllable Source Audio Magnetotelluric Method [M]. Changsha: Central South

ISSN 2663-1563 Vol. 6, Issue 4: 49-53, DOI: 10.25236/AJAGE.2024.060408

University of Technology Press, 1999
[2] Sun Hongyan, Radar, Tang Jingtian, et al. Technical Specification for Controlled Source Audio Magnetotelluric Method (DZ/T 0280-2015) [M]. Ministry of Land and Resources of the People's Republic of China. October 10th, 2015
[3] Zheng Yan, Song Dechao, Song Hao, Zhang Ning, Li Zhuoyu, Zhao Zhichao et al. Research on Coal Mine Goaf Detection Based on Controllable Source Audio Magnetotelluric Method [J]. Energy and Research. 2022.08
[4] Hu Qixuan, Tan Handong, Yu Cui et al. Research on Three Dimensional Inversion of Time Shift Controllable Source Audio Magnetotelluric Method [J]. Energy and Research. 2022.02
[5] Pu Wenlong, Ding Jieqiong. Application of transient electromagnetic method in the detection of hidden goaf in Xintie coal mine [J]. Value Engineering. 2022.02
[6] Liu Zengping. Application of high-density 3D seismic exploration technology in fold recognition [J]. Energy Technology and Management. 2022.02
[7] Zheng Dezhi, Yang Binbin. Comprehensive evaluation of water inrush risk in coal seam floor [J]. Coal Mine Safety. December 2012
[8] Guo Kai, Zhu Lu, Ma Wenzhao. Transient Electromagnetic Detection of Rich Water Areas in Coal Mines [J]. Shandong Coal Science and Technology. April 2022