Research on the application of Seismic exploration technology in the protection of shallow water resources in northwest China

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***Abstract*—In northwest China, the widespread Laterite of Neogene Pliocene series (N2) is the direct aquifuge above Jurassic coal seam, which plays a vital role in the protection of shallow water resources. With the rapid growth of coal production in this area, the N2 Laterite was severely damaged by the extensive and excessive modes of production, which caused a series of ecological and geological disasters of shallow strata. Identifying the spatial distribution of N2 Laterite and interpreting its lithology are the basic work for the prevention and control of the mining failure of it. Based on the practical data of Cuimu Mine 22 panel located in Baoji city of Shanxi Province, the technology of seismic numerical simulation, impedance inversion and probabilistic neural network were used comprehensively in this paper, in order to study the application of seismic exploration technology in the protection of shallow water resources. The spatial distribution of N2 Laterite in this area was identified and the lithology and water-resisting property of it were evaluated through this study.**

Keywords—seismic numerical simulation; impedance inversion; probabilistic neural network; the protection of shallow water resources

I. INTRODUCTION

China is a country with the largest coal production in the world. The coal production reached 3.7 billion tons in 2013 [1]. At the same time, the disaster of water inrush in coal mine of China is the most serious in the world. According to statistics, from the 2006 to 2010, 306 accidents of water inrush in coal mine occurred in China, which caused the loss of 1325 people and direct economic losses of more than 350 one hundred million yuan [2]. What's more, the water inrush in coal mine will change the flow field of groundwater, which will induce and trigger the geological disasters of shallow strata [3].

Jurassic coalfield is the largest coal field that has been found in China, which is mainly located in the northwest. Currently, the coal that has been found accounted for 39.6% of the total amount of coal in China. It is predicted that geological reserves accounted for 65.5% [4]. The widespread N2 Laterite is a territorial peculiar soil in northwest China. The distribution area of it is about 500000km^2, and its thickness ranges from a few meters to several hundred meters. N2 Laterite is the most critical aquifuge above Jurassic coal seam. The shallow water above it such as the unconfined aquifer in sand seam of Quaternary Pleistocene series (Q3 Salawusu aquifer, watery yield property of it is moderate to strong), gully runoff and lake is precious water resource, which maintains the development of industry and agriculture in arid and semi arid areas in northwest China [5].

Due to the shallow burial depth and large minable thickness of the Jurassic coal seam, coal mining will lead to the partial or total destruction of N2 Laterite, and induce the decline of sand groundwater level. In the past 20 years of coal mining, the underground water level has dropped and the spring or lake has dried up in this area located in the edge of Maowusu Desert in northwest China, which caused a series of secondary geological disasters such as difficulties of industrial and agricultural water, vegetation destruction and intensified desertification. Thus, the geological and ecological environment in this place is very fragile, and the surface ecosystem heavily relies on ground water level[6]. The continuous expansion of the scale of the Jurassic coal seam mining resulted in the mining failure of the N2 Laterite. Accordingly, the secondary disasters will become increasingly serious, and the scope of the impact will expand continuously. The measures must be taken to prevent and control the mining failure of N2 Laterite. The first and most important step is the identification of spatial distribution and lithologic interpretation of N2 Laterite [7].

At present, the method of coalfield seismic exploration is mainly used in the identification of spatial distribution and structural interpretation of the coal seam and lithological interpretation of coal measure strata. However, the relevant study of Cenozoic strata is deficient. Based on the technology of seismic numerical simulation, impedance inversion and probabilistic neural network, the application of seismic exploration technology in the protection of shallow water resources in northwest China was studied in this paper, so as to identify the spatial distribution of N2 Laterite and evaluate the lithology and water-resisting property of it.

II. THEORY AND METHOD

On the premise that the structure of underground medium and the corresponding physical parameters are known, the seismic numerical simulation based on convolution model is a

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method to simulate the seismic wave propagation in the underground medium. The numerical simulation in this paper is based on the finite difference method, which uses the discrete difference equation with finite unknown number to approximate the differential equation with the continuous variant and boundary conditions. And then regard the results worked out from difference equation as approximate solution of differential equation [8-9].

Using the lateral continuity of seismic data and vertical high resolution of logging data, the seismic inversion technology is a method for solving the spatial structure and physical properties of the underground terranes. Based on the seismic data acquired from earth surface, this method takes the known geological regularity and logging data as constraint conditions[10]. The impedance inversion method in this paper is post-stack logging constrained inversion. In this method, the impedance model based on the interpolation and extrapolation of logging data should be set up, then constantly compare the original seismic data with synthetic seismogram calculated by the wavelet and reflection coefficient acquired from the impedance model. According to the comparative result, the parameters of impedance model should be modified until meet the optimal solution. Finally, the modified impedance model can be regarded as inversion results [11-12].

Artificial neural network is a new information processing technology, which can imitate the operation mode of the human brain due to its exceptionally strong ability of nonlinear mapping. Seismic data and logging data can reflect the information of geological body underground. But it is difficult to express the mapping relationship between them using a specific function expression. Artificial neural network just can be used to solve this problem. The structure of probabilistic neural network is similar to the feedforward neural network. It was proposed by mathematician Specht in 1989 and Hampson applied this technology to the field of seismic exploration firstly [13].

III. APPLICATION EXAMPLE

The study area in this paper is Cuimu Mine 22 panel located in Baoji city of Shanxi Province. This area is a concealed coalfield where is in the middle of Jurassic Coalfield in Huangling-Longxian located in the east of Yonglong mining area. The main stratum from the old to the new as follows: Triassic tongchuan formation, Jurassic fuxian formation, yanan formation, zhiluo formation, anding formation, Cretaceous yijun formation, luohe formation, Neogene nut brown claypan and Quaternary loess formation.

Based on actual geological data, eight models in two groups were designed for numerical simulation in this paper. All size for each model is 1000×1000m. The spacing of CDP is 5m and there are 201 traces in each model. Group1 and group2 are distinguished by the thickness of loess formation in Quaternary. The thickness of N2 Laterite changes from 10 to 120m in two groups (the thickness of N2 Laterite in modle1-1 and model2-1 are 10m, model1-2 and model2-2 are 40m, model1-3 and model2-3 are 80m, model1-4 and model2-4 are120m). The detailed parameters of the models are listed in table 1.

TABLE I. MODEL PARAMETERS

	Lithologic characters	*Density (g/cm^3)*	*Thickness (m)*	*Velocity of longitudinal wave (m/s)*	*Velocity of share wave (m/s)*	*Dip angle (°)*
Group 1	Quaternary	0.737	40	1100	635.84	0
	N2 Laterite	1.206	10~120	1800	865.38	0
	Cretaceous sandstone	1.742	100	2600	1556.89	0
	Jurassic sandstone	2.412	0~160	3600	2352.94	10
	Coal seam	1.474	10	2200	1176.47	10
Group 2	Quaternary	0.737	80	1100	635.84	0
	N2 Laterite	1.206	10~120	1800	865.38	0
	Cretaceous sandstone	1.742	100	2600	1556.89	0
	Jurassic sandstone	2.412	0~160	3600	2352.94	10
	Coal seam	1.474	10	2200	1176.47	10

The stacked seismic sections calculated by using 60Hz ricker wavelet based on model 1-1and 4-2 are displayed in Figs.1 and 2. Obviously, compared with the event of N2 Laterite bottom boundary, the event of Quaternary bottom boundary can be traced continuously.

Based on the models designed previously, the logging constrained inversion technology was applied to the inverse calculation of stacked seismic sections, in order to verify the feasibility that the spatial distribution of N2 Laterite can be identified by impedance inversion technology. Two constrained boreholes were selected and the constraint conditions were the simulative logging curves of the velocity and density after the processing of smoothing filtering. The bandwidth of inversion model is 10 to 150Hz and the iteration number is 50. Form the inverted result of model 1-1 (Fig.3), it is obvious that the N2 Laterite can be identified easily in impedance section.

In conclusion, the bottom margin of N2 Laterite cannot be identified accurately through the normal seismic section, but this shortage can be remedied by seismic inversion technology.

Through the above studies, the impedance inversion was applied to the inverse calculation of practical seismic data of Cuimu Mine. The bandwidth of inversion model is 10 to 150Hz and the iteration number is 50. It is also clear that the N2 Laterite can be identified easily by impedance information (Fig.4).

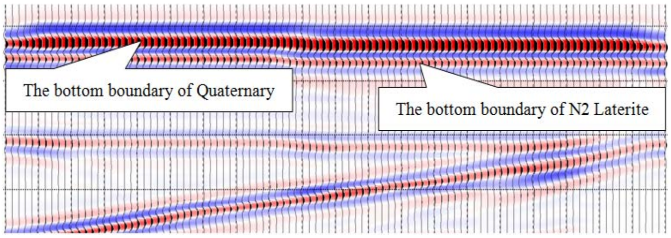

Fig.1 The stacked seismic section of model 1-1

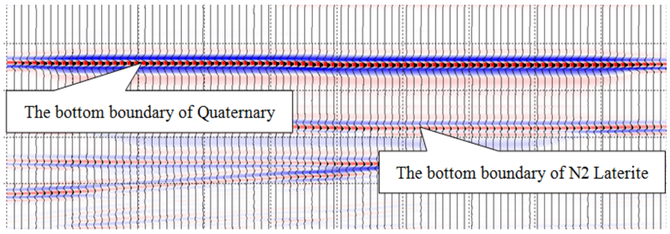

Fig.2 The stacked seismic section of model 4-2

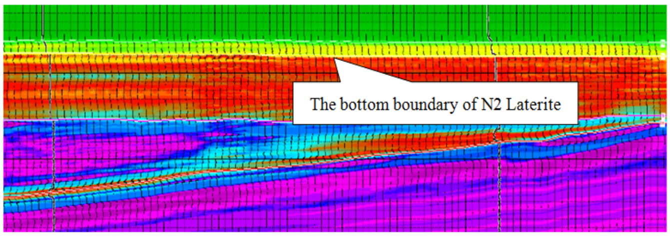

Fig.3 T the inverted result of model1-1

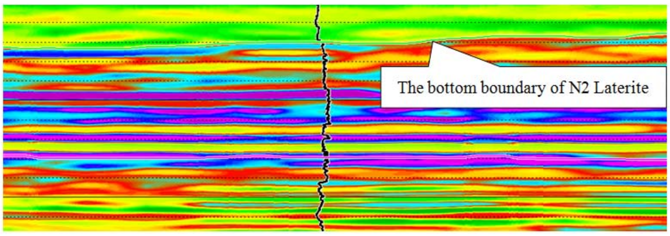

Fig.4 the through-well impedance section

The spatial distribution of N2 Laterite can be identified by the normal seismic data and impedance information. Fig.5 is the floor contour map of N2 Laterite identified by impedance information, and Fig.6 is the isopach map of N2 Laterite identified by normal seismic data, impedance information and the boring data.

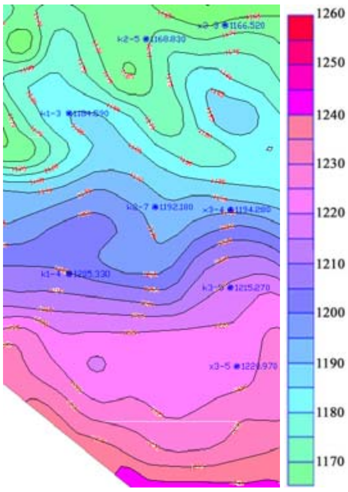

Fig.5 the floor contour map of N2 Laterite

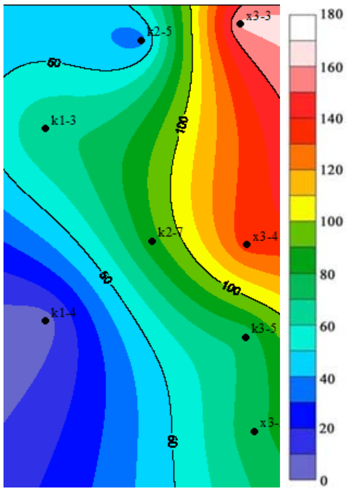

Fig.6 the isopach map of N2 Laterite

In order to evaluate the water-resisting property of N2 Laterite, the porosity and apparent resistivity of N2 Laterite were evaluated by probabilistic neural network inversion technology. Fig.7 is the slice of average impedance values calculated by setting up 20ms time window upward from the bottom boundary of N2 Laterite. Fig.8 and Fig.9 are the slices of average porosity and apparent resistivity calculated by the same time window.

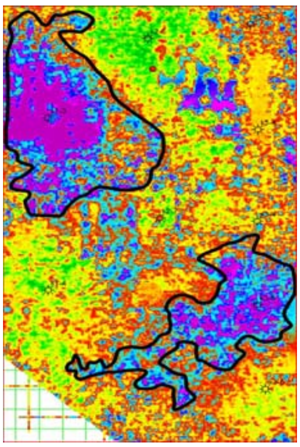

Fig.7 impedance slice

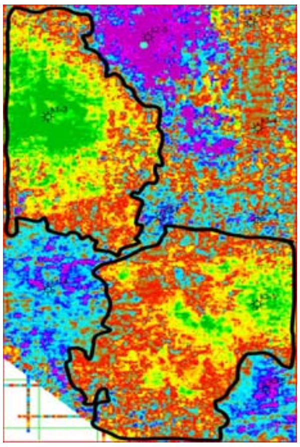

Fig.8 porosity slice

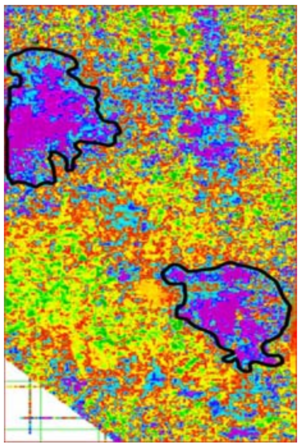

Fig.9 apparent resistivity slice

In the above figures, purple indicates the high level and green indicates the low level.Theoretically, the area with high impedance values, low porosity and high apparent resistivity has the high water-resisting property. Synthesising the resulsts of impedance inversion, porosity inversion and resistivity inversion, the area circled in the northwest and southeast can meet the conditions.

IV. CONCLUSIONS

(1) Verified by the study of seismic numerical simulation, the spatial distribution of N2 Laterite can be identified by using normal seismic data and impedance information.

(2) Based on the comprehensive utilization of the technology such as impedance inversion and probabilistic neural network inversion, the lithology and water-resisting property of Laterite can be evaluated.

(3) In the area with poor water-resisting property of N2 Laterite, coal mining will cause the disasters of water inrush in coal mine easily. The N2 Laterite can be protected by adjusting the roadway layout timely and setting the reasonable upper mining limit.

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