

Frequency Resonance Exploration Method Feasibility Analysis

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Abstract

The Through the processing and analysis of the seismic signal data measured by frequency resonance exploration instrument, the principle of frequency resonance exploration is programmed and the algorithm is designed. The required result map is obtained and compared with the result map obtained by frequency resonance exploration software. The underground structure and stratum distribution are studied, and the result map is compared with the mature H / V spectral ratio method, The feasibility of frequency resonance exploration method is verified. Before the design of frequency resonance exploration algorithm, the data preprocessing is studied in detail. In the case of not changing the original data as much as possible, the outliers in the original signal data are removed, so as to better study the frequency resonance exploration method. Next, the theoretical derivation process of frequency resonance exploration method is studied. The theoretical basis of frequency resonance exploration method is studied by establishing a layered model. After obtaining the corresponding theoretical basis, the frequency resonance exploration method is applied in practice, and the frequency domain data is obtained by Fourier transform of the preprocessed data, The frequency domain data is converted into depth domain data through standard well parameters, and the depth domain data is imported into the resonance method software. Finally, the wave impedance data of each layer is calculated, and the data is imported into the mapping software to get the final image. The feasibility of frequency resonance exploration method is comprehensively analyzed.

Keywords

Frequency Resonance Exploration; Fourier Transform; Standard Well Parameters; Wave Impedance.

1. Introduction

Exploration methods have been the focus of physical prospecting scholars, and frequency resonance exploration methods, as an emerging technology is currently receiving the attention and research of many geophysical scholars [1]. In the past three years, seismic wave frequency resonance exploration technology has been the seismic frequency resonance exploration technology has been applied in a large number of applications in the past three years [2]. The experimental and production practice proves that this technology has high exploration accuracy and economic practicality, and can be used as a new method in the field of exploration. A new method in the field of exploration. However, because it is a new technology, many geophysical explorers still do not recognize it. The frequency resonance exploration technology is viewed with skepticism, and the practical application of frequency resonance exploration technology is very limited due to the conditions The accuracy and feasibility of frequency resonance exploration technology cannot be determined because of the limited conditions. The main content of this design is the analysis of the frequency resonance The main content of this design is to analyze and study the principle of frequency resonance exploration

technology company, and prove whether the technology is feasible according to my experiments, hoping to get I hope to get satisfactory results[3].

2. Frequency Resonance Exploration

2.1 Brief Description of Resonance Method

As early as 1940, the United States Tacoma Bridge in Washington, D.C. was destroyed by the breeze, this scene happened to be captured by a camera team at the time, from then on, the discussion of the bridge sound incessantly, of course, this phenomenon has also caused many experts to wonder, moreover, many scholars to explore the reasons for its destruction, until now, more and more resonance phenomenon out. Nowadays, more and more resonance phenomena appear in our life (such as glass being shattered by sound, the swaying of Nautilus Bridge, the swinging of the swing, etc.), and the term resonance is gradually becoming a hot topic[3]. The term resonance has gradually become a hot topic, so that a new technology in the physical exploration industry ---- frequency resonance exploration technology was created[3].

With the development of science and technology, many scholars have studied that the Tacoma Bridge collapsed because the frequency of the wind and the resonant frequency of the bridge were the same at that time. The resonant frequency of the bridge is the same, so we can explore that any object has its own resonant frequency, once Once the frequency of external input vibration is the same as its frequency, it will amplify the amplitude of external vibration.

Beijing Patterson Technology Co., Ltd. invented a patent named "Passive source seismic frequency resonance exploration method". Ltd. invented a patent named "Passive source seismic frequency resonance exploration method", which focuses on the exploration principle and method of frequency resonance. Based on this patent, this paper researches and analyzes the theory and technology of frequency resonance exploration, and the following is the specific principle of the application of frequency resonance exploration[3].

In early studies, a multi-layered geoseismic wave propagation equation was derived[3]:

$$\text{Re}_j = \text{Re}_{j-1} \cos S_{j-1} - \text{Im}_{j-1} \sin S_{j-1} \quad (1)$$

$$\text{Im}_j = \alpha_{j-1} (\text{Im}_{j-1} \cos S_{j-1} + \text{Re}_{j-1} \sin S_{j-1}) \quad (2)$$

$$\text{Amp}_{(\omega)} = \frac{1}{\sqrt{\text{Re}_{N+1}^2 + \text{Im}_{N+1}^2}} \quad (3)$$

$$\alpha_j = \frac{\rho_j C_{j(\omega)}}{\rho_{j+1} C_{j+1(\omega)}} \quad (4)$$

Resonance occurs at $S=90^\circ$, α :ratio of wave impedance parameters

This leads to the single-layer geodesic seismic wave propagation equation:

$$\text{Amp}_{(\omega)} = \frac{1}{\sqrt{\text{Re}_{N+1}^2 + \text{Im}_{N+1}^2}} = \frac{1}{\alpha_1} = \frac{\rho_2 v_2}{\rho_1 v_1} \quad (5)$$

According to the above equation, it can be concluded that when the resonance of the stratum occurs and the amplitude unit is 1, the amplitude value of the wave field is the transmission The value is the ratio of the wave impedance of the lower layer to the wave impedance of the overlying rock layer.

2.2 Tuning Effect of Thin Layer

Thin layer definition: In the formation of the top and low reflection wave resolution is not known as thin layer or thickness $\Delta h < \lambda/4$

Classification of thin layers:

(1) rhythmic thin layer: the wave impedance of the thin layer is higher or lower than that of the upper and lower layers.

(2) Graded thin layer: the wave impedance of the thin layer is between the wave impedance of the upper layer and the lower layer.

Thin layer effect of seismic waves: In the process of seismic wave propagation, the factors affecting the dynamic characteristics of seismic waves, other than the sphere Diffusion, absorption, reflection, refraction, transmission, but also affect the formation structure. When the ground is thin, it's special Question.

Tuning-effect of thin layers: Since underground strata are layered on top of each other, seismic data will only record signals in a limited frequency range, usually between 10Hz and 60Hz. The seismic amplitude data contains a variety of geological information such as lithology, voids, fluids, etc., and part of the amplitude is related to the tuning effect. It can be said that the variation of amplitude is related to the thickness of the strata. The thickness of the formation becomes thinner when the amplitude increases. Therefore, when using the properties of the amplitude to interpret the formation, it is necessary to pay attention to the variation of the amplitude caused by the thickness of the formation, rather than the differences in the physical properties related to the formation. The wedge-shaped model is used to explain the thin - layer coordination effect. It is common to analyze the amplitude corresponding to the composite record made by the wedge model. Assuming that the sandbody rock in the model is homogeneous, that is, the velocity and density remain constant as the thickness changes, that the surrounding rock is also homogeneous and is mudstone, and that both sandbody rock and mudstone have impedance differences, then when the formation of the model is thick, the sandbody rock has amplitude reflection interfaces in the top and bottom interfaces. The waveform characteristic of the amplitude is related to the subwave sign, and the amplitude of the amplitude has a weak change. As the model layer thinned, the amplitude of the reflection at the top and bottom interface of the sandbody rock gradually overlapped and increased, reaching a maximum amplitude at a certain thickness and then decreasing. We call this amplitude change of amplitude caused by the change of formation thickness as tuning effect.

For rhythmical thin layer, the wave phase interference occurs when $\Delta h = \lambda/4$, and then the amplitude reaches a maximum. This phenomenon is called the tuning effect of thin layer, and then the thickness of the stratum is the tuned thickness.

The principle of frequency resonance imaging: put a geophone on the ground to observe seismic noise waves for a long time. The source of the waves is complex. There are noise waves e_a that reach through the physical boundary, noise waves e_c that do not reach through the boundary, noise waves e_b that pass through the interface but the path length does not conform to the resonance relationship, and so on.

Any type elastic wave, the type is equivalent to $\lambda_0 = 4H$, namely the wavelength is equivalent to four times the thickness.

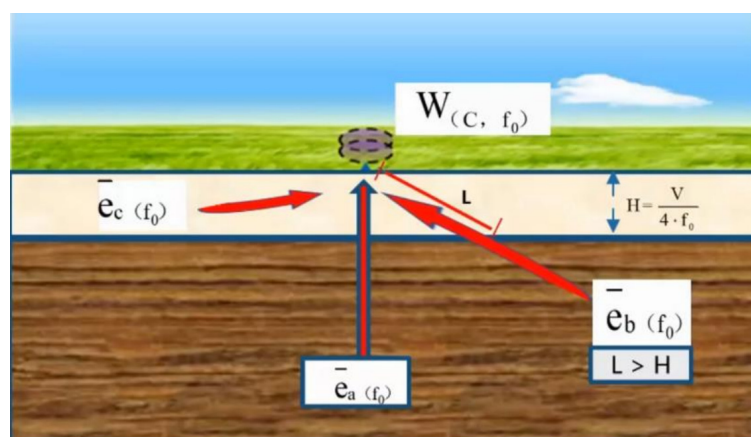


Figure 1. imaging principle of frequency resonance exploration

The random noise from underground is observed on the ground time, and the amplitude superposition is carried out in the frequency domain. We can find that the average amplitude of the non-resonant noise wave which does not satisfy the resonance relation equation of H, V and f_0 will become small, and only the amplitude of the excitation wave which satisfies the resonance relation of H, V and f will be amplified. This becomes a non-random function of the underground medium.

3. Frequency Resonance Exploration Algorithm and Implementation

3.1 Frequency Resonance Exploration Mechanism

Using an infinite series of harmonics as input, the steady-state response of the layered system can be calculated, from which an amplified spectrum can be constructed, that is, the ratio of steady-state amplitude of the surface response to that of the incident wave. The amplified spectrum accurately reflects the frequency selectivity of the layered system. However, steady-state analysis is not always sufficient to study the effects of layered systems on seismic-like excitations because the actual seismic motion is not steady-state, and therefore transient analysis may be required to show the motion in detail. A well-known method to solve the transient response of a layered system is to calculate the transfer function of the system in the frequency domain. When the Fourier transform of the input motion is multiplied by the transfer function, it produces the Fourier transform of the output. The inverse transformation gives the time history of the output, but some scholars have found that the digital inversion is poor unless a smaller frequency interval is used. A concentrated mass model on infinite rigid half space is used to calculate the surface motion.

A simple layered system excited by a vertically propagating plane wave has the same differential equation of motion as a so-called "shear beam", which only undergoes shear deformation, and in fact a vertical square column extracted from a layered system can be regarded as a similar shear beam model. Since the motion of a beam is easier to discuss and visualize, the following discussion is made in terms of the shear beam model and shear wave motion. By replacing the corresponding elastic and viscous constants, the results can be easily converted to the results of longitudinal wave motion.

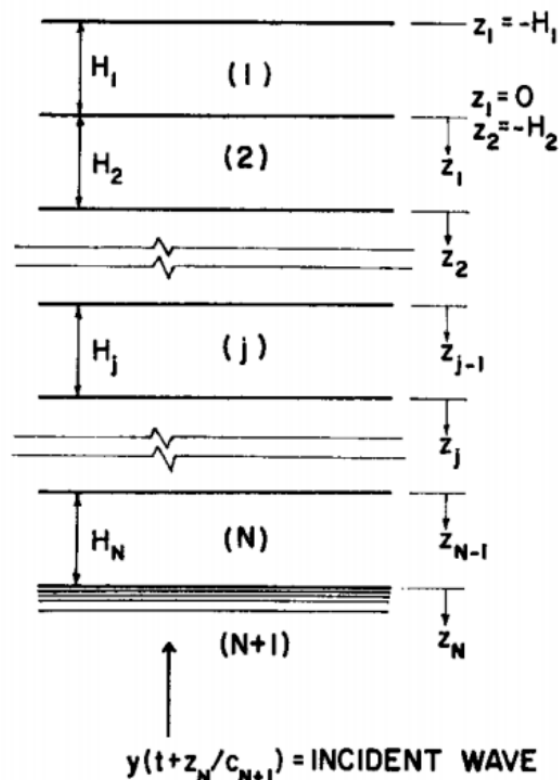


Figure 2. layered model

3.2 Principle of Frequency Resonance Exploration Algorithm

Everything from the Earth to microelectrons has its own natural frequency. Due to the different geometry and structural size of the material components, their natural frequencies are also different. Natural frequencies are the natural properties nature assigns to objects. When a vibration is applied to a body, the body must react accordingly. When the frequency of the vibration coincides with the natural frequency of the object, the object resonates, amplifying the amplitude of the vibration. Elastic seismic waves contain rich frequency components. If the seismic waves propagate to the ground through reflection or refraction below the ground, the strata with natural frequency will be excited by the seismic waves of the same frequency to resonate, and the underground vibration U received at the surface will be a function of G and M .

3.3 Test Data Analysis

Sampling frequency, also known as sampling speed or sampling rate, defines the number of samples extracted from continuous signals to form discrete signals per second, expressed in Hz. The reciprocal of the sampling frequency is the sampling period or sampling time, that is, the time interval between samples. In plain English, the sampling frequency is how many signal samples a computer takes per second. Since seismic signals in the test data below are recorded at a point every 2 ms, the sampling frequency of seismic signals can be obtained at 500Hz.

Nyquist's theorem, in the process of analog/digital signal conversion, when the sampling frequency f_s is more than 2 times of the maximum frequency F_{max} in the signal (refers to low-pass, band-pass or high-pass conversion modes), namely: $f_s \geq 2F_{max}$, then the digital signal after sampling completely retains the information in the original signal, that is, the original analog signal can be recovered without losing the truth. In general practical application, the sampling frequency is guaranteed to be 5 ~ 10 times of the highest frequency of the signal. The sampling theorem is also called Nyquist sampling theorem. According to Nyquist's theorem, the maximum frequency of the test signal data used should be 250Hz.

Because the field seismic record contains underground structure and lithology information, but these information is superimposed on the interference background, is distorted by some external factors, and the information is often interwoven. Seismic signal processing is to carry out some operations on the field seismic record, extract the relevant geological information from it, and provide reliable data for geological interpretation. Therefore, in the early stage of frequency resonance exploration technology implementation, we need to conduct preliminary processing of the test collected near the south gate of Henan Polytechnic University.

By means of de-averaging and normalization of the original seismic signal data, the following images are obtained:

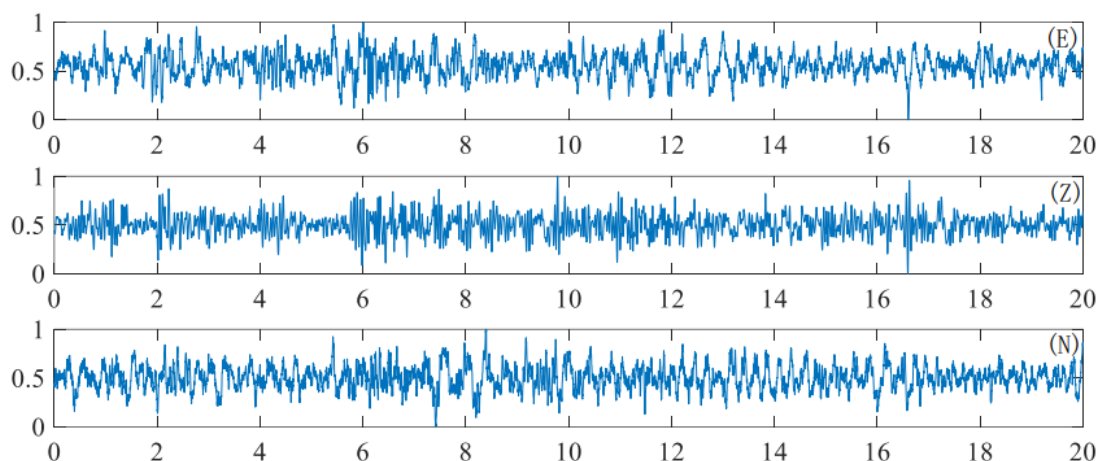


Figure 3. Time domain diagram after averaging and normalization

According to the flow of frequency resonance exploration technology, Fourier transform is carried out on the seismic data in the next step. However, it is found through experiments that the value of zero frequency and near-zero frequency data in the spectrum diagram after Fourier transform is very large, which can be judged as abnormal data, resulting in errors in the spectrum diagram. After learning, it is found that zero frequency is also called DC component. In the superposition of Fourier series, it only affects the overall upward or downward direction of the entire waveform with respect to the number line, without changing the shape of the waveform. So the next major task is to remove the DC component.

The detrending process can eliminate the influence of the offset generated by the sensor in the process of data acquisition on the later calculation. Removing trends from the data allows the analysis to focus on fluctuations in the data trends themselves. Data detrending is the subtracting of a best (least square) fitted line, plane, or surface from the data so that the mean of the detrended data is zero.

In order to remove the DC component, detrending is performed on the above data to obtain:

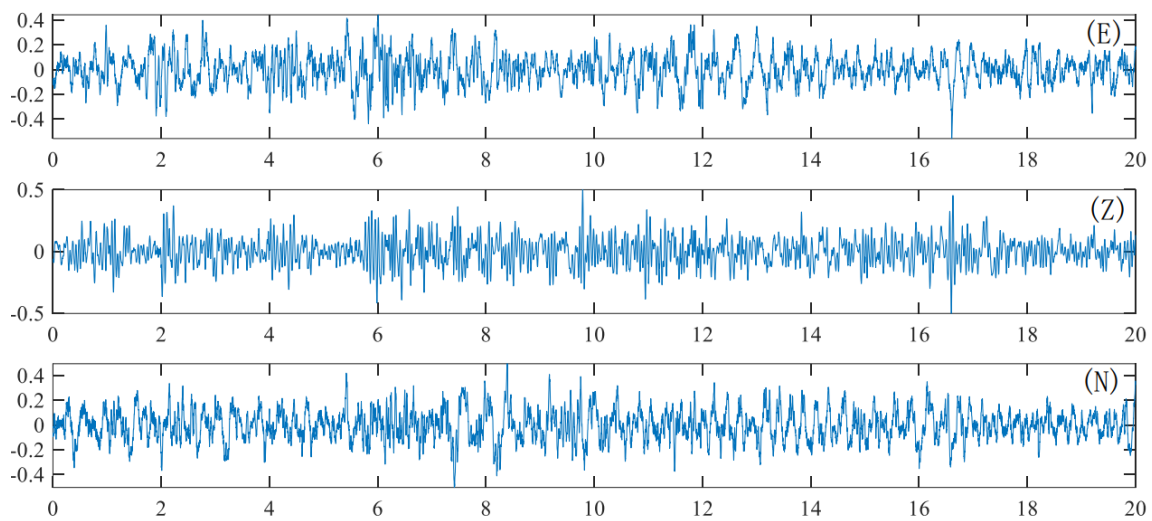


Figure 4. Time domain diagram after detrended

Next, Fourier transform operation is performed on the seismic signal after detrending, and the following is obtained:

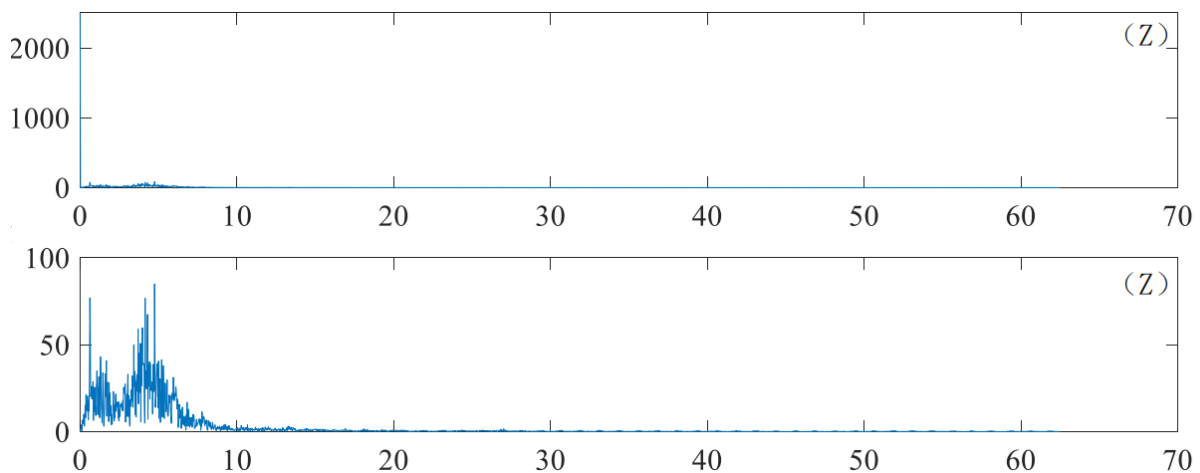


Figure 5. Spectrum comparison before and after detrended

As can be seen from Figure 4, the spectrum diagram after Fourier transform has not changed significantly after the frequency is greater than 10Hz. Therefore, about 1 million data points are divided into segments. Since the interval of each signal point is 2 milliseconds, it is temporarily

divided into a segment at the interval of 20s, and 10,000 signals are taken as a segment. After mean, normalization and detrending of each segment, signal points with obvious changes before 10Hz are screened out, and the following images are obtained:

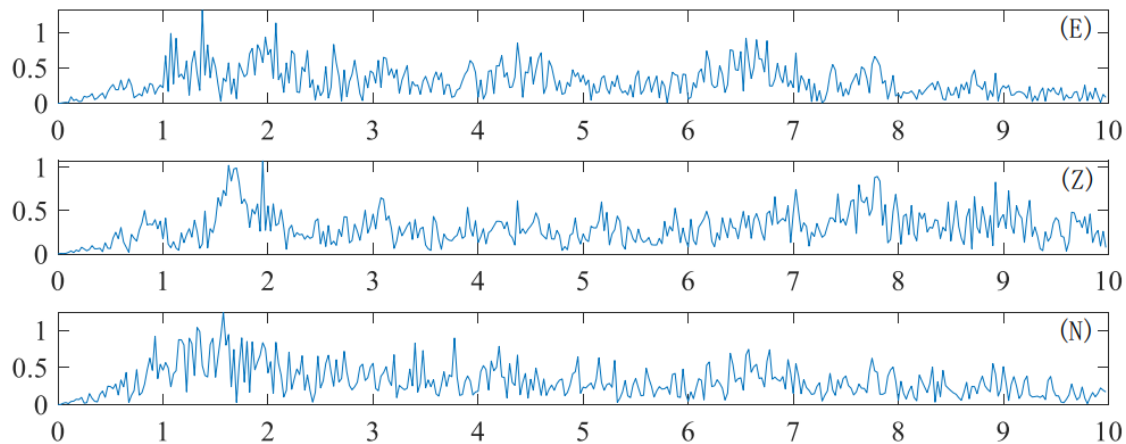


Figure 6. 20s is the spectrum of a section

4. Practical Application

Figure 7 shows that there is a good correlation between the hardness of the site and the site amplification factor. For the general site on the covered soil or soft soil layer, there is no significant amplification of vertical ground motion in the frequency range of horizontal ground motion amplification, but for the hard or bedrock site, horizontal ground motion and vertical ground motion are very close in amplitude and spectral shape. Therefore, it can be seen from the figure that when the ratio of H/V is small, the geological condition at this time is relatively hard or bedrock site, which can be used to judge the iron ore, while when the ratio of H/V is large, the geological condition is relatively weak soil layer.

H/V spectral ratio is a relatively mature technology. In this paper, H/V spectral ratio method is used to make a comparison with the frequency resonance exploration method, so as to provide a more correct application reference for the feasibility analysis of frequency resonance exploration.

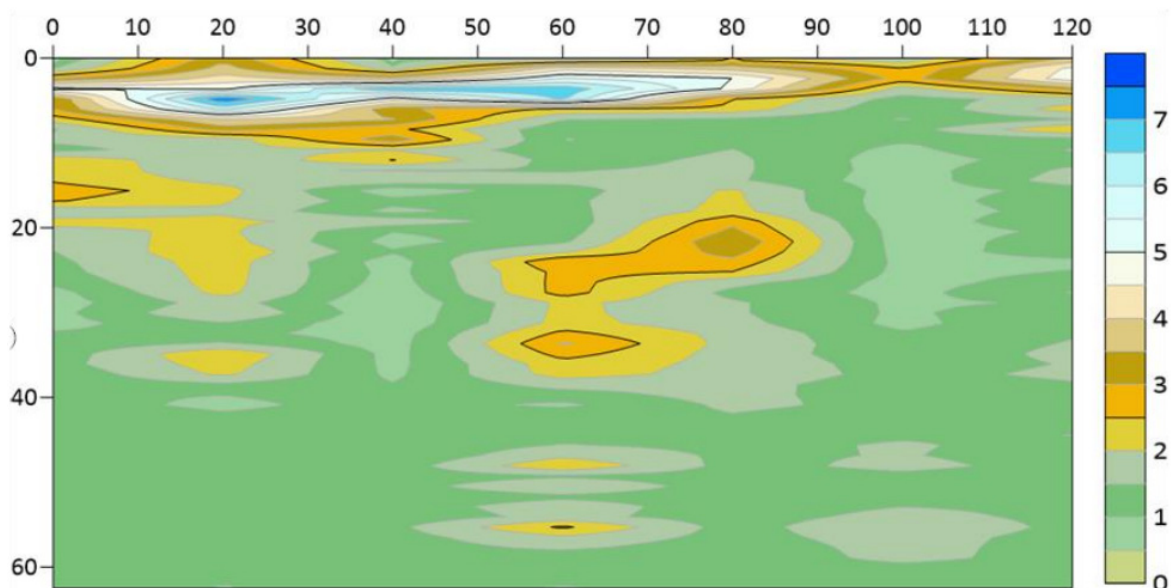


Figure 7. H/V spectral ratio method results

Figure 8 shows the mapping of the measured data using Beijing Paterson software and the comparison of H/V spectral ratio method. It can be seen that the frequency resonance exploration method can have a relatively clear division of underground structures, but the accuracy and precision of the

division cannot be determined. Therefore, the feasibility of the frequency resonance exploration method is still questioned.

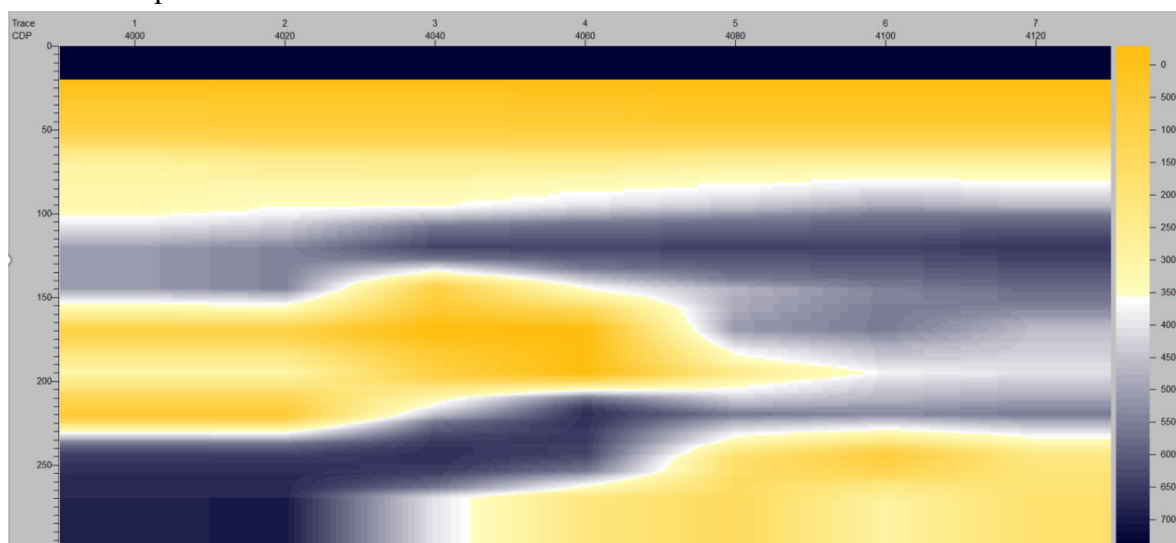


Figure 8. Results of frequency resonance method

5. Conclusion

By studying the mechanism of frequency resonance exploration method, the correlation resonance model is established, and the calculation formula of amplitude spectrum and apparent wave impedance ratio in single-layer media is obtained. The apparent wave impedance ratio in multi-layer media obtained by recursion is the ratio of the underlying wave impedance that varies with depth to the average wave impedance of overlying strata. This is the core of calculating the underlying wave impedance as resonance method. The established model does not have sufficient rationality to prove the solution formula of wave impedance, and many complex problems in the model need to be studied. Therefore, the algorithm basis established through the model can only be used as the basis of theoretical research, and its real feasibility cannot be obtained in practical application. The frequency resonance exploration is used in practice, and the comprehensive analysis of the results obtained by the resonance method shows that the results presented by the resonance method can reflect the characteristics of the formation structure at the depth of 300 meters underground. The characteristics of the formation structure and wave impedance are positively correlated, and the distribution location of iron ore can be roughly found. Some elements of the results obtained by resonance method and H/V spectral ratio method.

So far, although the frequency resonance exploration method can judge the distribution location of high-wave impedance strata, its accuracy still cannot be proved. In the actual application process, the correctness of the result graph obtained by using the resonance method has not been proved favorably. Therefore, I am still skeptical about the feasibility of the frequency resonance exploration method in practice.

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