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Application of Spectrum Imaging Technology in the Identification of Volcanic Facies in Songliao Basin

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Abstract

In recent years, the volcanic reservoirs in Songliao Basin of China are important strata for deep oil and gas exploration and development in the basin. However, volcanic rocks are often erupted in multiple stages and multiple craters, and their distribution range is difficult to determine. Therefore, volcanic facies recognition and reservoir prediction are the bottleneck technologies restricting the deep oil and gas exploration in Songliao Basin in recent years, and they are also the difficulties of oil and gas exploration in this area. Based on the geological characteristics of volcanic rock development in deep Cretaceous of Songliao Basin and the data of drilling, logging and earthquake, this paper puts forward the seismic data to identify the eruption period of volcanic rock. Moreover, on this basis, using spectrum imaging technology to identify the main body of volcano and volcanic lithofacies, to provide technical support for volcanic reservoir research, has important research reference significance.

Keywords: Volcanic Rock, Volcanic Facies, Spectrum Imaging Technology.

1. Introduction

Volcanic rocks are widely distributed in basins all over the world. In recent years, volcanic oil and gas fields have been found in the United States, Japan, Indonesia, Cuba, Mexico, Argentina, Russia, Ukraine, Ghana and Pakistan. In Songliao Basin, Junggar basin, Erlian Basin and Bohai Bay Basin, a number of volcanic reservoirs have been discovered successively. However, there are few research results that can be used for reference in volcanic facies and volcanic reservoir seismic prediction. Moreover, seismic prediction is a worldwide difficult problem in oil and gas exploration, which is mainly manifested in: (1) volcanic eruption forms are rarely isolated, most of which are the intersection or superposition of multiple eruption forms, resulting in great changes of volcanic lithofacies distribution in vertical and horizontal directions, and the volcanic targets are difficult to describe; (2) the thickness of volcanic rocks is large, the research time window is difficult to select, and seismic inversion and attribute analysis are difficult; (3) crater control The distribution of volcanic facies directly affects the evaluation of volcanic reservoir, but it is difficult to identify the location of volcanic crater. With the increasing attention to volcanic reservoirs in recent years, more and more attention has been paid to the seismic identification of volcanic rocks at home and abroad. How to effectively predict the distribution and development of volcanic facies is of great significance for the study of volcanic reservoirs.

2. Spectrum Imaging Technology

In theory, spectrum imaging technology is mainly based on the tuning principle of thin-layer reflection.

According to this principle, for the thin layer with thickness less than one quarter wavelength, in time domain, with the increase of thin layer thickness, the seismic reflection amplitude increases gradually. When the thickness of the thin layer increases to the tuning thickness of the quarter wavelength, the reflection amplitude reaches the maximum value, and decreases with the increase of the thickness of the thin layer. The maximum reflection amplitude value in time domain corresponds to the maximum amplitude energy value in frequency domain. The interference characteristics of amplitude spectrum caused by thin layer tuning depend on the acoustic characteristics and thickness of thin layer. If the 3D seismic data are processed specially, a series of amplitude energy bodies with a single frequency can be generated. The thin-layer interference characteristics can be seen on the 3D seismic energy bodies with different frequencies. In a given frequency of three-dimensional seismic energy body, there are similar acoustic characteristics and thickness of the stratum. In the tuning frequency, it shows similar amplitude tuning characteristics. Spectrum imaging technology provides a tool to use the multi-scale information of 3D seismic data to image the reservoir with high resolution and to describe the time thickness change of the reservoir.

Spectrum imaging has a good lateral resolution, which can be used to describe sedimentary facies and sedimentary environment, such as detecting the spatial distribution of channel sand bodies, imaging the spatial distribution of special underground geological bodies (such as volcanic rocks). It can effectively describe the discontinuity of the thickness of geological reflection layer and the heterogeneity of lithology. Spectrum imaging technology provides high-resolution imaging of reservoir using multi-scale information of three-dimensional seismic data, and characterizes the change of formation time thickness. The thickness near the crater is large, the stratification is poor, the seismic reflection structure is disordered, and the energy changes greatly, resulting in small tuning energy of thin layer. However, the sedimentary strata dominated by volcanic ash deposition or sandstone mudstone interbedding are easy to produce tuning, and the maximum energy of spectrum imaging is relatively high.

Previous studies (Castagna and sun, 2003) compared the algorithms related to wavelet transform and spectrum imaging technology, such as fast Fourier transform, discrete Fourier transform and maximum entropy method. Their research proved that instantaneous spectrum analysis based on wavelet transform can get accurate time-frequency analysis results, while avoiding the problem of time window. The spectrum imaging technology based on wavelet transform can be used to describe the time thickness change and horizontal geological discontinuity of the formation. Therefore, the spectral imaging technology can effectively describe the spatial changes of formation or reservoir characteristics.

3. Application Effect of Spectrum Imaging Technology in Identifying Volcanic Lithofacies

Through the well simulation and the interpretation of the frequency division processing results of the seismic traces near the well, the quantitative relationship between the formation characteristics and the amplitude spectrum and the phase spectrum can be established, which has more physical and geological significance for the interpretation of the processing results of the spectrum imaging technology. Generally, the seismic energy spectrum is composed of three parts, which are the amplitude spectrum of thin-layer interference with geological significance, the spectrum of seismic wavelet and the noise. The amplitude spectrum of thin-layer interference is related to the acoustic characteristics and thickness of the reservoir. In order to obtain the high-resolution amplitude spectrum of thin-layer interference, it is necessary to remove the influence of seismic wavelet spectrum without losing geological information. For all the wells to be analyzed, firstly, the well logging data are used to carry out horizon correlation and calibration, extract seismic wavelet, and determine the best phase of seismic wavelet. Then, we use the seismic wavelet to process the seismic traces and remove the influence of seismic wavelet. The results show that after removing the influence of seismic wavelet, the seismic energy spectrum consists of two parts, which are the amplitude spectrum and noise of thin-layer interference with geological significance. The amplitude spectrum of thin-layer interference without the influence of the envelope of seismic wavelet almost changes along the same horizontal line, and the effective high-frequency part is strengthened, which makes the geological phenomenon of thin-layer interference easier to detect from the interference amplitude spectrum.

In the same volcanic eruption period, the lateral upper volcanic rock facies can be divided into four facies areas, namely, volcanic channel facies, explosive facies, effusive facies and volcanic sedimentary facies, and the contact relationship of the vertical upper facies belts is the explosive facies in the lower part and the effusive facies in the middle upper part; the accumulation thickness of the explosive facies near the crater is the largest, and the thickness decreases with the distance from the crater. The slope also slows down.

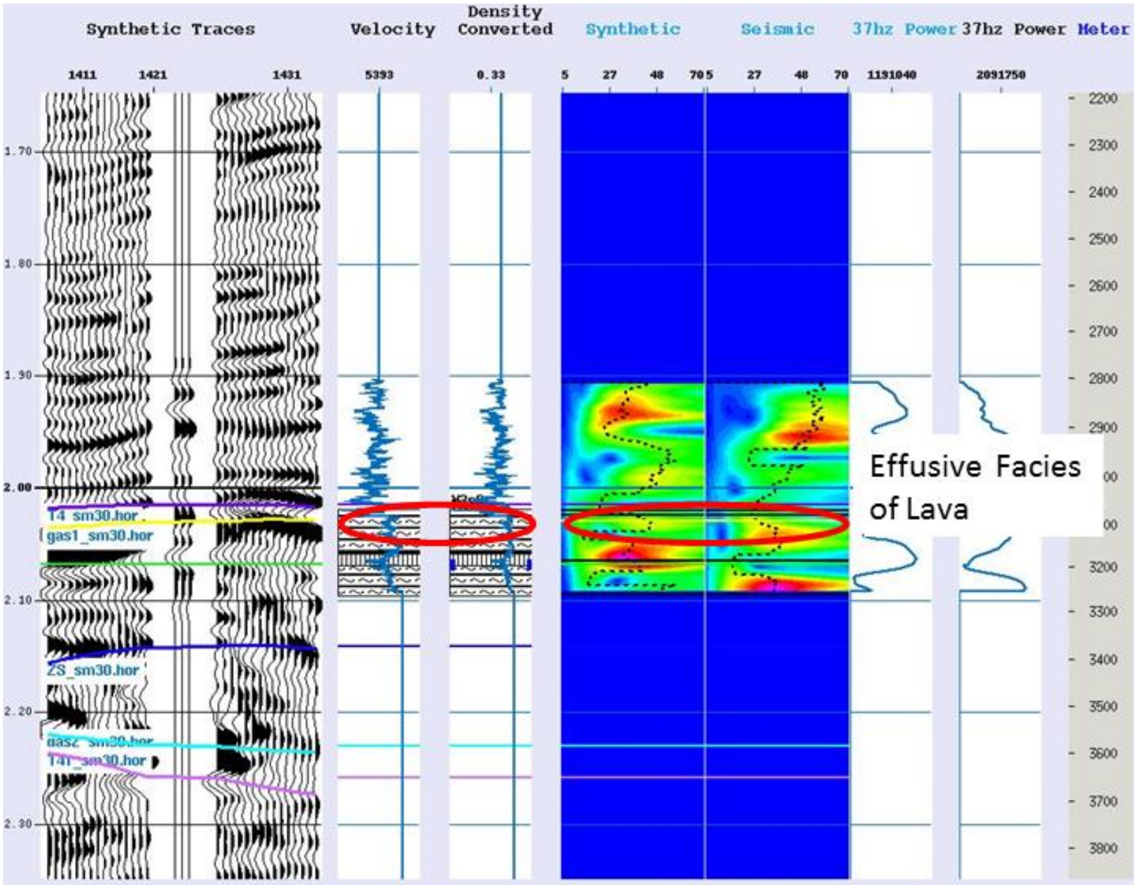

Fig. 1. Spectrum imaging of overflow phase passing through well A

As mentioned before, the amplitude and phase spectrum of a single frequency obtained by spectral imaging can identify the lateral discontinuity of volcanic rocks, including the discontinuity of the lateral geological characteristics of volcanic rocks and the determination of volcanic lithofacies, reveal the changes in the characteristics of volcanic rocks and reflect the lateral distribution of volcanic rocks. For deep volcanic rocks in Songliao Basin, this feature can be used to detect the lateral heterogeneity of volcanic rocks. The spectrum imaging technology based on wavelet transform is applied in this area to qualitatively analyze the spatial distribution characteristics of volcanic main body. In the area of volcanic eruption facies and volcanic sedimentary facies, the stratification is good, and the tuning energy is high; in the area near the eruption facies and volcanic channel facies of the crater, the reflection is disordered, and it is not easy to produce tuning, as shown in Fig. 1 and Fig. 2.

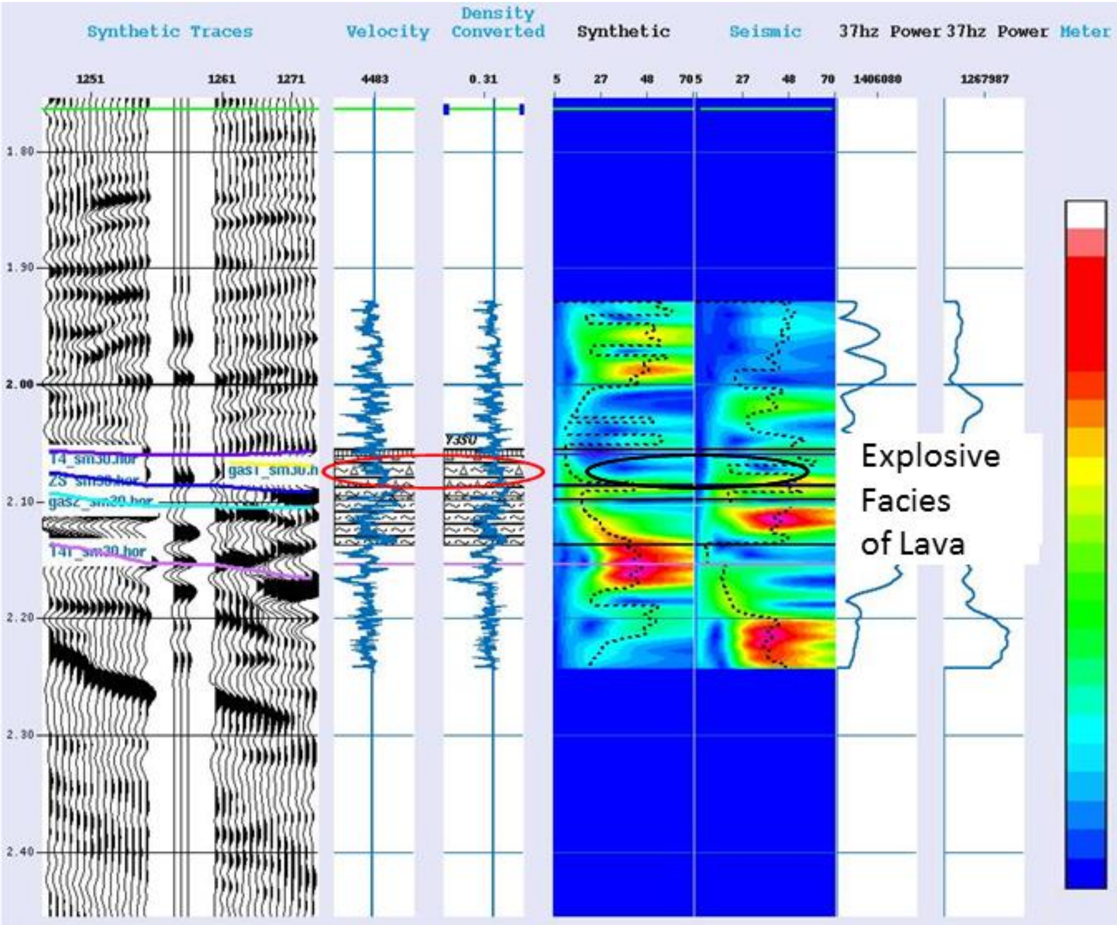

Fig. 2. Spectrum image of explosive phase passing through well B

Using the tuned energy attribute obtained by spectral imaging processing and seismic profile to identify the seismic reflection characteristics of different volcanic lithofacies in the earthquake: (1)the explosive facies belongs to the volcanic eruption scattered accumulation formation, and the thickness of the stratum gradually thins from the crater to the outside; the seismic reflection is disordered, and the vertical distribution is roughly in the shape of hills or shields, and the amplitude changes. (2) characteristics of effusion facies: the flow characteristics of lava flow are shown as discontinuous in-phase axis on the seismic section; the thickness of stratum is generally characterized by near source thickness and far source thin; it is sub parallel, medium amplitude and relatively continuous reflection facies; the near Crater has a hill shape and the far crater is sheet shape. (3) characteristics of volcanic sedimentary facies: far source volcanic ash deposition, sheet shape, medium strong amplitude, subparallel and relatively continuous reflection characteristics.

Near the crater, the seismic reflection is disordered, and the tuning energy is low; while far away from the eruption and volcano sedimentary facies, the seismic reflection is relatively continuous, and the tuning energy is high as shown in Figure 3.

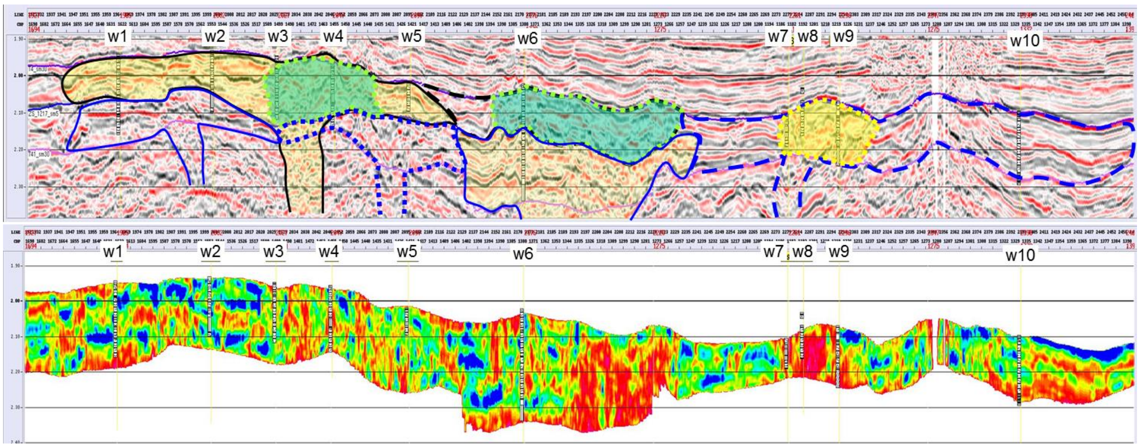

Fig. 3. Seismic section of connected well passed from w1-w2-w3-w4-w5-w6-w7-w8-w9-w10 (above) and tuning energy attribute (bottom)

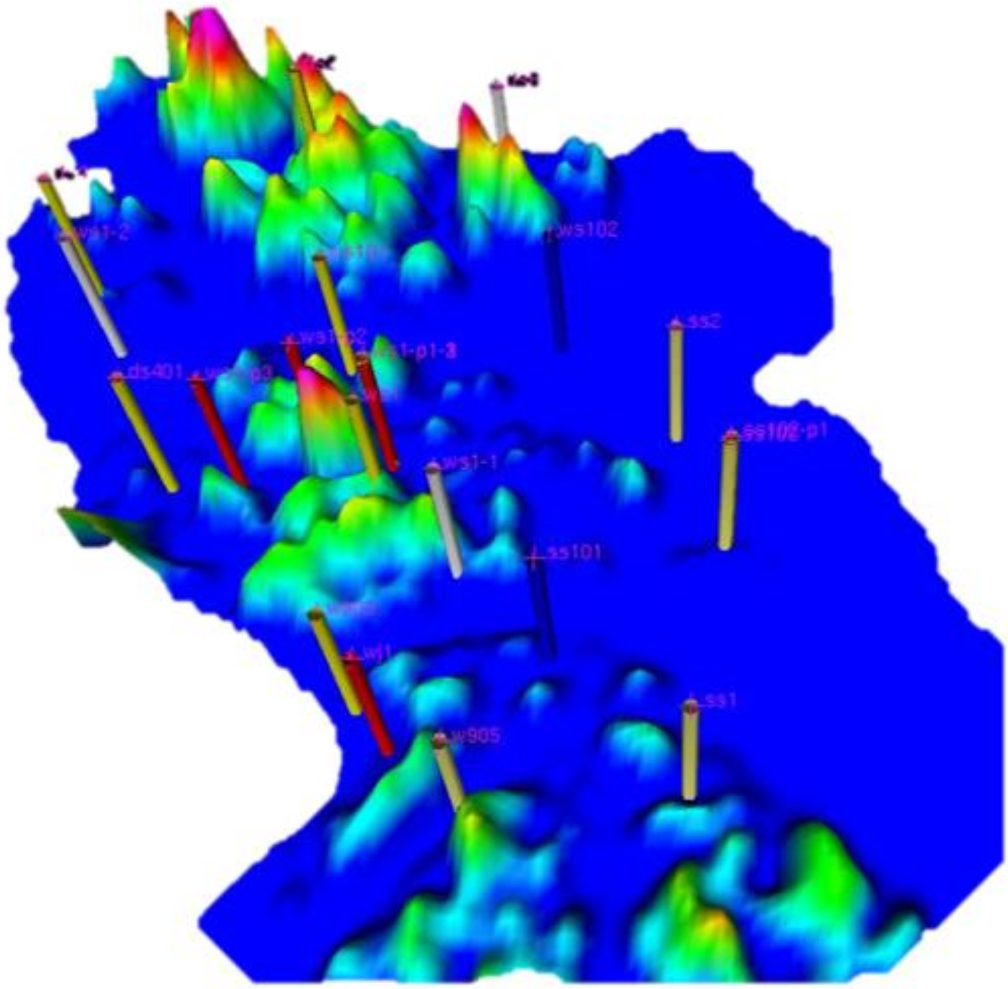

Fig. 4. Main distribution map of volcanic rocks in the study area

The plane distribution of volcanic lithofacies in volcanic rock section is identified through the joint calibration of tuning energy attribute of drilling lithofacies and seismic spectrum imaging. On the basis of volcanic facies recognition, according to the different distance from the crater, the seismic reflection characteristics and tuning energy also change, further identifying the main body of volcanic rocks. In the volcanic rock section of this area, 7 volcanic main bodies are identified, with a total area of 34.31km2. The main body of the volcano is distributed in nearly north-south direction, as shown in Figure 4. The area of W6 volcano is the largest, and the area of other volcanoes is relatively small. The analysis shows that the volcanic magma in this area is from shallow layer, with low temperature and high viscosity, which is easy to form explosive eruption. The explosive and falling volcanic rocks are deposited near the crater, forming the relatively small scope of the main volcano, and the thickness changes greatly.

6. Conclusions

Based on the above-mentioned seismic profile recognition and spectrum imaging technology, the division of each facies zone of volcanic rocks is studied, and the following conclusions are obtained:

(1) The spectrum imaging based on wavelet transform has a good lateral resolution, and the recognition effect is good for volcanic rock mass with large thickness change in this area.

(2) The thickness of the explosive phase near the crater is large and the stratification is poor, which results in the small tuning energy of the thin layer. However, the strata dominated by volcanic overflow facies or volcanic sedimentary facies are easy to produce tuning, and the maximum energy of spectrum imaging is relatively high.

(3) The main body of deep volcanoes in Songliao basin is mainly distributed in the north-south direction. The volcanic magma comes from the shallow layer with low temperature, which is easy to form explosive eruption. The main body of volcanoes is relatively small, which is in line with the geological understanding of the distribution of volcanoes in this area.

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