Application of Hydrocarbon Detection Technology in the Thin Sand Reservoirs

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Abstract: In response to the complex geologic conditions, such as many broken fault blocks, small scale of reservoirs, and big lateral and vertical variations of reservoirs in the research area, the drilling success ratio in the margin of the oil area has been increased and the traditional deployment idea of development wells have been upgraded into the new idea aimed at thin sand bodies by using of the hydrocarbon detection technology based on the integrated achievements of geology, sedimentary and reservoir. The hydrocarbon detection technology has obtained remarkable effects and effectively increased drilling success ratio in the development process of the research area.

1 THEORETICAL BASIS OF PREDICTION OF RESERVOIRS BEARING HYDROCARBON

According to the seismic exploration principle based on the reflected wave method, the seismic signals are gradually attenuated in their propagation process in subsurface. There are many factors affecting the attenuation of seismic signals, mainly including the interface between adjacent lithofacies, the reflection mechanism in faults and fractures, spherical spreading in the homogeneous medium, and variation of physical properties in the homogeneous medium (including oil, gas, water, etc.) (Batzle et al., 1997). Among these attenuation factors, that we most care about is the last one, i.e. seismic attenuation caused by the variation of physical properties in the homogeneous medium (Figure 1).

The instantaneous spectral analysis technology provides us with a means for the analysis of seismic wave attenuation attributes in frequency domain. In general, the energy attenuation of seismic signals is increased in the high frequency part under the same geologic conditions due to the existence of oil and gas. In comparison with the frequency features without attenuation, the whole frequency band after attenuation will shrink towards the low frequency part. Energy attenuation is often indicated by the several physical methods such as the energy attenuation gradient with frequency, low frequency energy, the frequency corresponding with the specified energy ratio, the energy ratio in the specified frequency band, etc. Different physical methods reflect the possibility of existence of oil and gas from different aspects (Batzle et al., 1992).

Attenuation gradient is one of attenuation attributes. As shown by the red arrow in Figure (2), attenuation gradient reflects the variation of seismic energy in the high frequency part with frequency, and can indicate the attenuation velocity during propagation of seismic waves. The attenuation gradient value (ATN_GRT) of seismic waves increases in the presence of the attenuation caused by such as oil and gas etc. in addition to the diffusion effect during seismic wave propagation in a single-phase media and the reflection mechanism of seismic waves at the reflection interface in multi-phase media (Li et al., 2014).

Low frequency energy is another important attenuation property and it indicates the intensity of low frequency energy (Sinha et al., 2005). Due to the existence of oil and gas, the energy attenuation in the high frequency part of seismic waves is larger than in the low frequency part, and the whole frequency range will shrink to the low frequency

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range after attenuation, causing the energy of low frequency part to be enhanced (Figure 3).

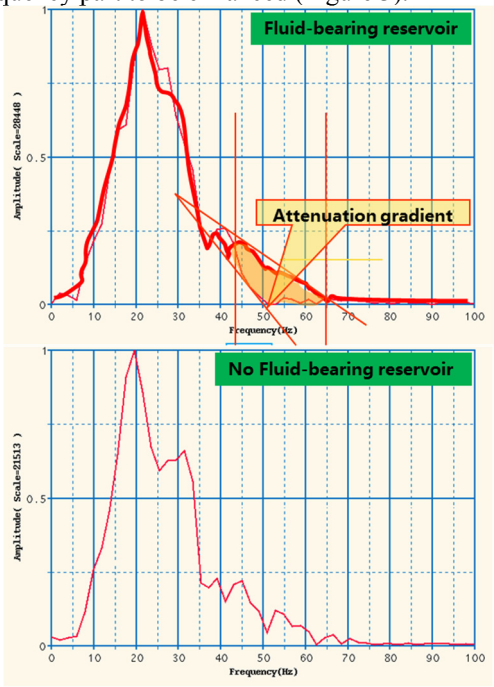

Figure 1: Principle of fluid detection with the attenuation gradient.

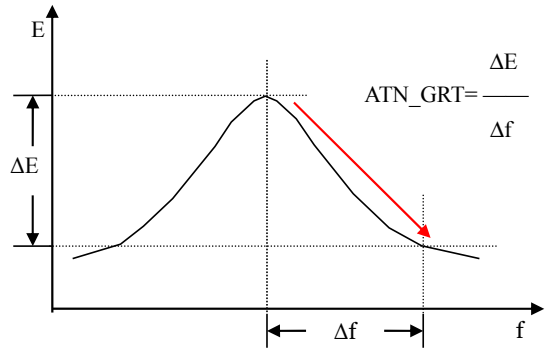

Figure 2: I Schematic of frequency attenuation gradient.

The third geophysical attribute that indicates hydrocarbon attenuation is the frequency corresponding with the specified energy ratio (Figure 4). The total energy is 1 in the effective frequency range. If the energy in the low frequency range specified is 85%, the frequency corresponding with 85% of the energy can be searched from the starting frequency in the effective frequency range, which is called F1. If the energy in the low frequency range specified is 65%, the frequency searched is called F2. The frequency corresponding with the specified energy ratio will decrease if there are oil and gas etc. Based on the same principle, the frequency corresponding with the maximum energy can be searched in the whole effective frequency range, i.e. initial attenuation frequency. The smaller the initial attenuation frequency, the greater the probability of oil and gas existing.

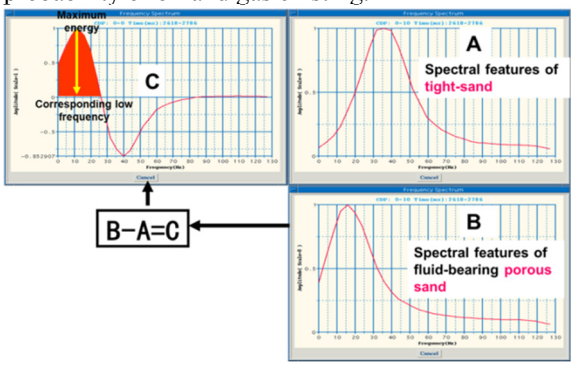

Figure 3: Schematic of low frequency energy.

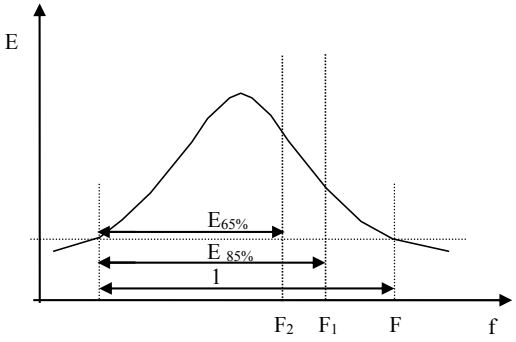

Figure 4: Schematic of the frequency corresponding with the specified energy ratio.

Another geophysical attribute that indicates hydrocarbon attenuation is the energy ratio corresponding with the specified frequency (Figure 5). In case of specifying a frequency F in the effective frequency range, the energy within the range from the initial frequency to the frequency F can be calculated, which is called the energy of the low frequency range (E_{low}). The percent of E_{low} to the total energy of the whole frequency range (E_{full}) is called the energy ratio corresponding with the specified frequency. If there exist oil and gas etc., the energy of the high frequency range will decrease, thus causing the energy ratio from energy corresponding with the specified frequency in the low frequency range to the total energy to be

increased (Wang, 2007). That is, if the energy ratio corresponding with the specified frequency increases, the possibility of existence of oil and gas is large, and can be determined according to the variation of the energy ratio corresponding with the specified frequency.

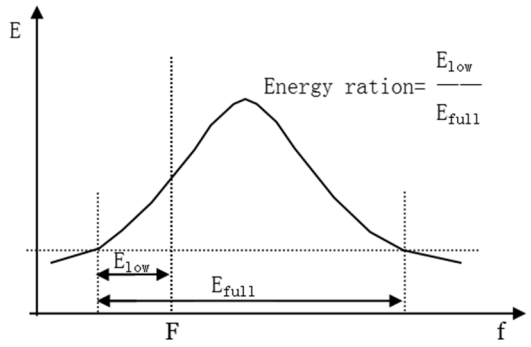

Figure 5: Schematic of the energy ratio corresponding with the specified frequency (Wang et al., 2012).

Oil and gas reservoirs show typical character of two-phase media. According to studies, when oil and gas existing, the seismogram show more obvious kinetics features such as “low frequency resonance, high frequency attenuation”. Therefore, the above various frequency properties can be used as the basis for judging the reservoirs bearing hydrocarbon (Wu and Liu, 2010).

2 APPLICATION EXAMPLE ANALYSIS (TAKING BY BLOCK IN THAILAND AS AN EXAMPLE)

According to the response analysis of attributes in wells, the reservoirs of Lancrabu Formation respond to frequency attenuation gradient and the energy attributes of the low frequency part (Figures 6 and 7), indicating high low-frequency energy and high attenuation gradient. However, the attributes prediction result completely comes from seismic information, so it is restricted largely by the quality of seismic data and has certain multiplicity.

Frequency attenuation gradient and low-frequency energy are sensitive to the reservoirs bearing hydrocarbon and have some certain correlation with the initial production of wells. According to the comparison result, the frequency attenuation gradient match well with the initial production of wells in the study area, and it can be used as the prediction basis for hydrocarbon detection. Figures 8 and 9 are the distribution map of hydrocarbon detection of K and L sand layers in Lancrabu Formation in the study area. According to the hydrocarbon detection result, the dominant area predicted bearing hydrocarbon is located mainly in the central part of the study area (indicated with red circle). Anomalies are weakened in the east and west part, the scope of anomalies is small in the south, there is no indication of hydrocarbon bearing in the north, and the indication bearing hydrocarbon of K sand layer is more obvious than L sand layer.

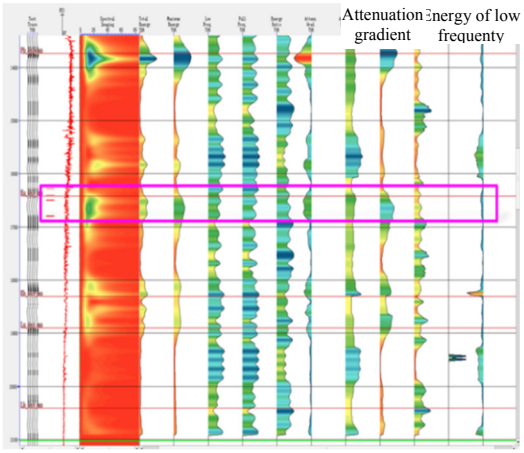

Figure 6: Diagram of well BY1-side seismic attributes.

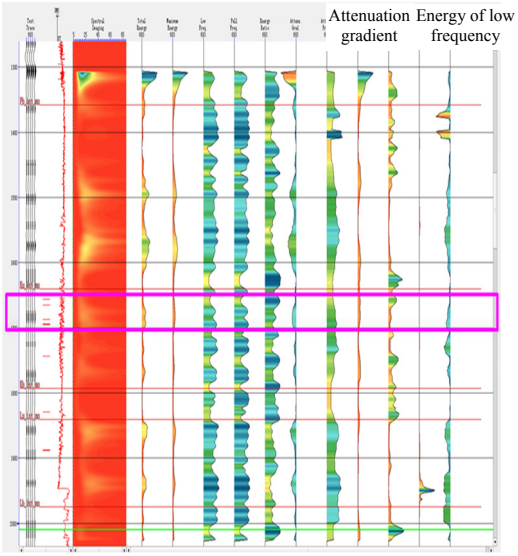

Figure 7: Diagram of well BM1-side seismic attributes.

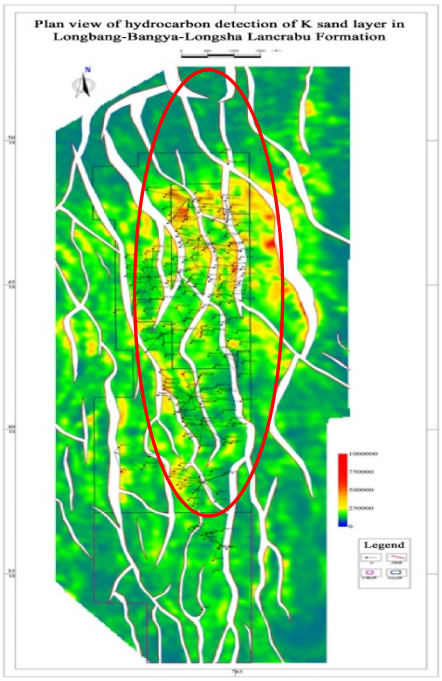

Figure 8: Map of hydrocarbon detection of K sand layer in Lancrabu Formation.

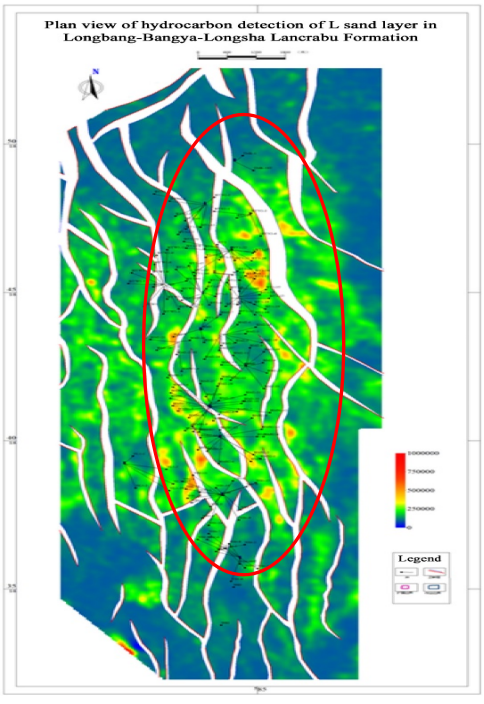

Figure 9: Map of hydrocarbon detection of L sand layer in Lancrabu Formation.

3 CONCLUSIONS

The research area in Thailand has complex geologic conditions, broken fault blocks, thin oil reservoirs, poor physical properties of reservoir, and complex and diverse controlling factors of reservoirs. After more than 20 years of development, the remaining oil and gas distribution is very complex, it is more and more difficult to tap the potential, and the development conflicts have become increasingly prominent. With the hydrocarbon detection technology, the distribution of the remaining oil and gas can be depicted accurately and drilling risks can be reduced greatly. According to the effect of application of the research area in Thailand, this method can be used to effectively predict the distribution of remaining oil and gas and especially has achieved a good effect in the prediction of thin reservoirs of complex fault blocks. However, the attribute prediction result completely comes from seismic data, so it is also mainly restricted by the quality of seismic data and multiplicity. Therefore, multiple factors shall be considered comprehensively such as structure, sedimentation, reservoir, reservoir forming, etc. in well deployment.

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