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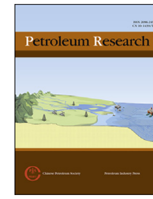

Full Length Article

Fluid identification method and application of pre-stack and post-stack integration based on seismic low-frequency

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A B S T R A C T

Seismic low-frequency component included more fluid information, which was still a focus in geophysics. Seismic pre-stack data contained more fluid information, but signal to noise ratio (SNR) was low. By comparison, seismic post-stack data had a high SNR, but some fluid information was lost during data processing. Different angel stacks reflected different fluid seismic amplitude, compared with near-angle stacks. Far angle stacks had more low frequency components, which were more benefit for fluid identification. Based on this principle, combined with the pre-stacks and post-stacks seismic data, more fluid information would be included. In this study, a new fluid identification method was proposed. This method combined the post-stack seismic and pre-stack seismic data, it took into consideration high SNR of the post-stack seismic data and the large fluid amplitude differences of the pre-stack different angles. Field testing indicated this method was quite effective in detecting fluids.

1. Introduction

Recently, the seismic low-frequency component has been a focus in geophysics (Castagna et al., 2003; Goloshubin and Korneev, 2000; Goloshubin et al., 2002; Korneev et al., 2004). Both the pre-stack and post-stack seismic data contained the low-frequency information, but the low-frequency information was applied to fluid identification in the post-stack seismic data firstly. Taner et al. (1979) firstly observed low frequency shadow (LFS) beneath hydrocarbon reservoirs, and realized the seismic low frequency might be used to indicate hydrocarbon possibility. Castagna et al. (2003) improved the application of seismic low frequency for hydrocarbon identification. Korneev et al. (2004) successfully simulated the low frequency effects fluid-saturated reservoirs by the diffusive-viscous wave equation with a model containing a dry zone and a water-saturated porous zone. Additionally, He et al. (2008) and Chen et al. (2009) obtained the positive results based on the formers. At present, the applying low-frequency shadow to detect hydrocarbon reservoir has gotten a good result in the post-stack seismic data, which was a hydrocarbon direct indication. However, compared with the pre-stack data, the post-stack seismic data had higher signal-to-noise ratio (SNR), but lost massive seismic amplitude information, which would give the raise to difficulties in fluid identification. On the contrary, the pre-stack seismic data had low SNR, but in different angle stack gathers, fluid-bearing layer seismic reflection had significantly differences, that were AVO (Rutherford and Williams, 1989). Chen et al. (2009) successfully proved the seismic far angle stacks had more anomaly than near angle stacks for bearing-fluid layer. Consequently, an inspiration was gotten from this. On the one hand, the seismic low-frequency components were more sensitive to fluid, the pre-stack seismic data included more low-frequency information, which was more favorable to detect fluid, but its SNR was low; on the other hand, the post-stack data had high SNR, but some seismic low frequency components were lost, this low frequency was very important in fluid identification. Besides, far angle stack contained more low

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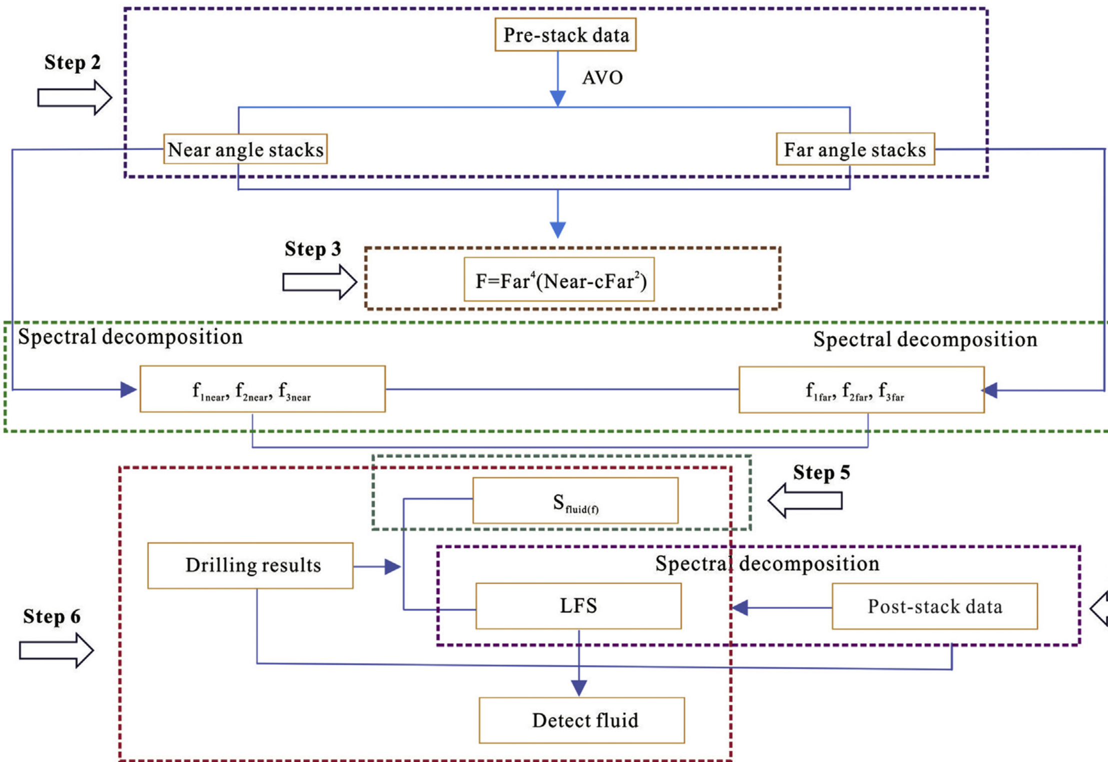

Fig. 1. The outline of the fluid identification method. This method was divided into 6 steps, combined the post-stack data and the pre-stack data to detect fluid, the drilling results were used to prove the confidence.

frequency information compared with other angle stack, if we could combine the advantages between the post-stack and pre-stack seismic data to construct a new fluid identification, it would enhance the confidence of fluid identification.

This study was just based on the inspiration, Fig. 1 was the method outline. Firstly, for the post-stack data, a series of single frequency data by spectral decomposition was obtained, the low-frequency shadow to detect fluid was applied (Step 1), the possible potential reservoirs was identified. Secondly, for the pre-stack seismic data, different angle stacks were extracted (Step2). Thirdly, through mathematics combination properly, the far-near angle stacks fluid identification factor was constructed as formula (1).

$$F = Far^4\left(Near^2 - cFar^2\right) \tag{1}$$

In formula (1), F was the new fluid facor profile; Far, $Near$ were far angle stack and near angle stack respectively; c is the adjusted parameter.

This formula was applied to identify possible potential reservoirs (Step3). Furthermore, the spectral decomposition was applied to get different frequency seismic data (f_{1near}, f_{2near}, f_{3near}, ……, f_{1far}, f_{2far}, f_{3far}, ……) from far and near angle stack gotten from the Step 4. For far and near angle stack, a new fluid identification factor by mathematics transform was constructed, that was to enlarge fluid anomalous response (Step 5). Finally, combined the Step 1 and the Step 5 to detect fluid, the most favorable reservoirs were confirmed, meanwhile, the drilling results were applied to prove the predict fluid's confidence (Step 6). Therefore, not only do we utilize the seismic post-stack high SNR characteristic, but also we get more low-frequency information from the pre-stack seismic data, which overcame shortcomings of the single pre-stack or post-stack seismic data.

2. Method and theory

2.1. Low-frequency shadow

The low-frequency shadow (LFS) means the strong energy (amplitude) low frequency area was located under the reservoir, which was one of important hydrocarbon direct indications (Sheriff, 2002). When seismic wave passed through the hydrocarbon reservoir, the energy attenuation of different frequency was different, the time-frequency spectral decomposition was used to detect energy differences of different frequency to seek for favorable reservoir. The time-frequency analysis was a very significant signal process approach in the seismic data process, the seismic data was transformed to frequency domain, which was the foundation of all seismic interpretation and process. So far, the time-frequency analysis was still a key factor in reservoir prediction. In this study, the general S transform was chosen as a kind of the time-frequency analysis tool. The wavelet function was defined as formula (2).

$$\psi(\tau - t, f) = \frac{\lambda |f|^p}{\sqrt{2\pi}} \exp\left[\frac{-\lambda^2 f^{2p}(\tau - t)}{2}\right] \exp(-i2\pi ft), \tag{2}$$
$$\lambda > 0, p > 0$$

In formula (2), τ was the central point of time window function, ms, which was used to confirm the wavelet time location; f was a frequency factor, Hz; the parameters of λ and p were used to adjust wavelet's time continuity and attenuation speed.

The general S transformation (GST) of signal was defined as formula (3).