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A joint high-resolution processing method and its application for thin inter-beds

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Abstract: Seismic processing characterizing thickness and borders of thin inter-beds has gradually evolved from post-stack migration to pre-stack migration, and the latter considers both vertical and lateral resolutions. As the key processing methods for improving vertical and lateral resolution, conventional deconvolution and pre-stack time migration (PSTM) are not simply dominated by the estimation and compression of the wavelet because of its instability. Therefore, considering the variations of wavelet frequency before, during and after PSTM can obtain good common reflection point (CRP) gathers and imaging profiles of thin inter-beds. Based on the frequency characteristics of the wavelet before, during and after PSTM, a joint high-resolution processing method for thin inter-beds is proposed in this paper, including inverse *Q* filtering for high-frequency compensation before PSTM, optimum weighting Kirchhoff PSTM for preserving high-frequencies during PSTM, and wavelet harmonizer deconvolution for consistent processing and frequency-band broadening after PSTM. An application to real data characterized by mudstone beds in the Oriente Basin proved that the joint high-resolution processing method is effective for determining the thickness and borders of thin inter-beds and is favorable for subsequent reservoir prediction and seismic inversions.

Key words: Thin inter-bed, seismic wavelet, inverse *Q* filtering, optimum weight function, harmonizer deconvolution

1 Introduction

Generally, thin inter-beds refer to a geologic body which is composed of two or more thin layers intermingled with beds of more normal thickness. The lithology difference results in different wave velocities in neighboring layers, so the bottom and top interfaces of one layer have opposite reflection coefficients, and the travel time is short. Because of limited frequency band of the wavelet, the seismic reflection of thin inter-beds is a result of superposition and interference of seismic wavelets (Widess, 1973). Vertically, the superposition and interference weaken the reflectivity coefficients of interfaces, and decrease the resolution of thin inter-beds. A seismic interpreter cannot properly distinguish the boundaries of a single layer (Knapp, 1990). Laterally, some wedges exist in the positions with lithologic changes in the seismic profiles, even the mudstone beds. These strong events appear discontinuous because the diffracted amplitudes of two sides of the diffracted point cannot be weakened after migration for different velocities (Robertson and Nogami, 1984). Therefore, thin inter-beds imaging is complex and requires high vertical and lateral resolution.

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Seismic vertical resolution refers to the ability to identify reflected interfaces from wavelets. Rayleigh studied Fraunhofer optical diffraction and proposed that two neighboring peaks can be visually distinguished if the time interval of the wavelet is not less than the peak-trough interval $\Delta\tau_R$, and the resolution limit is a quarter of the wavelength, commonly called the Rayleigh criterion (Fig. 1). Ricker (1945; 1953) studied the composite waveform by convolving a zero-phase wavelet with two pulses of equal amplitude and polarity, and showed that the composite waveform becomes flat between the two pulses when the time interval of the two pulses is $2\Delta\tau_r$, which is defined as the vertical resolution limit, i.e., 1/4.6 of wavelength, now called the Ricker criterion (Fig. 1). Widess (1973; 1982) studied a composite waveform by convolving a zero-phase wavelet with two pulses of equal amplitude and opposite polarity. He concluded that the composite waveform converges to the derivative of the wavelet with a decreasing interval between the two pulses and indicated that the resolution limit is 1/8 of the wavelength if the amplitude of the composite wave is considered. Kallweit and Wood (1982) made a summary of vertical resolution and showed that the Ricker criterion can be applied to both equal and opposite polarity situations of one doublet. Van Riel and Berkhout (1985) pointed the disadvantages of the above criteria: 1) only the interference