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A Stable Q Compensated Reverse Time Migration Method Based on Excitation Amplitude Imaging Condition

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Abstract. The stability and efficiency, especially the stability, are generally concerned issues in Q compensated reverse time migration (Q-RTM). The instability occurs because of the exponentially boosted high frequency ambient noise during the forward or backward seismic wavefield propagation. The regularization and low-pass filtering methods are two effective strategies to control the instability of the wave propagation in Q-RTM. However, the regularization parameters are determined experimentally, and the wavefield cannot be recovered accurately. The low-pass filtering method cannot balance the selection of cutoff frequency for varying Q values, and may damage the effective signals, especially when the signal-to-noise ratio (SNR) of the seismic data is low, the Q-RTM will be a highly unstable process. In order to achieve the purpose of stability, the selection of cutoff frequency will be small enough, which can cause great damage to the effective high frequency signals. In this paper, we present a stable Q-RTM algorithm based on the excitation amplitude imaging condition, which can compensate both the amplitude attenuation and phase dispersion. Unlike the existing Q-RTM algorithms enlarging the amplitude, the exponentially attenuated seismic wavefield will be used during both the forward and backward wavefield propagation of Q-RTM. Therefore, the new Q-RTM algorithm is relative stable, even for the low SNR seismic data. In order to show the accuracy and stability of our stable Q-RTM algorithm clearly, an example based on Graben model will be illustrated. Then, a realistic BP gas chimney model further demonstrates that the proposed method enjoys good stability and anti-noise performance compared with the traditional Q-RTM with amplitude amplification. Compare the Q-RTM images of these two models to the reference images obtained by the acoustic RTM with acoustic seismic data, the new Q-RTM results match the reference images quite well. The proposed method is also tested using a field seismic data, the result shows the effectiveness of our proposed method.

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1 Introduction

High-resolution seismic data processing is necessary for the detailed description of oil and gas reservoirs. In this paper, we discuss one resolution enhancement technique, which is the Q compensated reverse time migration (Q-RTM). When a seismic wave propagates in viscous media, especially the gas-bearing strata, the fundamental properties of the wavefield are changed with energy attenuation and phase dispersion [1]. As a result, the energy reflected from the deep layers below the gas-bearing layers is reduced, and the events are with a low resolution in the conventional migration images. The worst thing is that the imaged position of the interface is distorted because of the phase dispersion. It is necessary to compensate for these viscous effects in order to obtain the migration images with high fidelity.

Anelasticity and inhomogeneity of the subsurface weaken the high frequency seismic energy, which decrease seismic amplitudes and cause the phase dispersion. These effects can be described as the earth Q filtering, defined in terms of a specified Q model of the earth (Futterman, 1962; Strick, 1967, 1970). In order to compensate these absorption and dispersion in seismic data processing, various schemes have been developed. Among these schemes, the inverse Q filtering method has been widely applied because of its effectiveness and high efficiency [2, 20]. Nevertheless, the inverse Q filtering method compensates the amplitude attenuation and phase dispersion along the depth direction trace by trace, while ignores the viscous effects in the horizontal direction. In fact, the viscous effects occur along the way of wavefield propagation, we should compensate the Q effects along the real paths. It is obvious that the seismic data after inverse Q filtering cannot be used to the subsequent amplitude versus offset (AVO) or amplitude versus angle (AVA) analysis due to the incorrectness of relative amplitude. Considering the weakness of the inverse Q filtering method, Li et al. adopted a two-step scheme to approximate the paths of the wave in order to compensate the amplitude attenuation and phase dispersion in both depth and horizontal directions [13].

A plenty of prestack depth migration studies based on one way wave equation have been conducted to compensate the viscous effects for the down-going and up-going waves in the frequency domain [5, 15, 16, 23, 25, 27]. These prestack depth migration schemes commonly compensate the attenuation using the imaginary part of a complex phase velocity. Although these schemes may be suitable for compensation, the one way wave equation migration is not suitable for the high dip structures.

The reverse time migration (RTM), which is based on two-way wave equation, has been considered as the most accurate migration technique for complex geological structures [10]. For Q-RTM algorithm, there are two kinds of viscoacoustic wave equations,