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3D viscoacoustic reverse time migration with attenuation compensation

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Abstract

Processes of attenuation and dispersion always degrading the resolution of migrated images. To improve the image resolution, we have developed a new approach for the numerical solution of the 3D viscoacoustic wave equation in the time domain and we developed an associated reverse time migration (Q-RTM) method. The main feature of the Q-RTM approach is compensation of attenuation effects in seismic images during migration by separation of amplitude attenuation and phase dispersion terms. In the Q-RTM implementation, attenuation and dispersion compensated operators are constructed by reversing the sign of the amplitude attenuation and keeping the sign of dispersion operator unchanged. The Q-RTM approach is tested on a 3D model. We validate and examine the response of this approach by using it within an RTM scheme adjusted to compensate for attenuation. Our 3D numerical test focus on the amplitude recovery and resolution of the Q-RTM images as well as the interface locations. Numerical results show that the Q-RTM approach produced higher resolution images with recovered amplitude compared to the non-compensated RTM.

3D viscoacoustic wave equation for extrapolating

3D decoupled viscoacoustic wave equation:

$$\frac{\partial P}{\partial t} = -K\left(\frac{\partial u_x}{\partial x} + \frac{\partial u_y}{\partial y} + \frac{\partial z}{\partial z}\right)\left[a_1(2/A) + i a_2(2/AQ)\right]$$

$$A = \left(\sqrt{1 + 1/Q^2} - 1/Q\right)^2$$

2/A: Dispersion-dominated

2/AQ: Amplitude-attenuation dominated

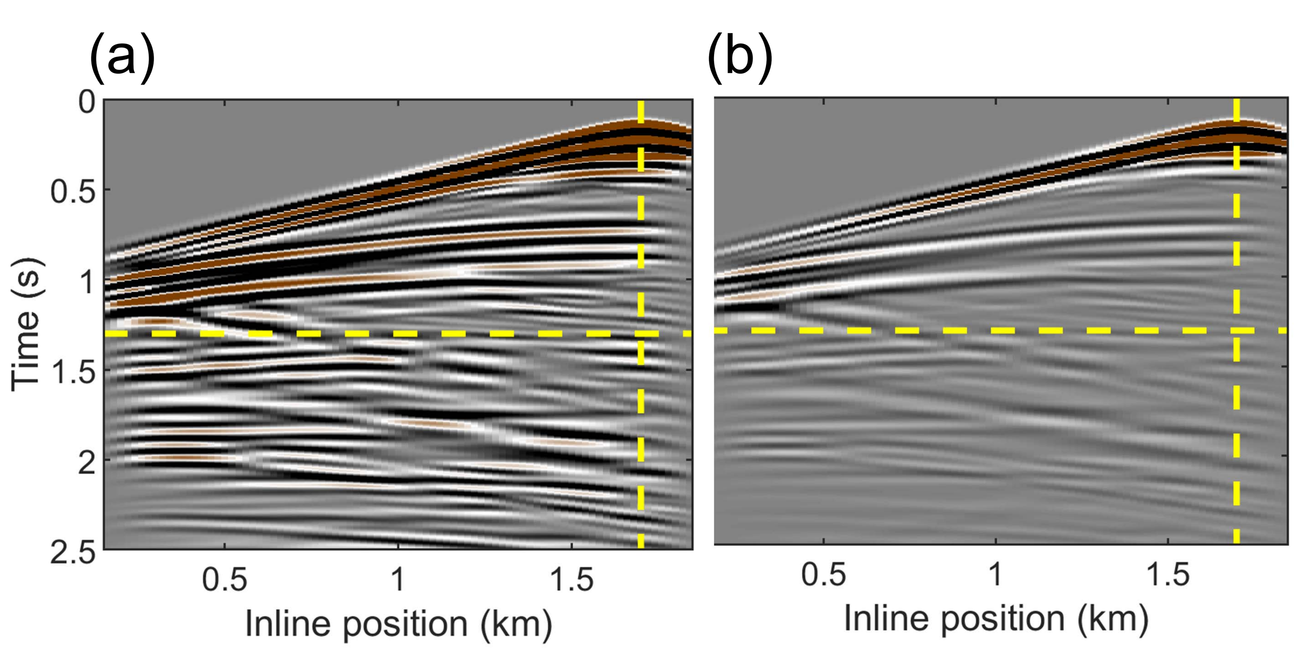

Figure 1. Synthetic data example: (a) Inline shot record in the acoustic approximation, and (c) inline shot records in the viscoacoustic case.

To amplifies the amplitude, the sign of the attenuation term (a_2 =-1) will be reversed. The viscoacoustic wave equation also contains a dispersion term that affects the phase during wave propagation. The sign of this term (a_1 = 1) does not need to be changed. For backward modeling, the 3D viscoacoustic wave equation with compensation of attenuation effects can be written as

$$\frac{\partial P}{\partial t} = -K\left(\frac{\partial u_x}{\partial x} + \frac{\partial u_y}{\partial y} + \frac{\partial z}{\partial z}\right)\left[a_1(2/A) - i a_2(2/AQ)\right]$$

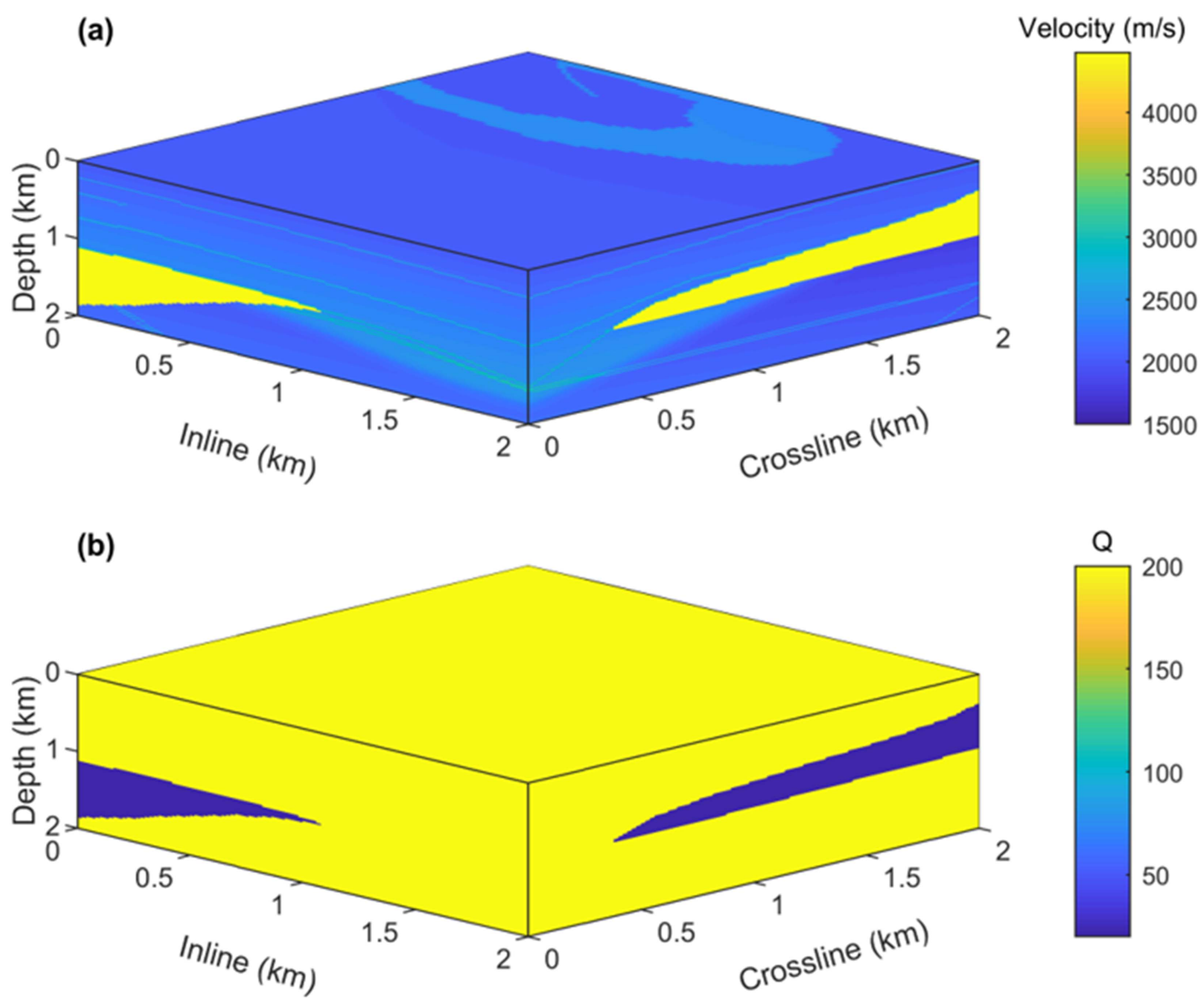

Figure 2: (a) True velocity model, (b) True Q

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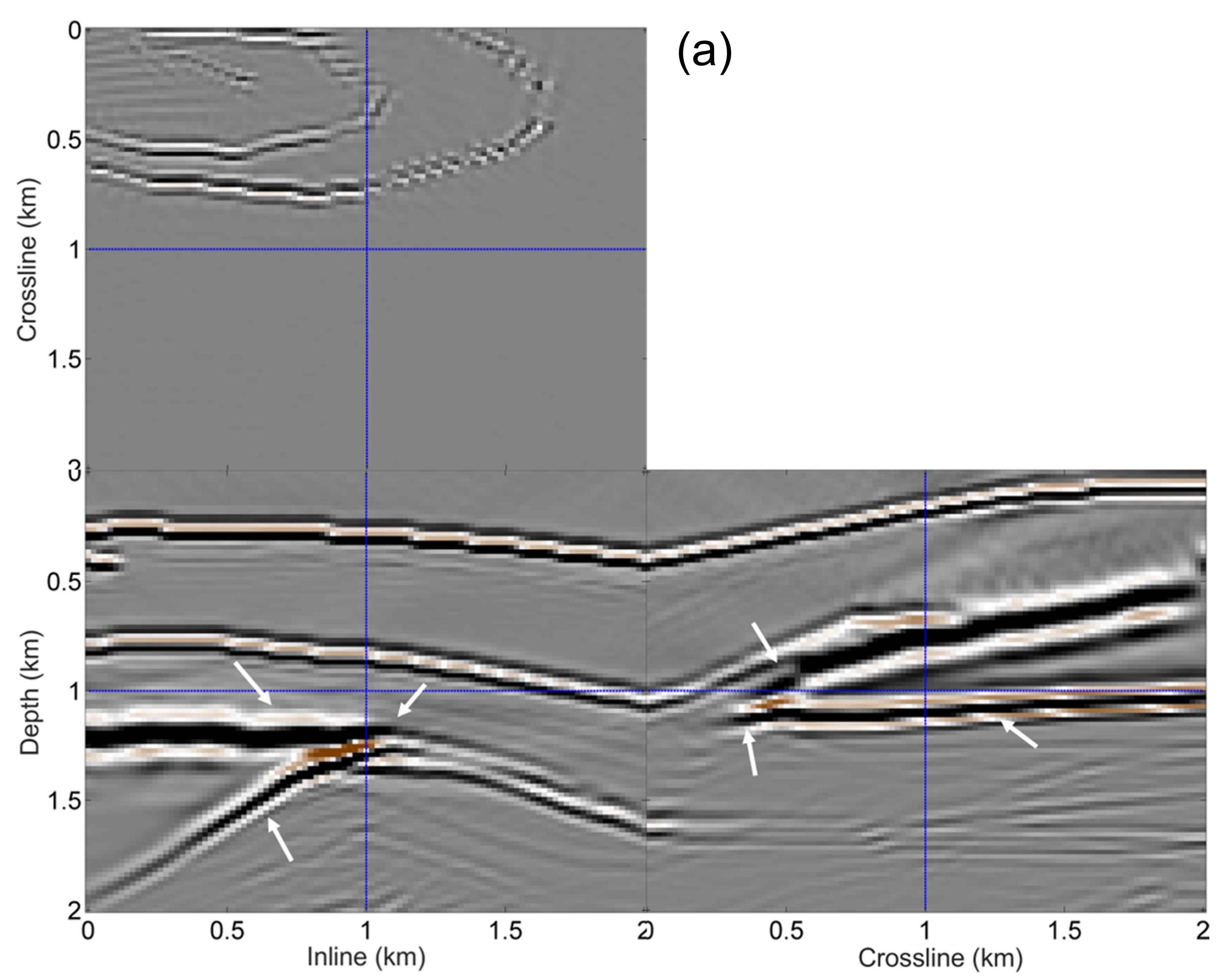

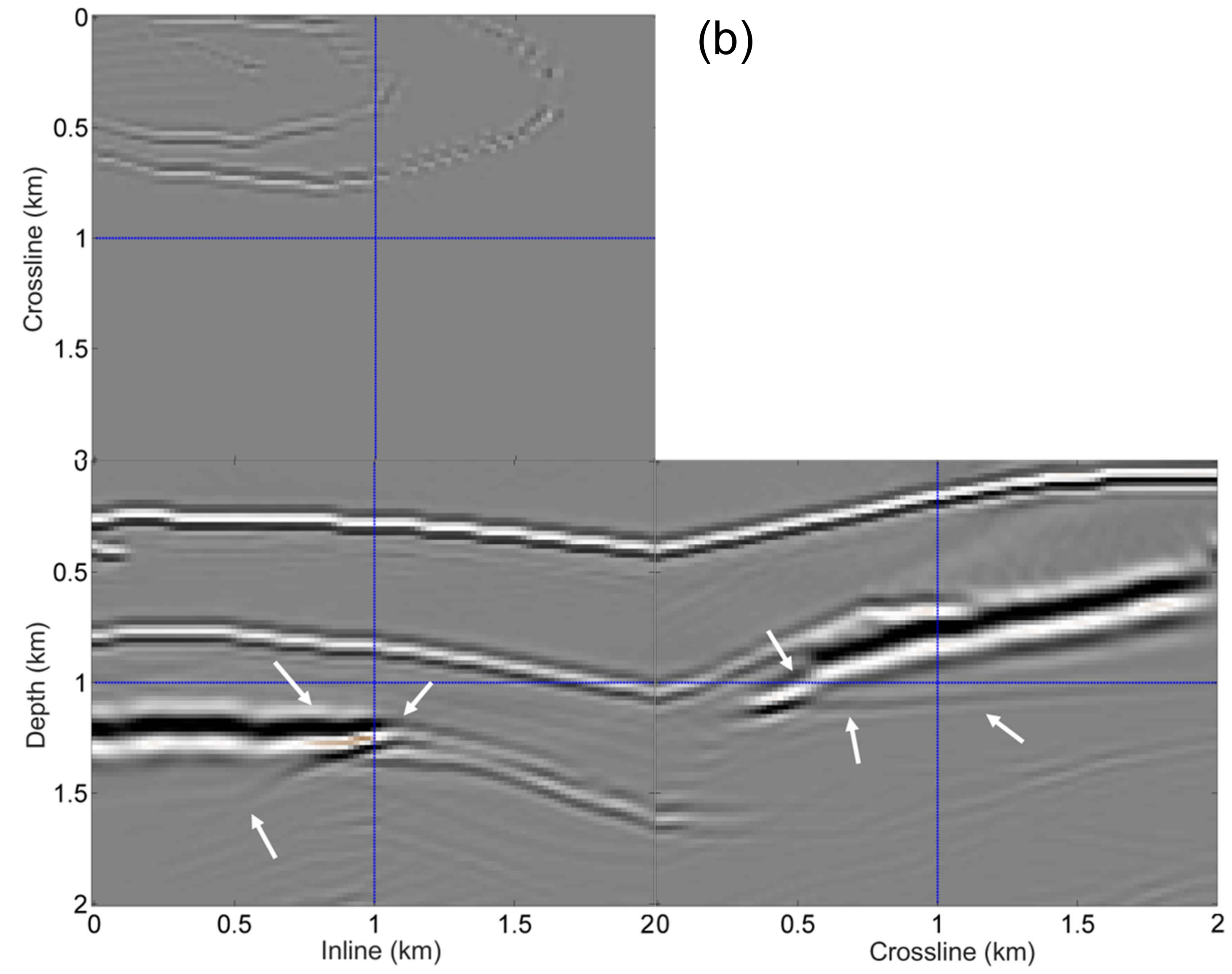

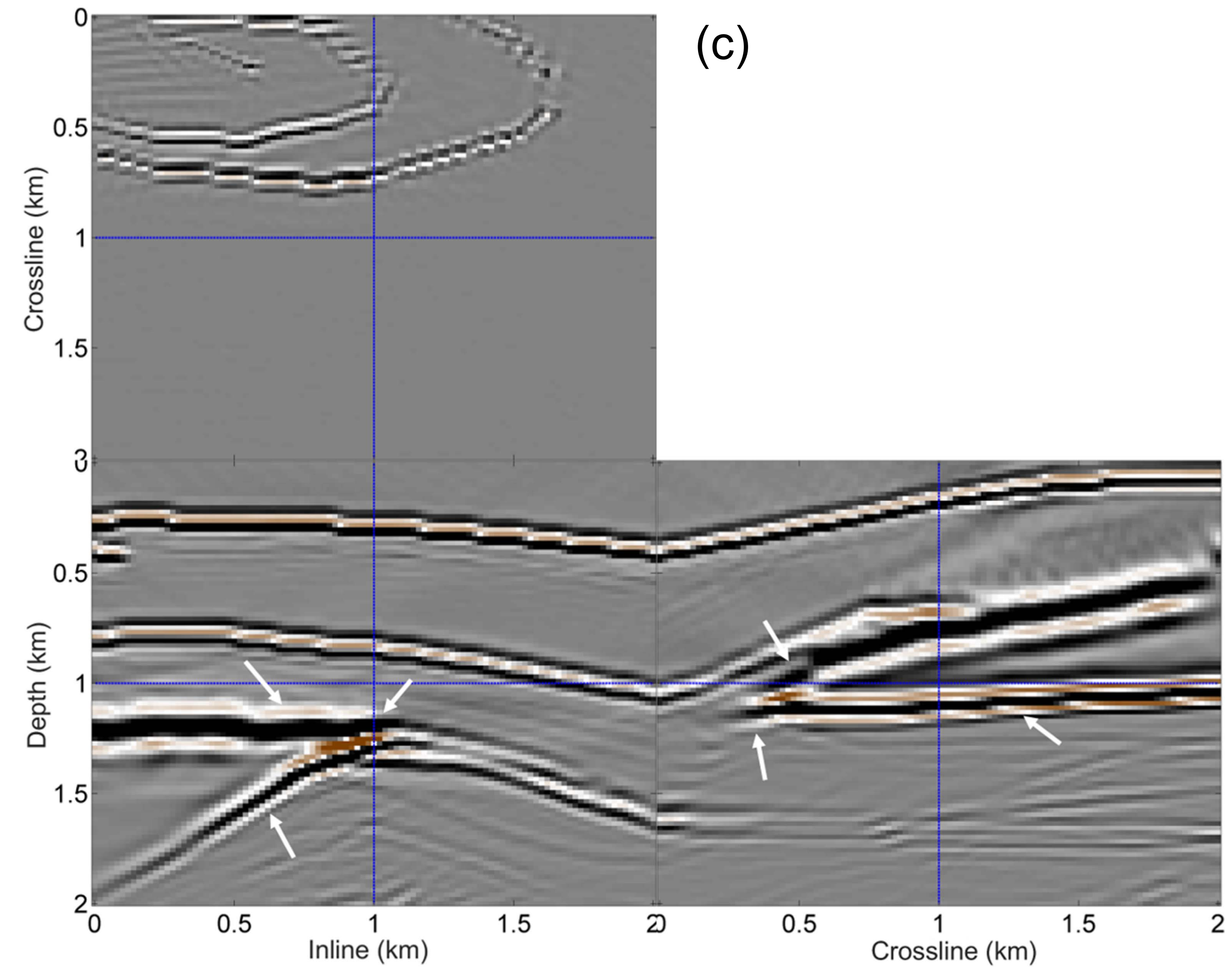

Figure 3: (a) Reference RTM, (b) aacoustic RTM image with viscoacoustic data (noncompensated), and (c) viscoacoustic RTM image (compensated). RTM image is clear, and the position is accurate from compensated viscoacoustic RTM.

Conclusions

The attenuation effects in the source and receivers wavefields can be recovered by applying compensation operators on the measured receiver wavefield. The phase dispersion and amplitude loss operators in Q-RTM approach are separated, and the compensation operators are constructed by reversing the sign of the attenuation operator without changing the sign of the dispersion operator. Numerical test in 3D on synthetic data shows that this approach can improve the image resolution, especially beneath areas with strong attenuation.

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