Multisource Reverse Time Migration in Anisotropic Media

Wenyong Pan*, Kris A. Innanen and Gary F. Margrave
wpan@ucalgary.ca

Summary

Reverse Time Migration (RTM) has great power in imaging the complex structures with dip angles. While isotropic RTM suffers from seismic anisotropy which can cause imaging and positioning problems for imaging underlying structures. In this research, the pseudo-spectral method is used to solve the P-wave equation in Titled Transversely Isotropic (TTI) media for anisotropic RTM. Furthermore, RTM suffers from extensively computational cost for traditional shot by shot method, which limits its practical application considerably. The plane-wave source migration with densely distributed sources has been introduced in seismic imaging to reduce the computational cost. While in practical application, the sources are always sparsely arranged. In this condition, the crosstalk artifacts which arise from the undesired interactions between unrelated shot and receiver wavefields will become very obvious. The phase encoding technique is introduced to shift or disperse these crossterms by slant stacking over sufficient number of ray parameters. In this research, we applied the phase encoded anisotropic RTM on Hess VTI (Vertical Transversely Isotropic) model. We also analyzed the influence of the number of encoded sources to the phase encoded images. And the imaging results for different phase encoding methods are also compared and discussed.

Wave Propagation in Anisotropic Media

- **Pseudo-spectral Method**

To implement the pseudo-spectral method, firstly, we apply a two dimensional Fourier transform for transforming the data from spatial domain to wave-number domain and accomplish the wave-number computation. Then, apply an inverse Fourier transform and return to spatial domain for anisotropic parameters calculation. Finally, we can calculate the wavefield in time domain.

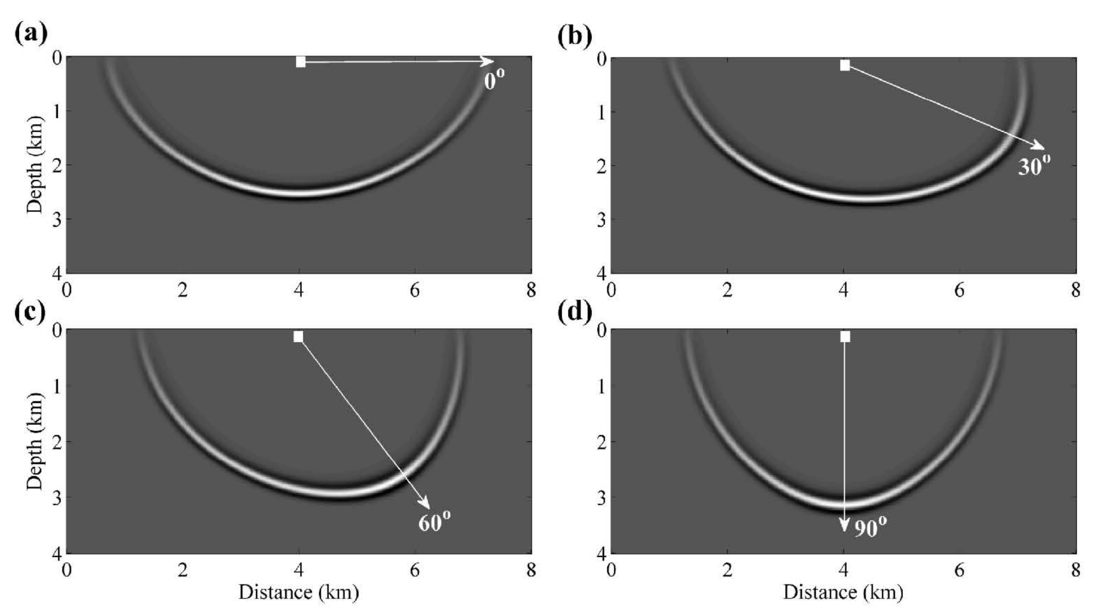

Fig.1. Snapshots in anisotropic media. (a) Snapshot in VTI media (ϕ=0 degree); (b) Snapshot in TTI media (ϕ=30 degree); (c) Snapshot in TTI media ($\phi = 60$degree); (d) Snapshot in TTI media ($\phi = 90$degree).

Phase Encoded Source Migration

- **Phase Encoding Strategy**

The phase encoding strategy is implemented by applying different phase shifts at different sources' locations. The crosstalk noise can be dispersed by slant stacking a set number of ray parameters. The phase encoded image can be expressed as:

$$\tilde{I}(\mathbf{r}) = \sum_{\omega} \sum_{\mathbf{r}_s} \sum_{\mathbf{r}'_s} \sum_{p=-\infty}^{+\infty} \Re\left\{\omega^2 \mid A(\omega)\mid^2 \tilde{G}(\mathbf{r},\mathbf{r}_s,\omega)\,\bar{G}^*(\mathbf{r},\mathbf{r}'_s,\omega)\,e^{i\omega p(\mathbf{r}_s-\mathbf{r}'_s)}\right\},$$

- **Wavefield Extrapolation in Titled Coordinate System**

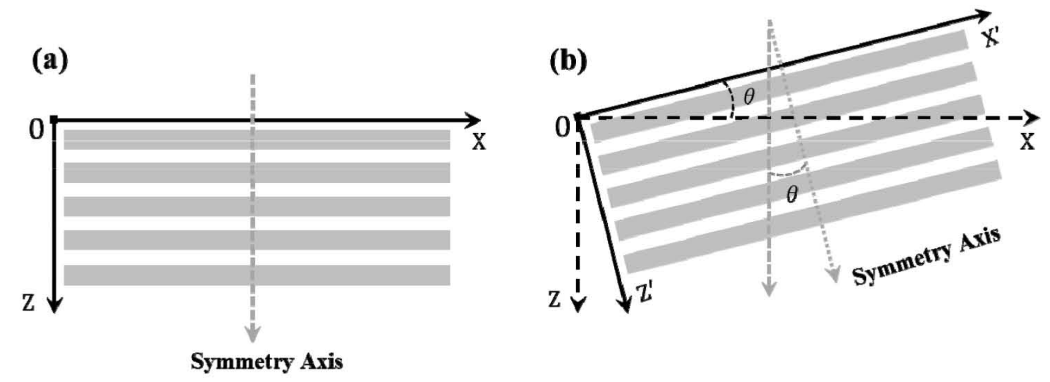

Fig.2. VTI media in Cartesian coordinate system (a) and VTI media in titled coordinates system (b). (X,Z) and (X',Z') indicate the Cartesian coordinate system and titled coordinate system respectively.

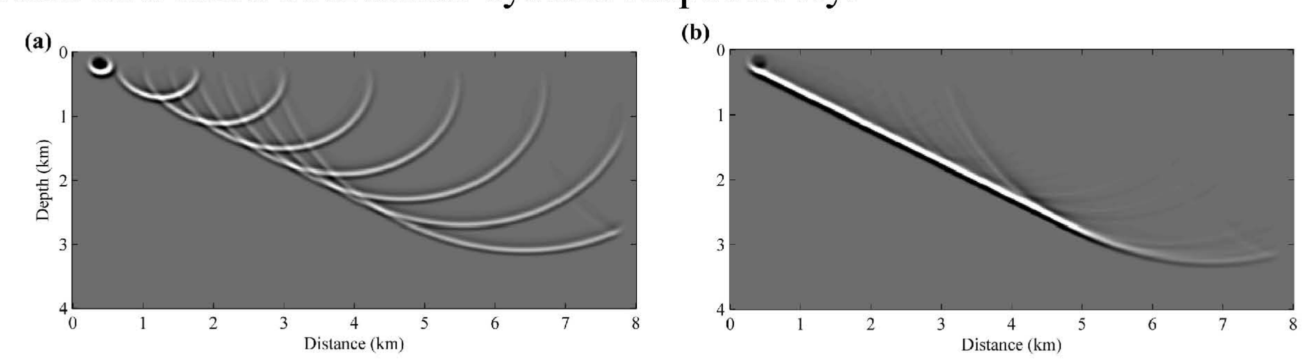

Fig.3. The snapshots in anisotropic media for sparse sources arrangement (a) and dense sources arrangement (b) with ray parameter p=0.2s/km. The Thomsen parameters δ=0.18, ε=0.15 and ϕ=45 degree. This figure is produced following Shan et.al (2009)

Numerical Example

Fig.4a shows the imaging result just using the P-wave velocity model. We can see that the geological structures and faults are imaged very. While it misses some structures where have anomalies in Thomsen parameters. Fig. 4b and c show the imaging results in the isotropic media and VTI media respectively. We can see that the image in isotropic media suffers from mispositioning problem.

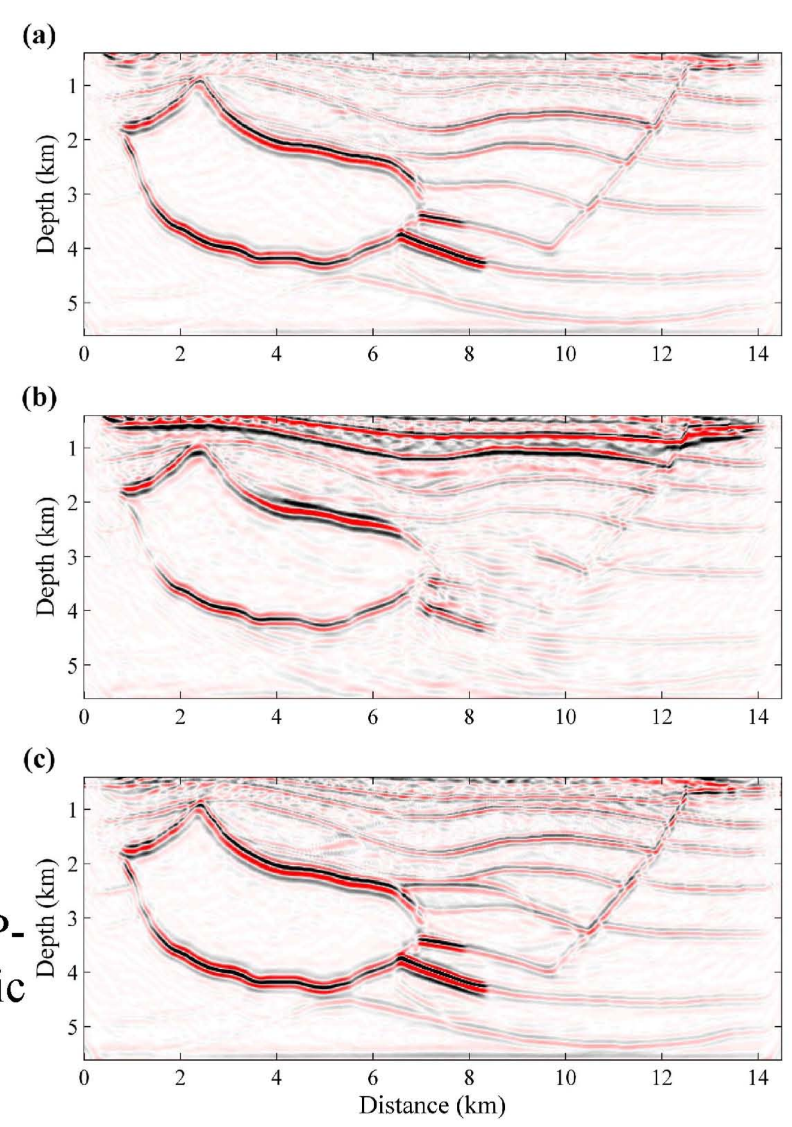

Fig.4. Imaging results using just P-wave velocity model (a), isotropic image (b) and anisotropic image.

Numerical Example

Fig.5a, b, c and d show the supergathers for linear phase encoding method when ray parameter p=0, random phase encoding method, linear phase encoding method when p=0.06s/km and chirp phase encoding method.

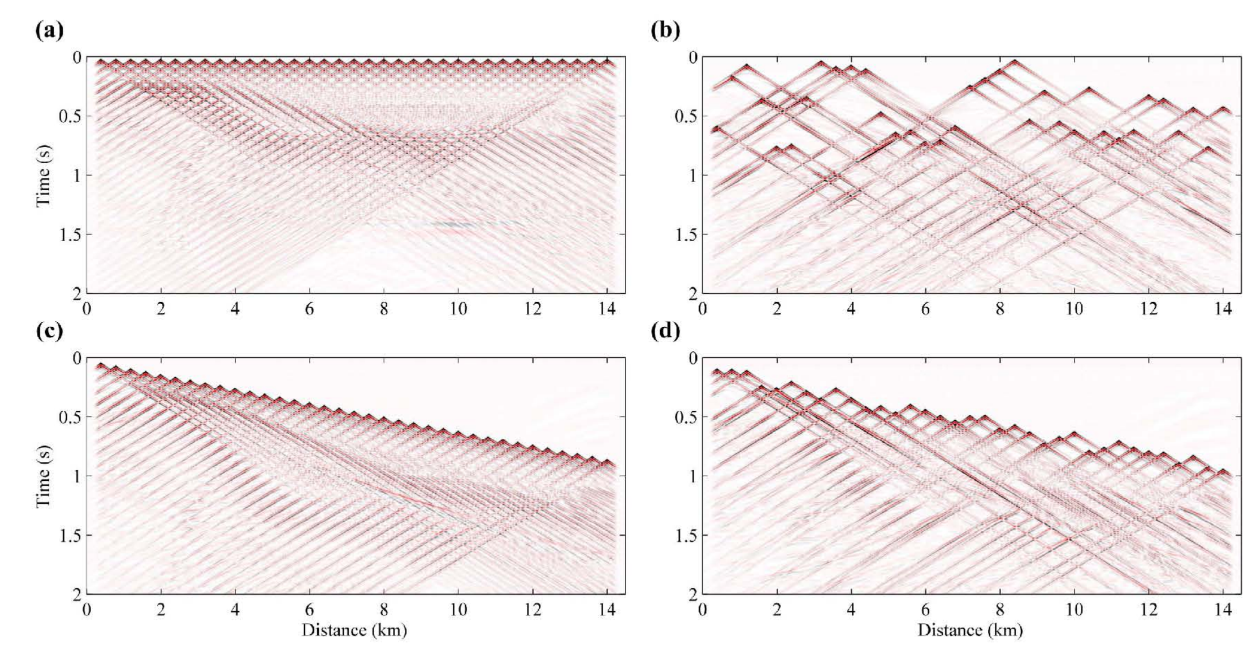

Fig.5 Supergathers

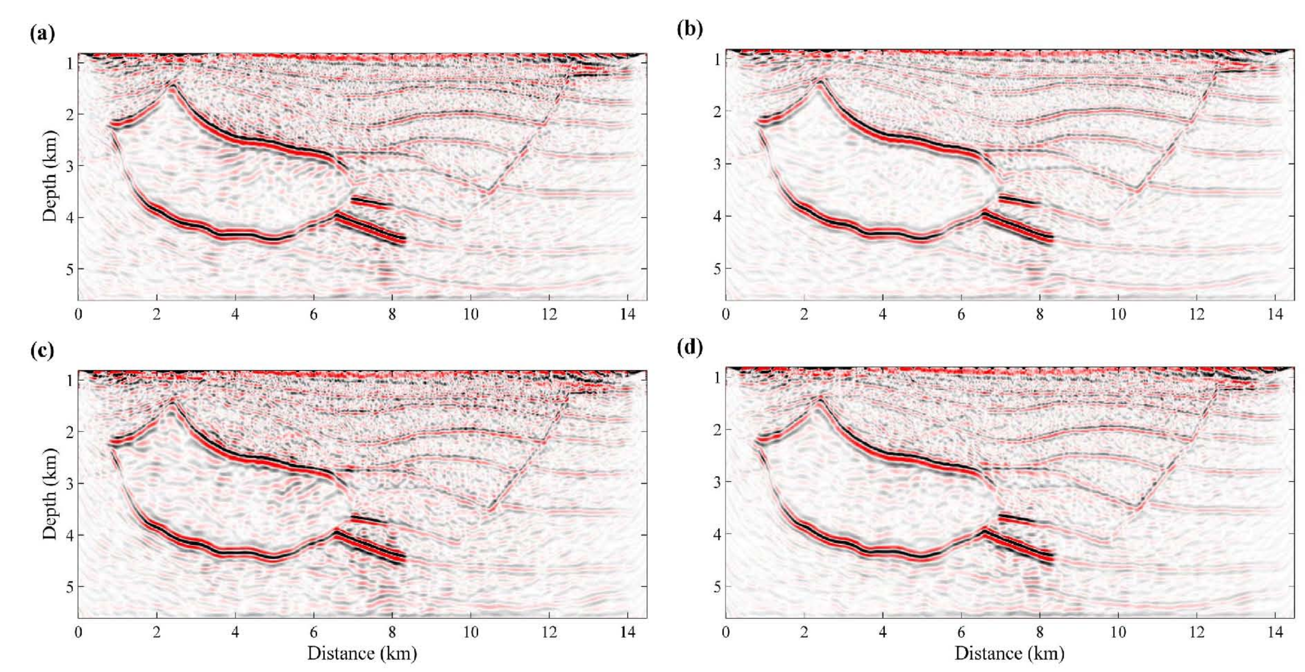

Fig.6. (a) and (c) are the imaging results by linear and chirp phase encoding methods with 7 simulations ranging the ray parameter from -0.06s/km to 0.06s/km. (b) and (d) are the imaging results by linear and chirp phase encoding methods with 13 simulations ranging the ray parameter from -0.06s/km to 0.06s/km.

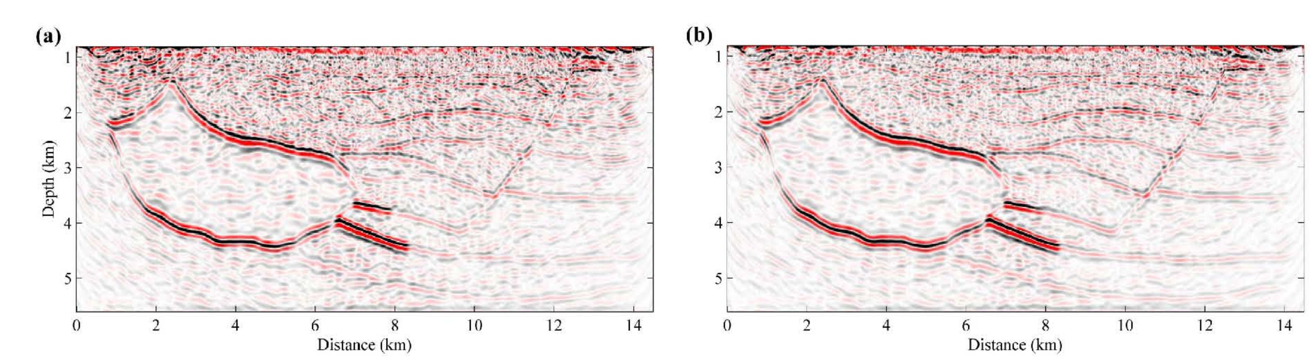

Fig.7(a) and (b) are the imaging results by random phase encoding method with 7 and 13 simulations respectively. And the source number is 37.

Acknowledgements

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