Application of Plane-wave Least Square Migration in Fault Block Reservoirs - A Case Study

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SUMMARY

The lithological migration and preserved-amplitude migration problem of fault block reservoirs is rather rough in the delicate exploration of China's oil field. In this paper, we implement the prestack least square reverse time migration based on plane-wave encoding to solve these problems with an improvement of efficiency. The imaging test of plane-wave LSRTM algorithm and its comparison with RTM and poststack LSRTM verify that the prestack LSRTM has the advantages including: (1) resolution enhancement and amplitude compensation in mid-deep part with the increase of iterations which can be compared to LSRTM (2) high computational efficiency to be practical (3) stable convergence even when the velocity model is complex.

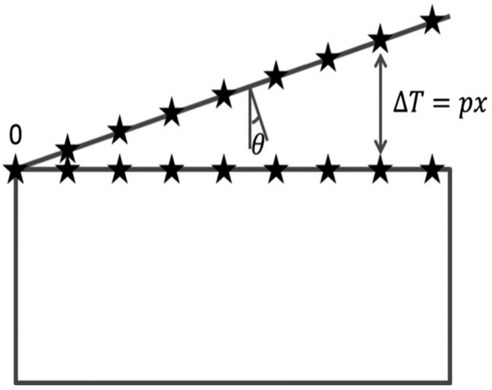

Figure 1 *Diagram of plane-wave encoding.*

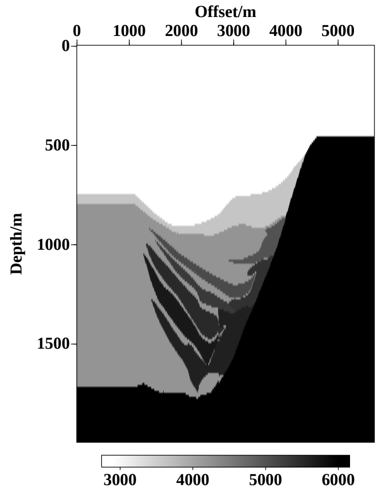

Figure 2 *Velocity of fault block model.*

Results

In this section, the plane-wave prestack LSRTM is applied to a synthetic data set of a complex fault block model in Shengli Oil-field (Figure 2). The velocity model is modified to be the size of 5.7 km × 2.0 km with a 10m grid interval. Several fault blocks are distributed in the mid-deep part and a high steep structure locates on the right. The strong velocity variation, the burial depth and fuzzy boundary of fault blocks make it a good velocity model to test the resolution and amplitude preservation of the imaging method.

The numerical scheme of the velocity model is implemented with a 2-8 finite-difference method. Shot-domain data are generated with a fixed spread geometry where 571 shots are distributed with a 10m shot interval at the depth of 10m. Each shot is recorded with 571 receivers with a 10m receiver interval. A Ricker wavelet with a 30Hz peak frequency is used as the source wavelet, and the record length is 2s in time with 0.5ms interval. The 571 shot gathers are encoded with linear plane-wave encoding (equation 1) to form 24 plane-wave gathers with ray parameters (p) ranging from −0.1742 ms/m to 0.1742 ms/m (the shooting angles range from -30 degree to 30 degree) with an even sampling in p. Three plane-wave gathers are showed in figure 3 with different parameters (p) which can be viewed as the shot gathers generated with discrete line source of different shooting angles. The reflection events are intricate because of complex velocity distribution.

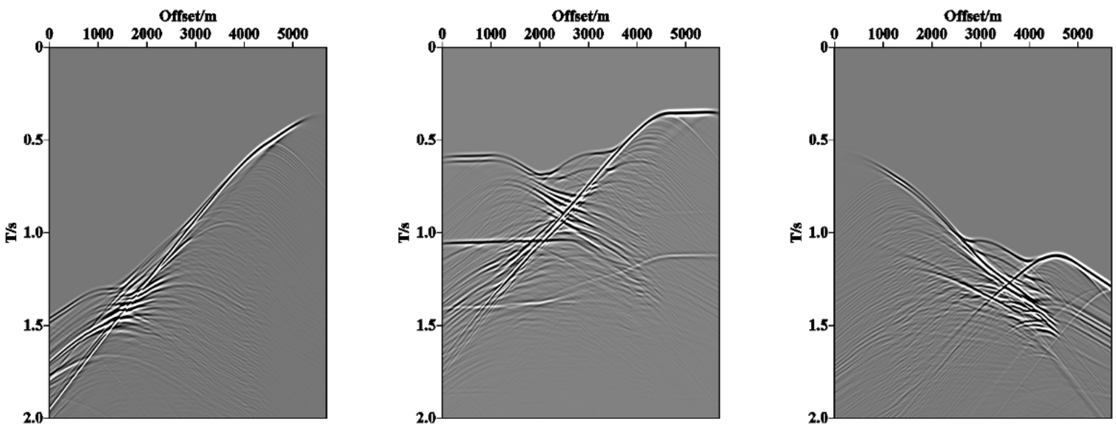

Figure 3 *a) plane-wave records with p=-0.1742ms/m. b) plane-wave records with p=0ms/m. c) plane-wave records with p=0.1742ms/m.*

Figure 4 shows the stacked image of 24 prestack plane-wave LSRTM images after 5, 15 and 30 iterations. Reduction of low frequency noise as well as crosstalk and amplitude compensation in mid-deep part is obvious with the increase of iteration. But the low frequency noise in the right part is still strong, which may be smoothed by precondition of smoothness constraint.

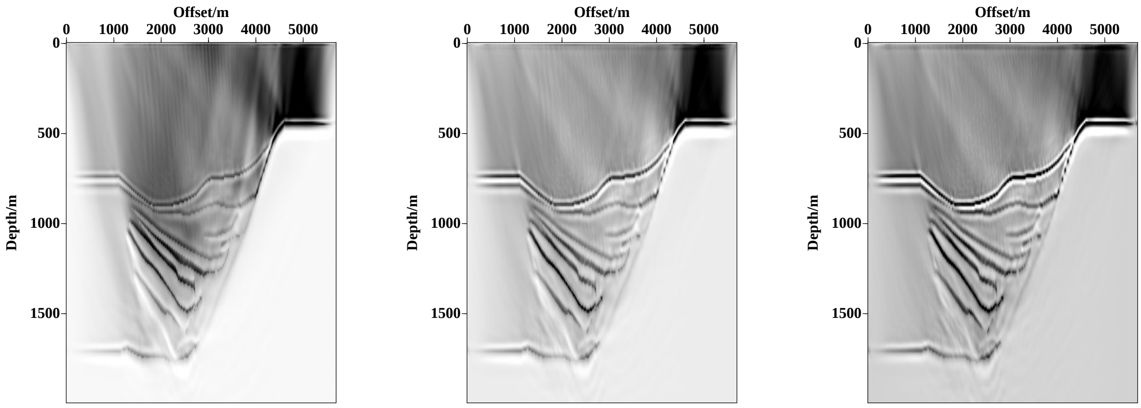

Figure 4 *a) image of plane-wave LSRTM using 24 plane waves after 5 iterations. b) image after 15 iterations. c) image after 30 iterations.*

Imaging tests of RTM with 91 shots and poststack LSRTM with 91 shots are also did for comparison. Figure 5.a shows the image of RTM with strong low frequency noise which covers up the event of fault blocks in deep part. Figure 5.b shows the image of LSRTM after 30 iterations which is considered to be the most satisfactory result with high resolution and balanced amplitude, but its computation cost is almost 45 times more than RTM. Figure 5.c shows the result of plane-wave LSRTM after 30 iterations. The image of plane-wave LSRTM has a comparable quality to LSRTM and the crosstalk is even weaker than the result of LSRTM because of the stacking of images from many different angles. The computational time of plane-wave LSRTM is only $N_p / N_s \approx 26\%$ times of LSRTM.

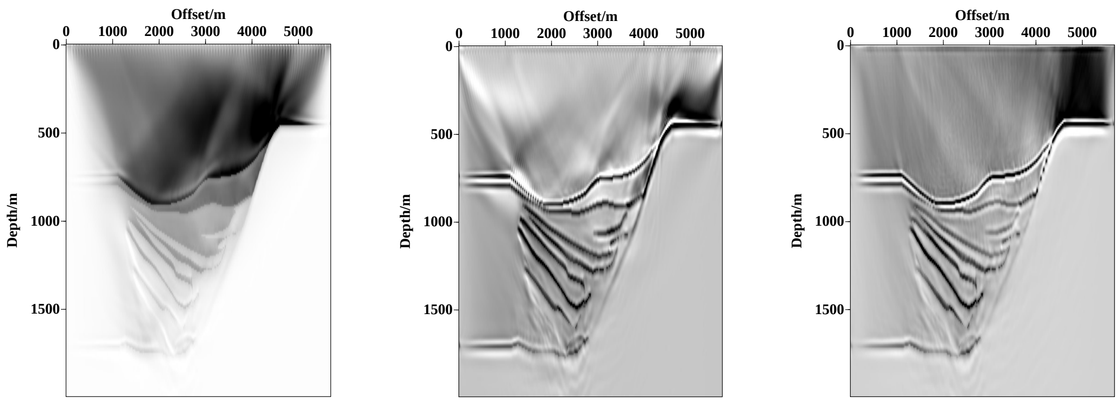

Figure 5 *a) image of RTM with 91 shots. b) image of LSRTM with 91 shots after 30 iterations. c) image of plane-wave LSRTM after 30 iterations.*

The residual convergence curves of LSRTM and prestack plane-wave LSRTM are plotted in figure 6. Prestack plane-wave LSRTM shows a stable convergence as well as LSRTM but a little faster in the former iterations.

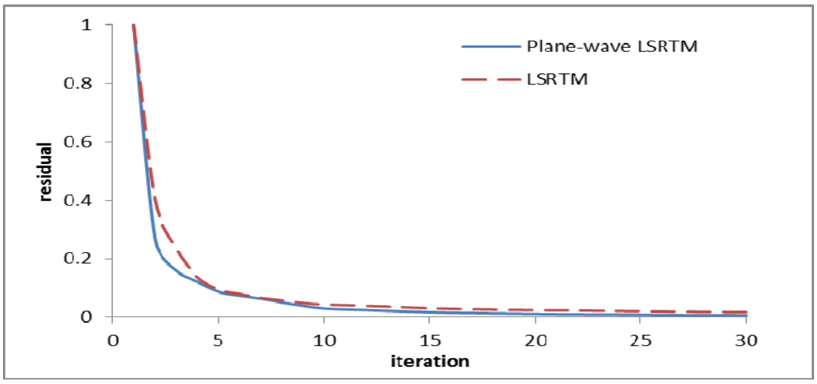

Figure 6 *The residual convergence curves of LSRTM and plane-wave LSRTM.*

Conclusions

In this paper, we implement the prestack LSRTM with a plane-wave encoding technique on the fault block velocity model in Shengli Oil-field. The imaging test of plane-wave LSRTM algorithm and its comparison with RTM and poststack LSRTM verify that the prestack LSRTM has the advantages including: (1) resolution enhancement and amplitude compensation in mid-deep part with the increase of iterations which can be compared to poststack LSRTM (2) high computational efficiency to be practical (3) stable convergence even when the velocity model is complex.

Acknowledgement

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References

Nemeth, T., Wu, C. and Schuster, G.T. [1999] Least-squares migration of incomplete reflection data. *Geophysics*, **64**(1), 208-221.

Kuehl, H. and Sacchi, M. [2002] Robust AVP estimation using least-squares wave-equation migration. *2002 SEG Annual Meeting*.

Hu, J., Schuster, G.T. and Valasek, P.A. [2001] Poststack migration deconvolution. *Geophysics*, **66**(3), 939-952.

Schuster, G.T., Wang, X., Huang, Y., Dai, W. and Boonyasiriwat, C. [2011] Theory of multisource crosstalk reduction by phase-encoded statics. *Geophysical Journal International*, **184**(3), 1289-1303.

Dai, W., Wang, X. and Schuster, G.T. [2011] Least-squares migration of multisource data with a deblurring filter. *Geophysics*, **76**(5), R135-R146.

Dai, W., Fowler, P. and Schuster, G.T. [2012] Multi-source least-squares reverse time migration. *Geophysical Prospecting*, **60**(4), 681-695.

Zhang, Y., Sun, J., Notfors, C., Gray, S.H., Chernis, L. and Young, J. [2005] Delayed-shot 3D depth migration. *Geophysics*, **70**(5), E21-E28.