Converted-Wave Prestack Time Imaging without using P-Wave

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Summary

In converted-wave processing, velocity analysis and CCP (common conversion point) binning depend on each other due to time varying nature of conversion-points. In pre-processing, velocity analysis usually is done on ACP (Asymptotic conversion point) gathers insteads of on CCP gathers, which affects accuracy of velocity model specially for shallow parts. Prestack time migration can naturally handle this problem, thus becomes more important in converted-wave processing to detect subsuface subtle straitigraphic variation. To update velocities for converted-wave prestack time migration, we have developed a method to use converted-wave data only without using P-wave data and applied it to several 4D 3C surveys. The advantages of the method are that it avoids converting velocities among different travel times and the procedure itself is more straight forward. The results show that the prestack time migration produces much better images compared with the CCP mapping and post-stack migration processed data even for less structural straitigraphic area.

Introduction

In recent years, 4D time lapse multi-component surveys become widely used technologies for helping heavy oil recovery, because shear waves carry more information about seismic absorption, viscosity and etc.. In the 3C processing, it is critical to build up an accurate subsurface velocity model for converted-wave imaging. Post-stack migration usually analyzes velocities in ACP gathers, which is less accurate for shallow zones. Therefore, even for relative flat area, converted-wave prestack time migration is strongly recommended, since it is a nature domain to take into account of binning and velocity updating together. However, to conduct converted-wave prestack time migration, there are more than one velocities need to be estimated. They includes C-wave velocity V_c, vertical velocity ratio γ_0 and effective velocity ratio $\gamma_{eff.}$ In this paper, we have shown a method to update velocities for converted-wave prestack time migration (Miao & Zuk, 2007) and applied it to several 4D 3C data.

Theory and Method

The velocity estimation for converted-wave prestack time migration is much more complicated than for P-wave. The conventional method is to process P-wave data first to get P-wave velocity (V_p), and process converted-wave data to get velocity ratio gamma (V_p/V_s), then derive S-wave velocity (V_s) from V_p and gamma. Since these velocities are in different travel times, converting among them requires very accurate vertical velocity ratio (γ_0). Errors in V_p estimation may be carried over to V_s too. Even though you have very good estimation of P-wave velocity from P-wave data, errors in vertical velocity ratio can also cause problems in migration velocities.

To avoid converting velocities among P-wave time, C-wave time, and S-wave time, we have developed a method by using converted-wave data (Miao & Zuk, 2007) to estimate velocities for prestack time migration without using P-wave data. It requires less accurate vertical velocity ratio, because all the velocities estimated are in C-wave travel time only (Miao & Zuk, 2007, Li, 2003). As mentioned in our previous paper, V_c controls the 1st order moveout, which is the hyperbolic moveout part. Effective velocity ratio (γ_{eff}) affects the intermediate offset moveouts and anisotropic parameter χ_{eff} only affects far offset in the moveout equation. However, binning of the data is mostly determined by $\gamma_{eff.}$ Errors in its estimates may produce poor images especially for shallow zone. Replacement shear-wave velocity is also an important parameter needs to be estimated. All these parameters can be naturally estimated using common imaging gethers in prestack time migration.

Examples

We have applied our technology to several 4D 3C data in heavy oil area. At first we used the initial velocities estimated from pre-processing and created initial imaging gathers for migration velocity updating. The C-wave velocity V_c was convergent quickly after a couple of times of iterations due to good resolutions in its semblance spectra (Miao & Zuk, 2007). But images in the shallow area were still not good. This is mostly due to incorrect $\gamma_{eff.}$ Since γ_{eff} only contributes to the intermediate and far offset moveouts, the resolution of its semblances is not high enough. γ_{eff} scanning was conducted to find more correct binning of the data.

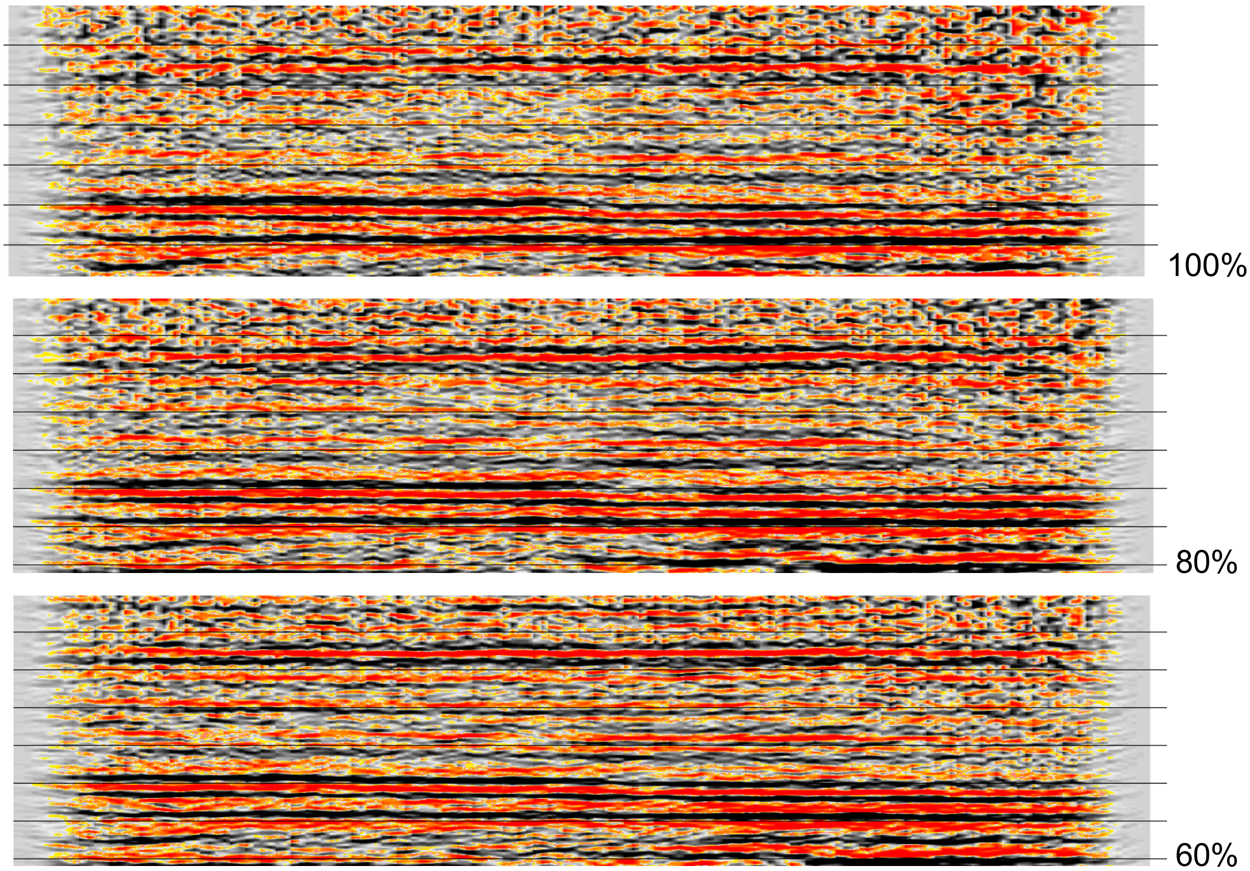

Figure 1: Effective gamma γ_{eff} scan. Top: the migrated section with 100% of the initial γ_{eff}; Middle: the migrated section with 80% of the initial γ_{eff}; Bottom: the migrated section with 60% of the initial γ_{eff} .

For relative flat area, lateral mis-positioning of the data due to errors in the converted-wave binning is a critical problem for image focusing. Figure 1 shows effective gamma scanning results. We created migration stacks for the shallow zones with 60% -120% of the initial γ_{eff} for every 10% increment. Figure 1 shows migrated stacks for 100%, 80% and 60% of the initial γ_{eff} without changing any other parameters. By comparison of the three sections, one can see that with 60% of $\gamma_{eff,}$ the image is much better focused, the seismic energies become much more coherent.

With new γ_{eff} picks we updated V_c again and created final images. Figure 2 shows a comparison between converted-wave post-stack time migration and prestack time migration. On the left side of the Figure 2 are the CCP mapping and post-stack time migrated sections, and on the right side are the prestack time migration results. Figure 2a is the migrated section for a chosen inline and Figure 2b is a crossline migrated section of the same data. They both demonstrate that the prestack time migration has greatly improved image qualities by producing more coherent reflection events with higher resolutions. The structures are more interpretable as well. The elevation change for this line is less than 60m in inline direction and 40m variation in crossline direction. The area is relative flat, but prestack time migration still produced better results mainly due to more accurate velocity estimation in prestack domain than in the post-stack domain.

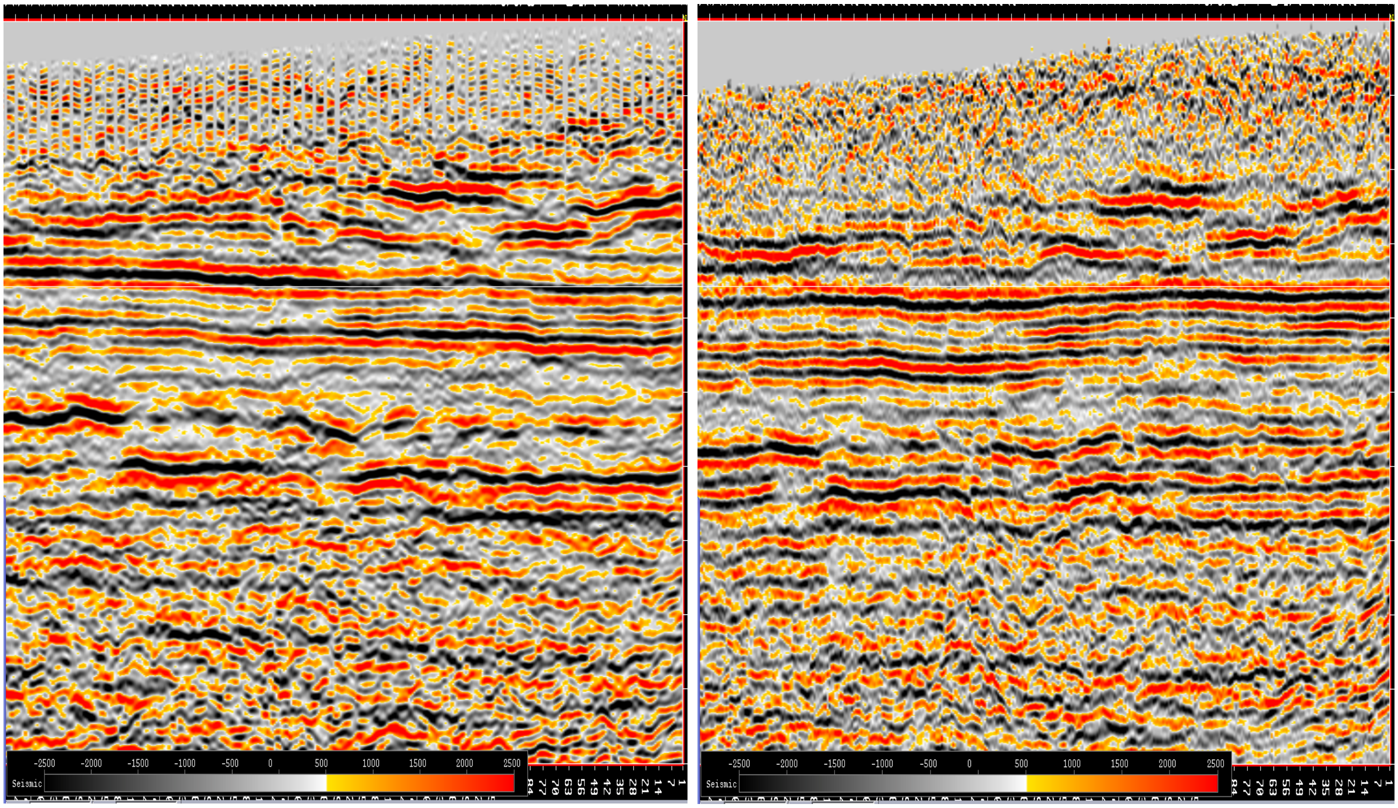

Figure 2a: Comparison of converted-wave post-stack with prestack time migration. An inline section. Left: post-stack time migration; Right: prestack time migration.

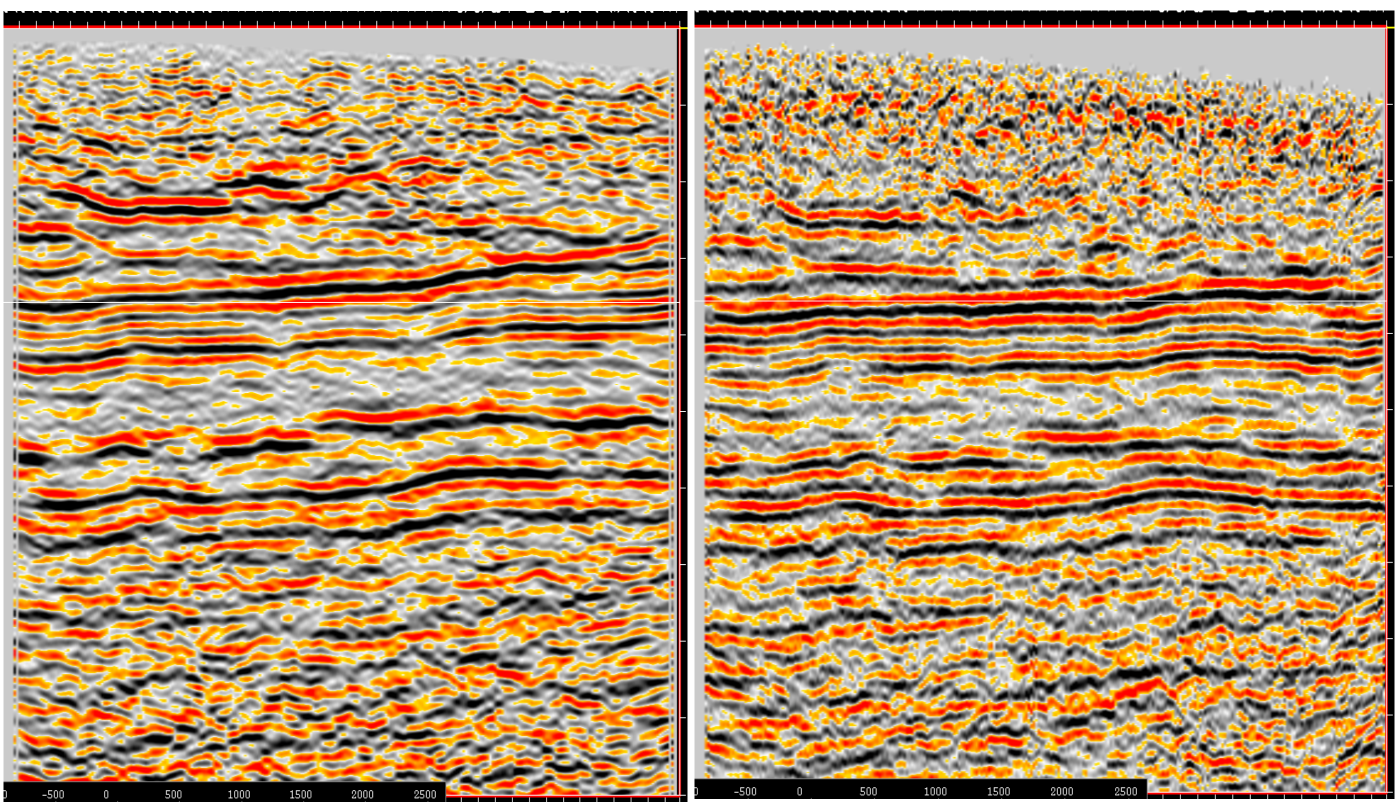

Figure 2b: Comparison between converted-wave post-stack and prestack time migration. A crossline section. Left: post-stack time migration; Right: prestack time migration.

Conclusions

Velocity updating is critical for converted-wave prestack time migration. Using converted-wave data only to estimate velocities for migration is more straight forwad. It avoids converting velocities from different travel times and reduces estimation errors. The results show that using our method the prestack time migration produces images with higher resolution and better continuities compared with the results by using CCP binning and pos-tstack time migration.

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