PSKey Technologies for Processing of Seismic Data in Gas Cloud Area, Bohai Bay Basin*

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Search and Discovery Article #42093 (2017)**
Posted June 19, 2017

*Adapted from poster presentation given at AAPG 2017 Annual Convention and Exhibition, Houston, Texas, April 2-5, 2017

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Abstract

There are great difficulties in structure imaging within a gas cloud area due to serious energy attenuation and the velocity lateral variation. Gas cloud imaging can be improved by using a multi-component data, or by using a special seismic acquisition geometry to avoid propagation of seismic wave through gas cloud. By optimizing conventional P-wave processing routine and combination of various specific techniques, this paper demonstrates how to reduce the effects of gas cloud and improve structure imaging. In the proposed workflow, matching pursuit Fourier interpolation (MPFI) is applied. By using anti-leakage Fourier transform, it reconstructs near-offset data, reduces acquisition footprints and then improves the quality of pre-stack data. Besides, MPFI avoids spatial aliasing on account of the weighted high frequency data with respect to prior. The workflow groups several methods to attenuate different kinds of multiples. First, single streamer deghosting is applied to attenuate ghost waves and enhance low frequency energy. Then, deterministic water-layer demultiple and general surface multiple prediction are applied to remove seabed-related multiples and long-range multiples respectively. A key step of seismic processing in gas cloud area is energy compensation. This workflow uses Q tomography to compensate energy during depth migration, which is a specific energy compensation technique for gas cloud area. It estimates a space- and depth-variant Q field by using attenuated traveltime tomography. Then, model-driven Q compensation is realized directly during depth migration. Conventional reflection tomography cannot build an accurate velocity model, where lateral variation of velocity is severe and quality of seismic data is poor. To address this problem, Diving-wave refraction tomography is applied to generate a relative accurate initial velocity model in shallow. Then, a global velocity model is generated iteratively by reflection tomographic. The low-velocity area of final velocity model matches very well with the low energy area of seismic data, and the model shows a similar trend with acoustic velocity. Processing of a real data set in gas cloud area from X oilfield, Bohai Bay, proves the advantages of the proposed workflow, which improves structure imaging inside the gas cloud area and is prominently superior in faults detection.

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Key Technologies for Processing of Seismic Data in Gas Cloud Area, Bohai Bay Basin

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Abstract: There are great difficulties in structure imaging within a gas cloud area due to serious energy attenuation and the velocity lateral variation. Gas cloud imaging can be improved by using a multi-component data, or by using a special seismic acquisition geometry to avoid propagation of seismic wave through gas cloud. By optimizing conventional P-wave processing routine and combination of various specific techniques, this paper demonstrates how to reduce the effects of gas cloud and improve structure imaging. In the proposed workflow, matching pursuit Fourier interpolation (MPFI) is applied. By using anti-leakage Fourier transform, it reconstructs near-offset data, reduces acquisition footprints and then improves the quality of pre-stack data. Besides, MPFI avoids spatial aliasing on account of the weighted high frequency data with respect to prior. The workflow groups several methods to attenuate different kinds of multiples. First, single streamer deghosting is applied to attenuate ghost waves and enhance low frequency energy. Then, deterministic water-layer demultiple and general surface multiple prediction are applied to remove seabed-related multiples and long-range multiples respectively. A key step of seismic processing in gas cloud area is energy compensation. This workflow uses Q tomography to compensate energy during depth migration, which is a specific energy compensation technique for gas cloud area. It estimates a space- and depth-variant Q field by using attenuated travel-time tomography. Then, model-driven Q compensation is realized directly during depth migration. Conventional reflection tomography can't build an accurate velocity model, where lateral variation of velocity is severe and quality of seismic data is poor. To address this problem, Diving-wave refraction tomography is applied to generate a relative accurate initial velocity model in shallow. Then, a global velocity model is generated iteratively by reflection tomographic. The low-velocity area of final velocity model matches very well with the low energy area of seismic data, and the model shows a similar trend with acoustic velocity. Processing of a real data set in gas cloud area from X oilfield, Bohai bay, proves the advantages of the proposed workflow, which improves structure imaging inside the gas cloud area and is superior in faults detection.

1 X oilfield and Seismic data

X oilfield is located at the eastern side of Tan Lu fault zone. Because of the activity of Tan Lu fault, gas transports upwards to the shallow structure. There is 20 km^2 gas trapped above the main structure of the oilfield. As shown in Figure 1, the gas area presents as a strip from south to north. Seismic energy is seriously attenuated in the strip. As shown in Figure 2, the profile across the gas cloud area is obscure and can hardly provide any information. Well A is drilled in this area and reveals 157.7m oil sand. However, it is hard to understand the structure or reservoir based on the conventional processed seismic data. Special processing technique is crucial for effective development of X oilfield.

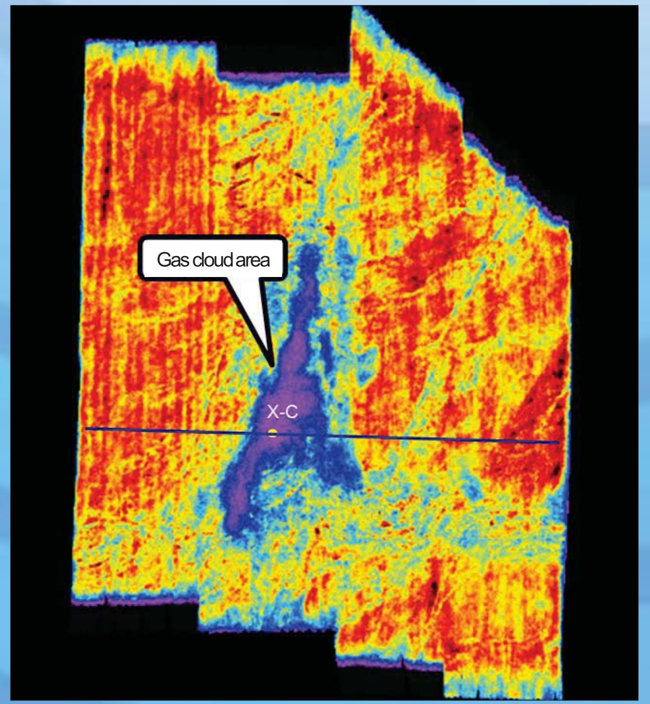

Fig.1 RMS amplitude of Seismic data in target layer.

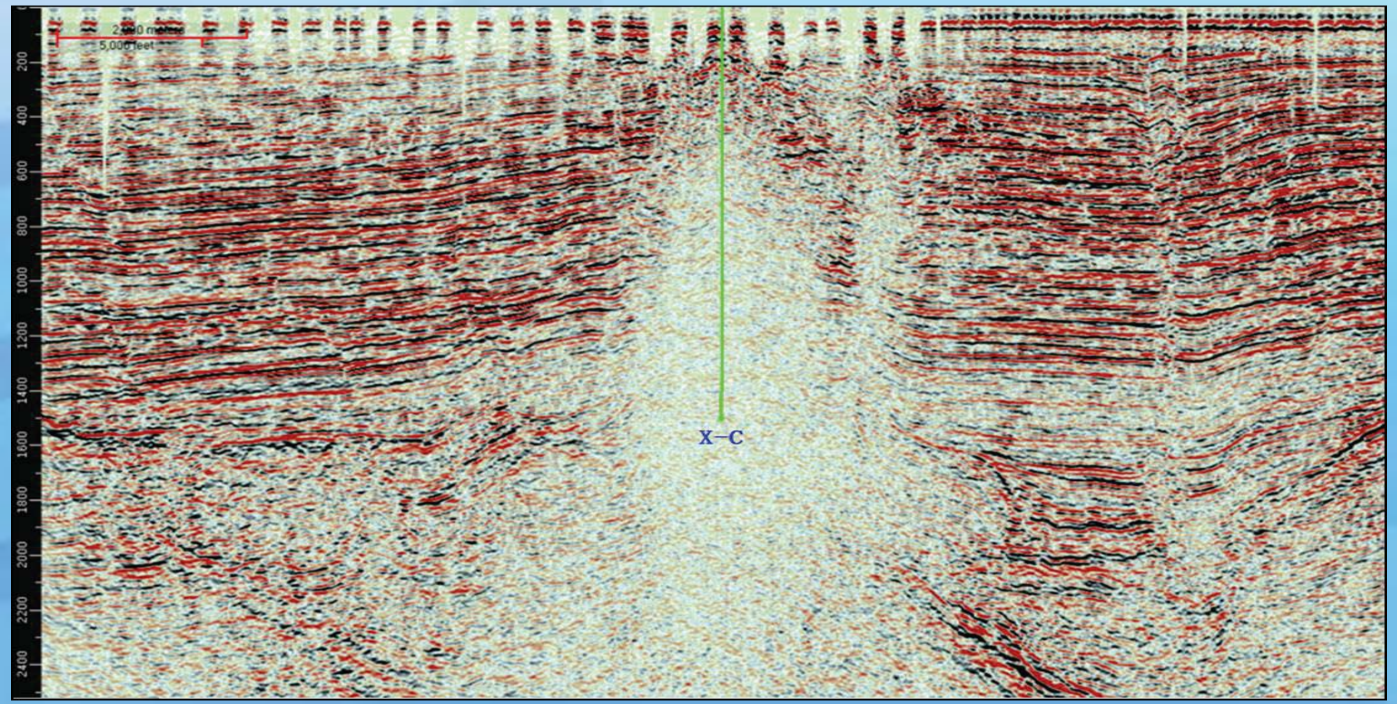

Fig.2 Profile across the gas cloud area at Well C location.

2 Processing technologies

To address two problems in gas cloud area, serious energy attenuation and lateral velocity variation, we uses Q tomography technology to compensate the energy lost in gas cloud structure, and DWT to build high precision velocity model. With the aid of other specific technologies, such as interpolation and de-multiple methods, a targeted processing workflow is presented.

2.1 Q tomography - energy compensating

A key step of processing in gas cloud area is energy compensation. This workflow uses Q tomography to compensate energy during depth migration, which is a specific energy compensation technique for gas cloud area. It estimates a space- and depth-variant Q field by using attenuated travel time tomography. Then, model-driven Q compensation is realized directly during depth migration. There are three main steps during Q tomography.

(1) Estimating attenuated travel time from amplitude spectrum or frequency shift characteristics.

(2) Generating space-variant Q field by using attenuated travel time tomography. The attenuated travel time is denoted as,

$$t^* = \int_{ray} \frac{Q^{-1}(s)}{v(s)} ds \qquad (1)$$

For a given velocity field, Q field can be solved from depth domain ray tracing,

$$\delta t^* = \sum_{(i,j,k)\in ray} t_{i,j,k} \delta Q_{ijk}^{-1} \qquad (2)$$

Where δt^* is the difference between attenuated travel time calculated from 3D original Q field and travel time estimated in step 1, t_{ijk} is travel time in grid (i,j,k), δQ_{ijk}^{-1} is updating amount in grid (i,j,k).

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(3) Considering the solved Q field in depth migration operator, and Q compensation can be realized directly during the depth migration.

As we can see in Figure 3, by using Q tomography, the energy in mid-depth is well compensated. Seismic response of the unconformity plane above buried hill is clearer.

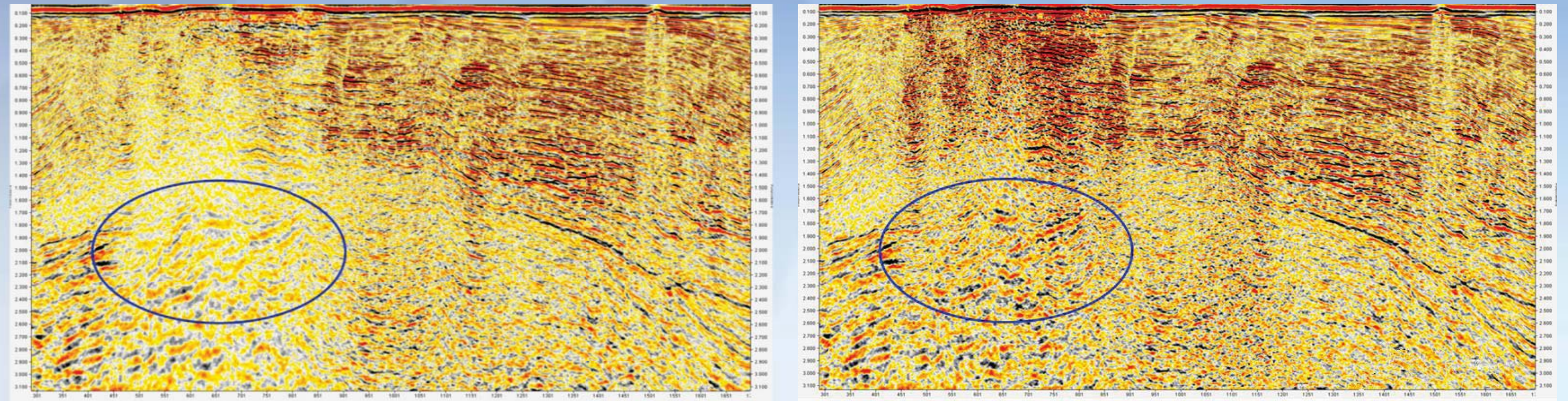
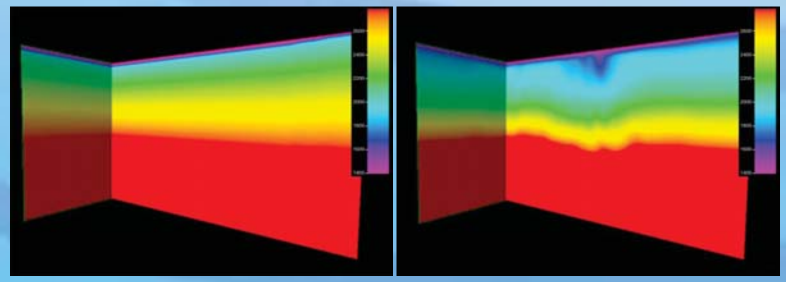


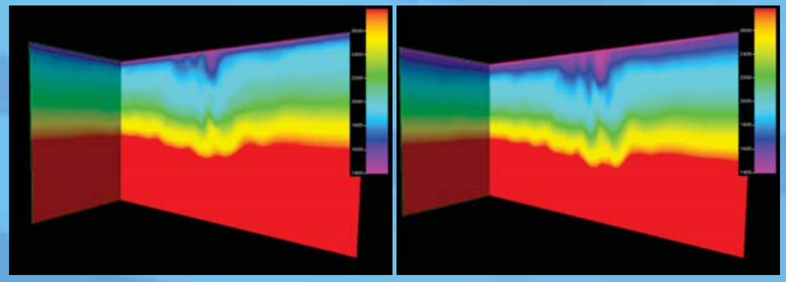
Fig.3 Stack section before Q tomography (Left)， and after Q tomography (Right)

2.2 Diving-wave refraction tomography - velocity modeling

Conventional reflection tomography can't build an accurate velocity model where lateral variation of velocity is severe and quality of seismic data is poor, especially in shallow structure where gas cloud accumulates. Comparing to reflection wave, the first arrival of diving wave carries more useful information for shallow structure. We combines reflection tomography and diving-wave refraction tomography (DWT) in velocity modeling, in which diving-wave refraction tomography is applied to generate a relative accurate initial velocity model in shallow structure. Then, a global velocity model is generated iteratively by reflection tomographic.

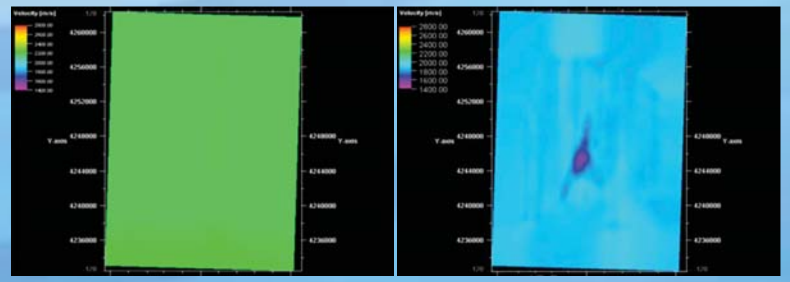


The initial velocity model The first iteration（200x200m）

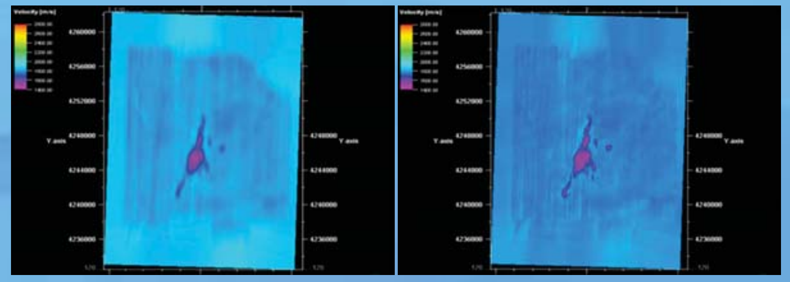


The second iteration（100x100m） The third iteration（50x50m）

Fig.4 DWT velocity model at different iteration



The initial velocity model The first iteration（200x200m）



The second iteration（100x100m） The third iteration（50x50m）

Fig.5 DWT velocity slices at depth 120m

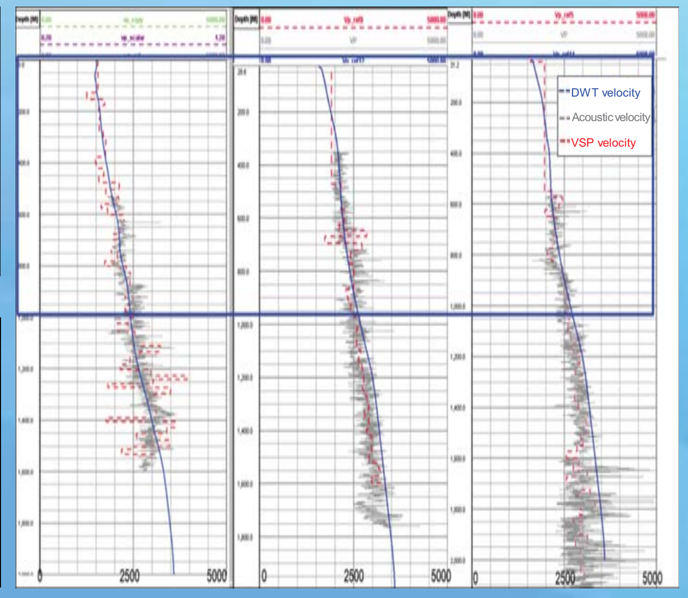


Fig.6 Comparing DWT velocity with sonic log and VSP interval velocity, for three wells

Figure 4 shows the DWT velocity model at different iteration. Figure 5 shows the velocity slices at depth 120m. As we can see, model details increase with iterations. Low-velocity area of the final model matches well with low-energy area of the seismic data, which indicates gas cloud. Figure 6 compares DWT velocity with sonic log and VSP interval velocity for three wells. For depth less than 1km, DWT velocity of all three wells are roughly in line with the trend in sonic and VSP. It provides an accurate initial velocity model for the following reflection tomography.

2.3 MPFI – data regularization

The seismic data of X oilfield is irregular, and the near offset data is badly missing. To address this problem, matching pursuit Fourier interpolation (MPFI) technique is applied. MPFI can reconstruct near-offset data, reduce acquisition footprints and then improve the quality of pre-stack data. Besides, it avoids spatial aliasing on account of the weighted high frequency data with respect to prior. Figure 7 and Figure 8 prove that MPFI is effective in regulating data and reducing footprints.

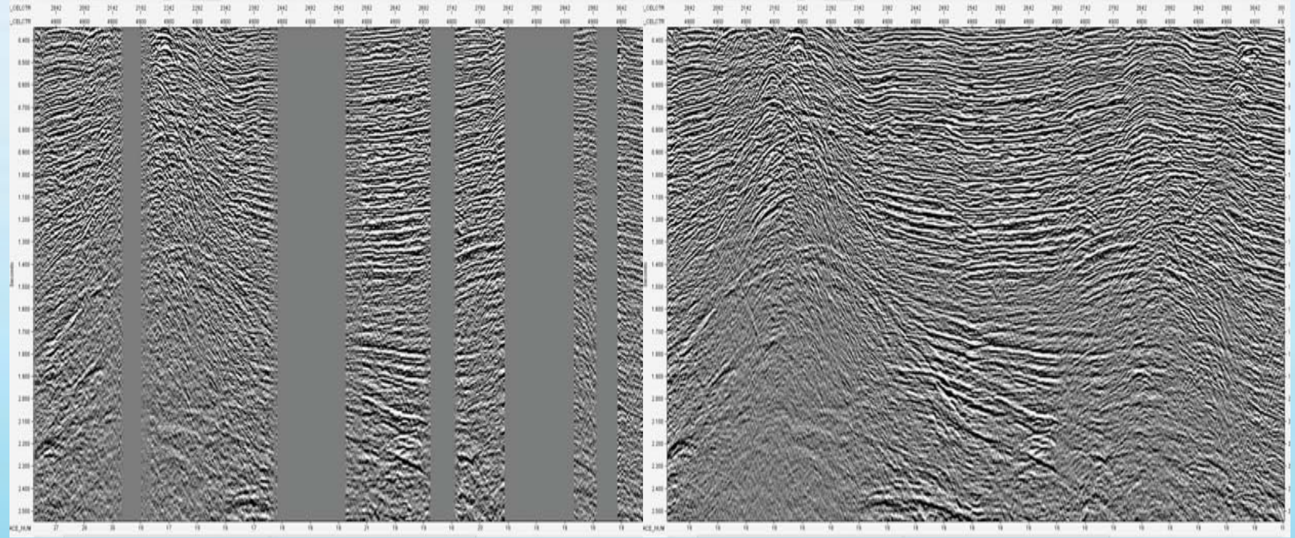


Fig.7 Single offset section before (Left) and after (Right) MPFI

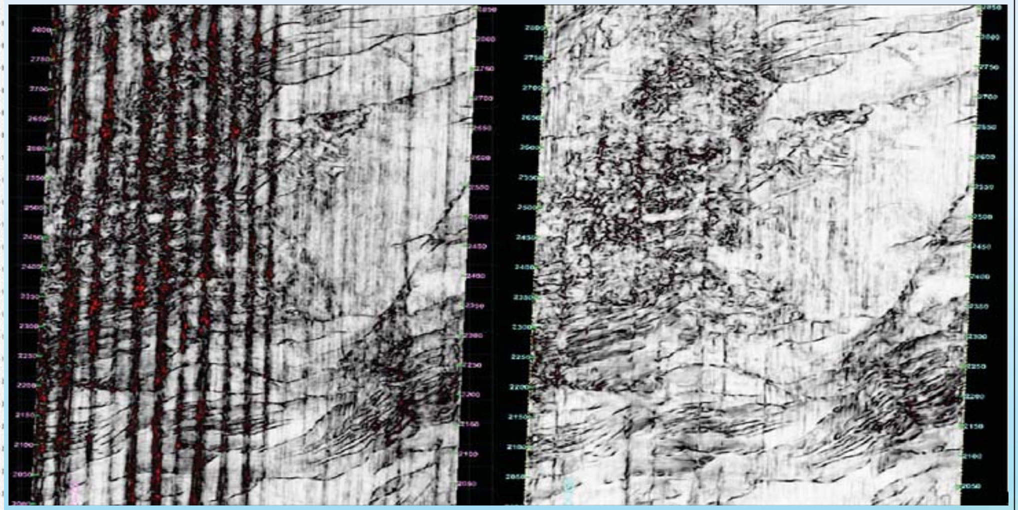


Fig.8 Variance slice before (Left) and after (Right) MPFI

2.4 DWD+GSMP – multiple suppression

Water depth at X oilfield is about 30m. Because of the shallow water, travel time of first arrival is close with seabed reflection. What's more, the nearest offset is bigger than water depth, which means seismic data lacks of seabed near offset reflection. In this case, de-multiple by prediction and subtracting, such as SRME, is not available. To address this problem, we use deterministic water-layer demultiple (DWD) and general surface multiple prediction (GSMP) to remove multiples.

DWD is specially designed to suppress multiples in shallow sea. Comparing to SRME, it depends less on near offset data. It mainly suppresses seabed related short-path multiple. Figure 9 shows the stack section before and after DWD, multiples at 300ms are well suppressed.

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GSMP is based on the principle of SRME. It extends SRME to 3D domain. As we know, multiples not only come from the vertical plane between source and receiver, but also come from offside reflectors. GSMP predict multiples with in a given 3D aperture. The predicted multiple model is more applicable to complex reflection. Figure 10 shows the stack section before and after GSMP, multiples in complex reflection are well suppressed.

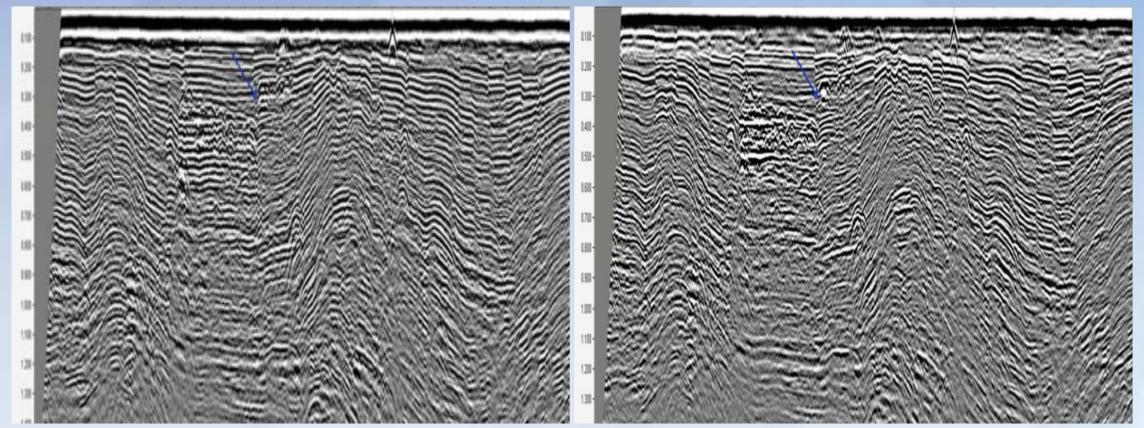

Fig.9 Stack section before (Left) and after (Right) DWD

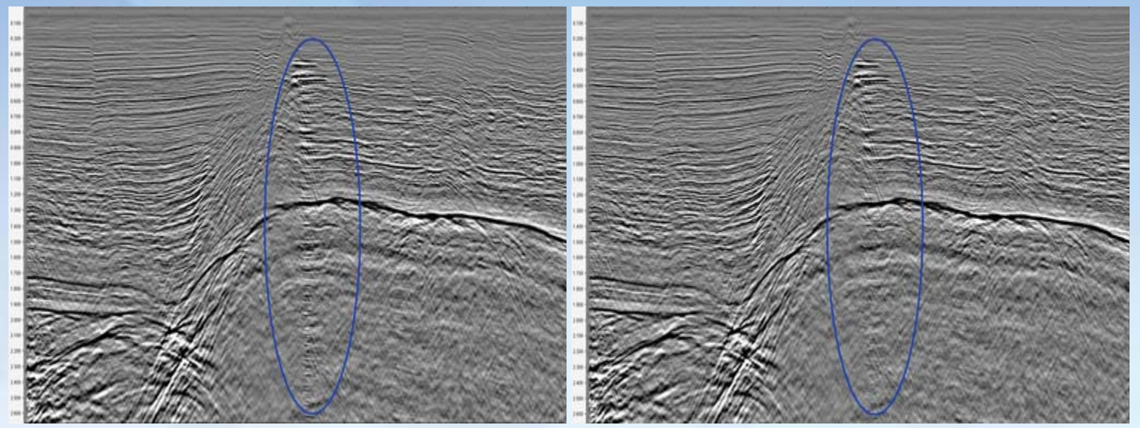

Fig.10 Stack section before (Left) and after (Right) GSMP

3 Work flow and application

Based on the processing techniques discussed above and other conventional routine, we organized the processing workflow specifically for gas cloud area. Figure 11and Figure 12 shows the seismic data and variance after application of the processing workflow.

Structure imaging is greatly improved inside the gas cloud area. The effects of gas cloud area are reduced. Structure interpretation is available.

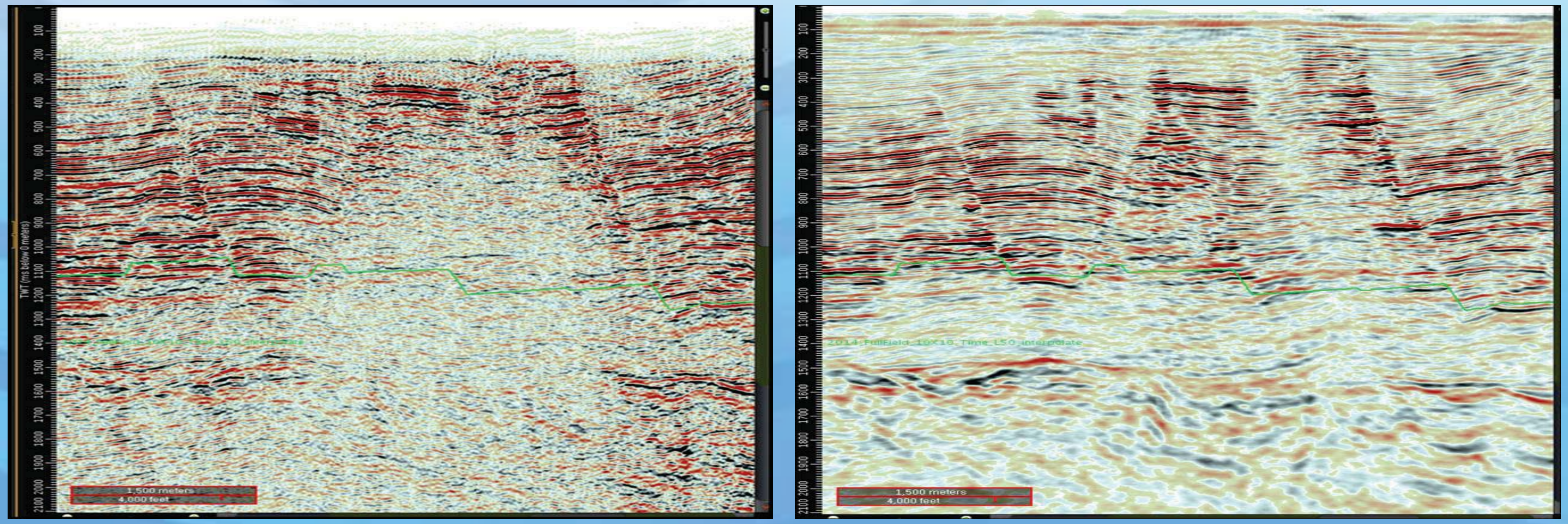

Fig.11 Conventional processed data (Left), new processed data (Right)

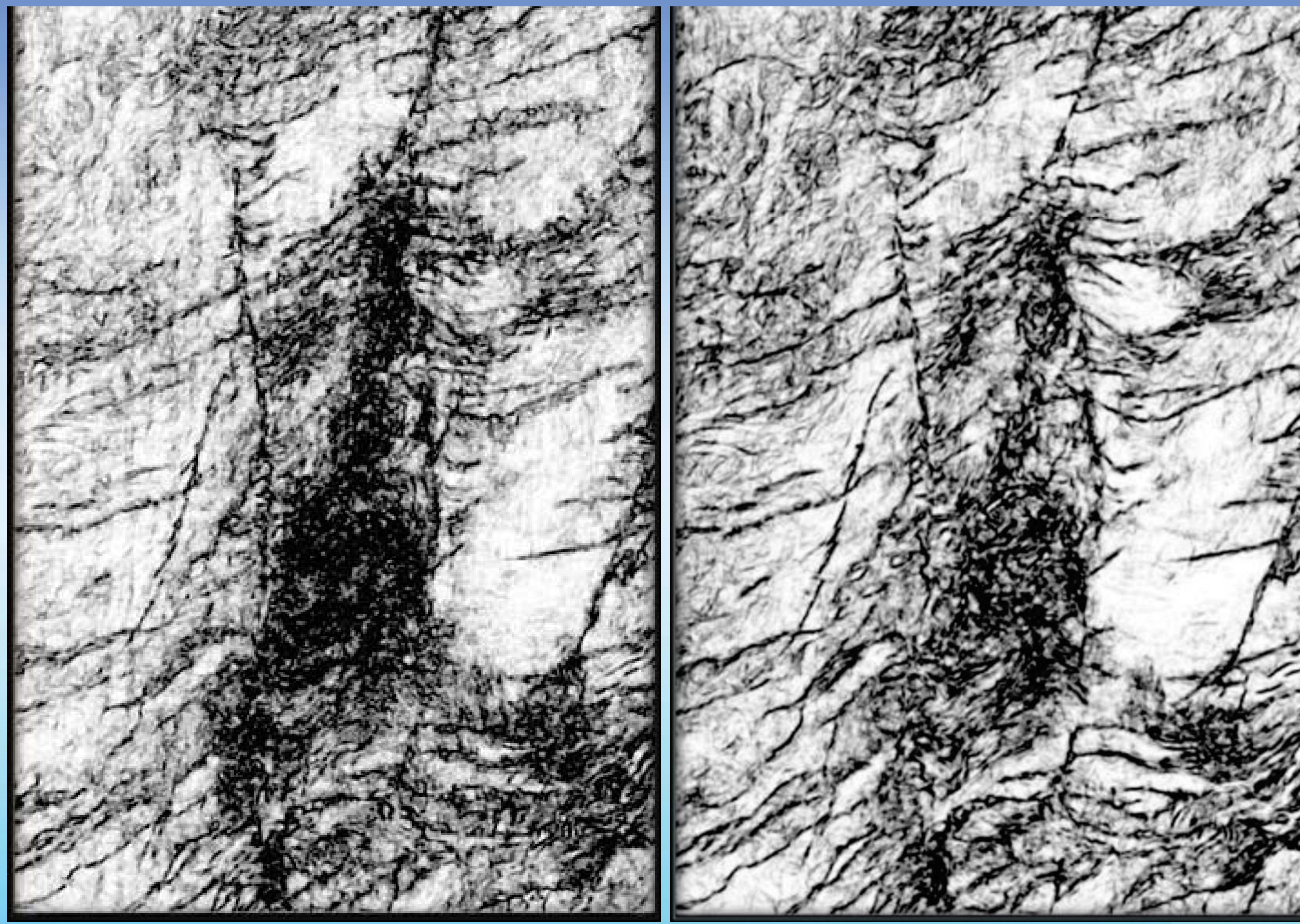

Fig.12 Variance of conventional processed data (Left) and new processed data (Right).

4 Conclusion

By optimizing conventional P-wave processing routine and combination with various specific techniques, including Q tomography, DWT, MPFI, DWD and GSMP, it reduces the effects of gas cloud and improves structure imaging. Processing of the real data set in gas cloud area from X oilfield, Bohai bay, proves the advantages of the proposed workflow, which improves structure imaging inside the gas cloud area and is prominently superior in faults detection.