Simplify the variable-depth streamer data processing through pre-migration deghosting: a case study from NWS Australia Data

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SUMMARY

Variable-depth streamer acquisition, as one of the key marine broadband solutions, has shown great advantages in providing high resolution seismic imaging and better low frequency penetration than conventional data from examples around the world. By utilizing the notch diversity, the receiver ghost was fully removed through proprietary joint deconvolution method in the imaging domain which produces broadband imaging with bandwidth up to six octaves. However, this post-migration deghosting method requires the receiver ghost to be well preserved prior to final migration thus introduces complexity in key steps like multiple attenuation, velocity analysis and migration than the conventional processing flow.

The objective of this work is to simplify the processing flow by applying bootstrap deghosting method right after shot domain de-noise. After this step, processing flow will be very similar to the conventional flow. This new flow has been tested on the variable-depth streamer data from NWS Australia. Compared to the post-migration deghosting flow, the new results not only provide similar benefit as to broader bandwidth and rich images, but also show improvement on multiple attenuation and primary preservation as well as seismic inversion.

Key words: bootstrap deghosting, joint deconvolution, variable-depth streamer, marine broadband

INTRODUCTION

For a variable-depth streamer (Broadseis) acquisition, the receiver deghosting has been performed in the imaging domain using a joint deconvolution method with both normal and mirror migration input (Soubaras, 2010). It allows a true 3D deghosting as well as an optimal signal-to-noise deghosted output, which has consistently produced high quality broadband images with bandwidth up to six octaves around world. However to obtain such a uplift, the receiver ghosts need to be well preserved until migration stage for post migration joint deconvolution thus the processing flow has to be adjusted to address the issues related to the variable receiver ghosts especially in the multiple attenuation steps like SRME and Radon, which add complexity and effort of the processing. If the receiver ghost can be reasonably eliminated in the early stage of the processing, then the standard marine processing flow can be applied after this step. With the most recent development of bootstrap deghosting algorithm (Ping, 2012), it becomes possible for us to simplify the Broadseis processing flow. To prove the concept, we tested the bootstrap deghosting algorithm right after the shot domain denoise on the NWS Australia 2D BroadSeis data, which was acquired with a cable profile from 7m to 50m over the major discoveries in Northwest Shelf of Australia including the Gorgon and Wheatstone fields.

In this paper, we will first discuss the multiple attenuation methods for the Broadseis data and then introduce the bootstrap deghosting method and its limitation. We will also show some PSTM imaging and inversion result to demonstrate the effectiveness of the simplified Broadseis processing flow.

DE-MULTIPLE PROCESS

For post-migration deghosting approach, de-multiple process is complicated and challenging. The different waveforms from near to far offsets make it difficult for SRME model prediction. A Broadseis SRME sequence has been developed to create multiple model that is close to the waveform of recorded multiples. In this sequence, SRME model is predicted using deghosted input and then the model is reghosted prior to model subtraction. This sequence has been proven to produce more superior results than a traditional SRME method (Sablon R, 2011). Diagram 1 illustrates the new SRME flow for post-migration deghosting.

Furthermore, the parameter of pre-migration Radon demultiple process has to be very mild in order to preserve the receiver ghosts. The recent development suggests splitting up and down going wave data, and then apply Radon de-multiple on both data before adding them again. This allows a harsher Radon parameter to be applied; nevertheless, the approach is resource intensive and requires much more time for testing and QC. Diagram 2 below demonstrates the new Radon demultiple flows.

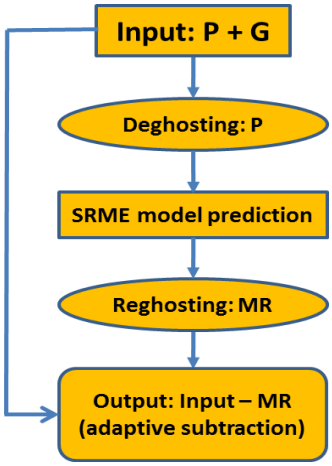

Diagram 1. New SRME flow for post-migration deghosting method

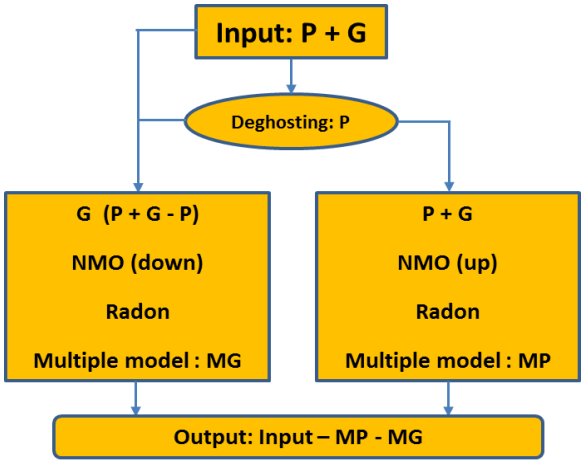

Diagram 2. New Radon demultiple flow for post-migration deghosting method

For pre-migration deghosting approach, the flow is almost identical to conventional data processing flow since the receiver ghost was removed in the beginning of the sequence. Hence this method significantly reduces the testing and production QC efforts as compared to post-migration deghosting approach.

Fig. 1 shows the PSTM stack comparison between pre-migration deghosting and post-migration deghosting. The former has less residual high frequency multiple in the stack section.

BOOTSTRAP DEGHOSTING

CGG bootstrap deghosting algorithm produces mirror data from recorded shot data through 1D ray tracing based normal moveout correction; then both the recorded and mirror data are used to jointly invert for the ghost-free data. The method works on a localized T-XY window in which all events should have a similar ghost-delay time. In a very complex geological area where ghosts will be received from different angles, the method may not work properly. The difference of ghost delay-time in a localized window needs to satisfy $\Delta t < 1/(4 f_{max})$, where f_{max} is the maximum frequency of the data.

Fig. 2 shows the CMP gathers before and after pre-migration deghosting using bootstrap deghosting method, the receiver ghosts were effectively removed.

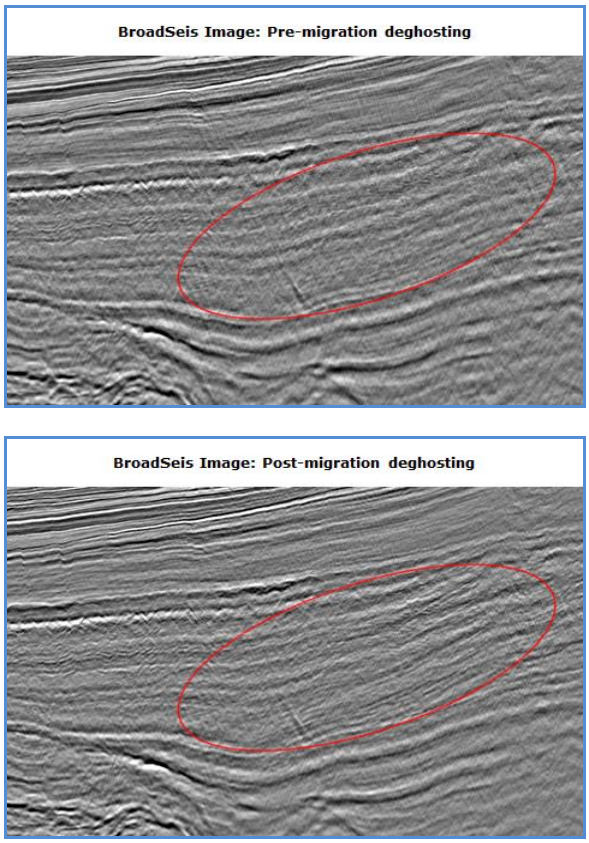

Fig 1. Pre-migration deghosting (above) gives better multiple attenuation result than post-migration deghosting (below) on this 2D data.

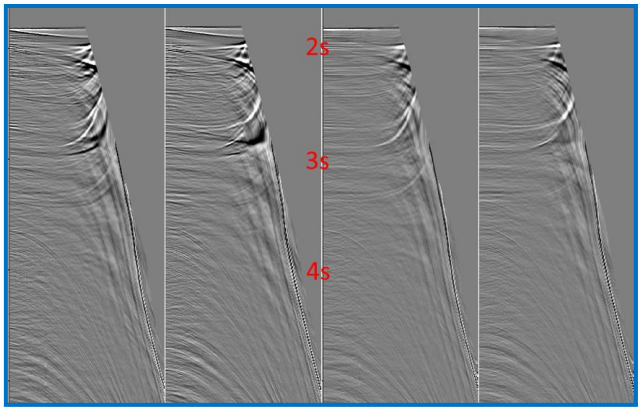

Fig 2. CMP gathers before deghosting (left) and after deghosting (right) in common shot domain.

DATA EXAMPLES

In additional to full stack QC, the comparisons of high frequency Bandpass filtered stacks and inversion results were checked carefully also as high frequency and AVO inversion are very important for NWS Australia data.

Fig. 3 shows that the band-pass filtered result of conventional and BroadSeis stacks using the two methods. Pre-migration deghosting stack clearly gives the best continuity on those circled events.

Simultaneous inversion studies play vital role in integration of well data and seismic data to understand the absolute properties of reservoir. Usually initial Low frequency model is generated by interpolating the calibrated seismic velocities (0-3Hz) in the structural frame of horizons. In absence of sufficient coverage of wells, the missing low frequencies in the range of 3-10Hz provided by BroadSeis helps us to attain better inversion results.

Fig. 4 shows the comparison of wavelets and its amplitude spectrums of conventional data, post-migration deghosting and pre-migration deghosting BroadSeis data. Both the BroadSeis spectrums have quite similar low frequency content with comparable band width.

The example shown in Fig. 5 is the inverted Vp/Vs attribute from conventional, post-migration deghosting and pre-migration deghosting BroadSeis data. Comparison of inversion attributes shows results are quite similar and even slightly better by using pre-migration data for inversion studies.

CONCLUSIONS

In this case study, we have demonstrated that the pre-migration deghosting method can simplifies the Broadseis processing flow significantly for the geological setting of NWS Australia. Compared to the post-migration deghosting flow, the new results not only provide similar benefit as to broader bandwidth and rich images, but also show improvement on multiple attenuation and primary preservation as well as seismic inversion.

ACKNOWLEDGMENTS

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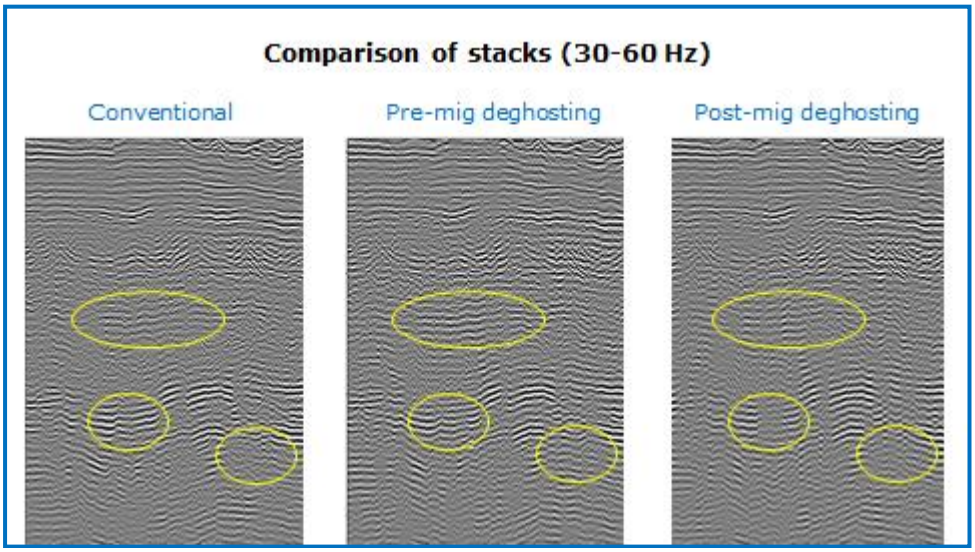

Fig 3. Continuity of high frequency data is better using pre-migration deghosting method.

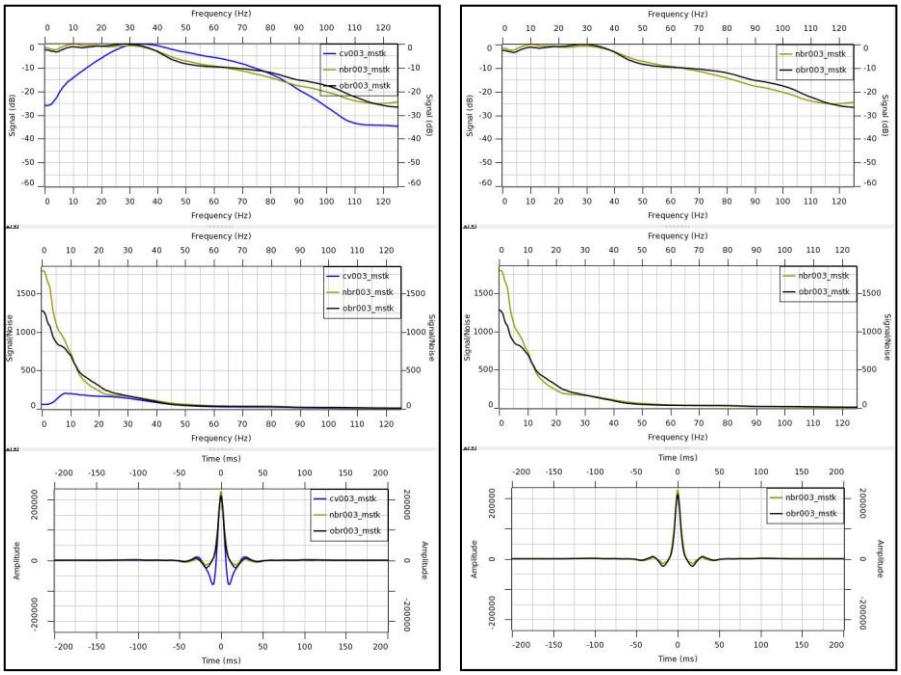

Fig 4. Comparison of wavelets and spectra of conventional (blue curve), post-migration deghosting (black) and pre-migration deghosting (green) data.

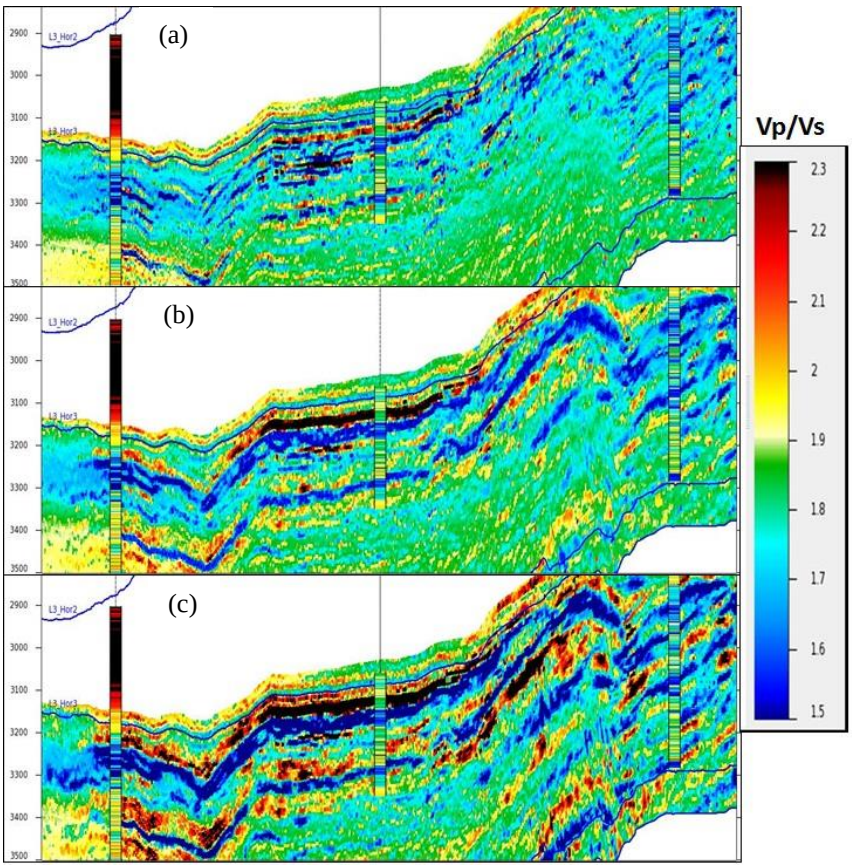

Fig 5. Inverted Vp/Vs section using (a) conventional (b) post-migration deghosting (c) pre-migration deghosting data