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Reviving Old Seismic Data Using Latest Broadband Processing Technology - A Case Study from West Of Shetland

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Summary

A merge of two legacy surveys representing 3500 km2 of marine data from West of Shetland have been reprocessed using the latest available broadband processing sequences and technologies such as offset dependent cold water statics, 3D multi-shot joint deghosting, 4D regularization, and amplitude versus angle compliant spectral enhancement. The result demonstrated successful application of the high-end tailored processing sequence on legacy conventional data, acquired in 1993, can lead to a significant uplifted broadband image with better resolution at shallow and more interpretable structures at depth for reducing the risk for oil and gas exploration.

Introduction

During the last few years, the advances of broadband marine acquisition and processing techniques have provided a huge uplift in the resolution and structural interpretation of the seismic image as well as better seismic reservoir characterisation, especially attributed to the ultra-low frequencies obtained by broadband variable depth streamer acquisition. Thanks to the evolution of modern processing technology, many legacy conventional shallow flat-tow seismic datasets, which were never processed beyond the ghost notches, have been revived by reprocessing them with the latest state-of-the-art broadband processing sequences. Combined with detailed quality control and processing experience, the immediate uplift on bandwidth and image quality can be significant.

This paper presents a reprocessing case study, using high-end technology, applied on two datasets acquired in 1993 and 1996 in the West of Shetland area.

There are various processing challenges in these old data. The water velocity is highly variable thus creates significant time-shifts between adjacent sail lines. The target reservoir interval suffers from water-bottom multiple and volcanic intrusions at depth deteriorates the deeper imaging targets. Finally the subtle pinch-out of the thin reservoir formation was difficult to interpret on the vintage data. The lack of resolution at shallow and interpretability of deeper structure are the reprocessing objectives. In Figure 1, we show the latest processing sequences applied on this data in order to resolve these challenges. We shall focus on the application of cold-water statics, customized water-bottom multiple attenuation, source and receiver 3D deghosting and finally amplitude-versus-angle compliant spectral enhancement.

Processing sequence

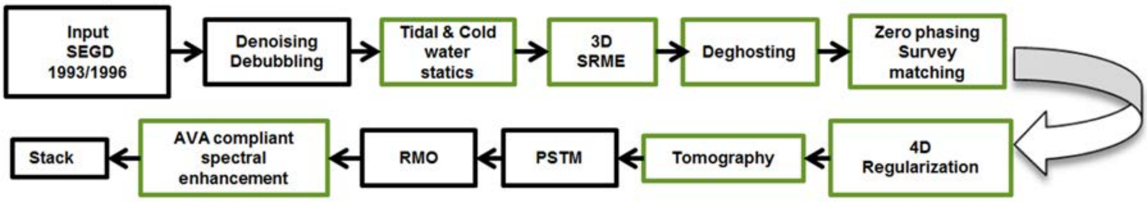

Figure 1:*Processing sequence applied to the dataset. The steps in green will be detailed in this paper*

Tidal and Cold water statics

As marine data are acquired per sail line over a long period, marine surveys in deep water areas often have statics variation between sail lines that are the result of changes of water level (tide) and water velocity. They appear as lateral discontinuity (jitter) on the water bottom and horizons below on a crossline section. As the travel path in the water is different for each offset, the realignment cannot be a simple shift of the data, but must be offset-dependent (correction increasing with offset). In the West of Shetland project these corrections were applied and QC was performed on crosslines to better see the difference between sail lines on near, mid and far offset planes (Figure 2).

To control the quality of the result, the water bottom was picked on near traces before and after statics application, then the gradient was computed in each case. On the gradient map the jitter due to cold water statics can be identified by red stripes in the sail line direction (left to right) (Figure 3a.). After statics application the red stripes have disappeared on the gradient map (Figure 3b.), showing the cold-water statics are well corrected.

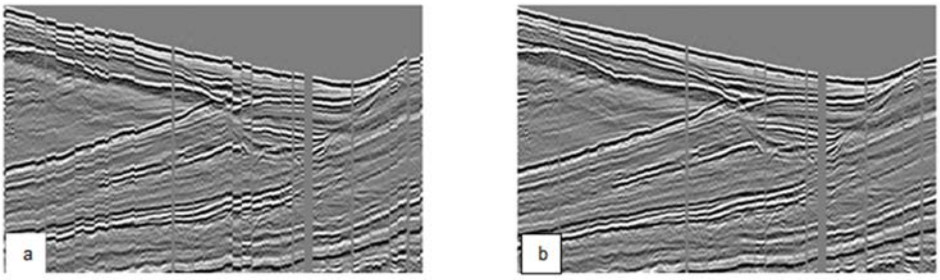

Figure 2: *Near traces in the crossline direction before statics correction (a), vs near traces in crossline direction after statics correction (b).*

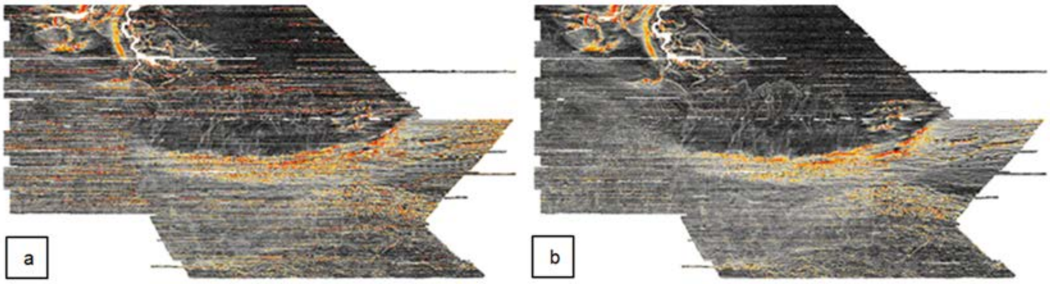

Figure 3: *Gradient map on the water bottom before statics correction (a), gradient map on the water bottom after statics correction (b).*

Broadband 3D SRME with primary protection

After the statics correction 3D Surface Related Multiple Elimination (SRME) was applied. A model of the water bottom multiple was computed and then subtracted. In this area the water bottom was varying from 500ms to 1500ms, and the water bottom multiple was crossing the target area (Figure 4a). In order to achieve broadest signal bandwidth, we need to attenuate the multiples across wide octaves without damaging any primary. After exhaustive testing, we developed a workflow: Subtract the predicted multiple model using frequency-dependent least-square adaptive subtraction, followed by a primary identification and recovery process to best preserve the signal.

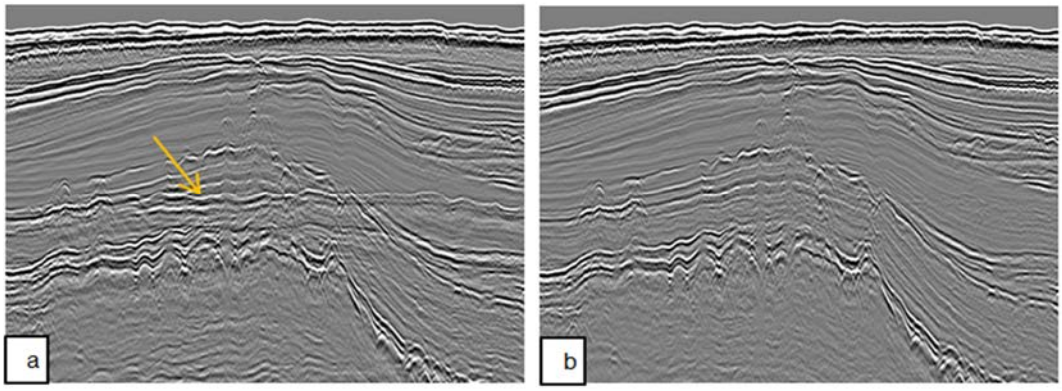

Figure 4: *Stack before (a) and after (b) 3D SRME. The water bottom multiple, highlighted with the arrow (a), overlays the target interval*

Multi-shot deghosting

The better the SRME and preservation of the primaries, the more effective the following deghosting step will be. Deghosting is considered as the most obvious improvement to revive this old seismic data.

In this sequence a 3D deghosting method in joint/shot receiver domain (Poole et al., 2016) was used. This approach is used to produce optimum shot-receiver deghosting results with improved spatial consistency on a conventional dataset, and better low-frequency stability**.** This step allowed us to achieve an image with less residual ghosts at the water bottom (Figure 5).

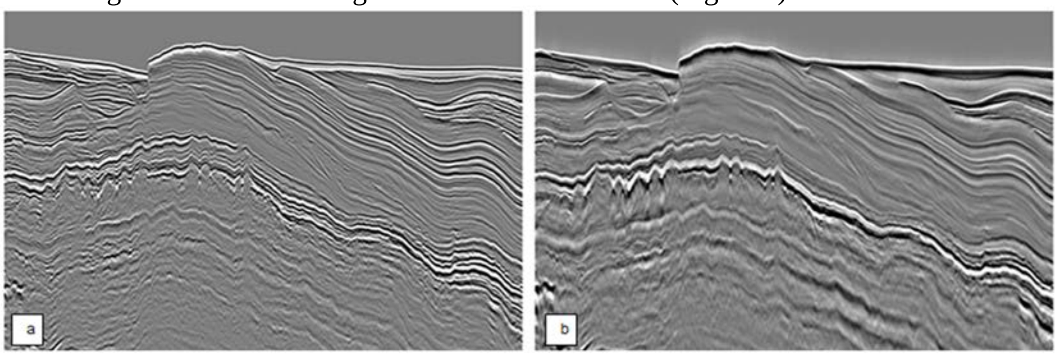

Figure 5: *Stack before (a) vs after multi-shot/receiver deghosting (b)*

4D regularisation, zero-phasing and survey matching

Due to important differences in acquisition parameters between the two surveys, particularly for the minimum offset, a 4D regularization (inline, crossline, time, offset) was performed which additionally helped to populate the first offset class in both cases.

Then, a statistical far field source signature was extracted from the near traces to compute a zero-phasing operator for each survey, QC'ed on octave panels to verify water bottom alignment between surveys (Figure 6b). However, remaining differences were still visible between surveys and so a residual matching operator was computed and applied on survey 1 for seamless merge (Figure 6c).

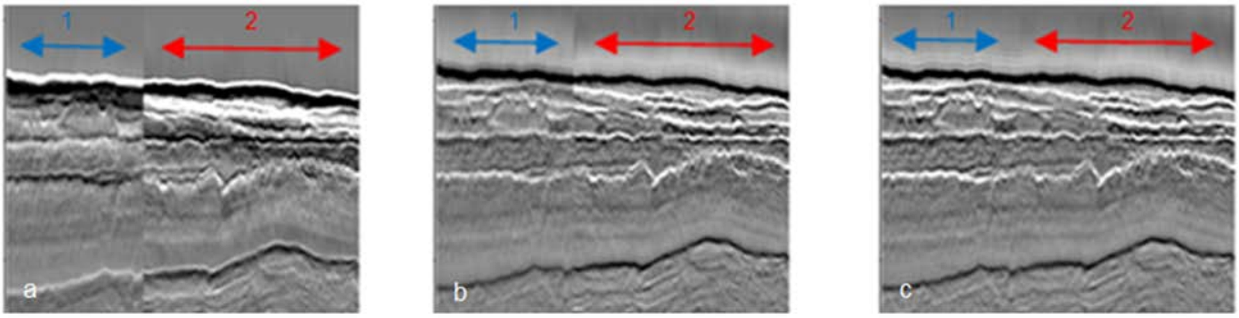

Figure 6: *(a) Inline stack before zero-phasing crossing survey 1 and survey 2, (b) Inline stack after individual zero-phasing , (c) Inline stack after individual zero-phasing and matching*

Pre-STM and AVA compliant spectral enhancement

We adopted a Pre-STM model building technology proposed by (Guillaume et al., 2001), (Lambare et al., 2014). The tomography gave a velocity field smooth enough to be used for the Pre-STM (Figure 7).

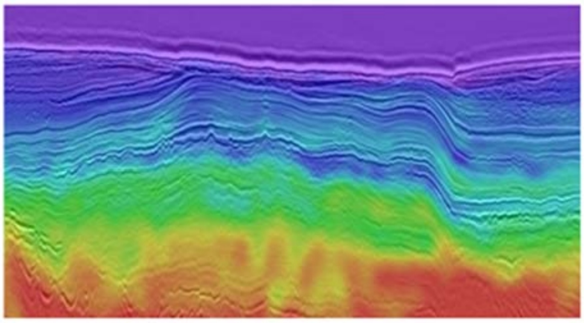

Figure 7: *Interval velocity field after tomographic update on an inline overlaid with seismic data.*

After the Pre-STM, the amplitude-versus-angle (AVA) compliant spectral broadening approach based on non-stationary wavelet deconvolution (Jafargandomi et al., 2016) was applied. The algorithm employs AVA coupling in the pre-stack domain to shape the spectra of all traces in angle gathers simultaneously. As a result, the characteristics of all AVA classes were preserved and spectra of all angles were enhanced and better balanced (Figure 8).

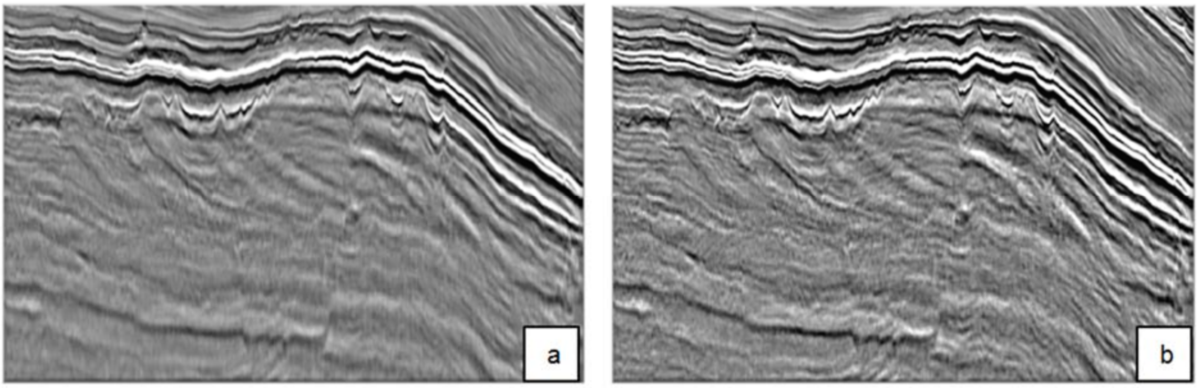

Figure 8: *Stack before (a) and after AVA compliant spectral enhancement (b).*

Result comparison

The objectives of the reprocessing were to better remove the water bottom multiple through the target interval, to improve fault definition and structural detail by increasing the bandwidth and improving the overall signal-to-noise ratio.

On this comparison with legacy volume (processed in 2000) the benefit of the broader bandwidth is obvious (Figure 9), with better continuity of horizons within the area of interest, better fault definition, and signal to noise ratio clearly improved at basement level.

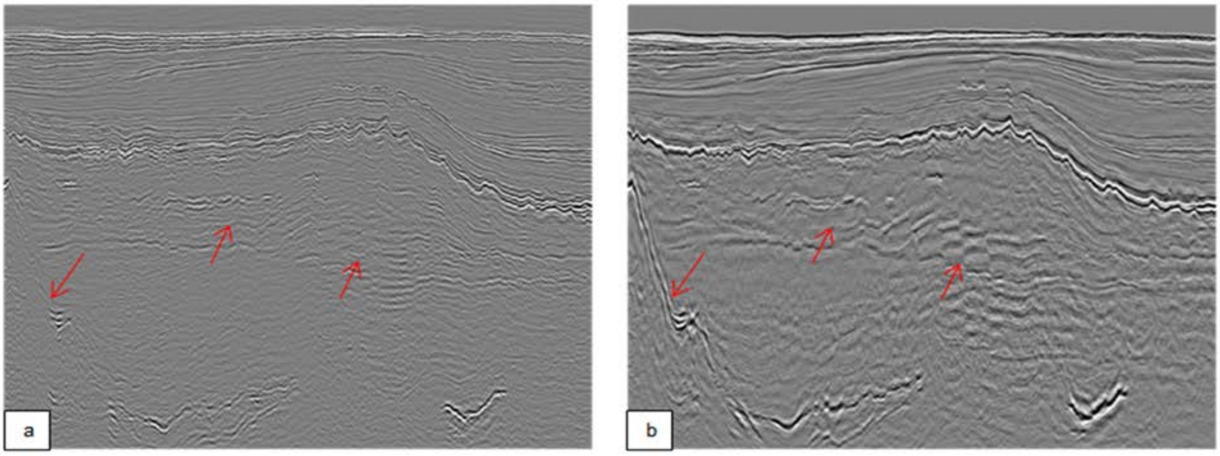

Figure 9: *Legacy stack processed in 2000 (a), vs reprocessed stack using a modern broadband sequence (b). Red arrows indicate areas of improvement including steeply dipping reflectors, fault blocks*

Conclusion

By using a state-of-the-art broadband processing sequence we are able to show a significant uplift in image quality, and at the same time successfully merge legacy conventional datasets acquired in a challenging area. Some steps such as deghosting provide a huge visible uplift in image quality, but in order to achieve the best result, it must be applied together with better statics correction, broadband demultiple and imaging and post-imaging processing sequence. This revived data has clear and obvious benefits for interpreters in revealing previously unseen geological formations. In addition, it provides pre-stack data which are AVA compliant for reservoir characterization and quantitative interpretation.

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References

Guillaume, P. Audebert, F., Berthet, P., David, B., Herrenschmidt, A. and Zhang, X. [2001] 3D finite-offset tomographic inversion of CRP-scan data, with or without anisotropy. *71th SEG Annual International Meeting*, Expanded Abstracts, 718–721.

Jafargandomi, A. and Hoeber, A. [2016] AVA compliant pre-stack enhancement. *86th SEG Annual International Meeting*, Expanded Abstracts, 1844-1848.

Lambare, G., Guillaume, P., Montel, J.P. [2014] Recent Advances in Ray based Tomography. *76th EAGE Conference & Exhibition*, We G10301.

Poole, G., King, S. and Cooper, J. [2016] Simultaneous source designature and receiver deghosting in the joint shot-receiver domain. *78th EAGE Conference & Exhibition*, We SRS3

Sternfels, R., Viguier, G., Gondouin, R. and Le Meur, D. [2015] Joint Low-rank and Sparse Inversion for multidimensional Simultaneous Random/Erratic Noise Attenuation and Interpolation. *77th EAGE Conference & Exhibition*, We N112 04.