

Advanced Multiple Elimination: Application to a complex seismic land data set

Introduction

In Wintershall's onshore concessions in the Libyan Sirte Basin the main challenges in processing seismic data are the attenuation of severe noise, high-amplitude surface related multiples and internal reverberations that are interfering and partially masking the primary signal. The application of pre-stack depth migration is vital to obtain the best structural image.

This TechLink discusses the 3D seismic dataset of C96 where the original pre-stack time migration data show a noisy character that makes it difficult to interpret the target horizons with confidence, especially along complex fault zones or in areas of matching dip angle between primary and multiple events. The subsequent re-processing with anisotropic pre-stack depth migration showed improvements in terms of better well control (50+ wells exist) and reduced noise, however, these gains were offset by the undesired enhanced imaging of multiples cutting through the tilted target events or masking the target reflections where dip differentiation disappears over flat events. Often, both horizon and fault interpretation remain obscured and challenging. The northward dipping field is bounded by a WNW-ESE trending major fault along the southern high end, outlining the area of potential field extensions at the same time, and therefore must be picked with the highest possible precision and confidence.

In Autumn 2004 Wintershall-Libya performed a detailed analysis of de-multiple techniques available on the market. This led to a testing phase with three seismic contractors. The techniques tried included:

- Velocity discrimination techniques (did not work for this dataset due to the fact that primaries and multiples have similar velocities at the target, see **Figure 1**),
- Deconvolution techniques (did not work for this dataset due to long and laterally variable period and too much lateral variability of the multiple generating surfaces),
- Pattern recognition techniques (useful to a certain degree, but these statistical techniques can also take out primaries - they do not account for waves or physics and do not treat lateral changes of the character of multiples), which was selected and

Summary

This TechLink discusses a case-history of the practical aspects of applying data-driven (SRME/IME) multiple removal techniques to complex onshore data from Libya. The main difficulties for processing seismic data in Wintershall's onshore concessions in the Libyan Sirte Basin are the presence of severe noise, high-amplitude surface related multiples and internal reverberations that are interfering and partially masking the primary signal, and some localized complexities in the overburden. The application of a cascaded demultiple approach is discussed that resulted in a significant enhancement of the structural image of the 3D seismic dataset in Concession 96.

It is shown how existing methodologies can be modified to optimally subtract the predicted multiples from the data while preserving weak primaries. Through optimized parameterization and processing strategies, the ample use of QC measures and high-end visualization tools, and the experience of the geophysical interpreter, the successful application of a cascaded pre-stack approach to data-driven multiple attenuation can be achieved.

applied in 2005 as producing the most favourable results, and

- Data-driven techniques (as described here).

The experience of the seismic interpreter is crucial in assessing the various de-multiple tests, as their judgement is backed up by geological understanding of the area and supported by significant well control allowing them to rate

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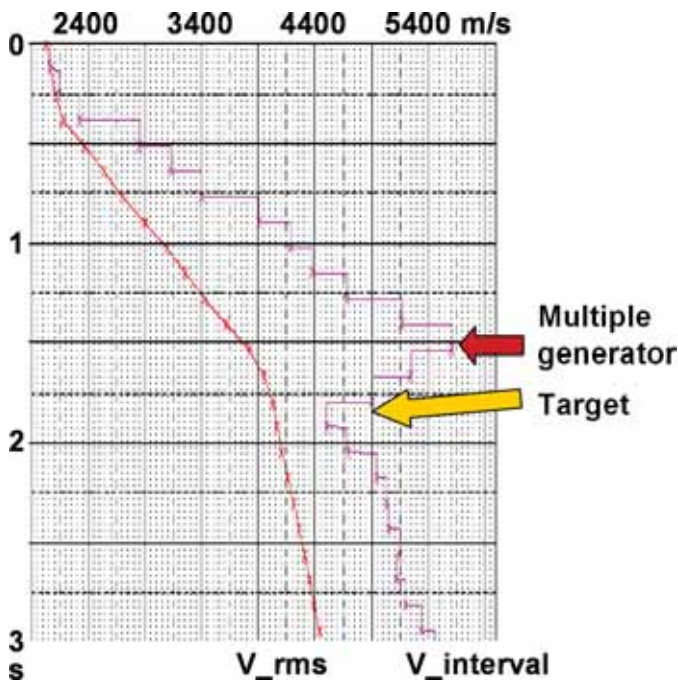


Figure 1: Primaries and multiples have similar velocities at the target.

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the various test results and to identify the best strategies for de-multiple.

In 2005 the test efforts were ended because none of the techniques gave satisfying improvements.

Then, in 2006 the project was revisited after modifications to the multiple prediction and subtractions process were implemented. One of the key changes made allowed for the incorporation of geological constraints into the energy minimization schemes used in the adaptive subtraction process. This modified technique gave very promising results and initiated another test project that finally led to an approved de-multiple application by Wintershall end-2006.

Surface-Related and Interbed Multiple Elimination

Surface Related Multiple Elimination (SRME) and Interbed Multiple Elimination (IME) techniques were tested on one inline and two cross-line subsets of the 3D onshore dataset. The dataset was pre-conditioned to improve the S/N ratio prior to SRME/IME application. Various noise suppression techniques were used. SRME and IME methods were tested both in pre- and post-stack domain (only pre-stack results are presented here). Two iterations of IME were required to attenuate interbed multiples associated with two horizons identified as generators of the most harmful interbed multiples.

However, the breakthrough of the 2006 test compared to the previous tests came from the new modified adaptive subtraction methodology that allows the feedback from the seismic interpreter to be incorporated in a much better fashion.

Pre-Conditioning of the Data prior to SRME / IME

For a successful application of SRME/IME the quality of the data (S/N ratio) needed to be enhanced first. In fact, high quality data is a pre-requisite for these methods. The applied pre-processing included field and residual statics, de-spiking, F-X coherent noise suppression and 3D random noise attenuation. **Figure 2** shows a selected pre-processed CMP gather (for the inline) before SRME, after SRME and after SRME/IME application. This figure shows the highly noisy nature of the multiples.

The Application of SRME and IME

After pre-conditioning, the CMP gathers were used as input to pre-stack SRME to predict surface-related multiples. Additional pre-processing steps were applied to the data for the purpose of predicting multiples only. These included 1D Fourier regularization, alpha-trimmed mean filter to improve S/N ratio, and trace extrapolation to zero offset. Free-surface multiples were then predicted using

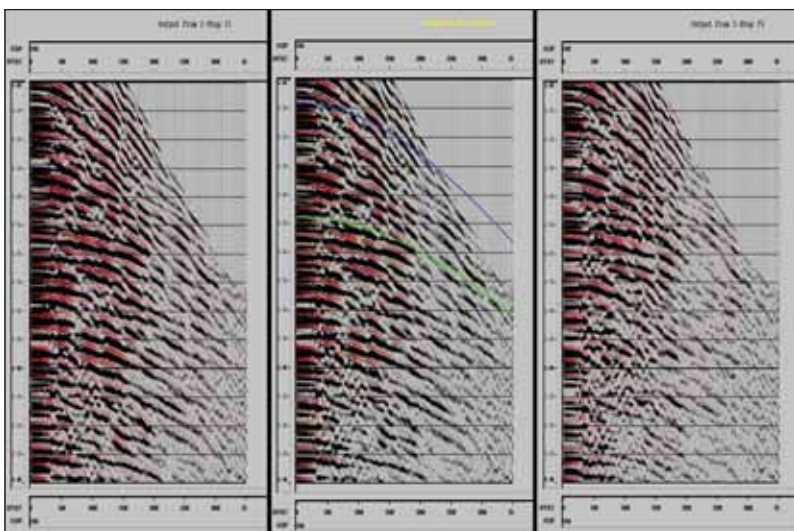


Figure 2 (from left to right): CMP gather before SRME, after SRME and after SRME/IME.

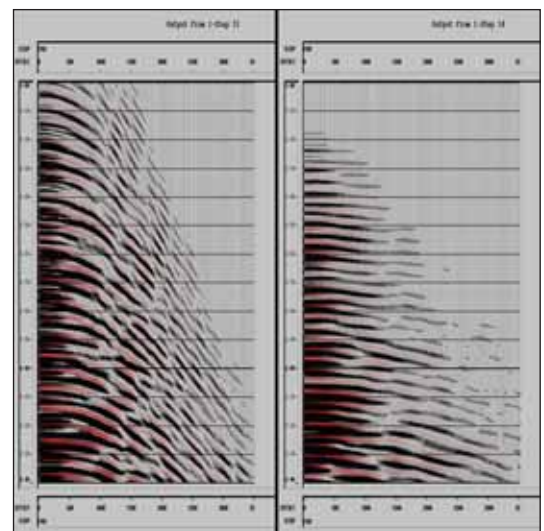


Figure 3: Left: Multiples predicted by SRME, right: multiples predicted by IME (blue boundary Figure 2).

SRME in the CDP domain. Once the multiples were predicted an inverse regularization has been applied to the predicted multiples to restore these data back to the original trace positions (non-regular geometry). **Figure 3** (left gather) shows an example of the predicted multiples

by the SRME method. The next step was to adaptively subtract the SRME predicted multiples from the original (non-regular) pre-conditioned data. The application of SRME alone did not lead to acceptable results.

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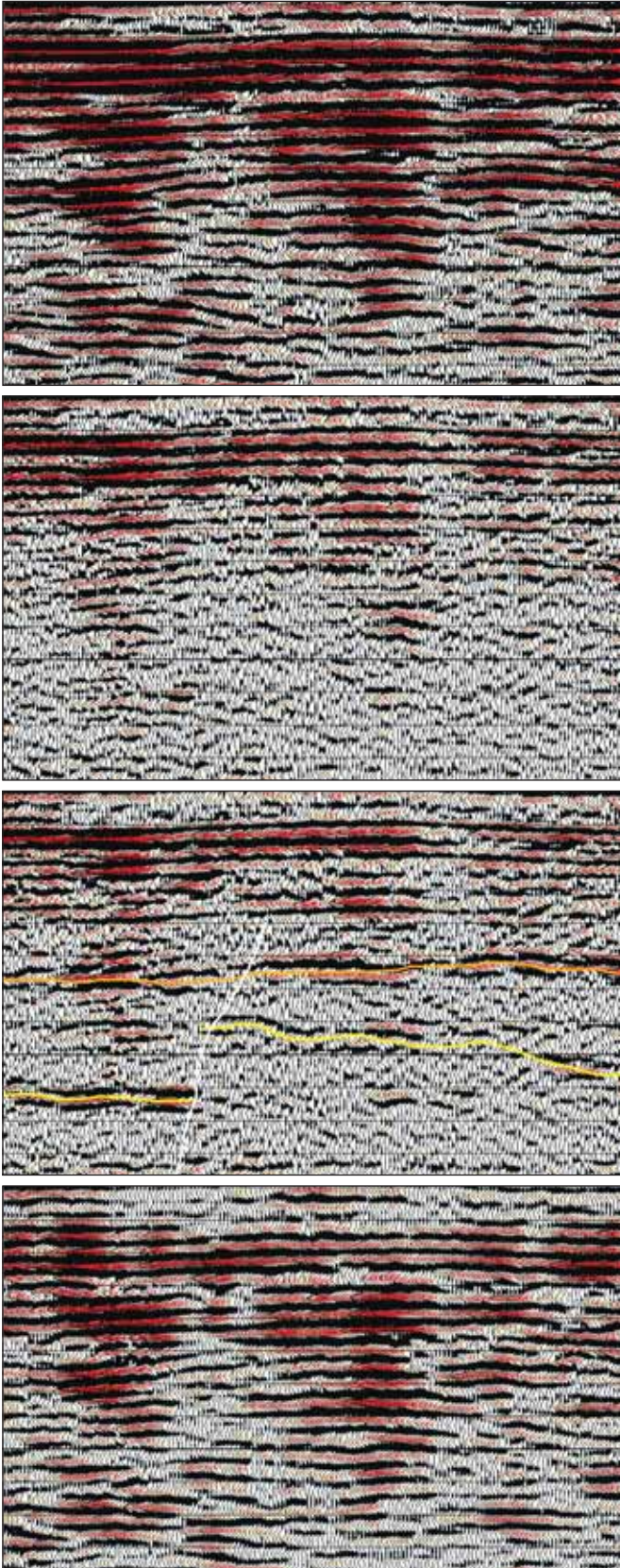


Figure 4: Inline stack, top to bottom: raw (a), standard SRME/IME (b), advanced SRME/IME (c, fault and target horizon can be interpreted), difference (d).

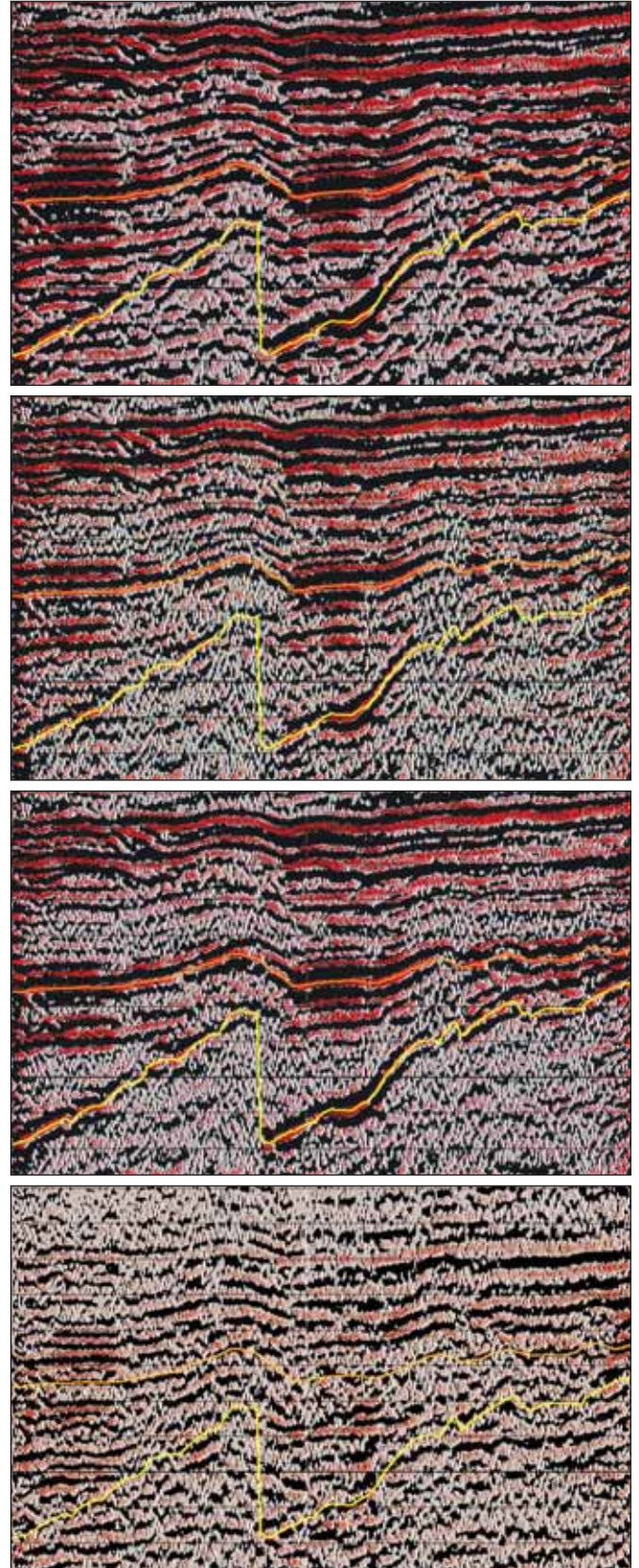


Figure 5: Cross-line stack, from top to bottom: raw (a), standard SRME/IME (b), advanced SRME/IME (c, target horizon and location of a steep fault can be picked with more confidence), difference (d).

The Application of SRME and IME

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Next, pre-stack IME was applied where the input to IME are the data with SRME applied. **Figure 2** (middle gather) shows two highlighted 'pseudo' boundaries (blue and green lines) that were selected for IME after extensive examination of potential multiple generators. During this stage of the application the experience and knowledge of the interpreter on the geological environment played an important role.

To increase the understanding of the results obtained, high-end visualisation tools which allow for interactive comparison of all results as well as deterministic tools that allow the user to gain insight in multiple generating processes were used.

In **Figure 2** (right gather) the CMP gather after the application of two cascaded pre-stack IME iterations is shown. **Figure 3** (right gather) shows the predicted interbed multiples associated with IME Boundary 1 (the blue line in the middle gather of **Figure 2**).

The raw stacked sections (before the application of SRME) for the inline and cross-line are shown in Figures 4a and 5a, respectively. **Figures 4b** and **5b** show the stacks after the application of pre-stack standard SRME and IME (not satisfying, the target horizon and steep fault cannot be picked with confidence on the inline, **Fig. 4b**). **Figures 4c** and **5c** show the final stack of this study after application of pre-stack advanced SRME and IME (two iterations). The comparison shows reduction in multiples energy and improved primaries and fault imaging in the zone of interest (1.8 - 2.3 s).

Adaptive Subtraction of the Predicted Multiples

Figures 4c and **5c** show the stacked sections after the application of pre-stack SRME and IME using the modified adaptive subtraction technique. The method allowed for a constrained application of adaptive subtraction where the input of the seismic interpreter was utilized to ensure that

weak primaries were preserved. From the stacked difference section (**Figure 4d** and **5d**) it can be observed that key primary events have hardly been affected by the cascaded SRME/IME application.

Figure 6 shows graphs comparing the maximum amplitude of the primary reflector of input data (blue color) with SRME/IME applied using conventional adaptive subtraction (red), and data with SRME/IME applied using the newly modified adaptive subtraction technique (green). The improved performance of SRME/IME in preserving primaries while attenuating multiples is attributed to the use of the modified adaptive subtraction procedure.

Conclusions

It has been shown that data-driven multiple elimination techniques can be applied successfully to land data after the application of careful pre-processing to improve S/N ratio. In comparison with all previous unsatisfying attempts of de-multiple testing, it is the use of a new sophisticated adaptive subtraction procedure that makes a major difference, attenuating persistent multiples and enhancing the structural seismic image while preserving primaries.

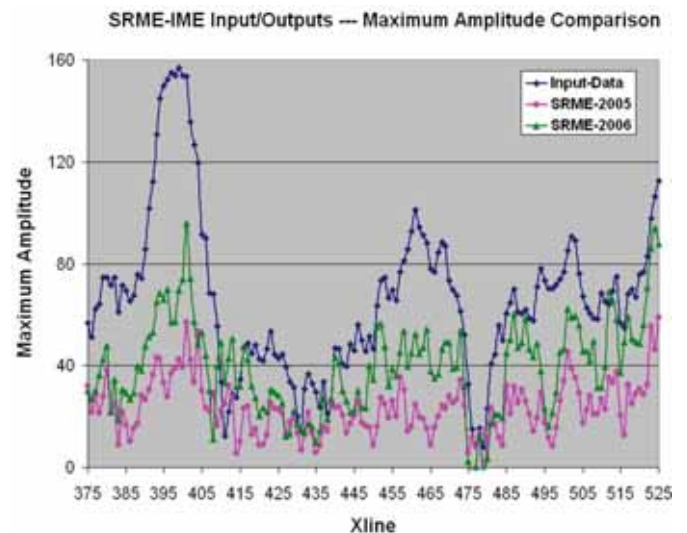


Figure 6: Input/output amplitude comparison (inline).

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