G047

Deepwater Seismic Data Collection and Processing - A Study from the 2006 Turkish Black Sea Kozlu 3D Program

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SUMMARY

Modern deepwater marine 3D surveys require advanced infield systems in both data collection and data processing, if imaging and turnaround targets are to be met. In this paper we present the case history of a marine 3D reconnaissance survey, which presented challenges for both data collection and data processing. The challenges stemmed from the deep and complex waterbottom which caused issues with streamer geometry and also major multiple contamination within the seismic data.

Introduction

In 2006 Türkiye Petrolleri A.O (TPAO) awarded WesternGeco the data collection and processing of the Kozlu (2850 km^2) Black Sea exploration 3D survey. This area (Figure 1) challenges both data collection and data processing technologies. The effect of rip currents, (related to water-bottom topography), on streamer geometry were controlled by the use of advanced infield systems. The rugose dipping water-bottom, and complex near surface geology in the area combined to give significant seismic multiple attenuation challenges, which were overcome by using a combination of advanced de-multiple techniques. TPAO also required fast track data volumes, to site wells for field appraisal. The nature of these geophysical challenges combined with the delivery requirements, required that intensive processing of the acquired data had to be performed onboard the vessel, These on-board processed datasets were also used as the basis for the full onshore processed products.

Figure 1: Location map.

Kozlu geological setting

Kozlu is located in a region with a variable, and at times, rugose water bottom. Water depths vary from 1100 to 2200 m, which equate to seismic reflection times of 1.5 to 3.0 s.

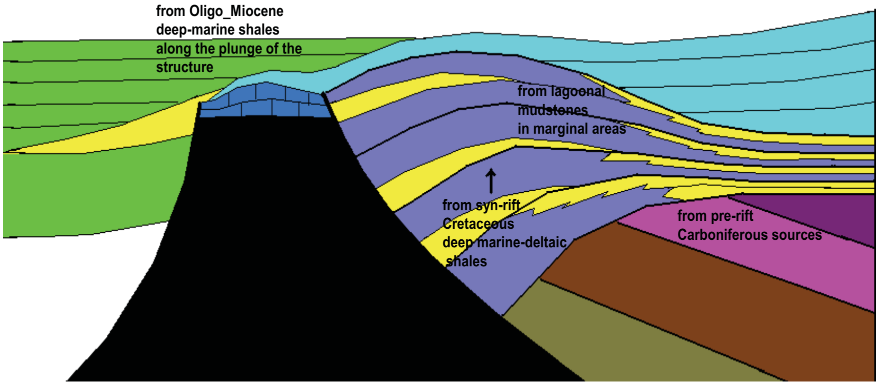


Figure 2: Kozlu structural setting.

The current phases of exploration and appraisal required an improved image of the complex target structure, which, as shown in Figure 2, comprises:

a) Limestone reefs overlaying volcanics at a depth of 3.5 to 4 km
b) Oligo Myocene Mycop shales.
c) Synrift deep marine deltaic shales.

It was crucial to provide a high-quality image, while ensuring that the data fidelity was preserved for subsequent seismically guided rock property prediction. Challenges to this objective included:

a) The geometry of the complex water bottom and complex overburden, which includes gas hydrates.
b) Water-bottom multiples and complex multiple diffractions from near-surface geology. The seismic survey is also oriented strike to the shelf water-bottom dip.
c) Weak primary energy at target that can be masked by significant multiple energy.
d) Imaging the base limestone reef / basement volcanic contact.
e) No well control is available in this area to aid anisotropic or velocity studies.

Kozlu seismic data collection and processing

Data collection was carried out from September 2006 to January 2007 using single-sensor acquisition and processing technologies.

Kozlu is a challenging area for both data collection and processing.
Seismic interference from onshore drilling activity, and severe rip currents in some localized areas impacted data collection. These currents were associated with major changes in water-bottom topography occurring at water depths of 1500 m and could cause large distortions in streamer shape.
Figure 3 demonstrates the effect of advanced infield control systems (steerable streamers and acoustic network) controlling the streamer array in this situation.
The left pictogram shows the streamer array as plotted from recorded navigation data.
The right pictogram shows the streamer positions biased to overplot each other, and hence, exactly compare the streamer shapes and spatial separations.

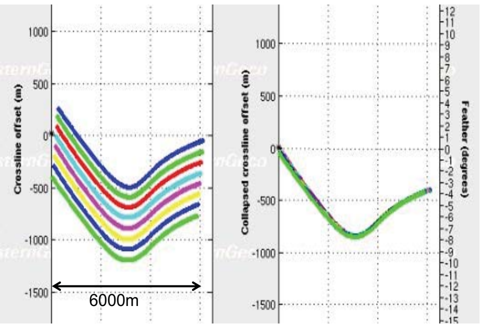


Figure 3: Streamer array pictogram.

An important point to note from Figure 3 is that the 6000-m streamers, although distorted, remain parallel and under control. The resulting data, although noisy, were usable following the application of adaptive noise removal technology and swell noise attenuation on the single-sensor data.
Data processing was expedited onboard the vessel using an integrated seismic data acquisition and processing workflow for near real-time seismic data analysis, that provides a high-quality, no-surprises, data volume to be used as input to the main processing in the onshore processing center as well as for fast-track volumes. This required close cooperation and communication between the onboard geophysical team, the processing center, and TPAO in Ankara in order to expedite timely and critical processing decisions.

To meet delivery requirements of the fast-track migrated volume, the processing schedule required a significant portion of the demultiple processing to be carried out onboard the vessel as the data were acquired, i.e., the surface-related multiple elimination (SRME). The 2D SRME technique required intensive compute resources to precondition the data (extrapolating to zero offset, and reducing the shot interval from 50 m to 12.5 m by interpolation) plus produce a multiple model, which was then adaptively subtracted from the input data. The interpolation to equalize common shot and receiver interval was seen as necessary to optimize 2D SRME demultiple performance. This was achieved onboard the vessel in semi-real time during acquisition. This demultipled dataset was used as input to both the fast-track volume, (which was stacked and poststack-migrated in the processing center), and the main production data volumes.

The complex multiple issues in the Kozlu area required application of additional demultiple processing to the final high-resolution production 3D volumes. These additional demultiple processes included two additional passes of weighted least-squares Radon processing – one before and one after imaging the data using isotropic Kirchhoff prestack time migration and residual multiple attenuation.

In the deepwater Black Sea, it was also noted that there were potential issues regarding the relationship between the shot interval (25 m ~ 12 s) versus data record length 10 s and a water-bottom reverberation period of up to 3 s. Here, in some areas, the reverberation energy from one shot contaminated the primary energy from the next shot. Although this unusual multiple energy was attenuated in high-fold CMP stack, it could generate noise in the common-offset prestack migration, and hence, introduce noise on low-fold AVO angle volumes. This issue was solved by the application of noise attenuation on the common offsets.

Ultimately, several passes of demultiple algorithms were required to address the issues in this area. An example shot record is shown in Figure 4, which shows a seismic record with and without the multiple energy removed.

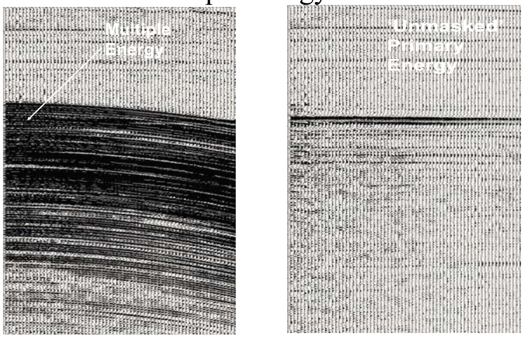
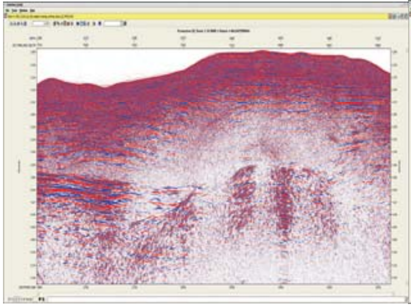


Figure 4: Seismic record, before and after multiple energy removal**.**

This intense demultiple effort was successful to varying degrees over the 2850-km^2 Kozlu survey area; therefore, it was decided to test a more sophisticated demultiple algorithm in one of the more challenging parts of the survey. The algorithm used was a new implementation of 3D SRME (3D GSMP). This 3D algorithm produces a high-quality multiple model, taking into account 3D effects generated by the complex, crossline dipping water bottom and the feather issues also observed in some areas. In addition, this algorithm did not require the computationally and logistically intensive zero-offset extrapolation and 4:1 shot interpolation. Comparison stack sections may be seen in Figures 5 and 6. Also, Figures 7 and 8 show diagnostic displays of cross correlations of the 2D and 3D predicted multiples with original seismic traces on single-fold common offsets. The cross correlations are computed for a cascade of short time windows, whose start times track the water bottom. The 2D SRME cross correlations show areas of non-zero lag – indicating prediction errors due to 3D effects, as well as areas of poor correlation, demonstrating a poor match between predictions and actual multiples.



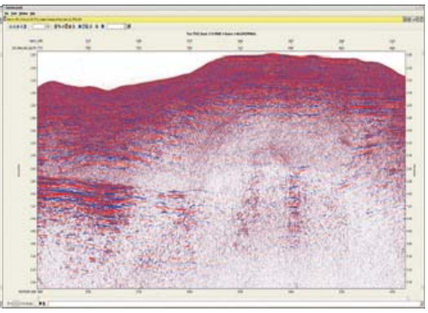


Figure 5: 2D SRME stack. Figure 6: 3D-GSMP stack.

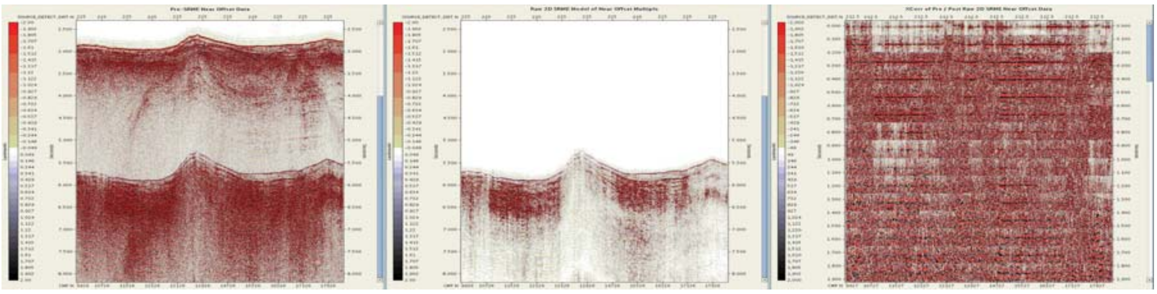


Figure 7: 2D SRME: Seismic, predicted multiples, cross correlation.

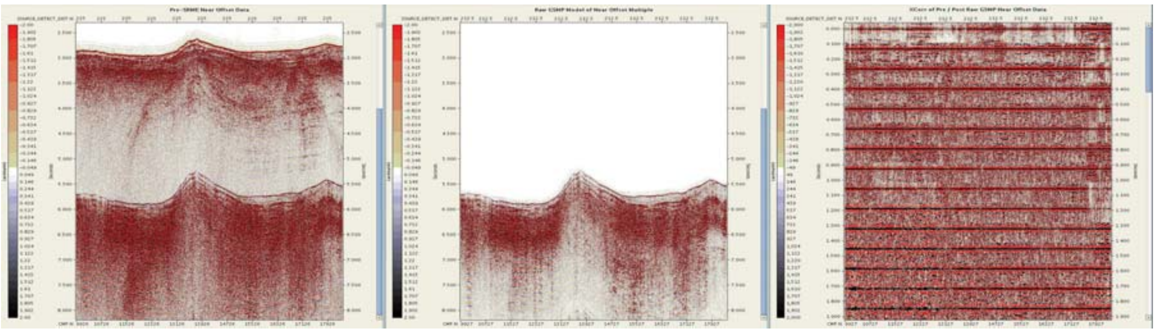


Figure 8: 3D-GSMP: Seismic, predicted multiples, cross correlation.

The cross correlations from the 3D GSMP show a significant improvement in the fidelity of the predicted multiples. We see a significant improvement in demultiple performance with the application of the 3D GSMP algorithm.

An example section from the final prestack data volume is shown in Figure 9, and demonstrates the complexity of the geology in this area.

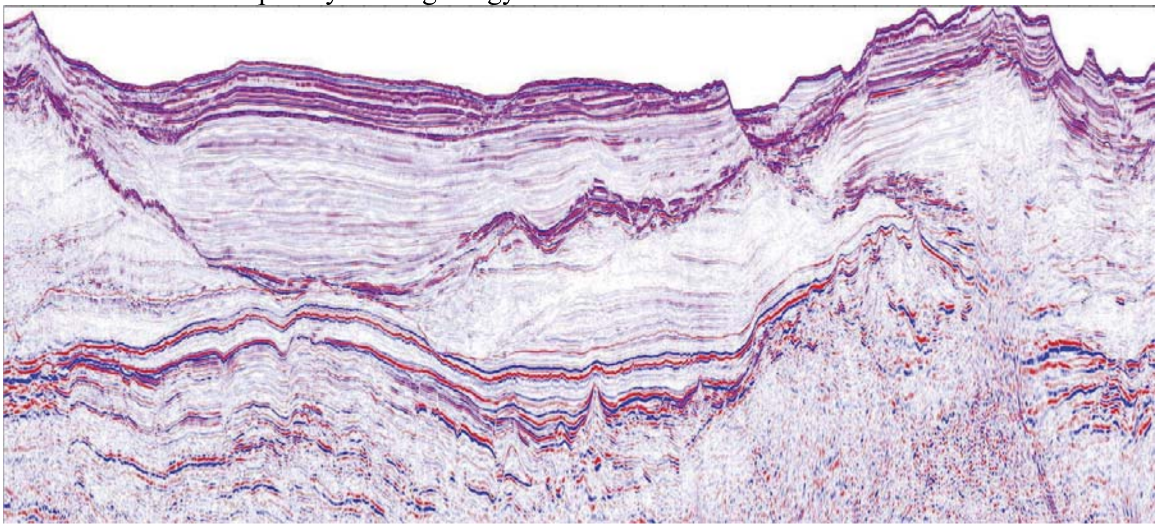


Figure 9: Kozlu final migration.

Additional angle stack volumes and reservoir property volumes, including fluid and lithology volumes (Whitcombe et al 2002), were also generated through inversion of the seismic data. These will be used to aid interpretation and well placement.

Conclusions

The deepwater Black Sea is a challenging region for both the collection and processing of high-quality seismic data, and required leading-edge seismic solutions.

Advanced data collection systems aided infield efficiency and data quality.

The requirement for high-quality fast-track products resulted in very intensive processing of large datasets onboard the vessel, with associated high levels of compute power and communication.

The main processing issue was the severe multiple seen in this deepwater environment, which required a combination of advanced and innovative demultiple solutions.

References

Whitcombe, Davod M., Patrich A.Connolly, Roger L Reagan and Terry C.Redshaw [2002] Extended elastic impedance for fluid and lithology prediction. *Geopyhsics,* **67** pp63-67.

Acknowledgements

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