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Mitigating Mediterranean Sea data challenges before imaging-case study

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Summary

Recent large-scale 3D seismic acquisitions across the Mediterranean Sea, acquired with multisensor broadband and triple-source configurations, present new processing challenges including overlapping shots, complex multiples, and strong P–S conversions from Messinian salt. We propose an integrated workflow that combines machine-learning denoise for stable inputs, FISTA deblending for triple-source separation, and advanced demultiple approaches such as SRME, wavefield extrapolation, and SWIM for near-offset reconstruction. A modelling-based attenuation strategy further suppresses converted modes, enhancing sub-salt imaging. A case study offshore Egypt demonstrates significant improvements in noise suppression, multiple attenuation, and converted-wave removal, delivering efficient, high-quality imaging.

Mitigating Mediterranean Sea data challenges before imaging: case study

Introduction

In recent years, many 3D seismic blocks have been acquired and processed across the Mediterranean Sea, creating an opportunity to establish a robust workflow that balances efficiency with data quality. The acquisition of large multisensor broadband datasets shot with triple-source configurations introduces new processing demands to address overlapping shots.

The acquired data extend from ultra-shallow waters with strong short-period reverberations to deeper basins with long-period multiples, demanding a robust and flexible demultiple flow, and the strong velocity contrast between the Messinian salt and its surrounding sediments produces significant P–S wave conversions. In addition, the salt composition varies from thick, relatively pure halite to more contaminated, mixed 'dirty' salt, further complicating the attenuation of these converted-wave energies.

Method

The proposed workflow connects several advances into a continuous sequence. First, to generate the up- and down-going wavefields from multisensory data it is essential to attenuate the noise from both records. Machine-learning denoise using RIDNet (Farmani *et al*., 2023) provide automatic, consistent and high quality denoised data. This provides stable inputs for wavefield separation and reduces turnaround time.

For many years dual-source configurations were the preferred option for acquiring seismic data. The revival of triple-source shooting extended the solution space for modern towed-streamer survey design to provide cost effective acquisition and mitigate operational risks, but it adds the necessity to deblend the data (Widmaier *et al*., 2019). A **F**ast **I**terative **S**hrinkage **T**hreshold **A**lgorithm (FISTA) method (Qu *et al.,* 2016) has been used and proven robust to separate triple source blended seismic data. Advanced multiple attenuation or imaging techniques such as SWIM, 3D SRME, and wavefield extrapolation demultiple helped to provide significant improvements in signal-to-noise and image quality. A key element of this workflow is Separated Wavefield Imaging (SWIM), which reconstructs missing near-offset information, generating reflectivity cubes suitable for multiple prediction.

Sub-salt prospects in the Mediterranean are often challenged by complex salt geometries and the presence of converted wave energy. A modelling-based attenuation strategy that require two 3D acoustic models effectively suppress both asymmetrical (PSPP, PPSP) or symmetrical (PSSP) converted modes (Kumar *et al*., 2018). This enhances pre-salt reflectivity, improves data interpretability, and reduces exploration risk.

Examples

The seismic data example shown here was acquired as part of a multi-client campaign in the Eastern Mediterranean Sea, offshore Egypt. The campaign covered area over many blocks with a triple-source configuration and most of the blocks has twelve 10 km long multisensor streamers at a depth of 20 m separated by 150 m. The nominal seismic acquisition bin size was 6.25 m by 25 m, with 100-fold of coverage.

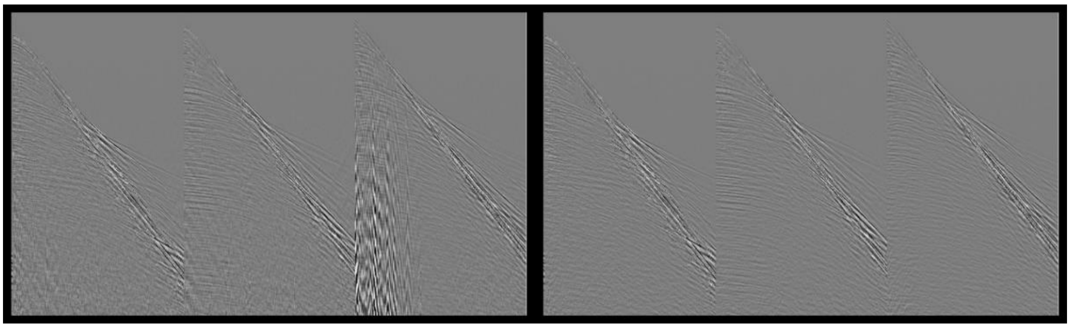

Figure 1: *hydrophone shot gathers before left and after ML denoise right.*

Figure 1, illustrate the effectiveness of ML denoise to attenuate swell and turn noise from hydrophone data without testing. The stack display on Figure 2, show the result of the advanced demultiple flow with robust attenuation of multiples from shallow to deep water. Finally, the image domain stack highlights the attenuation of the mode conversion energy which appear as a ghost of the base salt reflection.

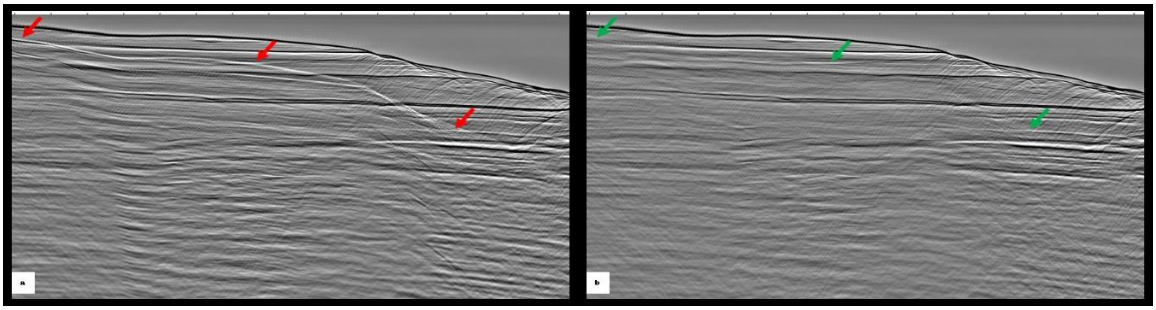

Figure 2: *stacked data before left and after demultiple right.*

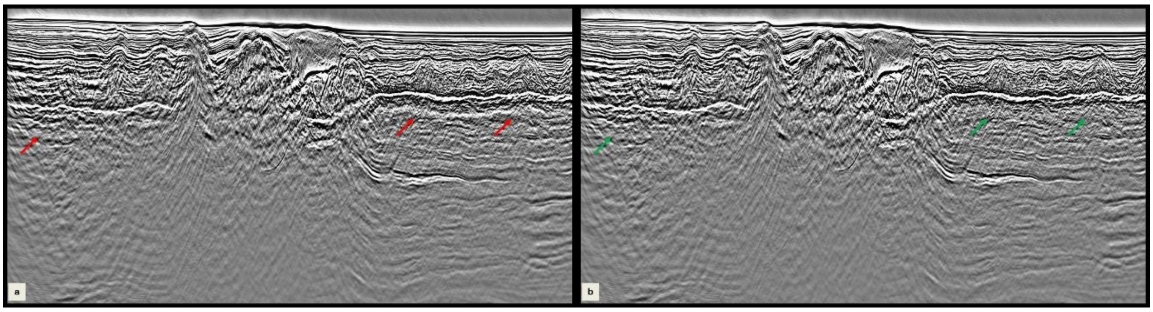

Figure 3: *Image domain stack obtained by migrating data using Kirchhoff algorithm without converted wave attenuation flow left and with converted wave attenuation flow right.*

Conclusions

Successful imaging in the Mediterranean requires an integrated workflow. Incorporating ML, advanced deblending, and robust demultiple techniques is key to mitigating the data challenges. Finally, modelling-based attenuation of converted-wave energy provides a reliable solution to the strong P–S conversions associated with Messinian salt. By linking these advances into a continuous sequence, the workflow balances efficiency with data quality

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