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Converted wave attenuation case study from East Mediterranean Sea

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Summary

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Introduction

In the presence of salt, the large velocity contrast between the salt and the surrounding sediments causes conversion between P-wave and S-wave energy, which frequently results in the recording of converted mode events. As the converted wave mode has a slower apparent velocity, the converted energy occurs deeper than the high contrast boundary and can affect data interpretability. The attenuation of such events is usually necessary to facilitate the interpretation of the P-wave image.

The presence of Messinian salt challenges hydrocarbon prospectivity in the Eastern Mediterranean Sea, where many concessions reveal Messinian layer with an interval velocity between 4200 and 4300 m/s, whereas sediments velocity in the post-Messinian and pre-Messinian sections ranges from 2400 to 3000 m/s. Mode conversion is frequently caused by the large acoustic velocity contrast at the top and base of the salt layer. Many prospects in this region are sub-salt, often obscured by converted mode energy. Suppressing this energy has a significant impact on prospect interpretation. The removal of the converted wave is also key to get more accurate velocity model. In this paper, we present the application of a method to attenuate converted wave energy (Kumar et al., 2018) on recently acquired multisensor dataset from Eastern Mediterranean Sea.

Method

Existing methods for suppressing converted modes include filtering out the unwanted energy based on normal move-out velocity (Jeff et al., 1996), surgically muting the energy using travel time ray-tracing (Lu et al., 2003), and dual-leg 3D acoustic modeling (Huang et al., 2013). Kumar et al. (2018) demonstrates a workflow to model converted wave by performing 3D acoustic modeling twice: once with and once without the base salt interface in the velocity model. This produces a considerably cleaner converted wave model that can be efficiently subtracted from pre-migration gathers even in the presence of complex salt geometries (Figure1).

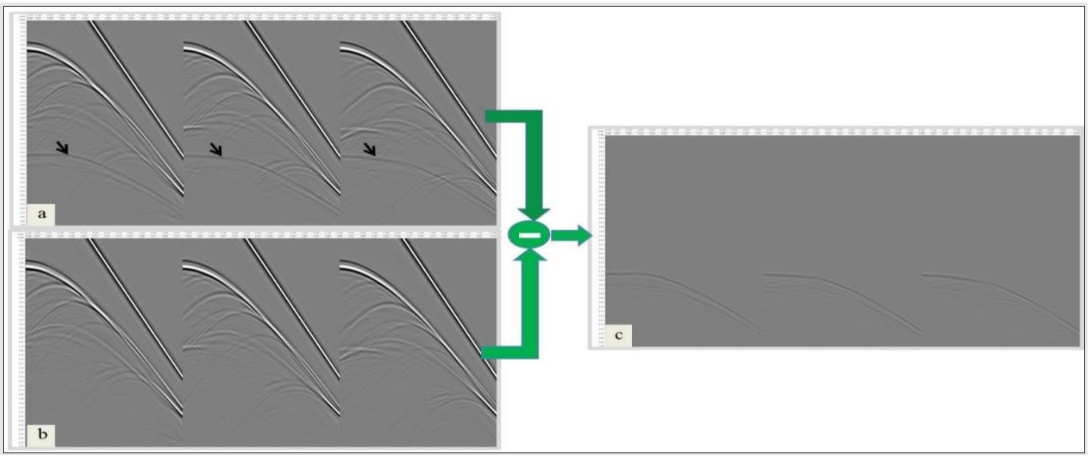

Figure 1: 3D acoustic forward modelling with base salt reflector included in the modelling (a); forward modelling without base salt reflector in the model (b); subtraction of the previous two models to generate clean converted wave (c).

The converted waves investigated in this study are those that convert to S-waves at the top and bottom of the salt and travel as P-waves outside the salt. As shown in Figure 2, three possible converted modes of base salt are PSPP, PPSP and PSSP. Because S-waves travel slower than their equivalent P-waves, the arrival time for symmetrical mode PSSP will be much longer than that of asymmetrical modes PSPP and PPSP. Furthermore, the symmetrical mode will be recorded with a significantly lower amplitude. This is because the velocity contrast between S-wave salt velocity and surrounding P-wave sediment velocities is less. A symmetrical mode is not always visible in recorded field data since its amplitude is substantially smaller than the P-wave amplitudes.

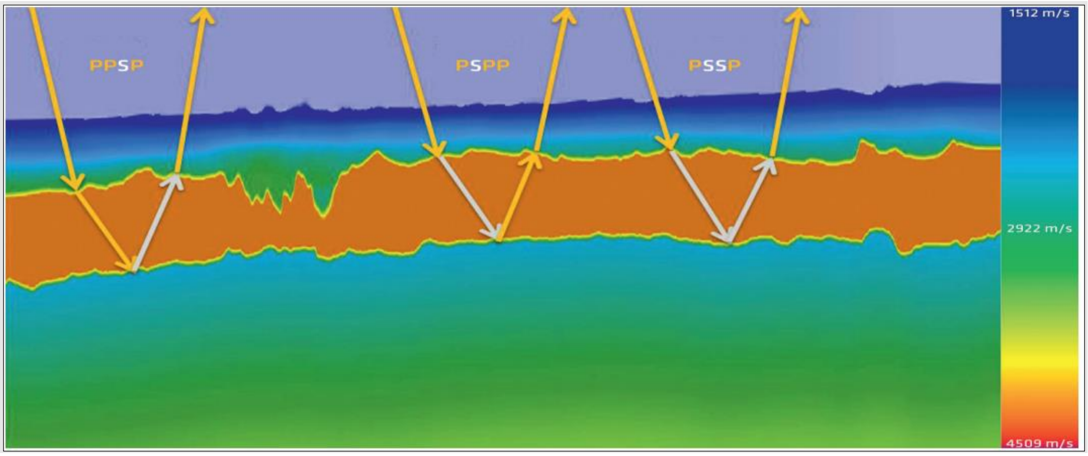

Figure 2: All possible ray paths of converted waves from the salt layer.

Examples

The seismic data example was acquired as part of a multi-client campaign in the Eastern Mediterranean Sea, offshore Egypt, with water depths ranging from 200 m to 3000 m. The survey was acquired using a triple-source configuration and twelve 10 km long multisensor streamers separated by 150 m. The campaign covered area over five blocks as shown in Figure 3. A very similar processing sequence was applied to those blocks and subsequently the data from all blocks were merged to produce a seamless mega volume of approximately 25000 sqkm. The proposed flow has been applied where the converted mode energy is obvious which typically occurs at thick salt section.

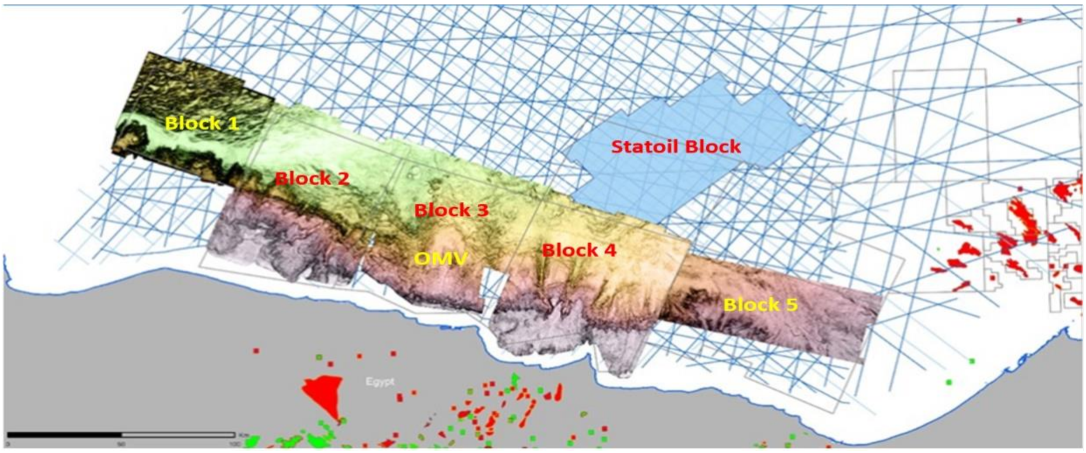

Figure 3: Different blocks acquired in the multi-client campaign in the Eastern Mediterranean Sea, offshore Egypt.

The velocity model for the modelling was generated using tomography in the post-salt section to estimate the sediment velocity. The salt layer velocity was estimated using a salt flooding methodology after interpreting the top salt reflection. The aim of this flooding step was to estimate the P-wave velocity that produce optimal flatness of the base salt reflection. S-wave velocity was obtained by scanning for the velocity which flattens the converted mode energy at the same depth as the interpreted base salt. For this dataset, the P-wave velocity of the salt was estimated at 4200 m/s, whereas the S-wave velocity was estimated at 2400 m/s. FWI was used in the velocity model building workflow, but it was not included in the velocity model for converted waves modelling.

Because of the complexity of the salt environment in this data the diffractions of the top salt were overlapping with the converted mode energy generated from the base salt Figure 5. This makes it difficult to subtract the converted wave energy before migration using one modelling step. Performing the 3D acoustic modelling twice, with and without the base salt interface in the velocity model used for the propagation generates a much cleaner converted wave model that can be effectively subtracted from the pre-migration gathers. The shot gathers show the converted wave energy starting from the middle to far offsets in Figures 4. The result on the image domain is presented in Figure 6, the effectiveness of the method is clearly visible on the image, and the difference display shows strong attenuation of the converted wave energy.

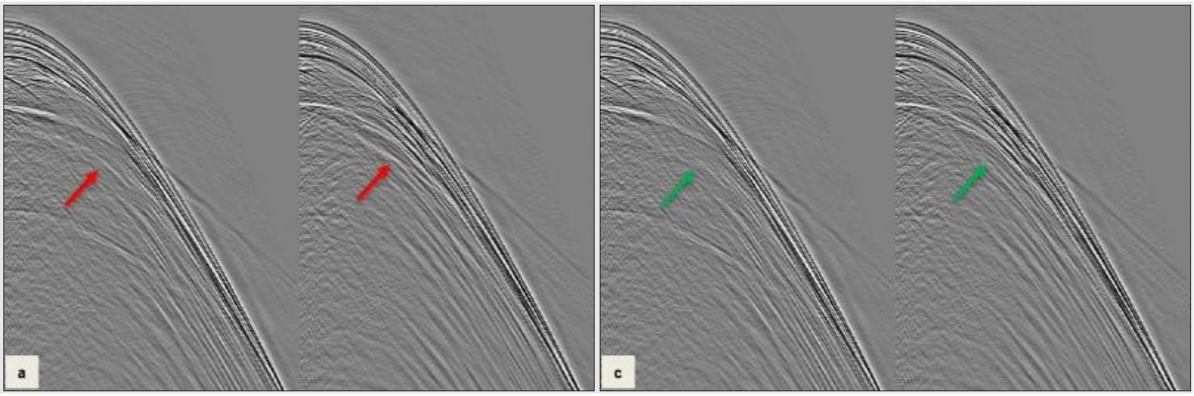

Figure 4: Block3- Shot gathers without converted wave attenuation flow applied (a), converted wave model (b) and with converted wave attenuation flow applied (c)

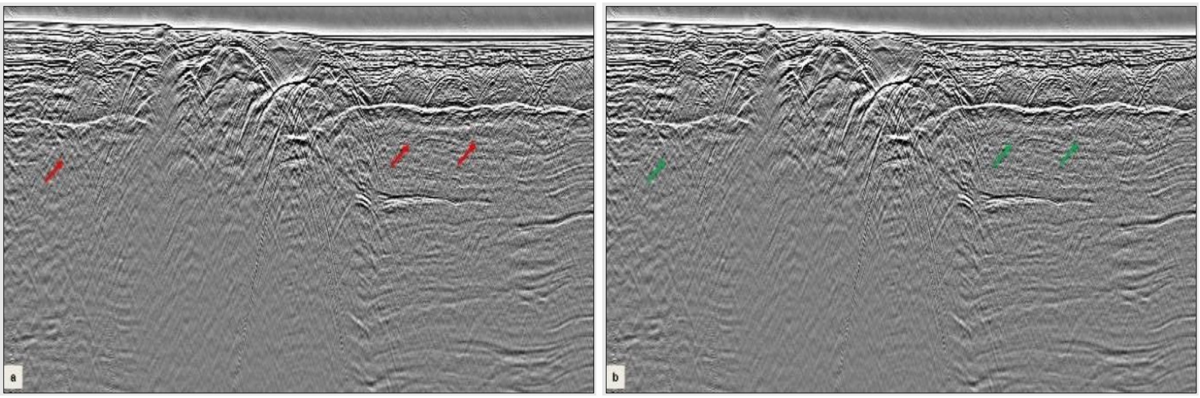

Figure 5: Block3- Stack in the data domain without converted wave attenuation flow applied (a) and with converted wave attenuation flow applied (b)

Conclusions

Many prospects in the Eastern Mediterranean Sea are sub-salt, which should benefit from converted wave energy attenuation. Despite the complex nature of the salt regime, the flow efficiently attenuated the converted wave energy, revealing the pre-salt reflectivity and lowering the risk associated with data interpretation.

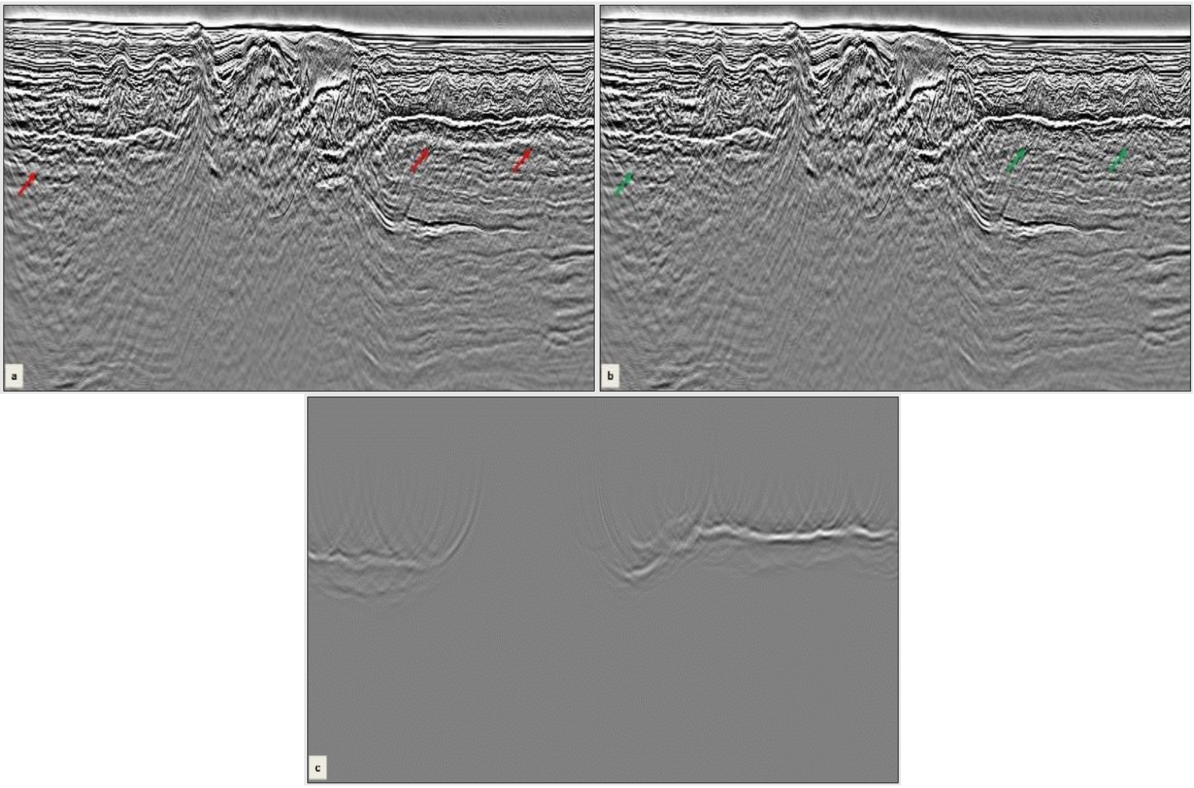

Figure 6: Image domain stack obtained by migrating data using Kirchhoff algorithm without converted wave attenuation flow applied (a) and with converted wave attenuation flow applied (b). the difference display only contains the converted wave energy (c).

Acknowledgements

The authors wish to thank PGS MultiClient for authorization to show examples from the different surveys acquired by PGS throughout the Eastern Mediterranean Sea. We would like to give special thanks to all the geophysicists from PGS who helped us in producing the results.

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