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6

Unlocking the Complex Subsurface Imaging Offshore Egypt

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Summary

Not provided.

Introduction

The recent Nefertari gas discovery in the Western Mediterranean offshore Egypt, has proved the potentiality of the area for hydrocarbon exploration; however, exploration remains challenging due to complex regional geology. Seismic imaging is particularly impacted by velocity heterogeneity within the Messinian layer, driven by interactions between mobile mud, sand bodies, and variable salt-anhydrite compositions.

To address these issues, a robust velocity model building (VMB) workflow integrating Full Waveform Inversion (FWI) and Reverse Time Migration (RTM) is performed (Brandsberg-Dahl *et al*., 2017). This abstract presents examples from a recent acquired NAZ seismic survey in the Eastern Mediterranean, showcasing how advanced VMB techniques improve imaging in such complex regime.

Velocity Model Building and Imaging

The pre-Messinian imaging is highly sensitive to velocity inaccuracies within the overlying complex Messinian evaporite sequence. Therefore, building a high-resolution, geologically consistent velocity model is required for accurate imaging of pre-Messinian targets. VMB of NAZ surveys typically involves Full Waveform Inversion (FWI) and reflection tomography. Figure 1 is a simplified version of the VMB workflow applied in this survey, when combined with state-of-the-art migration algorithms-such as, Reverse Time Migration (RTM), helps overcome illumination challenges in the target zone and significantly enhance final image quality. The workflow generally initiates from a smoothed fast track (FT) velocity model in combination with interpretation-based velocity flood of salt and mud intrusion, which serves as a baseline for iterative refinement.

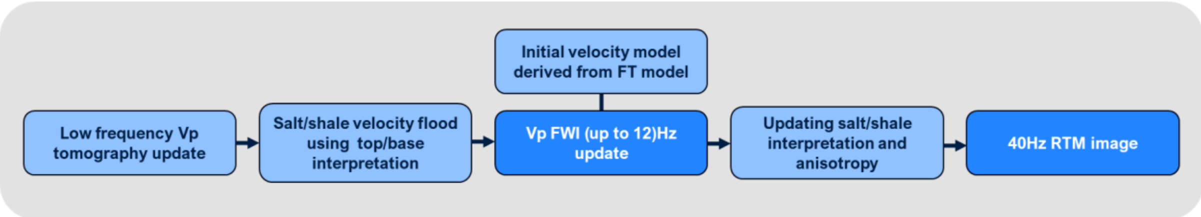

Figure 1 *shows the proposed VMB Workflow applied in this survey, including the application of FWI and RTM.*

Data Example 1: Post Messinian

There are anomalous features in the post-Messinian section, such as gas pockets, buried channels and mud volcanoes, that require careful handling with FWI and tomography. FWI benefits from refracted and diving waves in shallow water. While in deeper waters, it relies on low-frequency reflected waves to achieve high-frequency updates (Zou et al., 2014). Figures 2a and 2b show initial and 12Hz FWI updated velocity models, respectively. Sharper velocity contrast along the geometry of the channel is observed after 12Hz FWI, a good match is seen as well in Figure 2c with the seismic, providing confidence in the velocity update.

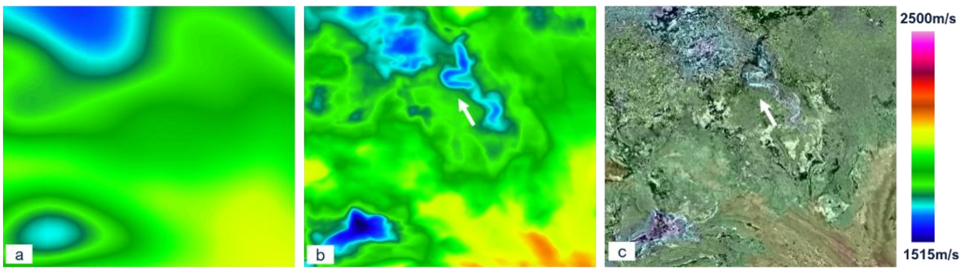

Figure 2 *shows Depth slice of initial velocity model (a), 12Hz FWI updated velocity model (b), and Kirchhoff image with FWI model overlaid (e).*

Data Example 2: Messinian Evaporites

The Messinian salt layer shows complex intra-salt reflectivity, likely due to thin interbedded clay layers within the salt matrix. The velocity model was built using top and base salt interpretations, with constant average velocities ranging from 4400 m/s in clean salt to 3600 m/s in mixture salt-clay regime. With mud and salt geo-bodies in place, FWI tends to converge faster in a more geologically plausible manner. As illustrated in Figures 3a and 3b, FWI sharpens velocity contrasts at salt interfaces and resolves intra-salt velocity variations, particularly in the lower Messinian unit.

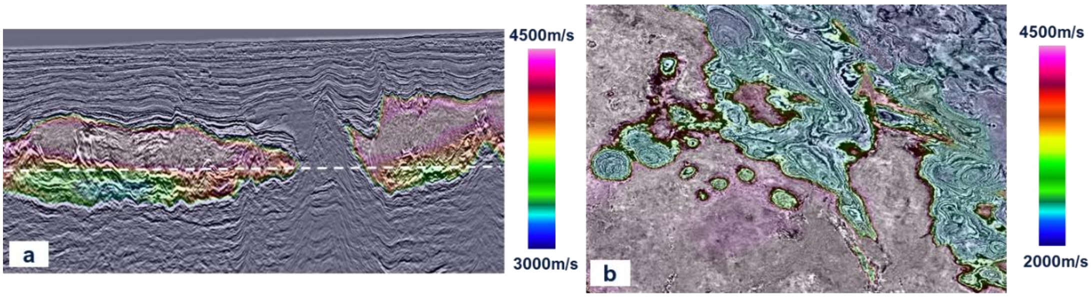

Figure 3 *An Inline display of 12Hz FWI updated salt velocity model (a) and depth slice of 12Hz FWI salt velocity model (b) overlaid on migrated Kirchhoff image.*

Data Example 3: Pre-Messinian Imaging

Imaging Pre-Messinian targets is particularly challenging due to poor illumination beneath the complex Messinian layer. Ray-based methods like Kirchhoff migration often produce irregular ray coverage and fail to adequately illuminate the sub-salt section. In contrast, (RTM) effectively handles complex wave propagation by extrapolating the full wavefield, resulting in improved subsurface illumination and reflection continuity. Unlike ray-based algorithms, RTM avoids wavefront-related artifacts and delivers higher signal-to-noise ratios. Figures 4b and 4c show a comparison between Kirchhoff and RTM migration, where the RTM is much better illuminated and has better S/N.

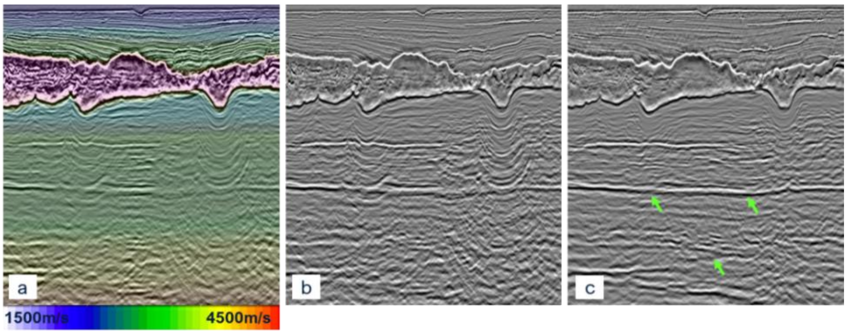

Figure 4 *An inline display with the final velocity model overlaid on the Kirchhoff depth migrated image (a). Comparison between Kirchhoff Depth image filtered to 40HZ (b) versus 40Hz RTM image (c).*

Conclusions

The proposed VMB workflow including FWI and RTM, have been successful in capturing most of the post-Messinian and Messinian complexities, helping in improving the pre-Messinian target image.

References

Brandsberg-Dahl, S., Chemingui, N., Valenciano, A., Ramos-Martinez, J. and Qiu, L. [2017] FWI for model updates in large-contrast media. *The Leading Edge, 36, 81-87.*

Zou, Z., Ramos-Martínez, J., Kelly, S., Rønholt, G., Langlo, L.T., Valenciano Mavilio, A., Chemingui, N., and Lie, J.E. [2014] Refraction Full-waveform Inversion in a Shallow Water Environment. *76th EAGE Conference and Exhibition 2014, Jun 2014, Volume 2014, p.1 - 5.*