EAGE ANNUAL 2026
87TH CONFERENCE & EXHIBITION
ABERDEEN | UK

Advanced Q-KPSDM Reprocessing in the Romanian Black Sea: Imaging Uplift Beneath the Danube Channel

Introduction

The Ana and Doina gas fields are located within the Ana-Doina-Bianca (ADB) area of the XV Midia Shallow Block in the Romanian Black Sea. Both fields produce dry biogenic gas from late Miocene-Dacian shallow-marine sandstones at approximately 1100 m depth. The ADB area lies beneath a complex near-surface regime dominated by Quaternary paleo-Danube submarine channels and shallow gas accumulations. These features introduce severe seismic imaging challenges, including frequency-dependent attenuation (amplitude loss and phase dispersion) and structural “push-down” of deeper reflectors. Such issues have long been recognized in the region: dimmed reservoir reflectors and sagged structures beneath channels were evident in early seismic interpretations (Duley & Fogg, 2009). Over the past decade, imaging approaches have evolved to address these challenges. The 2016-2018 benchmark processing (Costriiciuc et al., 2018) integrated Full Waveform Inversion (FWI) and preliminary Q-compensation, yielding improved images but continued to struggle beneath the largest Danube channel.

In 2024-2025, a full 3D seismic reprocessing program (577 km²) covering the ADB area was undertaken to achieve a step-change in image quality using Q-compensated Pre-stack Depth Migration (Q-KPSDM). The workflow incorporated industry advances in attenuation handling (e.g., spatially variable Q models as described by Matta et al., 2021), while being tailored to the specific data characteristics and project constraints. Although a formal Q-tomography inversion was not applied, the Q model was data-driven, derived from spectral analyses and iterative calibration tests on the seismic data, including 1D Q-tomography-style trials and reference-frequency sensitivity studies. The outcome is a state-of-the-art, depth-migrated seismic volume that provides significantly enhanced imaging beneath the Danube channel and shallow gas features, resulting in improved clarity for leads located below this complex overburden.

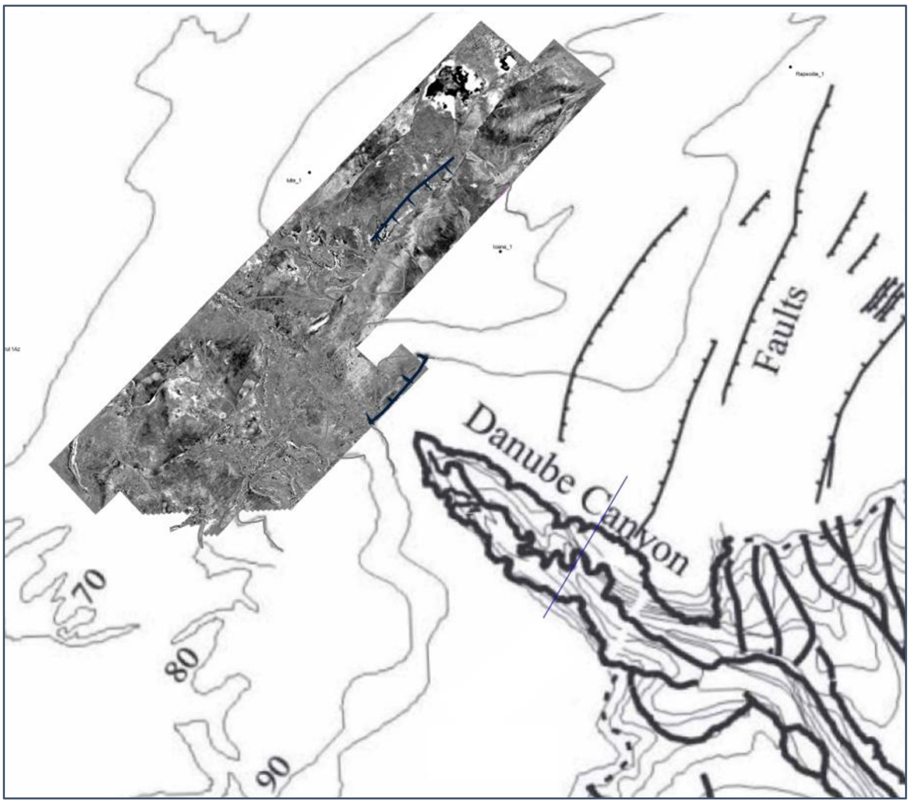

Figure 1 *Map of the Midia Block, showing the 2024 ADB re-processing area and the network of paleo-Danube channels on the seabed.*

Project Overview and Objectives

The project focuses on a conventional marine 3D dataset covering ~577 km² offshore Romania in the Block XV area, acquired in Dec 2013–Jan 2014 and reprocessed during 2024–2025. Legacy processing and imaging attempts (including PreSTM and earlier PSDM/Q-PSDM variants) had highlighted limitations related to absorption, multiple energy, and residual distortions beneath the shallow channel and gas-affected zones.

The reprocessing project covered the Ana, Doina, and Bianca area (ADB). The input was the 2013/14 vintage conventional-tow (single hydrophone) 3D seismic. Key objectives were to enhance the spatial resolution and imaging of the reservoir intervals and to improve subsurface clarity beneath the challenging shallow features. Specifically, the project aimed to:

- Improve spatial resolution, structural positioning and event continuity across the full stratigraphic section, especially in shadowed zones beneath channels, gas and faults;
- Broaden the seismic bandwidth for finer stratigraphic details;
- Build a high-fidelity depth model including velocity, anisotropy, and absorption (Q) to correctly position structures;
- Mitigate the distortions caused by shallow channels, gas pockets, and multiples.

From an operational standpoint, robust processing steps were applied to tackle noise and multiples up-front. For example, aggressive swell-noise attenuation and source/receiver deghosting were implemented to recover low frequencies and true amplitudes from the shallow-towed data. An extensive demultiple sequence (including 3D multi-model SRME, Separated Wavefield Imaging – SWIM) addressed the short-period water-bottom reverberations and peg-leg multiples, given the 30–80 m water depth. Equally important, a continuous quality control loop was maintained by generating interim migrated volumes during processing; these were compared to legacy images to ensure that each step provided an improvement. By the end of processing, the final product had been confirmed superior to the legacy data in all key aspects of signal-to-noise and image continuity.

Model building strategy and summary

A sophisticated velocity model–building workflow was central to the reprocessing, integrating Full Waveform Inversion (FWI), tomography, and well calibration in an iterative approach. The initial model was based on the legacy velocity model and available well data. Diving-wave FWI (up to 12 Hz) was then applied to resolve the shallow velocity structure to ~600 m depth, successfully capturing low-velocity anomalies associated with near-surface channels at ~100 m depth and significantly improving channel infill velocity definition.

In the deeper section, multiple cycles of reflection tomography interleaved with reflection FWI (10–12 Hz) were performed to progressively improve velocity contrasts at reservoir level and update velocities in structurally complex areas. Throughout model building, well ties using checkshots and formation markers from the Ana and Doina wells were used to constrain anisotropy parameters (Thomsen δ and ε) and ensure accurate depth positioning. While anisotropy was calibrated to minimize well misties, further geological refinement of the anisotropy model remains a potential improvement for future work. An absorption (Q) model was developed in parallel. A constant background Q of ~100 was initially assumed, with significantly lower Q (~20) assigned to the Danube channel based on spectral attenuation analysis. Following the first FWI update, a data-driven Q refinement linked very low velocities (<1500 m/s) to reduced Q values, capturing absorption effects from gas-charged or unconsolidated sediments. Two additional Q updates, following the 6 Hz and 12 Hz FWI stages, combined velocity-derived anomalies with geological interpretation of the channel extent. The final Q model therefore accounts for strong shallow absorption while preserving higher Q in more consolidated units.

The final product was an anisotropic TTI Q-Kirchhoff Pre-stack Depth Migration (Q-KPSDM), incorporating the refined velocity, anisotropy, and Q models to accurately position reflectors and compensate for absorption. Intermediate PSDM volumes, with and without Q compensation, were generated for quality control and guided successive updates. Iterations continued until improvements became marginal. The resulting earth model provides a significantly more accurate representation of both shallow and deep velocity variations, supporting improved seismic amplitudes and structural interpretation beneath the Danube channel.

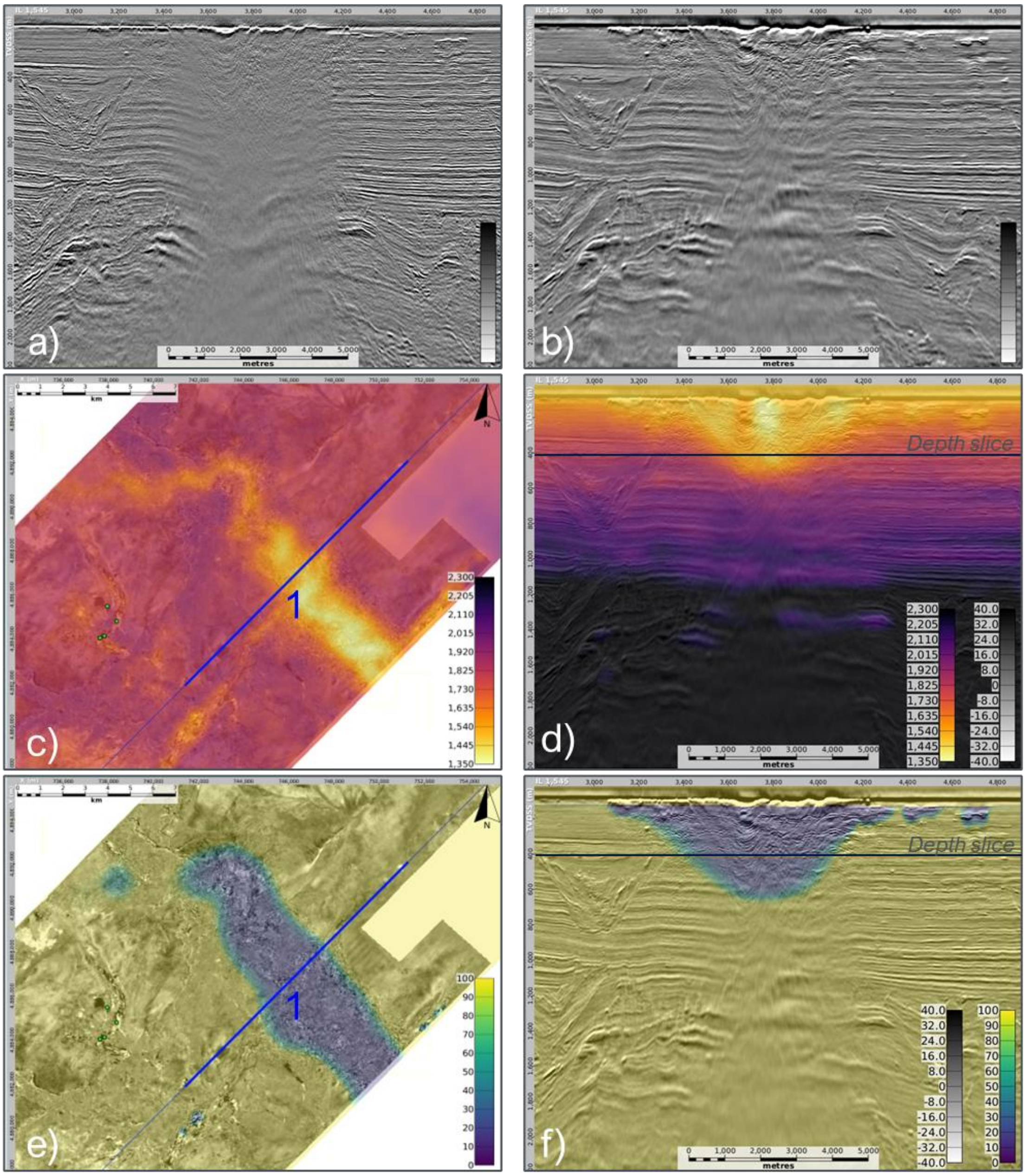

Figure 2 *Comparison of seismic imaging beneath the Danube channel in the ADB area. a) Legacy Q-KPSDM section showing amplitude dimming, wavelet dispersion, and structural pull-down beneath the shallow channel. b) Reprocessed Q-KPSDM section along the same line, displaying improved bandwidth, reflector continuity, and reduced pull-down. c) Depth slice from the reprocessed volume with updated velocity model overlaid; blue line indicates section location. d) Corresponding vertical velocity section illustrating improved velocity definition beneath the channel. e) Depth slice with seismic amplitude and final Q model overlaid, showing low-Q anomalies associated with the channel and shallow gas. f) Seismic section with the Q model overlaid, highlighting the relationship between attenuation and imaging improvements.*

Results and way forward

Imaging Uplift: The reprocessing delivered a clear uplift in image quality, particularly beneath the Danube channel and shallow gas zones. The final Q-KPSDM volume shows markedly improved reflector continuity, amplitude fidelity, and structural definition compared with the legacy data, especially beneath the channel (Figure 2). Previously dimmed and defocused events are now imaged with clearer geometry and higher frequency content. Faults obscured by shallow gas in the legacy results are better resolved, supported by the refined velocity and Q models that more accurately capture channel-related low-velocity and high-attenuation anomalies (Figure 2c-f).

Reflections from the Ana and Doina reservoirs exhibit increased bandwidth, more stable phase, and improved signal-to-noise ratio, indicating effective compensation for absorption and dispersion. Faults previously obscured by shallow gas are better resolved due to the high-resolution velocity and Q models. Quantitative analysis confirms bandwidth recovery to ~60 Hz at reservoir level (from ~40 Hz previously) and improved imaging of channel-induced pull-downs, which are largely collapsed in the new depth-migrated volume

Reservoir Perspective: These imaging improvements enable more confident geological interpretation. Reservoir horizons can now be mapped continuously across channel-affected areas, and amplitude variations are more reliable following attenuation correction. Amplitude extractions at reservoir level show more continuous, geologically meaningful anomalies over the Ana structure compared with the legacy data, underscoring the uplift in interpretability beneath the Danube channel. Preserved relative amplitudes and restored high frequencies provide a stronger foundation for AVO analysis, inversion, and reservoir characterization, supporting more robust development decisions.

Way Forward: Further improvements could be achieved by extending FWI to higher frequencies. The current 12 Hz limit resolved the main velocity framework, but higher-frequency updates could better capture fine-scale shallow variability and further reduce residual channel effects. Additional refinement of the anisotropy model, incorporating greater geological detail, may improve depth positioning and seismic-to-geology ties. Continued enhancement of the Q model, potentially through joint velocity–Q inversion, could further improve amplitude fidelity and usable bandwidth.
Future reprocessing or new acquisition with wider azimuths and longer offsets would also benefit low-frequency model building and imaging beneath gas-affected zones. Overall, this project demonstrates that advanced depth imaging incorporating attenuation (Q) effect can unlock substantial value from legacy seismic, delivering a significantly improved subsurface image and a more reliable basis for exploration and development in the ADB area.

Acknowledgements

The authors thank Black Sea Oil & Gas for permission to publish this work. Special thanks are extended to Glenn Morley for his valuable technical input, constructive discussions, and continued support throughout the project. The authors also gratefully acknowledge Dorina Țambrea (Danubian Energy) for her geological and interpretation support, which contributed significantly to the understanding of the subsurface and the overall progress of the project.

References

Costriiciuc, O., Fogg, A., Holden, R. and Moore, J., 2018. Reservoir imaging using FWI, Q-tomography and Bayesian classification – Black Sea case study from acquisition to drill bit. *Extended Abstracts*, 80th EAGE Conference and Exhibition, We A10 12.
Duley, D. and Fogg, A., 2009. Old dogs and new tricks; unlocking the hydrocarbon potential of the Romanian Black Sea: Ana and Doina gas fields and the role of inversion in derisking. *First Break*, **27**, 9, 63–70.
Matta, M., Anstey, I., Cavalca, M., Kanrar, A. and Steiger-Jarvis, M., 2021. Match-filter Q-tomography – A case study from the Black Sea. *Extended Abstracts*, 82nd EAGE Conference and Exhibition, We P05 08.