Efficient 3D acquisition and imaging in ultra-shallow water for frontier exploration in the Black Sea, Ukraine

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Summary

The text discusses the acquisition and imaging of 3D seismic data in the ultra-shallow waters of the Black Sea's northwestern shelf, focusing on the Dolfin Inner shelf license areas. Despite depths ranging from 14m to 40m, an efficient acquisition setup has been chosen to navigate seafloor obstacles. The data underwent advanced processing, including 3D wavefield separation, deghosting, demultiple, and machine learning-guided denoising. Results demonstrate the final migration velocity model's ability to capture high and low velocity contrasts critical for depth imaging. Separated wavefield imaging (SWIM) enhances imaging of the seafloor providing a very good match with bathymetry data. Comparing 2D and 3D seismic data emphasizes the latter's superior quality, crucial for evaluating the Dolfin Inner shelf area's hydrocarbon potential. Next study will focus on the exploration in the Outer Shelf and adjacent deepwater domains, highlighting the Black Sea's Ukrainian waters as a promising frontier for oil and gas exploration. The acquired 3D seismic data plays a pivotal role in advancing this exploration, contributing valuable insights in a cost-effective manner.

Introduction

The northwestern shelf of the Black Sea mega-basin is a gas producer no. 1 within the Southern petroleum province of Ukraine and still offers great exploration opportunities in largely unexplored acreage. Many large structural and potential stratigraphic hydrocarbon trapping features were identified by a regional 2D survey. The area depicts a promising frontier for 3D seismic exploration, holding the potential to significantly contribute to the country's future energy security. In 2021, Naftogaz of Ukraine contracted PGS to acquire 5000 km^2 of high-quality multi-sensor seismic data in the inner shelf area of the Dolfin license.
The geology of the NW Black Sea was revealed thanks to more than 100 deep wells and a rather dense 2D seismic lines grid. The depth of the wells varies from 2000 to 4600 m (Tauvers, 2022). The sediments covering the NW Black Sea are represented by terrigenous and carbonate formations of Triassic to Neogene sequences with thickness up to 9 km in total. The productive horizons are in Upper Cretaceous and Tertiary reservoir rocks. A major feature is the Karkinit Trough, an extensive Early Cretaceous rift basin filled with Cretaceous to Quaternary post rift sediments. The newly acquired 3D dataset plays an important role to understand the integral geological image of the region and to identify new hydrocarbon prospects.

Methodology

Despite the areas ultra-shallow water depth which varies from 14 m to 40 m, an efficient acquisition set-up with eight 8 km long streamers towed 112.5 m apart utilizing triple sources had been selected. In addition to the very shallow water depth, a high-resolution bathymetry study conducted prior to the streamer operations uncovered various obstacles on the seafloor. To mitigate the risk of hitting the ground or one of those obstacles, the streamers had to be towed at a depth between 8 m and 10 m.
As the first depth imaging project in the area, the data was processed using a state-of-the-art broadband flow, comprising of techniques such as 3D wavefield separation (Carlson et al., 2007), 3D deghosting, 3D demultiple, 4D regularization, velocity model building incorporating full waveform inversion and reflection tomography followed by VTI Kirchhoff depth migration and post-processing. Separated wavefield imaging (Whitmore et al., 2010) provided an accurate image the water bottom that aligns with the bathymetry. The results show how an efficient 3D acquisition and state-of-the-art imaging can provide cost-effective and high-quality data to accelerate exploration in a frontier basin.

Results

The geology consists of both low and high velocity contrasts, from channel systems and gas pockets, but also uplifted basement close to the sea floor. An accurate velocity field capturing these velocity contrasts is essential for successful depth imaging. Figure 1 shows the final migration velocity model overlaid onto a stack. To the west, velocities up to 3000 m/s can be observed as shallow as 200 m below the sea floor. To the east on the contrary, low-velocity features can be observed, some very locally, most likely from shallow gas and channel systems. Overall, the final velocity model is capturing the velocity variations of the subsurface, critical for a good final image.
In ultra-shallow waters, near surface imaging with primaries can suffer from the lack of near-offsets when using efficient acquisition configurations. This is evident from the final stack in Figure 2a, where the water bottom is distorted and shows a significant mismatch with the overlaid water bottom from the high-resolution bathymetry study. Imaging with multiples, achievable with separated wavefield imaging (SWIM) can overcome the challenges from lack of near-offsets as each receiver is used as a virtual source, reducing the effective near-offset gap. Figure 2b shows the final stack after merging images from primaries and multiples. The high-resolution bathymetry data shows how the SWIM image accurately represents the water bottom, also capturing small scale details.

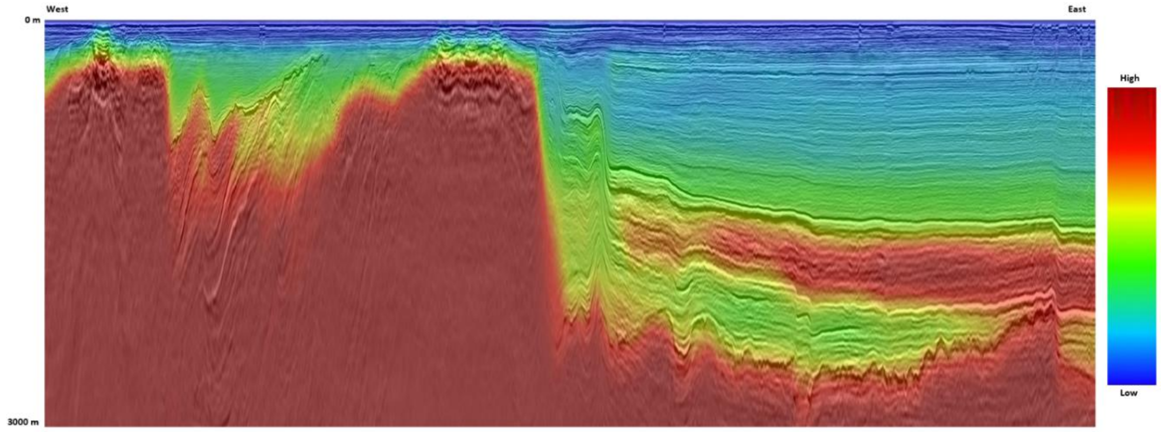

Figure 1 *Migration velocity model overlaid onto final stack. Large velocity contrasts are present over the seismic section, from the uplifted basement of high velocity in the west to the low-velocity shallow channel systems and gas pockets in the east. The velocity model is overall very conformable with the geology.*

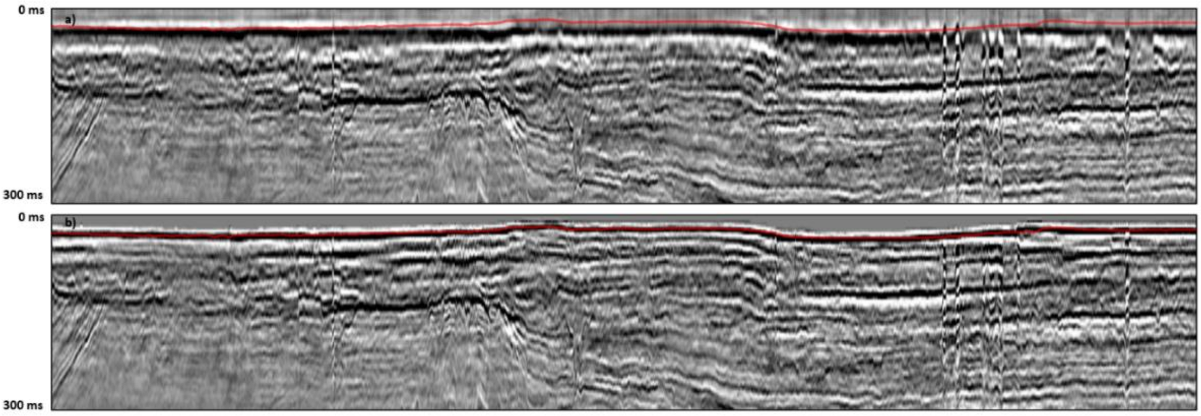

Figure 2 *a) Final KPSDM stack and b) final KPSDM stack with SWIM imaging in shallow section. The SWIM imaging helps to improve the shallow imaging, especially evident from the good match with the bathymetry data (red line overlaid). An increase in acoustic impedance is shown as a black event (peak).*

Conclusions

The Black Sea's Ukrainian waters stand as a promising frontier for future oil and gas exploration. The efficient acquisition and imaging of 3D seismic data over the Inner Dolfin area has provided a new data set that will be key to further develop and evaluate the prospectivity in the area. Utilizing SWIM, we were able to provide a high-resolution image of the shallow section which opens the option to also use the data set for wind farm site evaluation and hydrogen exploration. The next exploration stage is to acquire the same quality 3D seismic data over the Outer Shelf and adjacent deepwater domain bordering with Domino and Sakarya gas discoveries in Romanian and Turkish waters respectively.

References

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