Rapid, High-Resolution Imaging via Real-Time Processing-Driven Acquisition: Onshore Northern Caspian: Gran Field

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Summary

In autumn 2025, a high-density 3D seismic survey was conducted over the Gran Field in the Atyrau region of western Kazakhstan. The objective was to refine the structural framework of suprasalt reservoirs and identify additional development opportunities within this mature brownfield asset. The survey integrated a high-channel-count nodal recording system, a mobile weight-drop seismic source, and a real-time processing workflow executed directly at the acquisition edge.

The edge-processing environment enabled immediate quality control, adaptive optimisation of acquisition parameters, and rapid delivery of preliminary subsurface images during acquisition. By reducing delays associated with data transfer and centralised processing, the project delivered a fully migrated 3D seismic cube within weeks of acquisition completion.

The resulting dataset provides high-resolution imaging of the suprasalt target interval between approximately 170 m and 850 m depth while preserving interpretable signal for deeper structural elements and potential Paleozoic targets down to roughly 4000 m. The survey significantly improves the structural understanding of the Gran Field and demonstrates the operational benefits of integrating high-density nodal acquisition with real-time edge processing for rapid seismic imaging in mature hydrocarbon provinces.

Introduction

This study forms part of a broader operator initiative aimed at addressing production decline across several mature onshore assets in western Kazakhstan. As fields mature, exploration efforts shift from discovery toward maximising the recovery factor of remaining reserves. Achieving this objective requires improved subsurface imaging capable of resolving complex structures that were poorly constrained in legacy seismic data.

The Pre-Caspian Basin contains a sedimentary succession exceeding 20 km in thickness and is divided by the Lower Permian Kungurian evaporite sequence into distinct subsalt and suprasalt domains. Regional structural development is strongly influenced by salt tectonics, with more than one thousand salt domes generating a complex system of traps and structural compartments (Ulmishek, 2001).

Hydrocarbon accumulations within the suprasalt interval are commonly associated with Jurassic and Cretaceous clastic reservoirs positioned along the flanks and crests of salt structures. In many areas, legacy seismic surveys lacked the spatial resolution necessary to image these geometrically complex environments, particularly near steep salt walls and within structurally disrupted zones.

The Gran Field represents a typical example of such a mature brownfield setting. Although several exploration and production wells have been drilled, uncertainties remained regarding the detailed structural configuration of the suprasalt reservoirs and the geometry of deeper structural features. The acquisition of a modern high-density seismic dataset was therefore undertaken to improve the geological model and support ongoing field development planning.

Geological Setting

The Gran Field lies within the northern Caspian coastal region of the Atyrau area of Kazakhstan. Structurally, the field is associated with a salt-related structural high formed by deformation of the thick Kungurian evaporite sequence. The regional tectonic framework is characterised by salt domes and associated depressions that strongly influence hydrocarbon migration and trapping.

The primary exploration targets in the study area are suprasalt reservoirs occurring within Jurassic and Lower Cretaceous terrigenous deposits. These reservoirs typically consist of sandstones, sands, and siltstones exhibiting favourable porosity and permeability characteristics. Hydrocarbons are interpreted to originate from deeper Paleozoic source rocks and migrate vertically through structural depressions where the evaporite sequence is locally reduced or absent.

Reservoir intervals in the Gran Field occur at relatively shallow depths, generally between approximately 170 m and 850 m. Despite the shallow nature of these targets, the structural complexity associated with salt tectonics and faulting has historically complicated seismic interpretation. Improved seismic resolution was therefore required to delineate structural closures and reservoir compartments more accurately.

Seismic Acquisition

To address these imaging challenges, a high-density 3D seismic survey was designed using a nodal recording system capable of supporting a large channel count and flexible receiver deployment. The acquisition geometry was optimised to maximise spatial sampling and enhance resolution in the shallow suprasalt interval. The survey employed a mobile weight-drop source that allowed efficient operations under the near-surface conditions typical of the coastal Atyrau region. The combination of dense receiver spacing and controlled source parameters enabled the acquisition of broadband seismic data with high signal fidelity. A key objective of the survey design was to provide sufficient spatial sampling to resolve complex structural features associated with salt tectonics while maintaining sensitivity to deeper targets within the basin. The final acquisition geometry allowed the imaging of both shallow reservoirs and deeper structural elements.

The survey location and acquisition layout are illustrated in **Table 1** & **Figure 1**

Survey Size	5.5 x 2.5 km
Source Type	500 kg weight Drop (6 drops)
Receiver Type	Wireless node (2 ms)
Source Line	50 m
Source Points	12.5 m
Receiver Line	50 m
Receiver Points	12.5 m
Binning	6.25 x 6.25 m

Table 1 – Seismic acquisition parameters

Figure 1 - Survey map in Coastal Northern Caspian

Real-Time Processing-on-the-Edge

The processing hardware utilised for this project is the same one used to manage the harvesting and reconstruction of field data from continuous nodal records. When idling, or in low-rate usage, this hardware is used as an on-the-edge processing system by hosting a temporary processing environment that is remotely accessible by our processing team located outside the country. This integrated approach ensures maximum hardware utilisation, a key to facilitate the rapid turnaround of results.

Integrated processing was important from the project's inception to enable real-time acquisition adjustments. During source testing, initial trials of 12 drops per location were decimated and analysed to evaluate signal-to-noise (*S/N*) ratios across stacked shots 1–*N*. By identifying a threshold where further effort yielded diminishing returns, we optimised the sequence to 6 shots per location. This halved the planned source effort while maintaining like-for-like data quality. A single shot and stacked shot (*N*=6) can be seen in **Figure 2**.

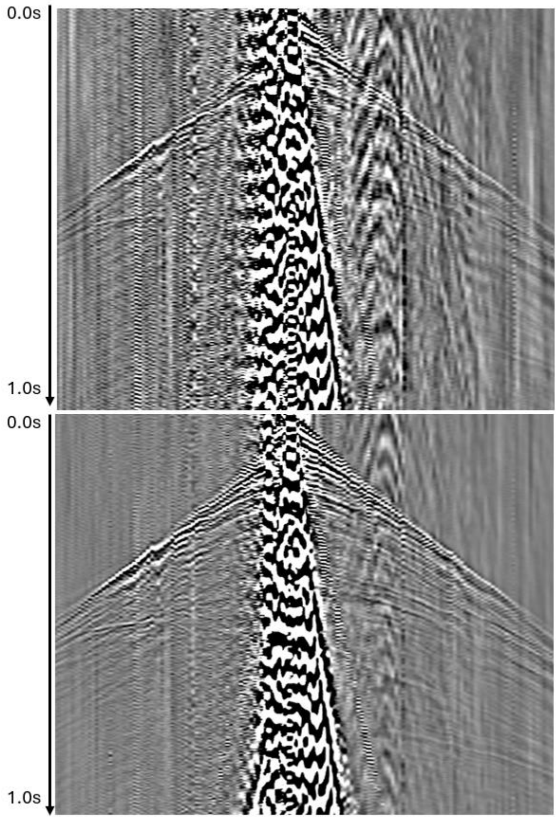

Figure 2 - Shot gathers from field showing single (top) and six stacked (bottom) examples

To maximise the benefits of this stacking, a "pop statics" correction was applied prior to summation. This process leveraged the high-density receiver coverage to statistically resolve subtle timing variations, typically less than 1.5ms (sub-sample) between individual drops (1-N) at the same location, the mean of which is 0ms. By applying these precision shifts, we corrected for source-side inconsistencies, enhancing the signal-to-noise ratio of the final stacked records and maintaining a streamlined data footprint for subsequent processing. A zoomed example in **Figure 3** shows a group of traces from the same source receiver pair for each shot, before and after the shift. After summation, the manageable survey size and available compute power allowed for a advanced processing sequence. This included

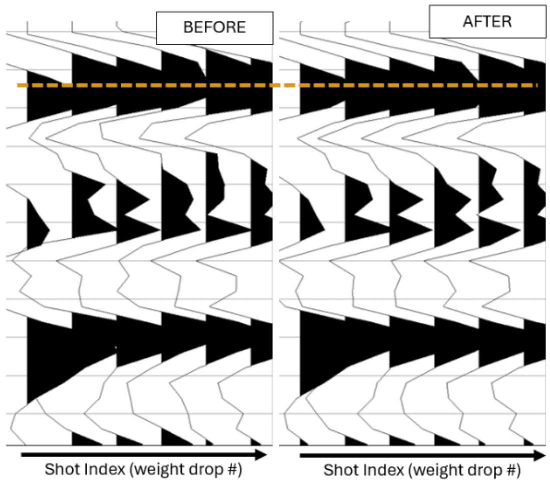

Figure 3 - Traces from source/receiver pair before (left) and after (right) pop statics correction

multiple passes of denoise, refraction tomography, residual statics, pseudo 5D interpolation followed by deconvolution. We put a lot of emphasis on velocity analysis, as it was clear this would be essential for imaging given structural complexity in the area at target. This was done via manual picking on regularised data and refined with 50m auto-picks on semblance gathers. The data were then migrated, and the process repeated several times to optimise imaging velocities.

To improve the final image, we used a pseudo-5D interpolation by running 3D regularisation on individual azimuth bins (60° sectors) and summing the results together. This approach maintained a superior signal than standard single-offset binning. Ultimately, it was an effective way to deliver a more sophisticated workflow whilst keeping the processing requirements proportionate to our available hardware. It also provided this multi-azimuth interpolated dataset which could be used in future for different, more advanced, imaging workflows.

Kirchhoff pre-stack time migration was used for imaging of the survey area, with migration to native 6.25 x 6.25 m bins, a high-resolution product was delivered. The multiple velocity analysis on high quality pre-processed data was the key for imaging of the complex structure at target.

Results and Discussion

The integrated acquisition and advanced processing workflow produced a high-resolution 3D volume with distinct high-angle faulting clearly visible down to the 1000–1500 m depth interval. The project successfully characterised primary suprasalt targets, the primary operator objective and critical for maintaining production in brownfield setting, while also revealing broader structural features and potential subsalt horizons down to approximately 4000 m (Figure 4). However, the resolution of these deeper features was constrained by an offset restriction of 1300 m within field data. This limited aperture introduced higher uncertainty in the deep velocity model and structural illumination compared to the shallower section. While the current results are robust enough to guide immediate development, future efforts incorporating a wider offset range and simultaneous 5D interpolation would likely improve velocity control and illumination for secondary targets of Paleozoic potential.

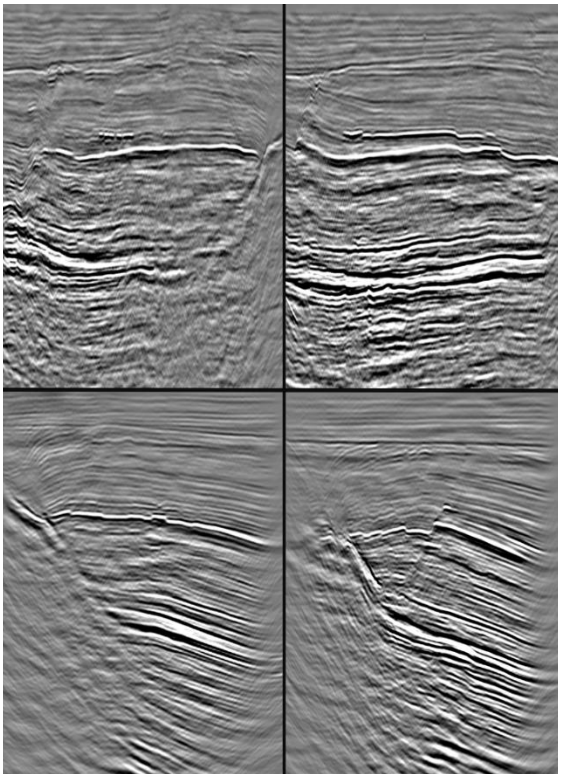

Figure 4 - Seismic sections from Kirchhoff time imaging of the Gran field high density nodal survey

Conclusions

The project demonstrates that high-trace-density seismic surveys with modern nodal technology, can not only accelerate the seismic acquisition and the delivery of raw dataset, but can also play a key role in delivering a very fast imaging turnaround thanks to the utilization of its "processing-on-the-edge" capability (Ourabah et al, 2005). With a total elapsed time of less than ten weeks from first shot to final volume, this streamlined approach provides a robust template for a “turnkey” solution. This methodology offers immediate, insights into a play, allowing for direct operational action while more traditional, long-term projects can be used to further refine the site later using the same field data.

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