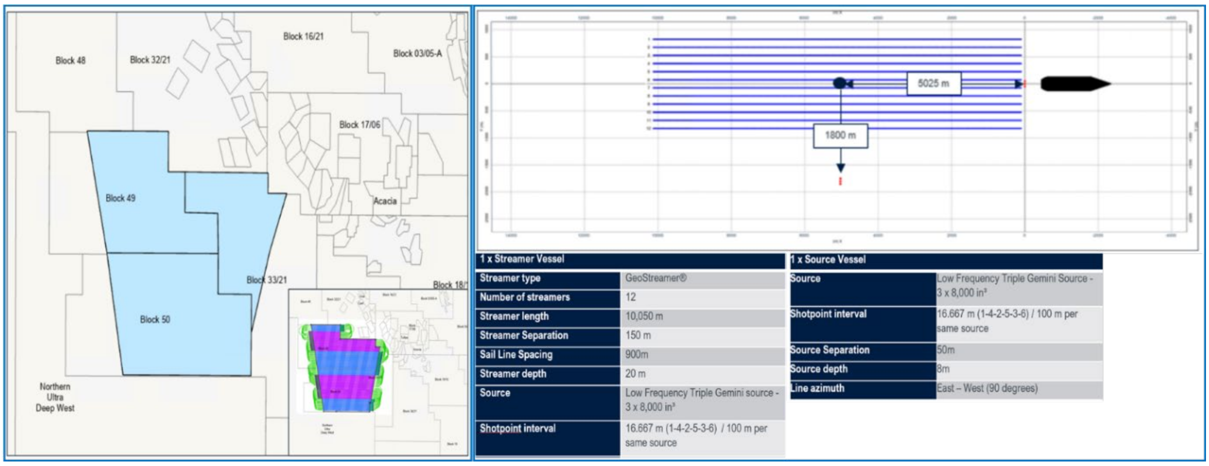
Imaging complex geology offshore Angola through integration of one-sided WAZ acquisition, low frequency sources and Elastic DMFWI model building

Introduction

In 2025 a 3D multiclient survey was acquired and imaged in an exploration setting offshore Angola where no 3D legacy imaging existed. Spanning blocks 33, 49, and 50, with a total survey area of 8726 km², the project was designed to address the complex subsurface challenges associated with salt structures by using advanced acquisition technology (multi-sensor streamers and low frequency sources) in a one-sided WAZ streamer configuration (Figure 1) while deploying modern earth model building technology such as elastic Full Waveform Inversion (FWI).

Acquisition Design and Geological Setting

Acquisition employed twelve multi-sensor 10 km cables spaced 150 m apart, two low-frequency triple sources (3 × 8,000 in³). Three sources were located behind the streamer boat and another three behind the source boat roughly 5 km down the cable and 1800 m to the side (Widmaier *et al.*, 2025). This allowed for acquisition of data orthogonally to the survey direction at the same time as the nominal direction. The bin size was 6.25 m x 25 m, with an east–west line azimuth optimizing spatial resolution for imaging steeply dipping structures and complex salt geometries.



1 x Streamer Vessel	
Streamer type	GeoStreamer®
Number of streamers	12
Streamer length	10,050 m
Streamer Separation	150 m
Sail Line Spacing	900m
Streamer depth	20 m
Source	Low Frequency Triple Gemini source - 3 x 8,000 in³
Shotpoint interval	16.667 m (1-4-2-5-3-6) / 100 m per same source

1 x Source Vessel	
Source	Low Frequency Triple Gemini Source - 3 x 8,000 in³
Shotpoint interval	16.667 m (1-4-2-5-3-6) / 100 m per same source
Source Separation	50m
Source depth	8m
Line azimuth	East – West (90 degrees)

Figure 1: Survey location map (left) and acquisition geometry (right)

The Lower Congo Basin is a rifted passive margin formed during the Early Cretaceous. Initial syn-rift half-grabens filled with continental clastic and lacustrine facies were overlain by marine shales and carbonates during post-rift subsidence. An extensive Aptian salt acts as a detachment surface driving basin-scale gravitational gliding and genesis of extensional, translational, and compressional domains. The post-salt region developed when Oligo-Miocene clastic sediments flowed from the Congo River creating layers as thick as 7 km and forming a deepwater turbidite fan system. This system serves as the main reservoir suite and also caused the salt to shift, shaping the allochthonous salt bodies (Marton, *et. al.*, 2000). Accurate mapping of the salt framework is critical for evaluating the petroleum system as salt tectonism is at the origin of many complex trap geometries, particularly around salt flanks and in sub-allochthonous salt settings.

Methodology

The adoption of a one-sided WAZ streamer acquisition geometry enabled efficient data acquisition for the survey. This configuration provided enhanced subsurface illumination and improved spatial and temporal resolution, both of which are essential for accurately imaging complex salt structures prevalent in the study area. In comparison, an ocean bottom node survey could deliver similar imaging benefits but would require substantially higher costs and operational complexity, particularly in early-stage exploration scenarios where economic efficiency is critical (Donaldson *et al.*, 2024).

Incorporating one-sided WAZ shots into FWI further improved the imaging. These additional azimuths increased subsalt illumination, especially in regions beneath salt overhangs where coverage from standard streamer geometries is limited. The inclusion of this data contributed to better-constrained velocity model updates in structurally complex areas, supporting a more reliable characterization of the subsurface. Figure 2 highlights the improvements on images and CDP gathers with the yellow arrows.

The energy source has large single chamber of 8000 in³. providing extended low frequencies without compromising high frequencies. Within the seismic bandwidth it is considered as point source.

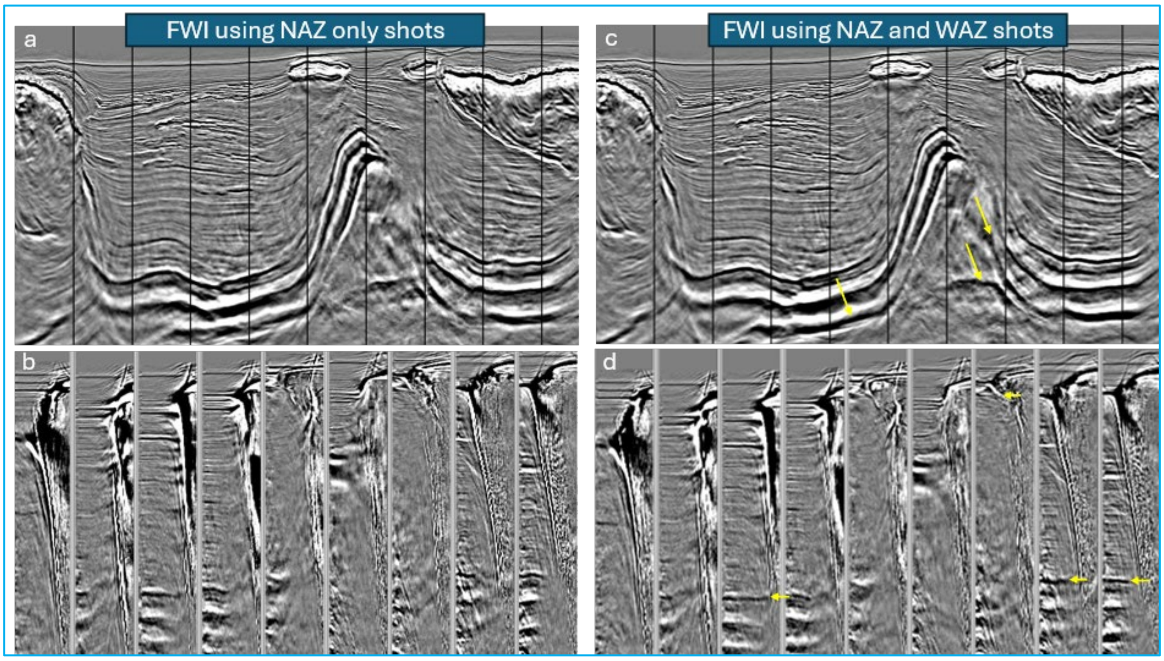


Figure 2: image and gathers after FWI using NAZ shots only (a) and (b) respectively, versus image and gathers after FWI using both NAZ and WAZ shots (c) and (d).

Our data-driven elastic FWI VMB workflow (Figure 3), consists of three interconnected elements: a fit for purpose initial model, E-DMFWI and, interpretation of the salt framework.

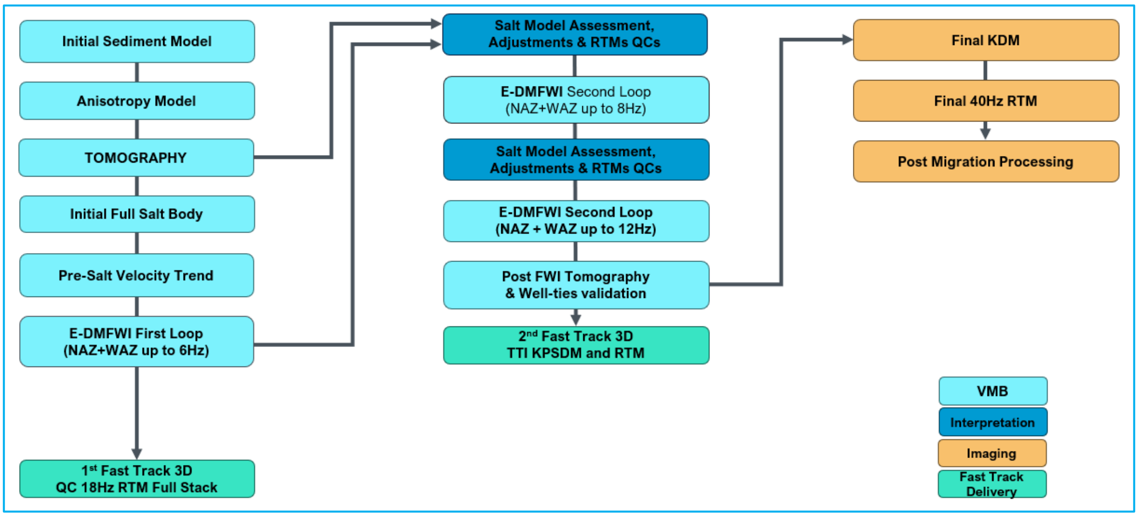


***Figure 3**: Velocity Model Building and Imaging workflow*

To honor the true subsurface physics, we use elastic modelling to effectively capture phase changes across angles and azimuths where the acoustic assumption breaks down. To take full advantage of the elastic modelling we calibrated our elastic relationships using neighboring wells (Figure 4).

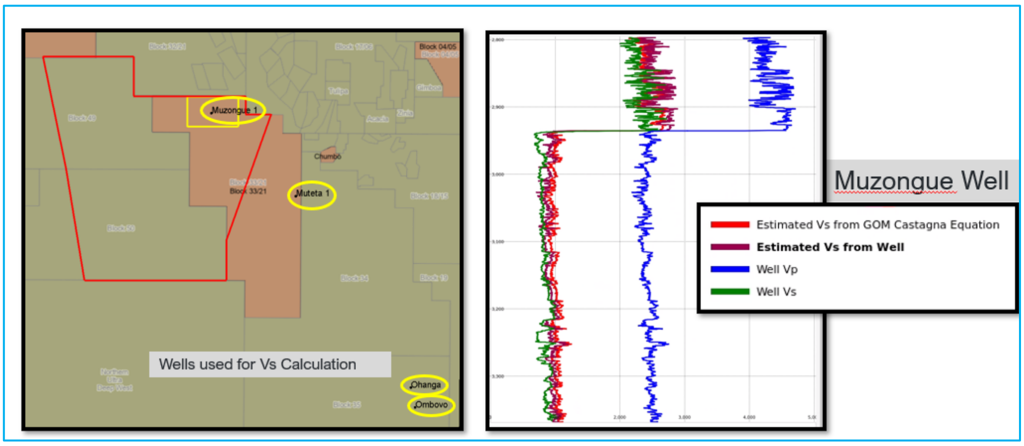


***Figure 4**: Well calibration of the Vp/Vs relationship*

The initial water column velocity model was developed by scaling the average TSDip profile. A preliminary sediment model was subsequently generated from 2D velocity profiles across the area, followed by 3D smoothing. Further refinement involved three iterations of tomography to resolve medium-wavelength velocity anomalies down to 2 km. Due to the absence of well data for deeper sediments, the legacy anisotropy function was used. This pre-FWI sediment background model was used in the interpretation of the top of salt. To expedite preliminary results, an initial salt body, featuring provisional overhangs and a regional base of salt were interpreted from a single salt flood. A smoothed version of this complete salt velocity model, combined with the sediment background, served as the input for the first sequence of elastic FWIs (3 Hz to 6 Hz) and utilized both NAZ and WAZ data to enhance illumination of salt geometries.

The initial E-DMFWI sequence, applied up to 6 Hz, established the background velocity essential for accurate kinematic modelling of the data. Insights gained from this phase guided a revision of the salt framework, leading to an updated model for the subsequent E-DMFWI sequence (up to 12 Hz). This iterative approach enabled further refinement of geological features, including salt and carbonate bodies, thereby improving structural imaging and enhancing the resolution of the velocity model in preparation for early imaging insights.

In tandem with an accelerated completion schedule, scenario testing was undertaken within the most complex survey areas. Insights gained from these scenarios were integrated into the salt framework resulting in the formulation of an updated salt model, which was applied in the second and final E-DMFWI sequence (1.5 Hz to 12 Hz). Comparisons between the velocity model and migrated images from the initial and updated models highlight the influence of the E-DMFWI VMB methodology (see Figure 5).

The results indicate that, notwithstanding offset constraints, E-DMFWI has enhanced the delineation of carbonate and salt geometries within the velocity models by utilizing the full wavefield down to depths of 5 km. This approach facilitated robust updates reliant solely on reflection data, extending to the regional base of salt or basement, thereby substantially improving imaging quality at those depths.

Conclusions

This case study illustrates that combining one-sided WAZ acquisition with low-frequency sources and a cascaded E-DMFWI workflow effectively addresses subsalt imaging challenges in the complex salt provinces of Angola. The approach enhances imaging beneath salt and pre-salt layers by refining salt and carbonate geometries and improving velocity model precision. The robust elastic implementation accurately captures wavefield behavior in regions of pronounced velocity contrast, yielding images that support more dependable interpretation and reduce exploration risk. This methodology offers a cost-efficient solution for early-stage exploration and establishes a foundation for future high-resolution imaging and prospect assessment throughout Angola's frontier plays.

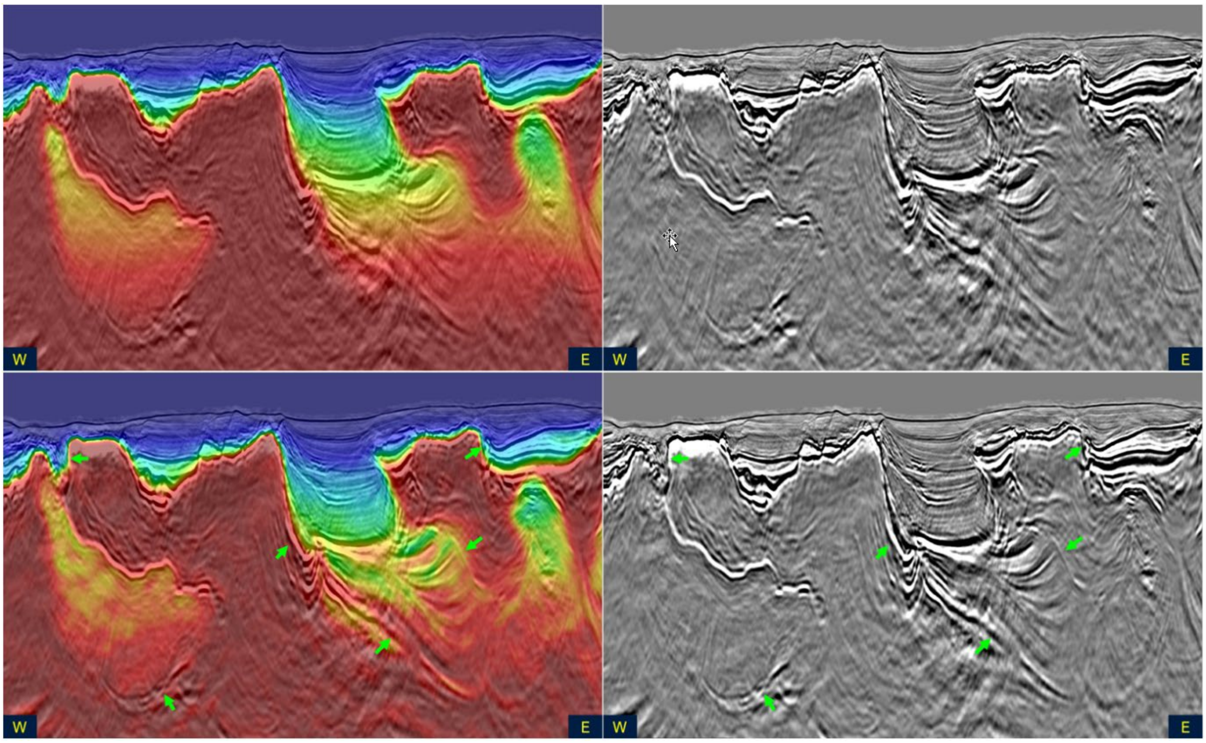


***Figure 5**: 18Hz RTM QC stacks with respective model overlays comparison using the initial model (top) and the velocity model after E-DMFWI sequence 2 (bottom).*

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