Enhanced Imaging of Complex Geology via WAZ Acquisition Design, Enhanced-Frequency Sources, and Elastic FWI Model Building

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Introduction

A 3D multiclient seismic survey was recently acquired and processed in a frontier exploration area offshore Angola, spanning blocks 33, 49, and 50 and covering 8,726 km². To address the subsurface challenges associated with complex salt tectonics, the project combined advanced acquisition technologies—such as multi-sensor streamers and enhanced frequency sources—with a one-sided wide-azimuth (WAZ) streamer configuration and employed state-of-the-art model building techniques such as elastic Full Waveform Inversion (FWI).

Acquisition Design

Recent projects have demonstrated the benefits of combining extended-frequency sources with deep-tow multisensor streamers in advanced seismic acquisition configurations. These include hybrid source solutions for extended long-offset acquisition (Offshore Energy news release, 2021) and one-sided WAZ acquisition (Donaldson *et al*., 2024). Following three successful surveys in the Eastern Mediterranean, a further survey using the one-sided WAZ configuration was acquired offshore Angola in early 2025 (Widmaier *et al*., 2025). The acquisition deployed twelve 10 km streamers spaced 150 m apart and six enhanced-frequency Gemini sources (Figure 1). This enhanced frequency source (Brittan *et al*., 2020; Udengaard *et al*., 2023) is an innovative marine source technology that employs a single large element (8000 cu in) engineered to produce both very low frequencies—down to at least 1 Hz—and high frequencies. This wide bandwidth enables it to function as the sole source for a variety of exploration objectives. Additionally, the omnidirectional behavior of single-element sources simplifies de-signaturing, de-bubbling, and FWI.

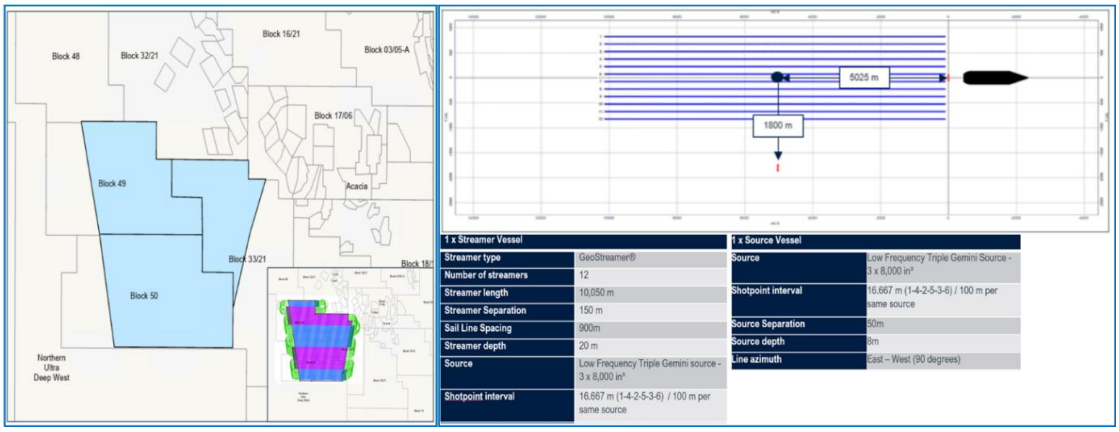

Figure 1: Survey location map (left) and acquisition geometry (right)

VMB Workflow

Incorporating one-sided WAZ shots into FWI improved imaging by increasing subsalt illumination, particularly beneath salt overhangs where conventional streamer geometries provide limited coverage. This additional azimuthal information helped better constrain velocity updates in structurally complex areas, improving subsurface characterization. Our data-driven elastic FWI velocity model building (VMB) workflow integrates three elements: a fit-for-purpose initial model, elastic dynamic matching FWI (E-DMFWI), and iterative interpretation of the salt framework. Elastic modelling was applied to capture phase variations across angles and azimuths where

acoustic assumptions break down, with elastic relationships calibrated using nearby wells. The initial model combined a scaled TSDip water velocity, a sediment model derived from 3D smoothing of legacy velocity, and three tomography iterations to resolve medium-wavelength anomalies to ~2 km depth.

A smoothed salt model merged with the sediment background formed the input to the first elastic FWI sequence up to 6 Hz using both NAZ and WAZ data to improve salt illumination. This stage established the background velocity required for accurate kinematic modelling and guided updates to the salt framework for the next E-DMFWI stage (up to 12 Hz). Comparisons between initial and updated velocity models and migrated images demonstrate the impact of this workflow (Figure 2). Despite offset limitations, E-DMFWI improved the delineation of carbonate and salt geometries by utilizing the full wavefield to depths of ~5 km, enabling robust reflection-based velocity updates to the regional base of salt or basement and significantly enhancing imaging quality.

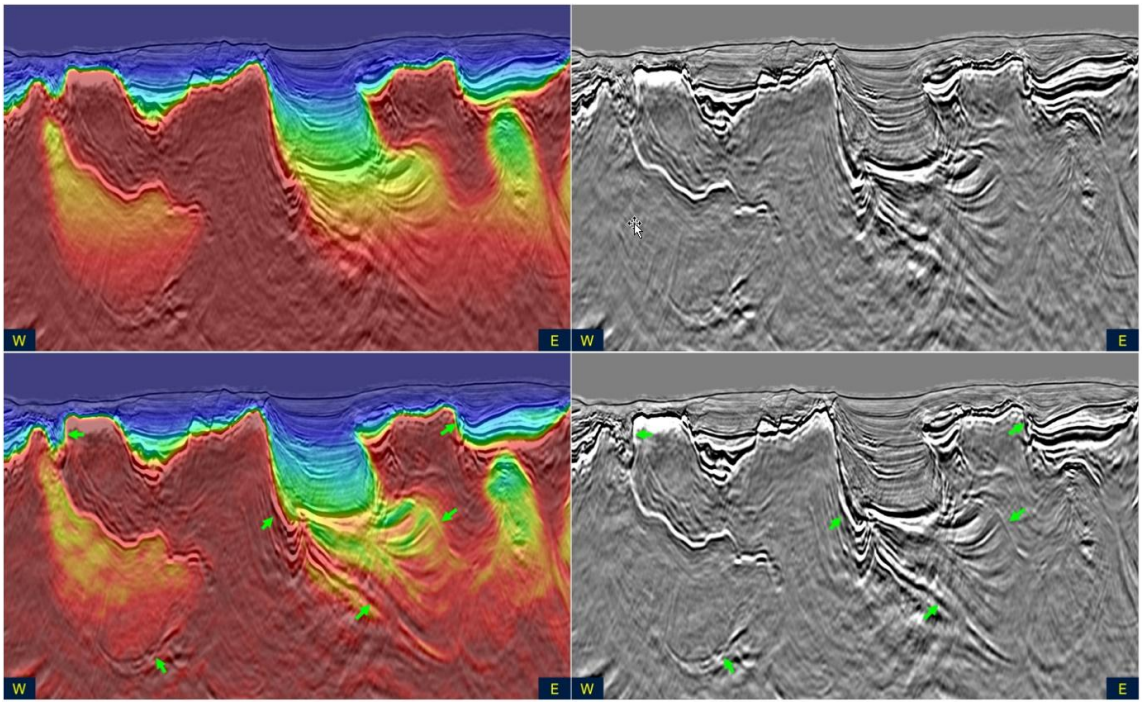

Figure 2: 18Hz RTM QC stacks with respective model overlays comparison using the initial model (top) and the velocity model after E-DMFWI sequence 2 (bottom).

Conclusions

Integrating one-sided WAZ acquisition, enhanced-frequency sources, and E-DMFWI provides an effective and cost-efficient approach for imaging Angola's complex salt provinces. The workflow improves subsalt illumination, salt-body definition, and velocity model reliability, supporting more confident early-stage exploration and future prospect evaluation.

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