NAZ and Beyond – What's Next for Marine Streamer Brazil Exploration

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Summary

Many parts of Brazil offshore basins, such as shelf Equatorial Margins and Pelotas Basin, deep-water Santos and Campos Basins, can still be categorized as under-explored as there is limited to none 3D data coverage. In order to de-risk exploration in frontier basin, seismic industry has been using marine narrow azimuth (NAZ) 3D streamer acquisition geometries as the best balance between data quality, efficiency and environmental impact.

In this abstract we will show recent 3D NAZ case studies, one in South Santos Basin and the other one in Para Maranhao Basin, where diligent survey planning and execution, along with robust multisensor wide streamer spreads, allows for inversion of high-resolution velocity models and high-quality imaging. Both datasets are acquired in operationally challenging environments, where combination of tailored acquisition and processing solutions help us acquire data in an efficient manner and minimize environmental footprint.

For most of Brazil programs, due to environmental, operational, and regulatory challenges, we expected 3D NAZ to continue to be the "working horse" of the seismic exploration.

In simple passive margin settings, we expect to see incremental improvements in NAZ, such as denser shot spacing, longer cable lengths, wide-tow sources, better multisensor streamers, and customized processing solutions. For more complicated basins with salt and volcanics, these improved NAZ configurations may not be sufficient to adequately delineate deep targets. Here we believe the next step-change will come from the use of low frequency sources, such as Gemini (Goertz et al., 2025, submitted), similar to recent successful model building and imaging programs in the Mediterranean and West Africa salt basin.

Introduction

Streamer-based 3D Narrow Azimuth (NAZ) acquisition has long served as the "working horse" of marine exploration offshore Brazil and globally. Most of the post-salt and pre-salt discoveries in Brazilian basins have been identified, mapped and subsequently drilled on 3D NAZ data. However, despite using state-of-the-art processing and velocity model building workflows, conventional 3D NAZ data will sometimes fail to adequately image complex geological targets, such as those found in outer parts of the Santos and Campos basins. In such environments, enhanced subsurface sampling- including denser spatial sampling, increased offsets, broader azimuthal coverage, and improved frequency content - can provide significant imaging improvements. Nevertheless, acquiring such optimally sampled data is frequently constrained by operational, environmental, and economic factors. For instance, wide-azimuth and long-offset acquisitions in Brazil are subject to regulatory restrictions on source vessel proximity, limiting survey design flexibility. Additionally, weather conditions and barnacle growth impose limits on streamer spread size and cable length, regardless of advances in source, receiver, and survey design technologies.

In the southern Santos basin, we implemented dense, triple-source 3D NAZ acquisition to cover large parts of unexplored basins within a highly challenging operational environment. The use of multisensor streamer technology, coupled with advanced barnacle-cleaning methodologies, allowed for effective data acquisition while maintaining an aggressive timeline dictated by industry demands.

In the Para Maranhão basin, where deeper and structurally complex exploration targets necessitate extended offsets, we propose a wider 3D NAZ acquisition spread with longer offsets. Here an advanced de-blending workflow is employed to preserve signal integrity, enabling clean record lengths even in the presence of strong ocean currents, where we have up to four shots in continues recording setup.

For more complex settings, such as the outboard regions of Brazil's salt basins, 3D NAZ acquisition can be further optimized by integrating low-frequency sources with multisensor streamers and extending the cable length within operational limits. Incorporating sparse Ocean Bottom Node (OBN) technology can provide additional subsurface information and can be integrated with existing or newly acquired 3D seismic to improve velocity model building and enhance subsalt imaging. These innovations in survey design and data acquisition workflows represent significant advancements in the ability to image and characterize hydrocarbon reservoirs in Brazil's offshore basins, ensuring that exploration efforts continue to evolve despite operational constraints.

NAZ - the "working horse" of seismic exploration

Like other hydrocarbon provinces worldwide, the evolution of marine seismic acquisition offshore Brazil began with sparse 2D lines, followed by the development of denser, more regularly spaced 2D grids covering large areas, often spanning multiple basins within a single program. Regional basin-scale analysis based on these datasets enables exploration companies to define petroleum systems and identify the most prospective areas. These high-potential regions are then targeted with 3D acquisition, which allows for detailed mapping of prospective features, quantitative analysis and volumetric assessment.

In the 1990s and 2000s, 3D seismic surveys in the shallow water and slope of several offshore Brazilian basins were acquired using relatively narrow spreads, usually 4-6km streamer offset and single or dual-source configuration. The next phase of evolution involved towing wider spreads with longer offsets, along with the introduction of triple-source configuration. The first commercial program to implement triple-source acquisition for streamer technology was launched in 2022 by TGS and CGG in the Foz do Amazonas basin. As such, the adoption of multi-source technologies for NAZ surveys in Brazil has been slower compared to other regions, where triple-source acquisition began as early as 2014-2015. Several surveys have also been conducted using dual-azimuth setups, along with various tests of new technologies on both the streamer and source sides (Figure 1).

This paper will explore potential improvements to the NAZ setup to sustain exploration success in Brazil, considering the environmental, regulatory, and economic constraints

Efficient NAZ configurations for large-scale exploration

Large areas of the Equatorial and Southern Atlantic Margins still rely on 2D seismic data for exploration. For these frontier basins, we propose efficient NAZ programs designed to image reservoir target intervals (Figure 2) while adhering to environmental, economic, and regulatory requirements. The southern Santos and Pelotas basins are conjugate to the Namibia basins, where recent giant discoveries by Shell, TotalEnergies and Galp have spurred significant interest (Zalan et al., 2022). This renewed exploration activity led to the acquisition of numerous Brazil open acreage blocks in a recent licensing round. As a result, there is a growing demand for high-quality 3D data to support expedited exploration efforts.

The stratigraphic fill on this volcanic passive margin includes an Albian carbonate unit over basement highs and Late Cretaceous-present clastic packages (Zalan, 2017). The primary source rock units (Aptian-Turonian) are among the earliest basin fill units. Reservoir targets, ranging from Late Cretaceous to Miocene, include channel complexes and mass-transport systems (Zalan, 2017).

Drawing from our 2D and 3D project experience in these regions, the primary challenges encountered were operational and environmental in nature. Maintaining 10 km of cable over a widespread area was identified as a risk that could extend exposure and prolong the survey duration. Based on modeling results and neighboring surveys to the north, an 8 km offset was chosen as the optimal balance between wave penetration and maintaining the cable spread. Despite having advanced preventive and reactive barnacle mitigation procedures in place, we encountered some of the most extreme barnacle growth observed anywhere globally. For this 2023-2024 acquisition, we utilize a triple-source setup with 12.5m shot spacing and a 3,280in³ source volume, providing high-data fold of 107.

For the Para Maranhão basin (2024-2025), based on existing data and survey design modeling work, we propose NAZ setup with larger spread and 10km of offsets. The key acquisition parameters for this ongoing survey are multisensor streamer with dense shot spacing in a triple-source configuration. The 10km of streamer offset will enable deeper penetration of the diving waves, as we aim to resolve a deeper set of targets compared to the southern Santos and Pelotas basins. Additionally, the presence of larger volcanic bodies in this area suggests that increased offset coverage will aid in model building. During the survey pre-planning, strong oceanic currents were anticipated, which are expected to result in variable "clean" record lengths during acquisition. However, with the Fast Iterative Shrinkage-Thresholding Algorithm de-blending approach, we are able to effectively manage this type of noise (Udengaard et al., 2025, submitted).

NAZ with lower frequency sources for complex targets

Environmental requirements in Brazil are similar to elsewhere in the world, where seismic marine surveys need to have minimal impact on marine life and fishing communities. TGS extended source solution Gemini™ (Brittan et al., 2020), has 10-30 times less output of high frequencies (above 1 kHz) and should be considered an environmentally friendly solution (Goertz et al. 2025, submitted). Gemini emits more low frequencies at the bands that are useful in DM FWI workflows and has successfully been used in production for marine streamer surveys in salt basins in the Mediterranean and Red Sea (Donaldson et al., 2024). These were wide-azimuth and extended long offset configurations where the goal is to acquire more azimuths and longer offsets to try to undershoot salt and illuminate pre-salt and sub-salt targets. Compared to other marine low frequency sources used in the industry, Gemini produces useful frequencies up to 50-60Hz that are used for imaging and not just model building. Figure 3 shows an acquisition configuration we are currently using in the South Atlantic salt basin on the conjugate margin on the African side. Although this is one-side WAZ dataset, we can create NAZ subset and simulate acquisition setup that would be compliant with regulations in Brazil (where 2 source vessels cannot shoot within distance smaller then 60km).

Figure 4 shows preliminary results where we compare the amplitude spectra of brute stacks for a deep-water line before de-blending, the Gemini source and a standard triple source air gun of 3,280in³. Co-located sequences over the same subsurface locations were not available, so we made the comparison over similar geological settings. We see more low frequencies between 2-5Hz with Gemini, similar to the modeled source signatures (Figure 5). Similar can be observed on octave panels, where we have more coherent energy and events with the Gemini source at frequencies from 0-8Hz (Figure 6).

Conclusions

We present the current state of marine streamer acquisition for exploration basins of Brazil where NAZ data has been the "working horse" of the industry. We see that efficient NAZ configurations will continue to be deployed in parts of Equatorial Margin and South Atlantic Margins where there is no 3D seismic data coverage. Given the range of environmental, operational, and regulatory challenges, we expect incremental improvements in NAZ, including denser shot spacing, longer cable lengths, wide-tow sources, multisensor streamers, and customized processing solutions.

For salt, volcanics and carbonate related targets, where existing NAZ is insufficient, we believe the use of low frequency sources, such as Gemini, will improve velocity model building and imaging, replicating success of recent programs in the East Mediterranean and West Africa salt basin.

Acknowledgments

We are grateful to TGS for permission to publish these results.

Type of acquisition	Sparse 2D	Dense 2D	NAZ	DAZ / MAZ	WAZ	RAZ / Coil	Sparse OBN	Dense OBN	Permanent monitoring
Done in Brasil?	Yes	Yes	Yes	Yes	No	No	No?	Yes	Yes
Relative cost	$	$	$$	$$$	$$$	$$$$	$$$$	$$$$$$	$$$$$$$
Regulatory / environment restrictions	Minimal	Minimal	Manageable	Manageable	Restrictive	Restrictive	Manageable	Manageable	Manageable

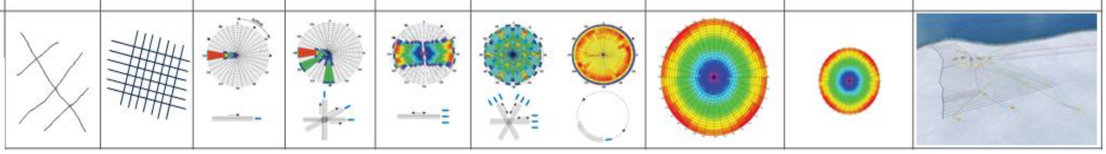

Figure 1 "Evolution" of marine streamer geometries and implementations in Brazil. Illustration of geometries modified after Mohapatra et al. 2013.

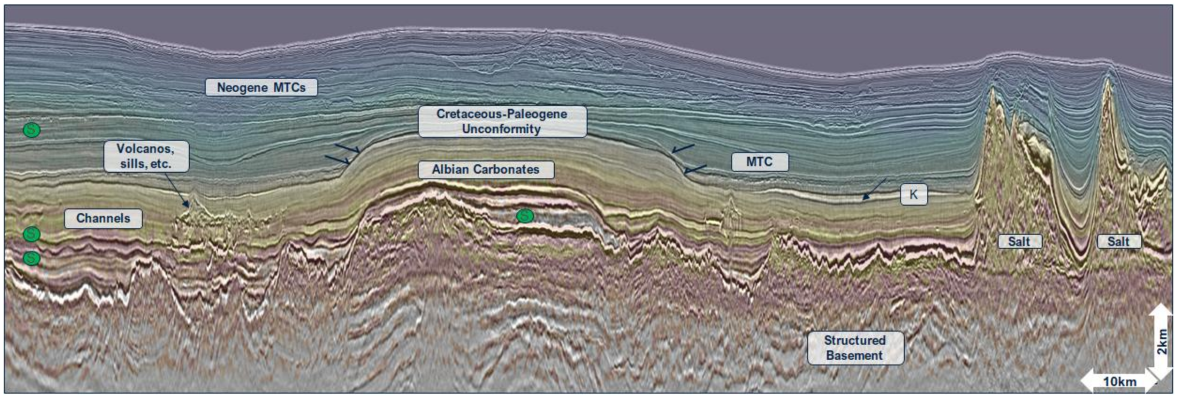

***Figure 2** Fast Track TTI PSDM stack with Dynamic-Matching Full Waveform Inversion (DM FWI) model while the data is still being acquired! Arrows point to the number of geological targets that we identified on this section, meeting the objectives of the survey.*

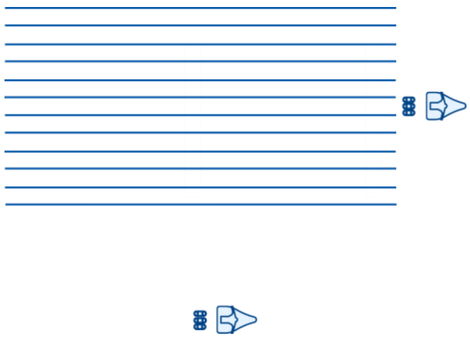

Figure 3 *One-side WAZ configuration with Gemini sources on streamer and source vessel.*

Figure 4 *Amplitude spectra comparison between standard triple-source air gun (red) and Gemini (blue), brute stacks before de-blending.*

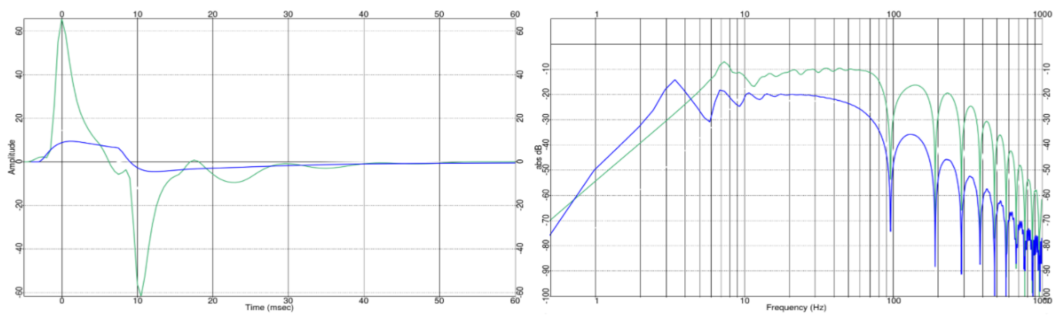

Figure 5 Modelled farfield signature for a conventional triple source array with a total volume of 3,280 in^3 (green) and the 8,000 in^3. Gemini low-frequency source (blue) (Goertz et al., 2025, submitted).

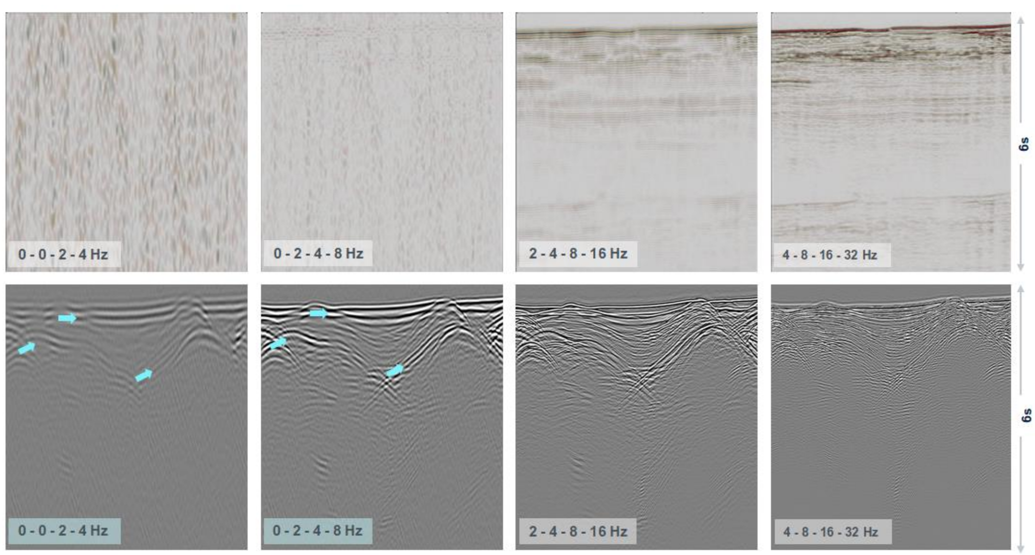

Figure 6 Octave panels comparisons between standard triple source air gun (top row) and Gemini source (bottom row), after de-blending. Arrows point to coherent events in the low frequency panels.