Submission code: LRXXJWZPRV

See this and other abstracts on our website: https://home.sbgf.org.br/Pages/resumos.php

Unlocking hydrocarbon potential in the North-Central Brazil Equatorial Margin by using pseudo-3D seismic volume from recent 2D reimaging

Raul Ysaccis (SLB), Frederico Xavier de Melo (SLB), Cen Li (SLB), Tao Zhao (SLB), German Zuluaga (SLB), Alastair Lewis (SLB)

Unlocking hydrocarbon potential in the North-Central Brazil Equatorial Margin by using pseudo-3D seismic volume from recent 2D reimaging

Abstract Summary

This paper discusses the impact of recent reimaging of 2D data and their 3D seismic projection on the prospectivity assessment of the Foz do Amazonas, Pará-Maranhão and Barreirinhas basins. The pseudo-3D volumes, which honor the reprocessing-enhanced 2D seismic used as input, have a total area of approximately 260,000 Km^2 covering the Brazilian Equatorial Margin (BEM) from the Foz do Amazonas basin to the Ceará basin.

These large-scale pseudo-3D volumes can be very useful in de-risking exploration decisions that involve significant investment in the early stages of evaluating a vast frontier exploration region, such as the BEM deepwaters. Instead of line-by-line views of the multiple 2D surveys available, pseudo-3D volumes provide a continuous seismic image that allows for faster data screening across the basins and better documentation of exploration opportunities, especially if they are related to stratigraphic plays.

Thus, after completing the interpretation of the geological horizons using mainly the 2D reimaged data and integrating the information from the wells located mostly in shallow waters, the visualization of seismic attributes extracted from the pseudo-3D volumes was incorporated into the play identification analysis.

With 2D-to-3D image conversion and regional 2D seismic mapping, we can filter huge data volumes for any stratigraphic interval to see spatial relationships of specific seismic properties. In this way, the attribute volume visualizations performed on the pseudo-3D seismic cubes aid in unraveling the geometry and volumetric extent of the stratigraphic plays in the outboard of the Foz do Amazonas, Pará-Maranhão and Barreirinhas basins. Here, we show that the application of volume trimming, co-rendering, opacity, and spectral decomposition blending is instrumental in delineating crucial seismic features that could suggest potential exploration opportunities.

Introduction

Globally, the BEM on the South America Atlantic margin has emerged as one of the most attractive areas for exploration, after recent discoveries in other Atlantic Margin basins in Guyana, Ivory Coast, Ghana and Namibia, which are considered geologically analogous.

When looking at the results of exploratory drilling over the last ten years, the South Atlantic margins stand out with the largest resources discovered during that period. Around 50 billion boe of the total recoverable came from discoveries in the South Atlantic margin basins since January 2015, representing around 30% of the oil and gas volumes discovered globally (Source IHS, 2025). To further highlight the successful exploration on the margins of the South Atlantic in this 10-year period, seven of the top 20 global discoveries based on total recoverable oil equivalent come from this prolific habitat. The most significant play openers are Liza in Guyana and Venus in Namibia.

The BEM comprises five basins in the northern part of the Brazilian offshore: Foz do Amazonas, Pará-Maranhão, Barreirinhas, Ceará and Potiguar. Understanding the regional tectonostratigraphic framework of the BEM is essential for its prospectivity assessment. Producing fields on the shelf of Ceará and Potiguar basins as well as sub commercial discoveries in Foz do Amazonas, Pará-Maranhão and Barreirinhas basins have shown that the petroleum systems work in these Equatorial basins. However, to improve the process of identifying and

assessing the risks of exploration opportunities in this region, it would be very useful to obtain an integrated geological view along this margin, from the continental shelf to deep waters; this would require the incorporation of information from wells drilled mainly in shallow waters into the regional seismic interpretation.

This study presents results of the ongoing regional interpretation over the Foz do Amazonas, Pará-Maranhão and Barreirinhas basins. The interpretation is based on 2D reimaged data from an extensive seismic reprocessing and reimaging project completed in 2024, together with a pseudo-3D seismic volume constructed from this same reprocessed and reimaged 2D data.

The 2D reimaged data with improved resolution and more accurate imaging of the geology, is key to achieving a more reliable stratigraphic and structural interpretation in these basins and its projection in 3D format enables the visualization of seismic attributes. The main objective of this work is to better understand the relationship between the different tectonostratigraphic domains along this margin and to enhance the documentation of the main exploration opportunities, especially in deep waters.

Database and Methodology

The 2D seismic data used are from a reprocessing project that was completed in early 2024 and included 383 2D lines with more than 67,000 linear kilometers in total, providing seismic coverage from Foz do Amazonas to Ceará basin (Figure 1).

The 2D reprocessing workflow started from field tapes and comprised a robust broadband signal processing sequence, focused on noise and multiple attenuation and using tools, such as deghosting, that were not available at the time of the original processing. This signal enhancement was combined with a pseudo 3D velocity model building process, which included five tomographic iterations and was then refined by 2D full-waveform inversion in the last stage. More details about the reimaging workflow are available in Butler et al. 2024. Geophysically, this reprocessed 2D data were matched in terms of phase, frequency and amplitude across multiple surveys. From the geological side, the resulting seismic images show significant enhancement in definition and resolution at both deep and shallow intervals, allowing for a more confident structural and stratigraphic interpretation.

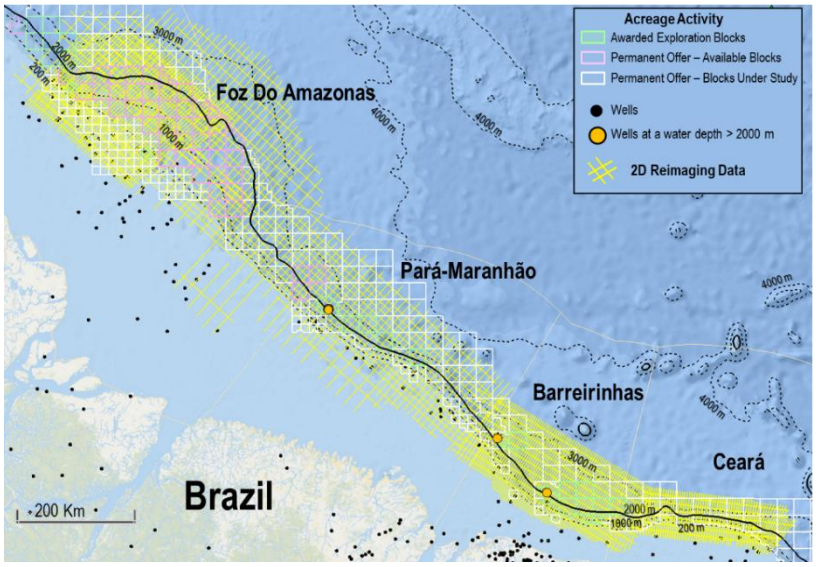

Figure 1: Map showing the extension of the 2D re-imaging program done in the BEM. More than 67,000 linear kilometers of 2D seismic data were included, from the Foz do Amazonas basin to the Ceará basin.

To improve the regional geological understanding, the enhanced 2D seismic data, along with horizon interpretations carried out on this dataset and calibrated with available well information, were used to reconstruct a plausible 3D image projection (Figure 2A). Deterministic and machine-learning-based approaches were applied to project the 2D data as pseudo-3D seismic images after constructing approximate 3D structural and randomly sampled amplitude proxies. Having the 2D data projected in 3D format enables the application of seismic interpretation tools such as volume rendering, geobody extraction, and multi-attribute overlay. Details of the 2D to 3D conversion in the BEM are discussed in Xavier de Melo et al. 2025.

Exploration Play Identification from 2D Seismic Reimaging and Pseudo-3D Volume

In this initial exploration assessment in the BEM, products from 2D reimaging and the 3D image projection are key to documenting the diversity of play types in Foz do Amazonas, Pará-Maranhão and Barreirinhas. As mentioned before, no commercial hydrocarbon discoveries have been found in these basins; however, oil and gas were recovered from several wells, indicating a working petroleum system. Previous exploration efforts targeted structural traps mainly in the shallow water, except for a few wells drilled at a water depth greater than 2000 m (Figure 1); therefore, BEM can be considered a deepwater frontier region.

In the complex tectonic framework of Foz do Amazonas, Pará-Maranhão and Barreirinhas, structural exploration opportunities remain relevant. In these basins, they can be identified both in the passive margin and syn-rift intervals. In the passive margin sequence, the structural plays are mainly related to gravitational tectonics, which produced listric and toe-thrust faults. In the syn-rift sequence, structural plays are tilted blocks and structural highs associated with normal faults generated during the rifting phase.

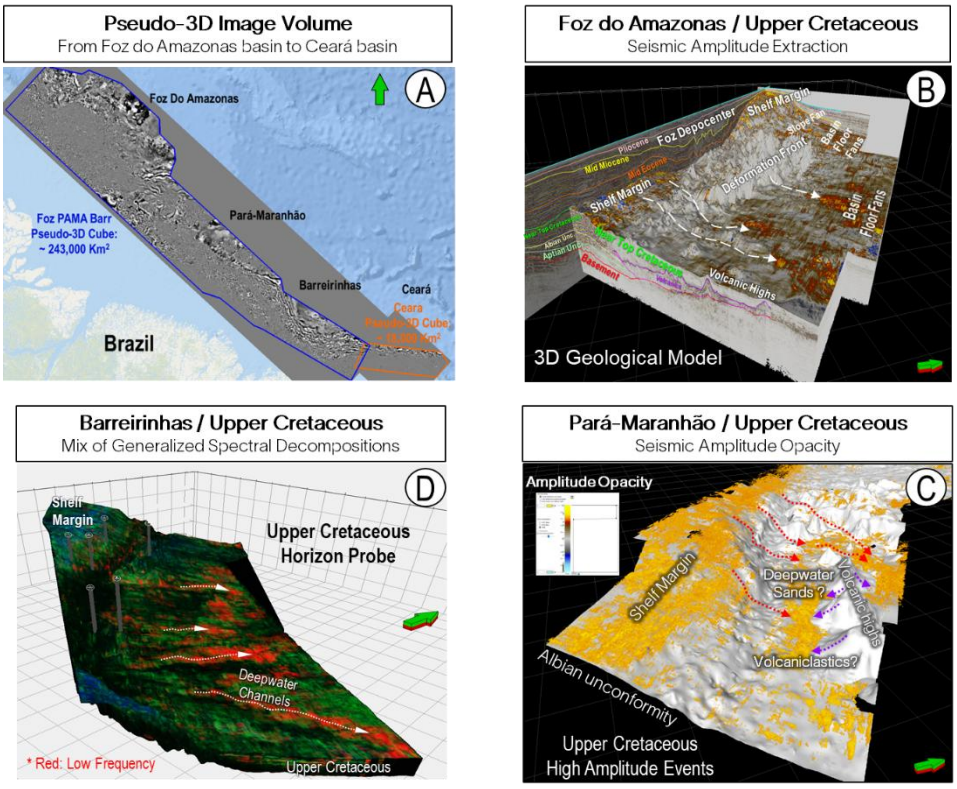

Figure 2: A) Pseudo-3D image volumes cover four Brazil Equatorial basins: Foz do Amazonas, Pará-Maranhão, Barreirinhas and Ceará. Examples of seismic attribute visualization performed in the Foz PAMA Barr pseudo-3D cube at regional scale are shown in B) Foz do Amazonas, C) Pará-Maranhão and D) Barreirinhas basins.

However, the most attractive opportunities are related to stratigraphic plays, which would be much better documented with a contiguous 3D volume rather than the available multi-2D surveys. Although the 2D-to-3D image conversion used here is not suggested as a replacement for 3D seismic acquisition, it can provide guidance at the BEM deepwater exploration frontier before committing to significant investments for further assessment.

Figure 2B shows a 3D geomorphological view of the Foz do Amazonas basin after applying a seismic cropping on the pseudo-3D volume, at the level of the Near Top Cretaceous surface. As seen in the figure, in the inboard of Foz do Amazonas the shelf margin is interrupted by the Foz depocenter, which is highly deformed by a gravitational collapse system, producing a contractional domain with a deformation front towards the central part of the basin. In the outboard of Foz do Amazonas, seismic amplitude anomalies stand out and could be interpreted as potential stratigraphic play type involving basin floor fans.

In the Pará-Maranhão basin, the opacity technique in the pseudo-3D cube was used to isolate high-amplitude anomalies in the Upper Cretaceous (Figure 2C). Some of these anomalies could be exploration targets as they may be deepwater sandstones terminating against volcanic highs. In the Barreirinhas basin, 3D general spectral decomposition and color blending have successfully highlighted low-frequency features in the Upper Cretaceous that could be suggested as deepwater channels with basin floor fans (Figure 2D).

Conclusions

Recent 2D reimaging data with significantly improved quality and their 3D image projection are key to documenting the diversity of play types in Foz do Amazonas, Pará-Maranhão and Barreirinhas; they can provide a better understanding of the different elements of the petroleum system across these Brazil equatorial basins.

The pseudo-3D volume used in this study simplifies the challenges of working with multiple 2D seismic vintages and offers the option of creating a series of seismic attribute volumes at the play and basin scales. This helps accelerate regional interpretation and exploration screening in a vast area where only 2D seismic data are available. For Brazil's equatorial basins, where the most attractive exploration opportunities can be related to stratigraphic plays, especially in the deepwater region, having contiguous 3D images from a pseudo-3D volume can be useful for the initial assessment of such opportunities.

Seismic attribute visualizations performed on a pseudo-3D volume have helped highlight lateral extensions of basin floor fans in the outboard of Foz do Amazonas basin, potential deepwater sandstones terminating against volcanic highs in the external portion of the Pará-Maranhão basin, and possible deepwater channels in Barreirinhas basin.

Acknowledgments

The authors thank SLB Exploration Data for their permission to publish this work.

References

Butler, D., D. Fernandez, O. Perez, R. Ysaccis, J. Thekkekara, J. Perdomo, C. McMorland, and A. R. Castelan, 2024, Re-imaging of 2D acquisition in Brazil's Equatorial Margin via pseudo-3D model building: SEG Technical Program Expanded Abstracts, 1401–1405.

IHS, 2025, EDIN Data Search. IHS Energy Log Services, Inc; Copyright (2012) IHS Energy Log Services, Inc. https://edin.ci.ihsenergy.com/portal/search

Xavier de Melo, F., C. Li, T. Zhao, R. Ysaccis, J. Zhang, G. Zuluaga, A. Lewis, A. Zarkhidze, F. Perez, and A. Rodrigues de Oliveira, 2025, Regional and ultrasparse 2D- to 3D-image projection of the Brazilian Equatorial Margin using multi-input machine-learning reconstruction: 86th EAGE Annual Conference & Exhibition, 1–5.