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Brazilian Equatorial Margin Prospectivity: Insights from Potential Direct Hydrocarbon Indicators

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Abstract Summary

Direct hydrocarbon indicators (DHI) are seismic features associated with hydrocarbon-bearing reservoirs and play a crucial role in prospect risk assessment. These features are largely applied in the petroleum industry and have been driving successful exploration worldwide. The Equatorial Atlantic has emerged as a new exploratory frontier due to recent discoveries, particularly those associated with the Jubilee-type play in both South American (Guianas) and African (Ghana and Ivory Coast) conjugate equatorial margins. In this way, frontier basins from the Brazilian Equatorial Margin have become key exploration targets and may guide the main national strategic efforts.

Introduction

The Equatorial Atlantic (Fig. 1a) is considered the new exploratory frontier of the petroleum industry due to the prospective success achieved in the 21st century on both conjugate margins (Tetteh, 2016; Pellegrini and Ribeiro, 2018). Several marginal basins are inherited from the breakup of Pangea between the Early Aptian and Late Albian, presenting a tectono-stratigraphic evolution influenced by transform tectonics (Azevedo, 1991; de Castro et al., 2022). Exploration along the Brazilian Equatorial Margin (BEM) remains modest, despite the exploratory success in Late Cretaceous deep-water plays (e.g., Guyana-Suriname, Ivory Coast, and Tano basins). The Barreirinhas and Pará-Maranhão basins (Fig. 1b) are located in the central BEM, conjugated with the prolific producers Ivory Coast and Tano basins in West Africa (Azevedo, 1991; Brownfield and Charpentier, 2006).

This study aims to contribute to the assessment of petroleum prospectivity in the Barreirinhas and Pará-Maranhão basins, based on the identification of potential direct hydrocarbon indicators (DHI) and their structural and stratigraphic controls. We interpreted dozens of 2D seismic surveys (Fig. 1b), using seismic attributes, and identified seismic features potentially related to migration and accumulation of hydrocarbons in deep water areas of the central sector of the BEM.

Method and/or Theory

Geophysical data from multi-channel 2D seismic (PSTM) and exploration wells were provided by the Brazilian Oil, Natural Gas, and Biofuel Agency (ANP), and were interpreted using Petrel E&P Platform v. 2018.2 and OpendTect v. 7.0 softwares. Seismic–to-well tie was performed using synthetic seismograms produced by the calibration of the sonic (DT) and density (RHOB) well logs, resulting in the identification of the main chronostratigraphic seismic horizons H1-H8 (Figs. 2 and 3). Seismic attributes were applied to optimize conventional seismic sections, highlighting potential DHIs. Instantaneous phase is applied to eliminate amplitude information and enhance reflection continuity and geometric configuration, making it useful to highlight flat spots (Alsouki et al., 2020). In contrast, instantaneous amplitude is performed to evidence amplitude anomalies, such as bright spots and dim spots, which are characterized by high and low impedance contrasts in the reservoir region, respectively (Nanda, 2021).

Results

Lower slope sedimentary sequences show an elongate geometry, moderate to good continuity, and vertically stacked reflectors (Figs. 2 and 3). These patterns are typical of frontal splays or depositional lobes (Cronin et al., 2023). Gravity-driven systems are widespread in both basins,

presenting depositional fairways that are deformed by gravitational processes (Fig. 4). Potential DHIs are located within the Middle Campanian and Maastrichtian units (H5 and H6), including flat spots (FS), bright spots (BS), and dim spots (DS), highlighted by instantaneous phase (Fig. 2c) and instantaneous amplitude (Figs. 3c and 4d).

Depositional systems associated with canyons-frontal splays complexes have been successfully achieved in the Equatorial Atlantic, characterizing the Late-Cretaceous Jubilee-type play (Brownfield and Charpentier, 2006; Cronin et al., 2023). As in the conjugate basins, the Pará-Maranhão and Barreirinhas basins exhibit similar structural and stratigraphic controls with various DHIs.

Source rocks in the area are localized within Aptian, Cenomanian, and Turonian intervals (H2 to H5). Potential stratigraphic traps for lobes and splays include lateral pinchouts (Figs. 2 and 3), whereas faults and anticlines are likely structural within gravity-driven systems (Fig. 4).

Conclusions

Late-Cretaceous depositional systems in the lower slope of the Barreirinhas and Pará-Maranhão basins underscore the prospective potential of the central BEM and are analogous to those in their South American and African counterparts, which also exhibit various DHIs. These characteristics are related to the successful Jubilee-type play of both conjugate margins. The presence of DHIs can be further validated through AVO analysis, significantly reducing prospect risk assessment in these new frontier basins.

Acknowledgments

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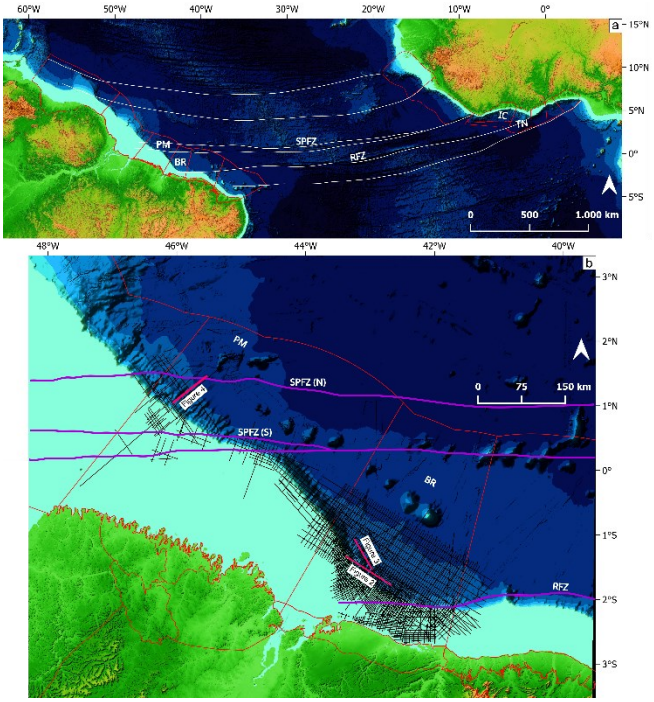

Figure 1: Simplified regional map of the (a) Equatorial Atlantic and (b) Barreirinhas (BR) and Pará-Maranhão (PM) basins. Ivory Coast Basin – IC; Romanche Fracture Zone – RFZ; Saint Paul Fracture Zone – SPFZ [north (N) and south (s) branches]; Tano Basin – TN. Structural data compiled from Azevedo (1991), Brownfield and Charpentier (2006), and de Castro et al. (2022). The digital elevation model is from GEBCO 2024 Grid (doi:10.5285/1c44ce99-0a0d-5f4fe063-7086abc0ea0f).

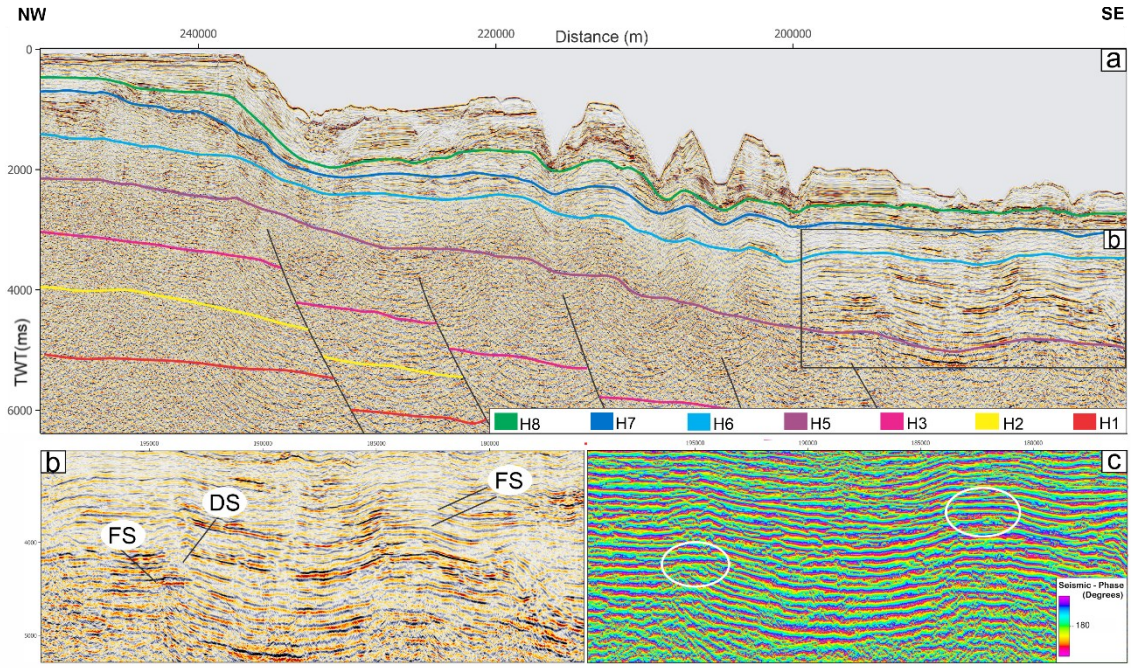

Figure 2: Seismic section showing potential DHIs in the lower slope of the Barreirinhas Basin.

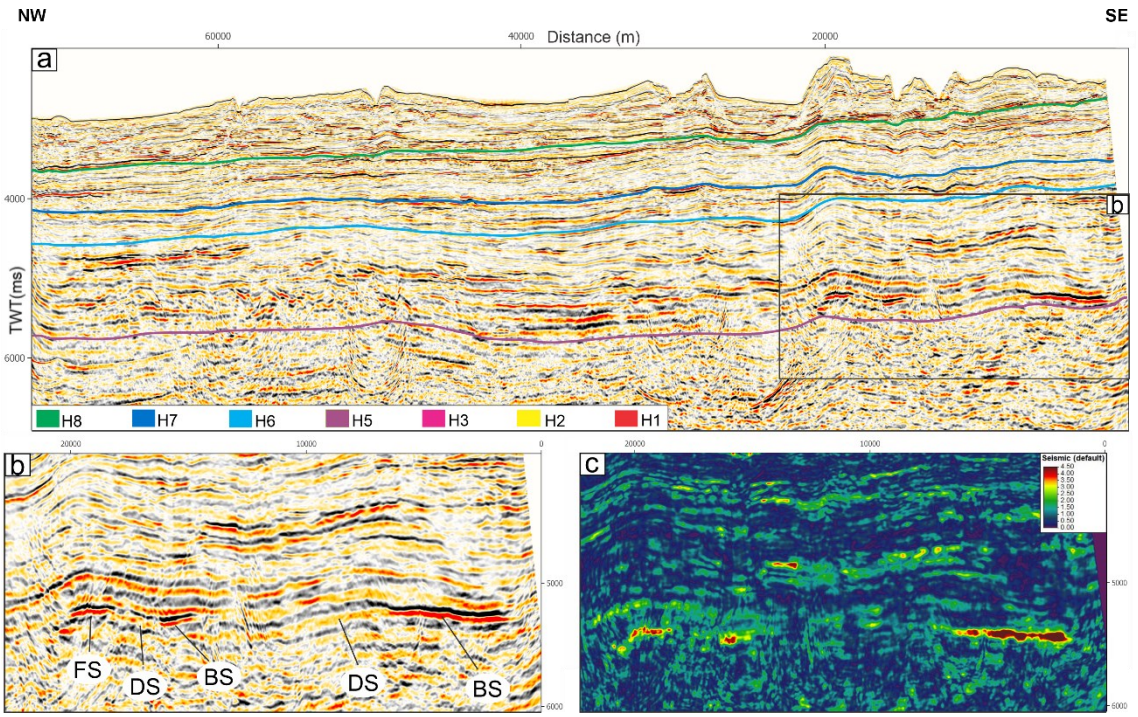

Figure 3: Seismic section exhibiting diverse DHIs in deep-water settings of the Barreirinhas Basin.

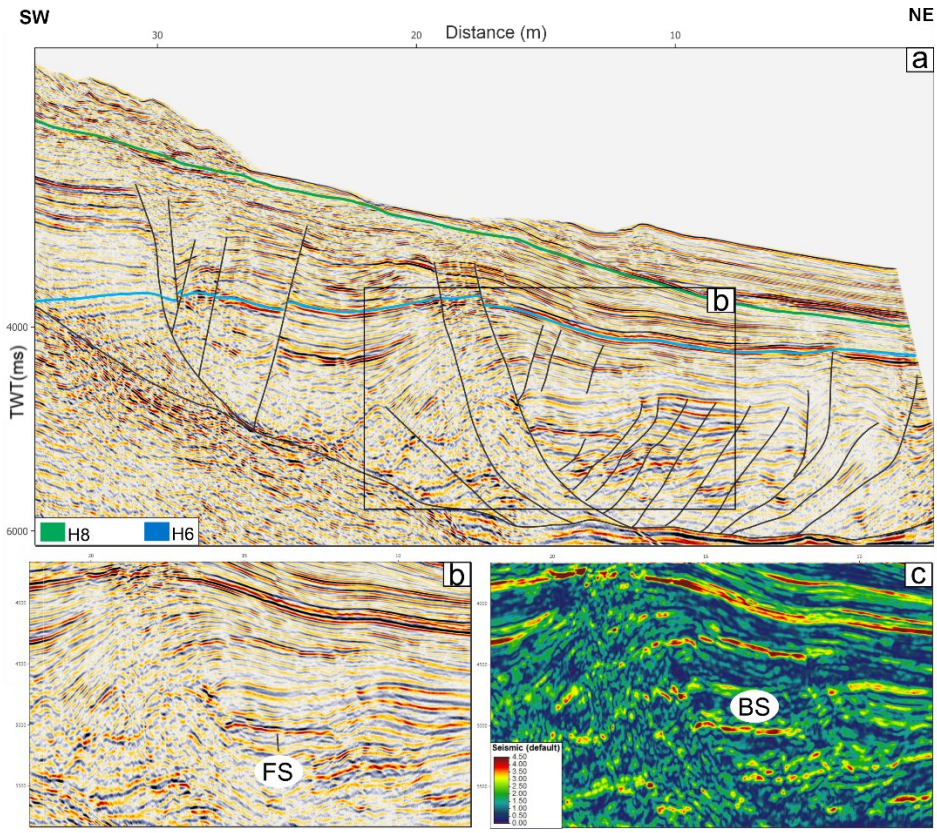

Figure 4: Seismic section depicting DHIs in a gravitational system of the Pará-Maranhão Basin.