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João Victor Moraes da Costa Anjos

Seismic Geomorphological Expressions of the Deep water sediment dispersals systems in the drift phase of the Mundaú Sub-basin, Ceará, Brazil.

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RESUMO

A Bacia do Ceará, localizada na Margem Equatorial Brasileira, representa uma relevante fronteira exploratória, porém marcada por uma complexa trama estrutural. Durante seu desenvolvimento, observa-se uma dinâmica de regimes extensionais, transtensionais e transpressivos, e sistemas erosivos com ciclos de corte e preenchimento. Além disso, tem-se o fato também de existirem poucos registros de poços, especialmente nas porções em águas profundas. Neste estudo, com base em dados sísmicos 3D e informações presentes em alguns poços da Sub-bacia de Mundaú, foram interpretadas as principais discordâncias da fase drifte da bacia a partir de uma nova abordagem para a interpretação sísmica via técnica de construção de um modelo de tempo geológico relativo (RGT). Uma análise de atributos sísmicos a partir de superfícies sísmicas extraídas do volume RGT destacam as principais rotas de dispersão de sedimentos, revelando uma mudança significativa após o Eoceno médio, quando a sedimentação ultrapassou uma barreira topográfica criada por reativações de falhas, em um regime transpressional, associado à Zona de Fratura Romanche. A integração de dados sísmicos e de poços via construção do modelo RGT proporciona uma compreensão mais profunda da dinâmica da bacia, revelando como os processos sedimentares respondem às mudanças no estresse tectônico nesta porção da bacia do Ceará

Palavras Chave: Bacia do Ceará, Sub-bacia de Mundaú, Atributos sísmicos, Modelo RGT, Dispersão de sedimentos.

Sumário

1. Introdução

O presente trabalho foi desenvolvido ao longo do período do mestrado e elaborado em formato de artigo, sendo submetido para a revista *Journal of South American Earth Sciences* em setembro de 2023 e aceito em dezembro do mesmo ano.

O estudo produzido se baseia no processo de caracterização utilizando dados sísmicos 3D para definir zonas de potenciais rotas de migração de sedimento ao longo da sequência drifte da Bacia do Ceará. Para isso, foi empregada a técnica de construção de um modelo de tempo geológico relativo (RGT) (Pauget et al, 2009) onde foram extraídas as superfícies das principais descontinuidades desta faixa e feito um estudo a partir das informações de orientação e padrão sismo gemorfológico de cada superfície extraída afim de compreender eventuais mudanças ao longo da evolução da bacia

1.1. Motivações

Para se ter uma compreensão da Bacia do Ceará é necessário observar seus aspectos particulares quanto bacia, mas também sua semelhança em relação a outras bacias que compõem a Margem Equatorial Brasileira. Sendo uma região que vem despertando interesse devido à sua similaridade com áreas que tiveram novas descobertas de hidrocarbonetos na margem conjugada africana e na Guiana Francesa, as bacias pertencentes a margem equatorial brasileira hoje representam possíveis protagonistas na busca por novas reservas.

Tal contexto acende uma necessidade de novos estudos na região, porém esbarra na complexidade geológica que muitas destas bacias apresentam, marcadas especialmente por uma diversidade de estilos estruturais, diversos intervalos estratigráficos com ciclos erosivos e atividade vulcânica. Em especial na Bacia do Ceará, soma-se o fato também de haver uma baixa distribuição de poços na porção de águas profundas (Figura 1), o que limita estudos, porém trás o foco da análise para os dados sísmicos já disponíveis nesta região.

Com base nas observações mencionadas, o estudo a seguir se propõem a abordar técnicas de interpretação sísmica que possam extrair mais valor do dado sísmico presente em águas profundas e consequentemente gerar novos *insights,* principalmente que descrevam a influência dos esforços tectônicos na região nos mecanismos de transporte de sedimentos em águas profundas.

2. Objetivos

O estudo proposto tomou como base o uso dos dados sísmicos como peça central para análise, tendo como controle as informações dos poços presentes na região. De maneira a extrair o máximo de informação possível dos dados sísmicos disponíveis, foi adotada a técnica de construção de um modelo de tempo geológico relativo para a região (Pauget et al , 2009). Desta maneira, os objetivos do estudo se basearam em 3 diretrizes principais:

I. Caracterizar as principais feições associadas a sistemas de dispersão de sedimentos na sequência drifte da sub bacia de Mundaú

II. Analisar a influência do tectonismo na fase drifte da bacia a partir da orientação das rotas de migração de sedimentos e do padrão sismo geomorfológico apresentado.

III. Avaliar a utilização do método de construção de modelo de tempo geológico relativo no fluxo de interpretação sísmica da bacia.

3. Artigo

Title: Seismic Geomorphology of the deepwater sediment dispersals systems in the drift phase of the Mundaú Sub-basin, Equatorial Margin, Brazil.

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Abstract:

The Ceará Basin, located in the Brazilian Equatorial Margin, represents an exploratory frontier situated in a complex structural framework. The basin observed a dynamic

interplay of extensional, transtensional, and transpressional regimes, registered by several sedimentary intervals and unconformities poorly documented by wells, especially at the deeper portions. In this study, based on 3D seismic and well data from the Mundaú Sub-Basin, we interpreted the main seismic sequences of the drift phase to build a Relative Geological Time (RGT) model, based on a semi-automatic seismic traces correlation matched with the well top formations. A seismic attribute analysis from key seismic surfaces extracted from the RGT, highlights the main sediment dispersal routes revealing a significant change after the Mid-Eocene, once sedimentation overpassed a topographic barrier created by fault reactivations, in a transpressional regime, associated with the Romanche Fracture Zone. The integration of seismic and well data affords a deeper understanding of basin dynamics, revealing how sedimentary processes respond to shifts in tectonic stress in this portion of the basin.

1. Introduction

The Brazillian Equatorial Margin can be divided into 5 basins (Figure 1): Foz do Amazonas, Pará-Maranhão, Barreirinhas, Ceará and Potiguar. Their evolution began after the continental breakup of the Gondwana in the Lower Cretaceous. The structural configuration of these basins is intricate, characterized by observed alternating tectonic states including extensional, transtensional, and transpressional regimes (Françolin & Szatmari, 1987; Matos, 2000; Milani & Thomaz Filho, 2000; Maia de Almeida et al., 2019; Oliveira, Oliveira et al., 2020).

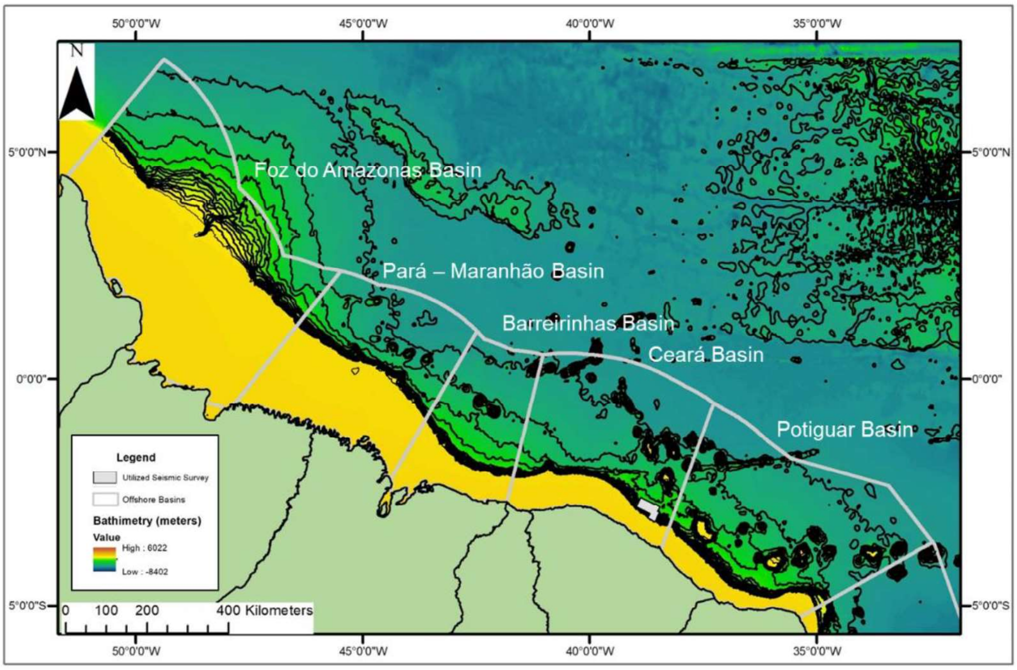

Figure 1 - *The Brazilian Equatorial Margin and its related basins.*

The continental rupture in the Equatorial Margin occurred later, in comparison with the Brazilian eastern margin (Françolin and Szatmari 1987, Szatmari et al., 1987; Matos, 2000) and was controlled by strike slip tectonics, with a predominance of dextral kinematics (Matos, 2000; Basile et al., 2005), diachronous subsidence and uplift events for each basin (Mohriak, 2003; Zálan, 2004) and the formation of sub-basins with both distinct tectonic and depositional configuration (Milani et al., 2000).

The Ceará Basin is bounded to the east by the Fortaleza High and to the west by the Tutóia High, to the south by the basement and to the north by the Romanche fracture zone. (Costa et al, 1990). Given its transpressive and transtensional segments, the basin is segmented into 4 sub-basins (Piaui-Camocim, Acaraú, Icaraí and Mundaú) (Figure 2) with distinct structures and depositional history (Morais Neto et al., 2003, Beltrami et al., 1994), being the Mundaú sub basin the one with the most preserved records of its depositional history.

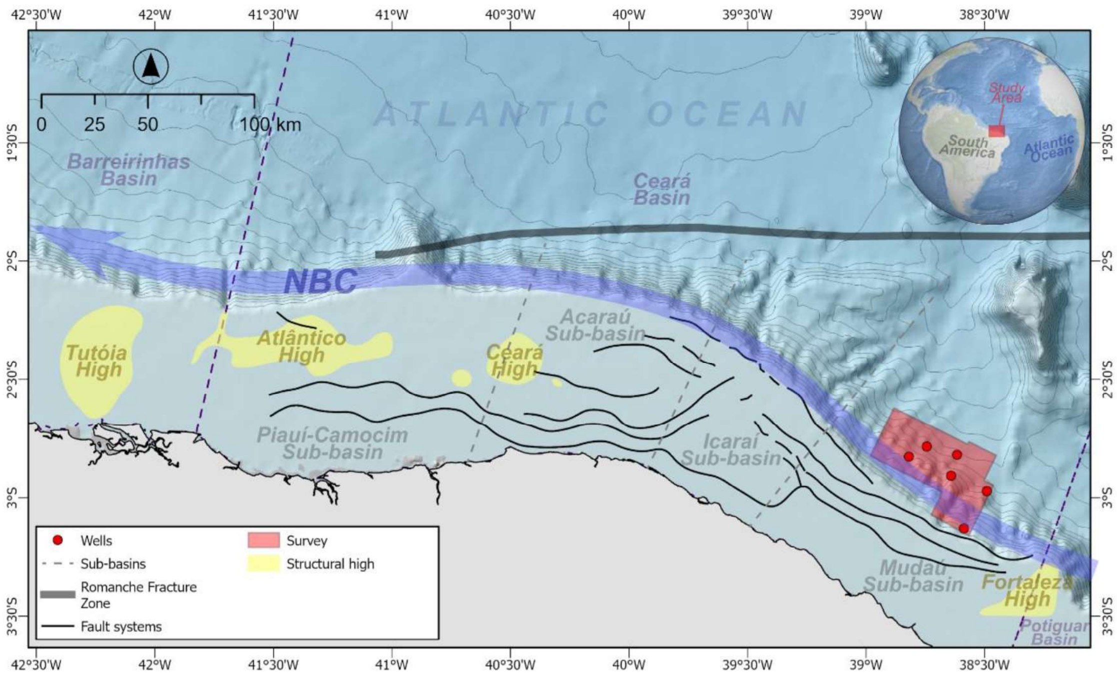

Figure 2 - The Ceará Basin main morphological features, and it's internal segmentation into sub basins with the location of the seismic and well data.

The Mundaú sub-basin is limited by the Fortaleza High to the east and the Aracati platform to the west (Figure 2) .It's tectono-sedimentary evolution can be divided into 3 large mega-sequences: syn-rift, post-rift and drift (Beltrami et al. , 1994).The syn-rift phase is marked by the development of normal NW-SE faults that lead to the formation of asymmetric hemi-grabens with fluvio-deltaic sandstones and shales from the Mundaú Formation (Beltrami et al, 1994).The post-rift phase is represented by the Paracuru formation, initially filled by fluvial, lacustrine and deltaic sediments, followed by the first marine incursions into the sub-basin recorded by carbonates and localized evaporites (Costa et al., 1990; Beltrami et al., 1994; Condé et al., 2007).Finally, the drift phase or marine mega-sequence was deposited during the thermal subsidence and is represented by the Ubarana, Guamaré and Tibau formations (Costa et al., 1990; Beltrami et al., 1994; Condé et al., 2007). This mega-sequence registers an initial marine transgression (Ubarana formation) with predominance of shales, followed by a regressive stage with related shales and deepwater turbiditic sandstones (Ubarana formation), proximal sandstones (Tibau Formation) and carbonates (Guamaré formation).

From a seabed morphology perspective, the study area is located on the Ceará Terrace, which is constrained by the E-W segment of the North Brazilian Ridge, following the direction of the Romanche Fracture Zone and the Canopus Guyot. Both datasets are located on the continental slope, in water depths from 1000 m to 1500 m (Figure 3). The complex morphology is represented by an upper slope deeply dissected by ravines oriented SW-NE, directing sediment dispersal through gaps between the North Brazilian Ridge and the Canopus Guyot.

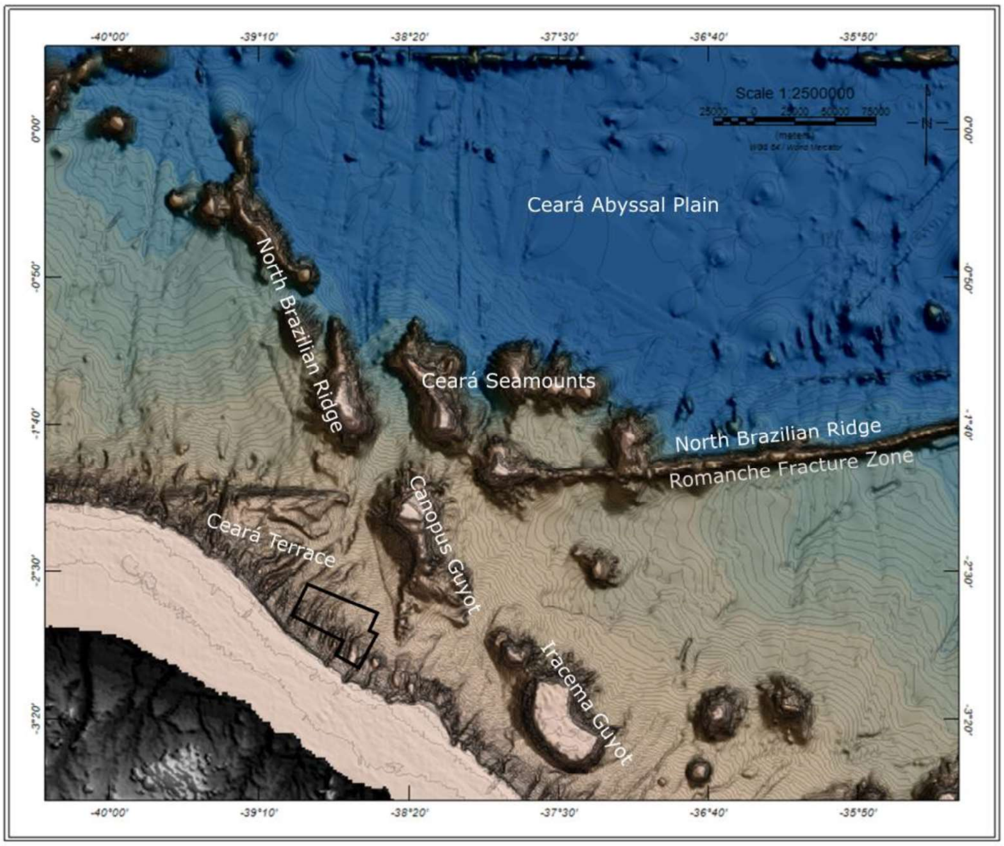

Figure 3 – Bathymetric map and main morphological features. The study area is located on the Ceará Terrace which is limited by the Canopus Guyot and the E-W segment of

the North Brazilian Ridge following the extension of the Romanche Fracture Zone. The terrace is deeply cut by ravines and canyons. The black polygon represents the location of the seismic survey.

2. Materials and Methods

For the present study, a seismic volume acquired in 2003 and 5 wells located in water depths ranging from 1000 to 1500 meters, drilled from 1993 and 2012 were used. The seismic volume consisted of a PSDM cube reprocessed in 2012 with spatial sampling of 12.5 x 12.5 meters, 5 meters vertical sampling, center frequency of 30 Hz and migrated using the Kirchoff technique.

Given the geological complexity of the basin observed in the seismic data, marked by several erosive unconformities, magmatic events, and strike-slip tectonics, it was decided to adopt the seismic interpretation method using the construction of a relative geological time model (RGTM) (Pauget et al, 2009). This approach could join the automatic correlation between the seismic traces with the interpreter corrections in a way to globally interpret the seismic data with control.

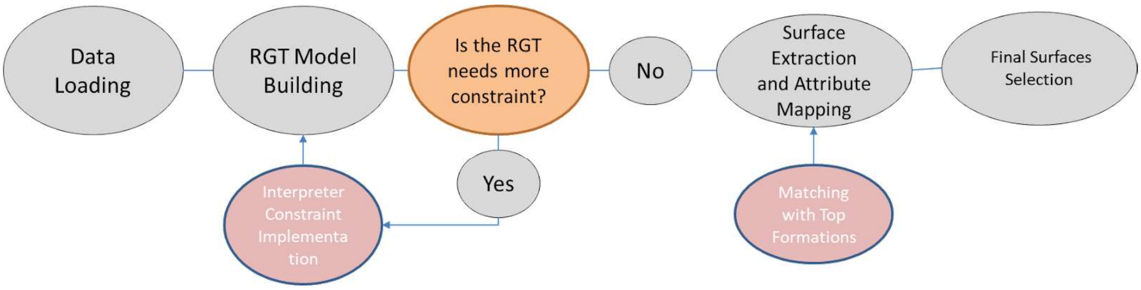

Figure 4 - *Adopted workflow after the generation of relative geological time (RGT) model.*

The method to obtain a RGT model involves the creation of a grid from a global optimization function (Hoyes & Cheret, 2011), which depends on the distance and similarity of the seismic traces. This process automatically tracks each horizon within the seismic volume which is used to constrain the grid and consequently define a relative geological time ages for each related point. Subsequently, the seismic interpreter checks the relationships between these generated horizons to refine the links between the points of the grid until an optimal solution is obtained (Beller et al, 2011).

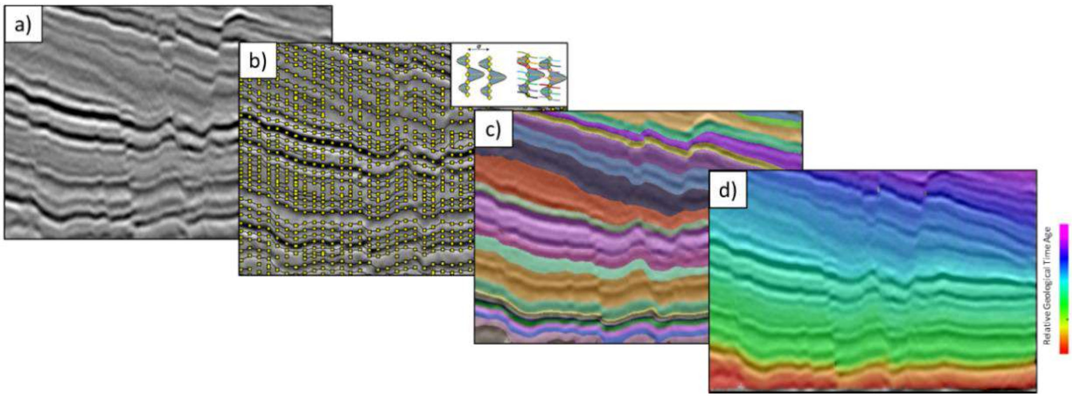

Figure 5 - *Steps of a RGT Model building. In a) initial input seismic data. b) grid generation step. c) Final RGT Model generated from the grid step with a discrete color bar. d)Final RGT model generated from the grid step with a continuous color bar highlighting the relative geological time ages.*

Because the RGT model has lateral and vertical continuity in its principles, it is possible to take advantage of its isolines to extract seismic surfaces in any desired interval of the seismic data (Schmidt et al, 2013). For the present study, surfaces were extracted following the main unconformity intervals described by Condé et al (2007) and Oliveira et al (2020) and and also being controlled by some of the main top formation data present in the available wells.

The seismic attribute of sweetness was applied to these horizons, following the work of Hart (2008), Li et al (2017) and Naewboonnien (2019), which proved to be a relevant tool to highlight geomorphological features related to deep water systems.

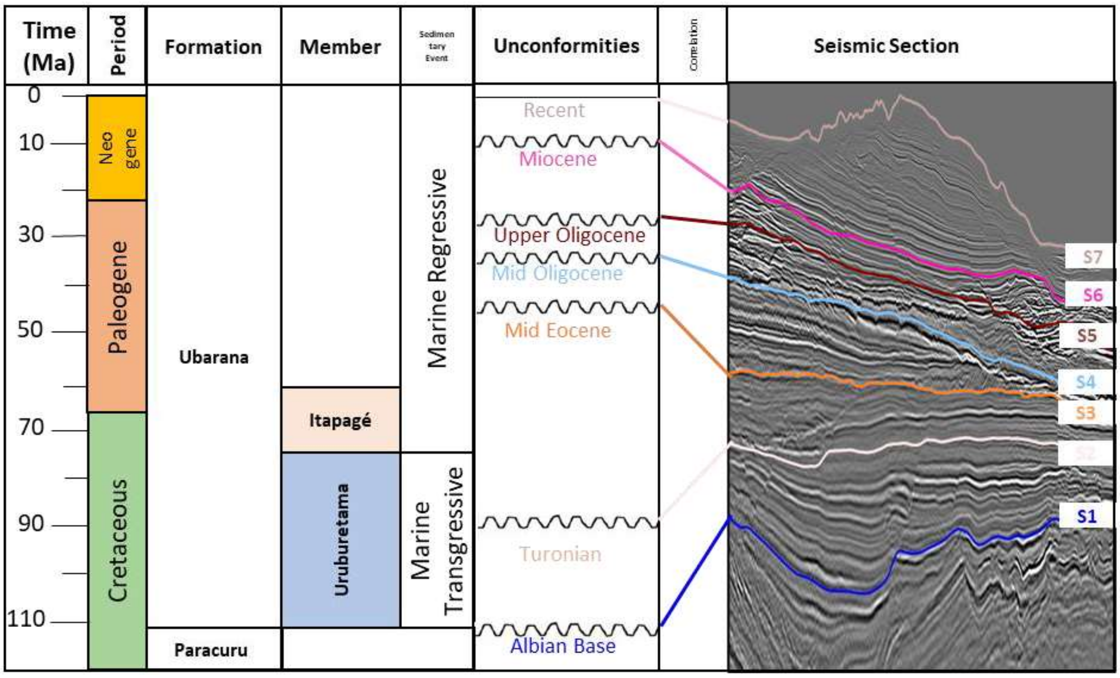

Figure 6 - The mega drift sequence of the Ceará Basin adapted from Condé et al. (2007) and the correlation with the extracted surfaces from the RGT model and the main unconformities in this interval.

3. Results

Surface 1 (S1):

This surface marks the discontinuity of the Albian base that represents the limits between the Paracuru and Ubarana formation and the transition from a continental synrift system to a shallow marine one. From the depth map, the influence of the NW-SE lineaments of the rift phase can be seen, influencing the topography in a way produzing local depocenters and topographic highs. On the Sweetness attribute map, a series of positive and local anomalies can also be seen in the East. These anomalies, when confirmed in the seismic section, also indicate volcanic intrusions (see Fig 7b and 7c), emplaced from Mid-Eocene to Lower Oligocene (Condé et al, 2007).

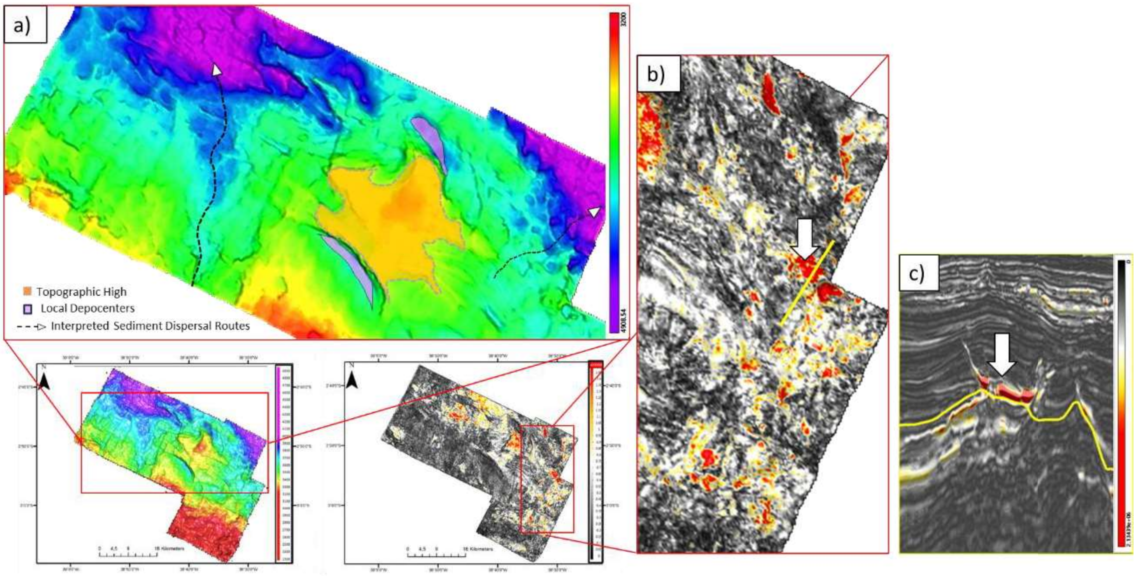

Figure 7- a) Morphological map of the surface 1, highlighting the sediment routes towards the local depocenters. b) Sweetness attribute response to the magmatic intrusions on the interpreted surface. c) Arbitrary section of the sweetness volume showing the signatures of the magmatic intrusions above a volcanic edifice in the seismic section

Surface 2 (S2):

This surface is represented by the discontinuity of the top of the Turonian, marking a significant excavation period (also observable in the more distal areas of the basin) that eroded a large part of the Albian interval. In the depth map (Figure 8) the rift NW-SE fault lineaments are still influential, creating topographic highs and local depocenters. The northward sediment dispersal is directed to the west of the topographic high.

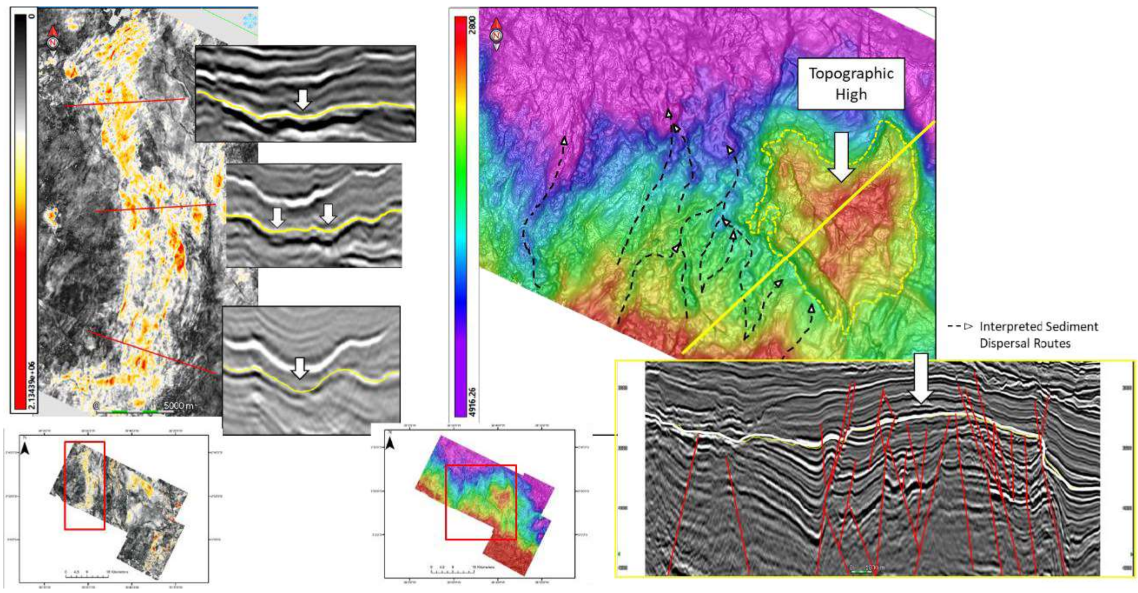

Figure 8 - On the left, the main sediment dispersal confined within a large (more than 5 km wide) channel belt highlighted with the sweetness attribute. On the right, a cross-section from the seismic volume showing the NW-SE faults and its influence in the generation of a topographic high in the Surface 2 which controls the sediment dispersals routes.

Surface 3 (S3):

The surface 3 represents the Mid-Eocene Unconformity. In the most proximal regions, it marks the beginning of the deposition process of the Tibau and Guamaré formations and demarcates a very effective excavation phase that erodes a large part of the interval between the Cretaceous and Paleogene. From the depth map, the topographic high still controls the sediment dispersal orientations. A broad elongated incised valley receives sediments from numerous alongside catchments at the northwestern upper slope (Figure 9a). Gamma ray values from well BRSA-1150 at the S3 depth indicates the dominance of sands, which is also confirmed by the sweetness attribute signatures (Fig. 9a). The structural high is highly deformed by faults, suggesting a possible reactivation of the fault systems (Fig. 9b). This high also acted as a sediment source originated from small catchments oriented from the high towards the southeast into an E-W incised valley (Fig. 9b).

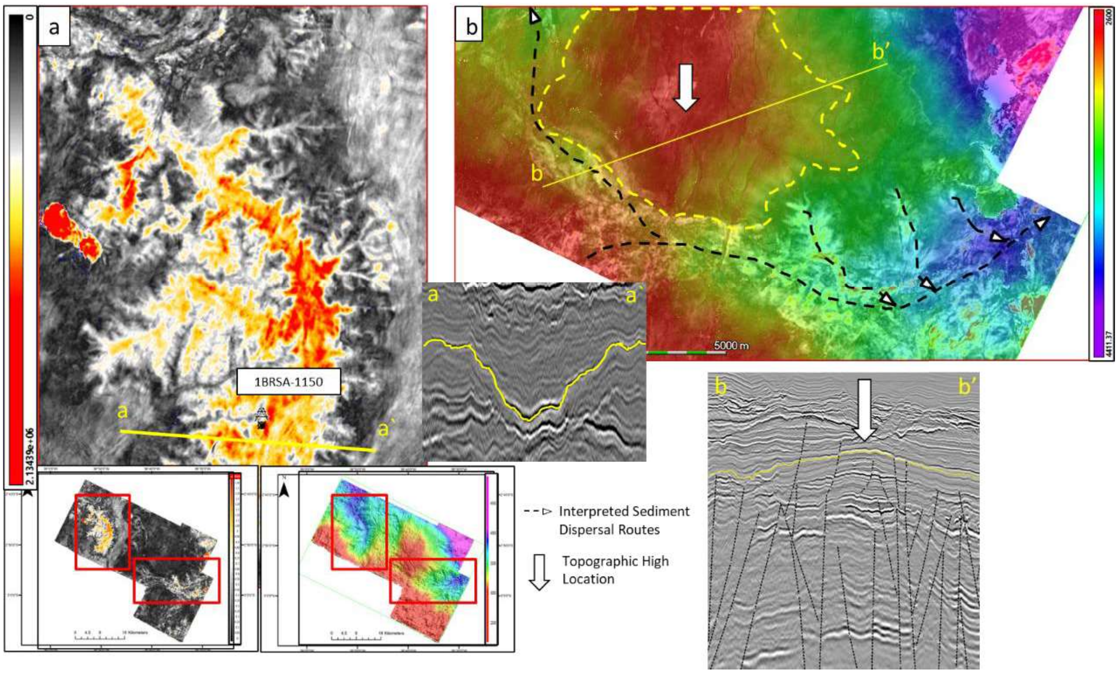

Figure 9 - a) Broad Incised valley fed by lateral catchment tributaries illustrated at surface S3 with the sweetness attribute and on a arbitrary line (a-a`) b) a blending visualization mixing the sweetness attribute and the depth map, showing the main

sediment dispersal routes and the influence of the topographical high. Below, a sesmic crosssection (b-b`) showing the main interpreted NW-SE faults.

Surface 4 (S4):

Surface S4 represents the Mid-Oligocene unconformity. This discontinuity, even though it represents a smaller-scale event compared to other known and more regional unconformities, is observable in the seismic data and marks a very important point of change in the geometry and arrangement of the main sediment dispersion routes. At this level we do not observe the signature of the NW-SE fault lineaments that affected the surfaces below. Generally, the sediment routes have a NE orientation, forming large, confined channel systems marked by cut and fill cycles. To the northwest, as they reach the slope, there is an increase in channel width and a slight change in orientation towards N.

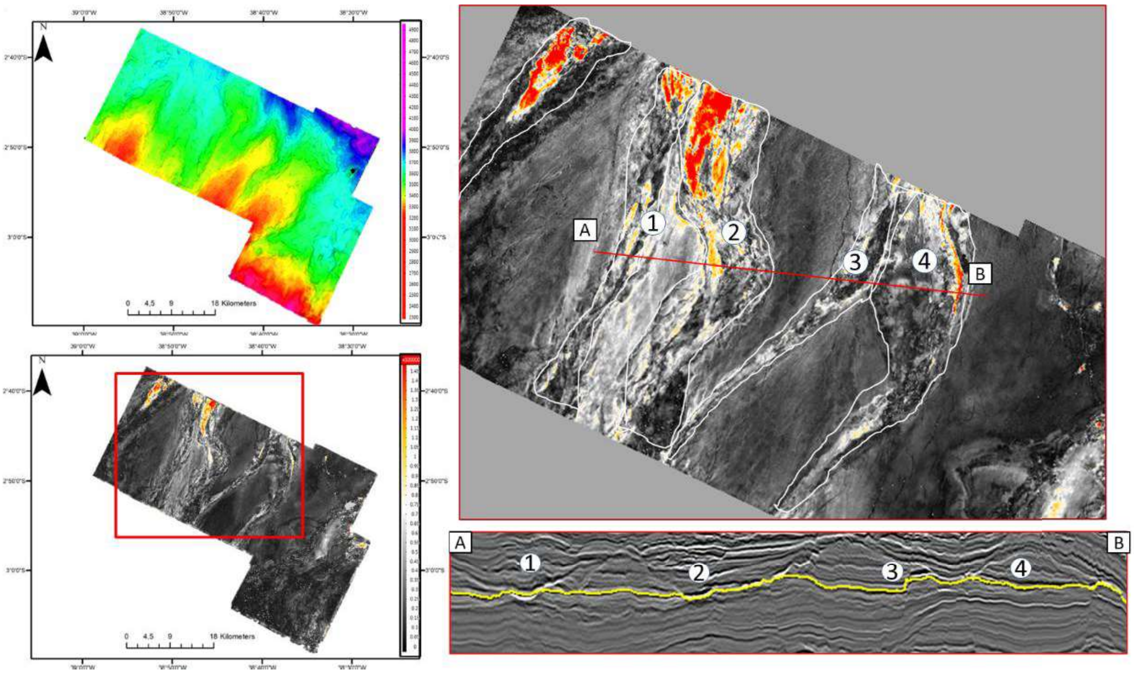

Figure 10 - Regional map of the Surface 4 showing the orientation of the main channel systems and on the right a surface zoom illustrating the channel response on the sweetness map and an interpreted section locating the channels observed at the surface map.

Surface 5 (S5):

Surface S5 corresponds as the Upper Oligocene unconformity, a relevant erosion event observable in the entire basin and marks the beginning of the deposition of large volumes of sand in the deep-water part of the basin. On the surface we observe slightly sinuous channels oriented NE-SW, some of them merging downslope and forming well-defined coalescing lobes at the northeastern distal extension (Fig 11a and 11b).

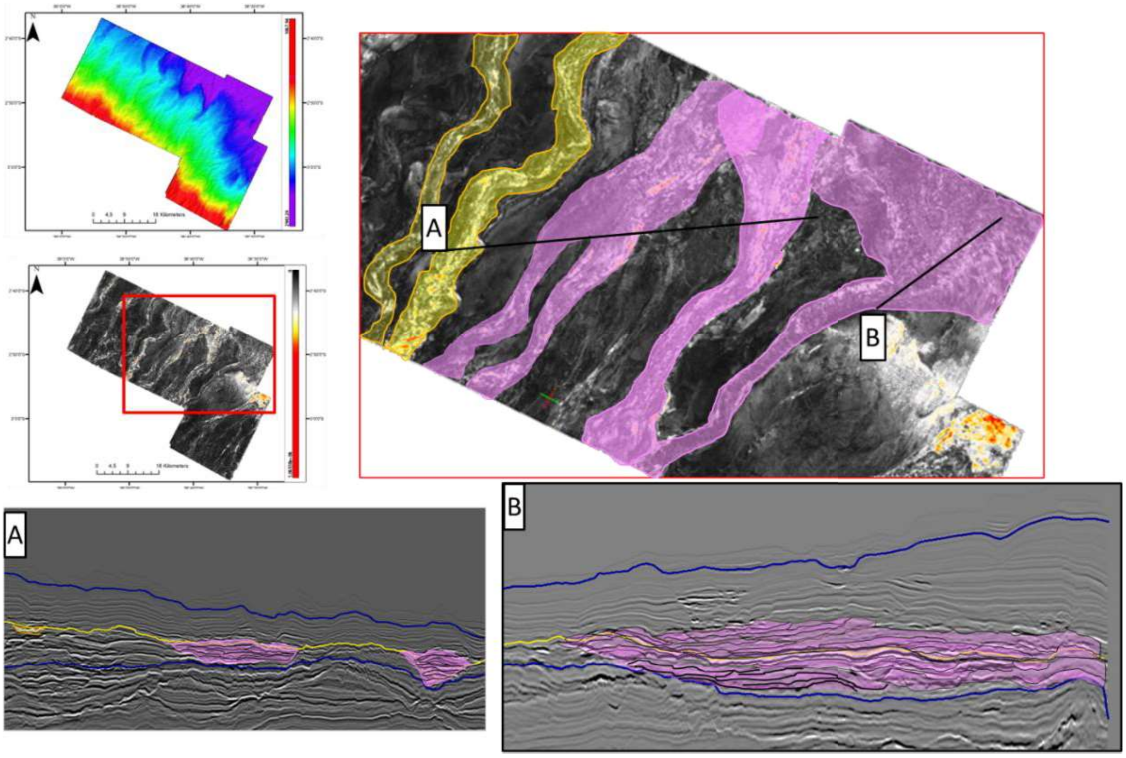

Figure 11: On the left the overview of sweetness and morphological maps of surface S5. On the right, a zoom of the sweetness map, highlighting the two interpreted channels groups. The first one in yellow, representing a more slightly and sinous system and the purple group, represented by wider group with the presence of depositional lobes at the distal portion.

<u>Surface 6:</u>

Surface S6 represents the Miocene unconformity, an important regional unconformity in the Ceará basin and also in the Potiguar basin. It marks an important change in the depositional geometry of the basin, from progradational to agrational. It is deeply dissected by numerous straight to meandering, narrow and shallow channels, oriented SW-NE.

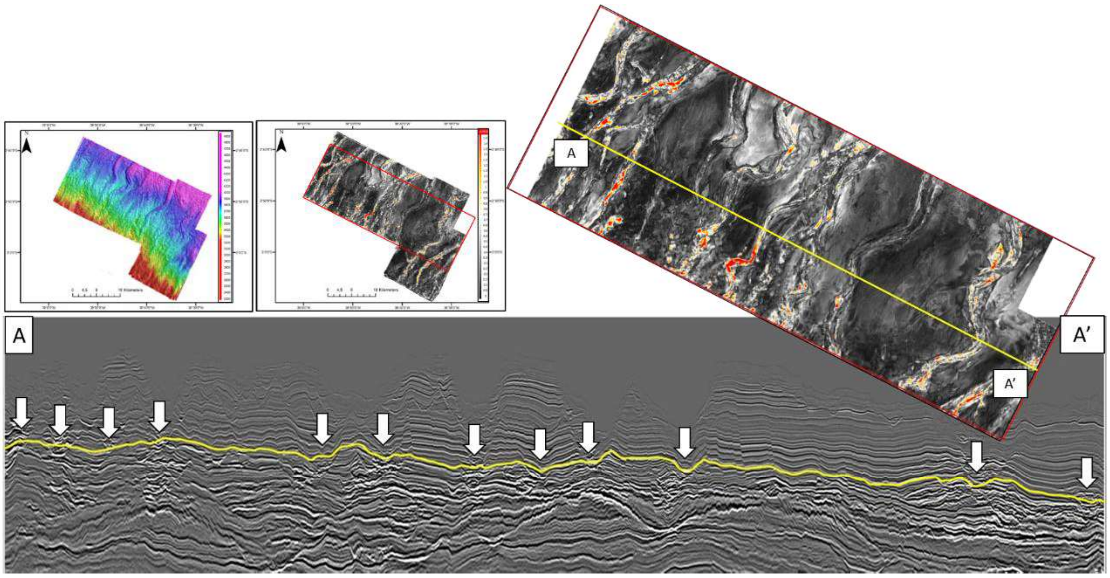

Figure 12: Regional map and zoom of Surface 6 illustrating the channels indicated in the arbitrary seismic section.

Surface 7:

This surface represents the present seafloor. There is a dramatic change in channel morphologies with increasing water depth. The proximal channels (1 in fig.13), have steep V-shaped valleys, with terraces and are partially filled with slump deposits. At intermediate positions (2 in fig. 13) occurs a transition to U-shaped valleys with internal subparallel aggradation. At distal locations very broad and shallow channels characterize the transition to depositional lobes (3 in fig. 13).

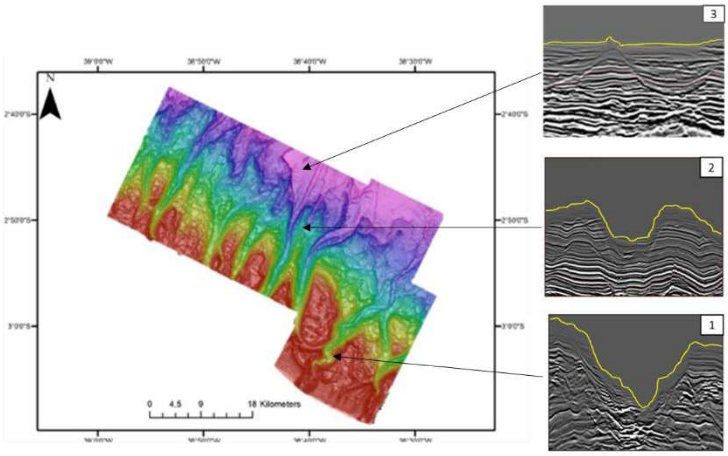

Figure 13: On the left, the present seabed map. On the right, examples of seismic sections illustrating the change in channel morphology from proximal (1), intermediate (2) and distal (3) slope positions.

4. Conclusions

Comparing the interpreted sediment dispersal routes through time on different surfaces, a distinct change in orientation is noticeable after the Mid-Eocene (surface 3). Sediment dispersal routes are diverted by the topographic high at Surfaces 1 (Base Albian), 2 (Top Turonian) and 3 (Mid-Eocene), while from the Mid-Oligocene to Recent, the influence of the topographic high ceases to exist and the channels are mostly oriented towards NE and ENE, associated with the cut and fill cycles of the main turbidite systems (Figure 14).

During the interval S1-S3, from Albian to Mid-Eocene there is a significant tectono-structural influence on the relief configuration, associated with the presence of E-W and NW-SE faults lineaments that can be related mainly to post-rift relaxation and the compressive events related to the Romanche Fracture Zone occurred on the Late Albian (Davison,2016, Oliveira, 2018, Tavares et al, 2020). Considering the structural features depicted on the maps, our interpretation suggests that during this period, there is a more pronounced influence of a tectonic subsidence process in comparison to the interval above (S3-S7).

From the Mid-Eocene to Recent, between surfaces S3 and S7, the orientation of the sediment routes is mainly NE and following the basin dip. This information together with no presence of faulting lineaments proves a possibly a period of tectonic quiescence and thermal subsidence. In this interval, the channels present distinct internal geometry and depositional features. Especially for the S5 and S6 the morphology of the channel systems indicates respectively a propagational and gradational events which are related with the observed morphology observed channel systems and the interpretation with its related unconformities.

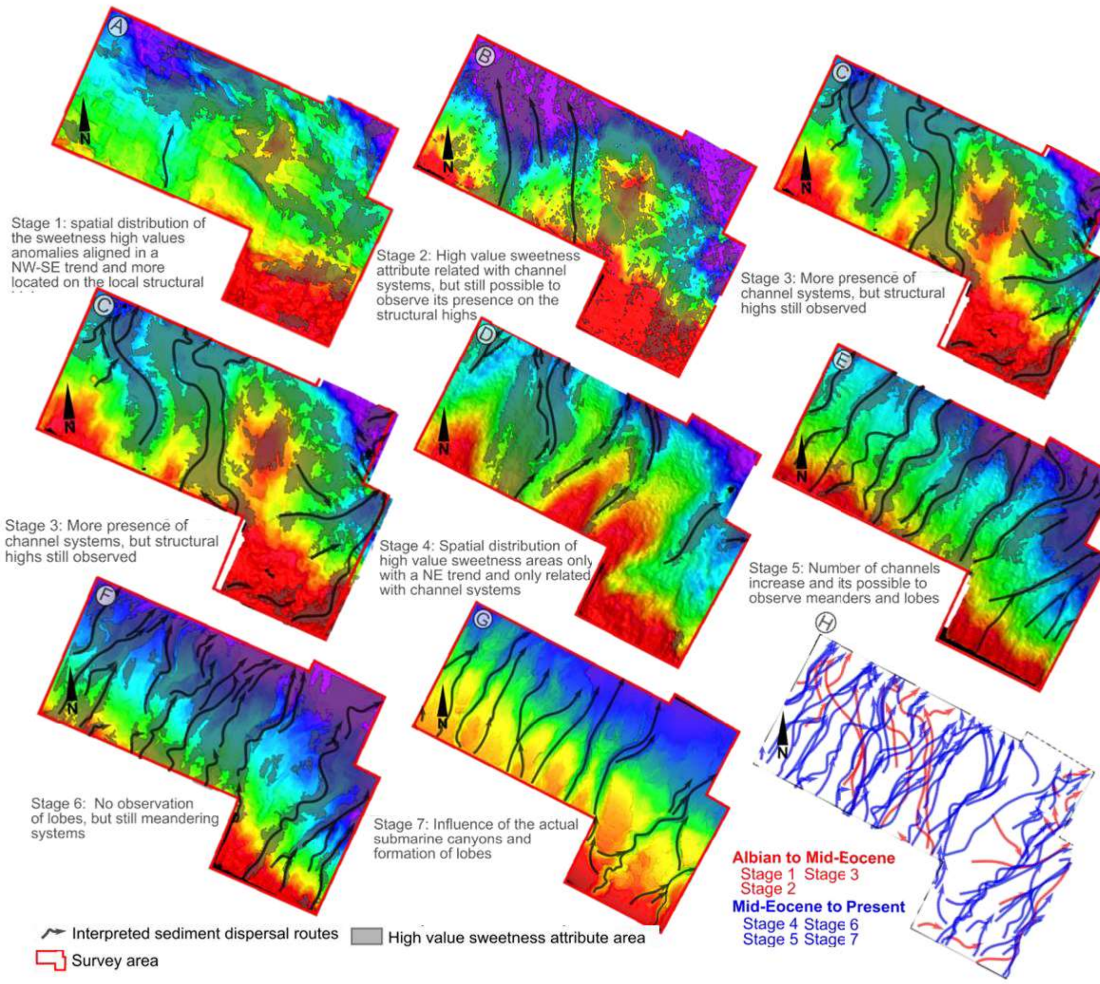

Figure 14: Generated surfaces and their related interpreted sediment dispersal routes and the zones with sweetness attribute high values. On h) the segmentation of sediment dispersal routes between the interval from Albian to Mid-Eocene (Red) to Mid-Eocene to present (Blue).

5. Acknowledgments

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4. <u>Referências</u>

Basile, Christophe, Jean Mascle, and René Guiraud. "Phanerozoic geological evolution of the Equatorial Atlantic domain." Journal of African Earth Sciences 43.1-3 (2005): 275-282.

Beller, M., et al. "Fast Leveraging of Seismic Information over Large Areas-A Central North Sea Case Study." 74th EAGE Conference and Exhibition incorporating EUROPEC 2012. European Association of Geoscientists & Engineers, 2012.

Beltrami, C.V., Alves, L.E.M., Feijó, F.J., 1994. Bacia do. Ceará. B. Geoci. Petrobras 8 (1),117–125.

Condé, V.C., Lana, C.C., Pessoa Neto, O.C., Roesner, E.H., Morais Neto, J.M., Dutra, D.C.,2007. Bacia do. Ceará. B. Geociências. Petrobras 15 (2), 347–355.

Costa, I.G., Beltrami, C.V., Alves, L.E.M., 1990. A Evolução tectono-sedimentar e o “habitat” do óleo na Bacia do Ceará. Bol. Geociencias Petrobras 12 (1), 65–74.

Hart, Bruce S. "Channel detection in 3-D seismic data using sweetness." AAPG bulletin 92.6 (2008): 733-742.

FRANCOLIN, JB L., and P. Szatmari. "Mecanismo de rifteamento da porção oriental da margem norte brasileira." Revista Brasileira de Geociências 17.2 (1987): 196-207.

Hoyes, Jack, and Thibaut Cheret. "A review of “global” interpretation methods for automated 3D horizon picking." The Leading Edge 30.1 (2011): 38-47.

Li, Quan, et al. "Detection of a deep-water channel in 3D seismic data using the sweetness attribute and seismic geomorphology: A case study from the Taranaki Basin, New Zealand." New Zealand Journal of Geology and Geophysics 60.3 (2017): 199-208.

Liu, Zeng-Qin, et al. "Application of sweetness and it’s fusion attribute in the research of Deep-water Reservoir." ShiyouDiqiuWuliKantan(Oil Geophysical Prospecting) 45 (2010).

Maestrelli, Daniele, et al. "Characterization of submarine depression trails driven by upslope migrating cyclic steps: Insights from the Ceara Basin (Brazil)." Marine and Petroleum Geology 115 (2020): 104291.

Matos, R. M. D. (2000). Tectonic evolution of the equatorial South Atlantic. Atlantic rift sand continental margins, 115, 331-354.

Maia de Almeida, N., Alves, T. M., Nepomuceno Filho, F., Freire, G. S. S., Souza, A. C. B. D., Normando, M. N., ... & Barbosa, T. H. D. S. (2020). Tectono-sedimentary evolution and petroleum systems of the Mundau subbasin: A new deep-water exploration frontier in equatorial Brazil. AAPG Bulletin, 104(4), 795-824.

Milani, E. J., & Thomaz Filho, A. (2000). Sedimentary basins of south America. Tectonic Evolution of South America, 31, 389-449.

Mohriak, Webster Ueipass. "Bacias sedimentares da margem continental Brasileira." Geologia, tectônica e recursos minerais do Brasil 3 (2003): 87e165.

Morais Neto, J.M., Pessoa Neto, O.C., Lana, C.C., Zalán, P.V., 2003. Bacias sedimentares brasileiras: bacia do Ceará. Fundação Paleontológica Phoenix 57, 1–6.

Naewboonnien, Kritanol. "The Use of Seismic Attributes for Submarine Channel Interpretation in Deepwater Taranaki Basin, New Zealand." Bulletin of Earth Sciences of Thailand 11.2 (2019): 134-143.

Oliveira, João Pedro de Souza. "Influência da Zona de Fratura Romanche na evolução tectono-sedimentar da Bacia do Ceará/Sub-Bacia de Mundaú." (2018).

Oliveira, Karen M. Leopoldino, et al. "Seismic stratigraphic patterns and characterization of deepwater reservoirs of the Mundaú sub-basin, Brazilian Equatorial Margin." Marine and Petroleum Geology 116 (2020): 104310.

Pauget, Fabien, Sébastien Lacaze, and Thomas Valding. "A global approach in seismic interpretation based on cost function minimization." 2009 SEG Annual Meeting. OnePetro, 2009.

Schmidt, Ingelise, Sebastien Lacaze, and Gaynor Paton. "Spectral decomposition and geomodel Interpretation-Combining advanced technologies to create new workflows." 75th EAGE Conference & Exhibition incorporating SPE EUROPEC 2013. European Association of Geoscientists & Engineers, 2013.

Tellez, Jerson J., and Roger Slatt. "Seismic Geomorphology and Characterization of Deep Water Architectural Elements and it's Applications in 3D Modeling: A Case Study in North Carnarvon Basin Australia." (2016).

Trosdtorf Jr, I., et al. "Bacia de Barreirinhas." Boletim de Geociencias da PETROBRAS 15.2 (2007): 331-339.

Zalán, Pedro Victor. "Evolução fanerozóica das bacias sedimentares brasileiras." Geologia do Continente Sul-Americano: evolução da obra de Fernando Flávio Marques de Almeida. São Paulo, Beca (2004): 595-613.

5. <u>Lista de Figuras</u>

das principais rotas de dispersão de sedimento interpretadas e seção sísmica arbitrária evidenciando o alto estrutural e sua relação com sistemas de falhamentos.

Figura 9: Superfície 3, relativa à discordância do Oligoceno. Em a) feição relativa ao vale evidenciado pelo atributo de Sweetness. Em b) junção dos mapas de topografia e de Sweetness mostrando a relação do alto topográfico com a orientação das rotas de migração de sedimentos.

Figura 10: Superfície 4, relativa à descontinuidade do Oligoceno Médio. Evidencia-se no mapa de Sweetness, os corpos turbidíticos de orientação NE e suas respectivas feições em uma seção sísmica arbitrária

Figura 11: Superfície 5, representada pela discordância do Oligoceno superior. A esquerda a visão geral dos mapas de topografia e de Sweetness. A direita, zoom do mapa de Sweetness, destacando os canais e lóbulos deposicionais. As seções sísmicas ilustram as geometrias internas do preenchimento do canal (A) e dos lóbulos deposicionais (B).

Figura 12: Superfícies 6, relativa a discordância do Mioceno. Mapa regional de topografia e do atributo de Sweeetnes, ilustrando os canais indicados na seção sísmica arbitrária.

Figura 13: Superfície 7, relativa ao fundo do mar atual. A esquerda, o mapa topográfico do fundo marinho. A direita, exemplos de seções sísmicas que ilustram a mudança na morfologia do canal nas posições de talude proximal (1), intermediária (2) e distal (3).

Figura 14: Esquema mostrando em cada superfície estudada as principais rotas de migração de sedimentos interpretadas.