Ocean and Coastal Research

ORIGINAL ARTICLE

http://doi.org/10.1590/2675-2824072.22151
ISSN 2675-2824

# Neotectonic control of shelf valley formation on the southern Pernambuco continental shelf - Brazil

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## ABSTRACT

Formed during marine regression periods, shelf valleys (SVs) are preterit river flows on the exposed continental shelf. This study investigates the influence of tectonic activity on forming these important morphological features. This research combines bathymetric, magnetometry, and seismic data to analyze the role of tectonic events in SV genesis and positioning. The bathymetric dataset provides information on SV locations and geometries along the continental shelf, whereas the 2D seismic sections illustrate that SVs formed above post-rift faults that reached Quaternary deposits. Aeromagnetic data indicates that the shallow and deep structures of the basement and sedimentary column-controlled SV locations and evolution. The multi-data integration demonstrates a strong correlation between neotectonic structures and SV location and geometries from the inner shelf (−25 m) to the shelf break (−55 m). The analysis of the 2D seismic data indicated that high-angle faults, formed under a strike-slip tectonic regime, primarily affected the Middle Miocene deposits beneath the shelf valleys. The formation of “negative flower pattern structures” was identified as a primary structural mechanism that contributed to SV formation. Reactivation events that occurred from the Late Cretaceous onwards, gave rise to these faults, which control SV formation and the capture of preterit drainage on the exposed continental shelf. The SV geometries display straight patterns and abrupt changes in direction (90°) due to the interplay of the NE-SW and NW-SE aligned faults. The results reinforce the importance of considering tectonic activity in the formation and evolution of shelf valleys.

**Keywords:** Shelf Valleys, Geophysics, Middle Miocene, High Angle Faults, Neotectonics

## INTRODUCTION

Shelf Valleys (SVs) are formed in the continental shelf from the cutting action of rivers during periods of falling sea levels, caused by marine regressions (Harris and Whiteway, 2011). These geomorphological features occur on the seafloor and have channel-like morphologies, partially filled with sediments, representing remnants of past rivers that once flowed across the exposed continental shelf. The SV length can vary, reaching depths of up to 120 m (Harris et al., 2014). Continental shelves that have low to medium sediment transport rates preserve well-developed shelf valleys; otherwise, they may become filled with sedimentary deposits during later marine transgressions or become too shallow to detect by bathymetry. These valleys can significantly impact oceanic circulation, sediment transport, and biodiversity (Harris et al., 2014; Li et al., 2020, 2023).

Submitted: 18-Nov-2022
Approved: 04-Aug-2023

Associate Editor: Eduardo Siegle

Considered a sediment-starved shelf, the Pernambuco continental shelf is characterized by tropical conditions (Manso et al., 2003; Araújo et al., 2004). The region features several geomorphic elements, including beach rocks, terraces, ravines, and submerged canyons (Camargo et al., 2015; Goes et al., 2019). In their recent study, Silveira et al. (2020) discovered and mapped numerous shelf valleys on the Pernambuco continental shelf by using satellite imagery. These shelf valleys, also known as submerged canyons, are important features and play a crucial role in the shelf oceanographic dynamics by transporting uplifted water from the ocean to the shelf (Silva et al., 2022).

The Southern Pernambuco Continental Shelf (SPCS) has a shelf break at a depth of 50 m (Camargo et al., 2015; Goes et al., 2019), which suggests that the SPCS was above sea level multiple times during past marine regressions. For instance, around one million years ago, the sea level in the region was approximately 62 m lower than it is nowadays (Lea et al., 2002; Waelbroeck et al., 2002). Approximately 110,000 years ago the marine regression reached its climax, and evidence suggests that the relative sea level was at a depth of 60 m or below (Hanebuth et al., 2003). This suggests that sub-aerial erosive processes and river evolution over the exposed shelf formed the valleys in the region. However, the structural framework of the Pernambuco Basin includes a structural outer high that runs parallel to the shelf break and the coast line, the Maracatu High (Buarque et al., 2016). This structure likely acted as an outer hinge and a region of potential stress concentration during the late reactivation events. The faults formed during the rift process, which included reactivated shear zones and new transfer faults cut this structure under the platform sector (Barbosa et al., 2014; Buarque et al., 2016).

The Southern Pernambuco Continental Shelf (SPCS) is part of the proximal region of the Pernambuco marginal basin, part of the eastern sector of the Brazilian continental margin (Figure 1-B, 1-A). With an area of around 950 km² (Figure 1-C), the SPCS stretches from the inner shelf to the shelf break zone, where the bathymetric depth plunges to approximately 55 m (Araújo et al., 2004). The surface sediments of the SPCS comprise biogenic carbonate sediments, comprising mostly sand, gravel, and bioclasts, resulting from the remains of calcareous algae (Kempf, 1970; Manso et al., 2003, 2004; Camargo et al., 2015).

Neotectonic activity has significantly impacted the shelf domain and coastal zone of the Pernambuco Marginal Basin (Correia Filho et al., 2019). This activity has led to a range of geomorphological features influenced by faults and fractures, including those found in the Quaternary Barreiras Formation, as reported by Bezerra et al. (2014). Of these features, the most notable are the numerous active and ancient faults that have altered the elevation and orientation of the sedimentary strata in the basin (Rossetti et al., 2011; Gandini et al., 2014; Souza et al., 2022). The reactivation of basement-seated faults created current structures, such as river valleys and fluvial terraces in the coastal zone, which can be observed from fault scarps formed by displacement along the fault line (Peulvast et al., 2006; Bezerra et al., 2014; Peulvast and Bétard, 2015; Correia Filho et al., 2019; Maia and Bezerra, 2020a, 2020b; Matos et al., 2021).

The Pernambuco Basin comprises several large subsidence basins that formed as a result of ongoing tectonic activity (Araújo Júnior et al., 2020). These basins have gently sloping surfaces covered by thick sequences of sedimentary rocks (Andrades-Filho et al., 2014; Correia Filho et al., 2019), which provide evidence of ongoing subsidence and act as valuable archives of the region's geological history (Matos, 1999; Riccomini and Assumpção, 1999; Peulvast et al., 2006; Peulvast and Bétard, 2015; Maia and Bezerra, 2020a, 2020b; Souza et al., 2022; Tavares et al., 2022).

The evolution of the Pernambuco Basin along the coastal zone and the platform, formed deep grabens filled with sedimentary rocks spanning from the Aptian to the Santonian due to the rift process (Barbosa et al., 2014). The crustal breakup in this region occurred in the Early-Middle Albian (Barbosa et al., 2014; Caixeta et al., 2017; Matos et al., 2021). Since the Late Cretaceous, reactivation events have been recorded in the Borborema Province that continued into the Miocene-Quaternary (Bezerra et al., 2014; Correia Filho et al., 2019). The structures responsible for the evolution of the

Pernambuco Basin include ductile pre-Cambrian shear zones in the northern portion of the shelf with a NE-SW and E-W direction and transforming faults trending NW-SE in the southernmost region of the basin (Nogueira et al., 2015; Buarque et al., 2016; Correia Filho et al., 2019). With the rift process, normal faults trending N-S and NNE-SSW were formed in the onshore region of the Pernambuco basin (Barbosa et al., 2014; Buarque et al., 2016; Correia Filho et al., 2019).

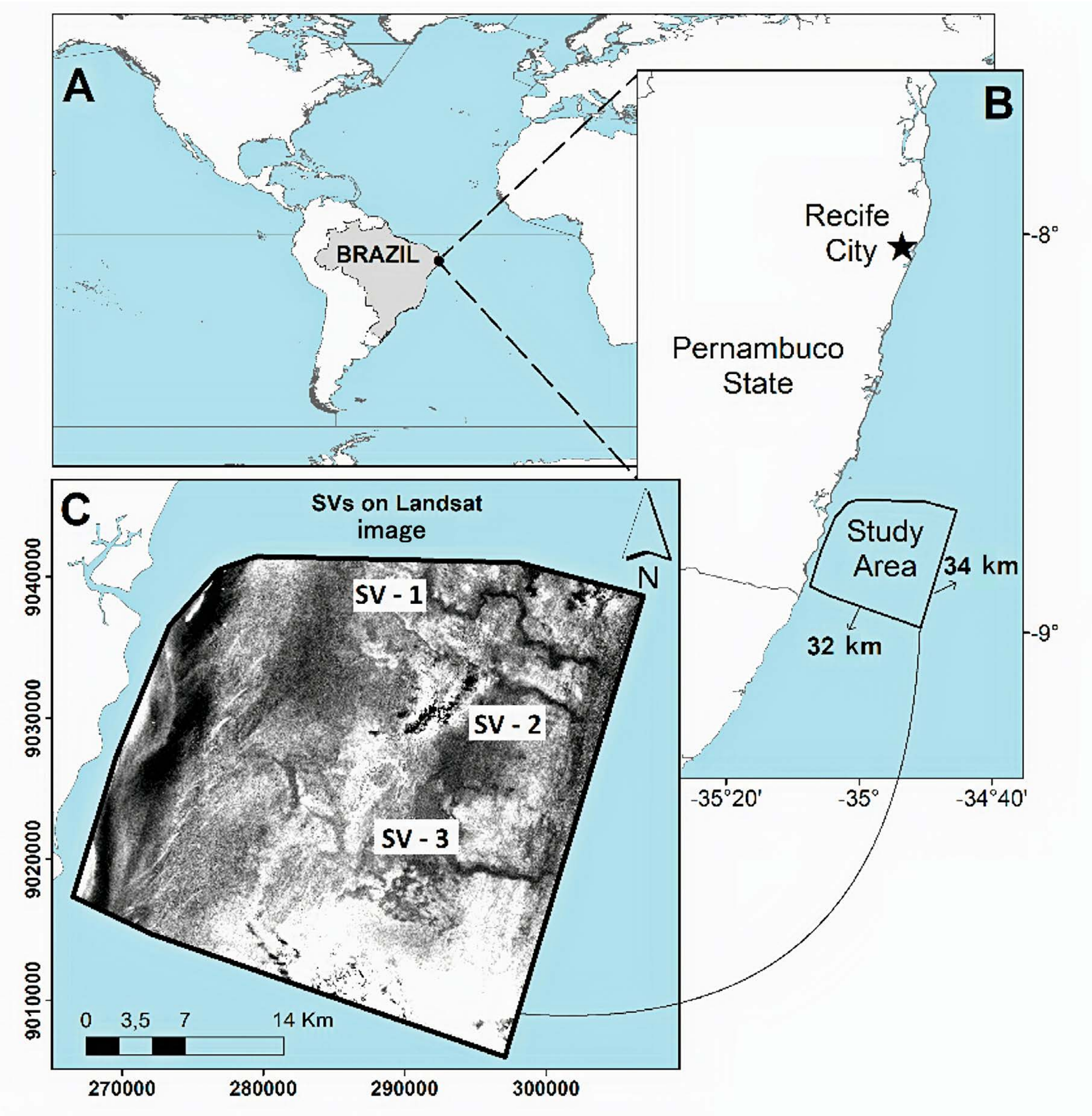


**Figure 1.** Location of study area: (A) South America; (B) Southern Pernambuco Continental Shelf; (C) Study area highlighting three shelf valleys (SVs) on a LANDSAT satellite image.

This study used geophysical data to analyze the geological processes that influenced Shelf Valley formation on the Pernambuco Continental Shelf. The multidisciplinary approach used enhances our understanding of valley formation by considering the interaction between eustatic events and continuous tectonic changes in the continental margin. This case study improves our understanding and validates similar cases in other regions. The use of specific modeling techniques for each dataset enhanced the accuracy and reliability of the results. Information obtained here will also contribute to advancing current knowledge on shelf valley formation in neighboring regions such as the Paraíba Basin platform to the north and the Alagoas Basin platform to the south.

## METHODS

The data used in this study consists of a compilation of multiple datasets from bathymetric, seismic line, and aeromagnetic surveys.

The single-beam bathymetric data, which covers the study area with dense but irregular sampling (Figure 2A), was gridded using the minimum curvature method (Briggs, 1974), with a cell size of 25 meters. We applied an upward continuation of 10 meters on the dataset to address the differing conditions present in the assembly of bathymetric data and remove the noise (Henderson and Zietz, 1949). This filter has characteristics of a low-pass filter and removed high-amplitude spikes due to boat movement (Figure 2B), resulting in a smooth signal, which emphasized shelf valley structures (SVs).

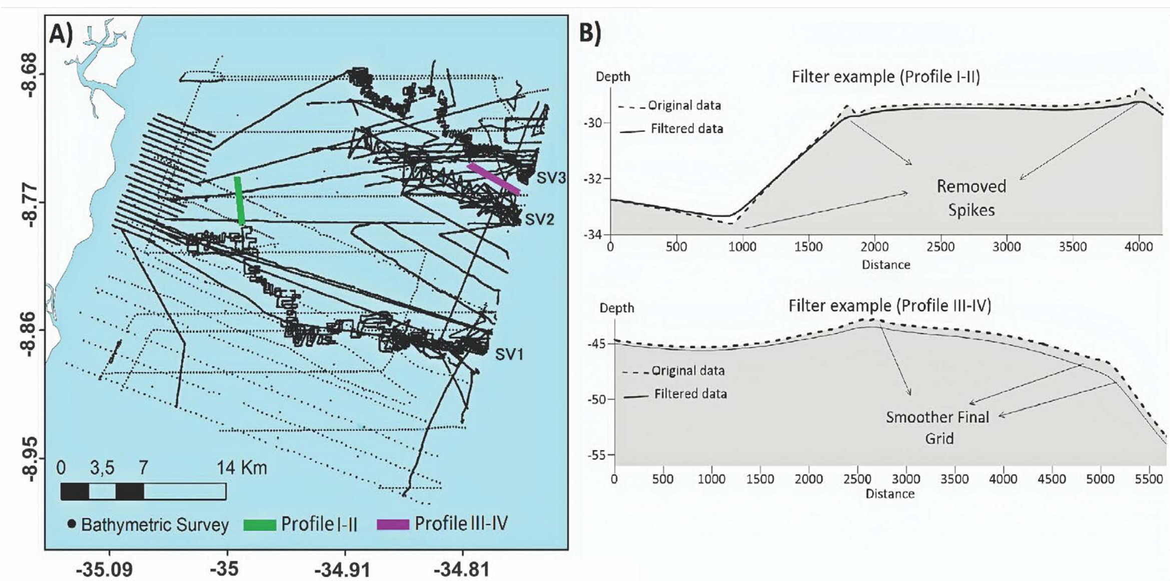


**Figure 2.** Compiled Bathymetric Dataset: This image displays a bathymetric dataset that was compiled using various surveys conducted in the study area. A) Survey Paths: The green and purple lines represent the paths followed during the surveys and the sections extracted from the interpolated grid. B) Example of a Bathymetric Section: This section displays an example of the bathymetric data extracted from the gridded survey and was subjected to a smoothing filter to remove spurious values and improve data accuracy.

The seismic dataset comprised 35 2D time-migrated sections provided by the National Agency for Petroleum, Natural Gas, and Biofuels (BDEP-ANP). The data represents a historical database compiled from various surveys conducted between the 1970s and 1990s. These sections were obtained using the seismic reflection method and multi-channel time-migrated surveys. Due to the varying quality of the seismic sections, different post-processing techniques were applied to enhance interpretation, such as gain filtering, low-frequency filtering, and Hilbert transform attribute extraction. We focused on structurally analyzing and interpreting the seismic lines throughout the first 500 m of each line, and the shelf valleys are mainly observed at 200 m on the sections.

This study used an aeromagnetic dataset acquired by the LASA company in 1988, which was provided by the BDEP-ANP. This survey, “Platô de Pernambuco,” covers the offshore domains of the Pernambuco Basin. The flight lines have a NW-SE direction with 3 km spacing and a flight height of 500 m. The aeromagnetic data was gridded using a bidirectional technique with a cell size of 2 km

(Figure 3). Further processing was conducted to enhance the magnetic response of shallow structures, such as producing a residual magnetic anomaly map and its derivatives, revealing magnetic lineaments in the region. (Figure 3, TILTs and TDRs).

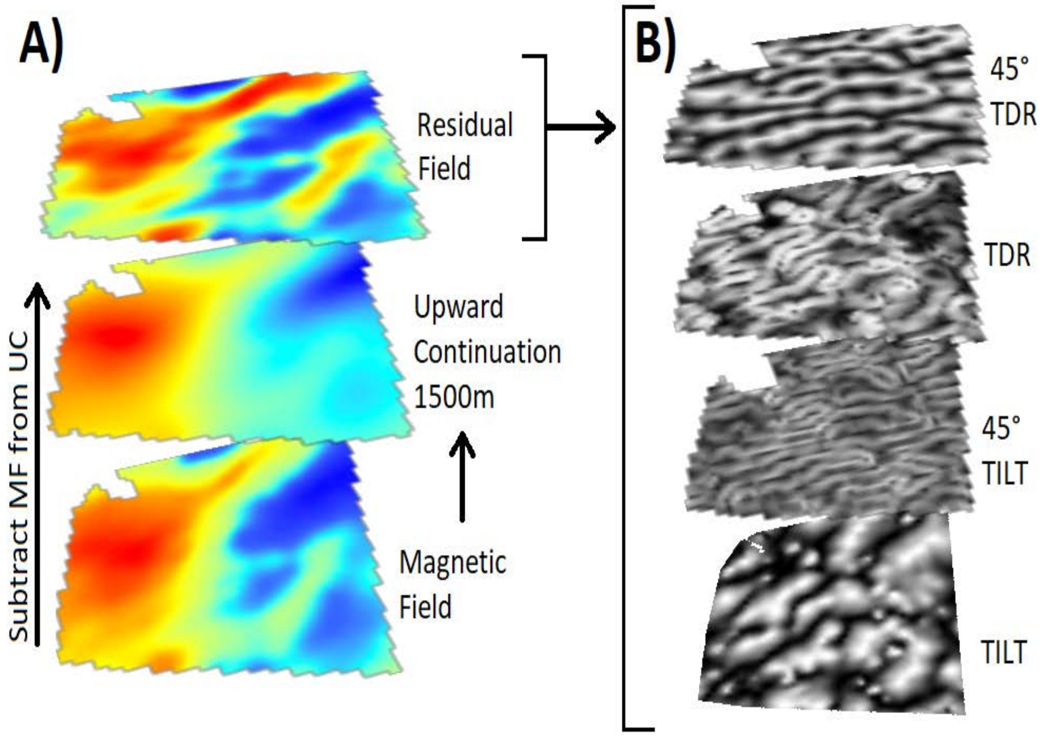


**Figure 3.** Illustration of the Aeromagnetic Data Processing Workflow: This image displays the steps involved in processing aeromagnetic data. A) Magnetic Anomaly Field Maps: The image shows a stack of three maps, from bottom to top, that represent the magnetic anomaly field map, upward continuation map, and residual magnetic anomaly map. B) TILT and TDR Maps: The image displays TILT, 45° TILT, TDR, and 45° TDR maps, which play a crucial role in aeromagnetic data processing and interpretation. These maps provide insight into the orientation and magnitude of magnetic anomalies and lineaments.

The processing of the aeromagnetic data involved several crucial steps. One of these was applying the upward continuation filter at a height of 1500 m, as described by Henderson and Zietz (1949). This filter minimized the influence of high-frequency anomalies in the magnetic data whereas preserving the low-frequency anomalies that could suggest deeper magnetic sources. Another significant step was the computation of the residual magnetic anomaly map. This map was generated by subtracting the magnetic anomaly map from the upward continuation filtered magnetic map, allowing the detection of shallower magnetic sources whereas simultaneously reducing the noise levels in the data.

To highlight the magnetic response from the shallow structures within the shelf basement, the adapted method proposed by Verduzco et al. (2004) was implemented on the magnetic data. This resulted in magnetic transformations, such as the TILT map and the horizontal derivative (TDR) from the residual field (Figure 3-B). The magnetic transformations accentuated the magnetic lineaments linked to high-frequency magnetic sources, thereby providing significant insights into the geological structures in the investigation area.

The TDR (horizontal derivative) is a magnetic transformation technique utilized to emphasize shallow structures within the magnetic field data (Ferreira et al., 2011, 2013). This method relies on calculating the first horizontal derivative of the magnetic field, which is achieved by subtracting the magnetic field data in the x-direction from that in the y-direction (Miller and Singh, 1994).

The resulting output corresponds to the gradient of the magnetic field, aiding in identifying shallow structures that are indiscernible by other techniques. The TDR technique is valuable when investigating the influence of shallow basement structures on the location of geological features and is exhibited as darker linear features in Figures 7D and 7F.

The TILT method is a valuable tool in modeling aeromagnetic data since it improves resolution for defining the borders of magnetic bodies, also known as magnetic lineaments, at different depths compared with other methods (Ferreira et al., 2011, 2013). Based on the ratio between the vertical and horizontal derivatives of the magnetic anomaly field (Miller and Singh, 1994), the TILT angle ranges between −90° and 90°, where the maximum values are at the center of the magnetic source. Limits of the source are indicated by zero or near-zero values (Verduzco et al., 2004). The TILT transform approach can uncover features that cannot be identified with other methods, such as shallower structures, as revealed by the horizontal derivative of TILT.

The dataset was integrated to investigate the link between tectonic activity and shelf valley (SVs) formation, which involved three stages as shown in Figure 4.

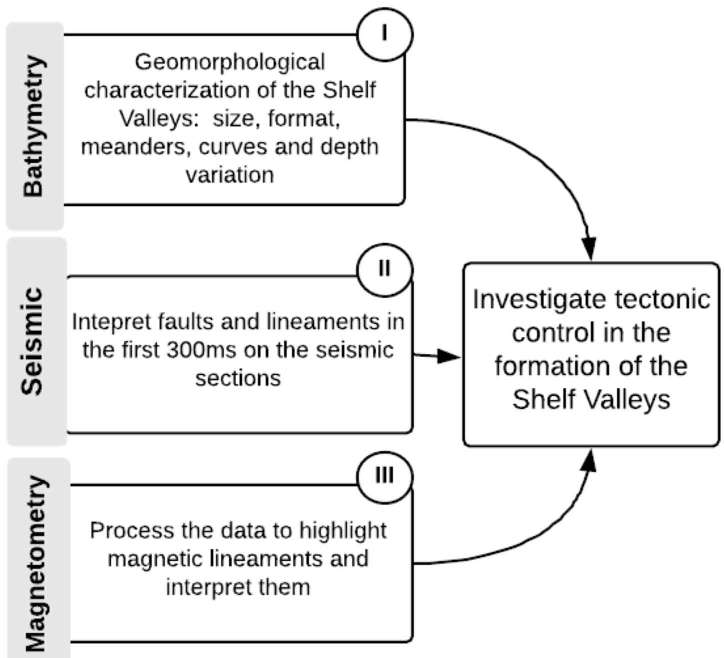


**Figure 4.** Flowchart of the Three-Step Data Investigation Process for shelf valleys in the study area. This image depicts the flowchart of the three-step investigation process for exploring the origin and characteristics of the shelf valleys in the study area. The three steps involved are: I) Bathymetry, which provides a detailed map of the seafloor topography and the location of the shelf valleys; II) Seismic, which involves interpretation of the seismic reflection data to identify the faults and fractures responsible for the formation of the shelf valleys; and III) Magnetometry, which provides information on the magnetic properties of the rocks and can help in determining the tectonic processes responsible for the formation of the shelf valleys.

The first stage (I) focused on the geomorphological characterization of the SVs using bathymetric data to identify their size, shape, meandering patterns, curvature, and depth variation. This stage provided valuable insights into the morphological features of the SVs and the processes involved in their formation.

In the second stage (II), faults and lineaments within the first 500 m of the seismic sections were interpreted using the seismic reflection method and multichannel time migrated surveys. This stage helped us to understand the structural elements that may have played a role in SV evolution. Faults and lineaments were identified, and their relationships with the SVs were determined to provide further insights into the tectonic control of SV formation.

Finally, in the third stage (III), the magnetic lineaments were interpreted by using the residual magnetic anomaly map, TILT, and TDR maps (Verduzco et al., 2004; Ferreira et al., 2011, 2013). This stage was crucial in understanding the distribution of magnetic sources within the study area and the relationship between these sources and the SVs. The TILT and TDR maps were used to determine the orientation and intensity of the magnetic anomalies, whereas the residual magnetic anomaly map identified the locations of the magnetic sources. The results from all three stages were combined to achieve a comprehensive understanding of the tectonic controls on the formation and evolution of the SVs.

## RESULTS

The bathymetric map of the study region, as depicted in Figure 5A, displays variation in continental shelf depth, ranging from −25 m close to the coastal area to approximately −55 at the shelf-break. The map depicts three SVs crossing the shelf extension almost perpendicularly towards the shelf-break. The SV geometries were observed, and sometimes the direction of the valleys changed abruptly, by almost 90°, forming rectangular meanders, as indicated by the white dotted circles in Figure 5A. To further illustrate the depth variations of the three SVs, four sections were plotted on the gridded data and displayed in Figure 5B. These sections demonstrated an increase in depth towards the ocean, where SV3 and SV1 were deeper than SV2.

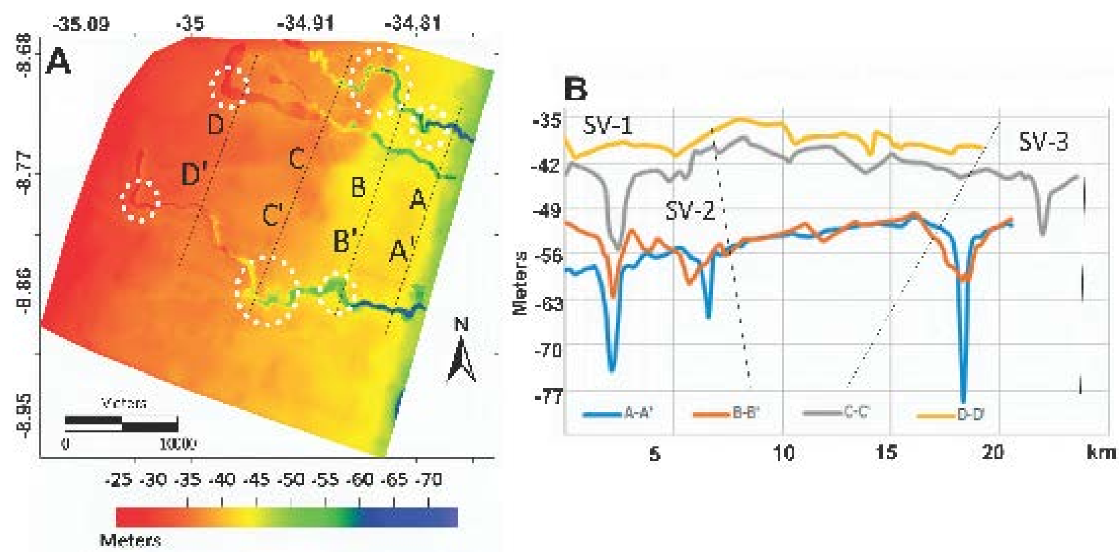


**Figure 5.** A) Bathymetric Map of the study area with three shelf valleys: This image displays a bathymetric map of the study area, featuring the three shelf valleys and their directional changes depicted by dotted white circles. B) Valley Depth Profiles: in the bathymetric map, profiles (D-D' and A-A') crossing the valleys are presented, revealing that the depth of the valleys increases from the proximal area near the coast to the shelf break. These profiles offer valuable insight into the geometry and depth of the shelf valleys, aiding our understanding of their evolution and development. (The gray lines indicate the location of the shelf valleys within the profiles).

Figure 6 illustrates the interpretation of shelf valleys in four seismic sections. The valleys are identified by the interruption and deformation of the reflectors within the first 500 m. The yellow lines represent faults resulting from the transpressive reactivation of deep faults from the rift stage, which are controlled by the basement structural framework. The valleys are located over these faults, and the successive cut and fold of the reflectors indicate that the excavation was governed by the faults, which reached the uppermost interval of sediments and the surface. The transpressive regime generated positive and negative flower-like structures with branching faults rooted in main vertical and sub-vertical reactivated faults, as described by (Correia Filho et al., 2019).

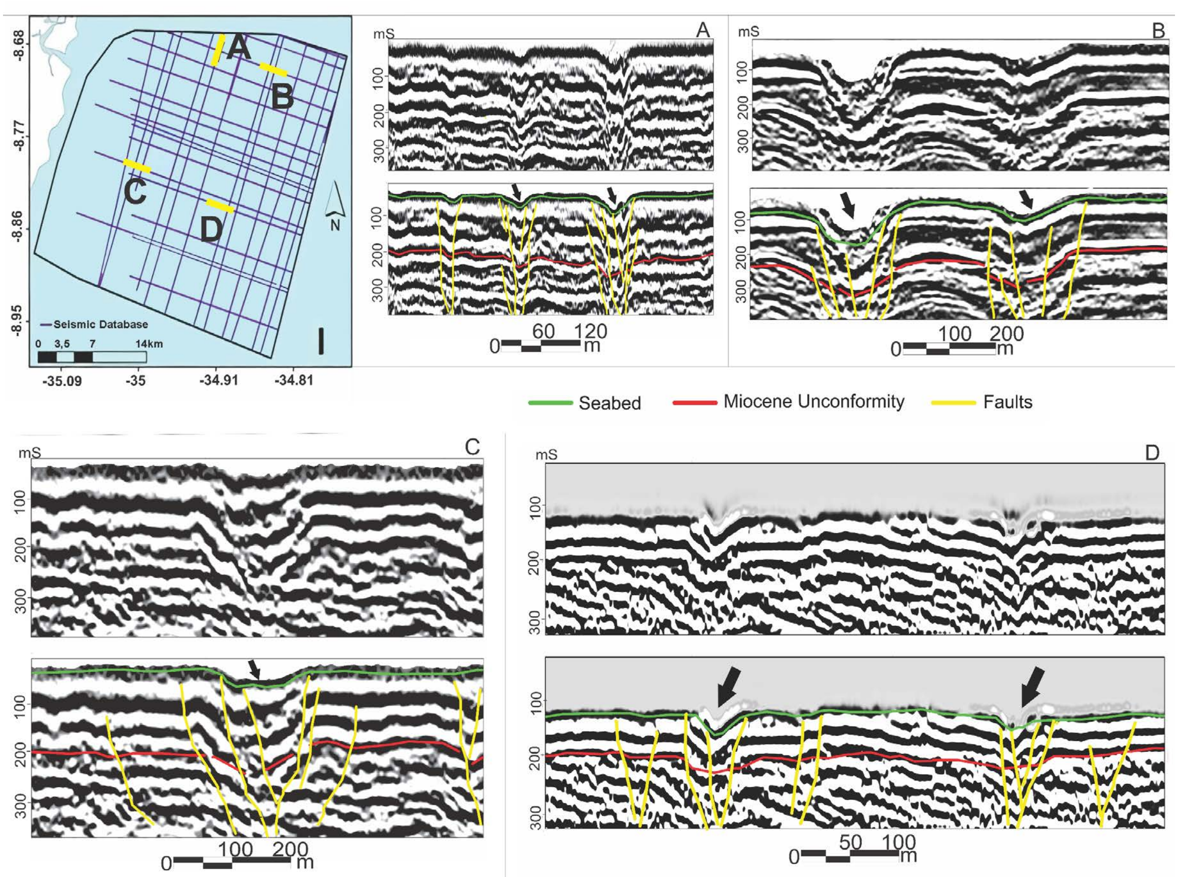


**Figure 6.** I) Seismic Line Locations in the studied region: This image shows the location of the seismic lines (purple) in the studied region, with four examples (A, B, C, and D) highlighted in yellow. II) Seismic Section Examples: The image also includes four examples of seismic sections (A, B, C, and D) in the studied region, both with and without interpretation. The interpreted sections use different colors to highlight specific geological features: Green: Sea floor. Blue: Modern incision of the shelf valley. Red: Middle Miocene unconformity. Yellow: Mapped geological faults, which controlled the location and development of the incisions. Additionally, note that the current shelf valleys were positioned over older shelf valleys buried by recent deposits.

The analysis of the total magnetic field was conducted to better understand the magnetic features of the study area. Figure 7 shows the analysis results. The total magnetic field map (Figure 7-A) depicts the normal magnetic dipole, with varying values ranging from 39 to −188 nanoTesla (nT). The upward continued magnetic field (Figure 7-B) also shows a similar dipole, but with values ranging from 10 to −153 nT. The residual anomaly map (Figure 7-C) demonstrated a response to shallow structures that could not be observed in the total magnetic field map.

The bathymetric map was analyzed in greater detail by integrating it with other datasets, such as shallow fault line locations derived from seismic data and the final lineament map. This integration revealed a clear influence of faults and fractures on two of the shelf valleys (SV-3 and SV-1). The bathymetric map, as illustrated in Figure 8, depicts a variation in continental shelf depth, ranging from −25 m near the coastal area to approximately −55 m at the shelf-break. The map also displays the meandering patterns of the shelf valleys, which are observed to abruptly follow the direction of the main structures in the basement beneath the shelf. The geometry of these shelf valleys exhibits rectangular meanders, which can be attributed to the capture of drainage by faults trending N-S and NNE-SSW. Some changes indicate a shift from an E-W direction to ENE-WSW direction. The SV-2, however, exhibits a more linear geometry, suggesting a lesser influence of these structures. This shelf valley may have been captured and placed along a deeper fault. All three shelf valleys appear to be seated over the propagation of strike-slip faults in the basement, which trend in a North-West to South-East direction, as shown in Figure 8.

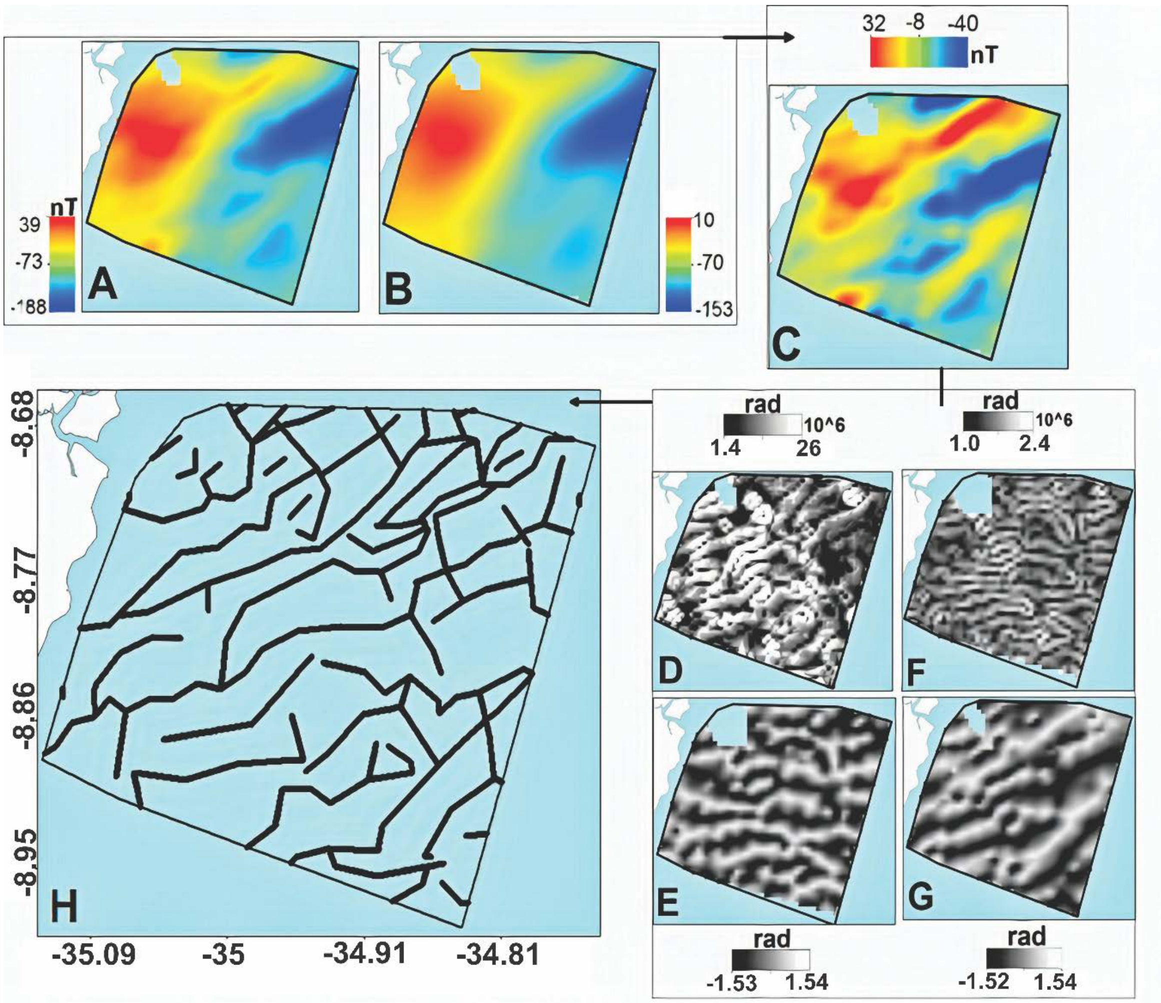


**Figure 7.** This image presents an integrated interpretation of the maps produced from the modeling of aeromagnetic data in the studied area. A) Total Magnetic Anomaly Map. B) Upward Continuation Map: shows the upward continuation of the magnetic anomaly field. C) Residual Magnetic Anomaly Map: displays the residual magnetic anomaly, which represents the difference between the total magnetic anomaly and the upward continuation. D) 45° TDR Filter Map: shows the results of applying a 45° TDR filter to the magnetic anomaly field data. The TDR filters are used to separate magnetic anomalies of different orientation and help to distinguish between magnetic sources. E) Default TDR Filter Map. F) 45° TILT Filter Map: shows the results of applying a 45° TILT filter to the magnetic anomaly field data. The TILT filters are used to separate magnetic anomalies of different magnitude and help to distinguish between magnetic sources. G) Default TILT Filter Map. H) Map of Basement Lineaments: shows the main lineaments of the basement in the studied area, which were interpreted based on the modeled aeromagnetic data. The lineaments provide information on the orientation and distribution of faults and other structural features in the subsurface.

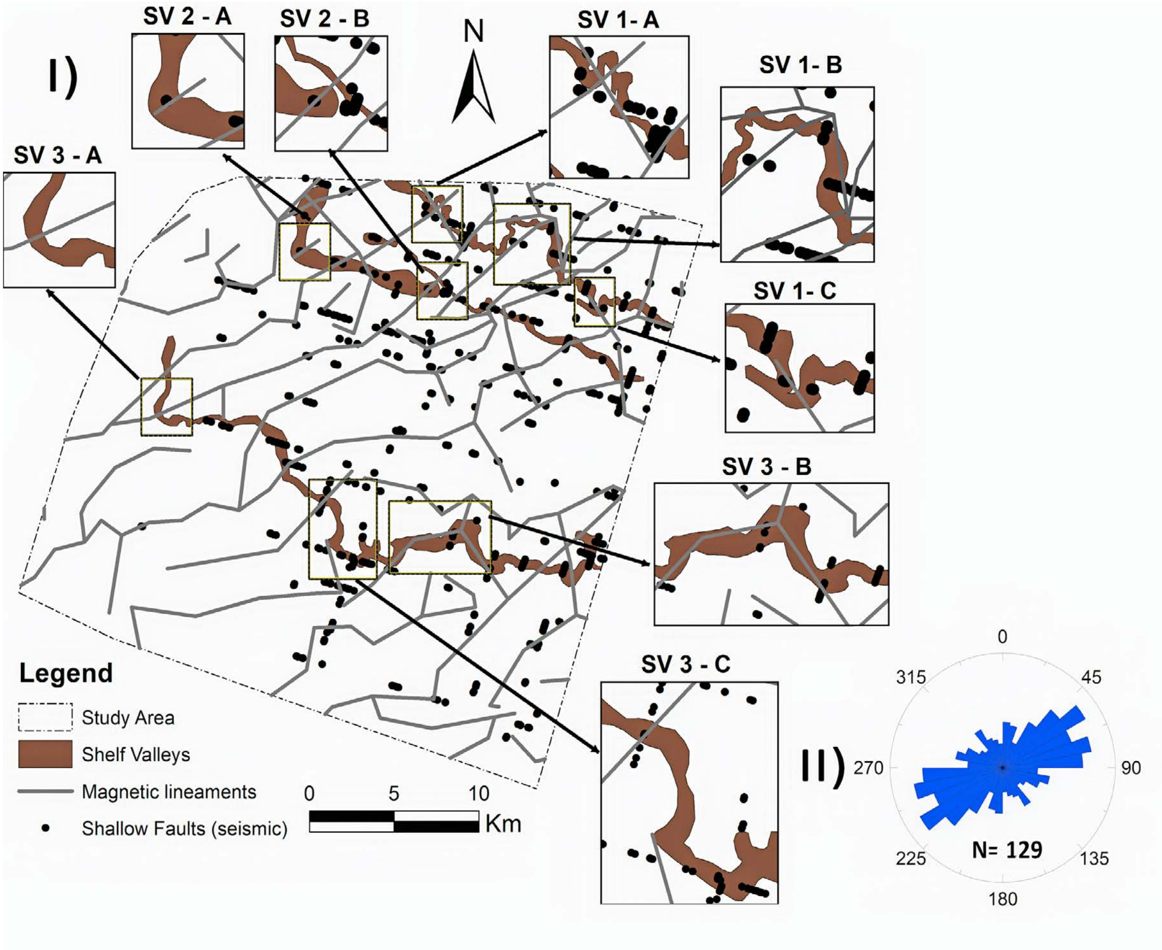


**Figure 8.** I) Data Integration: The figure depicts the integration of diverse data sets, such as the filtered bathymetric grid, the point cloud of mapped faults from the seismic sections, and the magnetic lineaments, to examine the shelf valleys in the study area. II) Rosette Diagram: This diagram presents the orientation of the magnetic lineaments in the study region in a rosette. The diagram emphasizes the NE-SW lineaments, which are prominent and linked to rift processes, and the NW-SE transfer faults.

## DISCUSSION

Shelf valleys are elongated, low-relief topographic features that occur along many passive continental margins (Figure 5). These valleys can span several kilometers in width and hundreds of kilometers in length, and they are often filled with sediment transported from the adjacent continent (Harris et al., 2014). In this study, the shelf valleys under investigation are partially filled, as evidenced by the seismic data, and exhibit negative relief, as observed in the bathymetric data and satellite imagery. The significance of climate and sea-level changes on shelf valleys in passive continental shelves can be understood from the following concepts: formation, sediment transport, and paleoclimate records.

Formation: During times of lower sea levels, rivers erode the exposed continental shelf and cut deeper into it, creating valleys which are later submerged as sea level rises again (Swift et al., 1980). These valleys become filled with sediment as they are flooded and covered by the sea, forming the shelf valleys we observe today (Figures 1 and 5).

Sediment transport: Climate and sea level changes impact sediment transport and deposition patterns in shelf valleys (Harris et al., 2003). Changes in sea level alter the depth and direction of ocean currents, which affect sediment transport and deposition as shown in the seismic data (Figure 6).

Paleoclimate records: Shelf valleys serve as archives of past climatic and sea level changes. The sediment accumulated in the valleys records long-term changes in climate and sea level, offering valuable insights into the Earth's history. Based on the seismic data, we can infer that the studied shelf valleys were excavated by rivers and buried by sediment from the Middle Miocene onwards. The shelf valleys were likely influenced by the regressions and transgressions that occurred during this period. The sedimentary layers deposited within the valleys have also been affected by tectonic activity since the Middle Miocene, as evidenced by both the seismic record and magnetic lineaments.

Neotectonic activity, or the movement of faults, has had significant control over the Una River Drainage Basin in the Pernambuco region of Brazil (Correia Filho et al., 2019). The effects of this neotectonic activity on rivers can be extrapolated to the formation of shelf valleys. Shelf valleys are like rivers, in that they both significantly impact the sedimentation, erosion, and transport of sediment in a region. Fault movement can also change the elevation and orientation of the seafloor, helping to form shelf valleys and submarine canyons (Micallef et al., 2014).

The results indicated that two out of the three shelf valleys, namely SV-3 and SV-1, were influenced by transfer faults that exhibited a North-West to South-East trend. These transfer faults are thought to have originated from the reactivation of the basement during the Cenozoic era. This finding highlights the substantial impact of this time period on the geological formation of the shelf via tectonic activity (Nogueira et al., 2015; Bezerra et al., 2017). Our analysis provides a comprehensive understanding of the geological features and their formation in the area under investigation. This study also identified secondary influences, which are likely to result from other types of faults. For example, faults formed by the reactivation of shear zones trending NE-SW and normal faults trending N-S and NNE-SSW were detected (Bezerra et al., 2014; Nogueira et al., 2015; Nicchio et al., 2022). These findings highlight the complexity of the geological processes that have shaped the area over time and provide important insights into the history of the shelf.

The sediment-starved characteristic of the shelf in the study region, as reported by Araújo et al. (2004), is evident when examining the different shelf valleys (SVs). The SVs close to the coast are shallower and contain more sediment compared with those further offshore (Figure 5A). The limited supply of continental sediments entering the ocean may explain why the shelf valleys were not filled during the Holocene's last sea level rise (Waelbroeck et al., 2002; Lambeck et al., 2014). Moreover, as seen in Xiao et al. (2021) river plumes can use SVs to transport sediments further on the continental shelf; consequently, burying the channel like structures. Extrapolating this to the study area we can infer that the continental sediment input was similar to nowadays throughout the Holocene, a sediment-starved continental shelf, since valley depth increases from the proximal area near the coast to the shelf break.

Based on the bathymetry map (Figure 5-A), the gradient of valley depth across the shelf is similar and the gradient of the shelf is consistent throughout the studied region, making it difficult to determine if the valleys were formed by different regimes of fluid flow. Therefore, for a more comprehensive understanding of the geomorphological features of the study area, we recommend complementing single beam bathymetric data with other datasets, such as multibeam bathymetric data.

The faults observed in the upper Cenozoic section of the shelf were likely generated by a reactivation of the rift faults in the basin basement, as reported by Correia Filho et al. (2019). These structures possibly result from the propagation of faults linked to the Pre-Cambrian shear zones and transfer faults, which were active during the rifting process that created the basin opening (Ziegler and Cloetingh, 2004). The faults depicted in Figure 6 are called "Flower structures" (Harding, 1985; Woodcock and Rickards, 2003), which are typically associated with strike-slip tectonics (Glover and Robertson, 1998). This suggests a component of current reactivation of older structures in the basement of the study area. The Flower structures cross filled strata, which are interpreted as past incisions from channels, and the Middle Miocene unconformity. The orientation of the shallow structures, depicted in the residual anomaly map (Figure 7-C), indicates that they are related to filled faults from the rift process (Rossetti et al., 2013; Bezerra et al., 2014; Gandini et al., 2014);

Correia Filho et al. (2019) reviews various models that attempt to explain the neotectonical reactivation events in passive margin basins. The chosen model for the specific study area explains that the reactivation of pre-existing structures, influenced by the Farfield effect, has resulted in faults that control the arrangement of the shelf valleys. The model suggests that the stress responsible for this reactivation was likely caused by the Andes and that the angle at which the Nazca Plate subducts beneath the South American Plate is a key factor in the reactivation. We believe a large subduction angle has imposed a stronger strain regime on the basement in Northeast Brazil, resulting in a dominant strike-slip tectonic regime with maximum compression in the E-W direction and extension in the N-S direction (Matos, 1999; Matos et al., 2021).

## CONCLUSIONS

This study has successfully demonstrated the importance of integrating multiple datasets for a comprehensive understanding of the geological structure of the study area. The use of bathymetric, aeromagnetic, and seismic data provides a complete picture of the impact of Cenozoic strata faults on the shelf, providing valuable insights for future studies and resource exploration initiatives. The single beam bathymetric data effectively highlighted the arrangement of the shelf valleys, while integrating seismic and magnetic data, providing a deeper understanding of their structural control. The analysis of 2D seismic data showed that the strata covering the shelf valleys since the middle Miocene have been affected by faults with a transcurrent regime, associated with magnetic lineaments, indicating the reactivation of structures under a current tectonic regime.

The three shelf valleys are organized into shear zones with a dominant NE-SW trend and faults with a NW-SE trend. The capture of pre-existing drainage on the exposed continental shelf has helped forming shelf valleys with rectilinear patterns and abrupt changes in direction due to neotectonic control with almost perpendicular dominant directions.

Shelf valleys are significant repositories of information about past variations in climate and sea level. According to the seismic data, we deduced that rivers had eroded the study shelf valleys and the resulting sediment has been deposited and buried since the middle Miocene. The shelf valleys may have been influenced by the successive regressions and transgressions during this era. The tectonic activity since the middle Miocene has affected the sedimentary layers in these valleys, as demonstrated by both the seismic data and magnetic lineaments.

This study highlights the significance of using a multi-disciplinary approach in geological studies, and the benefits of integrating multiple types of data to achieve a comprehensive understanding of geological processes and structures. The results will serve as a valuable contribution to understanding the geological structure of the area and will guide future studies and resource exploration efforts in the region.

## ACKNOWLEDGMENTS

The authors acknowledge the support of the M.Sc. Scholarship from Conselho Nacional de Desenvolvimento Científico e Tecnológico to the first author. They express their appreciation to the Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (ANP) for providing the seismic data, and to dGB Earth Sciences for providing the OpendTect Software for seismic interpretation. We thank the crew of R/V Velella for the help with the bathymetric surveys and the CEPENE/ICMBio and the Instituto Recifes Costeiros for logistical support. This article contributes to the Ciências do Mar I & II CAPES project (CAPES 419/2010 and CAPES 1979/2014) and to the Instituto Nacional de Ciência e Tecnologia para Ambientes Marinhos Tropicais do Brasil – INCT AmbTropic (CNPq/ FABESB Grants 565054/2010-4 and 8936/2011).

The authors also extend their gratitude to the reviewers from Ocean and Coastal Research for their valuable contributions and insightful suggestions. The reviewer's thorough examination and constructive criticisms have helped to improve the quality of this work, bringing it to its current form. The authors thank the reviewers for taking the time to review their submission and for their dedication to advancing the field of oceanography and marine geology.

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L.F.M.T.: Conceptualization, Data curation, Formal analysis, Methodology, Writing – Original draft.

T.C.M.A.: Supervision, Funding Acquisition , Methodology , Validation, Writing– Review & editing.

J.A.B.: Conceptualization, Methodology, Software, Validation, Writing – Review & editing.

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