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TECTONO-STRATIGRAPHIC MODELING OF THE WILDCAT PROSPECT (GATO DO MATO), SANTOS BASIN, BRAZIL FOCUSING ON PRESALT CARBONATE RESERVOIRS

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ABSTRACT. The Santos Basin is the largest Brazilian offshore basin and is currently the main hydrocarbon producer in the country, comprising an area of approximately 350,000 km^2. Given the importance of understanding and analyzing its carbonate reservoirs (Itapema and Barra Velha formations), a tectono-stratigraphic model of the Wildcat Prospect was created. This area is in the Outer High of the Santos Basin, main region of the presalt carbonate reservoirs in the Santos Basin. The 3D model is focused on the presalt reservoir and the understanding of the main tectonic structures in this area and their relationships that conditioned the carbonate successions deposition. Four steps were followed to analyze the depositional and structural framework and build the tectono-stratigraphic model: (i) generation and analysis of seismic attributes to identify and characterize seismic terminations (erosional truncation, toplap, and onlap), seismic facies (debris, build-ups, platform carbonates, and bottom lake), and assist in the tectono-stratigraphic analysis; (ii) seismic interpretation of horizons and faults, which were used as input for the modeling as surfaces and fault planes, creating compartmentalized blocks; (iii) construction of the stratigraphic column to classify the succession of tectonic and sedimentary events; and (iv) the construction of the model. This study helps to understand the depositional and structural evolution of the presalt and provides a three-dimensional understanding of the influence of faults on the reservoir geometry. Faults influenced the eroded zone observed in the Upper Barra Velha Formation, since this erosion occurs mainly at the edges of the large-throw faults. The build-up seismic facies, the main reservoirs in the study area, have a trend NW-SE to N-S following the large-throw faults.

Keywords: Tectono-stratigraphic modeling, carbonate reservoirs, Wildcat Prospect, Santos Basin.

INTRODUCTION

The construction of three-dimensional (3D) geological models has become indispensable in the development of geosciences. These models allow an integrated interpretation of different geological and geophysical elements such as faults, stratigraphic horizons, topography and well log analysis, which improves the visualization and knowledge of a study area. The oil and gas industry plannings has been support by structural and stratigraphic modeling techniques, because the 3D view of reservoir minimizes the risks, the costs, and uncertainties inherent in the exploratory and production activities.

The 3D modeling of sedimentary basins aims to build geological models that represent the structural and stratigraphic complexity of the strata (Antunes, 2003). These models are key to making decisions in the operation (Polson and Curtis, 2010), and have several applications such as: (i) geological models from different seismic interpretations (Bond et al., 2007); (ii) optimization model to minimize risk (Refsgaard et al., 2006; Bond et al., 2008); and (iii) geomechanical models to assist in well drilling (Xie et al., 2018).

Some 3D models are focus on the reservoir intervals and are essential for the reservoir characterization. Typically, the structural model of the reservoir is limited by the top and base of the reservoir and the presence of faults. These 3D models are used for modeling facies properties, as porosity and permeability (Ferreira and Lupinacci, 2018; Peçanha et al., 2019; Penna and Lupinacci, 2021), and geological process modeling (Ferreira et al., 2021a). Reservoir models allow to understand and determine volumes and heterogeneities of distribution of properties and seismic facies (like seismic facies variations of the respective reservoir properties). These models help to plan more efficiently the development of the field and well locations, reducing the costs and risks inherent in drilling.

Given the importance of understanding and analyzing underexplored areas to obtain a more comprehensive knowledge and understanding, we construct a 3D tectono-stratigraphic model was constructed for the Gato do Mato Prospect (called in this work as Wildcat Propect) in the Santos Basin, Brazil. This 3D model is focused on the presalt reservoir and will be used in future property modeling. In addition, we discuss the main structures found in this area and their relationships, that conditioned the deposition of the presalt carbonate rocks.

2. Geological setting

The Santos Basin extends from the southern coast of the Rio de Janeiro State to the north of the Santa Catarina State, with an area of approximately 350,000 km² and bathymetric dimension up to 3,000 m (Figure 1). This basin is bounded to the north by the Cabo Frio High from the Campos Basin, and to the south by the Florianopolis High from the Pelotas Basin (Figure 1). The origin and evolution of the Santos Basin is tied to the rupture processes of the Gondwana paleocontinent. Its tectonostratigraphic evolution is characteristic of passive margin, indicated by geological records caused by processes such as lithospheric distension, crustal stretch, continental crust disruption, oceanic crust implantation and thermal subsidence (Petersohn, 2013).

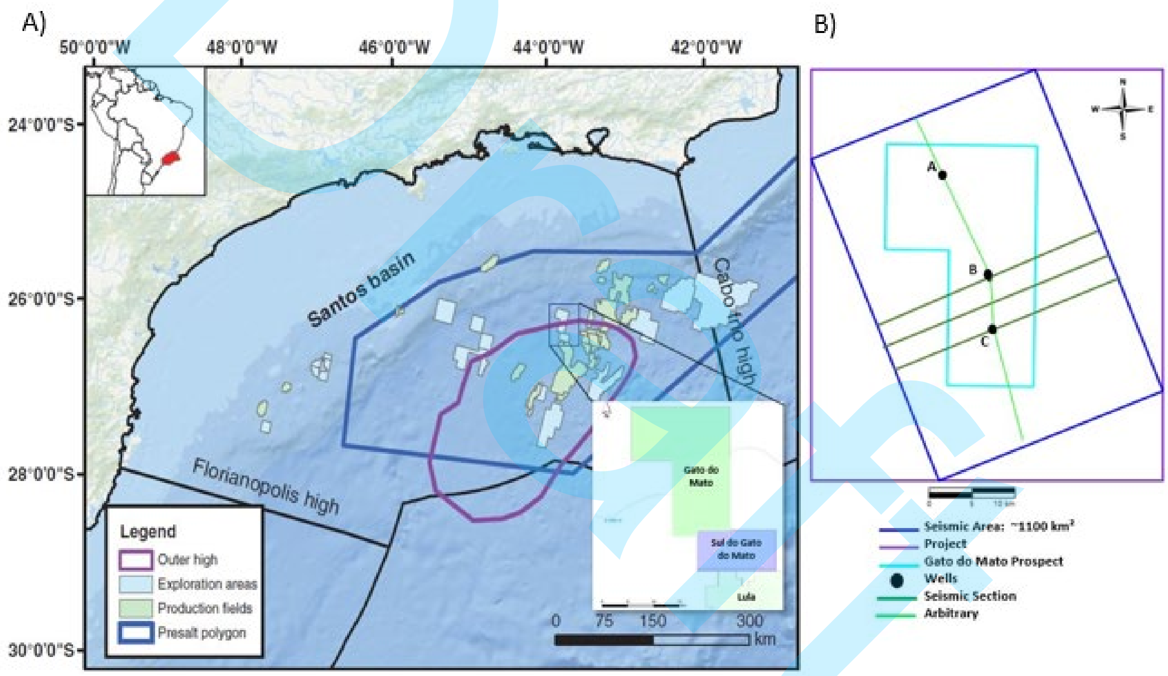

Figure 1: A) Location map of the Santos Basin highlighting the Wildcat (Gato do Mato) Prospect. B) Simplified dataset of the study area, including the location of studied wells and seismic sections.

The presalt succession of the Santos Basin, focus of this work, consists of four lithostratigraphic units: Camboriú, Piçarras, Itapema, and Barra Velha Formations (Figure 2). The Camboriú Formation is composed of Eo-Cretaceous basaltic effusions represented by dark gray basalts that correspond to the Economic Basement of the Santos Basin (Moreira et al., 2007). The age of these rocks (130-136,4 Ma) is correlated to the peak of basaltic effusions in the Magmatic Province of the South Atlantic (Szatmari and Milani, 2016).

The Outer High is an important geologic feature of the Economic basement (Figure 1). This morphology represents an uplifted structure from the basement and records a transition from volcanoclastic deposition to an almost continuous deposition of carbonate during Barremian and Aptian Ages (Carminatti et al., 2008; Buckley et al., 2015). The NE-SW trend faults defined the structure of this high before the evaporites deposition (Ariri Formation; Carminatti et al., 2008). The Outer High is interpreted as a less stretched continental crust area, which would have aided in its maintenance like an old structural high, because subsidence would have been more effective in areas where the continental crust was thinner. Then, the Outer High remained a positive feature throughout its tectonic history, where its distal location and the pronounced elevation impacted the depositional thicknesses and accumulation patterns that followed, affecting from Cretaceous carbonate deposition to Neogene sediment strata (Gomes et al., 2009). Such characteristics would have favored the accumulation of presalt carbonates by providing the isolation of the region of external clastic sediments (Buckley et al., 2015). Therefore, most of the production fields and exploratory blocks of the presalt section of the Santos Basin are located in this high.

The terrigenous sediments of the Piçarras Formation were deposited unconformable on the basalts of the Camboriú Formation (Figure 2). The Piçarras Formation was deposited during the Upper Aratu and Buracica local stages and is composed of conglomeratic alluvial fans and polymythic sandstones in the proximal areas, as well as sandstones, siltstones, and shales talc-stevensitic in the lacustrine distal areas. The deposition of these sediments occurred from the initial to the final stage of maximum activity of the half-grabens developments (Moreira et al., 2007). The sediments of the Itapema Formation have deposited overlapping the siliciclastic Piçarras Formation, being separated by regional Jiquiá-Buracica unconformity (Figure 2). The Itapema Formation is represented by grainstones to bivalves (coquinas), wackestones and bioclastic packstones, calcimudstones, and organic-rich dark shales (Moreira et al., 2007).

The Barremian Sequence (Aratu, Buracica and Jiquiá local stages), composed of the Piçarras e Itapema formations, consists of essentially continental sediments and represents the main deformation period of the rift phase. According to Moreira et al. (2007), the deformation was concentrated in the upper crusty parts, with the formation of fault systems with a lower dip angle than the faults that affected the basalts of the Camboriú Formation.

Still under the influence of the rift phase processes, the sediments at the bottom of the Barra Velha Formation were deposited (Buckley et al., 2015; Wright and Barnett, 2015; Neves et al., 2019). The Barra Velha Formation thickness varies significantly along the Santos Basin, reaching a thickness of more than 500 m, and sometimes is locally absent (Moreira, 2007). Buckley et al. (2015) highlight that these deposits show a prominent wedge geometry and may represent differences in the rate of movement of faults that, consequently, create accommodation space. Thus, the authors claim that this may mean an increase in the sedimentation rate at the top of the Barra Velha Formation when compared to Piçarras and Itapema formations. As a consequence of the controlled water influx and the high evaporation rates resulting from the dry and hot climate during the Aptian, deposition of a thick evaporitic sequence occurred. In this way, during the Neoaptian (Upper Alagoas local stage), the evaporites of the Ariri Formation were deposited overlapping the Barra Velha Formation. The Ariri Formation consists of thick packets of halite and anhydrite, although there are also occur salts more soluble as tachyhydrite, carnallite, and sylvite (Moreira et al., 2007; Teixeira et al., 2020).

The Barra Velha Formation is composed of varying proportions of different sediments: shrubs, spherulites, carbonate muds and Mg-rich clays. Lithotype classification varies depending on the origin and composition of the component sediments but lithotypes can be divided into three main groups: mudstones, in situ carbonates and reworked carbonates (Moreira et al., 2007; Terra et al., 2010; Wright and Barnett, 2015; Neves et al., 2019; Gomes et al., 2020; Ferreira et al., 2021a,b).

The passive margin or drift phase of the Santos Basin, that overlaps with the evaporitic succession, consists of marine sediments deposited from Albian to the recent, corresponding to the groups Camburi, Frade and Itamambuca, modeled in this work as post-salt. This phase is associated with thermal subsidence and the diastrophic tectonism, and presents its formations strongly affected by the tectonics of the underlying salt beds (Petersohn, 2013).

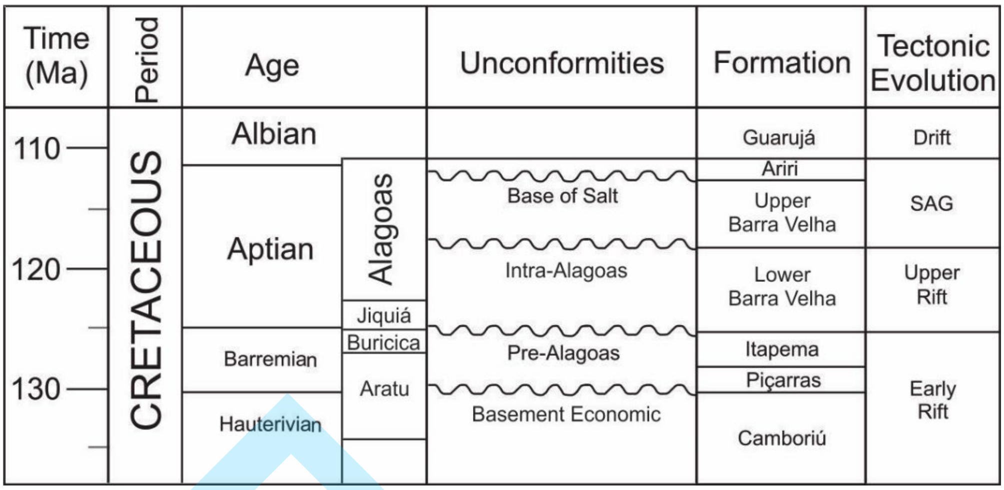

Figure 2: Lithostratigraphy of the presalt interval in the Santos Basin, its phases of tectonic evolution, and regional unconformities. After Moreira et al. (2007), Wright and Barnett (2015), Buckley et al. (2015), and Neves et al. (2019).

3. METHODOLOGY

The data used in this work are a PSDM (post-stack depth migration) volume with approximately 1100km^2 and three wells (Figure 1). To analyze the main geological configurations and to develop a tectono-stratigraphic model of the Wildcat Prospect, we performed the following steps (Figure 3): (i) seismic attributes generation and analysis; (ii) seismic interpretation (horizons and faults); (iii) stratigraphic column construction; (iv) faults and horizons modeling; and (v) construction of the tectono-stratigraphic model.

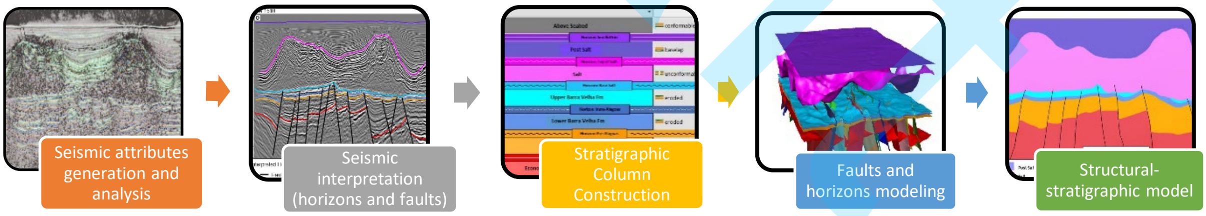

Figure 3: Flowchart with the steps used to construct the tectono-stratigraphic model.

(i) Generation and analysis of seismic attributes: seismic attributes are tools for inferring geology from seismic reflection data (Barnes, 2016). Seismic attributes allow reveal hidden features and identify similar patterns, which often cannot be identified only in the seismic data. We generated the following seismic attributes to assist in the seismic interpretation:

a) Dip steered enhancement: it acts as a seismic filter oriented to dip and azimuth, which performs lateral filtering along the surfaces (Chopra and Marfut, 2007). This filtering improves the lateral continuity of reflectors and removes noises. This attribute was used to reduce the migration “smiles”;

b) Coherence attribute: trace-to-trace discontinuities in the seismic data may be due to the presence of faults or stratigraphic features, which change the characteristics of traces promoting a loss of similarity between neighboring traces (Bahorich and Farmer, 1995). Coherence attribute allows the analysis of structural characteristics since it measures the similarity or non-similarity of seismic data. This attribute was used to understand the lateral extent of geological features (seismic patterns) and to assist in the interpretation of faults and fractures;

c) Relief (TecVA): it was developed by Bulhões and Amorim (2005), called Amplitude Volume Attribute (TecVA), and aims to increase the visualization of reflectors and faults, showing small variations in amplitude in a lateral trace-to-trace correlation. This attribute was used to assist in the interpretation of the Economic basement.

(ii) Seismic interpretation (horizons and faults): to determine the geologic structures present in the studied area, we interpreted the main faults that affect the presalt interval, that is, from the basement to the base of the salt. Faults interpretations was based on co-rendering of amplitude and relief attributes, and sometimes, on co-rendering of amplitude and coherence attributes. These combined attributes allowed to better show the discontinuities, improving the interpretation of the faults and, consequently, of the horizons influenced by them (Figure 4).

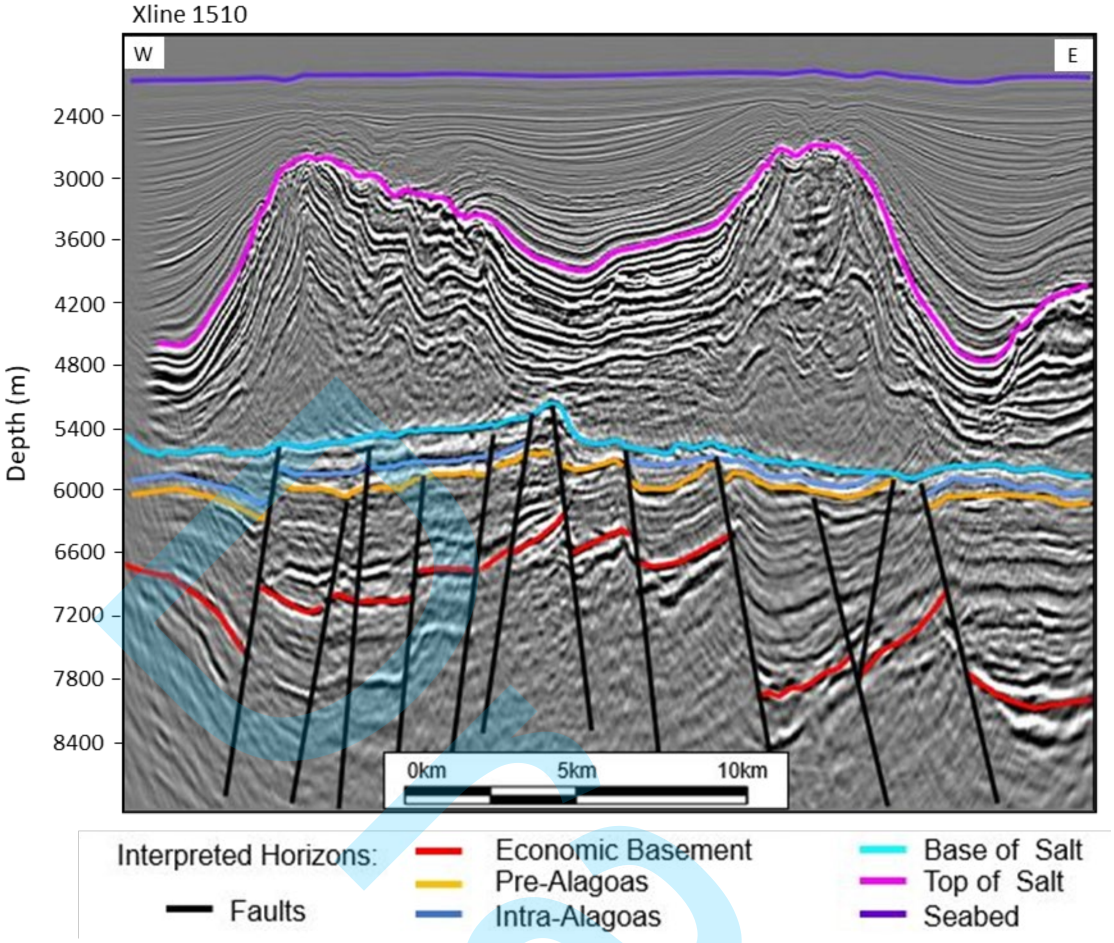

Figure 4: Seismic section with reflectors that were interpreted in the study area.

(iii) Stratigraphic column construction: the stratigraphic column specifies to the software of 3D modeling the main stratigraphic information (chronological order of layers; contact between the layers and erosive surfaces) used to rank the succession of tectonic and sedimentary events, being used as a reference for the construction of the tectono-stratigraphic model.

(iv) Modeling of faults and horizons: it generates the surfaces respecting the fault limit and the horizons according to the stratigraphic column, allowing the compartmentalization of blocks affected by the faults.

(v) Construction of the tectono-stratigraphic model: the constructed model is based on the UVT Transform, a paleogeographic coordinate system that allows to use all available geological information, whatever its complexity, for geochronological representations of horizons (Gringarten et al., 2008). T stands for stratigraphic time and is the vertical axis of the UVT paleospace, where the image of all horizons is flat as opposed to the (X, Y, Z) real space (e.g., of the seismic). U and V are the other two axes to complete the coordinate system.

This coordinate system permits to represent all geological information between chronostratigraphic surfaces, this means representing the surfaces on a time scale when they were deposited. By simultaneously constructing the volume with the faults and horizons the technology employed minimizes the loss of information, honoring the available data, without the need for implication, which allows for generating a model more consistent with the local geology.

4. RESULTS AND DISCUSSION

4.1 Stratigraphy and geologic features of the Wildcat Prospect

The Barra Velha carbonate deposits have characteristics of continental depositional environments, with a complex depositional and diagenetic history (Buckley et al., 2015; Wright and Barnett, 2015; Faria et al. (2017); Gomes et al., 2020). The lacustrine carbonates deposition is more complex than in marine settings, being controlled by many factors, such as sedimentary input, temperature variations, hydrology reflecting the interaction with the local climate, pH, water chemistry, and tectonics (Herlinger et al., 2017; Wright and Rodriguez, 2018). Water chemistry plays one of the most crucial roles in lake environments due to the control of the sedimentary processes, chemical precipitation, and the widespread of the biota, which includes the development of microbial communities, precipitation of clay minerals, and abiotic carbonate precipitation (Pozo and Casas, 1999; Wrigth and Barnett, 2015; Herlinger et al., 2017). Likewise, the tectonic setting was fundamental to determining the carbonate platforms geometry and distribution, like the horst-graben configuration of the Economic Basement, interpreted in the studied area (Figure 4).

In the Wildcat Prospect was possible to identify the entire carbonate succession of the Barra Velha Formation, including the intra-Alagoas unconformity, which divides the unit in Upper and Lower Barra Velha intervals (Figures 2 and 4).According to Wright and Barnett (2015), the lower part of the Barra Velha Formation still belongs to the rift phase, bounded by the pre-Alagoas unconformity at the base and the intra-Alagoas unconformity on the top (Figure 2). Buckley et al. (2015) affirm to be able to identify in seismic sections the evolution of the rift phase to a tectonic quiescence phase, highlighting the presence of a sag phase. They add that most extension faults end at the base of the sag phase and that they can be correlated with intra-Alagoas unconformity. Besides, Buckley et al. (2015) highlight that it is possible to identify two phases of rifting separated by pre-Alagoas unconformity, a lower one that would affect the Piçarras and Itapema formations and an upper one that would affect the Barra Velha Formation. In this way, the upper part of the rift is related to the carbonates of Barra Velha Formation that are deposited to the limit with intra-Alagoas unconformity, where the sag phase would begin. The phases of tectonic evolution adopted by Buckley et al. (2015), Wright and Barnett (2015), and Neves et al. (2019), as well as the characteristics of the terminations of major fault systems, both were observed in the Wildcat Prospect (Figures 4 and 5).

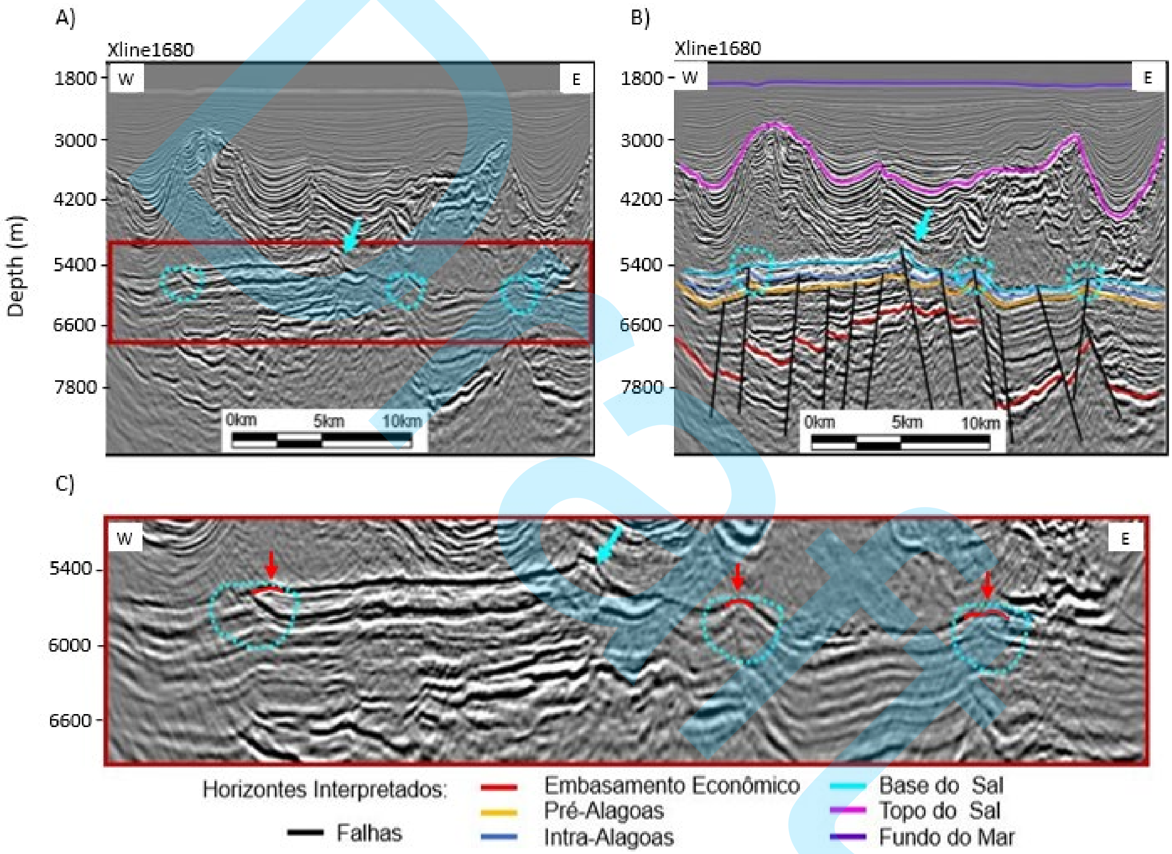

Figure 5: Noninterpreted (A) and interpreted (B) seismic sections; (C) Zoom showing the identified erosional truncation (red arrows and lines) in faulted strata zones (dotted blue circles), and the build-up at the border of the fault (blue arrow).

Recent works to characterize the seismic patterns of the Barra Velha Formation shows that the main configurations found are build-ups (carbonate mounds), aggradational/progradational platforms, slope (debris), and lake bottom facies (Ferreira et al., 2019; Jesus et al., 2019; Neves et al., 2019; Ferreira et al., 2021b). Jesus et al. (2019) performed a multi-attribute facies classification to discriminate good reservoir quality carbonate mounds. Ferreira et al. (2021b) proposed a workflow for classifying and mapping seismic facies, the results showed that build-up and debris seismic facies commonly occurs aligned with faults and displays higher porosity and permeability and as such they were inferred to be the best reservoirs. The identification/description of these seismic patterns and their responses to seismic attributes led to the understanding of the sedimentary-tectonic evolution of the Barra Velha Formation on the Wildcat Prospect.

4.2 Seismic stratigraphic facies of the Wildcat Prospect

The identification of the horizons was based on the interpretation of the seismic reflection terminations (onlap, downlap, toplap, and erosional truncation), which are considered the main criteria for the recognition of stratigraphic units (Mitchum, 1977). Considering that patterns of reflection terminations may indicate depositional sequence limits and system tracts (Brown Jr. and Fisher, 1977), six horizons were interpreted: (i) Economic Basement; (ii) Pre-Alagoas; (iii) Intra-Alagoas; (iv) Base of Salt; (v) Top of Salt; and (vi) Seabed. Although the focus of the work is the presalt reservoir where the horizons are the Pre-Alagoas, Intra-Alagoas and Base of Salt, other horizons were interpreted, once that they were necessary for the construction of the tectono-stratigraphic model. In addition, the Economic Basement mapping also aimed to assist in the structural understanding of the area, since it influenced the carbonate deposition and is strongly affected by the faults (Figure 4).

The analysis of seismic attributes allowed a better understanding and identification of seismic patterns, allowing a better interpretation of the Wildcat Prospect, and provided the identification of some terminations like erosional truncations. These terminations were crucial to evidence the erosion to which it was subjected the Upper Barra Velha Formation by the Base of the Salt at the beginning of the Sag phase (Figure 5). In addition, from the seismic amplitude, we identified the main seismic facies present in this formation and already highlighted by Wright (2012), Ferreira et al. (2019) and Ferreira et al. (2021b): build-ups, debris, carbonate platform, and lake bottom. These seismic facies are shown in Figure 6 and later, their responses to other seismic attributes presented here are analyzed.

Dip steered enhancement filter removed noise and improved reflector continuity. The preconditioned data attenuated the migration smiles. Subsequently, this data was used as input for the generation of the coherence cube. This attribute is very sensitive to the presence of noise, so it is important to be well parameterized to minimize seismic footprints. The coherence cube assisted in the analysis of seismic patterns and highlighted the structural characteristics, evidencing faults and discontinuities of the interpreted reflectors. In addition, when co-rendering with the seismic amplitude, highlighted the build-ups facies showing chaotic seismic textures with an external geometry in conical format (convex-upward), where the reflector a not continue inside the geometry, and the lake-bottom facies with a parallel flat and convergent-baselapping internal structure. These characteristics of the build-ups and lake bottom facies are highlighted in the Figure 7.

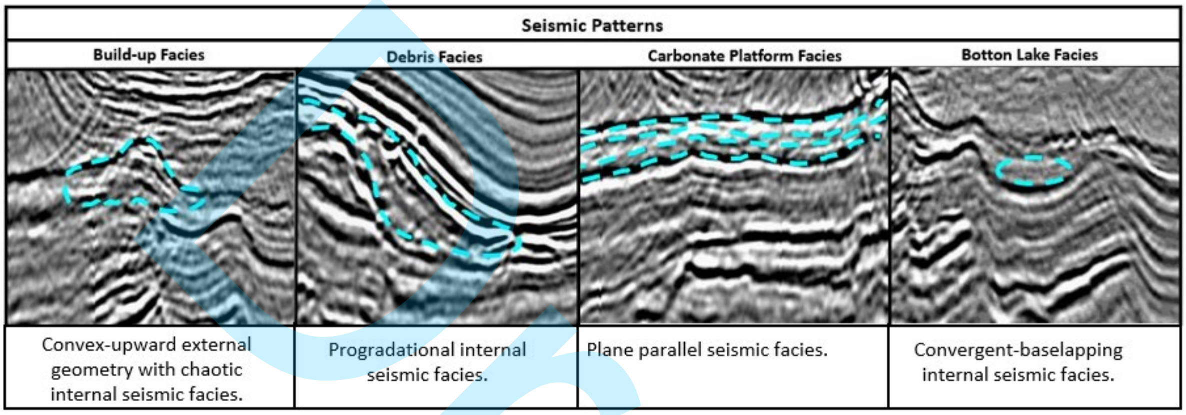

Figure 6: Seismic Facies patterns of the Barra Velha Formation identified in the seismic amplitude.

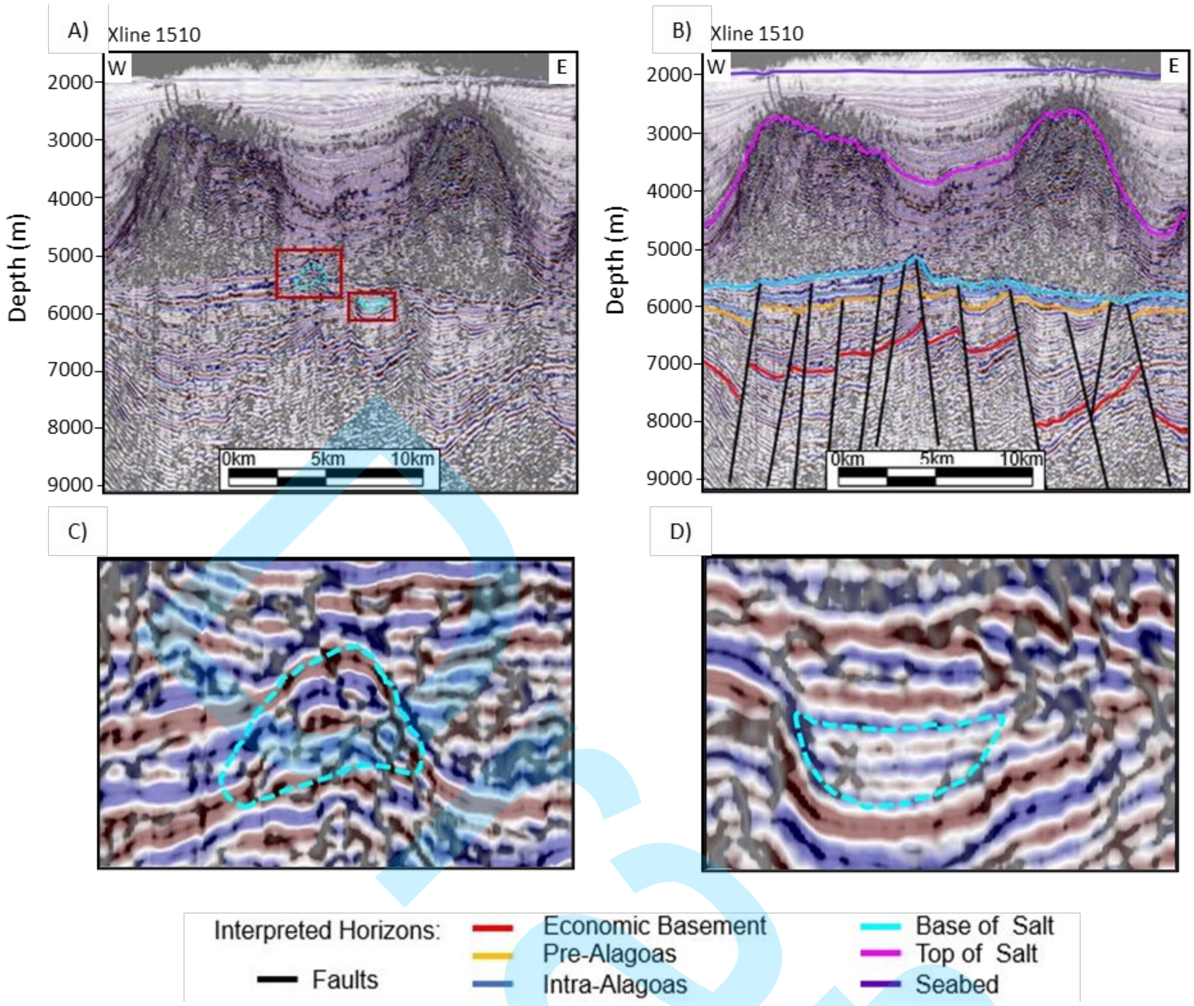

Figure 7: Co-rendering of coherence and amplitude attributes by highlighting features of the build-up facies and lake bottom: noninterpreted (A) and interpreted (B) sections; (C) Zoom in the build-up showing your fractured internal structure and conical morphology; (D) Zoom in the lake bottom facies showing their parallel plane reflectors.

The relief attribute assisted in the interpretation of the Economic Basement (top of the Camboriú Formation), which is strongly influenced by the faults and displays very discontinuous reflectors. The co-rendering of the amplitude and relief attributes highlighted the continuity of the reflectors and the chaotic zones. The Economic Basement was interpreted as a positive high reflector, being the upper limit of chaotic zones and following a structural model formed by horst and grabens with normal faults (Figures 8A, 8B and 8D). The relief attribute also helped identify the debris seismic facies, showing a progradding geometry with a chaotic internal texture, and the carbonate platform facies, characterized by well-defined plane-parallel reflectors. From the mapped horizons (Figure 9), we can observe a strong domain of the faults, that in general, influence more the eastern part of the Wildcat Prospect. In this region, there are more large-throw faults (Figure 8), evidenced by the Base of Salt map that shows large differences in the level curves at the edges of the build-ups (Figure 10). The interpretation of Intra Alagoas unconformity, show, at some areas, a seismic reflector termination ending up as erosional truncation at the Base of Salt, evincing erosions of the Upper Barra Velha Formation (Figures 5, 7, and 9). This occurs in some areas of the structural high of the basement and close to the large-throw faults. Some faults reach the horizon of the Base of Salt (top of the Barra Velha Formation), which is evidenced because of the cutting reflectors, especially where carbonate build-ups occur.

Wells B and C were drilled in build-up seismic facies on the south-central Wildcat Platform (Figure 11). In the well B, the build-up presents a mounted (convex upward) geometry with chaotic reflectors. In contrast, the build-up of the well C has an inclined geometry and progradational-shaped reflectors (Figure 11). On the other hand, the well A is located to the north in a tabular and aggradational carbonate platform seismic pattern. The evaluation of the well logs shows that the oil-water contact is at depths 5261m for the well B and 5284m for the well C, and that in well A the top of the Barra Velha Formation is below that depth, that is, there was no oil column. Table 1 shows the percentiles (P10, P50 and P90) of the clay volume, porosity and permeability of the wells in the Upper Barra Velha Formation. We can notice that wells B and C have higher porosity and permeability, proving that carbonate build-up seismic facies have excellent permoporous conditions in the study area. In this way, the chaotic reflector pattern in the middle of the build-ups appears to be an indicator of carbonates that present better permo-porous properties.

Table 1: Percentiles (P10, P50 and P90) of the clay volume, porosity and permeability of the wells in the Upper Barra Velha Formation.

Upper Barra Velha Formation									
	Well A			Well B			Well C		
	P10	P50	P90	P10	P50	P90	P10	P50	P90
Clay Volume	1.17%	7.16%	19.35%	0.41%	8.51%	17.09%	0.31%	5.59%	51.03%
Porosity	0.11%	1.76%	6.57%	7.54%	15.06%	20.76%	0.29%	8.83%	16.06%
Permeability (mD)	0.0001	0.0003	0.0138	2.243	49.617	213.849	0.002	5.901	66.972

4.3 Tectono-stratigraphic model of Wildcat presalt carbonate reservoirs

From the surface of the Economic Basement (Figure 9), we observed the presence of a structural high of NW-SE direction, here named Wildcat Platform. This high of the basement conditioned the deposition of the Piçarras, Itapema, and Barra Velha formations as shown in the Pre-Alagoas, Intra-Alagoas, and the Base of Salt unconformities (Figure 9). The biggest structural differences in the Base of Salt occur to the east of the Wildcat Platform where the large-throw faults and the depocenter are located. Hydrocarbon-generating shales may be in this depocenter and these faults may be important conduits for fluid migration to the carbonate build-ups. To the west of the platform, the increase in depth is smoother and has low-throw faults. The Intra-Alagoas surface has some areas eroded with the Base of Salt on edges of large-throw faults in the NW-SE trend (Figures 5 and 9).

The surface modeling (horizons and faults) respected the geochronology and the type of layer defined for each horizon following the stratigraphic column (sequence limits). At this stage, the model is compartmentalized into blocks. Figure 12 shows the tectonic-stratigraphic evolution of the 3D model, can be observed that the large-throw faults influence the rift phases (Camboriú, Piçarras, Itapema, and Lower Barra Velha formations). The Economic Basement compartmentalizes the high structural of the Wildcat Prospect, which conditioned the deposition of carbonate reservoirs of the Barra Velha Formation (Figures 9 and 13). The model shows that the Piçarras and Itapema formations (Light Blue) follows the structure of horsts and grabens, highlighting that most of the faults that reach the basement also reach these formations (Figure 12).

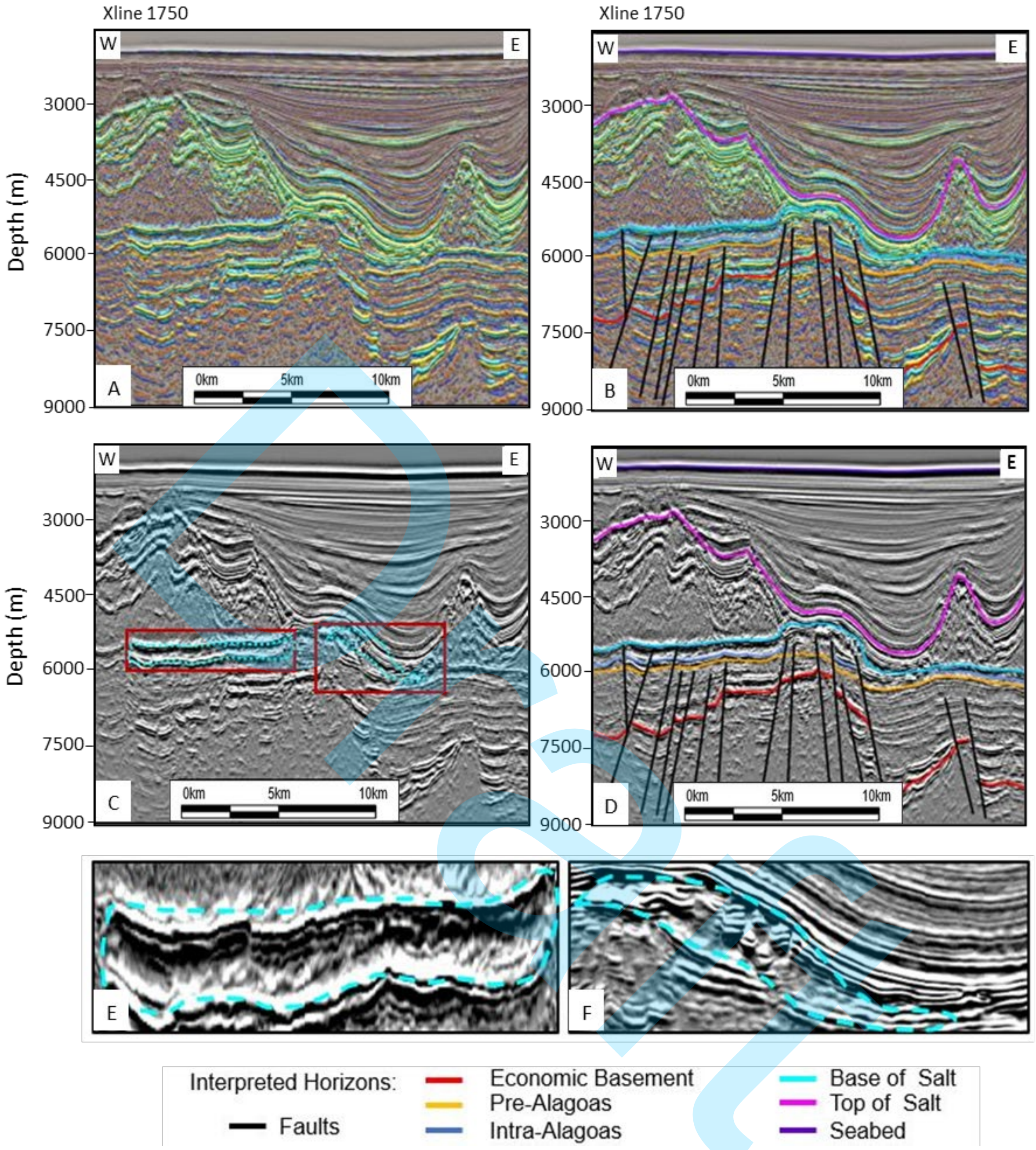

Figure 8: (A) and (B) co-rendering of the relief and amplitude attributes highlighting the discontinuities of the reflectors, mainly the Economic Basement, uninterpreted and interpreted sections, respectively; (C) Seismic section of the relief attribute delimiting in red the carbonate platform (E) and debris (F) facies; (D) Seismic session interpreted of the relief attribute; (E) Carbonate platform facies with plane-parallel reflectors highlighted by the relief attribute; (F) Debris facies with chaotic and fractured internal structure.

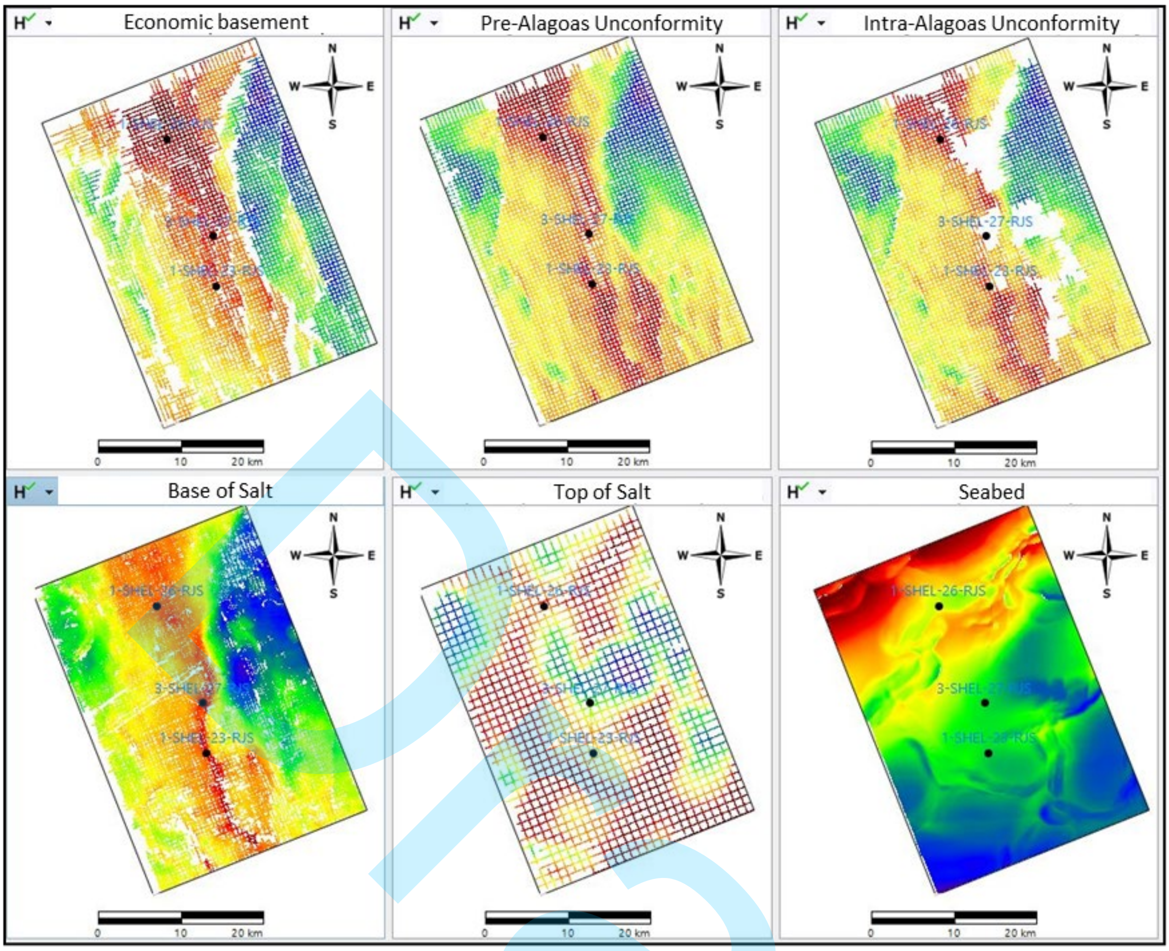

Figure 9: Horizons interpreted for the construction of the tectono-stratigraphic model. The Economic Basement unconformity shows the depositional control of the presalt section.

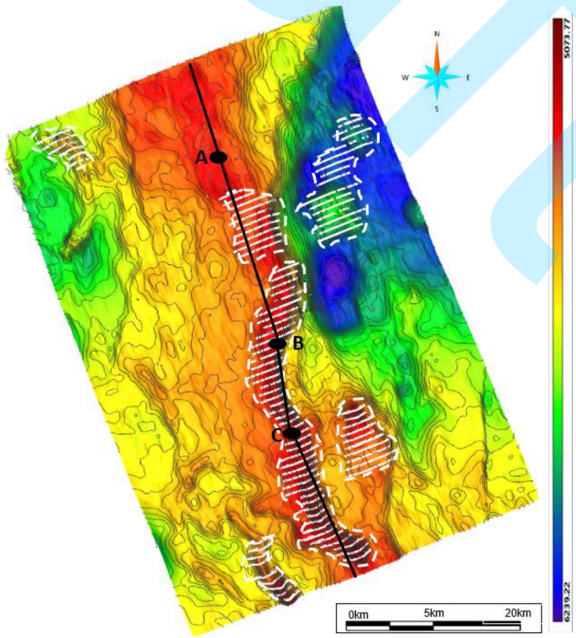

Figure 10: Base of Salt surface model showing the location of carbonate build-up seismic facies (white dashed lines) and the wells (black circles).

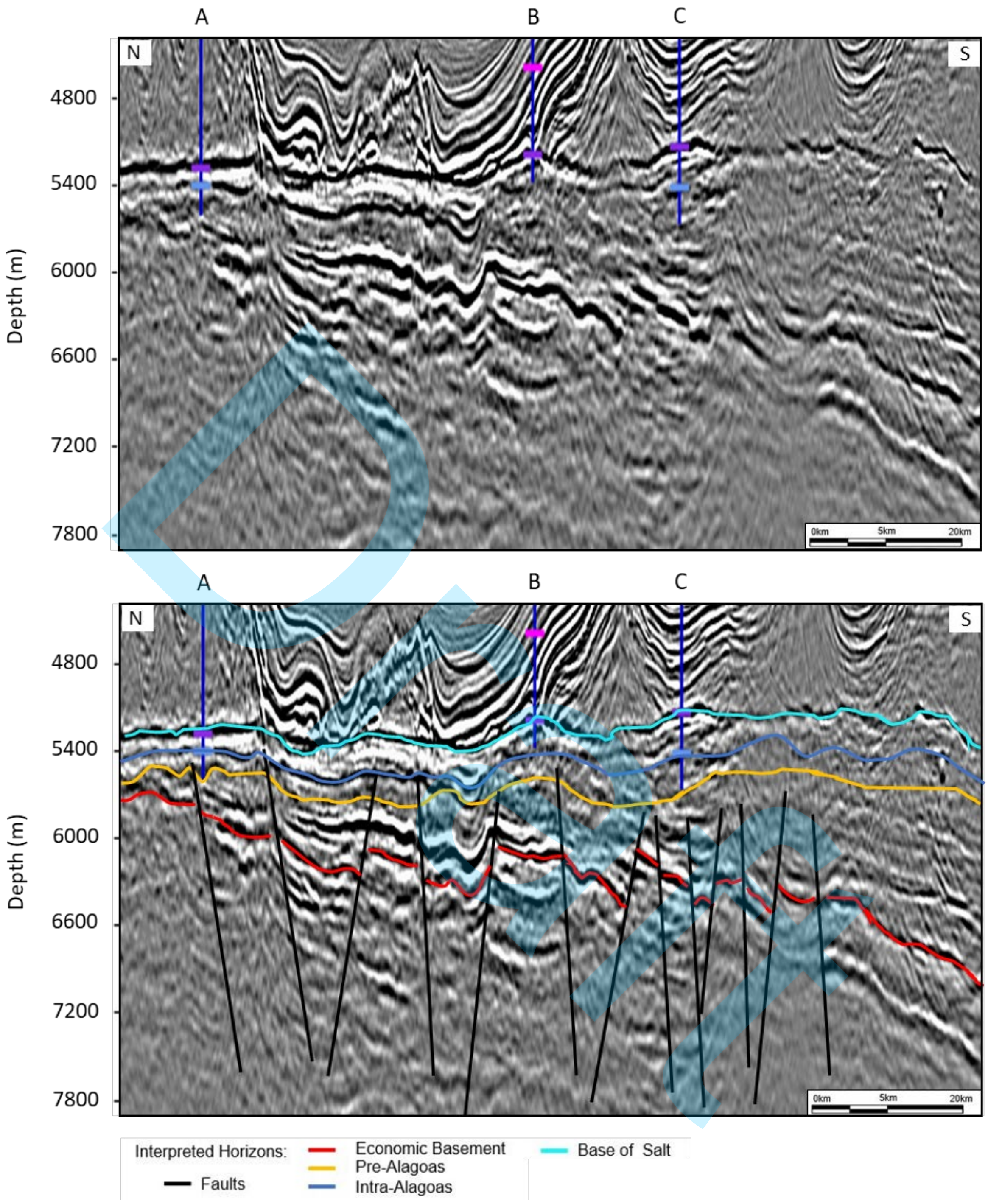

Figure 11: Arbitrary line passing through wells: noninterpreted (top) and interpreted (bottom) sections. Wells B and C were drilled in build-up seismic facies and well A was drilled in an aggradational carbonate platform seismic pattern.

Few faults in the Intra-Alagoas and Base of Salt unconformities (Sag Phase) are showing a moment of greater tectonic acquiescence. This is related to the time of its deposition since there was a tectonic activity of less intensity. The faults that reach the Intra-Alagoas unconformity may be from the rift phase which were reactivated. This same tectonic evolution has already been observed in other presalt areas by Buckley et al. (2015), Wright and Barnett (2015), and Neves et al. (2019).

Eroded areas of the Upper Barra Velha Formation coincide with the direction of the main faults (Figures 9, 11 and 12). Another important factor is that the carbonate build-ups found in the Wildcat Platform are associated with the main direction of the large-throw faults. The main direction of the build-ups identified has N-S orientation (Figure 10). This relationship between faults and carbonate build-ups in the Santos Basin may be associated with hydrothermal fluids that have already been discussed in the Wright (2012) and Buckley et al. (2015).

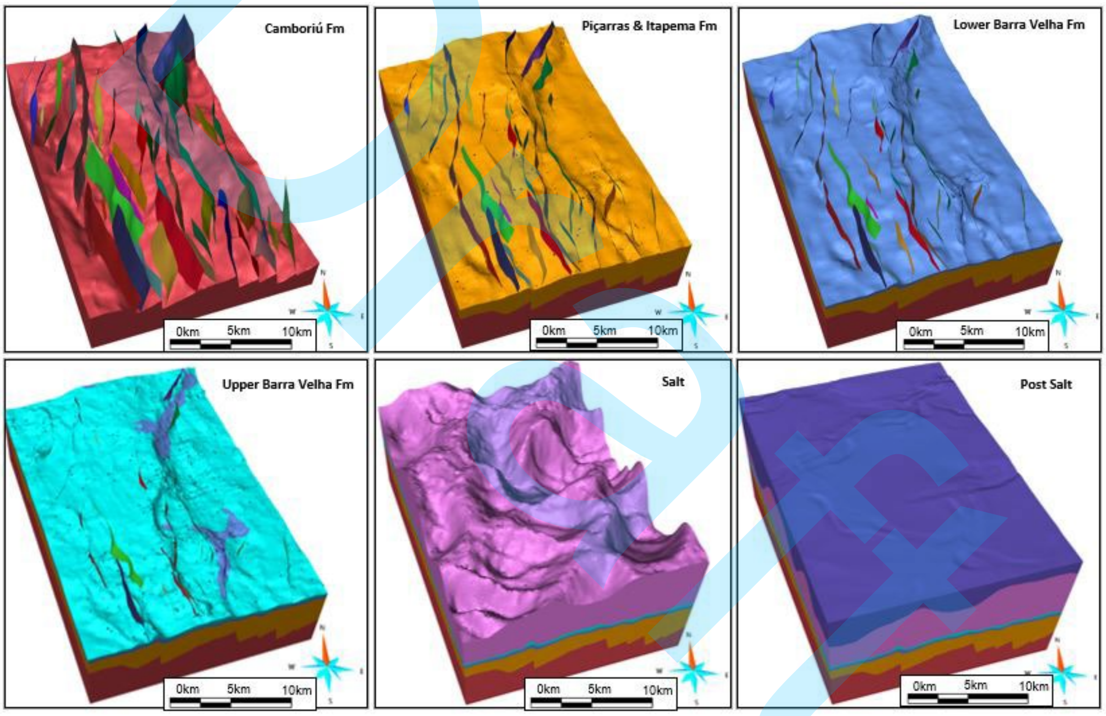

Figure 12: Faults influence in the Camboriú (red), Piçarras & Itapema (orange), Lower Barra Velha (blue) and Upper Barra Velha (light blue) formations. We note that the eroded zones in the Upper Barra Velha Fm. are influenced by the faults.

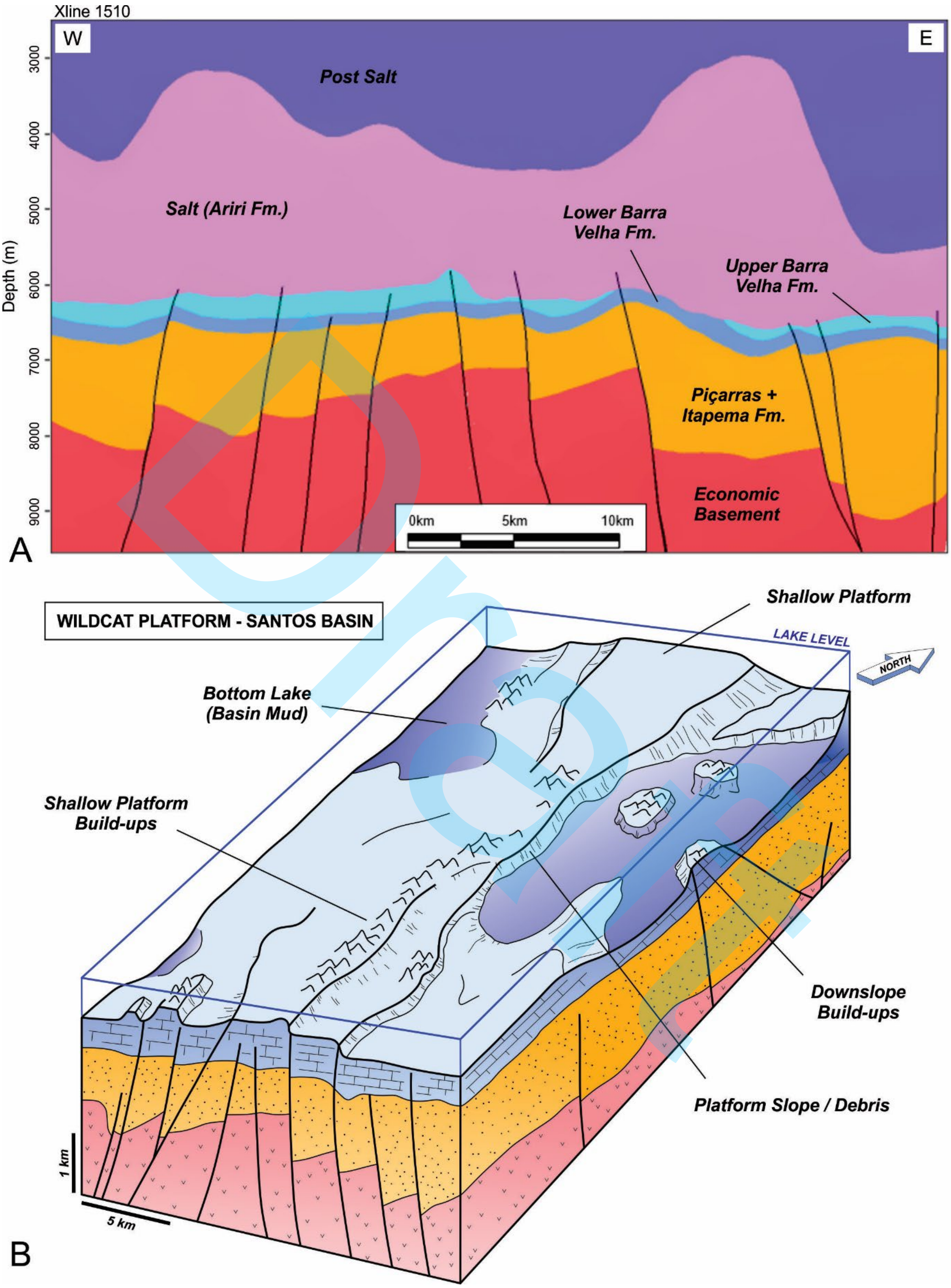

Figure 13: A) Interpreted section generated from the tectono-stratigraphic model. Observe the influence of faults, mainly in the rift phase, where there is bigger to the east of the section. It is possible to check the Upper Barra

Velha eroded by the Base of Salt (Sag Phase). B) Schematic model illustrating the morphological elements (based on the seismic facies patterns) of the Barra Velha Formation in the Wildcat Prospect.

5. Conclusion

The construction of the tectono-stratigraphic model allowed to understand the extent and geological structures of the Wildcat Prospect. The proposed methodology individualized stratigraphic units from the faults and the six interpreted horizons (unconformities). We show how the rift phases influenced the Camboriú, Piçarras, Itapema, and Lower Barra Velha formations, where many faults were mapped with N-S orientation. This study showed that few faults reach the Upper Barra Velha Formation (Sag phase) and highlighted erosive regions with the Base of Salt.

We identified and characterized the seismic patterns of the carbonate build-up, carbonate platform, debris and lake bottom facies, helping to understand the Wildcat Platform. The carbonate build-up facies are aligned in the N-S direction near the large-throw faults, and they represent the main reservoir in the study area. The evaluation of the well logs showed that the build-up seismic facies have high porosity and permeability. The applied methodology allowed a three-dimensional analysis of the Wildcat Prospect, opening new paths for the seismic facies, fracture, and porosity modeling of its reservoir.

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