UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL

INSTITUTO DE GEOCIÊNCIAS PROGRAMA DE PÓS-GRADUAÇÃO EM GEOCIÊNCIAS

ANÁLISE SÍSMICA INTEGRADA PARA CARACTERIZAÇÃO DE RESERVATÓRIOS - UM EXEMPLO NO MEMBRO MUCURI, APTIANO DA BACIA DO ESPÍRITO SANTO

ANDRÉ BASSO SCHILLING

ORIENTADOR – Prof. Dr. Juliano Kuchle

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RESUMO

O Pré-Sal brasileiro é atualmente uma das fronteiras exploratórias da nova década. Localizado nas bacias da margem leste brasileira e depositado no aptiano, demandará cada vez mais dados e modelos para essa próxima fase de exploração e produção. O foco desse estudo foi a margem clástica do Pré-sal, na Bacia do Espírito Santo, o Membro Mucuri. A principal metodologia utilizada nessa dissertação foi a interpretação sísmica, alinhada com a interpretação de fácies e a descrição de seções delgadas. Os dados utilizados foram seis volumes sísmicos 3D, três linhas sísmicas 2D e dezesseis testemunhos - dois dos quais incluem seções delgadas. Definimos 4 Sismofácies: (I) SF1 com alta continuidade e paralelismo; (II) SF2 com baixa continuidade e paralelismo; (III) SF3 a partir da geometria em mound e (IV) a SF4 baseado na geometria e no contexto estrutural. A partir da correlação entre o registro de testemunhos, definimos quatro associações de fácies mais representativas dos testemunhos descritos, são elas: (a) offshore; (b) shoreface inferior; (c) shoreface superior; e (d) canal fluvial pouco confinado. A correlação das associações de fácies com as sismofácies trouxeram os seguintes resultados: (1) A SF1 está associada a uma dominância de sedimentos finos nos testemunhos, por isso foi interpretado como predominância offshore e sucessões inferiores da superfície da costa; (2) a Sismofácies SF2 é predominantemente composta por sedimentos de areia derivados de canais fluviais pouco confinados; (3) a SF3 foi interpretado como um delta devido à sua geometria externa semelhante a um mound. Esta é composta pela intercalação de shoreface inferior e superior com as associações das fácies fluviais e (4) as sismofácies SF4 se originaram da interação entre as associações de fácies costeiras e as elevações do embasamento, mas sem dado de poço. A interpretação das unidades sísmicas mostrou que existe uma grande influência dos altos estruturais na disponibilidade de sedimentos, sendo fonte de sedimentos de areia para áreas distais, formando clinoformas no limite da resolução sísmica. Uma análise integrada de seções delgadas, poços com núcleo e dados sísmicos indica que o principal alvo para o acúmulo de petróleo na região é o SF3 e, secundariamente, o SF4.

ABSTRACT

The Brazilian Pre-Salt is currently one of the exploratory frontiers of the new decade. Located in the basins of the east bank of Brazil and deposited in Aptian, will demand more data and models for this next phase of exploration and production. The focus of this study was the pre-salt clastic margin in the Espírito Santo Basin, the Mucuri Member. The main methodology used in this dissertation was seismic interpretation, aligned with facies interpretation and the description of thin sections. The data used were six 3D seismic volumes, three 2D seismic lines and sixteen cores - two of which include thin sections. We defined 4 Seismic facies: (I) SF1 with high continuity and parallelism; (II) SF2 with low continuity and parallelism; (III) SF3 from mound geometry and (IV) SF4 based on geometry and structural context. From the correlation between the well cored descriptions, we defined four facies associations more representative of the core described, they are: (a) offshore; (b) lower shoreface; (c) upper shoreface; and (d) poorly confined fluvial channel. The correlation of facies associations with seismofacies brought the following results: (1) SF1 is associated with a dominance of fine sediments in the cores, so it was interpreted as offshore predominance and inferior successions of the coast surface; (2) Seismic facies SF2 is predominantly composed of sand sediments derived from poorly confined river channels; (3) SF3 was interpreted as a delta due to its mound-like external geometry. It is composed by the intercalation of the lower and upper shoreface with the river facies associations and (4) the SF4 seismic facies originated from the interaction between the coastal facies associations and the basement elevations, but without well data. The interpretation of the seismic units showed that there is a great influence of the high structures on the sediment availability, being source of sand sediments to distal areas, forming clinoforms at the limit of seismic resolution. An integrated analysis of thin sections, core wells and seismic data indicates that the main target for oil accumulation in the region is SF3 and, secondarily, SF4.

SUMÁRIO

1. INTRODUÇÃO

Ainda com muita problemática cientifica, apesar do todo o investimento em aquisição e interpretação de dados, o andar Aptiano da margem leste brasileira continua sendo uma incógnita em muitos aspetos. Desde a geoquímica à tectono-estratigrafia, modelos novos serão cada vez mais demandados para a nova fase de produção e exploração de óleo que o Brasil passará nessa nova década. Localizada entre a Bacia de Campos e a Bacia de Cumuruxatiba, a Bacia do Espírito Santo pode ser correlacionada através da paleogeografia e da estratigrafia com as bacias adjacentes (Vieira, 1998). Essa possui o andar Aptiano representado por sedimentos relacionados à fase Rifte e pós-rifte/SAG.

Da mesma forma que as principais bacias do pré-sal (Campos e Santos), a Bacia do Espírito Santo possui as geradoras que foram sedimentadas em lagos profundos, ocasionados por falhas de grande rejeito vertical (Asmus and Porto, 1972). Diferente dos casos supracitados, o foco dessa dissertação é no onshore da Bacia do Espírito Santo, em que o reservatório se concentra na fase SAG/pós-rifte, sendo representado apenas por membros siliciclásticos. O representante Aptiano da Bacia do Espírito Santo, o Membro Mucuri, tem como base o embasamento Pré-cambriano e a Formação Cricaré. O Segundo é o representante rifte da bacia, e seus sedimentos são concentrados nas calhas do rifte, possuindo um forte controle estrutural (França, 2007; Vieira, 1998). O topo do Membro Mucuri ocorre em contato com os evaporitos do membro Itaúnas, em que, os movimentos halocinéticos deformaram e romperam os estratos de sal remanescente. O período do foco do trabalho foi amplamente estudado por Viera (1998) França (2007), Kuchle et.al. (2019), Amarante et. al, (2019) Althaus et. al. (2019). Segundo esses autores, esse período na região era caracterizado por um clima seco, com área fonte próxima, com fluviais depositando em um corpo de água com geoquímica apontando para um lago fechado. Os rios eram efêmeros, fracamente canalizados e se depositavam no lago em um contexto de deltas dominados por ondas. A tectônica foi discutida por Amarante et. al, (2019), que mostrou que, além de ainda possuir falhas com rejeito expressivo, a base do Membro Mucuri aproveitou da paleotopografia para sua deposição. A tectônica remanescente do Rifte, muito ativa na base do Mucuri, foi diminuindo sua influência em direção ao topo (Amarante et. al, 2019; Vieira, 1998).

Levando em conta as necessidades da academia e da indústria, esse trabalho visa a contribuir com a compreensão das sismofácies, e sua relação com a geologia local e com os potenciais reservatórios de hidrocarbonetos da região. Visamos, também, compreender os fatores que controlaram a sedimentação na região e sua relação com o clima e com o tectonismo.

1.1 OBJETIVOS:

1.1.1 OBJETIVO GERAL:

- Elaborar um modelo de sismofácies que contemple os principais contextos deposicionais, relacionando-os com seu potencial como reservatório de hidrocarbonetos.

1.1.2 OBJETIVOS ESPECÍFICOS:

- Reconhecer os principais ambientes deposicionais e os fatores controladores de sua sedimentação.

- Separar as reflexões sísmicas em diferentes sismofácies, de forma que melhor contemplem o dado sísmico.

- Agrupar as descrições petrográficas em reservatório e não reservatório.

- Correlacionar os dados sísmicos, petrográficos e sedimentológicos a fim de fazer uma interpretação conjunta, apontando os possíveis reservatórios do local de estudo.

1.2 ESTADO DA ARTE:

A sismoestratigrafia foi iniciada no APPG memoir 26 em 1977, com Vail et.al. (1977 A, B, C, D). Partindo da premissa de Sloss (1963), em que os refletores representam não uma camada de rocha, mas sim linhas de tempo, Vail e Mitchum (1977A) elaboraram uma metodologia para a interpretação sismoestratigráfica baseada em 3 etapas. Primeiro na interpretação das sequências sísmicas, segundo na análise do nível relativo do mar e por último no estudo das sismofácies.

A análise das sequências sísmicas baseia-se principalmente nas terminações de topo em base (Figura 1), já que essas representam um hiato temporal. Na base há onlaps e downlaps. O primeiro representa terminações horizontais em um substrato inclinado, enquanto o segundo representa terminações inclinadas em um substrato horizontal. Dessa forma, os downlaps são interpretados como progradações, enquanto os onlaps representam um aumento no espaço de acomodação. No topo há os toplaps e o truncamento erosivo. Ambos sendo terminações inclinadas sob uma terminação horizontal, mas se diferenciam pelo refletor de topo. Os toplaps podem ser vistos como topo de clinoformas, ou estruturas complexas, enquanto os truncamentos ocorrem devido a erosões. Para delimitar as sequências sísmicas, usa-se dessas discordâncias e das suas concordâncias correlatas (Figura 2).

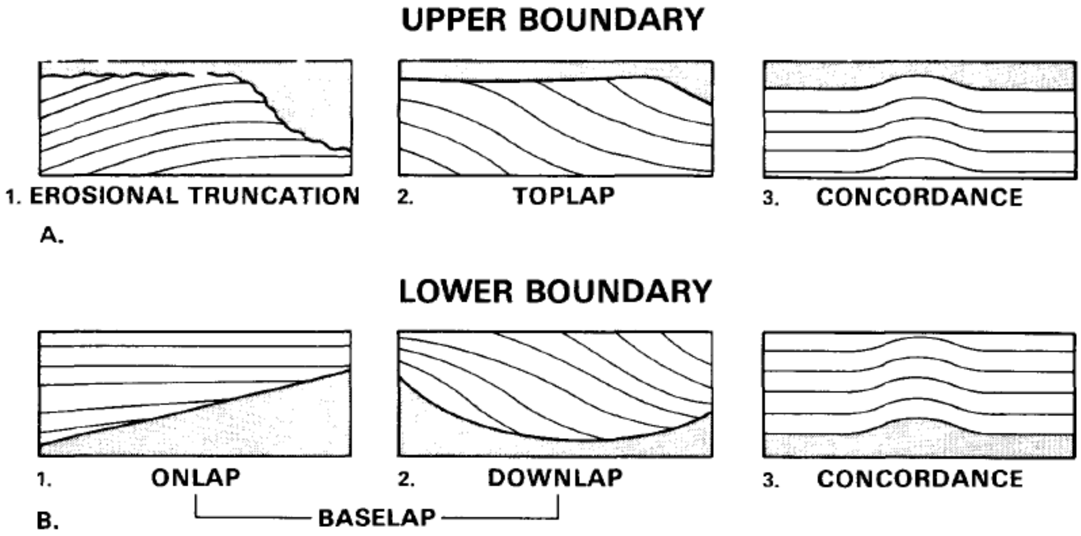


Figura 1. Terminações de topo e de base. Retirado de Vail and Mitchum (1977B).

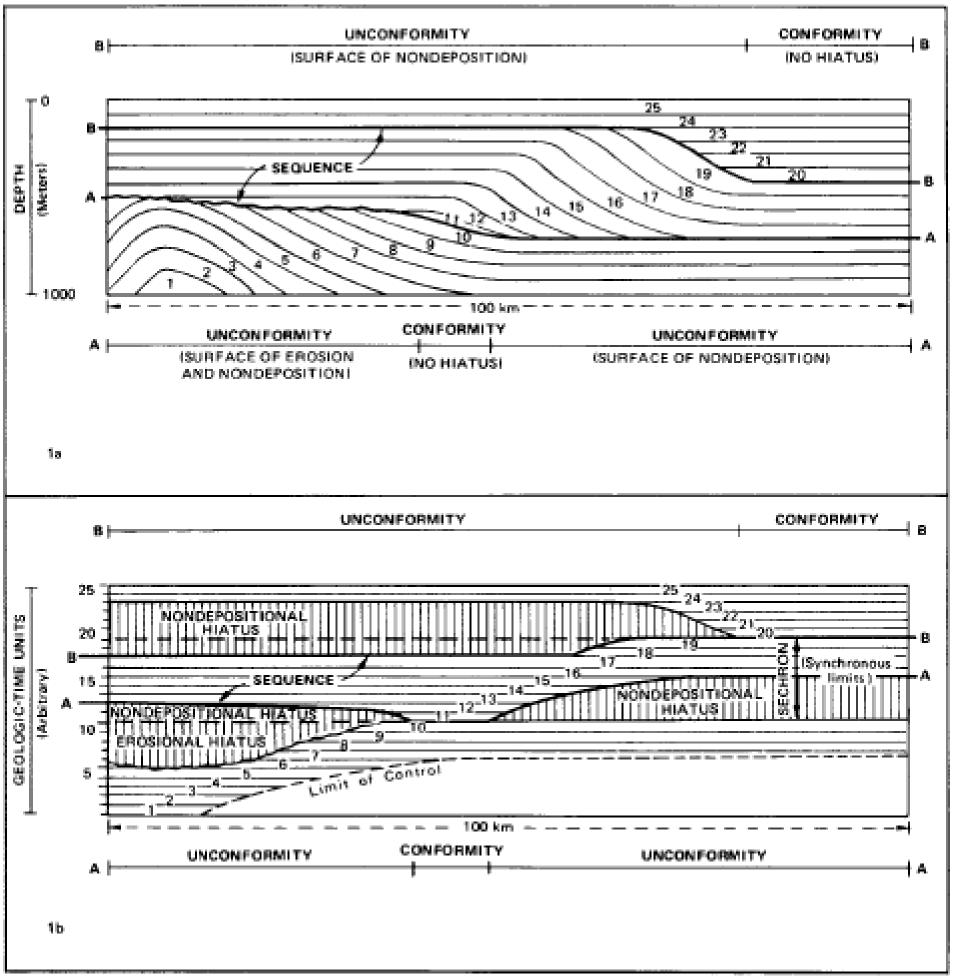


Figura 2. Exemplo de limites de sequencias. Exemplo em refletores e sua interpretação cronoestratigráfica. Retirado de Vail and Mitchum (1977B).

A investigação do nível relativo do mar (nrm) é feita baseada em Vail e Mitchum (1977C), Catuneanu et al. (2009) e Catuneanu (2019). Vail e Mitchum (1977C) já enxergavam as variações do nrm como cíclicas, com um período de subida, um período constante, e outro de queda. Estes já mostravam os conceitos de agradação, progradação e retrogradação, relacionados à sucessão vertical de fácies. Dentro desses conceitos, esse autor usava como forma mais confiável para a definição do nrm as terminações de base e de topo, que representam, por sua vez, discordâncias. Catuneanu et al. (2009) padronizando a estratigrafia de sequência, trouxe as sequências deposicionais, as sequências T-R e a sequência genética. Todas essas com o objetivo de melhor descrever e compreender a variação cíclica do nrm e sua influência na formação do registro sedimentar. Todos esses autores mostram a trajetória da linha de costa como uma ferramenta na definição da variação do nrm (Figura 3).

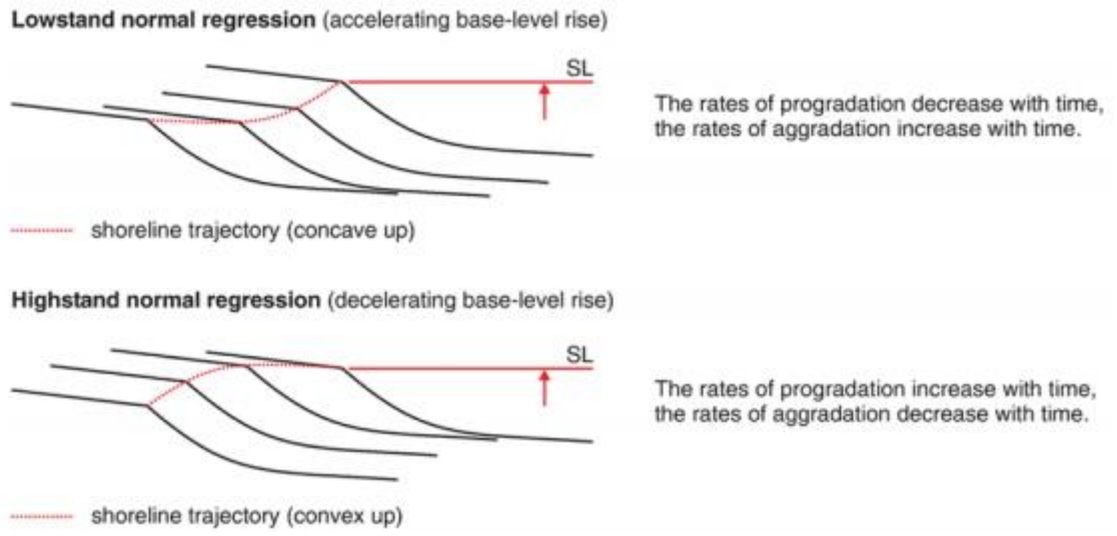


Figura 3. Interpretação do nível relativo do mar através da interpretação do dado sísmico. Retirado de Catuneanu et. al (2009).

A sequência deposicional III (Van Wagoner et. al, 1988; Christie-Blick,1992) divide um ciclo deposicional em quatro tratos de sistema. Três tratos de sistema progradacionais e um retrogradacional. O trato transgressivo TST, ocorre quando a taxa de criação de espaço de acomodação é superior ao aporte sedimentar. Entre os tratos progradacionas, o trato de sistema de nível alto, ou TSNA, inicia com uma alta taxa de agradação, aumentando a taxa de progradação até a taxa de agradação ser zero, e iniciar o trato de sistema de estágio de queda (TSEQ). O TSEQ ocorre quando há queda do espaço de acomodação e destruição do registro. O TSNB, o trato de sistema de nível baixo, ocorre, idealmente, após o TSEQ, com uma grande taxa de progradação, aumentando a agradação com o passar do tempo. O limite de sequência ocorre na base do trato de sistema de nível baixo. A sequência T-R (Johnson e Murohy, 1984; Embry e Johannessen, 1992) parte das mesmas premissas, mas divide em apenas um trato transgressivo e um trato regressivo, sendo que o limite de sequência é na base do trato transgressivo. A sequência genética (Galloway, 1989; Frazier, 1974) se assemelha à deposicional, com o limite de sequência na base do TST.

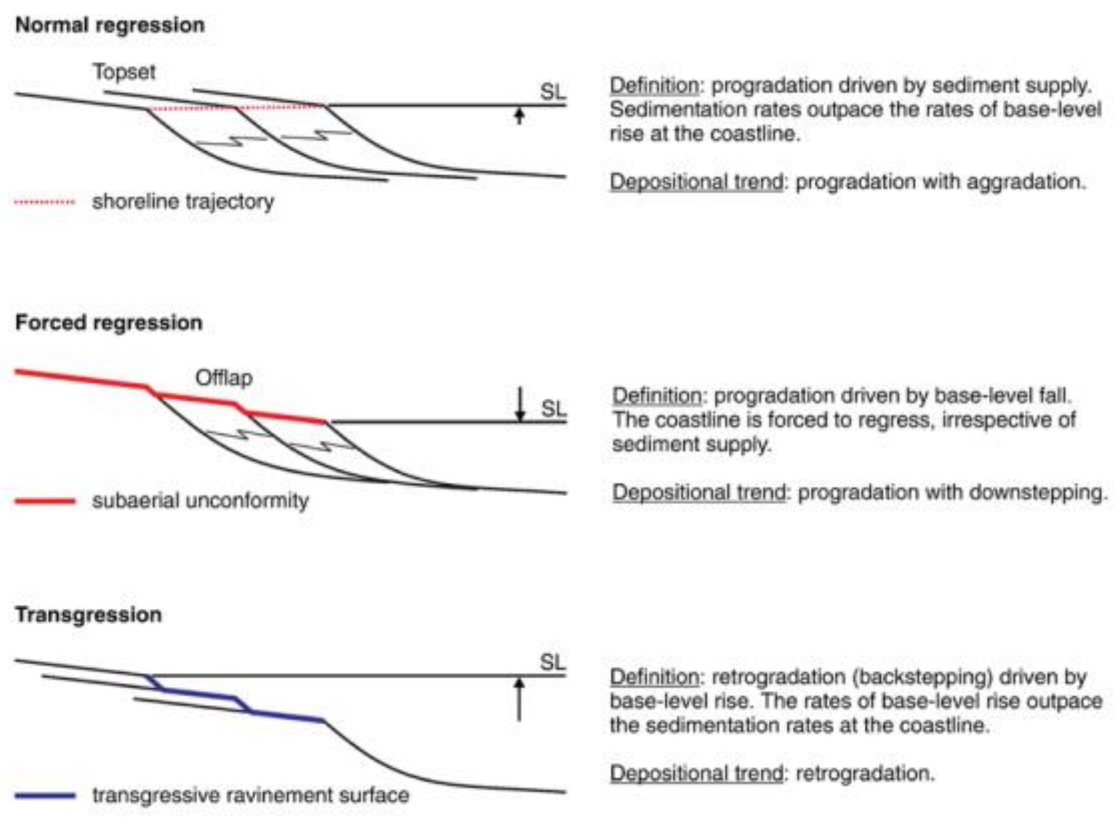


Figura 4. Tratos de sistema e trajetória da linha de costa. Retirado de Catuneanu (2009)

As sísmofácies são parâmetros de reflexões, mapeáveis tridimensionalmente, que podem se diferenciar das reflexões adjacentes (Vail e Mitchum, 1977D). Essas podem ser baseadas na continuidade, na amplitude, na frequência ou na geometria dos refletores. A continuidade da reflexão é relativa à continuidade e à constância da deposição (Sangre and Widmi, 1977; Liro and Pardus, 1990; Barnes, 2016; Strecker et.al 1999). A amplitude dos refletores é relacionada ao contraste de impedância das camadas e à distribuição vertical dessas (Sangre and Widmi, 1977), enquanto a frequência possui uma maior relação ao sinal sísmico. A geometria externa descrita por Vail and Mitchum (1977D) pode possuir uma diversidade de formas. Quando relacionada à linha de costa, é correlacionada ao nível do mar, e ajuda a descrever suas variações (Figura 5). Há, também, uma diversidade de formas desde canas fluviais (Zeng, 2004) até estruturas de escorregamento que podem ser identificados em time-slice da sísmica (Figura 6). Além disso, o uso de atributos geométricos, que destacam a convergência e a divergência de refletores pode auxiliar na detecção de superfícies chave para a intepretação estratigráfica, (Figura 7) (Van Hoek, et. al, 2010), ou mesmo na automação da detecção de sismofácies (Figura 8) (Van Hoek, et. al, 2010).

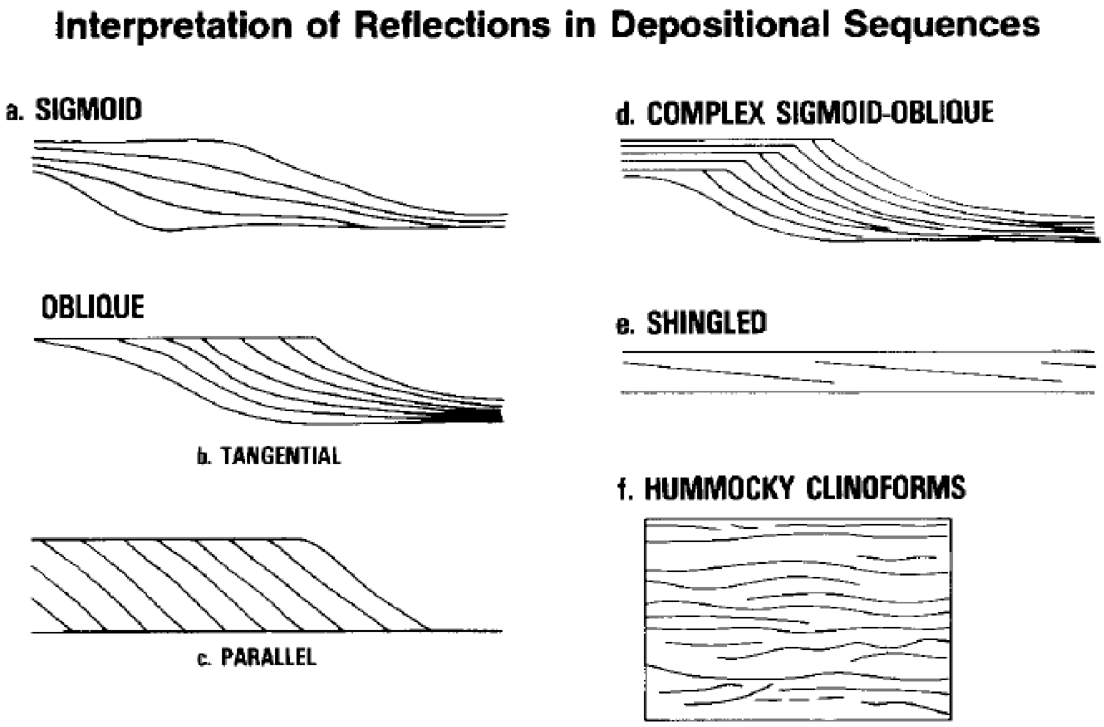


Figura 5. Geometrias de clinoformas. Retirado de Vail and Mitchum (1977D).

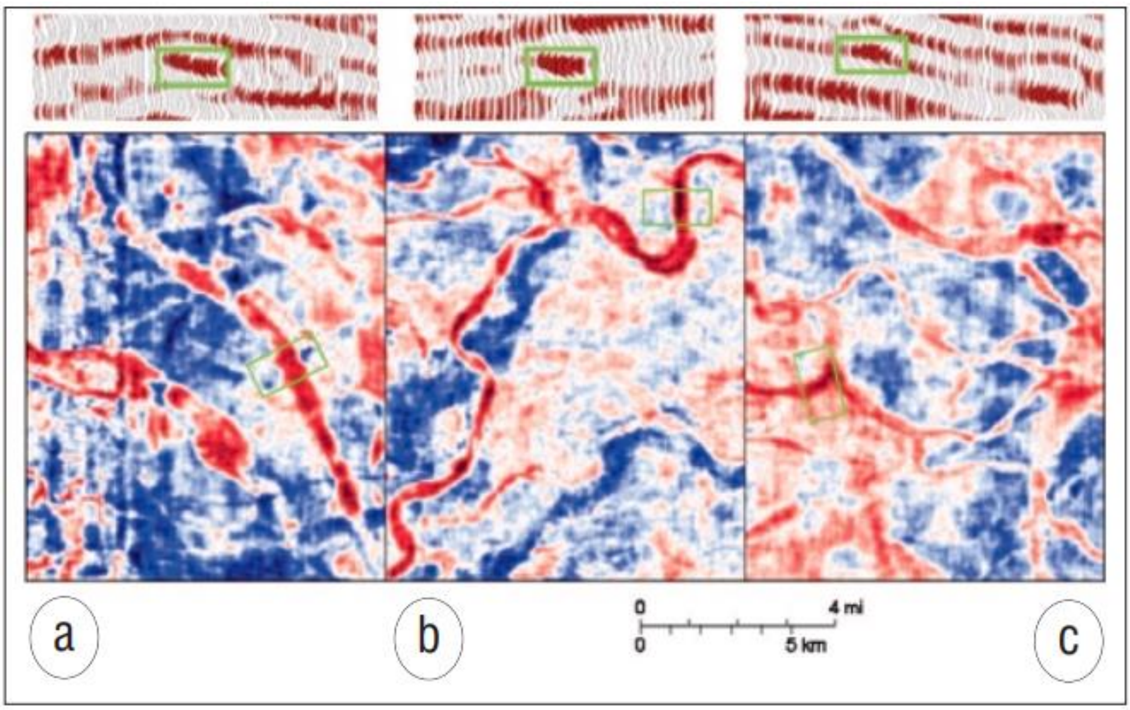


Figura 6. Canas fluviasis interpretados em time-slice da sísmica. Retirado de Zeng (2004).

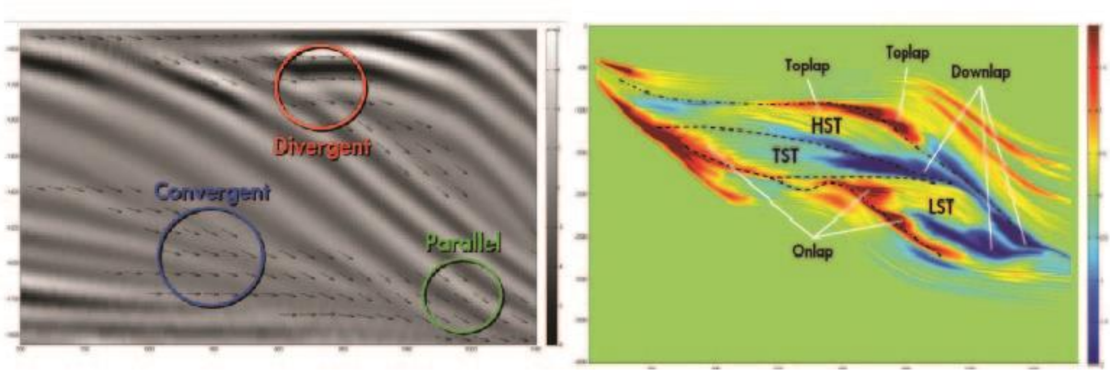


Figura 7. Uso de atributos sísmicos para a identificação de superfícies e trados de sistema chave dentro de clinoformas. Retirado de Van Hoek, et. al, 2010.

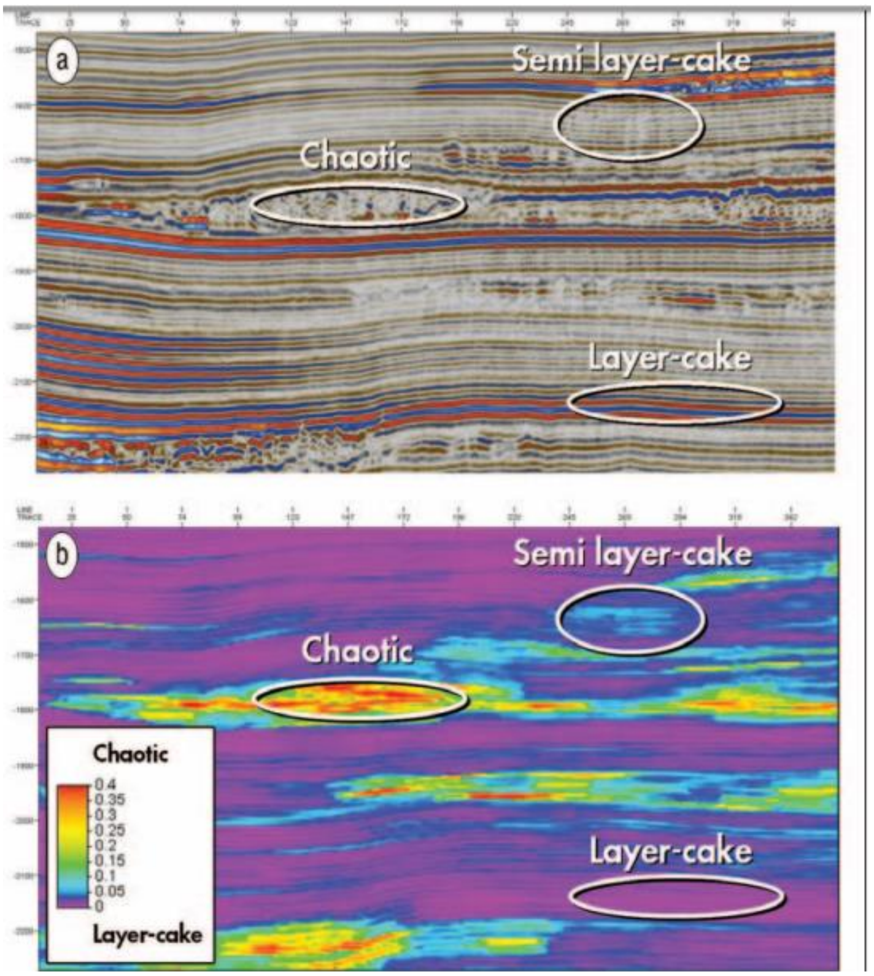


Figura 8. Interpretação de paralelismo e continuidade de camadas sistematizada através do atributo de fácies. Retirado de Retirado de Van Hoek, et. al, 2010.

1.3 SOBRE A ESTRUTURA DESTA DISSERTAÇÃO:

Esta dissertação de mestrado está estruturada em torno de artigo publicado submetido em periódico. Consequentemente, sua organização compreende as seguintes partes principais:

a) Introdução sobre o tema e descrição do objeto da pesquisa de mestrado, onde estão sumarizados os objetivos, o estado da arte sobre o tema de pesquisa.

b) Artigo submetido em periódicos com corpo editorial permanente e revisores independentes, escrito pelo autor durante o desenvolvimento de seu Mestrado.
c) Comprovante eletrônico de submissão do manuscrito ao periódico.

d) Referências bibliográficas citadas no capítulo 1 desta dissertação

2 ARTIGO

SEISMIC-BASED RESERVOIR CHARACTERIZATION OF PRE-SALT APTIAN CLASTIC DEPOSITS – MUCURI MEMBER OF ESPÍRITO SANTO BASIN, BRAZIL

André Basso Schilling, Juliano Kuchle, Francyne Bochi do Amarante, Elias Cembrani, David Iacopini, Renata Alvarenga Kuchle, Luiz Fernando De Ros

ABSTRACT

The controversial Aptian of eastern Brazilian margin holds one of the most important discoveries in the oil industry of the century. Therefore, this paper aims to understand the representative onshore of pre-salt on Espírito Santo Basin, clarifying the seismic facies in the commonly noisy seismic data in an effort to assign geological meaning to them. In this paper, the main methodology was seismic interpretation, align with facies interpretation and description of thin sections. The database to analyze the Mucuri Member comprises six 3D seismic volumes, three 2D seismic surveys and sixteen cores – two of which include thin sections. From the correlation between well log and seismic data, we defined four facies associations that represent more than 95% meters of the described cored wells: (a) offshore; (b) lower shoreface; (c) upper shoreface; and (d) poorly confined fluvial channel. The facies associations were correlated with four seismic facies SF1, SF2, SF3 and SF4. SF1 is associated with a dominance of fine sediments on the cores, so it was interpreted as predominant offshore and lower shoreface successions. Seismic facies SF2 is predominantly composed of sand sediments derived from poorly confined fluvial channels. SF3 was interpreted as a delta due to its mound-like external geometry, composed by the intercalation between lower and upper shoreface with the fluvial facies associations. Seismic facies SF4 originated from the interaction between coastal facies associations with basement highs, and is characterized by sandspits morphology. Seismic stratigraphy shows there is a great influence of basements highs on sediments availability, being source of sand sediments to distal areas forming clinoforms in the edge of seismic resolution. An integrated analysis of thin sections, cored wells and seismic data indicate that the main target for oil accumulation in the region are the SF3 and secondarily the SF4.

INTRODUCTION

The Aptian onshore of Espírito Santo Basin is a well-stablished oil producer interval with dozens of operational fields in almost 60 years of activity. Offshore along the south-eastern Brazilian margin, the Aptian interval represents one of the most important discoveries in the oil industry of the last two decades – the Pre-salt. This means that the marginal clastic deposits located onshore are synchronous to the distal carbonates of the Pre-salt. Even with significant operations active for decades both onshore and offshore, no detailed characterization of reservoir of the clastic Aptian was published. The comprehension of clastic sedimentation environments can contribute to the understanding of the main carbonate reservoir of Campos and Santos basins that based on Vieira (1998), have paleogeographical correlation with Espírito Santo Basin.

Aligned with increasingly more efficient methods of predicting porosity and lithology, alternatively to seismic inversion (Jackson 1972) and recent geophysics processing (Treitel and Lines 2001), the sequence stratigraphy (Posamentier and Venkatarathnan 2003; Catunean et al. 2009; Catunean 2019) is an important and timeless tool widely used by the oil industry. Initially determined by Vail and Mitchum in the AAPG memoir 26, seismic and then sequence stratigraphy went through numerous modifications and improvements aiming to correlate and understand the paleosystems more efficiently. In its early stages such method was applicable only in marginal basins; presently it is practiced in all diversity of basins and environments, from eolian to lake systems in rift basins. This turns this methodology available and useful to all sorts of petroleum system. Then, in this paper, the interpretation was based on the concepts developed by those authors

The most recent non-confidential seismic data onshore Espírito Santo Basin was acquired from the year of 1970 to 1992. Being a relatively old data, surveyed onshore onto and close to highly populated cities, the amount of noise within the Aptian succession is considerable. This makes the seismic interpretation and correlation with cored wells a difficult task, unless the right tools are used in a big volume of data. In this sense, this paper is an effort to clarify seismic facies for the proximal pre-salt in the onshore Espírito Santo seismic data, aiming to assign geological meaning to them through lithological correlation. The target unit is the marginal Mucuri Member, on the onshore zone of Espírito Santo Basin (Figure 1). Database comprises six 3D seismic volumes, three 2D seismic surveys and sixteen cored wells, selected from a large dataset managed by ANP (Brazilian National Agency for Petroleum, Natural Gas and Biofuels). Additionally, in order to understand the relation of seismic texture with the time and the tectonism, we mapped the seismic units and analyzed their relation with seismic facies.

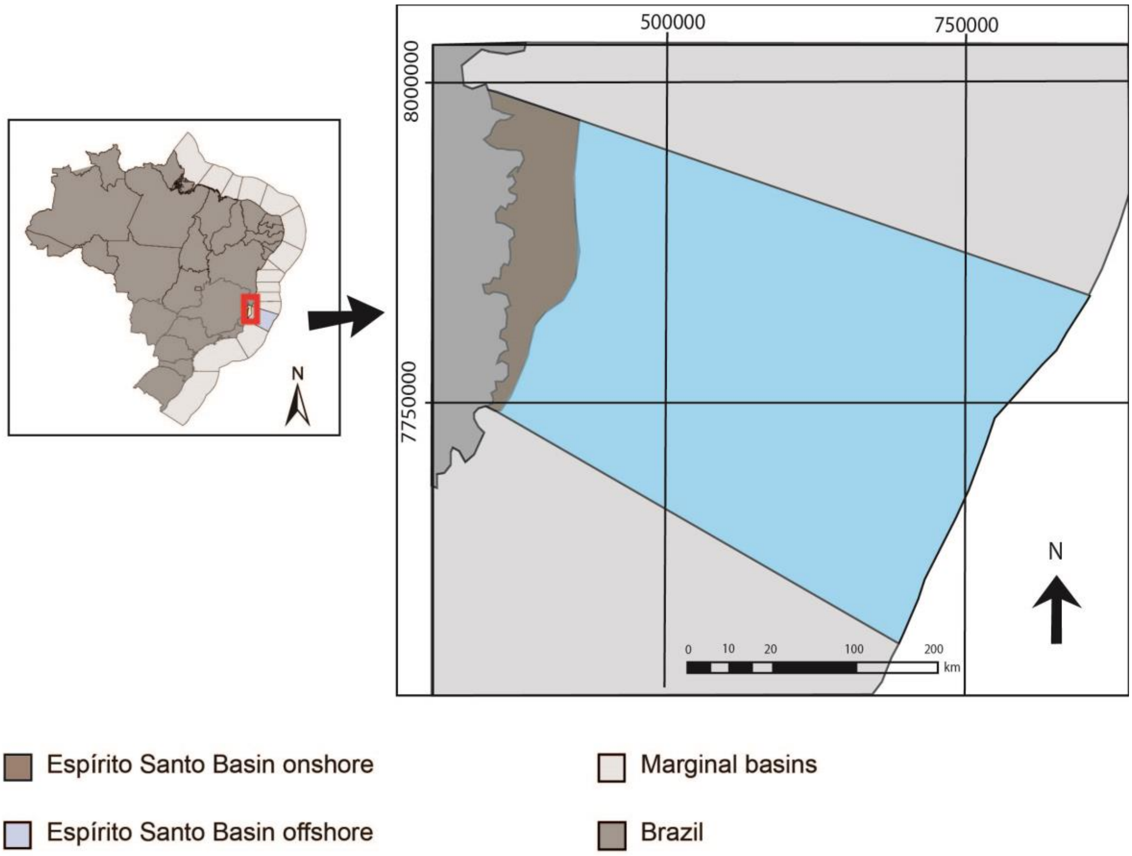


Figure 1. Location of marginal basins and Espírito Santo Basin. Espírito Santos Basin onshore evidenced by the red box.

GEOLOGICAL SETTING

The Espírito Santos Basin is a passive margin basin located between Mucuri and Campos Basin. As indicated on the stratigraphic general chart (Figure 2), The deposition begins under rifting context from Valaginian to

Aptian, when tectonic effort was reduced, giving place to thermal subsidence. Vieira (1998) defined the rift and transitional phase as Nativo Group and Mariricu Formation, respectively. Nativo Group is divided in Cricaré and Cabiúnas formations. The first is a predominantly lacustrine system with fluvial input, and alluvial sediments associated with ESE WNW large vertical reject faults (Vieira, 1998), forming conglomerates associated with tectonic pulses and with the shallow basement (Franca, 2007). These lacustrine sediments formed by deep lakes systems are explained by expressive vertical reject faults (Asmus and Porto, 1972). Cabiúnas Formation is a rift-associated volcanic sequence which occurs interspersed with clastic sediments.

The Sag phase of the basin is represented by Mariricu Formation, and it's divided in Mucuri and Itaúnas members. The deposition of Mucuri Mb. starts influenced by remnant tectonism of the rift with fluvial and lacustrine sediments intercalary with thin layers of salt (França, 2007). Itaúnas Member is formed by evaporites and carbonatic layers with tens of meters on the onshore and hundreds of meters on the offshore of the basin, due to the halokinetic movements (França and Mohriak, 2008). There are some divergences on naming this tectonic period of the basin on the literature. Vieira (1998) considers as transitional, Dias (2004) as fragmented passive margin and França (2007) as post-rift. Above the Mucuri Member the Urucutuca formation deposited fine sediments with turbidites associated. This last formation is deposited above the erosion from Paleogene in the paleocanyons of the basin.

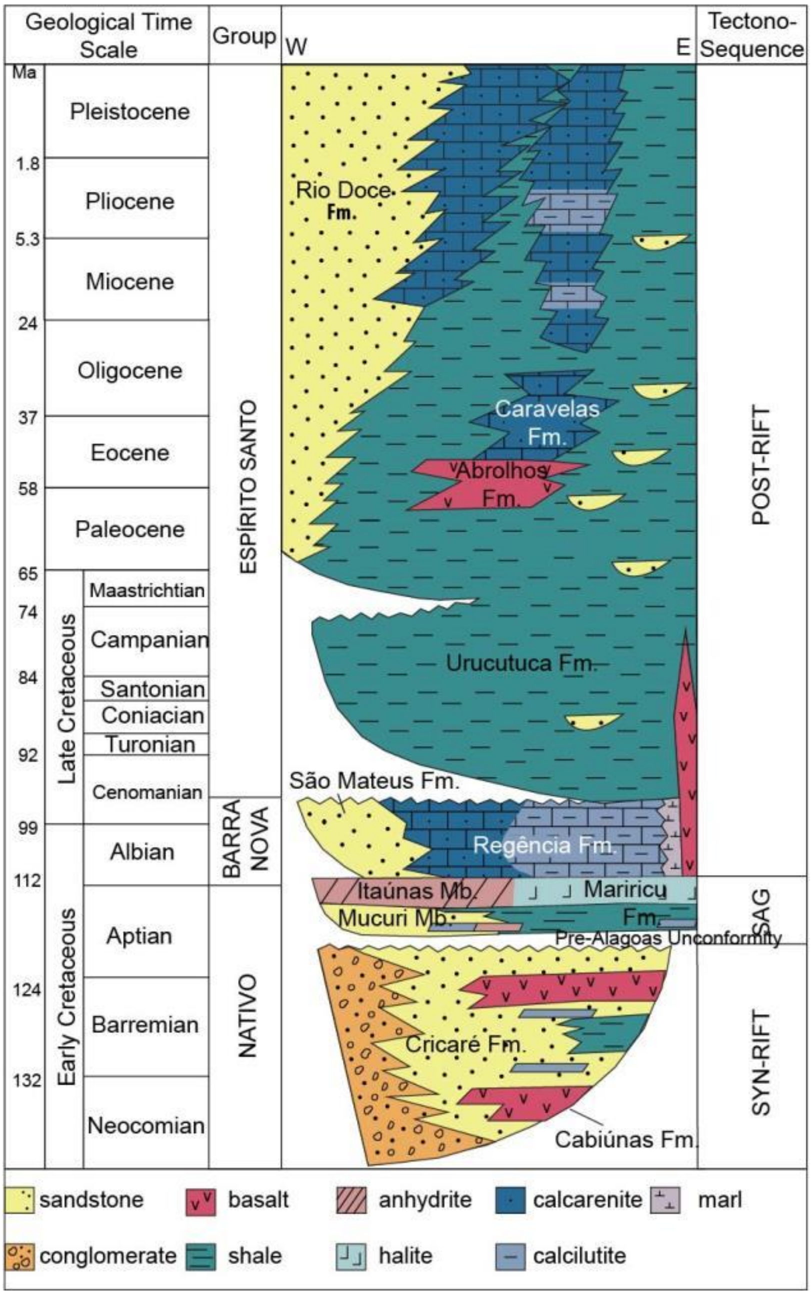


Figure 2. Chronostratigraphic chart of Espírito Santos Basin. Modified from Mohriak (2003), *apud* Amarante et.al (2019). The Mucuri Member deposition followed the Pré-Alagoas Unconformity (Aptian).

METHODOLOGY

In this paper, the data was obtained by Mucuri Project, an integrated study that includes seismic stratigraphic, sedimentological, geochemistry and petrologic data, in a partnership between UFRGS and Shell-Brazil, using the Special Participations Levy laws of ANP to R&D. The analyzed seismic data were the following 3d seismic volumes: Fazenda Alegre, Fazenda Cedro, BTES27, Fazenda São Jorge Sul, Rio Preto Sul, Fazenda Santa Luzia, Fazenda São Jorge Norte and the 2d seismic lines: ES-0215-0096, ES-0215-0086, ES-0032-0031. No time-depth conversion was performed, due to the lack of reliable parameters - velocity models. Also, the wells had no checkshot data available, and the connections of depth/time on wells were made from Delta Transit Time (DT) log curve. The 16 cored well logs were described in a scale of 1:50, interpreted accordantly on grain-size and sedimentary structures, based on Miall (1978). The facies associations were based on Althaus (2019). Thin sections descriptions from 2 wells were used to support the characterization of seismic structures of interest found on the analyzed seismic volume (Figure 3).

To distinguish the interval of study and the different seismic units, we performed horizon mapping in all seismic volumes, based on concepts of sequence stratigraphy defined by Vail and Mitchum (1977b) and following the methodology of Vail and Mitchum (1977a). The mapping of the seismic horizons was accomplished systematically for each 10 dip lines and 20 strike lines. This mapping leads an interpretation with enough density to perform an auto-tracking mapping to the non-mapped lines. Then, after mapping the top and bottom of all seismic units, maps of seismic thickness (two-way travel time based), helping us to understand the filling of each seismic unit.

A seismic cube flattened, on Mucuri Member base, was generated in order to assist in the seismic facies analysis, allowing us to analyze a time-slice view. A plain seismic cube is generated from a seismic horizon, based on the assumption that this horizon was deposited at the same time. This slice on the Z-axis allows the identification of fluvial channels, deltaic systems, or other kinds of depositional features.

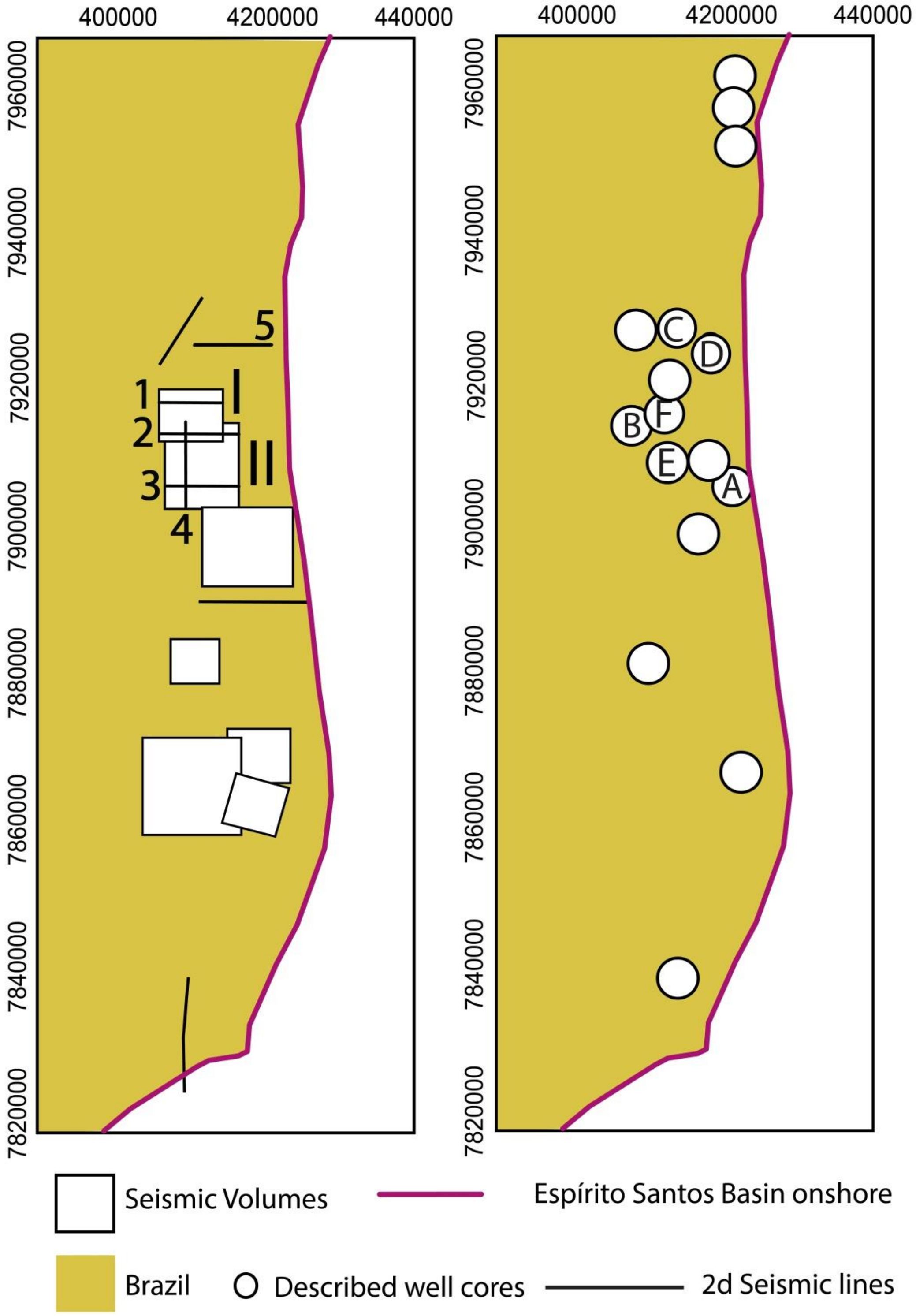


Figure 3. Location of 3D volumes, cored well logs and 2d lines. Wells, cores, 2D lines and 3d volumes cited in the paper named in the figure.

RESULTS

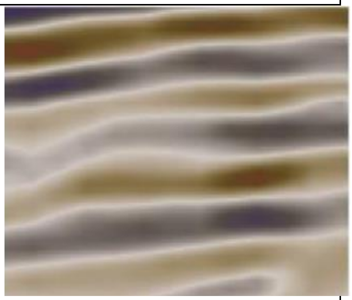
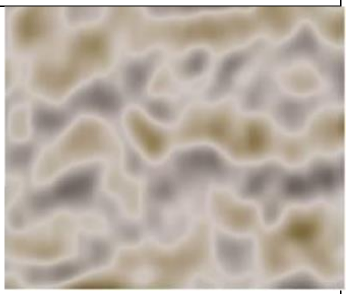
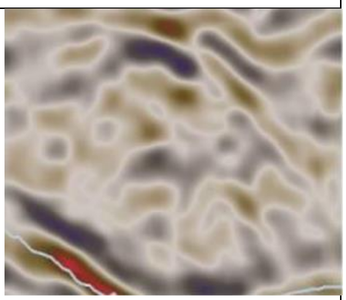
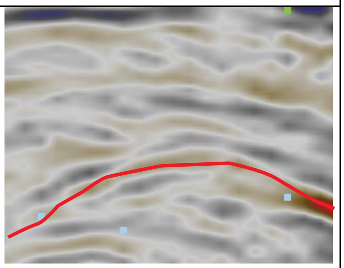
SEISMIC STRATIGRAPHY

Seismic interpretation was developed by Vail and Mitchum (1977A) linking surfaces on the seismic data to their meaning on time. According to Sloss (1963) a surface on seismic is not a layer of rocks, but rather an isochronous line, deposited either as a conformity or an unconformity. They aim to improve the geological prediction in passive margins basins, in a context that the change of base level is influenced only by tectonics, sedimentary contribution and especially sea level. The present study, however, was developed in a sag/post-rift basin, where the base level is equivalent to a lake margin (Vieira 1998). This translates in the record as a vertical variation that is beyond seismic resolution. Due to that, in this paper, seismic facies were interpreted not as a lithology or a depositional context, but as an arbitrary zone of predominance of offshore, fluvial or deltaic sediments.

Seismic facies are a set of reflectors composed of characteristics and parameters distinct from the surrounding reflections patterns, mappable in three dimensions (Vail and Mitchum, 1977d). The internal parameters that should be analyzed are configuration, continuity, amplitude, and frequency. Continuity is related with the continuity of deposition, amplitude with contrast on seismic impedance and density between layers (Sangre and Widmi, 1977). The frequency is more related to the source of the wave. Another parameter that contains information about the depositional setting is the external geometry of the layers. According to Mitchum and Vail (1977d), it can be deposited as parallel, sub-parallel, divergent reflectors or as progradational forms. Beyond that, the data used was acquired closely to 1970 with noise interference of roads and cities, showing some lateral amplitude variation that cannot be explained by geological features. Thus, in this paper, the signal amplitude was considered secondary to define seismic facies.

Four seismic facies were recognized within the study area (Table 1), based on reflection frequency, continuity, and interval velocity, and their resulting external geometry. Amplitude was taken into account secondarily, due to its visible association with survey-related noise. Seismic Facies SF1 is characterized by continuous reflection, high parallelism and high signal amplitude; SF2 presents discontinuous reflection and low amplitude; SF3 is progradational, composing mounds-like structures and SF4 by low continuity low amplitude reflection but in a geological context above basement highs with clinoforms in the edge of seismic interpretation. The attributes analyses showed us that the Seismic facies SF1 can be distinguished from other with the attribute Local gradient structural dip. So, the amount of mud is proportional to the continuity of the reflectors (Figure 4).

Table 1. Description, interpretation and example of seismic facies.

Seismic Facies	Description	Interpretation	Example
SF1	Continuous to semi-continuous reflectors. Parallel reflection, with constant thickness. High to moderate amplitude.	Predominance of offshore sediments.	
SF2	Chaotic reflection, with broken reflector without parallelism. moderate to low amplitude.	Predominance of fluvial sediments.	
SF3	Mound-like structure, with complex internal structure in downlap.	Predominance of costal sediments, with influence of fluvial system.	
SF4	Clinoforms in the edge of seismic resolution, with structural control.	Sandspits influenced by basement high.	

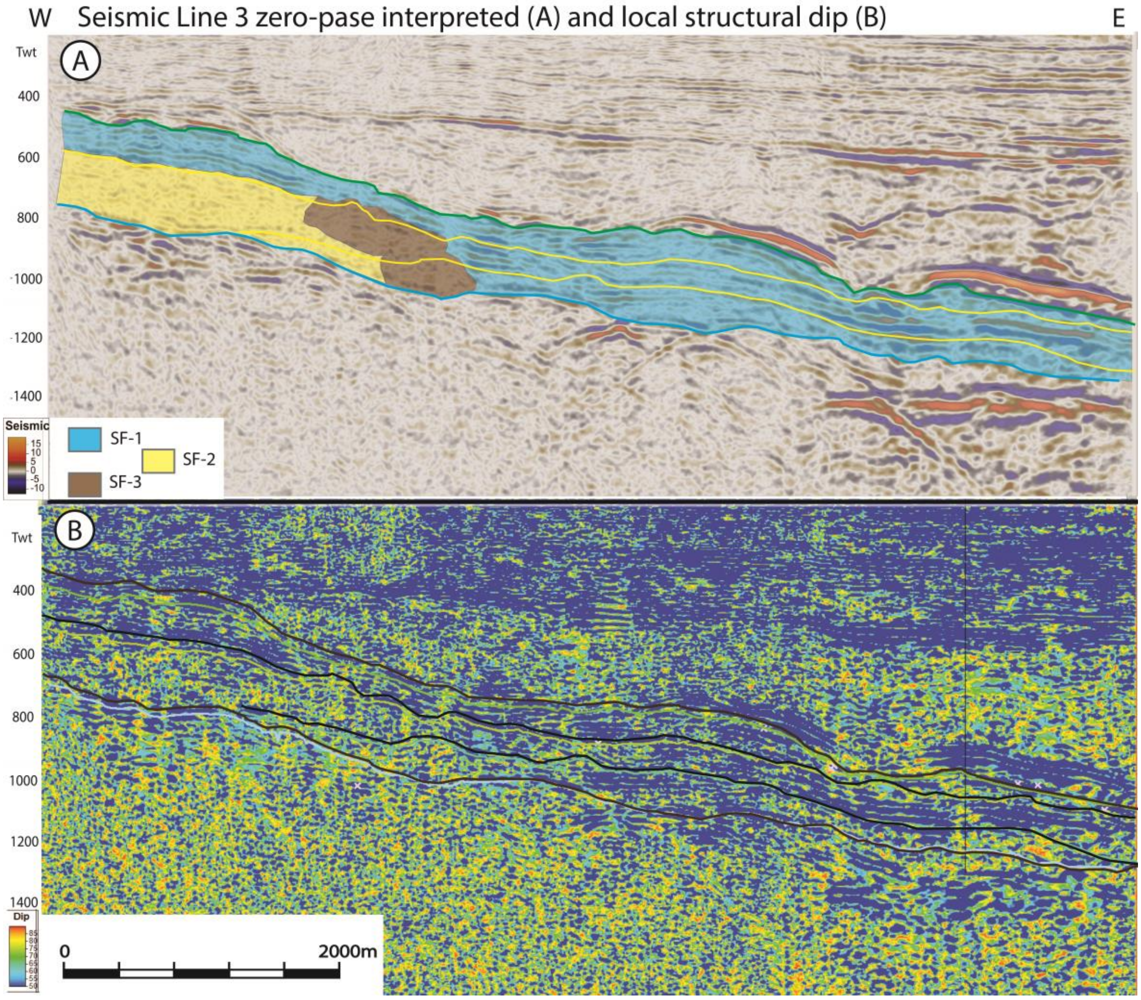


Figure 4. Seismic facies correspondence to Attribute Local Structural dip. Pictures showing the correspondence of SF1 (picture A, blue) to the low dip (picture B, blue). Due to the high parallelism and continuity of this seismic facies.

In order to check the stratigraphy control of the seismic facies, three Seismic Units were mapped in the Seismic Volume Fazenda Alegre: the seismic unit US1 is the basal older and the top and younger is the US3. The US1 is restricted to the east and central portion of the seismic volume, the US2 is onlapping, with the record in the whole seismic volume and the US3 have a broad deposition, but eroded in the top by halokinetic movements and by Paleogene erosion. No chronostratigraphic details were made due to the lack of biozones within the Aptian period of Espírito Santo Basin.

WELL CORES AND SEDIMENTARY SYSTEMS

There were six facies associations recognized in the Mucuri Member, accordantly to Althaus et al. (2019). As this paper aims to correlate the well with seismic data, we selected the four main facies associations that represent more than 95% in thickness of the described well-logs cores (Figure 5 A,B,C,D). It was identified an offshore facies, composed specially by mud and anhydrite, interpreted as a calm environment deposition bellow the wave action (Figure 5 D). A fluvial facies with sand sediments, in coarsening upward cycles, with thickness up to 4 meters, with dominance of tractive structures that suggest fluvial channels (Figure 5 A). The absence of meter-based size cross stratification, aligned with the low angle and parallel stratification, indicate poorly confined sheet flows (Blair, 2000). The variation of structures of upper and lower flow regime shows a major oscillation in flow during sheet inundation. Also, an upper and lower shoreface was recognized. The first, with a range of 0.5 to 20 meters, shows amalgamated layers of sand with structures changing from oscillatory to tractive flow (Figure 5 B). The lower shoreface is dominated by the centimetrical to decimetrical vertical change of sand and fines sediments, with a combination of wave and tractive small ripples, and punctuated with centimetric to decimetric layers of anhydrite (Figure 5 C). The medium to thick grain size, with poor selection, and the continuous transition from fluvial association to upper and after lower shoreface indicate a wave dominated deltaic system. Althaus et al. (2019) defined those deltaic systems as input zones of the fluvial intensely reworked by wave action. In Mucuri Member, the high cyclicity of the base level is notable. In the cores described it is possible to observe offshore sediments being interspersed metrically with fluvial or costal sediments.

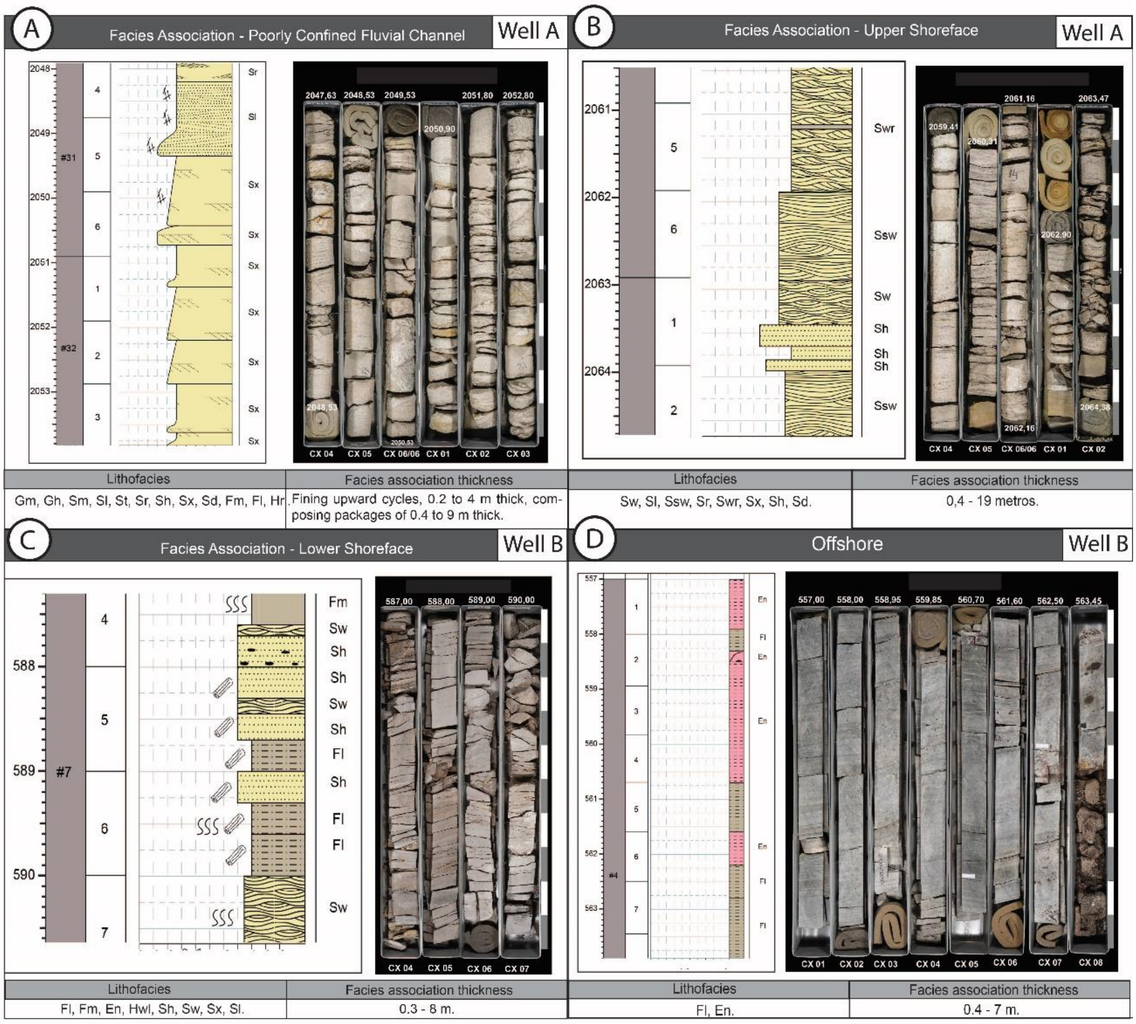


Figure 5. Predominant facies associations of the Mucuri Member with examples of occurrence and appearance in described cored wells, modified from Althaus et al. (2019). A- Poorly Confined Fluvial Channel, with predominance of sand. B- Upper Shoreface, amalgamated sands with oscillatory flow structures. C- Lower Shoreface, sand and mud showing oscillatory flow structures. D- Offshore, with mud and anhydrite.

PETROGRAPHY AND RESERVOIR QUALITY

The petrographic analysis of the Mucuri Member shows that the fluvial deposits are essentially characterized by medium to very coarse sandstones and conglomeratic sandstones, with moderate sorting, arkoses and show parallel, irregular or cross stratification (Figure 6 A, B). These sediments do not show muddy matrix and are typically grain-supported. The clastic coastal deposits, which are predominant over the non-clastic, are essentially characterized by very fine to fine sandstones, sometimes containing muddy matrix, and usually show parallel, unidirectional or bidirectional cross stratification, evidenced by the high concentration of mica grains. These deposits comprehend mostly tightly-packed micaceous sandstones, commonly cemented by smectite, the most common diagenetic constituent, and mud deposits now replaced by calcite or anhydrite. Coarser-grained sands of fluvial deposits show pore-filling and grain replacive kaolinite and are commonly cemented by calcite, which is the most abundant diagenetic constituent and sometimes obliterate the intergranular porosity of the samples.

To better understand the interval heterogeneity, the thin sections were grouped into three basic classes: (i) good reservoirs (GR), which comprehends sandstones and conglomerates with values of petrographic porosity above 8 percent; (ii) poor reservoir (PR), which comprehends sandstones and conglomerates with values of petrographic porosity below 6 percent; (iii) non-reservoir (NR) corresponding to the samples that would act as barriers to fluid flow, such as mudstones (Figure 6 C), evaporates (Figure 6 D), and heterolites with high contents of mud . The statistics for each class can be found on Table 2. Most of the sampled intervals analyzed in this work do not present high porosities values since the most porous intervals of the section consist of extremely friable material. Even so, some intervals show significant porosity (8-17%) which usually corresponds to fluvial sand bodies and superior shoreface facies.

Table 2 - Petrographic porosity values found on wells 1 and 2, located within the mound structures discriminated for each defined class.

	Mean	Median	Minimun	Maximum	Standard deviation
NR*	2,46	2,67	0,00	5,67	1,81
PR	4,11	4,00	0,00	7,99	2,03
GR	11,07	10,33	8,32	17,00	2,78
*Porosities values above 6 percent were not considered to statistics calculation due to influence of artifact and rock fracture porosites.					

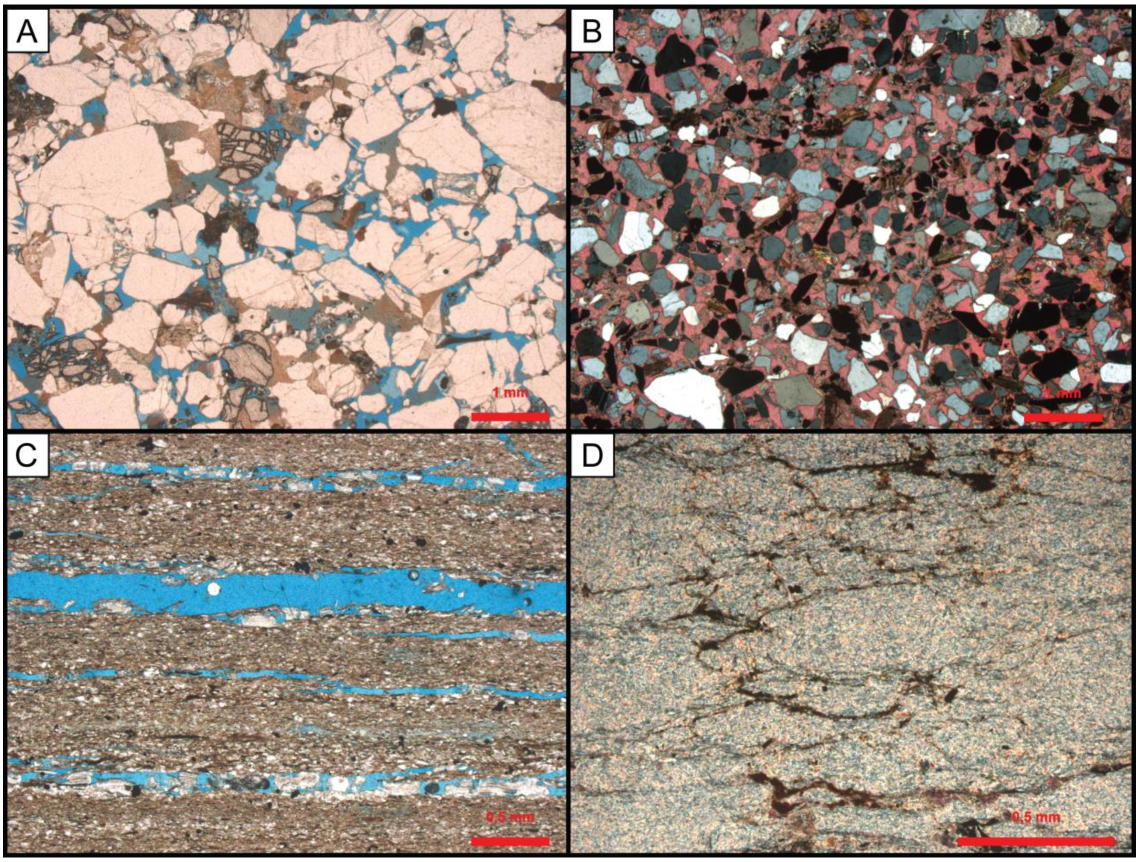


Figure 6 - Representative photomicrographs for each of the three defined classes: A) Coarse-grained, poorly-sorted conglomeratic sandstone, arkose partially cemented by kaolinite, from the good-reservoir class (Well C, 1116.2m); B) Medium-grained, slightly conglomeratic sandstone cimented by calcite as example of the poor reservoir class (Well C, 1024.2m); C) fractured mudstone, with partially dissolved gypsum filling the porosity (Well C, 1142.5m) and D) evaporite, as result of replacing of mud by nodules of anhydrite, both examples from the non-reservoir class (Well D, 1036,8m).

DISCUSSION

WELL-SEISMIC TIE TO THE STRATIGRAPHIC INTERVAL

In order to calibrate a well with a seismic data it is necessary to match two different measurements: two-way travel time and meters-depth. The best method used is checkshot survey. Unfortunately, such data was absent from the acquired well logs. So, in this area, the top and the bottom of Mucuri Member and the tie of the seismic data with the wells were based only on seismic data and petrophysical parameters.

Amplitude signal results from the seismic impedance difference between two layers. Seismic, or acoustic, impedance is a product of the material's density and seismic wave velocity. With those concepts in mind, the calibration was based specially on two points: (i) the upper boundary was set by high impedance contrast at the transition from Mucuri to Itaúnas Members, or the large trough immediately below the large peak of Itaúnas member (showing the transition from evaporitic to siliciclastic rocks); (ii) the bottom of Mucuri Member was defined by the contrast of seismic velocity of clastic sediments with the basement, displayed by the pronounced peak in the bottom of Mucuri Member. In between those two points, the seismic wave velocity is near constant, with some exceptions. So, it is possible predict the well position with reasonable degree of certainty. This can be observed on the figure 7: when comparing the upper and lower contacts at the wavelet of dip line 3 and the delta transit (DT) log curve of the well E, it is clear that the peaks and troughs of the first match the greatest variations of the second, as is expected for a zero-phase seismic. Also, the wavelet from the relative acoustic impedance attribute clearly matches the sonic DT log variations.

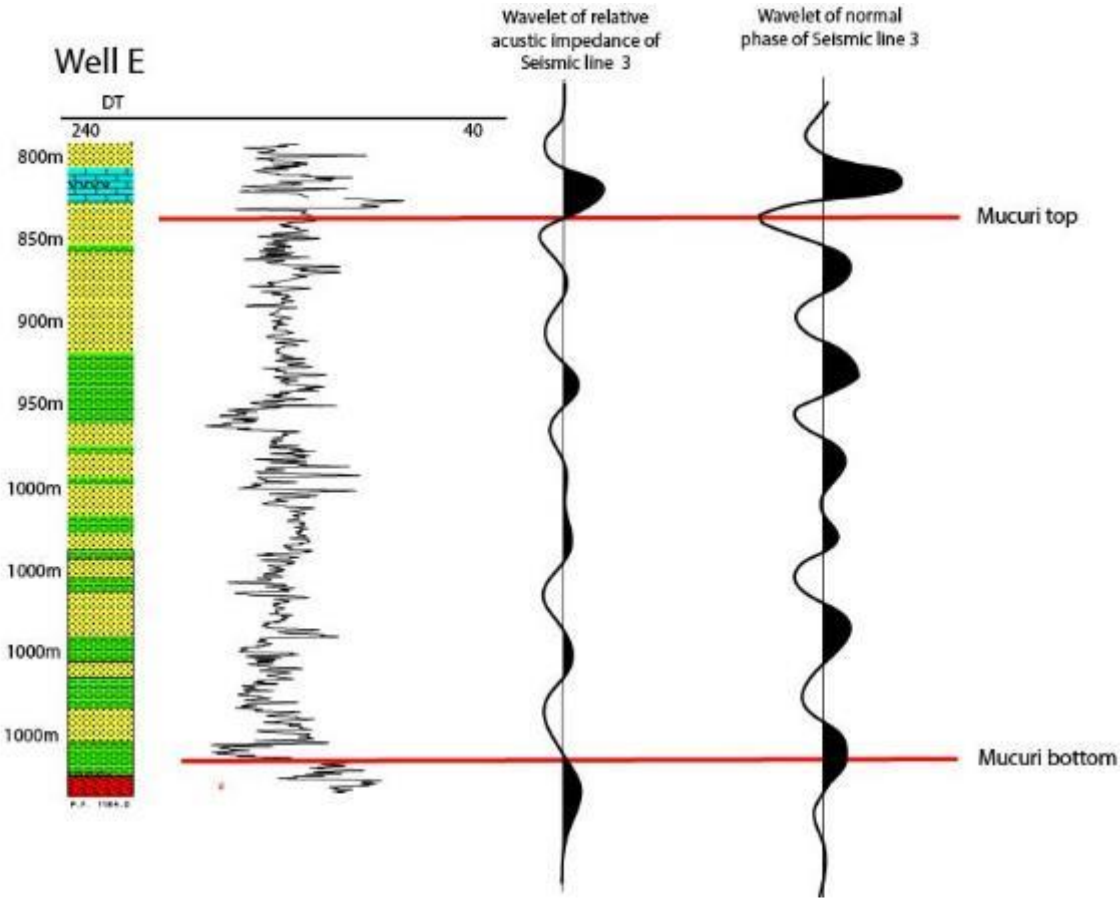


Figure 7. Example well-seismic tie. Well and wavelets from the seismic line 3 peaks and troughs matching with the variations of sonic velocity.

Also, there is no straightforward correlation between the units-bounding horizons mapped on the seismic data and the wells. Thus, definition of the mapped intervals relies only on the seismic interpretation. Figure 8 shows the criteria of separation between Itaúnas Mb., Mucuri Mb. and basement. To differentiate Mucuri Mb. from Cricaré Fm. in 2D seismic lines, Amarante et al. (2019) used a frequency blend attribute and showed an increase of frequency in Cricaré comparing with Mucuri Mb.

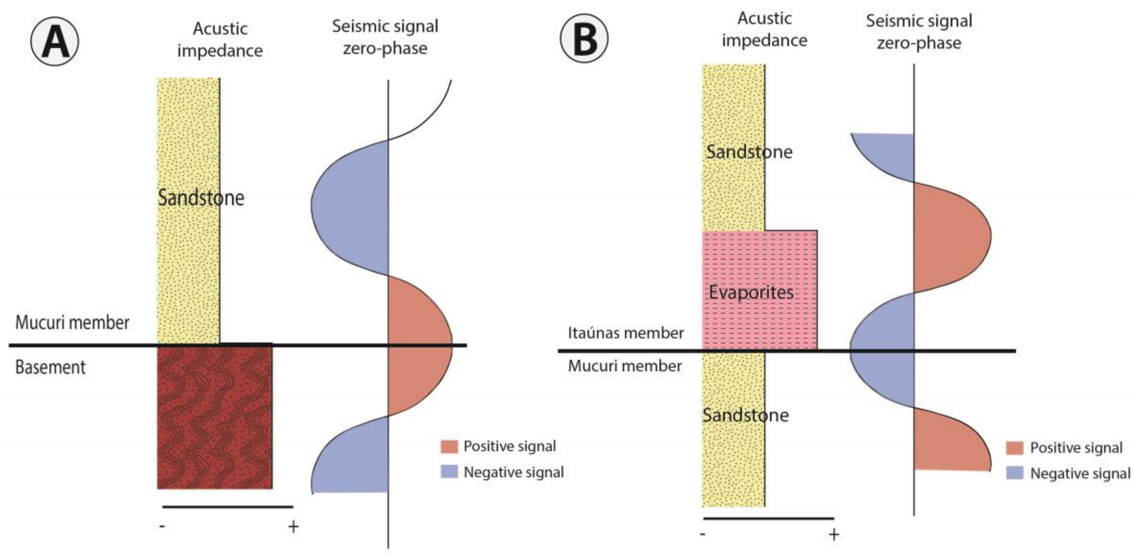


Figure 8. A- Parameters for definition of Mucuri base B- Parameters for definition of Mucuri base.

INTEGRATED CHARACTERIZATION OF SF1

Seismic facies SF1 (Figure 9 A, B and C) is associated with a dominance of fine sediments on the cores, so it was interpreted as predominant on offshore and lower shoreface sediments. SF1 reflectors shows the largest continuity, showing a laterally continuous deposition with good parallelism, which denotes low energy environment and fine grained deposits (Barnes, 2016; Strecker et.al 1999). As observed on the cores, there is a predominance of sand in the Mucuri Member, even on portions with onshore predominance there is presence of sand bodies. Therefore, mud interbedded with sand generates a higher impedance contrast than pure sand. So, is expected a higher signal amplitude in offshore sediments (Sangre and Widmi 1977). Also, we observe in some cores, the relation of the signal amplitude of this seismic facies with the deposition of evaporites interspersed with the mud, resulting in higher amplitude on this seismic facies when free of noise.

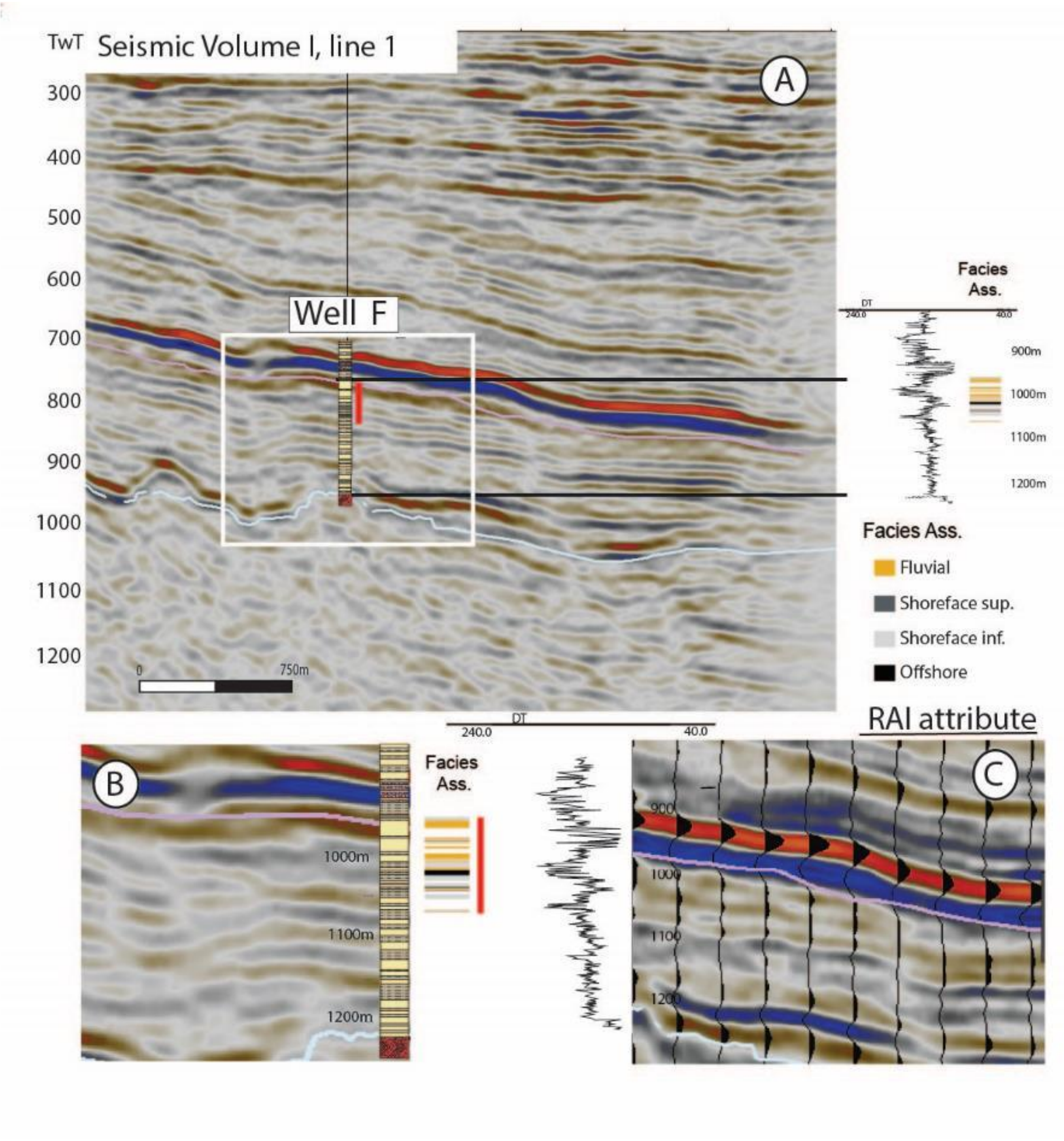


Figure 9. Seismic facies SF1, integrating the Seismic data in normal phase and Relative Acoustic Impedance with in cored well-log with Facies association. A- description of well F tie in seismic volume I, line 1. B- zoom with facies association. C- sonic log of well F tied based on RAI attribute.

INTEGRATED CHARACTERIZATION OF SF2

Seismic facies SF2 is predominantly composed of sand sediments (Figure 10 A, B and C). The cores that intercepts this seismic facies shows fluvial sediments interspersed metrically with offshore sediments with no architectural elements. SF2 composing reflectors present the smallest continuity, showing a laterally discontinuity, as complex sediment bodies amalgamation, as expected for a fluvial system (Sangre and Widmi, 1977; Liro and Pardus, 1990). As mentioned before on facies associations, the fluvial system is weakly channelized, characterized by highly-fluctuant flow associated to seasonal humidity variations under arid climate context (Vieira, 1998). Another important fact is that Mucuri fluvial system in the time-slice of the plain seismic volume did not show fluvial channels, which corroborated to the interpretation of an ephemeral fluvial system, poorly confined (Althaus et al. 2019; Kuchle et al., 2019), That will lead to a complex and laterally disconnected deposition of sediments in different parts of the lake shore.

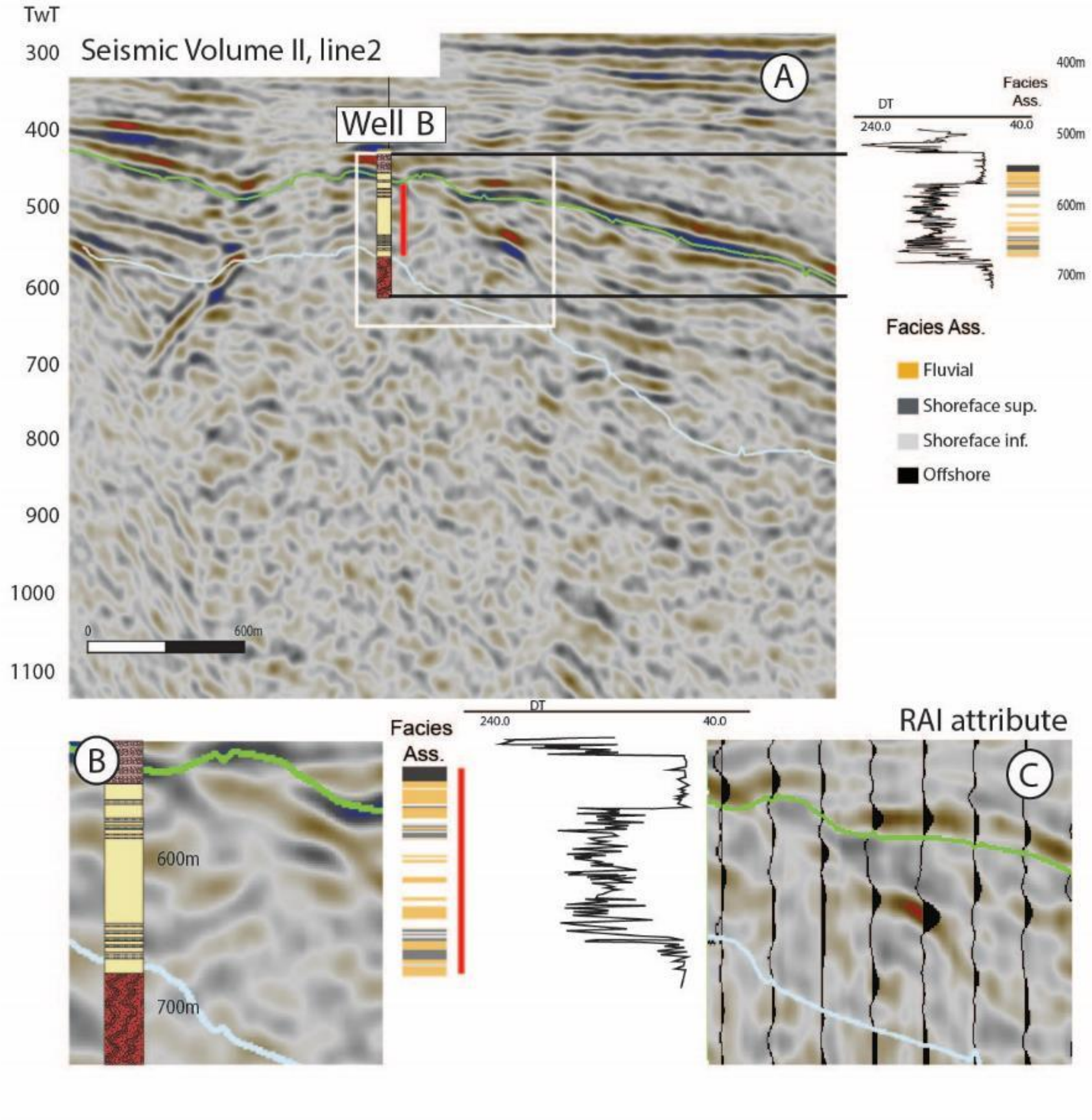


Figure 10 . Seismic facies SF2, integrating the Seismic data in normal phase and Relative Acoustic Impedance with in cored well-log with Facies association. A- description of well B tie in seismic volume II, line 2. B- zoom with facies association. C- sonic log of well B tied based on RAI attribute.

INTEGRATED CHARACTERIZATION OF SF3

Seismic facies SF3 was interpreted as a delta system. The sampled intervals within the mounds are characterized by the intercalation of coastal deposits predominantly (lower and upper shoreface facies), but also presents a significant amount of fluvial deposits, and consequently have a diverse faciological and diagenetic characteristics. Due to its mound-like external geometry, such external geometry as the one established by Mitchum and Vail

(1977d) as sigmoid clinoform, who interpreted it as deltaic lobes outbuilding as upbuilding, with a rapid sea rise. The mounds identified have a magnitude of 500-meter dip, 1500-meter strike and between 150m and 225m high (Figure 11 and Figure 12). They have a complex internal geometry that shows an amalgamated deposition, with reworking and deposition in pulses. The reflectors are being deposited also vertically in the clinoforms, which indicates a delta with an aggrading component (Figure 11 and 12) (Catuneanu et al., 2009; Vail and Mitchum, 1977c).

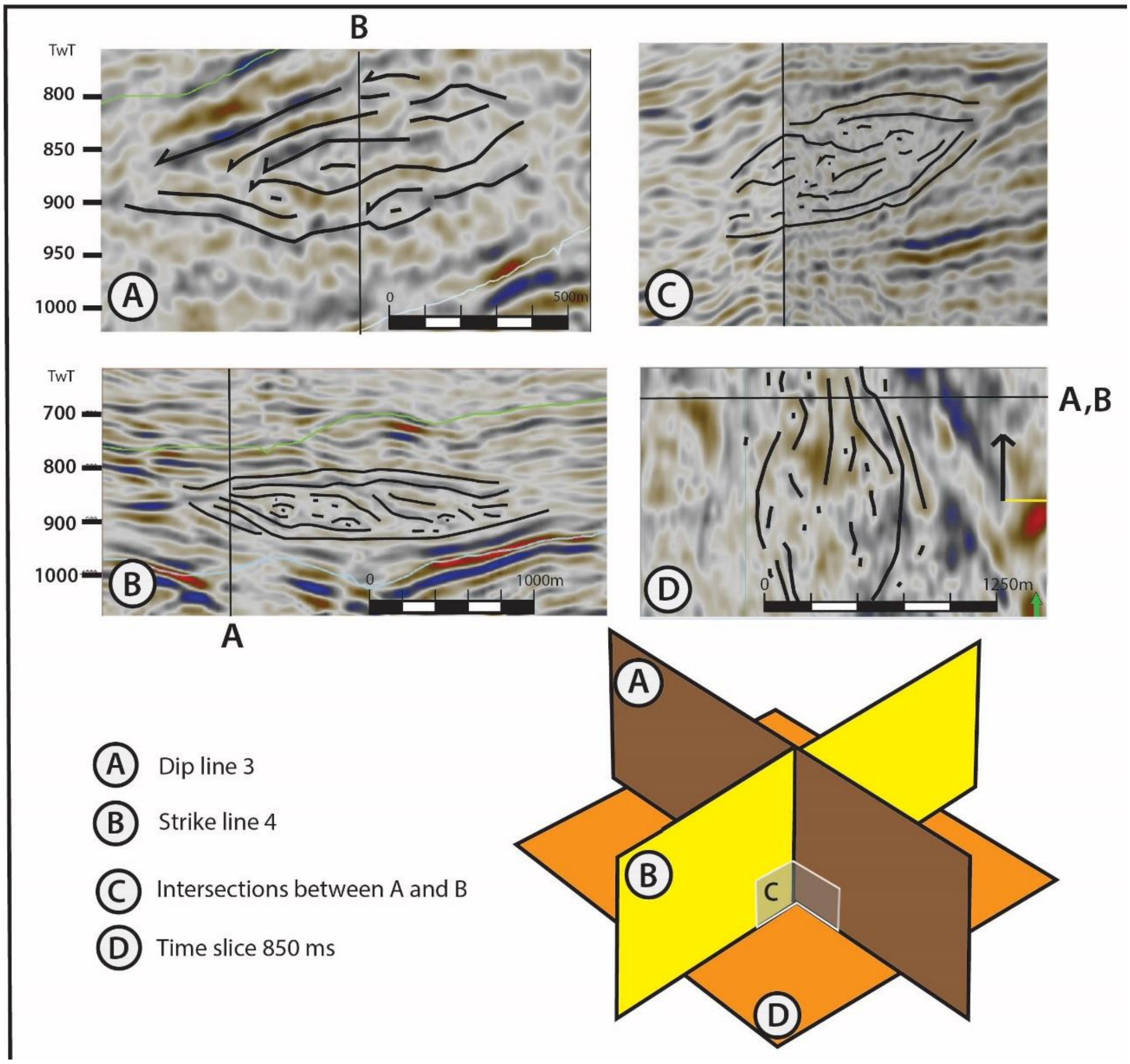


Figure 11. Example of a mound in the Seismic Volume II in three dimensions. A- dip line, B- strike line, C- strike and dip line intersected, D- time-slice of the same mound on the seismic

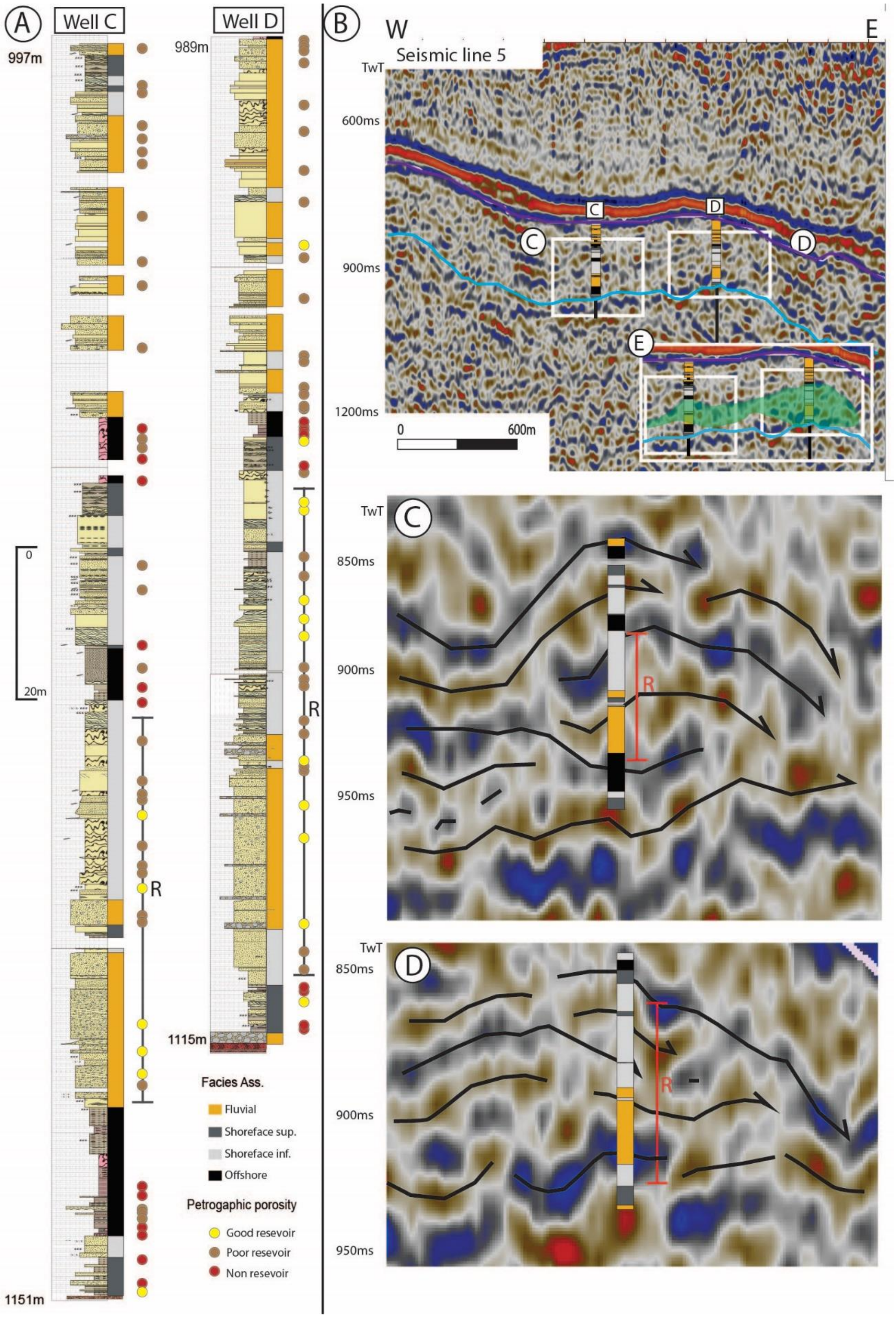


Figure 12. Seismic facies SF3, integrating the Seismic data in normal phase and Relative Acoustic Impedance with in cored well-log with Facies association and Petrographic data. The colored icons represent the classes defined by petrographic porosity, as Table 2. C and D show the correlation between the seismic and facies association. E-shows potential reservoir.

INTEGRATED CHARACTERIZATION OF SF4

SF4 presents a relation between the identified basement movements and the seismic facies distribution. Onto structural highs, it is observed a major incidence of discontinuous seismic facies. This case were interpreted as a small scale spit system caused by the oblique incidence of waves on this high, transporting sand sediments to north (Figure 13). In the seismic volume III, an increase of sandy sediments with clinoforms of small scale trough to the North of the basement high is recognizable within the second seismic unit (Figure 13 A). Zecchin et al. (2010) and Rasmussen and Dybkjær (2005) showed the influence of tectonics highs or coastal line breaks and paleotopography as sediment source to sandspits systems. This geometry is noticeable in an isochrones map of the seismic unit time-based thickness, in the distribution of seismic facies (Figure 13 B) and in the arbitrary line, with clinoforms in the limit of seismic resolution (Figure 13 C). In this sense, Dreyer et al. (2005) was also able to map sandspits on the sedimentary record, based on the seismic data, in Norwegian North Sea, basing his interpretation on the clinoforms of the system.

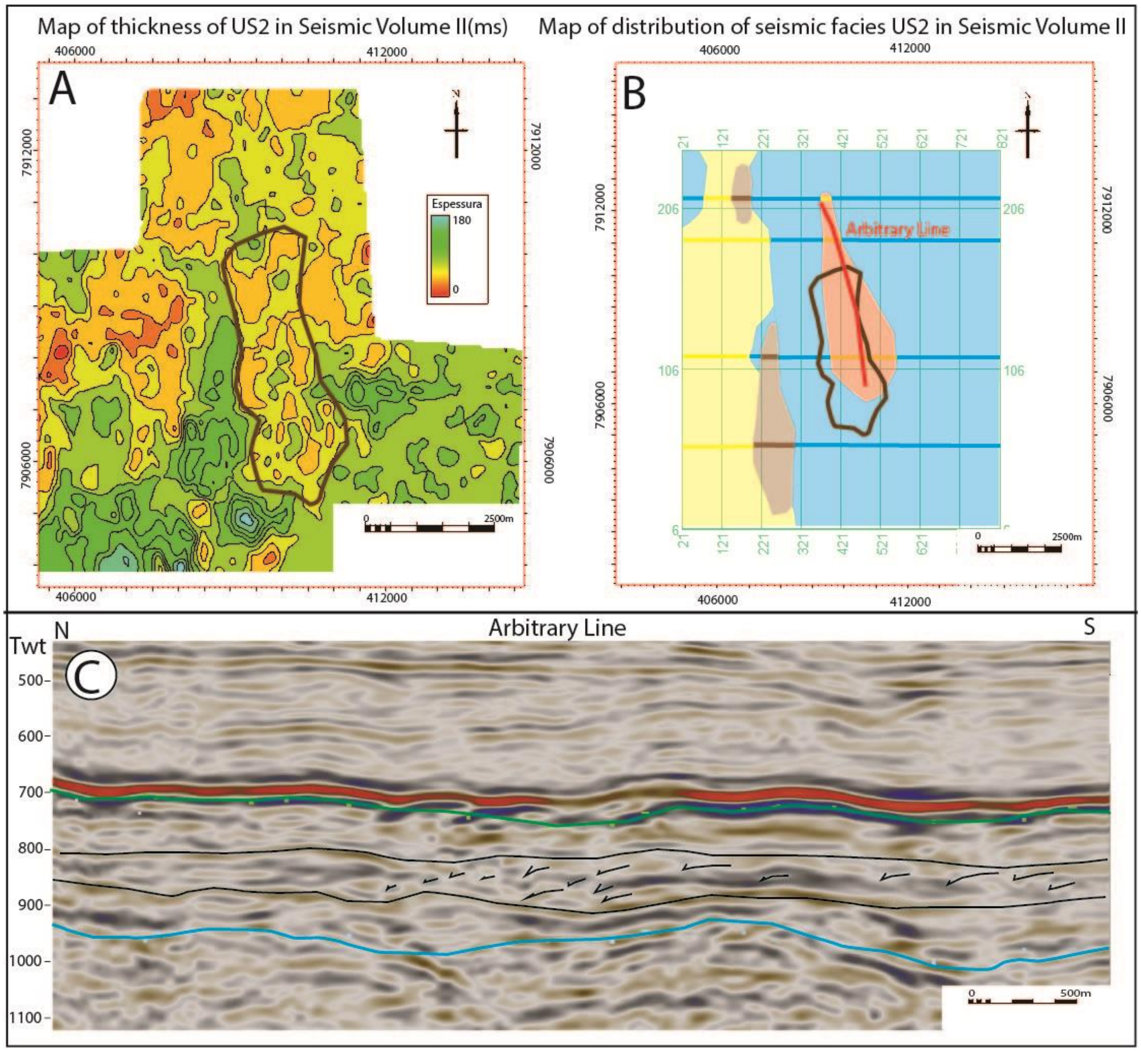


Figure 13. Relation of basement high with seismic facies in seismic unit US-2. A- map of thickness of US-2 with base high circle in brown. B - seismic facies distribution on Seismic Unit US-2, Seismic facies S-1 blue, S2 yellow and orange, S3 brown. C- clinoforms with downlaps indicates migration to North.

CONTROL OF DEPOSITION AND SEDIMENTATION

In order to understand the complexity of the clastic Aptian of Espírito Santo Basin (margin of pre-salt lake) and its record, it is necessary to determine the sedimentation and accumulation controlling-mechanisms and the geological setting of the period. Lakes isolated from the ocean are greatly influenced by climatic changes, resulting in a more unstable base level, susceptible to variations caused by higher frequency cycles (Nichols, 2009). In this sense, expressive changes in the water column are expected, as attested by many studies on active African Rift Lakes (Haberyan and Hecky, 1987; Talbot and Laerdal, 2000; Wood et al., 2017). Apart from active rifts, lakes of diverse tectonic settings in the global Holocene and Pleistocene showed changes of tens to hundreds of meters in a few thousands of years (Placzek et. al. 2006; Olsen, 1986) or even hundreds of years (Fritz, 2008; Licciardi, 2001), clearly non-tectonic, climatic related. In the Mucuri Mb, a significant rise in accommodation space was identified by the mapping the surfaces of maximum flooding (Kuchle et al., 2019; Althaus et al., 2017), but a trend of flooding could not be recognized to the whole regional basin. Although it is possible to observe high frequency base level fluctuations in the Mucuri Mb, the same does not seem possible at regional scales.

Another important feature of Pre-salt clastics on the studied area, is the interaction between wave dominated coastal system with a highly unstable base level, with the ephemeral and weakly channelized distributary system. This relation resulted in the formation of a complex of deltas with cusp morphology that developed along all the coastal line. This is evidenced in the crossline intercepted by the mounds, where it is possible to observe a increasing of thickness across the shoreline, and on the time-slice, which shows the cusp morphology of a delta (Figure 11). Similar features are found in the Turkana lake, a confined lake that was developed in a semi-arid and hot weather (Frostick and Reid, 1986), in which the morphology and magnitude similarities between its deltas and the mounds identified in this paper, so that it constitutes an analogous sedimentary environment to the one that resulted in the Mucuri Member deposition (Figure 11 and 12). According to Frostick and Reid (1986), in the Mucuri Member, the growth and migration of the Turkana Lake deltas was associated with lake level changes caused by climate and tectonic factors. The authors also showed that although the deltas had a fast construction as they only had sediment supply a few hours per year, with sediments being remobilized during the rest of the year by waves and wind action. In the same sense, Peizhen et al. (2001) agreed to the interpretation of a sediment contribution due to a climate manifestation that resulted in increase of sedimentation rate during humid seasons. These sedimentation dynamics allowed the development of a delta with a big ratio of sediment accumulation parallel to the shoreline, with plenty of reworking by wave action, as the similar scenario suggested from our data and interpretation of the Mucuri Member.

Another high dimension structure found is the sandspits linked to the sctructural highs (Figure 13). Nielsen & Johannessen (2009) showed the contrast between the high amount of spit system recognized in quaternary sediments and the few described on pre-quaternary record. Such disparity can be explained by the lack of knowledge regarding spit system identification on the seismic and sedimentological record, which can lead to misinterpretations. Zecchin et al. (2010), Rasmussen and Dybkjær (2005) and Dreyer et al. (2005) also showed that the wave action needs to be oblique to the coast line, parallel to the sediment transport direction, and with the paleo winds coming from the opposite direction of spit growing. Scherer and Goldberg (2007), in a study of early Cretaceous record showed a monsoonal wind pattern coming from Northeast. Conversely, Hay and Floegel (2012) brought a wind pattern from Southeast for the Albian, due to the break of the Gondwana. The discussion about the wind patterns in Gondwana during the Aptian still reverberates, but there is no clue about when the pattern changed. Even so, the spit system presented in this work is an evidence of an already changed wind configuration to a South pattern in Aptian, as Hay and Floegel (2012) showed.

RESEVOIR RANKING

In the studied area, we consider the mounds as the main target for oil and gas accumulations, based on lithological, diagenetic, geometrical and frequency parameters. The occurrence of porous sand bodies within the mound-like structures, which are bounded by a stratigraphy trap, evidence the potential of this structure for oil and gas emplacement. In this structure, which is observed in Figure 9, the sand bodies are located in fluvial and upper shoreface facies. Due to the high remobilization of sediments in deltas and unconfined distributary systems, the reservoir can be classified as jigsaw puzzle, with morphology of lobes and sheets. An internal compartmentalization can occur as a result of internal erosions common to this system, with a great number of deltas lobes and unconfined fluvial system (Galloway; Hobday, 1996). The high frequency occurrence of flood and regression events (demarked by offshore, fluvial and costal deposits intercalation) caused limitations to the reservoirs. A vertical compartmentalization occurs due to the facies contacts between lower shoreface facies and offshore facies. Also, diagenesis is another important factor impacting the Mucuri Member reservoirs. Due to the fact that mudstones are rare in the Mucuri Member, petrographic data shows that diagenetic anhydrite nodules, carbonate concretions and microbial mats occur in the mud and fine-grained coastal deposits, which now represents non-reservoir intervals. These intervals occur intercalated with good and poor quality sandstone and conglomerate reservoirs of fluvial deposits, which commonly present loose packing and significant macroporosity values when not pervasively cimented by calcite. On the other hand, the biotite-rich sediments accumulated in shoreface facies suffered more from compaction than coarse-grained fluvial deposits, and can generate a flux anisotropy that can act as a potential barrier for the vertical flux.

Another probable reservoir in the region, but still not tested, corresponds to the spit systems. Their morphology are also favorable to hydrocarbons accumulation. Although, it is compartmentalized by the small-scale clinoforms. Its structure and stratigraphy trap becomes a probable target for hydrocarbons accumulation, but need more stratigraphic and petrological studies to assure its potential, due to the lack of data.

CONCLUSIONS

- The Mucuri Mb. seismic data is divided in four seismic facies. Two based on seismic reflections, especially on continuity and parallelism (SF1 and SF2), and two based on external geometry and geological context (SF3 and SF4).
- Four facies associations composed more than 95% of Mucuri Mb. They are: poorly confined fluvial channels, upper shoreface, lower shoreface and offshore.
- The thin section data can be divided in 3 classes. Non-resevoir, poor reservoir and good reservoir. Non-resevoir composed by anhydrites and mud, and reservoir by sandstones. Poor or good reservoir is differenced by diagenesis.

- The integrate interpretation shows the relation between SF1 and offshore sediments, SF2 and fluvial sediments, SF3 and shoreface sediments. The seismic facies SF4 does not have correspondence due to the lack of data, but due to its geometry and geological context it is interpreted as a sandspit system.
- In the region, the two main stratigraphic interest points for hydrocarbons accumulation are the seismic facies SF3 and SF4. The cored well logs and the thin sections showed the stratigraphic and the diagenetic potential for this seismic facies. The SF4 is still not tested, and still lacks of data and information, but may be a possible secondary target.

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3 DISCUSSÃO

O artigo submetido, que compreende o corpo cientifico dessa dissertação, apresenta relevância para o conhecimento da Bacia do Espírito Santo. O onshore do ES, que depois de décadas em produção, não possuía nenhuma publicação atualizada, contando apenas com a dissertação de mestrado de Vieira (1998), recebeu recentemente uma série de publicações relacionadas a um projeto de pesquisa acadêmico – Projeto Mucuri (UFRGS), podendo citar principalmente Kuchle et.al. (2019), Amarante et. al, (2019) e Althaus et. al. (2019) Nesse contexto, esse trabalho, relacionado também ao projeto de pesquisa acima citado, trouxe a conexão da sísmica com os ambientes sedimentares da região, e trouxe também a caracterização de reservatório para o onshore Espírito Santo. Além disso, o Membro do estudo representa a borda do lago do pré-sal, que ainda necessita de novos modelos e informações.

Esse trabalho vinculou o sinal sísmico a seu significado em relação à rocha de forma diferente dos atributos matemáticos, que são os mais comuns na bibliografia. Isso é de grande utilidade para o onshore brasileiro, já que esses atributos necessitam de uma sísmica de alta resolução para possuir confiabilidade. Além disso, na literatura, há poucas referências atualizadas relativas a sismofácies geométricas, que integrem, não só a rocha, mas as estruturas de grande escala e o ambiente deposicional à sísmica. Dessa forma, trouxemos uma visão das fácies sísmicas em diversas escalas (desde a lâmina delgada a poços e testemunhos), que pode ser usado como análogo nesse contexto deposicional. Além disso, trouxemos uma pequena atualização na metodologia para a investigação em sísmicas de menor qualidade e que não tenham uma amarração de grande confiabilidade.

Nesse trabalho, nós apresentamos uma estrutura geológica muito observada em sedimentos quaternários, mas muito pouco descrito na sísmica de reflexão, devido a poucas referências sobre esse registro geológico – os spit systems. Além disso, baseado nessa estrutura (spit systems), nós apresentamos um dado sobre o padrão de vento do Aptiano, o qual não possui publicações para as bacias da margem leste brasileira. Esse período se encontra na transição de dois padrões de vento distinto, um monsonal, vindo do Nordeste (Scherer e Goldberg, 2007) e outro vindo de Sul (Hay e Floegel 2012)

Dentro das restrições de um trabalho com um forte componente interpretativo, há também a limitação em que os dados indiretos e a correlação com eles podem trazer. Uma limitação nesse artigo é a ausência de checkshot em poços, que embora não tenha impossibilitado a correlação sísmica/poço (já que essa foi baseada em critérios estratigráficos), aumentou o erro vertical associado. Outra limitação é a qualidade do dado sísmico, que, com média resolução, causou dificuldade em observar estruturas que possuem uma escala menor que dezenas de metros. Além da baixa resolução, o ruído da sísmica não nos deu confiabilidade em um dos parâmetros de reflexão mais importante para a definição de fácies sísmicas: a amplitude.

Para os próximos passos, espera-se mais evidencias sobre spit systems no registro geológico, com mais exemplos de sismofácies associadas a essas estruturas, para que ela possa ser reconhecida, também, no dado sísmico. Devemos buscar mais diversidade em relação às sismofácies geométricas, especialmente em sísmica de maior resolução, para que se traga robustez, na interpretação do registro baseado na interpretação de sismofácies. Finalmente, é de interesse que se busque mais evidências sobre o padrão de ventos do Aptiano na margem leste brasileira, já que esse e outros dados climatológicos desse período ainda carecem de mais informações.

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5 HISTÓRICO ESCOLAR

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Universidade Federal do Rio Grande do Sul
Programa de Pós-Graduação em Geociências

Histórico Curso

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Período	Código	Atividade de Ensino/Professor	Cré-ditos	Carga Horária	Con-ceito	Frequên-cia (%)	Situação	Instituição
2019/02	GEB00142	ANÁLISE EXPLORATÓRIA	4	60	A	100.00	Aprovado	UFRGS
2019/02		Estágio Docência: TRABALHO DE CAMPO II	2	30	A	-	Aprovado	UFRGS
2019/02	GEB27-34	T.E. em GEOLOGIA MARINHA: MUDANÇAS CLIMÁTICAS E ZONAS COSTEIRAS	2	30	-	-	Matriculado	UFRGS
2019/01	GEB00044	Estratigrafia Avançada	4	60	A	100.00	Aprovado	UFRGS
2019/01	GEB00045	Fácies e Sistemas Deposicionais	5	75	A	100.00	Aprovado	UFRGS
2019/01	GEP19-42	T.E. EM ESTRATIGRAFIA: PETROFÍSICA DE POÇO	2	30	A	100.00	Aprovado	UFRGS
2019/01	GEB27-32	T.E. em Geologia Marinha: Ferramentas Matemáticas e Computacionais para - Ferramentas Matemáticas e Computacionais para a Análise de Dados Magnéticos de Sedimentos I	4	60	A	100.00	Aprovado	UFRGS
2019/01	GEP19-40	T.E. em Geologia Sedimentar: GEOLOGIA DAS ROCHAS CARBONÁTICAS	4	60	A	100.00	Aprovado	UFRGS
		Inglês em 09/08/2019	-	-	-	-		

Conceitos
A - Conceito Ótimo
B - Conceito Bom
C - Conceito Regular
D - Conceito Insatistfatório
FF - Falta de Frequência

Totais	
Créditos Cursados com Aprovação neste Curso:	25
Total:	27

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6 PARECERES DA BANCA