T-R SEQUENCE STRATIGRAPHY OF THE ALBIAN OF THE ESPIRITO SANTO BASIN, BRAZIL: HIGH-RESOLUTION CORRELATION BETWEEN FLUVIAL AND PARALIC SUCESSIONS

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ABSTRACT

The main aim of this paper is to present a high-resolution stratigraphic framework of the basal section of the São Mateus Formation, Albian of the Espírito Santo Basin. In the studied stratigraphic interval, five distinct facies associations were identified: (1) shallow, hypersaline marine platform (AF-I); (2) carbonate ramp (AF-II); (3) fluvial channels (AF-III); (4) overbank deposits (AF-IV) and (5) siliciclastic plataform (AF-V). Overlying the evaporitic section, three regionally-correlatable transgressive–regressive (T-R) sequences are defined. Each sequence is formed by one transgressive basal tract, and one regressive tract at the top.

INTRODUCTION

The main objective of the present work is to provide an analysis of the facies architecture and stratigraphic framework of the siliciclastic-carbonate section of the São Mateus Formation (Espírito Santo Basin), aiming at establishing a prediction model of the geometry, lateral extension and thickness of reservoirs bodies. The collected data will allow the qualitative characterization of the sand bodies, as well as the understanding of the sedimentology, and stratigraphic and depositional controls on their distribution.

STUDY AREA LOCATION

The Espírito Santo Basin is located in the central area of the eastern Brazilian continental passive margin, between $18^0 20'$ S and $21^0 00'$S parallels, (**Figure 1**). The basin occupies an area of approximately 50.000 km^2, 5,000 km^2 of which correspond to the outcropping part. Its prospectable area is around 25.000 km^2. This basin is one of the passive margin basins formed during the Lower Cretaceous, in response to the breakup of the Gondwana mega-continent. As all the other marginal basins, the Espírito Santo Basin presents two main tectonic phases: the rift phase and the passive margin phase. The studied interval, of Albian age, includes the São Mateus Formation, composed of siliciclastic deposits, and the carbonate deposits of the Regência Formation. These units pertain to the initial period of the passive margin, during which the basin was structured as a gently-dipping ramp, favoring the development of the mixed platform.

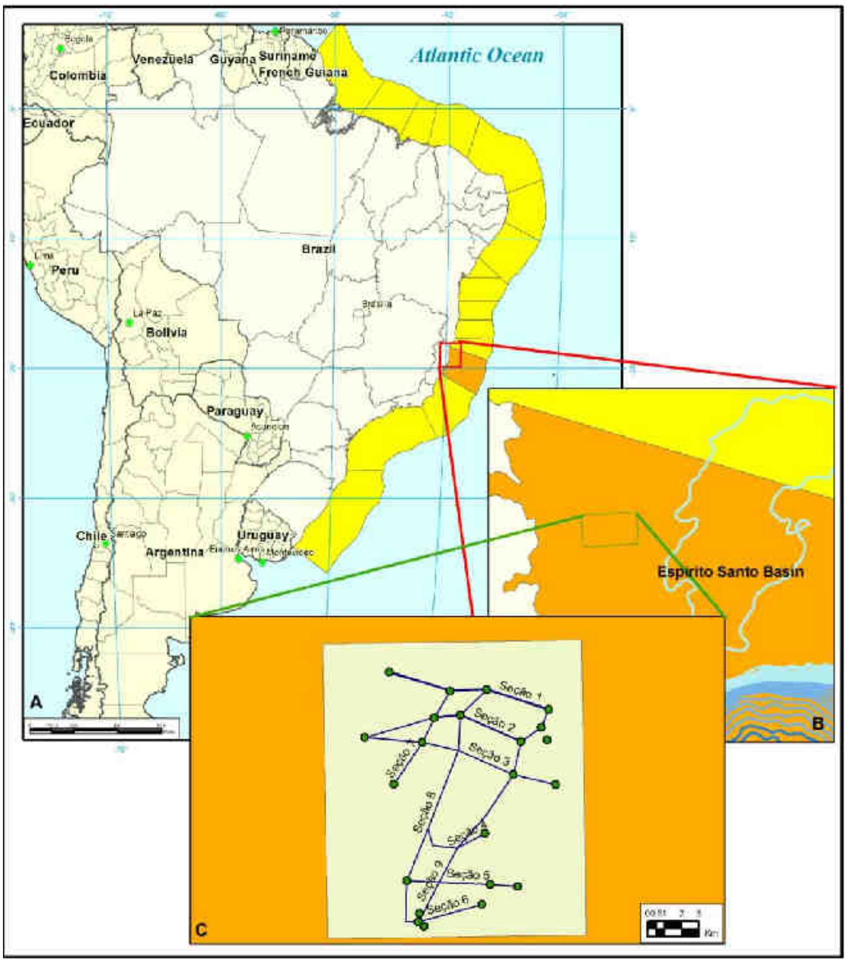

Figure 1: Location map. A) South America with Brazil coastal margin. B) The Espírito Santo Basin, showing a detail of the studied area. C) Studied area, with the correlation sections.

SEQUENCE STRATIGRAPHY IN FLUVIAL SYSTEMS: AN ALTERNATIVE APPROACH

The Sequence Stratigraphy concepts have been widely used in hydrocarbon exploration, especially in the analysis of coastal and shelf deposits (Van Wagoner et al., 1990), where the patterns of accumulation and the preservation of the sediments are products of the base level variation. In continental deposits, such as fluvial systems, the variation of the rate of accommodation space creation through time is the main factor for the preservation of sediments (Shanley & McCabe, 1994). In near-coastline fluvial systems, the relative sea level controls the changes in the balance profile, making the determination of the stacking pattern of alluvial deposits possible. This relationship allows the interpretation of important chronostratigraphic surfaces and the depositional systems tracts (Brown & Fisher, 1977; Van Wagoner *et al.,* 1990).

In this work, the identification of the conventional systems tracts in fluvial deposits was difficult, especially the separation of the LST (lowstand systems tract) and the HST (highstand systems tracts), since both are characterized by amalgamation of the fluvial channels. In a context where the stratigraphic framework is built by using only wells, with discontinuous coring, the identification of the sequence boundary is extremely complicated. Considering these limitations, the well-based concepts that can be applied in the studied area are the transgressive-regressive (T-R) sequences, proposed by Embry & Jonhannessen, (1992). This model, developed from studies carried out in the Mesozoic of the Sverdrup Basin, Canada, is based on the signature of the stacking patterns (progradation and retrogradation) that reflects the relationship between accommodation and supply.

Each sequence is limited by maximum regressive surface (MRS). The system tracts recognized internally in the sequence have been called transgressive systems tract (TST) and regressive systems tract (RST), and separated by the maximum transgressive surface (MTS). Therefore, Embry & Jonhannessen (1992) eliminate the problem of the differentiation between HST and LST, joining them in the regressive systems tract.

In this way, the model of T-R sequences allows the integration of continental and coastal stratigraphic frameworks, using the correlation of the stacking patterns as a basis. In the fluvial interval of the study area, the transgressive systems tract was marked by an upward increase in isolated channels, whereas in the regressive systems tract channel amalgamation increases upward. The MTS was placed where the thickest package of overbank deposits occurs. The MRS was considered as the thickest package of fluvial channel deposits.

APPLICATION OF T-R SEQUENCES IN THE ESPIRITO SANTO BASIN

STRATIGRAPHIC ANALYSIS

This study comprises the analysis of 160 meters of cores from four wells located at the north of the Espírito Santo Basin. This succession includes a basal evaporitic facies (not considered in this study), two carbonate facies and ten siliciclastic facies. The siliciclastic facies are part of the São Mateus Formation, the carbonate facies compose the Regência Formation and the basal evaporitic facies is included in the Mariricu Formation. The characterization and interpretation of lithofacies allowed the grouping into five facies associations, related to depositional systems or sub-environment of deposition, as shown in **Table 1**.

Facies associations	**Facies**	**Interpretation**
AF-I	Evaporite, Shales.	Platform in hypersaline marine context
AF-II	Calcarenite with truncated wavy stratification and plane-parallel lamination.	Carbonate ramp
AF-III	Trough-stratified sandstones and conglomerates, sandstones with plane-parallel, low-angle and trough-wavylamination.	Fluvial channels
AF-IV	Trough-wavy sandstones, ritmites, shales and paleosols.	Overbank fluvial deposits
AF-V	Truncated wavy lamination, trough cross-bedding, plane-parallel lamination and massive sandstones.	Siliciclastic shelf

Table 1: Facies associations with component facies and interpreted depositional environments.

STRATIGRAPHIC FRAMEWORK

The stratigraphic framework was established based on the facies associations in 25 wells distributed along nine correlation sections, six along the dip direction and three along the strike. A dip cross-section showing the facies associations, systems tracts and depositional sequences is presented in **Figure 2**. From the key surfaces, four depositional sequences, three of which complete, were identified. Each sequence encompasses two T-R tracts as discussed above.

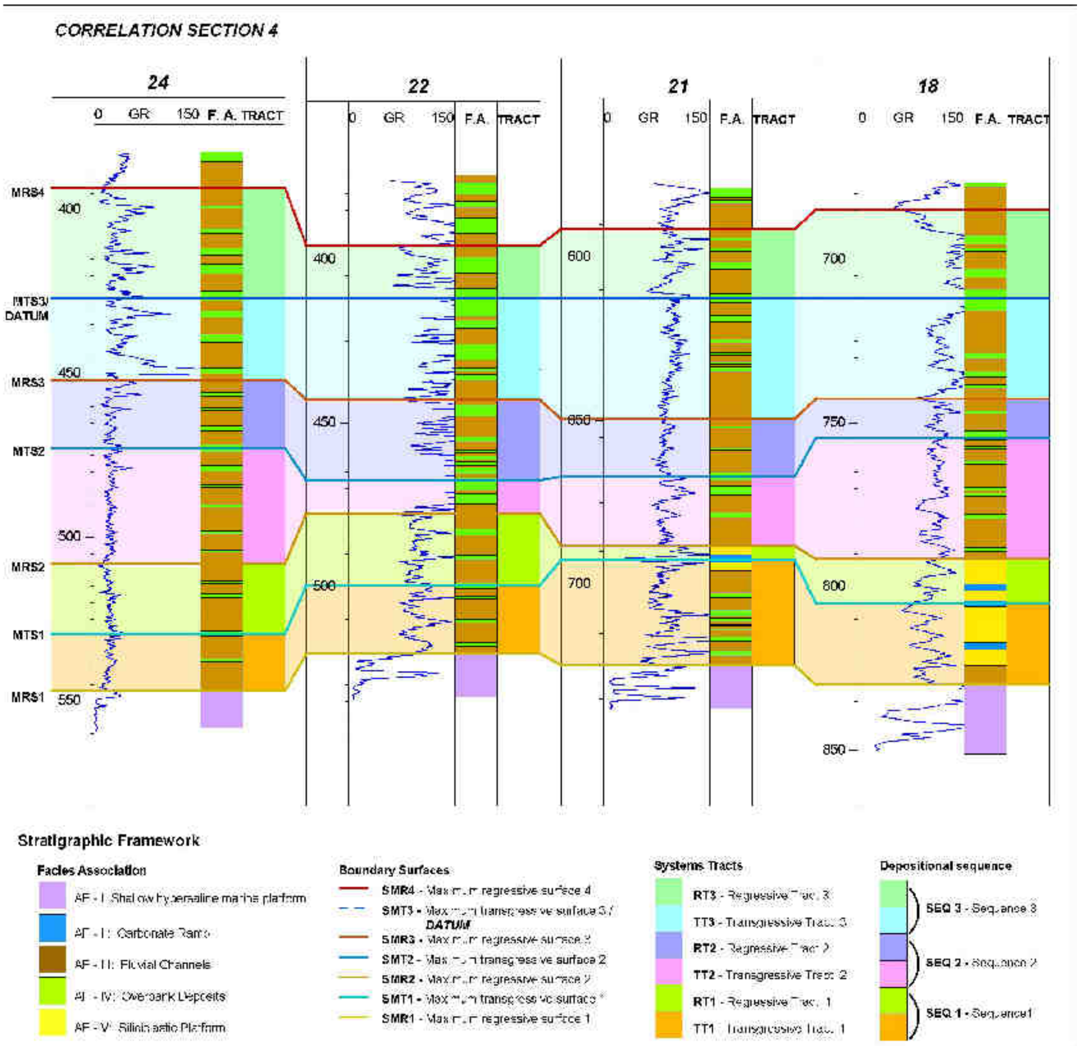

Figure 2: Dip cross-section 4 showing the facies associations, systems tracts and depositional sequences**.**

Depositional sequences, Systems Tracts and boundary surfaces

T-R Sequence 1 (T-R SEQ 1): With thickness up to 57 meters, this sequence is at the base of the studied interval, presenting the main contribution of marine deposits (AF-II and AF-V) in the study area. In the west, it is represented by continental deposits (AF-III and AF-IV), where the maximum transgressive surface is delimited by the increase of overbank deposits (AF-IV) in relation to the channel deposits (AF-III). Increased fluvial channel amalgamation occurs at the base and at the top of this sequence. Marine deposits (AF-II and AF-V) predominate in the east, and the identification of the MST was based on the displacement of the shoreline from east to west.

T-R Sequence 2 (T-R SEQ 2): Thickness in this sequence reaches 94 meters. There is a reduction in the marine deposits (AF-II and AF-V) in the east, and consequently an increase in the proportion of continental facies (AF-III and AF-IV). An increase of fluvial channel deposits (AF-IV) over overbank deposits (AF-III) is recorded in Transgressive Systems Tract 2, followed by the amalgamation of the fluvial channels in the Regressive Systems Tract 2. The marine deposits that occur in the eastern margin are related to the siliciclastic platform (AF-V).

T-R Sequence 3 (T-R SEQ 3): With a maximum thickness of 82 meters, this sequence lies at the top of the analyzed interval. It comprises only continental deposits (AF-III and AF-IV), thus the identification of the stacking patterns was based on the ratio between fluvial channel and overbank facies associations. At the base and the top of the sequence the increase of amalgamation thickness in the fluvial channels is observed, where the maximum regressive surface (MRS3 and MRS4) has been delimited. The MTS 3 in this interval was placed where the channels were more isolated.

The three sequences identified form a sequence set or Composed T-R Sequence Set. The identification of the stacking patterns in the sequences led to the interpretation of a progradational pattern, perceived by three factors: (Figure 3):

1) The fluvial deposits (channels and overbanks) occur mainly towards the top of the studied interval. The marine deposits (AF-III and AF-IV) occur more conspicuously in sequence 1, gradually reducing its occurrence in sequences 2 and 3.
2) The channel amalgamation increases towards the top of the sequence set, being more obvious at the base of transgressive systems tracts 2 and 3 (TT2 and TT3).

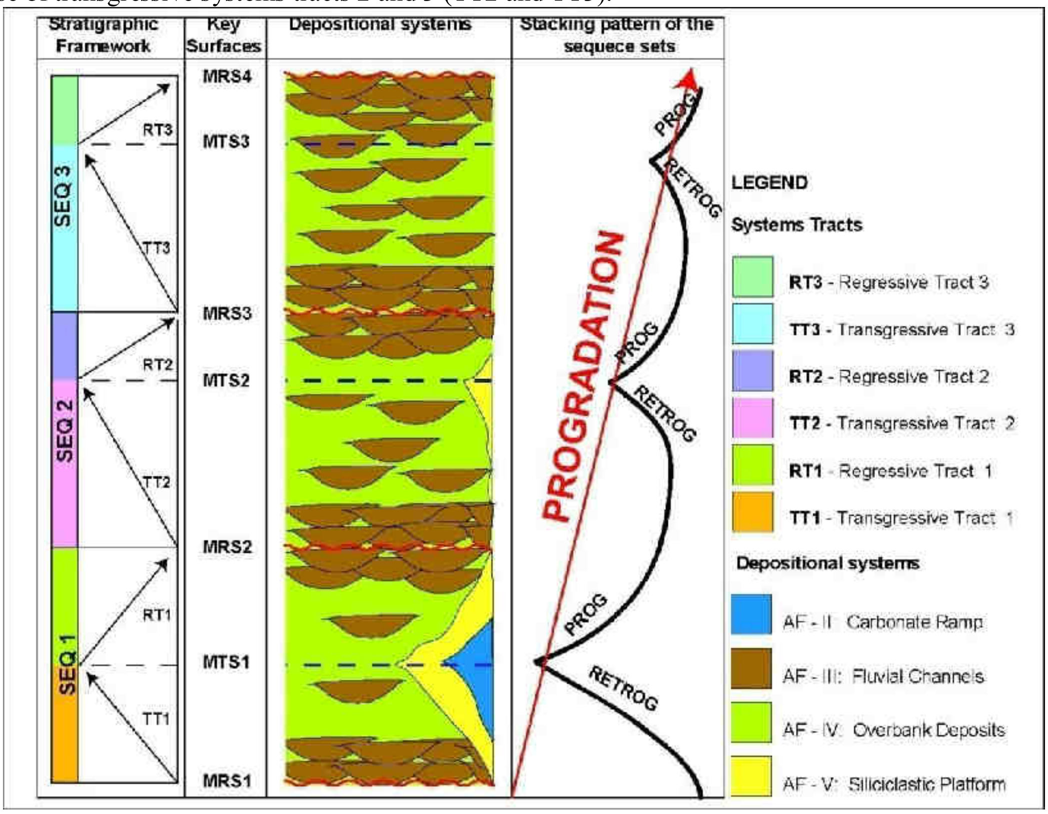

Figure 3: Stratigraphic summary of the depositional sequences, systems tracts and boundary surfaces, as well as the identified sequences and the stacking patterns of the set of sequences.

FINAL CONSIDERATIONS

In the present study, the use of the classical sequence stratigraphy (e.g. Posamentier et al., 1988, Van Wagoner et al., 1990) was not possible due to the difficulties found in the separation of the HST and the LST in alluvial successions, since both are characterized by the amalgamation of fluvial channel deposits. The development of the stratigraphic framework used the model of T-R Sequences (sensu Embry & Jonhannessen, 1992, 1993). The identification of 3 complete T-R sequences (SEQ 1, SEQ 2 and SEQ 3) was based on the stacking patterns, which determined two systems tracts for each sequence: a trangressive (TST) and a regressive (RST) systems tract. The sequence boundaries correspond to the MRS, whereas the boundary surface between TST and RST corresponds to the MTS.

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