Seismic stratigraphy analysis of south Santos Basin and it implications on the early South Atlantic evolution.

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Abstract

This study consists of the analysis of seismic facies of regional sedimentary sequences of Santos Basin. We have analyzed the relationship between the south sedimentary edge against the Sao Paulo structural high. The interpretation of 2D seismic lines 500-0059A (LEPLAC) and 999-3235, 999-3237, 999-3239, provided by FUGRO as a courtesy for the study, allowed the individualization of 8 seismic units. The DSDP356 well was tied to seismic to age-dating the units recognized on line 999-3235. This well was located exactly on the south sedimentary edge of Santos Basin. A time-depth conversion validated the construction of a regional geological section. Seismic and well data have been integrated in order to establish the timing of São Paulo Ridge (SPR) acting as a barrier against free marine circulation. Finally, this study helps to understand the salt deposition setting and the base-level variations since the opening of the north part of South Atlantic Ocean.

Introduction

The recent discovery of giants accumulations of oil and gas in the deep water of Santos Basin has pushed new studies to better understand the Brazilian pre-salt play. That new exploratory frontier contains significant amounts of HC, and the production must exceed the productivity at Campos Basin in the next few years. (Carminatti *et al*, 2008). As an essential element to the success of that petroleum system, salt layers were deposited in mostly of the Brazilian margin basins, located to the north of Sao Paulo Ridge (figure 1), from Santos to Alagoas basin.

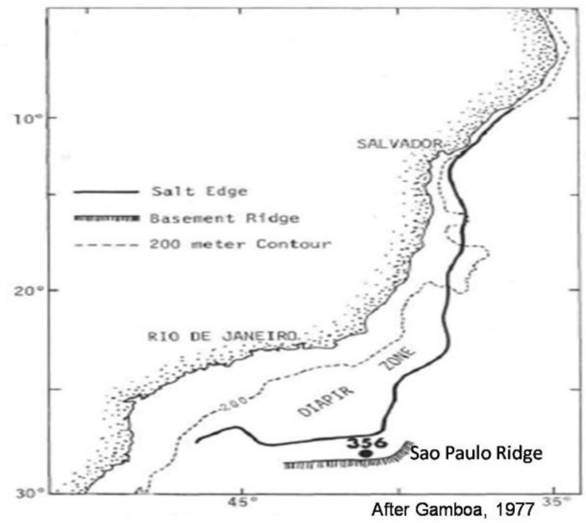

Figure 1: Location map showing the extension of salt deposits and the position of the DSDP356 well, located between the Diapir zone and the Sao Paulo Rigde.

The Aptian sedimentary setting of northern south Atlantic basins, suggests that the Sao Paulo Ridge acted as a barrier to free marine circulation, already establish in Pelotas basin. This important structural high is a positive feature aligned into the E-W direction and it represents the south limit of Santos basin. Apparently, as originally suggested by Kumar *et al*, 1977, the Aptian climatic condition has changed and a restricted environmental have been implanted. The Aptian gulf should have an extension of 800km longer (Gamboa in Moriahk, 2008). In the present paper we used the seismic stratigraphy to analyzed how effective was that barrier along the sedimentary history of south Santos basin.

Method

The 3 regional 2D seismic lines used on this work, extends from shallow water up to 3500 meters water depth, aligned into the NW direction (figure 2). The line 999-3235 cross the well DSDP356 and was the line used to tie temporally the units interpreted. Line 500-0059A are aligned on NE trend, crossing the Sao Paulo Ridge into the strike direction.

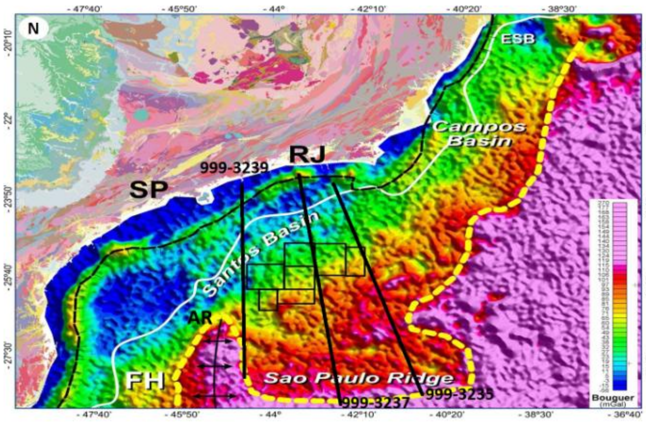

Figure 2: Location of the study area and position of seismic lines used. Note that line 999-3239 intercept the AR (Aborted Rift) at a low angle, where a depression basement region is observed (see figure 7)

That line was the chosen one to interpreted the structures that compose this high. The seismic units were described following the criterions exposed by Vail, 1977, in the classic Memoir #26. Separation of 8 seismic units limited by non-corformities at the top and base of each, were associated to well data available in the DSDP 356 first publication (Kumar *et al*, 1977). The sonic velocities measurements associated with depth data were used to build a time-depth table (figure 3). A conversion from time to depth became possible using a simple velocity model (figure 4) built to the seismic line 999-3235.The velocities were chosen based on the sonic data and through tests run to get better image. The model is assume constant velocities between layers. To limit the layers, we used the mapped horizons. Once the conversion done, we generate a regional geologic section (figure 5).

South edge interpretation

The first seismic unit described, correspond to the volcanic basement, and is based characterized by an internal chaotic pattern, disposal in grabens and horsts structures. The upper limit is non conformative. Unfortunally due to operations problems, the DSDP356 did not hit the basement. By the correlation with the stratigraphic chart of Santos basin, it corresponds to the Camboriu formation, based dominated by basalts. Seismic unit 2 corresponds to the rift section, which doesn't occurs in the south portion, and to the SAG section. In general, at the lower part of the SAG sequence, the reflectors are parallel/subparallel, showing a very expressive regional control, disposed in a tabular external geometry. The limit with the sequence above is conformative, while the lower limit shows an angular unconformity. The upper SAG corresponds to salt layers, and represents seismic unit 3. This unit is responsible to the deformation of all units above. The main salt domains are ilustred in the geological section (figure 5). The SAG section appears in thin layers to the east part of SPR (figure 6). To the west, the SAG section seems to be thicker, clearly onlapping the SPR (figure7). Is important to note that in all seismic lines analised the salt is interrupt by the SPR. Units 2 and 3 were not drilled in the DSDP356 well, however the clear correlation between the basement and the salt layer indicate that those units corresponds to the Guaratiba group. The unit 4 , at south portion, is plan parallel dominated, showing high amplitudes. This unit also onlaps the SPR. Acording the DSDP356 well, this seismic unit corresponds to Albian deposits, correlated with Camburi group. The Unit 5 is marked by the must clear erosion unconformity at the upper limit. The Unit occurs in all basin area, in the proximal area the unit corresponds to the must expressive siliciclastic influx registered on the basin, smashing the salt layers to the deeper portion of the basin. The top reflector that marks the sequence correspond to the late cretaceous time. Because his nature is hard to tell whether the Unit 5 onlap the SPR. Unit 6 is the unit that clearly by-pass the west SPR (figure 7). Observing the seismic line 500-0059A, is possible to verify that the external geometry changes abruptly on the deposition of that sequence (figure 8). The external geometry is characterized by a mound form associated to a drift deposit, internally the unit 6 is comprise by minors orders deposits. The age of top reflector of Unit 6 is Early Eocene. Units 7 and 8 are quite similar and corresponds to a final level variation, sheets geometries presenting internally a fill pattern. The age for that Units goes from Middle Eocene to recent times.

Conclusions

During the geological history of the basin, the SPR seemed to be higher to the east, and consolidated as an effective barrier until today. Hence, to the west, next to the aborting rift center, the barrier was less effective what allowed the entrance of South Atlantic sea water. In the early Aptian stages, as the ocean was already open to the south. High energy deposits in the Late SAG stage, first documented by Carminatti *et al*, 2008, corroborate with that hypothesis. The eustatic variations during the Late SAG phase, associated to a climatic change, caused an unique restrict conditions in the sedimentary evolution. The restrict environmental allowed that salt deposits sealed carbonates in a perfect timming. Later in the history, from the end of deposition of evaporitic layers, with the basin completely filled by sediments, in the Early Eocene, drifts deposits controlled by strong currents has by passed the barrier at south portion. This event is probably associated to an important tectonic-oceanography event. Since that Age, the SPR stops to work as a barrier to free marine circulation.

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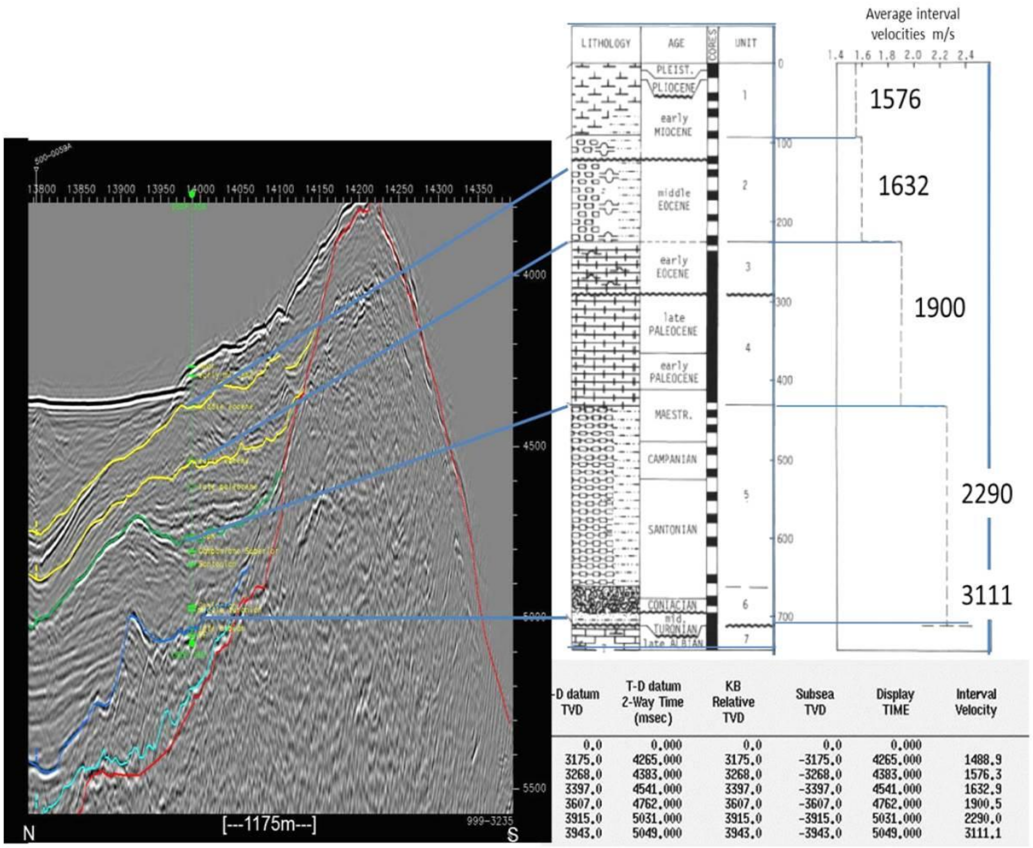

Figure 3: Line 999-3235 interpreted on the south limit, showing the time-depth data used to tie the well.

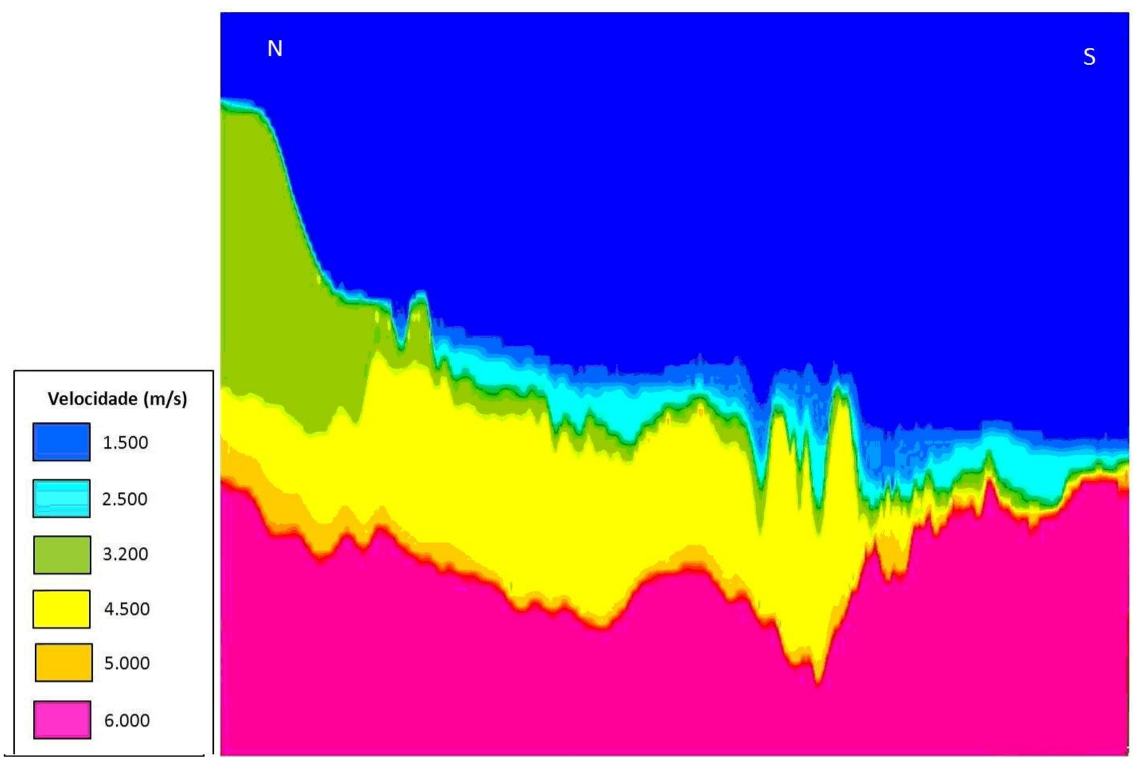

Figure 4: Velocity section used to convert line 999-3239 from time to depth.

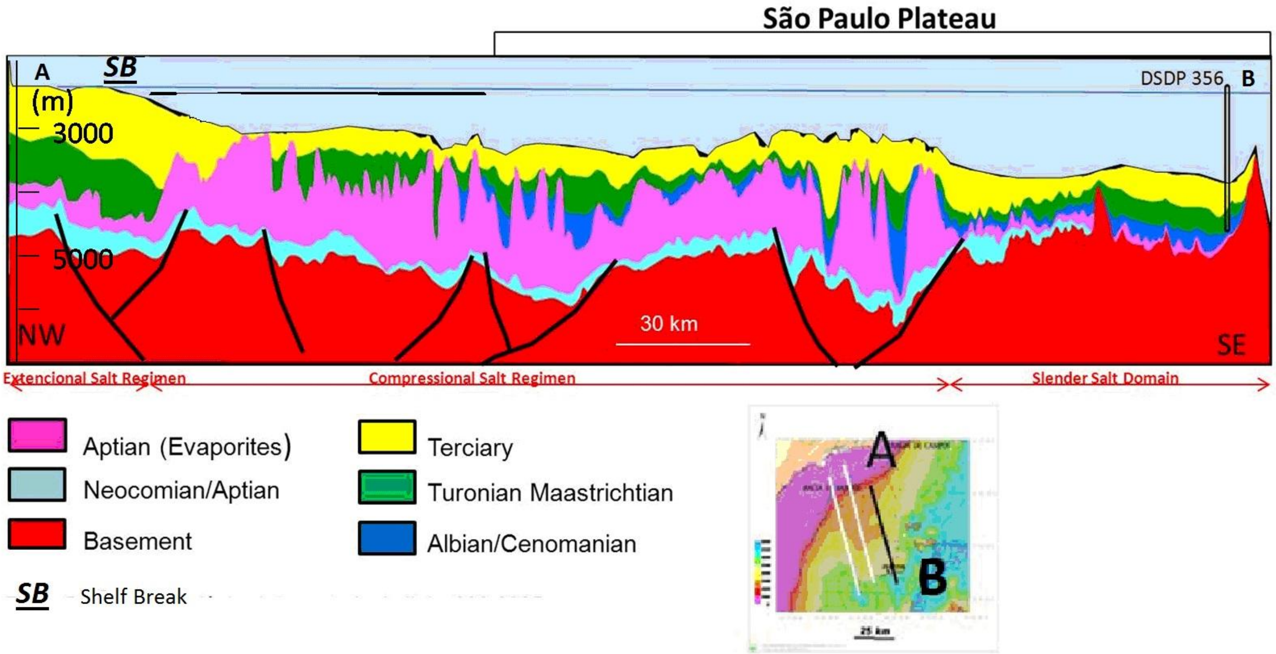

Figure 5: Regional geological section separating the differents salt domains indentified.

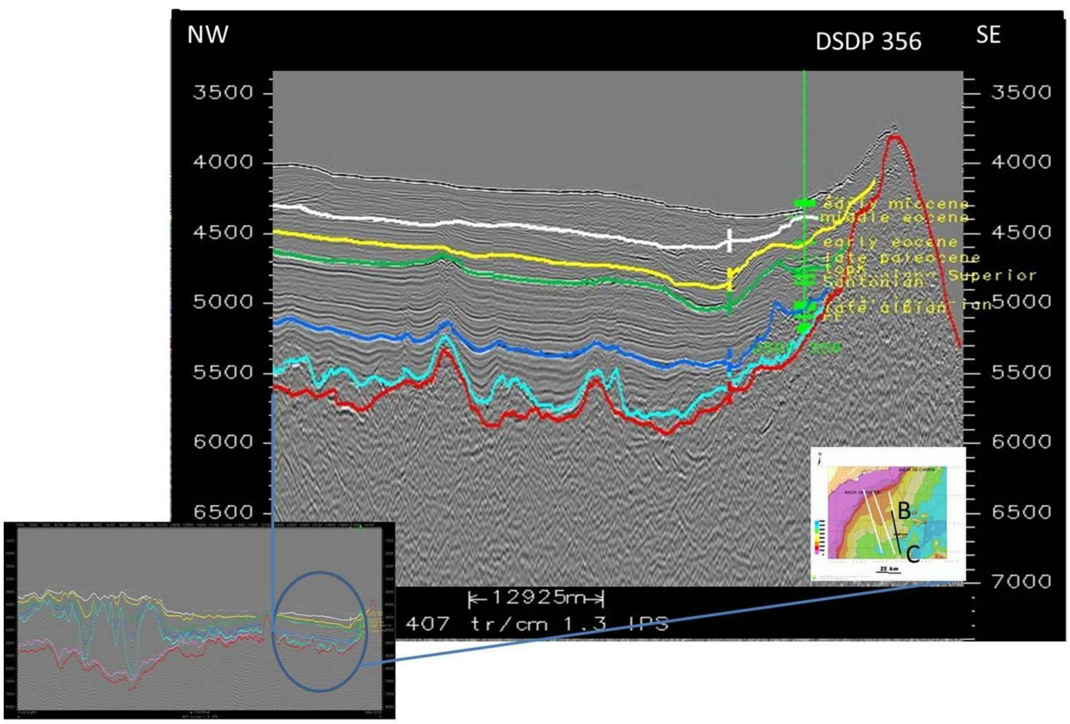

Figure 6: Positioning of DSDP356 well. Note the SAG section thinning at that point.

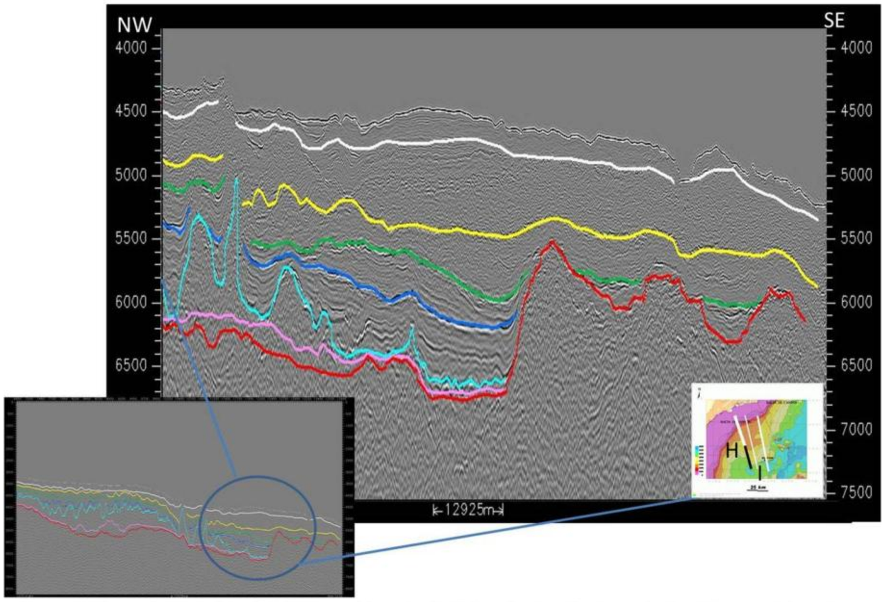

Figure 7: Line 999-3235 interpreted, shows clear onlaps of units 2, 3 (top reflector is dark blue). Unit 5 (top yellow reflector) clearly by-pass the Sao Paulo Ridge. Note that the basement top (red reflector) is

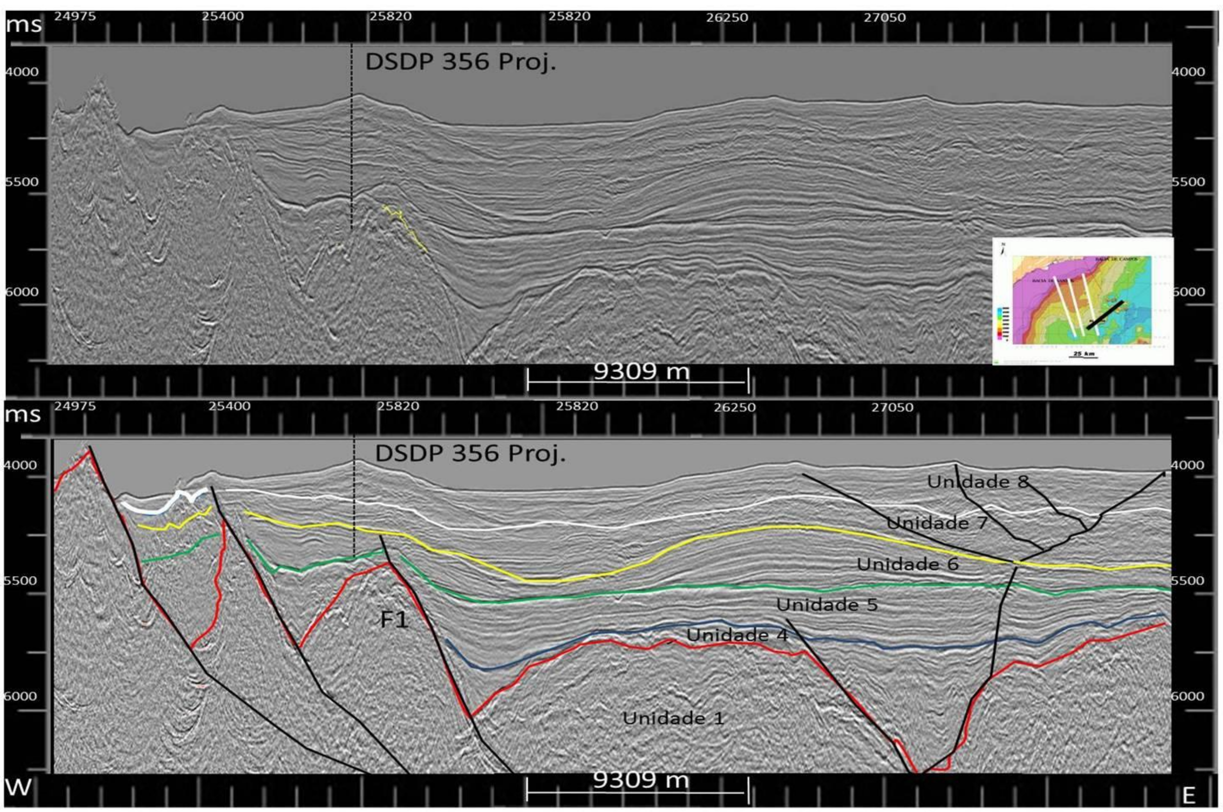

Figure 8: Seismic line 500-0059A (LEPLAC) cutting the Sao Paulo Ridge in the strike direction. Note that from unit 6 (top reflector yellow) the external geometry changes abruptly.