INTEGRATED GEOCHEMICAL-STRATIGRAPHIC ANALYSIS OF A NE-SW CROSS-SECTION FROM RECÔNCAVO BASIN, NORTHEAST BRAZIL

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ABSTRACT

The Recôncavo Basin, NE Brazil, comprises three main compartments (northeast, central and southeast) limited by faults. Those compartments have distinct geological frameworks and sedimentation conditions, due to variations in the tectonic activity during basin evolution. Based on an integrated geochemical-stratigraphic study, it was observed that beyond controlling the sedimentation conditions, the different tectonic pulses were also responsible for the variable quality of the organic matter in the basin. Samples from the central compartment have the better potential for oil generation, based on Total Organic Carbon contents (TOC) and Rock Eval Pyrolysis (Hydrogen and Oxygen Index). The Hydrogen Index (HI) increase in samples from Rift Initiation to Rift Climax System Tracts and decrease in samples associated to the Rift Filling Systems Tract. The average of the HI values tends to increase during transition from Pre-rift to Rift Filling System Tracts and diminish through the southwestern compartment direction.

INTRODUCTION

The Recôncavo Basin integrates the Recôncavo-Tucano-Jatobá rift, located in the Bahia State, Northeast Brazil (Figure 1). It comprises a NE-SW-strike assymetrical graben, filled by organic matter-rich fluvial-aeolian-lacustrine sediments during Jurassic-Cretaceous in more than 10,000 km^2.

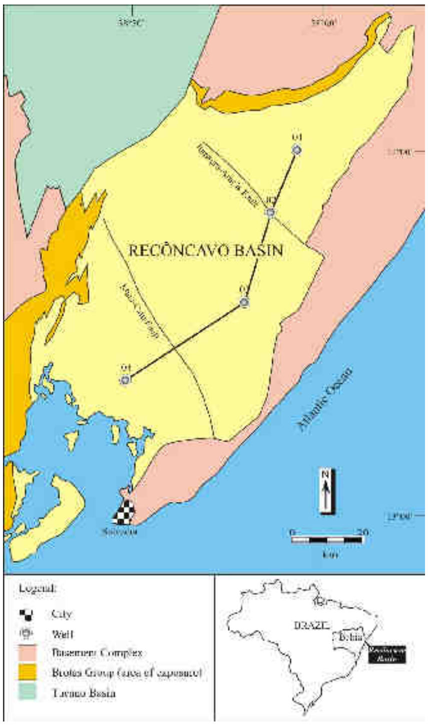

Figure 1. Localization map of the Recôncavo Basin and localization of the wells (01 to 04) used to elaborate the studied cross-section. Modified from Scherer et al. (2007).

The Recôncavo Basin was generated during crustal stretching that culminated with the Gondwana paleocontinent fragmentation during Lower Cretaceous (Neocomian). In the end of the Lower Cretaceous the western part of the rift was aborted before the complete rupture of Gondwana, which prevent the deposition of marine sediments.

At the beginning of the 40's were discovered indications of oil in the Recôncavo Basin and since then, several studies have been made to recognize the habitat of oil, its generation potential and possible reservoirs. On the other hand, even with a significant volume of geologic information about the Recôncavo Basin, there is no published study dealing with integrated data, mainly due to the structural and stratigraphic complexity of the basin.

The Recôncavo Basin comprises three main compartments (Northeast, Central and Southeast) that are limited by the Itanagra-Araçás and Mata-Catu Faults. These compartments have distinct geological framework and conditions of sedimentation that, according to Penteado (1999), had possibly been responsible for variable quality of the organic matter in the basin. This hypothesis is supported by the author through elementary and Rock Pyrolysis analyses of rocks from Gomo Member (Candeias Formation) sampled in the different compartments. However, there is no published data using the lithostratigraphic units of the basin and its potential to generate hydrocarbons. Moreover, there is also no integrated study using geochemical and stratigraphic data that could clarify the changes in the geochemical signatures with regard to the deposicional settings during different tectonic pulses in each basin compartment.

The present work has the aim to: (i) to verify the potential of the lithostratigraphic units to generate hydrocarbons during the different tectonics pulses in the basin, from the analysis organic geochemistry (TOC and Rock Eval Pyrolysis); (II) to elaborate a geologic cross-section with all three basin compartments using well-logs and electric profile correlations; (III) to observe geochemical variations of TOC, HI and OI (Oxygen Index) values that could be associated to changing depositional patterns during different tectonic pulses of the basin and at different compartments, i.e. based on integrated geochemical-stratigraphic analysis.

METODOLOGY AND CONCEPTUAL REVISION

STRATIGRAPHIC FRAMEWORK

A geologic cross-section (NE-SW) was obtained from correlation of four composite profiles (containing lithological, Gamma Ray and Spontaneous Potential data). From those profiles, it was chosen one well from each basin compartment and one near the Itanagra-Araçás Fault (Figure 1).

This study uses a new method for stratigraphic mapping of rift basins proposed originally by Prosser (1993) and that have been applied in the Brazilian rift basins by Küchle et al. (2005, 2007). This method is based in the knowledge that the stacking patterns are not controlled solely by changes of base level (Schanley & McCabe, 1994) or of accommodation space (Jervey, 1988), but mainly by episodes of tectonic activity in the basin.

ORGANIC GEOCHIMICAL ANALYSIS

Fifty-one samples were analyzed by the following methods:

Total Organic Carbon

The organic matter contents of rocks is usually expressed as TOC (Total Organic Carbon), which includes: (i) insoluble matter (kerogen) and (ii) soluble matter (betumen).

The classification of the potential to generate hydrocarbons used in this study follows the TOC content table proposed by Peters & Cassa (1994).

Rock-Eval Pyrolysis

The Rock-Eval Pyrolysis consists in a laboratory simulation of natural process of the organic matter maturation. This simulation is used to identify the rock potential to generate hydrocarbons (Epistelié et al., 1977).

The Rock-Eval Pyrolysis registers the following parameters: peak S_1 (mg HC/ g rock); peak S_2 (mg HC/ g rock); peak S_3 (CO_2/ g rock); T_{max}; Hydrogen Index (mg HC/ g TOC) and Oxygen Index (mg CO_2/ g TOC).

The T_{max} parameter is maximum temperature of hydrocarbons generation (the temperature corresponds to the S_2 peak). T_{max} increases with increasing maturation levels.

Based on HI and OI values it is possible to classify the main kerogen types and to identify the origin of the organic matter and the generation potential of the analyzed sample.

RESULTS

STRATIGRAPHIC FRAMEWORK

The geologic cross-section was divided in two main deposition stages, i.e. on two depositional sequences, under the influence of different tectonic activity:

Sequence I (SEQ I):

The sequence I (pre-rift) is represented by fluvial-aeolian-lacustrine deposits of Sergi Formation, the lacustrine deposits of Itaparica Formation and fluvial sediments that were reworked by aeolian systems of Água Grande Formation. It is not possible to observe the basal limit of this sequence, because the wells do not reach enough depths. The upper limit of Sergi Formation is marked by the maximum flooding surface I (MFS I). The MFS I comprises fine-grained lacustrine sediments of Itaparica Formation. The top of the sequence have an abrupt change in the stacking pattern that marks the sequence boundary II (SB II).

Sequence II (SEQ II):

The sequence boundary II marks an important climatic change (from arid to humid conditions) and the beginning of rift stage.

The SEQ II began with the deposition of lacustrine shales from Candeias Formation (Tauá Member) that overlies in unconformity the Água Grande Formation sandstones (Rift Initiation Systems Tract). With the relative increase of the basin subsidence taxes began the deposition of shales, limestones and turbidite sandstones of the Candeias Formation (Gomo Member) and the lacustrine shales of the Maracangalha Formation. A retrogradation stacking pattern is evidenced in all the studied wells and suggests a Rift Climax Systems Tract. With a new climatic change (humid to arid) and a relative tectonic quiescence in the basin, thick packages of turbidite sandstones of the Marcangalha Formation were deposited (Pitanga and Caruaçu members). With the shallowing of the basin, a progradation initiated with the deltaic systems of Pojuca Formation and the fluvial-deltaic of São Sebastião Formation, suggesting a Rift Filling Systems Tract.

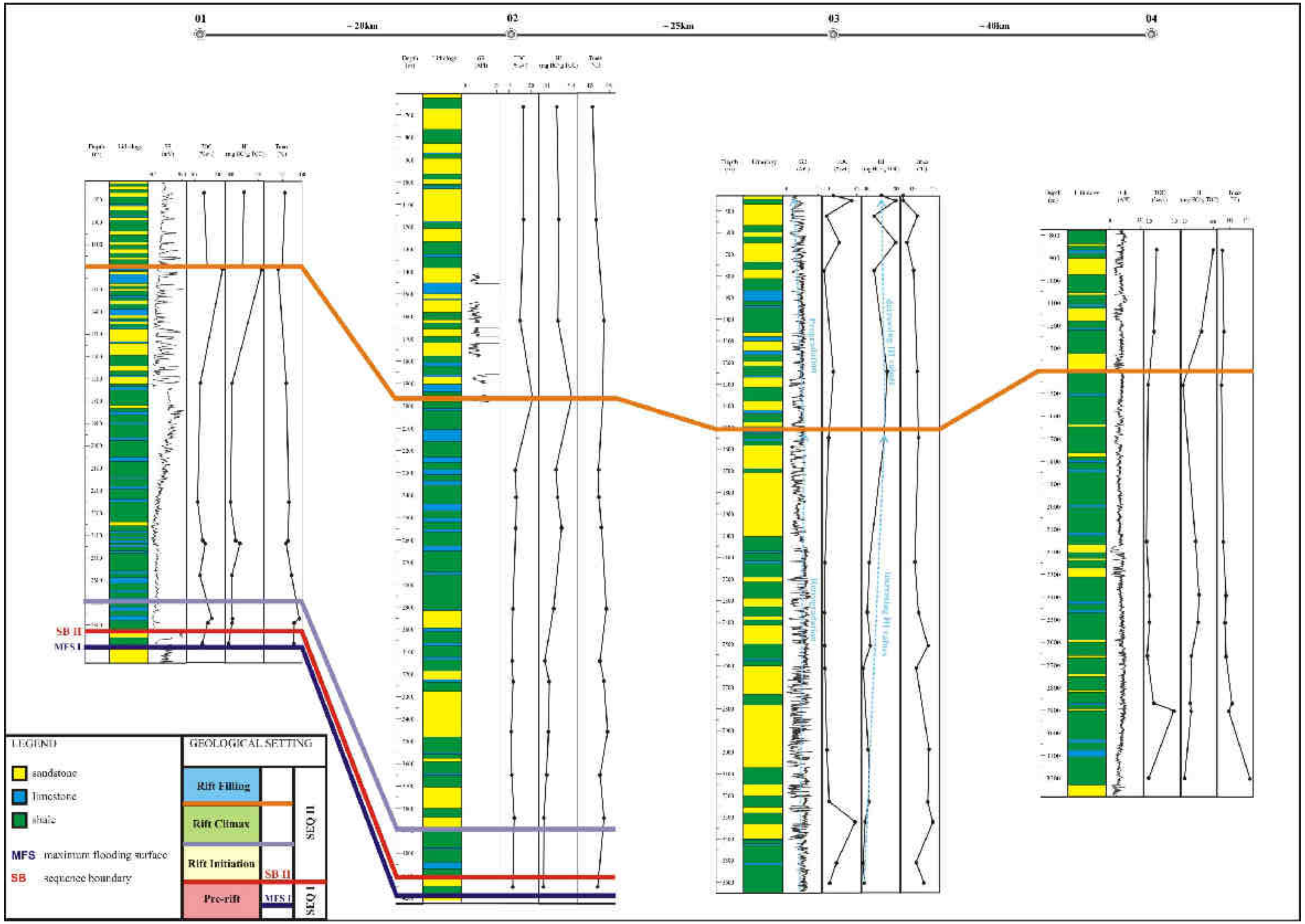

Figure 2. Geologic section NE-SW of the Recôncavo Basin composed for 4 wells.

ORGANIC GEOCHIMICAL ANALYSIS

Figure 2 shows that samples from SEQ I have TOC values between 0.78 – 1.00% wt., that indicates high potential for generation of hydrocarbons. Samples from SEQ II have TOC values between 0.68 – 4.31% wt., which indicates intermediate to excellent potential for generation of hydrocarbons. This parameter indicates that Candeias Formation is the lithostratigraphic unit with the greater hydrocarbon generation potential (4.31% wt.).

Figure 2 also notices for all the wells that increasing depths correspond to increasing T_{max} values. The majority of the samples plot in the oil window (435 - 452 °C). Only four samples have temperatures < 435ºC (immature rocks) and one sample have temperature > 465ºC over mature. Based on the obtained HI and OI values, the Van Krevelen diagram (Figure 3) was plot using all the analyzed samples.

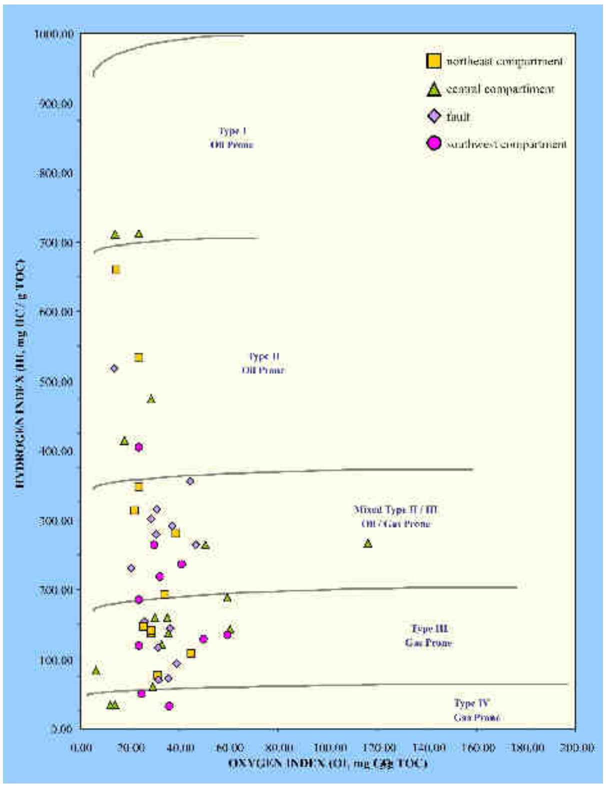

Figure 3. Plots of HI vs. OI values from all the analyzed samples in the Van Krevelen diagram.

It can be noted that samples from wells 01 and 02 are quite similar. Both plot in the fields of type III kerogen, mixture II/III and II, with low to high HI values and potential to natural gas generation, mixtures of oil/gas and oil. Samples from well 03 are widespread over the diagram area, from type IV kerogen (low HI values and no oil generation potential) to the field type I kerogen (high HI values and high potential for oil generation). Samples from well 04 plot in the fields of type IV to type II kerogen, with HI values that are slight lower than those from samples of the central compartment.

INTEGRATED GEOCHEMICAL-STRATIGRAPHIC ANALYSIS

Observing the geochemical and geological data proposed on Figure 2, we can notice that HI values increases with the general retrogradation stacking pattern developed during rift initiation and rift climax systems tracts.

However, those values decrease with the progradation of fluvial-deltaic systems during the Rift Filling Systems Tract. Well 01 have HI values between 72.00 – 326.01 mg HC/g TOC from pre-rift to Rift Filling sequence. Well 02 shows HI values between 62.82 – 348.64 mg HC/g TOC from Pre-rift to Rift Filling. Well 03 have HI values between 140.68 – 479.21 mg HC/g TOC from the Rift Climax until the Rift Filling. Finally, well 04 presents HI values from 133.46 up to 329.79 mg HC/g TOC from the Rift Climax until the Rift Filling.

In such a way, it is possible to conclude that in all wells the HI values increase to the top. Moreover, these values tend to decrease through the southwest direction in samples from rift climax and rift filling system tracts.

CONCLUSIONS

Through the TOC analysis of generating potential in samples from SEQ I and II, it is possible to observe a similarity between the well from the northeast compartment and the well near Itanagra-Araçás, as well as a similarity between the wells from southwestern and central compartment. Moreover, samples with the better potential for oil generation are from the central compartment.

Integrating geochemical and geological data from the Recôncavo Basin, it can be concluded that the values of HI increase during the Rift Initiation and the Rift Climax and decrease during the Rift Filling Systems Tract. As a conclusion, the values of HI vary in accordance with the stacking pattern. Moreover, the average of the HI values tend to increase during transition from Pre-rift until Rift Filling stage and diminish through the southwestern compartment direction. This can confirm the hypothesis that beyond controlling the conditions of basin sedimentation, the different tectonic activity stages also yielded fluctuations in the quality of the produced organic matter.

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