LOWER CRETACEOUS TURBIDITE RESERVOIR CHARACTERIZATION IN THE SOUTH PART OF THE RECÔNCAVO BASIN, BRAZIL

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Abstract

The Maracangalha Formation was mapped using 2D and 3D seismic data on BT-REC-8 Block of the Recôncavo Basin. Within the block area the Maracangalha Formation is present as the Pitanga and Caruaçu members. Geological and petrophysical studies were conducted on the Caruaçu Member sandstones as they are commercially important in the area.

The geological model of Caruaçu Member used in this paper was based on Jacuípe and Miranga Profundo field analogues where turbidite channel and lobe deposits form hydrocarbon bearing resorvoirs. Porosity and permeability within the Caruaçu turbidite sandstones at BT-REC-8 form the reservoirs of the Jaó discovery field.

The Jaó Field, discovered by 1-QG-4 well drilled by Queiroz Galvão Óleo & Gás and Brasoil do Brasil in 2007, has potential resources estimated between 1,1 and 3,6 MMBO over a 9 km^2 area.

Introduction

The BT-REC-8 Block was acquired during the fourth ANP Round of bidding in 2002. It is located in the south compartment of the Recôncavo Basin (Fig. 1) and is situated on the hanging wall of the Mata-Catu Fault. The block, towards west is delimited by Massapé, Caruaçu and Taquipe fields. The presence of these fields and the source depocentre to the southeast confirm the presence of hydrocarbons in the area (Fig. 2).

In the Recôncavo Basin, the hydrocarbon migration process usually occurs through normal faults and discontinuities. This appears to be the case at Jaó Field. The trapping mechanism at the Jaó Field is a combination of structure and stratigraphic factors.

The Caruaçu Member reservoirs found in the 1-QG-4 well are characterized by sandstone layers between 5 and 10 m thick interbedded with shales.

The sandstones are clean, with low clay content and show a fining upward sequence with variable lateral thickness and discontinuity.

At the base of the Maracangalha Formation package, the Pitanga Member sandstone is found. It exhibits, a blocky gamma ray character over its entire thickness. It has a maximum thickness of approximately 370 m and is interpreted as reworked sandstones deposits (Fig. 3).

The stratigraphic correlation between three wells(1-QG-3, 1-QG4 and 1-TI-4) in the Jaó Field area made the interpretation of Caruaçu turbidite deposits in the area possible (Fig. 3).

In the 1-QG-4 well area the sandstones are not fractured and tend to have good to fair porosities and low permeabilities. The equivalent sandstones found in the Jacuípe and Miranga Profundo fields have enhanced permeability and reservoir quality as a result of fault and drape related fractures.

Methodology

Reprocessing of 3D seismic data by Geo-x in Calgary, Canada improved Caruaçu Member resolution and made it possible to map a stratigraphic/structural trap on the block. Geological information was tied to the seismic data by check shot information obtained from the 1-QG-4 well.

Stratigraphic correlation of the 1-QG-3, 1-QG-4 and 1-TI-4 wells in the area used sequence stratigraphy concepts. The sequence datum used is a continuous shale layer that occurs in the clay zone in the three wells where a correlatable gamma ray interval was picked.

The hydrocarbon presence in the 1-QG-4 well was detected in the well cuttings and gas detector measurements. Formation tests and production tests were then conducted on these intervals.

Oil in place volume estimates were achieved through a deterministic distribution using area, porosity and water saturation as variables.

Seismic Data

Seismic interpretation over the area was based on a time data set. A time-depth conversion was performed by using check shot data from 1-QG-4 well and sonic information from the neighbouring offset wells of 1-TI-4, 1-TI-3 and 1-FFL-1.

Two prospects were generated from the 3D seismic interpretation. These resulted in the drilling of 1-QG-3 and 1-QG-4 wells.

The main objective of the 1-QG-3 well were the Caruaçu Member turbidites sandstones. Despite indications of gas detected in these sandstones during drilling, the formation tests recovered water in these zones and the well was abandoned.

The target of the 1-QG-4 well was a tilted fault block at the Sergi Formation level that exhibited structural closure. The sandstones of the Caruaçu Member were considered as a secondary objective due to poor seismic resolution of this member. The Sergi sandstone encountered was wet and abandoned while the overlying Caruaçu Member was encountered as oil bearing. After confirming oil in the Caruaçu Member, 3D data reprocessing improved the seismic quality in this interval. It was then possible to map the structural/stratigraphic trap and observe the discontinuous reflectors related to the productive sandstones (Fig. 4).

The seismic structure map and seismic sections of the oil bearing sandstones show reflector discontinuities in several directions and are interpreted as sandstone pinch outs within the Caruaçu Member. In the NW, NE and SW directions the reflector disappearance is related to reservoir pinch out and to SE direction is controlled by faulting. The 1-QG-4 well was drilled near the reflector disappearance (Fig. 4).

Stratigraphy

The Maracangalha Formation is a third order depositional sequence divided into transgressive tract at the base and a regressive tract at the top (Carlotto & Scherer, 2006).

In this work, the transgressive tract of this third order sequence, which contains the main reservoirs in the Jaó Field area, was studied.

The sequence boundaries interpreted are fourth order and were identified from block patterns sandstones in the gamma ray pattern in the three wells.

The stratigraphic datum used is a continuous shale layer identified as a transgressive surface of the fourth order sequence. It is characterized by a pick on the gamma ray in the 1-TI-4 well.

A basal fine sandstone package found at the base of the Maracangalha Fomation as seen in the 1-TI-4 and 1-QG-4 wells (Fig. 3) belongs to Pitanga Member. Thickness varies between 110 and 370 m. The Pitanga Member sandstones are characterized by a serrated gamma ray pattern and API values around 60. These Pitanga characteristics are similarly found in the Jacuípe and Miranga Profundo fields (Caixeta, 1988; Magalhães, 1990; Carlotto, 2006).

The Pitanga Member deposition marks a climatic change within a lacustrine environment. According to Silva & Picarelli (1990), during the transition from Middle Rio da Serra Stage to Upper Rio da Serra Stage, a climatic change occurred from humid to dry and was combined with a period of relative tectonic quiescence. These two concurrent factors made possible, during the Upper Rio da Serra Stage, an increase in sedimentary deposition basin ward. Erosion occurred in the platform areas in the N-NW direction and deposition, of thick aggradational reworked sediment of the Pitanga Member occurred in the regional lows (Fig. 5). These deposits are interpreted by Carlotto (2006) as intermediary slope stages characterized as slump and debris flows. These gravity flows were triggered by episodic earthquakes related to rift induced tectonic activity.

In the 1-TI-4 well, the serrated pattern observed in the gamma ray with API around 75 indicates silt-sand sediment deposition. Interbbeded, sandstones packages with API 50-60 record the initiation of the new fourth order sequence (figures 3 and 5). In the 1-QG-4 and 1-QG-3 wells, the API values increase to around 90, which suggest dominant shale deposition. It is possible to correlate these deposits to the turbidite lobe deposits identified in the Jacuípe (Caixeta, 1988) and Miranga Profundo fields reservoirs (Magalhães, 1990) .

The two sequences toward the top were defined by a gamma ray pattern which suggests an increase clean sandstone entering the depositional system with better lateral reservoir continuity. These sequences can be classified similar to the channel turbidite deposits of Caixeta (1988) (Fig.3).

According to Caixeta (1988) and Magalhães (1990), the better reservoirs of the Maracangalha Formation are 1) lobes or sandy fans (proximal area); 2) sandstones deposited within channels and related to high density turbidite currents (distal area) and 3) sandstones bars of the delta front (shallow water) (figures 3 and 5).

Conclusively, within the Maracangalha Formation of the 1-QG-3 and 1-QG-4 wells area are sandstones considered equivalent to the main reservoirs in the Jacuípe and Miranga Profundo fields. A factor influencing the poorer reservoir quality at the Jaó Field in terms of permeability may be the absence of fractures. In Jacuípe and Miranga Profundo fields, fractures generated by listric faults along diapir flanks and drape significantly enhanced the porosity within the Maracangalha reservoirs.

At the top of the Maracangalha cycle, the repetitive coarsening upward gamma ray pattern of the sandstone deposits may possibly indicate the earliest deltaic sediment depositions of the Pojuca and Marfim formations and mark the last discontinuity interpreted.

Reservoir Characterization

Wire-line log interpretation combined with gas detector anomalies revealed five oil bearing sandstone intervals in the Caruaçu Member. Intervals 2055 - 2062m and 2130 -

2135m were tested through casing (Fig. 6). Later the remaining three intervals were perforated and all five zones were co-mingled and produced during a long duration production test.

Despite having good to fair porosities of 10% to 15% the long duration test showed sands in Test #1 (2130 - 2135 m) with very low oil productivity and calculated permeabilities in the order of 10 mD or less. According to Test #2, the interval 2055 - 2062 m did not produce any formation fluid indicating absence of effective permeability.

Sonic correlations revealed the presence of non connected secondary porosity and helps explain the low productivity of these sands with their good to fair porosities (the larger pores remain isolated in the sand matrix and only the low permeability micropores are interconnected). Sonic transit times lower than the expected values were derived from correlations with neutron and density logs. Lower than expected sonic values are characteristic behaviour of sonic waves traveling in a sand matrix while bypassing isolated pores. This sonic character suggests that effective interconnected porosity in reality is extremely low or absent.

In order to characterize porosity in the area of well 1-QG-4 a geological section was prepared highlights porosities from the density logs. The geological section (Fig. 7) shows no regular pattern with respect to lateral and vertical continuity of the Caruaçu Member reservoir sandstones**.**

Resources

The hydrocarbon volumes of the accumulation discovered by the well 1-QG-4-BA were calculated using deterministic analysis of isochores and HxPhixSo maps.

The isochore map was calculated from the structural depth maps assuming that the topmost reservoir is the top of the producing zone and the base is the last perforated zone. The oil water contact was interpreted at 2078 m.

From the isochore map a net to gross sand/shale value was calculated. The petrophysical parameters (porosity and oil saturation) interpreted from the well logs were applied to the net sand values over the area.

Oil in Place calculations resulted in a range of 9.4 to 30 million barrels. For the recoverable volume a recovery factor of 12% was used resulting in a range of 1.1 to 3.6 million of barrels.

These volumes are classified as contingent resources (3C) according to SPE Petroleum Resources Management System (PRMS).

Conclusions

The 1-QG-4 discovery has revealed an oil accumulation in a structural/stratigraphic trap with sandstones thinning up dip on a homoclinal structure. The closure up dip is reservoir sandstone pinch out.

The oil reservoirs are in Caruaçu Member sandstones over five separate intervals whose overall oil effective net oil pay thickness is 21 m. The maximum area of accumulation reaches 9 km^2.

The main sandstone reservoirs in the 1-QG-4 well were interpreted as turbidite channel deposits. Porosities measured on the logs averages 12 to 16%. The permeabilities calculated from the formation tests varied between 1mD and 10 mD.

In the Recôncavo Basin, the Caruaçu Member sandstones are good reservoirs when they are naturally fractured like at the Jacuípe Field. The Caruaçu sandstones of the Jaó Field on the BT-REC-8 Block lack these fractures and their enhanced permeabilities. As a result they tend to be low productive reservoirs. Artificial fracture technology may improve reservoir productivity at this location.

References

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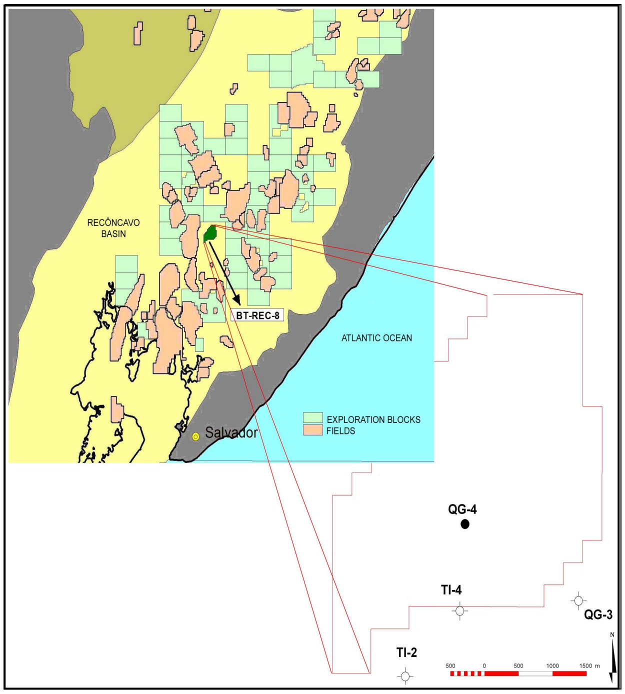

Figure 1 - Location map of the BT-REC-8 Block and wells.

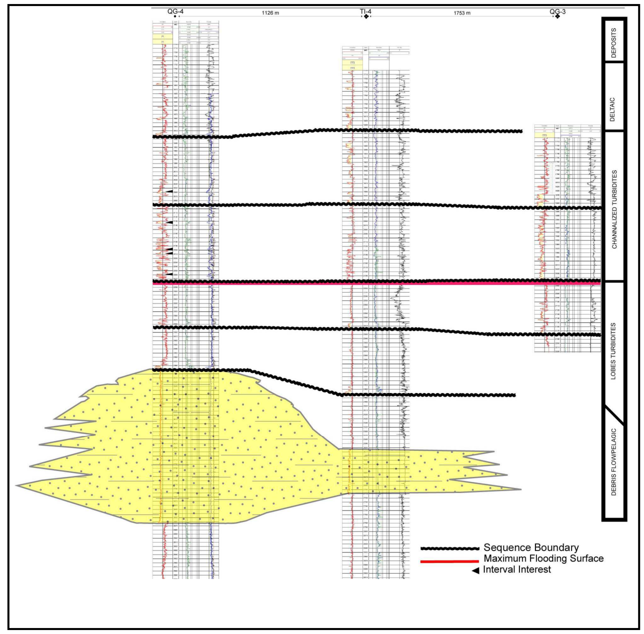

Figure 3 - Correlation section showing fourth order sequence boundary, Caruaçu sandstone interval of interest and Pitanga deposits identified in 1-QG-4 well area.

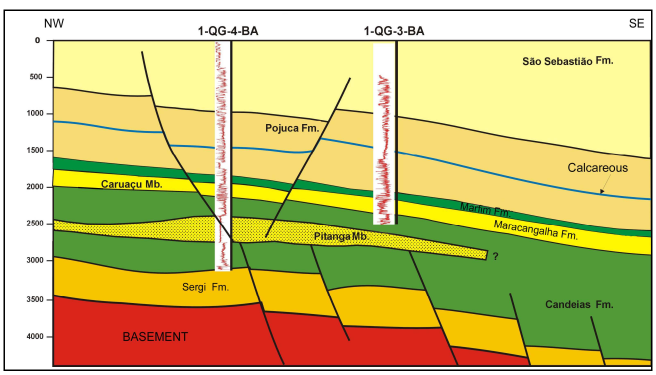

Figure 2 - Schematic geological section of the Caruaçu Member.

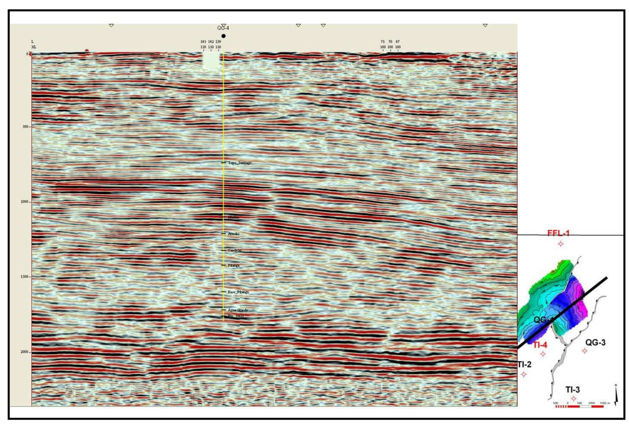

Figure 4 - NW-SE seismic section showing the sandstone reflector of the Caruaçu Member in the QG-4 well.

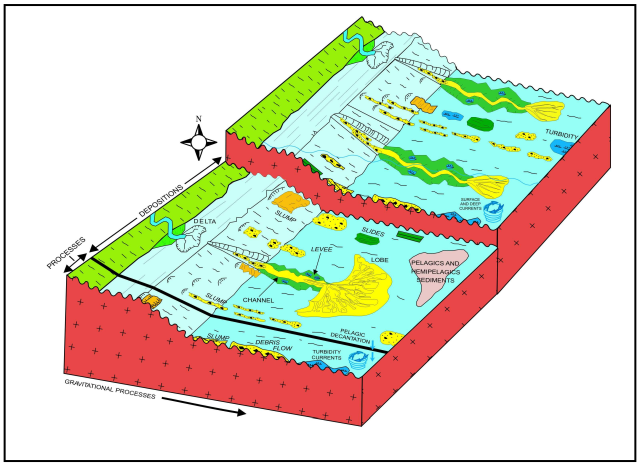

Figure 5 - Block diagram showing the depositional system of the Maracangalha Formation. Shows lobes and channel turbidite deposits of the Caruaçu Member.

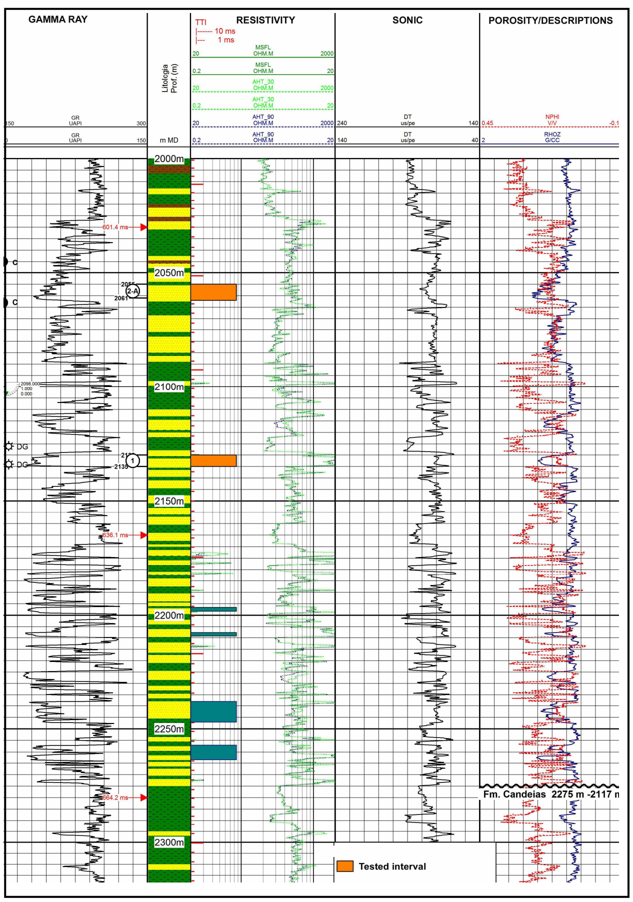

Figure 6 - Perforated interval of the Caruaçu Member in the 1-QG-4 well.

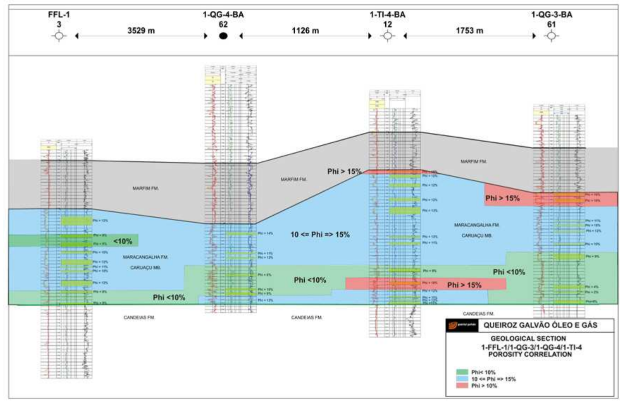

Figure 7 - Geological section showing the porosity distribution between wells in the BT-REC-8 Block area.