# Well Log Lithological Analysis and Petrophysical Parameters Calculation of Miocene to Recent Formation Reservoirs in Well P10, Offshore, Northern Rio Del Rey Basin (Southwest Cameroon, Gulf of Guinea)

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# Abstract

The P10 well is located offshore, in the Northern part of the Rio Del Rey basin in southwest Cameroon. Although the Rio Del Rey basin is the most prolific coastal basin in Cameroon given the production results from several fields in the southern part, yet it remains very little explored in its northern part. This work evaluation the petroleum potential in the northern part of the Basin using a combination of the "Quick Look" interpretation of the logs recorded in well P10 and "complex matrix" facies analysis of the different lithofacies through the neutron porosity - bulk density (NPHI-RHOB) and delta time sonic - bulk density (DT-RHOB) diagrams. The composite log includes the Gamma Ray log; Caliper log; Deep Resistivity log; neutron porosity log and bulk density log. In addition to this composite log, a geological end of well report is completed to refine the results. Ten (10) near sand/sandstone reservoirs were delineated between 950 and 1803 TVD m (true vertical depth in meter) with very good porosities ( $12\% < \Phi < 30\%$ ) as well as a mineralogical composition dominated by quartz. Clay volumes are relatively lower than 18% except in reservoirs R5 and R6 where they are around 24%, giving the latter a sandy-clay lithology. Reservoirs R2 and R4 contain oil, the latter with a WOC (Water Oil Contact) at ~1172 m and a GOC (Gas Oil Contact) at 1169 m. Reservoirs R6; R7; R8; R9; R10 all contain Gas and Water with WGC (Water Gas Contact) located at ~1431 m; 1530 m; 1690 m and ~1790 m respectively. In the light of these results, there is a clear dominance of gaseous hydrocarbon reservoirs over oil-impregnated ones in the study area. The results provided by this work can serve as baseline data for future oil and gas exploration projects in the northern part of the Rio Del Ray Basin.

Keywords: Rio Del Rey, logging, lithofacies, reservoirs, petrophysical parameters, hydrocarbon

# 1. Introduction

Petroleum geology of Cameroon showed that the country has several types of sedimentary basins (Aptian – Recent) with petroleum systems identical to those found in other countries located in the Gulf of Guinea (Abolo, 2008; Fozao et al., 2017). On the one hand, there are intracontinental basins consisting of the Logon Birni (Zina and Makari) basins; the Mamfe basin and the Garoua basin. On the other hand, there are the coastal basins occupying the Cameroonian margin are made up of the Rio Del Rey (RDR) basin and the Douala-Kribi/Campo (D-K/C) basin. Hydrocarbons is currently being produced in this latter type of sedimentary basin in Cameroon (SNH, 2018). According to results obtained from oil exploitation, the Rio Del Rey Basin, which is the eastern extension of the Niger Delta oil basin, is the most prolific basin in Cameroon. Here more than 96% of the national crude oil has been produced since 2015 in about 60 fields (SNH, 2017). The exploited wells are mostly located in the southern part of the basin. Despite the high production rates, the northern part has remained less studied due to its accessibility and the border conflict between the Republic of Nigeria and Cameroon. Also, several studies on petroleum geology have been carried out using logs in the southern part (Kabbabe, 2008; Noudjo et al., 2018), but very few combine the quick look analysis method and complex matrix facies analysis to

bring out formations' evaluation. This study is therefore aimed to characterize the different Miocene reservoir formations of well P10 in terms of their lithology, type of fluid contained, mineralogy and petrophysical parameters.

# 2. Geological Settings

The Rio Del Rey basin occupied part of the Cameroonian Atlantic margin (Fig. 1). It is located between latitude  $3^{\circ}$  and  $5^{\circ}$ N and between longitude  $8^{\circ}$ 20' and  $9^{\circ}$ 10' E (Longmore and Lee, 2010). It is a passive margin basin, formed by the dual processes of rifting and oceanisation (Saugy et al., 2003; Mvondo et al., 2011). It represents the south-eastern extension of the Niger Delta in the Gulf of Guinea (Coughlin et al., 1993). Its stratigraphy is broadly similar to that of the Niger Delta basin, from which it is contemporary received sediments. At the base, basin is made up of Paleocene Akata clays with intercalation of Eocene Oongue turbidites (Doust and Omatsola, 1990; Schlumberger, 1993). We find above Miocene deltaic sequences of the Abagda with intercalation of Lower Miocene Isongo and Upper Miocene Nguti turbidites. More at the surface, Pliocene-recent Benin sands (Fig. 2)



Figure 1. Location of the study area in the Gulf of Guinea (modified Fozao et al., 2017)



Figure 2. Lithostratigraphic column of the Niger Delta basin, similar to the RDR basin (Doust and Omatsola. 1990, modified by Schlumberger 1993)

The Rio Del Rey mangrove belongs to the Cameroon coastal domain (Din and Blasco, 1998). In this basin, the altitudes of the different geological forms vary from sea level to more than 4000 m at the top of Mount Cameroon (Fig. 3). There are elongated banks of solid ground, a few meters high. In the middle of the mangrove these firm ground banks support forest vegetation. This basin is separated from the Douala-Kribi/Campo basin by the Cameroonian volcanic line (Ntamak-Nida et al., 2010).



Figure 3. Digital elevation model (DEM) illustrating the geomorphology of the study area

## 3. Data and Methods

This study uses log data recorded in LAS (log Ascii standard) format in well  $P_{10}$  drilled in 2005 to a depth of 1850 TVD m in the shallow sea at the northern part of the Rio Del Ray basin (Fig. 4). The log composite consists of Gamma ray (GR); bulk density (RHOB); neutron porosity (NPHI), deep resistivity (RDEEP) and delta time (DT) sonic log. Data completed by different ages of formations identified inside this well contained in the geological end of well report.



Figure 4. Location of the P<sub>10</sub> well in the Rio Del Ray basin

## 3.1 Quick Look Qualitative Analysis

The lithology, potential reservoirs and the type of fluids they contain were analyzed qualitatively using the "Quick look" analytical method developed by Serra (1979). In order to distinguish between sandy lithofacies (negative polarization) and clay lithofacies (positive polarization), the GR logs were calibrated between 0-150 API, 0-75 API for sand/sandstone and 75-150 API for the clays (after Serra 1979). This lithology was defined using a combination of NPHI (0.6-0.0  $\text{m}^3/\text{m}^3$ ) and RHOB (1.71-2.71 g/cm<sup>3</sup>) (Meunier 2011; Delalex 2014). The deep resistivity RDEEP (100-2000 Ohm m) was used to indicate the presence of hydrocarbons in the different reservoir Formations. Their differentiation was achieved using the "gas effect" (GE) after combining once again the NPHI-RHOB.

#### 3.2 Quick Look Quantitative Analysis

The petrophysical parameters of the reservoir formations such as porosity, net to gross and the volume of shale were characterized quantitatively using empirical formulae on the composite log (Asquith 2004).

## - Porosity calculation

The porosity of the different reservoirs was determined using the RHOB and NPHI curves. It is expressed as a percentage (%) and is classified as poor to excellent depending on whether it is between 5 and 35%, respectively (Rider, 1986). Porosity is generally determined from the RHOB log using equations 1. Only the porosity of water-bearing reservoirs remains reliable with the known fluid density ( $\rho$ f). Currently, the neutron porosity log is used to calculate the porosity of reservoirs depending on the nature of the reservoir gas; oil or water impregnated reservoir (equations 2; 3 and 4; Meunier 2011; Varhaug 2016).

Porosity from the bulk density curve

$$\Phi d = \frac{\rho m a - \rho b}{\rho m a - \rho f l} \tag{1}$$

with

 $\Phi d$ : porosity from bulk density rock

pma : bulk density of rock matrix given

 $\rho b$ : bulk density of bulk, sandstones/sand (SiO<sub>2</sub>)= 2.65g/cm<sup>3</sup>

ρfl : bulk density of fluid

Total porosity of a reservoir impregnated by oil and water:

$$\Phi t = \frac{\phi_{N+\phi d}}{2} \tag{2}$$

Total porosity of a reservoir impregnated by the gas:

$$\Phi t = \frac{\Phi N + 2\Phi d}{3} \tag{3}$$

Effective porosity of the reservoir:

$$\Phi e = \Phi t \left( 1 - V s h \right) \tag{4}$$

#### - Volume of shale

Using the baselines of the sands and clays, the GR log allows the volume of clay (Vsh) to be calculated through the linear relationship (equation 5). This procedure is simple and straight forward, and can give reasonable results for some deep reservoirs. However, the linear shaliness indicator (IGR) often results in an overestimation of the clay volume of the rock (especially for young and shallow reservoirs). To overcome this, several empirical formulas have been developed to correct and reduce the reservoir rock clay volume. These are a direct function of the IGR (Vsh= f (IGR)). In this case, the non-linear formula for Tertiary rocks of Larionov (1969) is used (equation 6).

$$V_{sh} = I_G = \frac{(GRlog - GRmin)}{(GRmax - GRmin)}$$
(5)

with

GRlog: GR value of the bank read directlyfrom the log (API);

GRmin: Minimum GR value of the same bank (API);

GRmax: Maximum GR value of the same bank (API);

IGR: Gamma ray radiation index;

Vsh: Volume of clay.

Ancient and Tertiary rocks have a non-linear equation (Larionov, 1969):

$$Vsh = 0.083(2^{3.7 \text{ IGR}} - 1) \tag{6}$$

Potential reservoirs have variable lithological compositions depending on the clay content (Serra 1979). Levels considered sandy (sandstone) will have clay volumes between 10 and 25%; sandy-clay 25 to 35% and sandy-clay between 35 to 50%.

- Net to Gross (N/G)

This is the cumulative height of the clean parts of a reservoir (sand/sandstone) over the total height (equation 7).

$$N/G = \frac{\sum_{i=1}^{n} Hi}{Ht}$$
(7)

with

N/G: clean tank thickness over the total thickness

Hi: thickness of the clean electrostatic precipitators

Ht: total thickness of the tank

In a second phase, another methodological approach will be combined with the previous one, namely the ''facies analysis in complex matrix'' (Augier, 1980; Mathis 1988) of the different lithofacies through the cross-plots in the selected Schlumberger abacuses (NPHI-RHOB and RHOB-DT). In addition to confirming the lithological nature and petrophysical parameters, it will give the mineralogical composition of the delineated reservoir formations.

## 4. Results and Interpretation

#### 4.1 Lithology, Fluid Types and Petrophysical Parameters of Reservoirs from Quick Look Analysis

In the well P10 a Pliocene to recent surface aquifers (TVD < 950 m) was identified. Besides this aquifer, ten (10) Miocene reservoirs with varying thicknesses were also delineated. The formations traversed by the well were dated using the end-of-hole geological reports. These are generally sandy reservoirs with Net to Gross (N/G) ratios > 81% and clay volumes 5% <Vsh < 25%. The exceptions are the  $R_5$  and  $R_6$  reservoirs with clay volumes around 24% (Table 1). The effective porosities vary between 12 and 30 %. According to the porosity classification by Rider, 1986, nine (09) of the ten (10) reservoirs have very good porosity 20% < $\Phi$ <30% and only  $R_4$  has good porosity ( $\Phi$ =12%). Amongst the 10 reservoirs identified,  $R_2$  is enriched in oil while the $R_4$  reservoirs contains oil, gas and water with a water oil contact (WOC) cited at 1172 m and a gas oil contact (GOC) at 1169 m. Reservoirs  $R_6$ ,  $R_7$ ,  $R_9$ ,  $R_{10}$  all contain gas and water with a water gas contact (WGC) located at 1431 m, 1530 m, 1690 m and 1790 m respectively (Figs. 6, 7). Finally,  $R_8$  contains only Gas while  $R_1$ ,  $R_3$  and  $R_5$  contain only Water (Figs. 5,6).



Figure 5. Reservoirs (R<sub>1</sub>; R<sub>2</sub>; R<sub>3</sub>& R<sub>4</sub>) with interpreted lithology and fluid types in Well P<sub>10</sub> (940-1200 TVD m)



Figure 6. Reservoirs R<sub>5</sub> and R<sub>6</sub> with interpreted lithology and fluid types in Well P<sub>10</sub> (1200-1470 TVD m)



Figure 7. Reservoirs R<sub>7</sub>; R<sub>8</sub>; R<sub>9</sub> & R<sub>10</sub>) with interpreted lithology and fluid types in Well P<sub>10</sub> (1470-1830 TVDm)

The computed petrophysical parameters for reservoirs in well  $P_{10}$  are shown in Table 1 below. Reservoir porosities ( $\Phi$ ) range from 12 to 30%, clay volumes (Vsh) from 5.6 to 24% and Net to Gross (N/G) from 81.25 to 94.44%. These clean formations contain mostly gas, water and less oil.

| Reservoirs            | Top Depth | Bottom | Lithology       | Thickness (m) |     | N/G   | Vsh   | Porosity | Fluids  |
|-----------------------|-----------|--------|-----------------|---------------|-----|-------|-------|----------|---------|
|                       | (TVDm)    | Depth  |                 | Ht            | Нр  |       |       |          | types   |
|                       |           | (TVDm) |                 |               |     |       |       |          |         |
| <b>R</b> <sub>1</sub> | 950       | 961    | Sand/Sandstones | 16            | 14  | 87.5  | 17.35 | 0.28     | W       |
| $R_2$                 | 988       | 996    | Sand/Sandstones | 8             | 6.5 | 81.25 | 18    | 0.22     | 0       |
| <b>R</b> <sub>3</sub> | 1078      | 1137   | Sand/Sandstones | 59            | 55  | 93.22 | 11    | 0.25     | W       |
| $R_4$                 | 1152      | 1185   | Sand/Sandstones | 33            | 31  | 93.94 | 5.6   | 0.12     | G; O; W |
| <b>R</b> <sub>5</sub> | 1202      | 1295   | Sand/Sandstones | 93            | 85  | 91.38 | 24    | 0.25     | W       |
| $R_6$                 | 1389      | 1457   | Sand/Sandstones | 68            | 62  | 91.17 | 24    | 0.21     | G; W    |
| <b>R</b> <sub>7</sub> | 1480      | 1552   | Sand/Sandstones | 72            | 68  | 94.44 | 13    | 0.30     | G; W    |
| $R_8$                 | 1629      | 1642   | Sand/Sandstones | 13            | 12  | 92.31 | 13    | 0.29     | G       |
| <b>R</b> <sub>9</sub> | 1660      | 1700   | Sand/Sandstones | 40            | 38  | 95    | 12.6  | 0.29     | G; W    |
| R <sub>10</sub>       | 1756      | 1803   | Sand/Sandstones | 47            | 44  | 93.62 | 12.65 | 0.28     | G; W    |

Table 1. Average petrophysical parameters of reservoirs in the wells  $P_{10}$ 

# 4.2 Facies Analysis in Complex Matrix

The cross-plots in the NPHI-RHOB diagram of the well  $P_{10}$  data generally show the configuration of sandstone lithobanks in almost all of the well's reservoirs with porosities of between 15 and 35%. However, there is a trace of limestone in reservoir  $R_{10}$  and traces of dolomite in reservoir  $R_6$  (Fig 8). Subsequently, the cross-plots in the DT-RHOB diagram of the same well show a mineralogical composition dominated by quartz (Fig. 9).



Figure 8. Cross-plots neutron porosity (NPHI)- bulk density (RHOB) of reservoirs in well P<sub>10</sub>



Figure 9. Cross-plots Sonic (DT)- bulk density (RHOB) of reservoirs in well P<sub>10</sub>

# 5. Discussions

This study, based on well log data from well P10 in the northern part of the Rio Del Rey basin, reveals large petroleum systems consisting of Miocene deltaic alternations of sandstone/sand (reservoir rocks: R1; ...R10) and clays (source rocks and cap rocks). In some cases, there are silt layers and rarely limestone. These sequences are identical to those described by Blin (2000) in the South of the Rio Del Rey basin. Based on the classification by Rider (1986) an average porosity of  $\Phi \approx 20\%$  obtained in the different formations are generally very good. Clay volumes are lower (between 6 and 24%) compared to those reported by Iboum et al., (2021) in the southern part of the basin. This variation in petrophysical parameters can be attributed to the fact that the North is the feeder zone of the basin, thus sediments deposited there are coarser and have not undergone long transport compared to those encountered in the South of the basin where much finer sediments such as clays and silts are found as indicated by Noudjo et al., (2018). Complex matrix facies analysis through cross-plots in the NPHI-RHOB and DT-RHOB diagrams, confirms sandstone reservoirs, with porosities between 15 and 35% as well as a mineralogical composition dominated by quartz. This study has shown that the deltaic alternations of the Abagda, where hydrocarbons is produced in the southern part of the basin and mentioned by the authors above, are also found in the northern part, with the only difference that here we have coarser sediments which give them very good porosities and low clay content in the reservoirs. On the other hand, the combined use of "Quick Look" (Serra, 1979) analysis and "Facies analysis in complex matrix" (Augier, 1980; Mathis 1988) approaches remain effective in the characterization of the reservoirs. The analysis of the oil results shows that out of 10 identified reservoirs, only 02 have thin oil layers and 06 have gas layers. This leads us to believe that in the northern part of the Rio Del Rey Basin, there are many more gaseous hydrocarbons than liquid ones.

# 6. Conclusion

At the end, the following conclusions can be drawn from this study

- Sand/sandstone lithofacies are abundant (5%<Vsh< 25%) with a minimum Net to Gross (N/G) of 81%. These facies show an average porosity  $\Phi = 20\%$  in all 10 reservoirs.

- Analysis of the cross-plot diagrams (NPHI-RHOB and DT-RHOB) confirms a sandstone lithological nature and a mineralogical composition dominated by Quartz.

- Most of the Miocene formations identified in this northern part of Rio Del Rey basin contain hydrocarbons. There is a clear dominance of gaseous reservoirs ( $R_4$ ;  $R_6$ ;  $R_7$ ;  $R_8$ ;  $R_9$ ;  $R_{10}$ ) over those containing oil ( $R_2$  and  $R_4$ ).

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