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ANALYSIS OF GEOPETROLEUM DATA FROM THE NGA-1, KNY-1 AND BYU-1 EXPLORATION WELLS IN THE NGANZI BLOCK, ONSHORE D.R. CONGO COASTAL BASIN

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Résumé

Les trois puits d'exploration forés dans le bloc Nganzi en Onshore du bassin côtier de la RDC, ayant pour objectif le réservoir présalifère Lucula démontrent la position stratigraphique sus-jacente de la roche mère Bucomazi moyen sur la roche réservoir Lucula. Malgré la bonne porosité moyenne de 18% et la perméabilité relative de 110 millidarcy de cette dernière, elle présente une saturation nulle en hydrocarbure liquide dans les trois puits d'exploration Kinganga Myanga-1 (KNY-1), Nganga-1 (NGA-1), et Byangu-1 (BYU-1). La compréhension de la position stratigraphique inversée entre la roche mère Bucomazi moyen et la roche réservoir Lucula conduira à une bonne connaissance sur la migration des hydrocarbures liquides dans la zone d'étude, leur piégeage ainsi que l'alimentation et l'accumulation en hydrocarbures liquide des structures- pièges du réservoir Lucula.

Mots clés : -

Abstract

In the Nganzi Block, onshore DR Congo, three wells have been drilled in plays that demonstrate an inverted stratigraphic relationship between the Middle Bucomazi source rock beds and the older Lucula Sandstone reservoirs. Despite having an average porosity of 18% and a relative permeability of 110 Millidarcy, the Lucula Sandstone reservoirs have little hydrocarbon saturation in the three exploration wells; Kinganga Myanga-1 (KNY-1), Nganga-1 (NGA-1), and Byangu-1 (BYU-1). An understanding of the relationship between the inverted stratigraphic relationship and the hydrocarbon charge will lead to greater confidence in migration, charge and trap of this play.

Key words : Hydrocarbon Saturation, halokinetic tectonics, trap, cratonic, pre-salt, listric faults, logs

1. INTRODUCTION

The existence of the petroleum basins along the West African coast, from Angola to Nigeria, is closely linked to the rifting of the Gondwana Supercontinent, which caused the separation of Africa and South America during the Mesozoic [1]
The Coastal Basin of the Democratic Republic of Congo is therefore part of the eastern passive margin basins of the South Atlantic [2], and contains the Nganzi oil exploration block concerned in this study (Fig.1a, 1b). Its architecture is similar to that of the basins of northern Angola, Cabinda and the Republic of Congo [3]. The main stratigraphic units in the littoral zone are, from bottom to top (Fig.2):
In this coastal basin, the pre-salt and post-salt lithostratigraphic units, separated by the Loème Salt Formation (Fig.2), are distinguished by two tectonic styles: cratonic tectonics and halokinetic tectonics (Fig.3), which respectively set up basement faults in the pre-salt formations and growth faults and diapir folds in the post-salt formations [4].

Among these formations, the organic-rich Middle Bucomazi formation is recognised as the only mature bedrock to have produced all the hydrocarbons in production in the Congolese basin [5].
Hydrocarbon production in the various oil fields in the coastal basin generally takes place in the post-salt Mavuma, Vermelha, Pinda, Kinkasi and Liawenda reservoirs, but also in the pre-salt Lucula reservoir for certain onshore oil fields, such as the M'boundi and N'koundi- Bindji oil fields located together with the Nganzi oil exploration block in the Lemba-Forabola depression [3].
Paradoxically, this Lucula reservoir is unproductive of liquid hydrocarbons in the Nganzi Block, as attested by the geological reports at the end of three exploration wells,

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Nganga-1 (NGA-1), Kinganga Nyanya-1 (KNY-1) and Bayingu-1 (BYU-1), drilled by [6].

The absence of producible hydrocarbons in the trap structures of this Lucula reservoir in the Nganzi block may be linked to the lack of communication between the different migration paths and the traps. We can also assume a gradual decrease in the volume of oil as it migrates laterally from the oil window zones distal to the Tshikoko and Sintu troughs towards the Nganzi block located almost at the edge of the basin, hundreds of kilometres along the listric faults.

The main objective of this work is to find the causes of the lack of charge of the Lucula reservoir trap structures in the Nganzi block. It will be of interest in deciding whether to continue oil exploration work in the Nganzi block area.
To achieve this objective, we used a description of the Lucula Formation cuttings from the three exploration boreholes NGA-1, KNY-1 and BYU-1 and analysed and interpreted the Gamma Ray, Spontaneous Potential, Sonic, Density-Neutron and resistivity logs carried out on the section of this reservoir.

2. GEOPETROLEUM DATA FOR THE LUCULA FORMATION

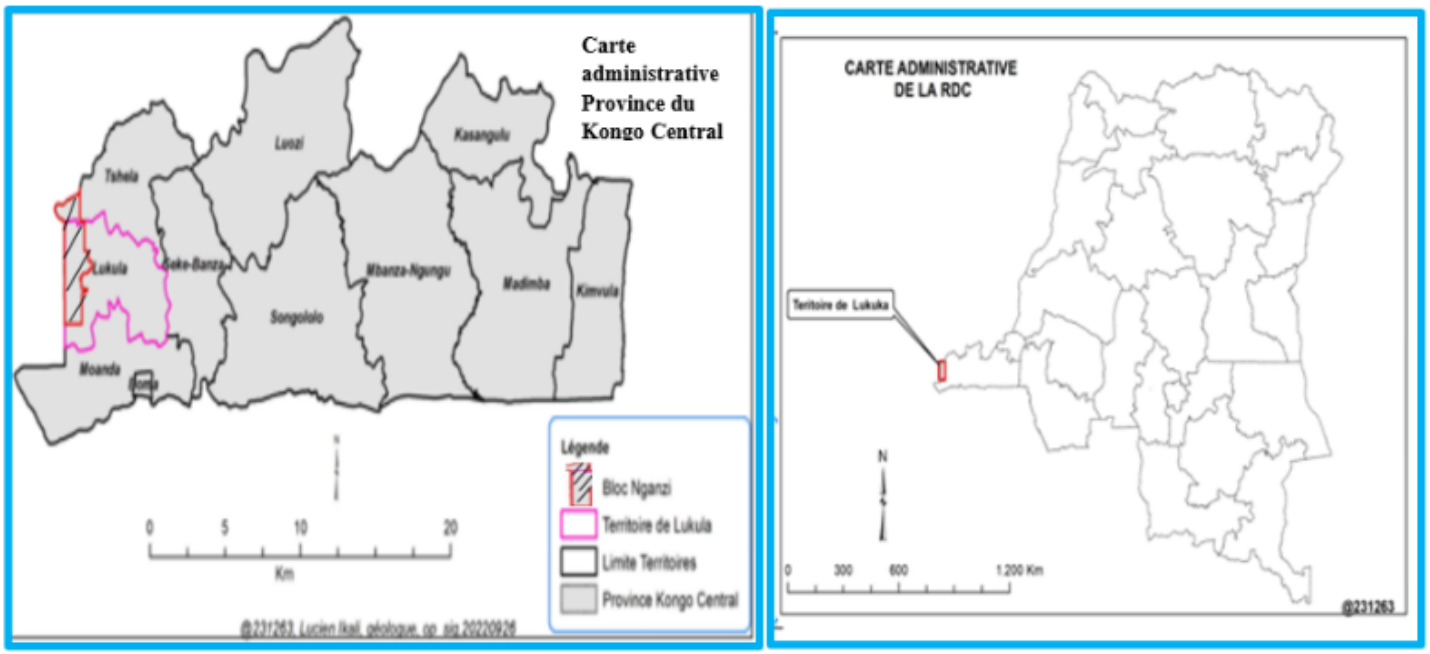


Fig.1a: Administrative location of Nganzi oil exploration block in Kongo Central province (Lucien Ikali, géologue, 2022)

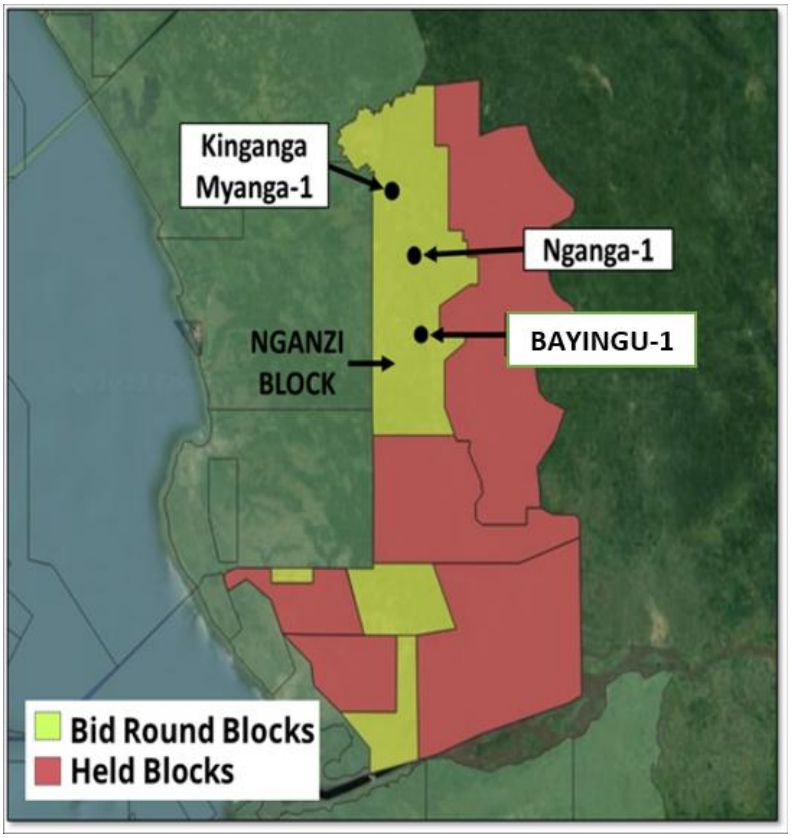


Fig.1b: Kinganga Nyanya-1well-Exploration, Nganga -1well-Exploration and Bayingu-1well- Exploration (SOCO E&P DRC, 2011)

2.1. Lucula Formation debris

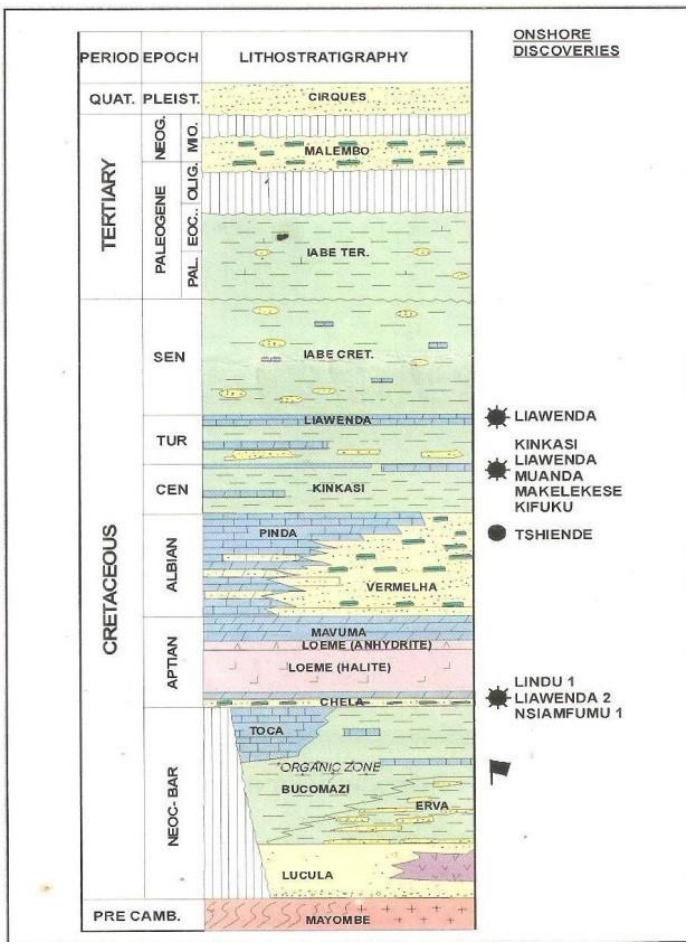


Fig.2: Stratigraphic column of the Coastal Basin (PETROFINA, 1984)

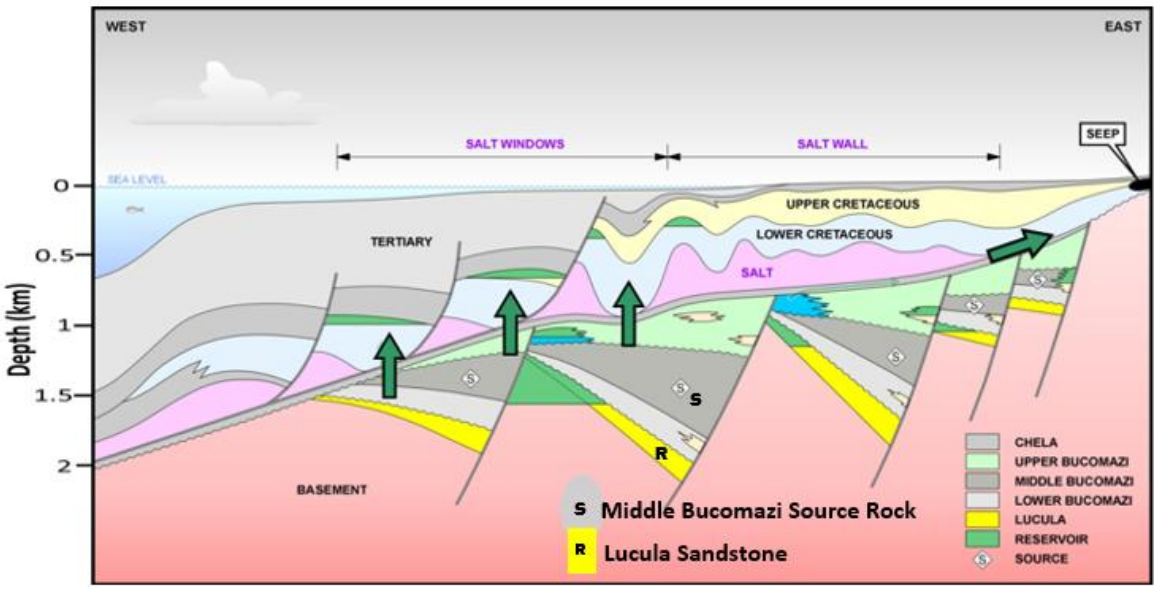


Fig.3: Schematic geological section of the Coastal Basin illustrating the relationship between the Lucula Reservoir and the overlying Bucomazi Source Rocks across listric faults. (SOCO E&P DRC, 2007).

The petrographic description of the Lucula reservoir cuttings, taken at a rate of one sample every 5 metres drilled, and the analysis of the hydrocarbon shows on it, have identified different lithological intervals in each of the three wells mentioned above.

a) Four intervals have been identified in the NGA-1 well:

- Range from 1700 m to 1800 m:
  - Reddish-brown clay, compact, amorphous, slightly dolomitic;
  - Fine to medium-grained sands of reddish brown, colourless, translucent, and angular to subangular, moderately assorted quartz, white, light orange feldspar and biotite flakes embedded in a clay matrix with traces of chlorite. Low to good porosity. No evidence of oil;
- Range 1800 m to 1900 m:
  - **Overall reddish-brown clayey sandstone with** very fine to coarse grains of quartz and feldspar, angular to subangular, moderately graded, some biotite flakes and rare traces of iron oxides. No evidence of oil;
- Range 1900 m to 2000 m:
  - Generally reddish-brown sandstone with very fine to coarse grains of quartz and feldspar, sub-angular to rounded, moderately graded;
  - Micas flakes, rare traces of chlorite and pyrite in a ferruginous matrix, good porosity. No evidence of oil.

These first three intervals make up the upper section of the essentially arenaceous Lucula reservoir.

- Range from 2000 m to 2105 m:
  - Limestone variously coloured white, light grey, beige, brown, loose and sometimes compact, amorphous, locally chalky, partially microcrystalline, slightly dolomitic;
  - Reddish-brown, soft, sticky, amorphous, loose to sticky, compact, slightly calcareous clays.

This interval represents the lower part of the calcareous-clay Lucula reservoir.

Ranging from 0.308% to 0.004% (Table 1), the total gas content captured during the crossing of the Lucula reservoir is sufficient proof, despite its good quality, that this reservoir is not loaded with hydrocarbons in the NGA-1 well.

Table 1: Grades of the various gases captured in the Lucula reservoir during drilling NGA-1.

	Total Gas (%)	**C1 (ppm)**	**C2 (ppm)**	**C3 (ppm)**	**iC4 (ppm)**	**nC4 (ppm)**	**iC5 (ppm)**	**nC5 (ppm)**
Avg	0.016	113	4	2	1	2	2	1
Min	0.004	10	0	0	0	0	0	0
Max	0.308	2420	47	14	3	8	9	4

b) In the KNY-1 well, two intervals correspond successively to the upper and lower Lucula sections.

- Range from 723 m to 823 m :
  - Sandstone alternating with multicoloured, friable, massive claystone with grains bound by a dolomitic cement and a clay matrix with very fine pyrite crystals. Quartz grains are colourless, pink, transparent, sometimes opaque, translucent, subangular, subrounded and moderately rounded.

This spoil comes from the upper section of the Lucula reservoir.

- Range from 823 m to 845 m :
  - Argillite with a sometimes earthy texture, multicoloured olive, grey to brown, sometimes greyish, blue-grey to green, sandy-silty with very fine micas flakes. During drilling, no evidence of oil was detected by the fluoroscope, on the vibrating sieve or in the drilling mud.

This essentially clayey interval represents the lower section of the Lucula reservoir in this well.

Varying from 0.022% to 0.007% (Table 2), the gas contents detected instantaneously as drilling progressed in the Lucula reservoir section indicate the absence of any type of oil in this reservoir.

Table 2: Grades of the different types of gas captured in the Lucula reservoir during KNY-1 drilling.

	Total Gas (%)	C1 (ppm)	C2 (ppm)	C3 (ppm)	iC4 (ppm)	nC4 (ppm)	iC5 (ppm)	nC5 (ppm)
Avg	0.011	60	13	1	1	1	1	1
Min	0.007	35	5	0	0	0	0	0
Max	0.022	156	37	10	3	6	3	3

c) In the BYU-1 well, four intervals have been identified.

- Range from 2194 m to 2380 m :
  - Very coarse quartz grains, subangular to rounded, light grey to reddish brown, sometimes pinkish;
  - Off-white, light, reddish-brown, soft, amorphous and soluble argillite containing grains of sand.
- Range from 2380 m to 2460 m :
  - Off-white, light, brown, soft, sandy limestone.
- Range from 2460 m to 2570 m :
  - Angular and fractured light reddish-grey quartz grains embedded in a reddish-grey clay matrix;
  - Grey to red clay.

These three intervals correspond to the predominantly sandstone and clay-limestone Upper Lucula section.

- Range from 2570m to 2591m :
  - Off-white, light, brown limestone, soft to the touch and locally clayey-sandy with very coarse quartz grains.

This last interval represents the lower Lucula section, which is essentially clay and sandstone.

With maxima of 0.022% and minima of 0.011% (Table 3), these gas contents are sufficient proof that the Lucula reservoir is not loaded with hydrocarbons in the BYU-1 well.

Table 3: Grades of the various gases recovered from the Lucula reservoir during drilling BYU-1.

	Total gas (%)	C1 (ppm)	C2 (ppm)	C3 (ppm)	iC4 (ppm)	nC4 (ppm)	iC5 (ppm)	nC5 (ppm)
AVG	0.011	60	13	1	1	1	1	1
Min	0.007	35	5	0	0	0	0	0
Max	0.022	156	37	10	3	6	3	3

2.2. Delayed logs

The following delayed logs: GR (natural radioactivity curve: gamma rays from: K, U and Th), SP (spontaneous polarisation curve), NPHI (neutron curve), ILD (deep induction resistivity curve), SFLU (spherically focused induction resistivity curve) and DT (sonic curve) were carried out at the Lucula reservoir section in the three wells drilled. (Fig.4).

3. RESULTS AND DISCUSSIONS

3.1. Well NGA-1

In the NGA-1 well, the Lucula reservoir section was logged in deferred and open hole from 2591 m to 2194 m with the following logs: GR (natural radioactivity curve: gamma rays from: K, U and Th), SP (spontaneous polarisation curve), NPHI (neutron curve), ILD (deep induction resistivity curve), SFLU (spherically focused induction resistivity curve) and DT (sonic curve) (Fig.4).

The analysis and interpretation of the various GR, NPHI, DT, ILD and SFLU logs from the Lucula reservoir in the NGA-1 well have made it possible to determine the main

petrophysical parameters below (Table 4):

- The total thickness of the Lucula reservoir, its various porous and clayey levels, including its petrophysical characteristics;
- Average porosity and relative permeability ;
- The useful height of the tank ;
- Fluid saturation.

The resistivity logs also revealed the presence of water in the porous zones of the Lucula Formation.

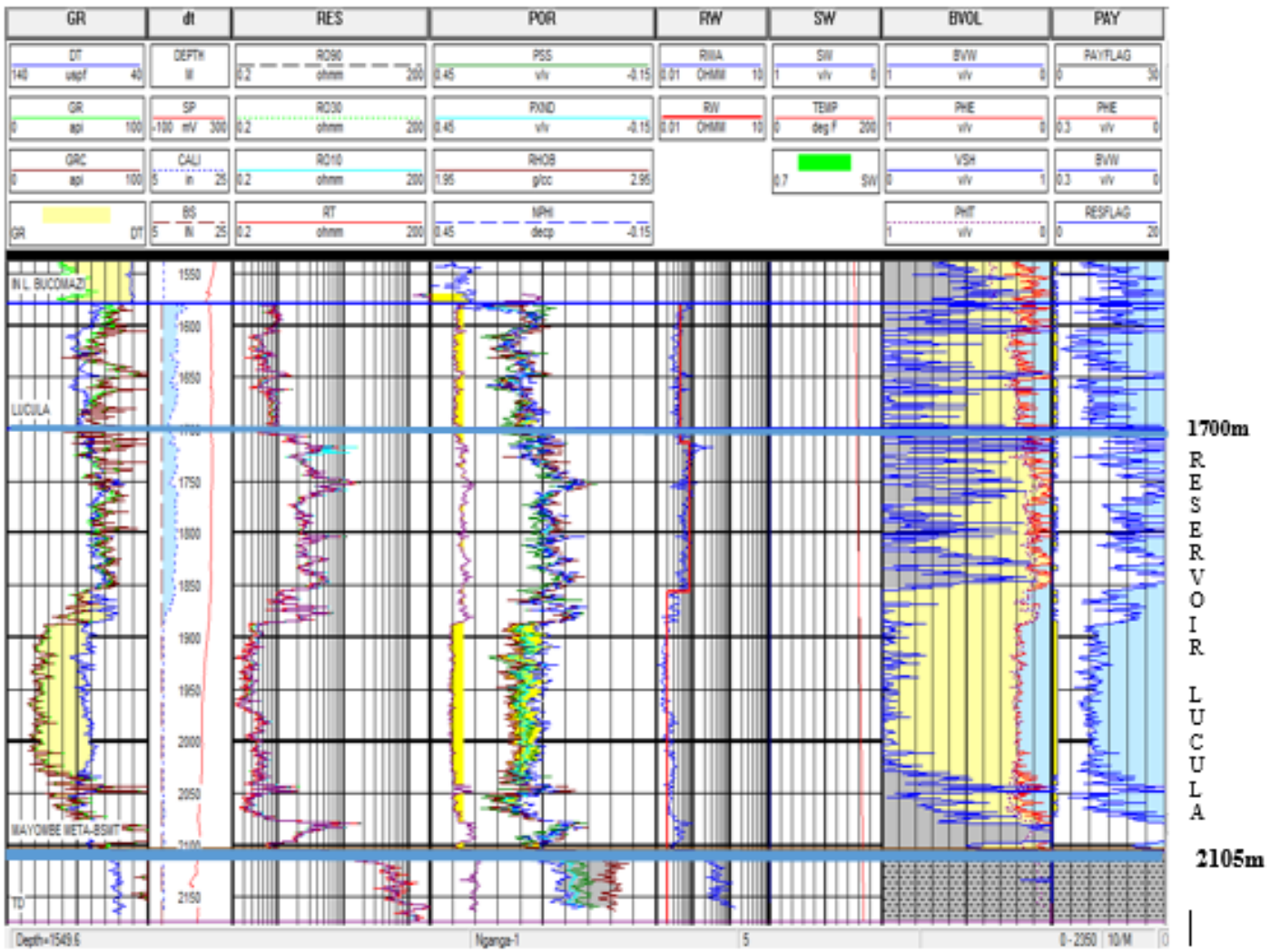


Fig.4 : Off-line and open-hole logs from the Nganga-1 well.

Table 4: Petrophysical parameters derived from the interpretation of the NGA-1 well logs.

NGA-1												
TANK												
CUTT OFFS												
TANK	Volume In Clay SVH < 55											
	POROSITY PHIE >10											
PAY	Saturation In Water SW< 60											
Well name	Training	Roof in metres	Wall in metres	(Formation thickness)	Reservoir thickness	Ep Reservoir/ ratio Total ep	Average porosity	Thick sat in oil	ratioEp sat/Ep total	Mean sats (SO)	Sat avg (SW)	Flight Hc in place
NGANGA	LUCULA SUP (clay)	1700	1885	185	73.4	0.397	0.145	0.000	0.000	0.000	0.000	0.000
	IOYEN (sand)	1885	2032	147	146.6	0.997	0.191	0.000	0.000	0.000	0.000	0.000
	LOWER LUCULA	2032	2105	73	33.0	0.451	0.162	0.000	0.000	0.000	0.000	0.000

3.2. KNY-1 well:

In the KNY-1 well, the section of the KNY-1 well containing the Lucula reservoir was logged off-line and in open hole from 1156 m to 503 m with the following main logs: GR, SP, NPHI, Res and DT (Fig.5).

Analysis and interpretation of the GR, NPHI and DT logs have enabled the following petrophysical characteristics to be determined (Table 5):

- The total thickness of the network, including the thickness of the various layers;
- Porosity ;
- The useful height of the tank ;
- Fluid saturation.

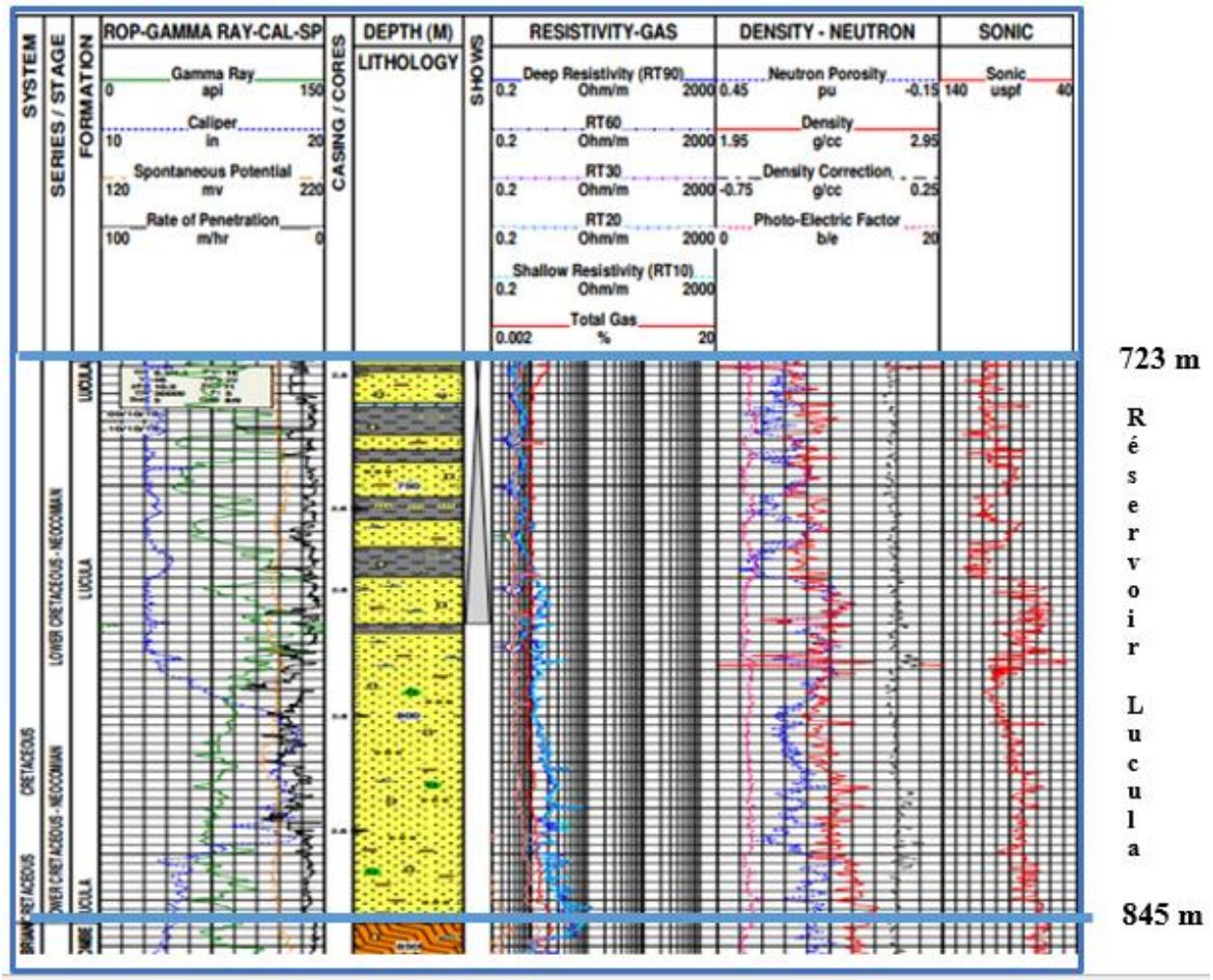


Fig.5 : Logs from the KNY-1 well.

On the other hand, the resistivity logs were used to highlight the presence of water in the porous zones of the Lucula Formation.

Table 5: Petrophysical data from log interpretation in the KNY-1 well.

KNY-1												
Reservoir												
Cutt offs												
Reservoir	Flight in clay Vsh < 55											
	Porosity Phie >10											
Pay	Sat en eau Sw< 60%											
Well name	Training	Roof in metres	Wall in metres	Thick training	Thick tank	Thick Reservoir/ Total thickness	Ø MOY	Thick, oil-saturated	Saturated thickness / Total thickness	average saturated porosity (so)	Sat avg (SW)	Flight Hc in place
	Lucula sst	720	846.5	126.5	28.6	0.226	0.156	0.000	0.000	0.000	0.000	0.000

3.2. BYU-1 well:

In the BYU-1 well, the Lucula reservoir section was logged in deferred and open hole from 2591 to 2194 m with the following main logs: GR, NPHI, Neutron, DT and Resistivity (Fig.6).

Analysis and interpretation of the GR, NPHI and DT logs have enabled the following petrophysical characteristics to be determined (Table 6):

- The total thickness of the network, including the thickness of the various layers;
- Porosity ;
- The useful height of the tank ;
- Fluid saturation.

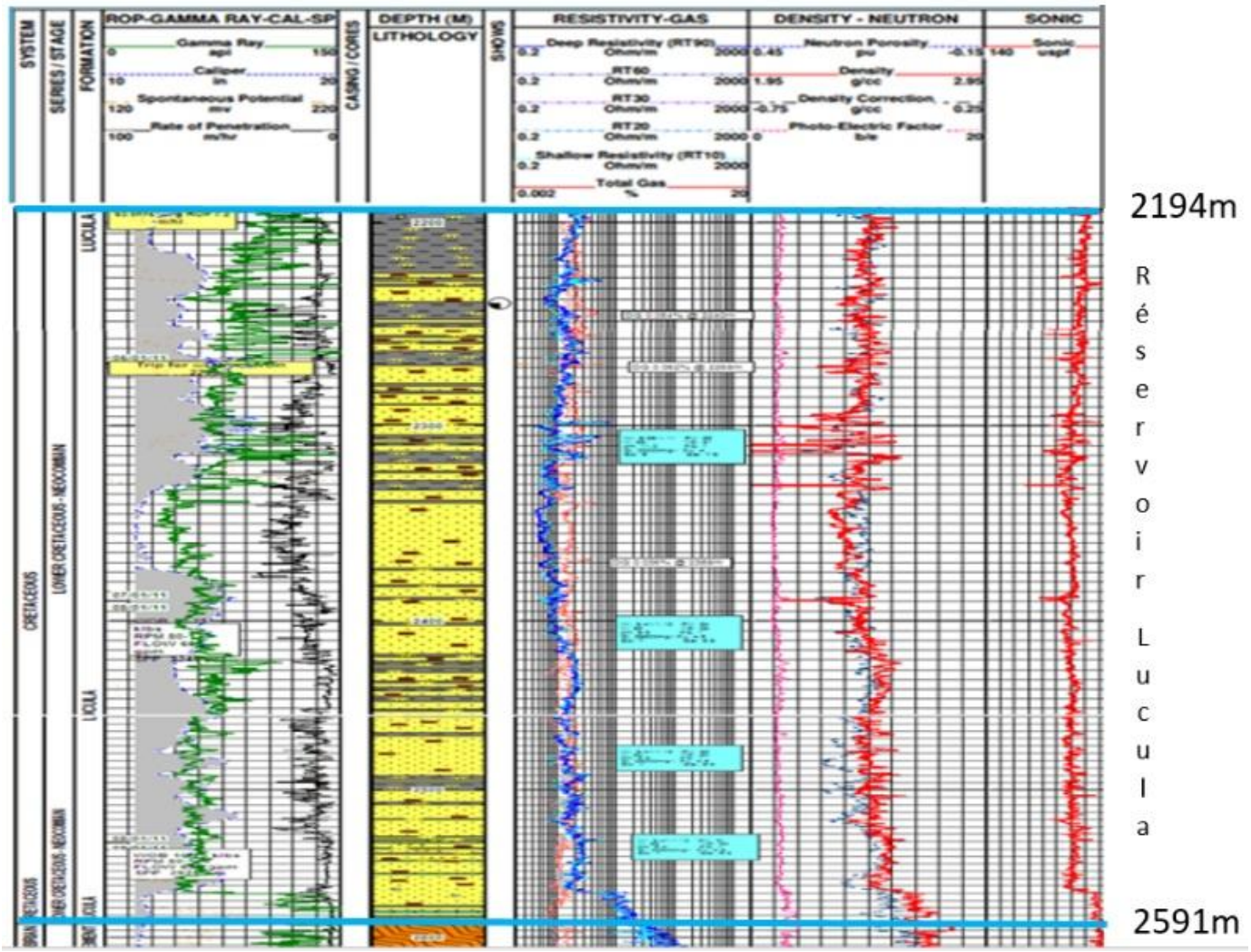


Fig.6 : Logs from the BYU-1 well

The petrophysical parameters (Table 6) obtained from reading the above-mentioned logs in their sections relating to the Lucula reservoir in the BYU-1 well are as follows:

Table 6: Petrophysical properties of the Lucula reservoir in the BYU well.

BYU-1												
TANK												
CUTTOFFS												
TANK	VOLUME IN CLAY SVH < 55											
	POROSITY Ø >10%											
PAY	WATER SATURATION SW< 60%											
Well name	Training	Roof in metres	Wall in metres	(Heavy training)	Tank thickness	Reservoir thickness/Total thickness	Ø MOY	Thick, oil-saturated	Saturated thickness / Total thickness	Ø MOY saturated with oil (SO)	Sat avg (SW)	Flight Hc in place
Bayingu-1	LUCULA (stoneware)	2194.0	2591.0	396.6	75.0	0.189	0.143	0.000	0.000	0.000	0.000	0.00
	Kimesian substrate	2591.0	-	-	-	-	-	-	-	-	-	-

4. CONCLUSION

The description of the excavated material under a binocular magnifying glass, supplemented by a photonic microscope, and the analysis of gas indices revealed the following:

a) The Lucula reservoir is generally a sandstone of continental fluvio-lacustrine origin with some clayey intercalations, which rests directly on the basement in the basin. The size of the constituent grains of its upper part (granulometric analysis) shows that it was deposited under medium-energy palaeogeographic conditions.

The absence of gas and oil indications during the macroscopic description of the cuttings and detection by fluorescence or chromatography indicates that the reservoir (Lucula) is not supplied with hydrocarbons from the source rock (overlying Bucomazi) of the Tshikoko trench, due to the lack of a direct relationship between the migration drains and the up-dip structures of the latter in the Nganzi block, or due to the absence of a nearby mature source rock in the Nganzi block area.

b) As well logs are continuous records of a number of physical parameters: spontaneous polarisation, natural radioactivity, speed of sound, resistivity, density and porosity, the variations in the amplitudes of their curves reflect the lithological and petrophysical make-up of the formations traversed, as well as their different fluid content.

We began by dividing the log signal into different segments or electrofacies of the Lucula reservoir (depth intervals with roughly similar log characteristics in the three wells), which represent the different lithological successions of the Lucula reservoir traversed by the boreholes.

The analyses carried out, with specific objectives to be achieved on each of these logs, led to the correlation of the top and base of the Lucula reservoir in the three wells, the determination of its thickness, its zonation, the determination of its petrophysical characteristics linked to lithological variations as well as the types of fluids present in the reservoir.

c) The approach to the succession of sedimentary formations in the pre-salt section of the coastal basin in general and in the Nganzi block in particular in relation to the petroleum system, places the Lucula formation stratigraphically as a reservoir rock with its various trap structures below the Bucomazi source rock. Given this stratigraphic position, the probable hydrocarbon loading of its traps can only be due to direct contact with the source rock in the event of an unconformity and gap in the lower Bucomazi, or by the up-dip position of its counter-fault traps, as in the Lukami field offshore.

d) The gas contents expressed with maxima of 0.022% and minima of 0.011% (Table 1) are sufficient proof that the Lucula reservoir in the Nganzi block is not loaded with hydrocarbons.

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