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ESTIMATION OF CARBON SEQUESTRATION CAPACITY OF GEOLOGIC RESERVOIRS WITHIN THE G-OIL FIELD OF THE NIGER DELTA BASIN

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ABSTRACT

The presence of CO_2 in the atmosphere constitutes a major environmental concern as it is a major trigger of global warming and climate change. Efforts to reduce its concentration in the atmosphere led to the exploration of sequestration possibilities into depleted/abandoned hydrocarbon reservoirs either for permanent storage or Enhanced oil recovery. It is against this background that this research was undertaken to estimate the storage capacity of the G-Oil field. The research location is within the Greater Ughelli depobelt of the Niger Delta Basin and between latitude 4˚N and 6˚N and longitude 5˚E and 8˚. The field covers a landmass of 36.9Km^2. Eighteen (18) delineated reservoirs from Eight (8) oil wells were analyzed for petrophysical properties such as Effective porosity ($Ø_e$) and Water saturation (Sw). Effective porosity ranged between 14.2% - 27.4% which is medium to very good porosity while Water saturation had its lowest value as 13.1% and its highest value at 40.3%. Mean values of effective porosity and water saturation are 22.8% and 31.0% respectively. These are excellent values that define quality reservoirs and suitable for carbon sequestration. The CO_2 Mass (GCO_2) Storage Capacity in metric tonne (T) across all reservoirs is within the range of 3,714Tonne and 1,219,701Tonne. The Average GCO_2 storage capacity of reservoirs in the study area is therefore 168,713Tonne (0.169 MegaTonne) while the Total storage capacity of the G-Oil field is 3,036,836 Tonne (3.04MegaTonne)**.** The mean reservoir storage capacity as per 1Km^2 reservoir area agrees with limits for point-source/test sites which is 0.1-1Mt, meanwhile the total storage capacity of the G-Oil field is slightly above test-site capacity. These notwithstanding, this research believe that reservoirs having areas larger than 1Km^2, can attain commercial storage capacity based on facts that reservoirs in the study area are of good quality.

Keywords: Carbon sequestration, effective porosity, reservoir, hydrocarbon, storage, CO_2

1. Introduction

Carbon sequestration is the process of capturing CO_2 from the atmosphere/ point sources and storing it in natural sinks such as vegetation and earth-bound reservoirs. This is to reduce the presence of greenhouse gases in the atmosphere (Dike and Akani, 2020). It is a third option for greenhouse gas mitigation after

improved fuel/engine efficiency and low carbon fuels (U.S. DOE, 2003). Its adoption in heavy-emitting industries has been proposed as a global de-carbonization strategy (Koehn *et al*., 2023; IPCC, 2021). CO_2 can be sequestered through structural injection into deep geologic reservoirs (Agada et al., 2026) or capturing from the atmosphere by flora into vegetation which acts as sink by processing CO_2 into organic carbon in the top soil sediment of up to 100cm depth (Arshad et al,. 2018). Considering the prolific geologic reservoirs and mangrove sediments of the Niger Delta, it is quite promising for CO_2 sequestration.

Beyond capturing for deep geologic sequestration, the process continues with converting the captured CO_2 into supercritical state (liquefaction), transport to suitable sites and injecting it into geologic formations, including depleted oil and gas reservoirs, deep saline aquifers, deep coal seams and salt caverns (Lai, 2008; Ojo and Tse, 2016; Umar *etor al*., 2020). Sundquist *et al*. (2008) noted that after CO_2 is injected underground, it rises buoyantly until it is trapped beneath an impermeable barrier, or seal. In order to ensure an effective sequestration of carbon dioxide, there ought to be adequate storage capacity in the reservoir, efficient injectivity process and proper containment in order to ensure that there is no leakage or migration of CO_2 out of the reservoir where it is stored (Griffiths *et al*., 2005). According to Griffiths *et al*. (2005), the reservoir storage capacity measures the mass of CO_2 that can be successfully and safely stored in the reservoir while injectivity deals with the ability of the reservoir to accept CO_2 at the rate it is produced by the source.

The need for carbon sequestration in geologic formations is not peculiar to Nigeria alone. As noted in previous works, several countries of the world such as Australia (Kaldi and Gibson-Poole, 2009), Canada (Bachu, 2007), the Middle East (Algharaib, 2013) and Norway (Solomon *et al.*, 2007) which have carried out their carbon capture and storage (CCS) programmes, including the fundamental work of carbon storage capacity estimation are currently deeply involved in the process. This research therefore seeks to estimate the reservoir storage capacity for CO_2 in selected wells within the G-Oil field in the Niger Delta. This further extends to implications of analyzed storage capacity in terms of international storage standards.

1.1 Study location

The research location is the G-Oil Field located in the Greater Ughelli depobelt of the Niger Delta Basin between latitude 4˚N and 6˚N and longitude 5˚E and 8˚E (Ugbor *et al.*, 2022; Ojo and Tse, 2016). The field covers a landmass of 36.9Km^2. Location of the 8 wells used could be seen in (Fig. 1) (Agada *et al*., 2026). The Niger Delta basin is underlain by the Benin, Agbada and Akata geologic formations (Short and Stauble, 1967). These formations are of the early Tertiary to Recent (Doust and Omatsola, 1989; Umar et al., 2020) in geological timescale and they define reservoir rocks and their properties. According to Short & Stauble (1967), the Niger Delta basin was formed in the third depositional cycle that cut across Eocene to Recent, and experienced the introduction of a threefold Litho-stratigraphic subdivision: upper sandy Benin Formation, alternating sandstone and shale unit called Agbada Formation, and a lower shaly Akata Formation (Amos-Uhegbu *et al.*, 2012).

2.0 Materials and Methods

Interactive Petrophysics (IP) software was used for this research. It is a software designed for geophysical analysis of subsurface data in varying formats ranging from ASSCII, LAS, to other compatible formats

(Agada *et al.*, 2026). The software was used for analysis of well log data to unveil geologic conditions and subsurface geophysical behaviours.

Surfer 13 is a software used for production of geo-maps with hydrological and geophysical representation of relevant properties. In this study, it was used to analyze elevation conditions of the study area. With the aid of reference coordinates, simple location map was produced indicating the 8 wells of interest.

Well log data in LAS format obtained by oil and gas multinational companies was used for this research. Eighteen (18) delineated reservoirs from Eight (8) oil well were analyzed for petrophysical properties such as Effective porosity ($\emptyset_e$) and Water saturation (Sw).

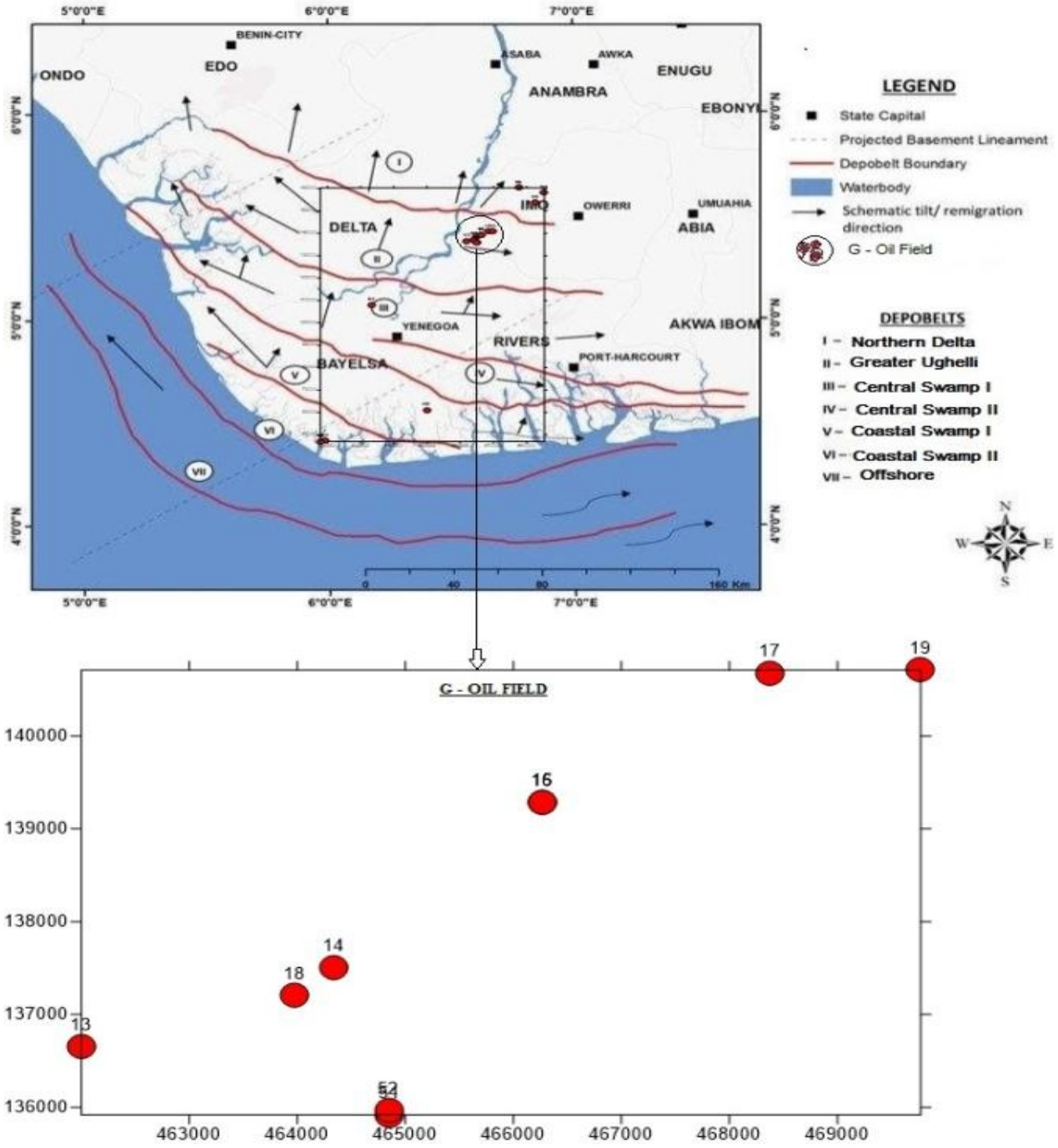


Fig. 1 Location map of G-Oil field within the Niger Delta Basin (culled from Agada *et al.*, 2026)

The Tixier equation for determining porosity was used while Indonesian model of calculating Water saturation was adopted in equations 1 and 3 respectively.

$$\text{Porosity } (\emptyset) = \frac{\rho ma - \rho b}{\rho ma - \rho fl} \quad . \quad . \quad . \quad . \quad (1)$$

$$\text{Effective porosity } (\emptyset_e) = \emptyset_t\,(1 - V_{sh}) \quad . \quad . \quad . \quad . \quad (2)$$

Where ρma is the density of matrix, ρb is the bulk density, and ρfl is the density of fluid. $\emptyset_t$ is total porosity while V_{sh} is shale volume.

$$S_w = \left[\frac{R_t^{-1/2} - V_{sh}^{\left(\frac{1-V_{sh}}{2}\right)} R_{sh}^{-1/2}}{\emptyset_e^{m/2}(aR_w)^{-1/2}}\right]^{2/n} \quad . \quad . \quad . \quad . \quad (3)$$

Table 1: Analyzed wells and delineated Reservoirs

S/N	Well Code	Depth (ft)	Number of reservoirs
1	IOA_13	1950.11 - 2748.99	4
2	IOA_14	1901.038 - 2199.742	1
3	IOA_15	2013.052 - 2590.8	2
4	IOA_16	1144.067 - 2558.339	2
5	IOA_17	1803.44 - 2403.043	3
6	IOA_18	2066.849 - 2516.429	2
7	IOA_19	1848.917 - 2492.502	2
8	IOA_52	3691.738 - 3811.524	2

Well logs analysed within the wells include: gamma ray, depth, neutron porosity, bulk density, sonic, deep/true resistivity, water saturation, and bulk volume of water.

To effectively estimate the storage capacity of reservoirs within the oil field, the mass equation for CO_2 (equation 4) was used in this work.

$$\mathbf{MCO_2} = 7758 \times \text{Area} \times \text{Thickness} \times \emptyset \times (1\ \text{Sw}) \times \text{NTG} \times \text{Rf} \times \rho CO_2 \times \text{Ɛ} \quad (4)$$

Considering the fact that reservoirs are discrete, equation 5 presents the total storage capacity of a well. Where R represents individual discrete reservoirs

$$\textbf{Total Storage Capacity (S)} = \text{R1} + \text{R2} + \text{R3} + \text{R4} \quad . \quad . \quad . \quad (5)$$

Niger Delta Mean values were applied for Recovery factor (Rf), and CO_2 storage efficiency (Ɛ) as 0.35 and 0.25 respectively while Acre conversion factor and supercritical density of CO_2 (ρCO_2) are given as 7,758 and 164Kg/m^3 respectively (Glover, 2000; Fozao *et al.*, 2019). 247.1acre (approx 1Km^2) was used as reservoir area in the absence of seismic data for area determination.

3.0 Results and Discussion

Reservoir models were produced for all 8 wells analysed (see Fig. 2 and appendices).

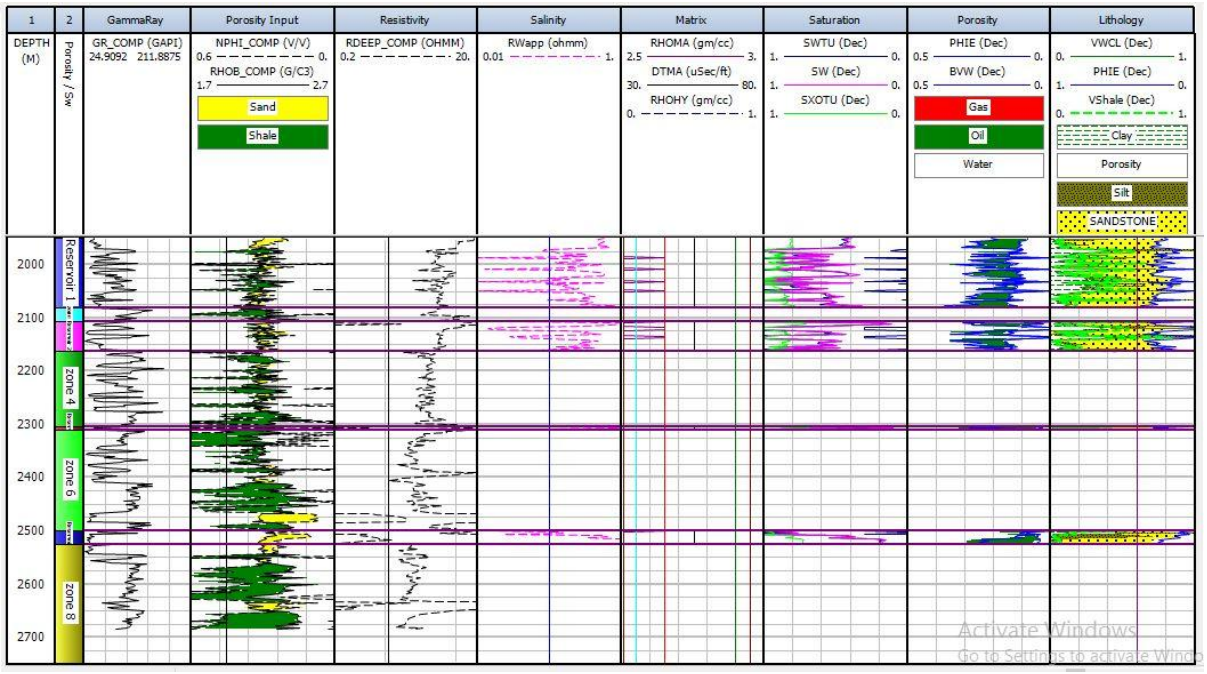


Fig. 2: Reservoir Matrix delineation of Well IOA_13

Table 2: Petrophysical Parameters reservoirs within the oil field

S/N	Well code	Reservoir	Effective Porosity ($\emptyset_e$)	Water Saturation (Sw)
1	IOA_13	Reservoir 1	0.21	0.457
		Reservoir 2	0.179	0.403
		Reservoir 3	0.245	0.198
		Reservoir 4	0.156	0.246
2	IOA_14	Reservoir 1	0.27	0.352
3	IOA_15	Reservoir 1	0.275	0.326
		Reservoir 2	0.255	0.34
4	IOA_16	Reservoir 1	0.274	0.2
		Reservoir 2	0.232	0.378
5	IOA_17	Reservoir 1	0.274	0.325
		Reservoir 2	0.255	0.439
		Reservoir 3	0.168	0.131
6	IOA_18	Reservoir 1	0.251	0.339
		Reservoir 2	0.252	0.156
7	IOA_19	Reservoir 1	0.266	0.289
		Reservoir 2	0.252	0.297
8	IOA_52	Reservoir 1	0.149	0.401
		Reservoir 2	0.142	0.304
			0.228	**0.310**

Four (4) reservoirs were delineated in Well IOA_13 as seen in Fig. 2 which shows minimal shale intercalation of below 50API within the sandstone reservoirs. High resistivity values above 10ohm-meter indicates presence of hydrocarbon (Glover, 2000). Petrophysical statistics for all wells and reservoir analysed are presented in table 2. It displays effective porosity and water saturation for 18 reservoirs. Effective porosity ranged between 14.2% - 27.4% which according to Atto *et al.*, (2025) is medium to very good porosity. Water saturation had its lowest value as 13.1% and its highest value at 40.3%. This is very good as it is below 50% (Fozao *et al*., 2019). Mean values of effective porosity and water saturation are 22.8% and 31.0% respectively. These are excellent values that define quality reservoirs, suitable for carbon sequestration.

Applying mean values of Rf, Ɛ, Acre conversion factor, ρCO_2, $\emptyset_e$, Sw and $1Km^2$ area to equation 4 gives the CO_2 mass as contained in table 3 both in Kg and Tonne.

Table 3: CO_2 Storage Capacity of reservoirs within the oil field

S/N	Well code	Reservoir	Mass of CO_2 (Kg)	Mass of CO_2 (Tonne)
1	IOA_13	Reservoir 1	49,965,168	49,965
		Reservoir 2	18,636,530	18,637
		Reservoir 3	3,713,990	3,714
		Reservoir 4	9,628,258	9,628
2	IOA_14	Reservoir 1	227,087,966	227,088
3	IOA_15	Reservoir 1	362,247,404	362,247
		Reservoir 2	58,828,080	58,828
4	IOA_16	Reservoir 1	1,219,701,061	1,219,701
		Reservoir 2	48,399,673	48,400
5	IOA_17	Reservoir 1	301,815,976	301,816
		Reservoir 2	30,508,955	30,509
		Reservoir 3	16,152,959	16,153
6	IOA_18	Reservoir 1	179,756,253	179,756
		Reservoir 2	15,452,153	15,452
7	IOA_19	Reservoir 1	423,502,189	423,502
		Reservoir 2	53,656,899	53,657
8	IOA_52	Reservoir 1	5,497,521	5,498
		Reservoir 2	12,285,304	12,285
Mean values			**168,713,130**	**168,713**
Total storage capacity of G-oil field			**3,036,836,339**	**3,036,836**

4.0 Conclusion

The mass CO_2 Storage Capacity in metric tonne (T) across all reservoirs is within the range of 3,714Tonne and 1,219,701Tonne. This puts the Mean CO_2 mass (GCO_2) storage capacity for the study area at 168,713Tonne (0.169 MegaTonne). The total storage capacity (S) of the G-Oil field is 3,036,836 Tonne (3.04MegaTonne). This quantity is below the US Department of Energy's CarbonSAFE Initiative minimum benchmark of 50 Mt of CO_2 for commercial geologic storage sites and the Australia/Canada requirement

of 50 - 200Mt as minimum standard for commercial sequestration. However, the mean value for the study area as per 1Km^2 reservoir area agrees with limits for pilot-scale/test sites which is 0.1-1Mt. These notwithstanding, this research believe that reservoirs having areas larger than 1Km^2, can attain commercial capacity status.

Acknowledgement/ Conflict of Interest

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Appendices

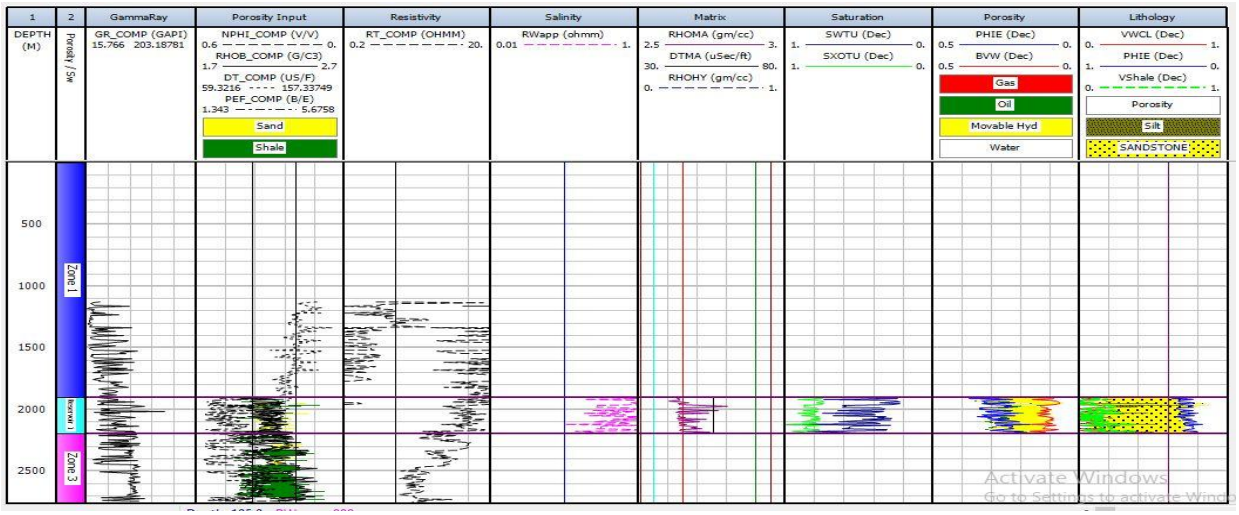


Plate 1: Reservoir Matrix delineation of IOA_14

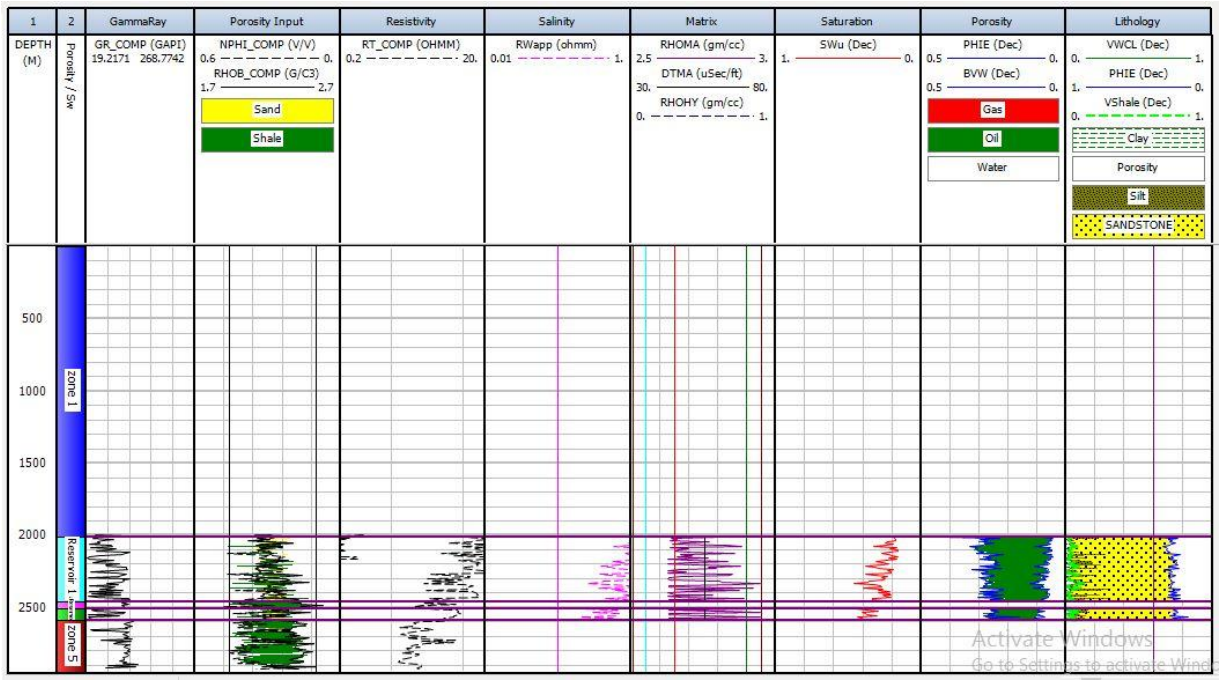


Plate 2: Reservoir Matrix delineation of IOA_15

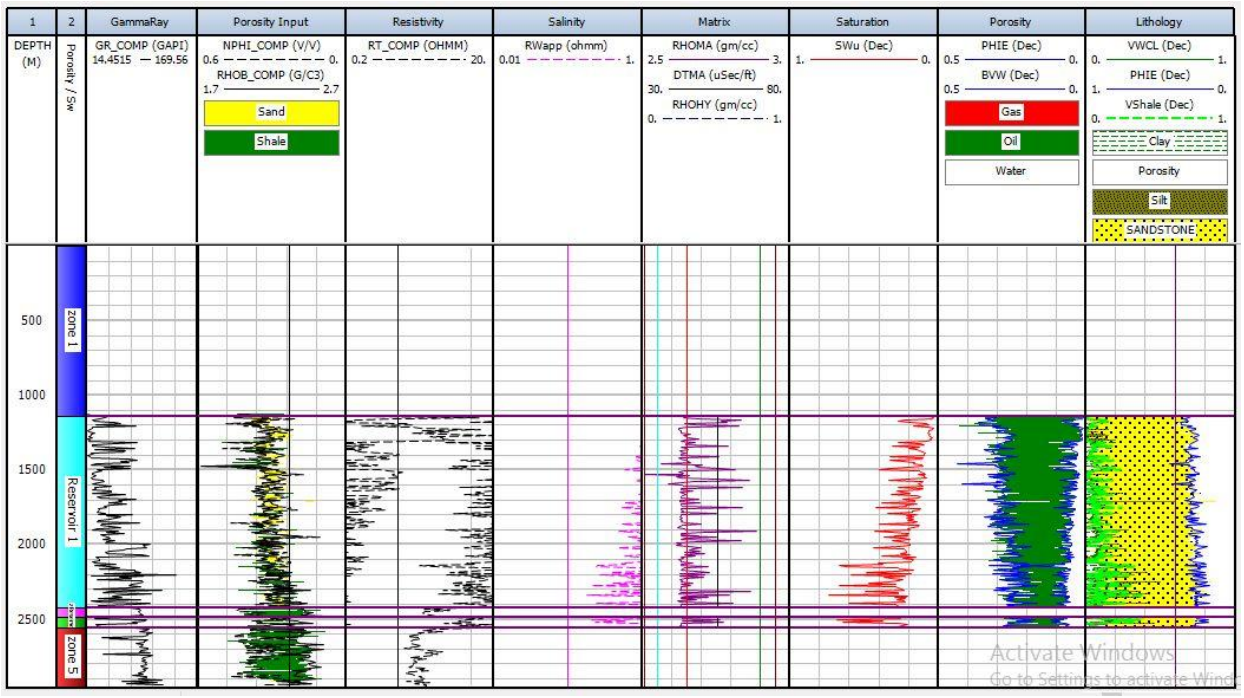


Plate 3: Reservoir Matrix delineation of IOA_16

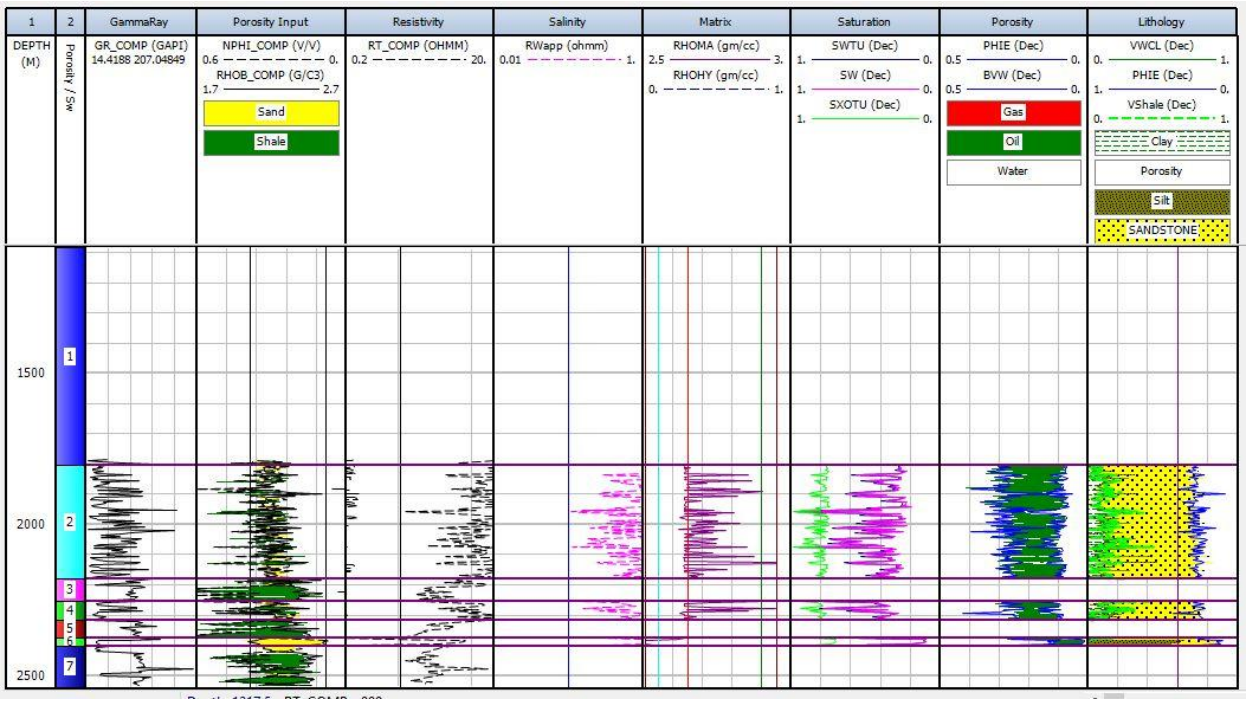


Plate 4: Reservoir Matrix delineation of IOA_17

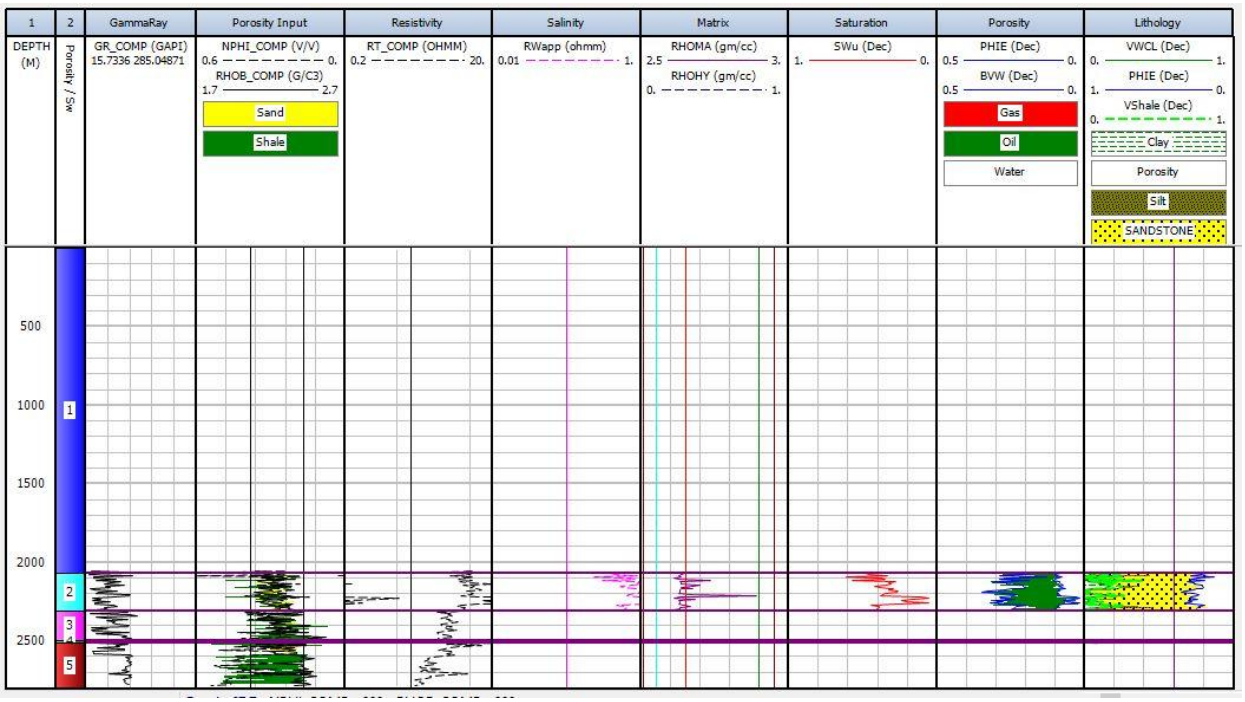


Plate 5: Reservoir Matrix delineation of IOA_18

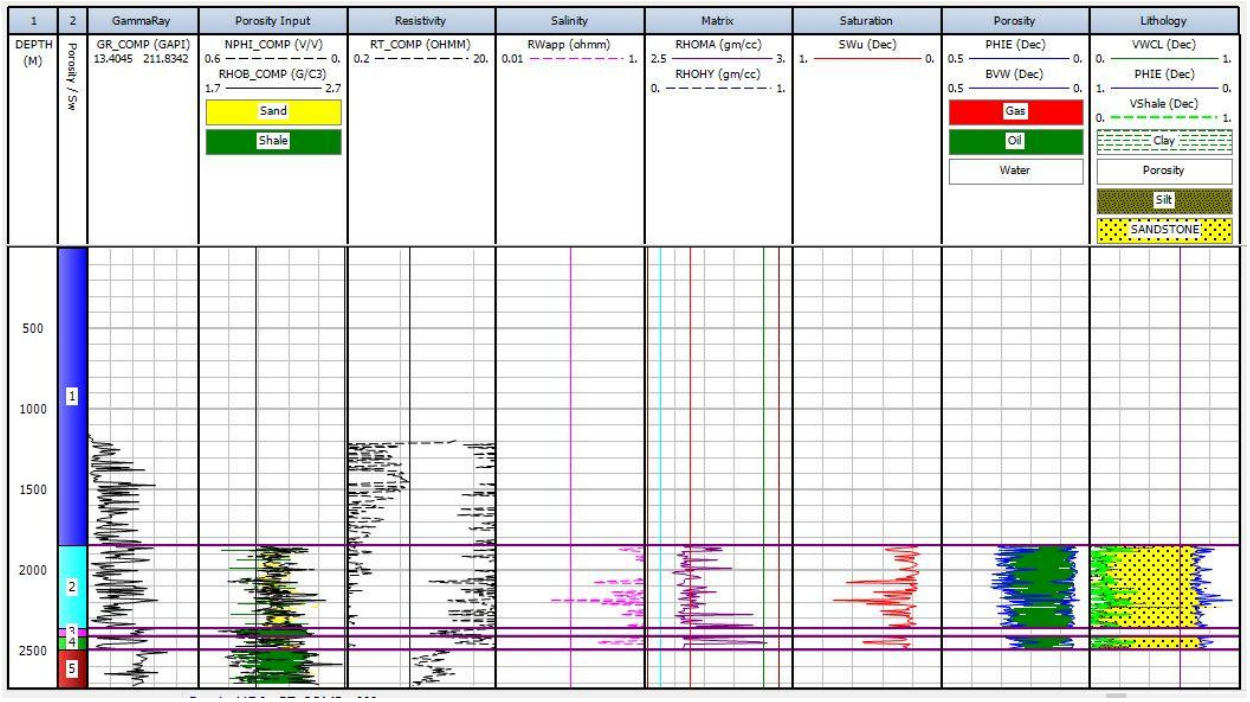


Plate 6: Reservoir Matrix delineation of IOA_19

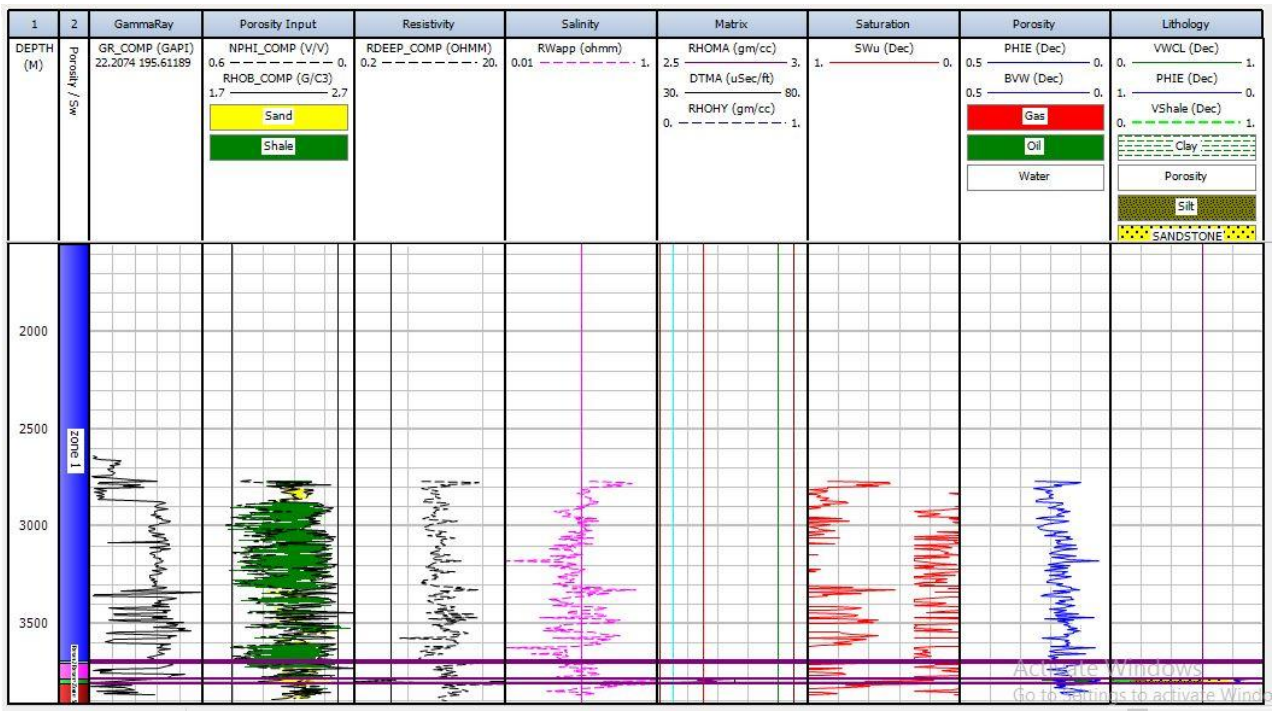


Plate 7: Reservoir Matrix delineation of IOA_52