Formation Evaluation of a carbonate Reservoir in a New Oil Field as a part of preparing preliminary Field Development Plan

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Abstract— Nasiriya oil field is one of the important southern oil fields in Iraq. Mishrif formation is the main reservoir in this field which mainly consists of sequences of limestone rocks. This study presents an integrated petro physical evaluation of the Mishrif reservoir in the Nasiriya oil field depending on available data. The available data include well-set logs conducted on 4 wells Petro physical evaluations were performed on 4 wells from the Nasiriya field,. The conventional petro physical evaluation, by using a neutron-density cross-plot for lithology and porosity and the Archi model for water saturation, can be adequate for evaluating Mishrif as a carbonate reservoir. The petro physical evaluation is needed for resource assessment and reservoir modeling of the Nasiriya oil field .The combining data from (4) Well Logs within 160 meters thick of mishrif reservoir , define layers of reservoirs and sealing strata. The quality of the reservoirs are moderate to good and in some distal reservoirs, they are excellent. The average porosity values are approximately the same, but have variation in permeability. Mishrif reservoir subdivided into three units ma,,mb1 ,mb2 and mb3 .mb1 and mb2 of the reservoirs are oil bearing, while ma and mb3 are water saturated. The upper part of lower lower mishrif formation is the primary hydrocarbon-bearing reservoir. The integration of well tests and core data is helpful for improving the formation evaluation results and the log interpretation results.

I INTRODUCTION

Formation evaluation is the application of scientific principles, engineering concepts, and technological innovations in the exploration and prospecting of hydrocarbon resources in geological formations. The main core of formation evaluation is measuring rock properties and establishing the relationship between these properties.. Petro physics is a viable tool for the detection and evaluation of hydrocarbon-bearing layers. One of the fundamental properties of a reservoir rock is porosity. However, for a rock to be an effective reservoir, it must have good pore interconnectivity. The main physical parameters needed to evaluate a reservoir are porosity, hydrocarbon saturation, permeable bed thickness, permeability, etc. are built-in; examples of the type styles are provided throughout t These parameters may be derived or inferred from electrical, nuclear, and acoustic Logs, which can be translated to qualitative information of depth/thickness of productive intervals, to distinguish between oil, gas, and water in the reservoir

Location of the Study Area

Nasiriya. field lies east of the River Euphrates, about 40 kilometers northwest of the city of Nasiriya Nasiriya field is located on the Arabian platform, in a gently folded zone, west of the Zagros fold belt. The field is operated by Thiqar Oil company TOC in Dhi Qar province as showing its location in (Figure 1).

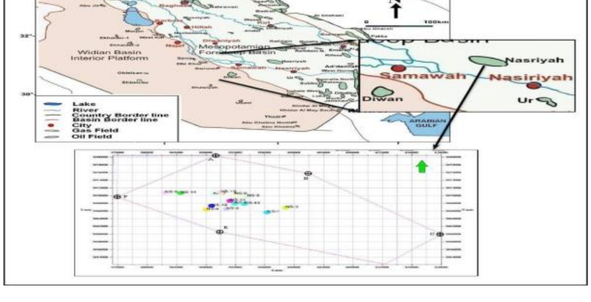
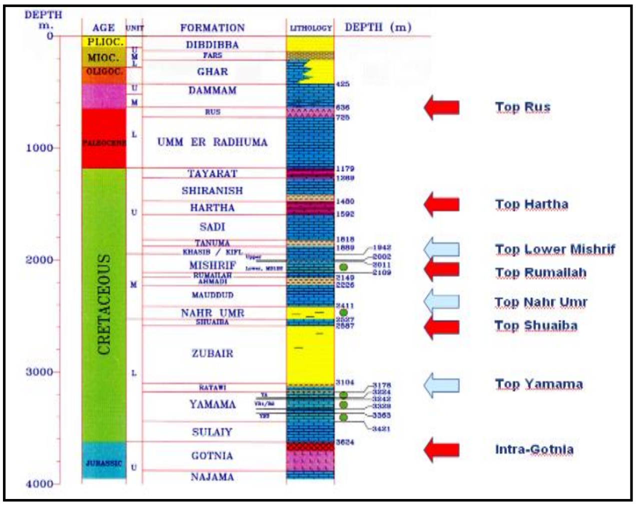


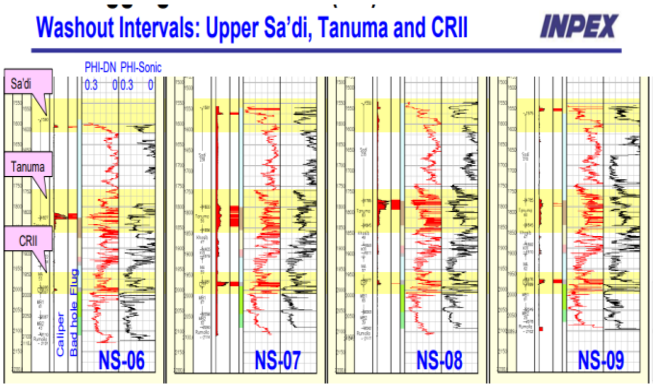
Figure 1. Index Map of Nasiriya oil field location

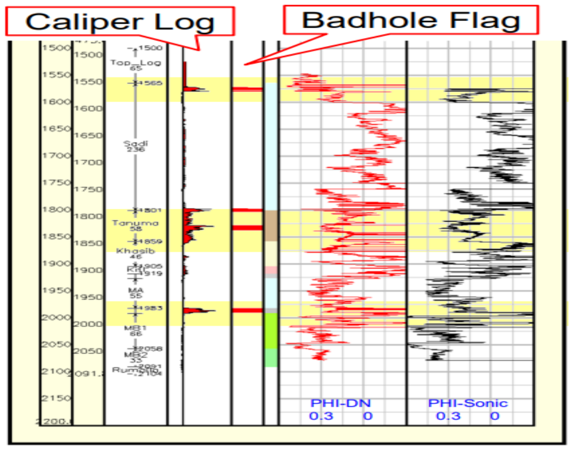
The first discovery was made by the Iraq National Oil Company (INOC) in 1978 by Ns-1 discovery well that when tested produced 2,550 b/d from the Mishrif formation and 4,300 b/d from the Yamama formation.. The field was subsequently appraised with two successful wells drilled in 1980 and in 1985. The field's primary reservoirs are the Early Cretaceous Mishrif and Yamama formations.The Late Cretaceous Mishrif formation is widely distributed across the Middle East and Iraq, in particular. The formation has been subdivided into 2 distinct sub-cycles within a total gross thickness of 160 m. The first sub-cycle exhibits a trend from open marine conditions to restricted lagoon conditions. The second sub-cycle has both outer shelf and inner shelf deposits which are separated by a high energy barrier sequence. Lithological, the sediments range from fine-grained calcareous mudstones to coarse-grained wackestone and grain stone deposits. Reservoir characteristics vary greatly through the formation and are typically at their best in the high-energy barrier deposits where porosities average 20- 29% and permeability's range from 10 mD to more than 1,000 mD. The Mishrif formation is productive in several major Iraqi fields, which include Abu Ghirab, Buzurgan, Jabal Fauqi, Majnoon, West Qurna, Rumaila and Zubair. Nasiriya field is a large collapsed crest rollover anticline trending north west-southeast structural trend



Data available and work performed

Logs from 4 wells Porosities and permeability from core data. The work performed include: - Quality check of the available logs Checked Items (Single Well) • Depth match • Bad holes • Formation Picking • Spikes • Discontinuity





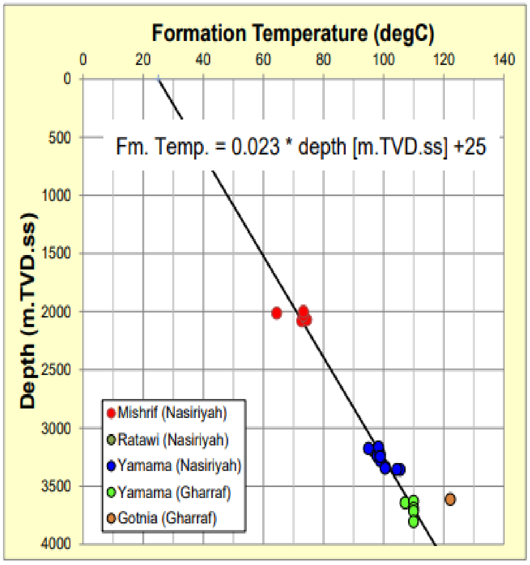
and making Reservoir analysis from logs such as Zonation, porosities, water saturation. Analysis of different cut offs General well correlation for Lower Mishrif .

All wells are treated as vertical wells. The subject to log analysis interval was drilled with 8.5 inches bit. Water-Base Mud (WBM) was used in all wells, with mud weight in the range between 1.0 to 1.35 SG over the logging interval.Main lithologies are limestone and dolomitic limestone in the Mishrif Washout Intervals are consistently observed in; • Upper most part of Sa'di • Tanuma • CRII The caliper log showed more than 2 inches lager than bore hole size.

Logging Environment, Temperature and Formation Water Salinity.

Geothermal gradient based on the DST and Prod. Test. From the available data was determined as shown in the Figure -5.where fhe following equation for the geothermal gradient is applied

Formation. TEMP (c) =0.023*Depth (m. TVDss} + 25



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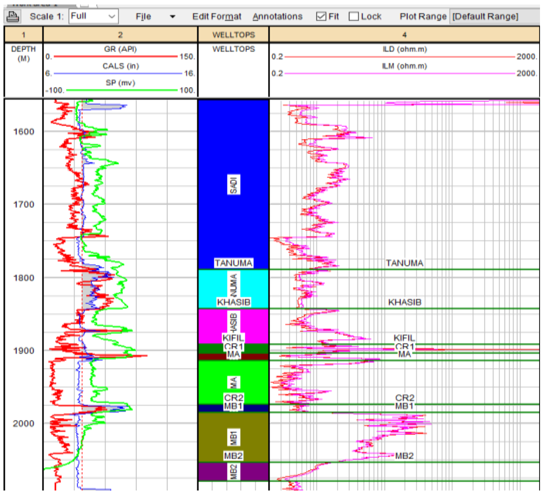
Formation salinity based on 3 water analyses

Taken from water samples taken from the first three discovery wells as shown in the below table

Fromation	Mishrif		
Well	NS-3	NS-2	NS-22
Depth	2076	2069	2069
pH	5.6	7.18	5.79
Rw	0.0562	0.0642	0.0431
at Temp C	-	-	15.6
SG	1.15	1.15	1.16
TDS[ppm]	124500	190788	202691
Na+	62626.2	65395.9	69915
Ca++	12800	12800	14000
Mg++	2916	3645	3888
K+	401.5	605.01	610.4
Ba++	-	-	-
Sr++	587.9	691.44	755.2
Cl-	127800	134616	144840
SO4--	1250	1000	590
CO3-	-	-	-
HCO3	97.6	109.8	63.44
NO3	-	-	-
TDS effective	178575	186971	198896
Average TDS eff.	188147		

*A. **Identification of reservoir rocks***

To discriminate potential reservoir rock from non-permeable rock, sp and gamma-ray logs (GR) were used. The GR logs measure the natural radioactivity information and can be used for identifying lithology for correlating zones. Shale–free sandstones and carbonates have low concentrations of radioactive material and give low GR readings. As content increases, the gamma-ray log response also increases because of the concentration of radioactive material in shale. For a quick look evaluation, the following steps were followed: - A sand line was constructed by reading the average GR level of thick clean sands (sands with the lowest. GR) and was called the sand line. Also, a GR level in thick shale beds was identified. This reading was assumed to represent 100% shale and called the shale line -A near-vertical line was drawn in the middle between the shale line and the sand line (cut-off line) with about 65- 69.5 API values. - All intervals where the GR log is on the left of this cut-off line were assumed to be a potential reservoir.(Figure-6)

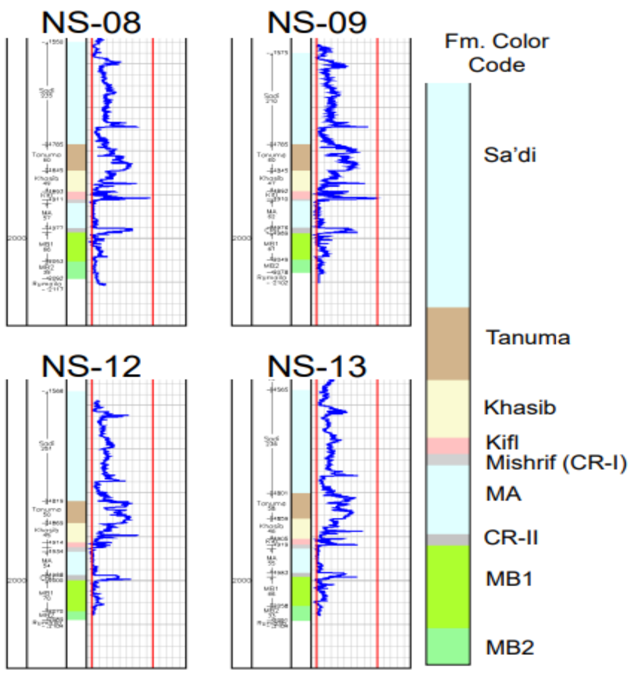


B. Determenation of shale volume

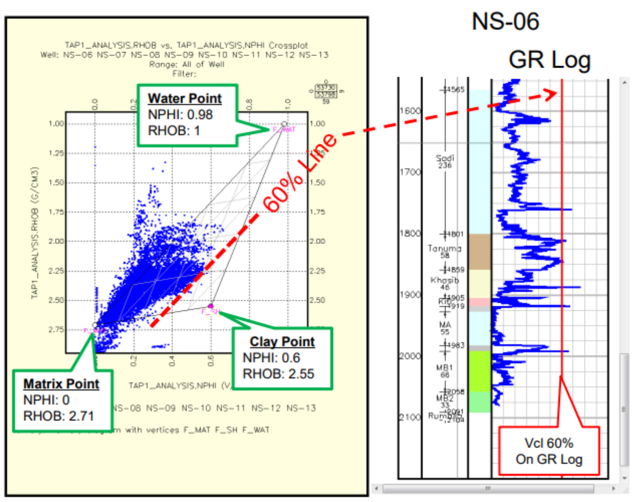
Methodology od Vcl(1): Total Gamma Ray with Linear equation : Vcl(2): Double Clay Indicator: Neutron-Density Cross Plot Decision to the most robust volume of clay The most robust curve: Vcl(1): and Vcl(2) ¬ Uncertainty to The VCL uncertainty ranges 4.3 TO 10.3 @ MB1 RESERVOIR .

Matrix (8 GAPI) and GR clay (100 GAPI) values are selected for GR index equation. Both values were applicable for the evaluation of the new wells.

The first step is to determine the volume of shale. The Gamma Ray Index was first calculated as: IGR = GR log – GR min (1) GR max – GR min The Shale Volume was then calculated using the (Larionov, 1969) linear response method.. GRmin = GR log reading in clean sandstone GRmax = GR log reading in shale zone. IGR = Gamma ray index. Vsh = volume of shale.



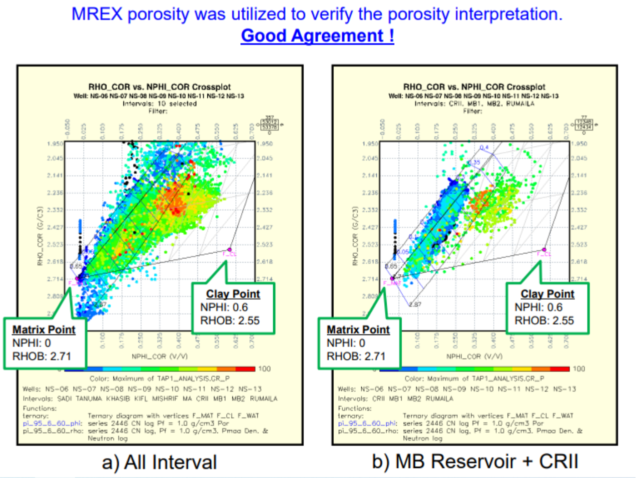
The matrix and clay points on the cross plot were defined by taking the consistency with the baseline of the GR method.



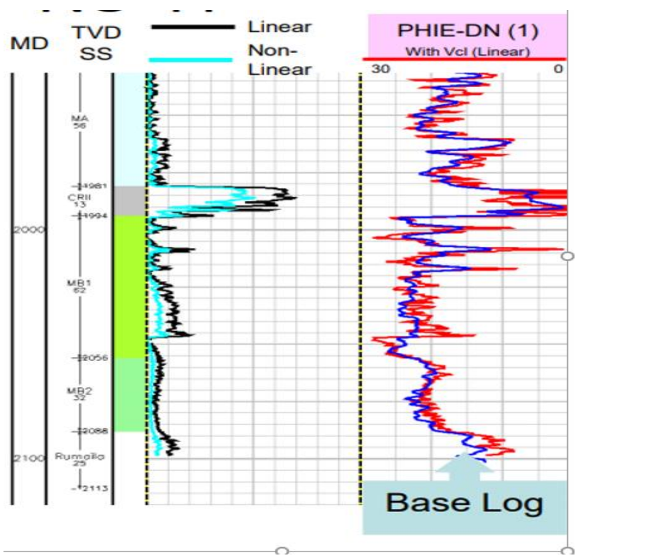
C. Evaluating porsity

Porosity Estimation by the following two methods; PHI(1): Density-Neutron Cross Plot . PHI(2): Sonic Porosity with Raymer-Hunt-Gardner

Porosity is the ratio of voids to the total volume of rock in percentage, Φ = Volume of pores Total volume of rock (3) This is usually called the total porosity, but the effective porosity is a function of interconnected void spaces and is most useful in characterizing a reservoir. Consequently, in this project effective porosity will be used.



Number equations consecutively. The reservoir porosity calculated from the density data for this project was done with this formula. ΦD = Pma - Pb (4) PMa - Pfl Where ΦD = Density porosity PMa = Matrix density (2.78g/cm3 for limestone). Pb = Formation bulk density (from wire-log). PFl = Fluid density (1.0g/cm3) . Average Neutron Density Porosity ΦA = (ΦD + ΦN) (5) 2 Where: ΦA = Average porosity. ΦN = Neutron porosity (from logs). ΦD = Density porosity. Effective Porosity The average porosity is corrected for shale effects to give effective porosity. ΦE =ΦA x (1 - V sh). (6) Where: ΦE = Effective porosity. Vsh = Shale volume. ΦA = Average porosity. In general, field appraisal classifications of reservoir porosity are; Percentage / Decimal 5% - 10% = 0.5 – 0.10 = poor. 10% - 20% = 0.10 – 0.20 = good. Above 20% = above 0.020 = very good.



II. Resistivity of Formation Water (Rw)

The resistivity of formation water is affected by water salinity and formation temperature .so , it is important to detect the most representative value of Rw to calculate water saturation precisely In this project the value of Rw was determined in by two approaches .The first one take the Rw from formation water analysis of water samples which done in the lab .the value of Rw for Mishrif water samples was determined in the lab as 0.023 at formation tempreture

The second approach to check the value from Picket Plot as shown in the below Figure-7."which Rw is detrmined as 0.022 @ 190 F

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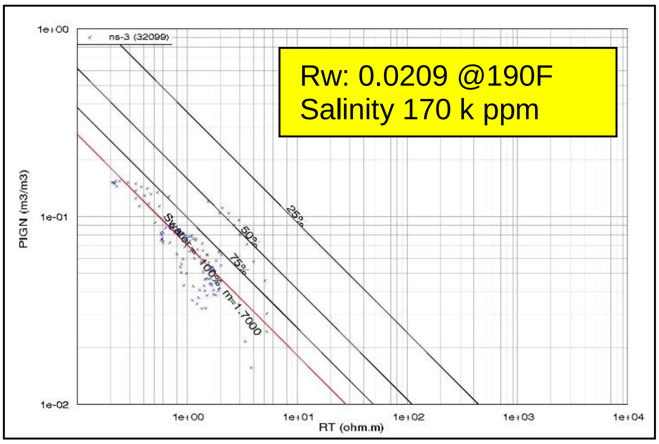
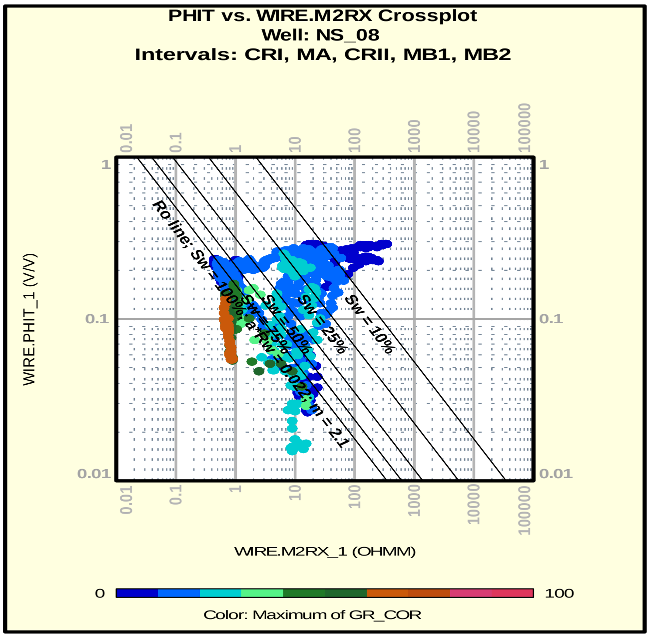


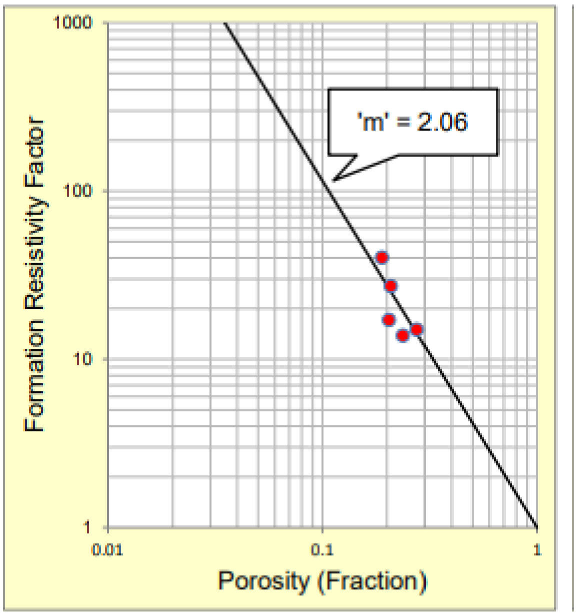


Rw is determined using picket plots (Φ vs Rt) in the water zone clean water bearing reservoir was identified for each well and porosity Φ was plotted against uninvaded zone resistivity RT on a double logarithmic plot (pickets plot).A best fit line was drawn through the point; the intersection point of this best fit line on the resistivity axis will be the value of the Rw

Determination of the Water Saturation (Sw) The amount of pore volume in a rock that is occupied by formation water is referred to as water saturation. The pores of the formation may be filled with gas, oil or water and the sum of the saturation of all the fluids in the formation must total 100%. Archie's equation (1942) was used to estimate Sw Sw = ⎨a x Rw ⎬ 1/ (7) RT x Φ m Where: Sw = water saturation (in v/v decimal or percentage). Rw = is the resistively of formation water. RT = Uninvaded zone resistivity from deep formation resistivity. Φ = Porosity of the zone. a = Tortousity factor = (0.81) or local correction factor m = is cementation factor = 2. n = is the saturation exponent = 2. Flushed Zone Water

Cementation Exponent m , m´ cementation is variable due to the complexity on porosity type (´m´ range 1.6-2.4)

Cementation Factor 'm'

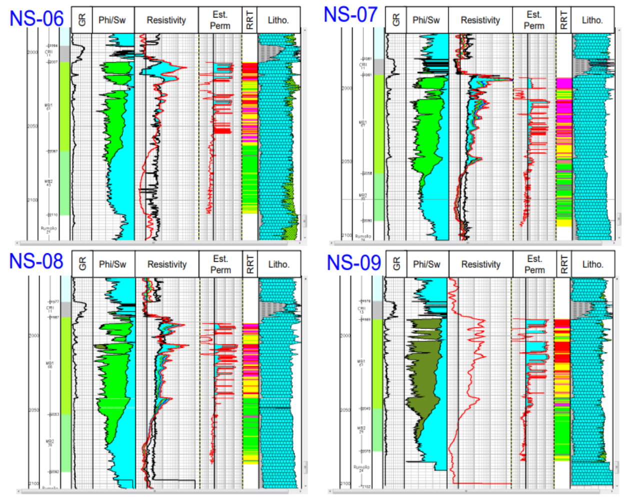


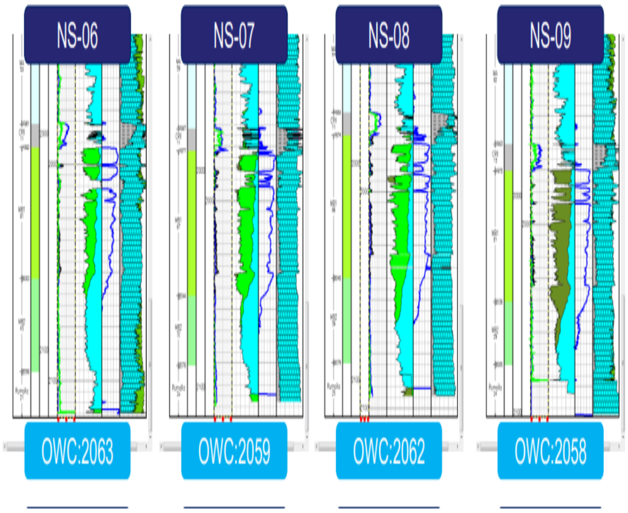
- Default n=2 and a=1 is applied as no information is available

A. *Detremination of Hydrocarbon Saturation*

The Hydrocarbon saturation is the fraction of reservoirs pore volume occupied by hydrocarbons. Sh = 1 - Sw. (9). Where: Sh = hydrocarbon saturation Sw = water saturation. Determination of Bulk Volume Water (Bvw) The proportion of water in the total formation is referred to as bulk volume water. It can be used as an indicator that the formation is at irreducible water saturation. It is a product of the formations water saturation and porosity. When a formation is at irreducible water saturation (Swirr), values of the Bvw calculated over a range of depths in a formation are constant or very close to constant. Water in the uninvaded zone (Sw) does not move because it is held on grains by capillary pressure. Therefore hydrocarbon production from a zone at irreducible water saturation should be water free (Morris and Biggs, 1967).Thus Bvw increases with decreasing grain size. $Bvw = Sw \times \Phi$ (10). Where: Bvw = Bulk volume water. Sw = Water saturation. Φ = Porosity. Determination of Permeability (k) Permeability is the ease of a rock to transmit fluids and is controlled by the size of the pore throat. It is measured in Darcy's (or milidarcy md). The Wyllie & Rose (1950) log derived permeability equation was used. It is valid for estimating permeability in formations at irreducible water saturation (Schlumberger, 1985).Then values gotten are compared to values of nearby producing wells of the same formation. $k = [250 \times \Phi^3] / Swirr$ (11) Where: k =log derived permeability Swirr = Irreducible water saturation. Φ= Porosity of the zone. Reservoir permeability's may be loosely described as follows: Very low: $k < 1$ md Low = $1 \text{ md} < k < 10$md. Fair: $10\text{md} < k < 50$md. Average: $50\text{md} < k < 200$md. Excellent: $k > 500$md. Reservoir permeability varies widely, in carbonate reservoirs. Determinations of the Movable Hydrocarbon Index (Mhi) The ratio of water saturation (Sw) to flushed zone water saturation (Sxo) gives the amount of hydrocarbons which have been moved by the invasion process. The ratio is referred as the moveable hydrocarbon index. This provides an estimate of the producibility of oil. $Sw/Sxo = \{Rxo/Rt\}^{1/2}$ Rmf/Rw (12) If the ratio Sw/Sxo is equal to or greater than 1.0, then hydrocarbon were not moved during invasion. This is true regardless of whether or not a formation contain hydrocarbons. Whenever the ratio is less than 0.7 for sandstones, the moveable hydrocarbon is indicated (Schlumberger, 1972). Identifying the Hydrocarbon Bearing and Water Bearing Layers (OWC) Hydrocarbon and water bearing layers can be easily delineated using resistivity log. From Archie's equation (1942). Rt increases when the water is replaced by oil with porosity and lithology remaining constant. $RT = Rw \, \Phi^{m} \, Sw^{n}$ (13)

Rt increases when porosity (Φ) decreases or density increases with lithology and Sw constant. Water bearing intervals was outlined by low resistivity and tram lining between density and resistivity. The density decreases when the water is replaced by oil in the formation with the same porosity, thus the hydrocarbon bearing intervals was not only characterized by high resistivity but often by an anti-correction between the density and the resistivity logs. Distinguish Between Oil and Gas. (OGC). Gas or light hydrocarbons within the zone of investigation of the Density or Neutron devices causes the". apparent porosity from density log to increase and the Neutron log to decrease. On a Density-Neutron plot, this results in a shift (from the liquid-filled point of the same porosity) upward and to the left, almost parallel to the iso-porosity lines. This implies that Density and Neutron logs in a cross plot will be shifted in opposite directions in a hydrocarbon bearing zones. Thus zones with large density-neutron separation are identified as gas bearing zones and zones with small separation as oil bearing zones.
OWC is defined for each well. The Average OWC of the new wells is 2061.5m.TVD.SS The average OWC is little higher

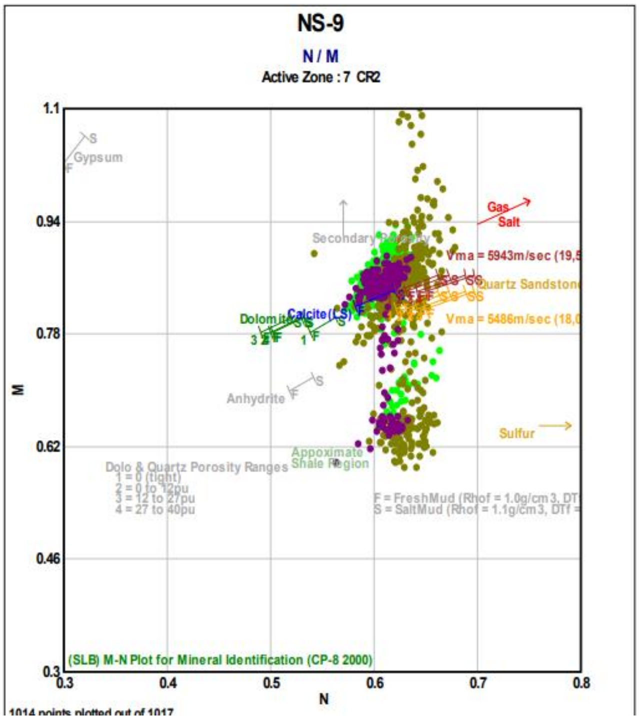


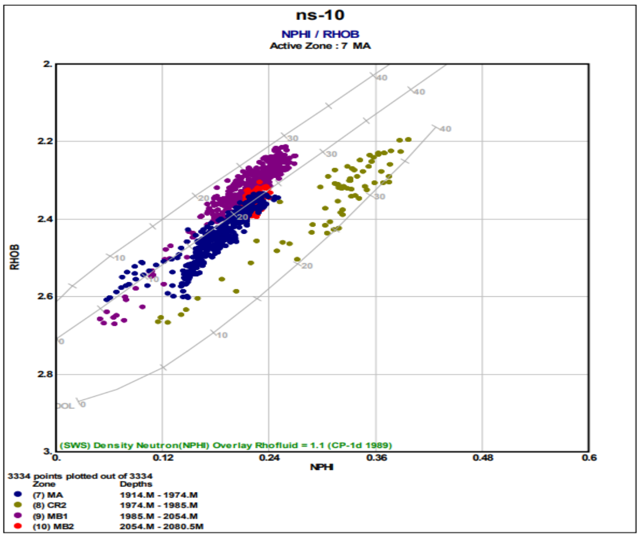


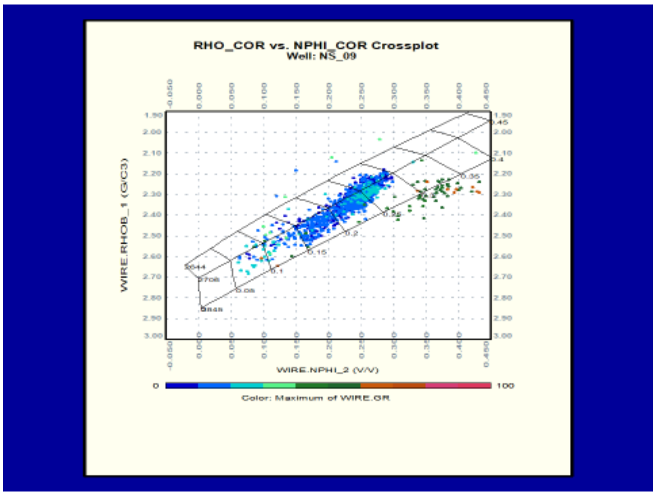
Lithology determination

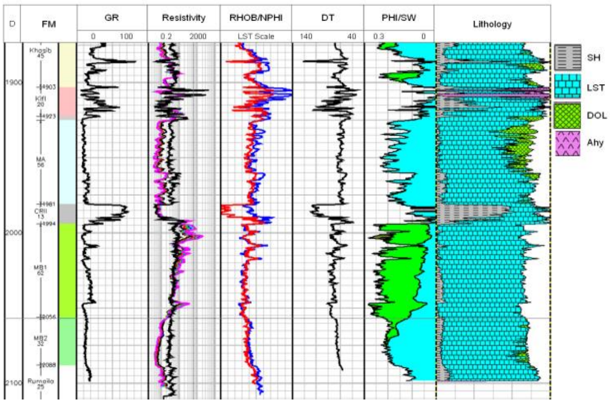
Lithological Determination

In this analysis, M-N plot method and Neutron-Density Crossplot method are used to understand the profile of the rocks in the reservoir. Based on the results in Appendix 3-1, it shows that Mishrif Reservoir in Naseryia field mainly consists of limestone and some dolomite and clay . The results also show that there is presence of



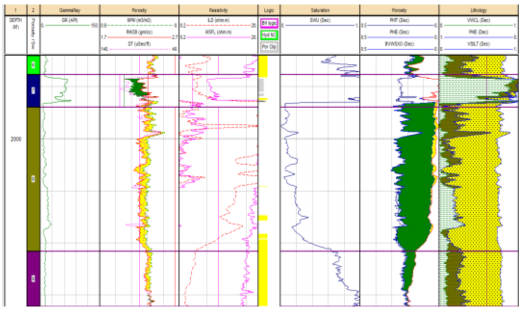


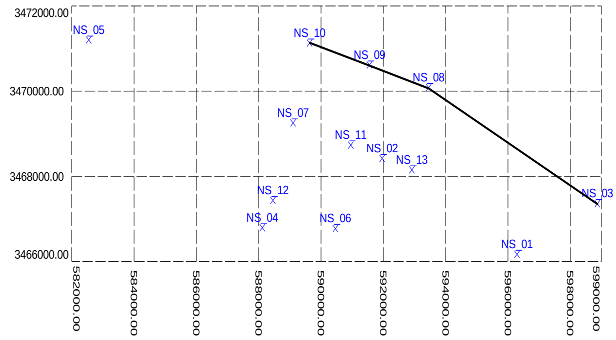


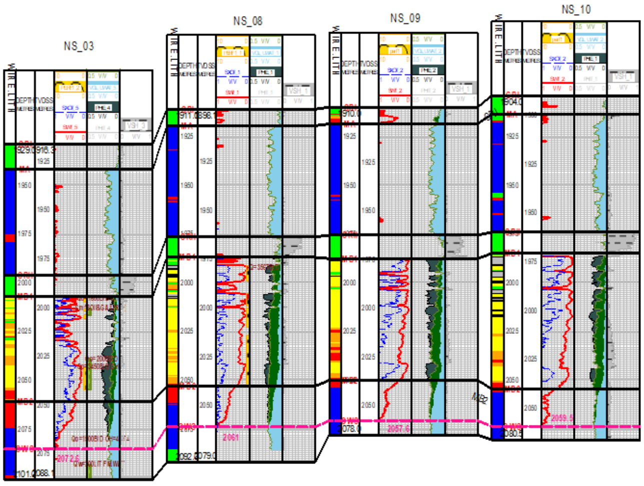


Results and Discussions

NS-9- Well 01 Six major reservoirs intervals A1-A6 were delineated for this well as showed in figure 4.







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The Petro physical properties are summarized in Table 3.

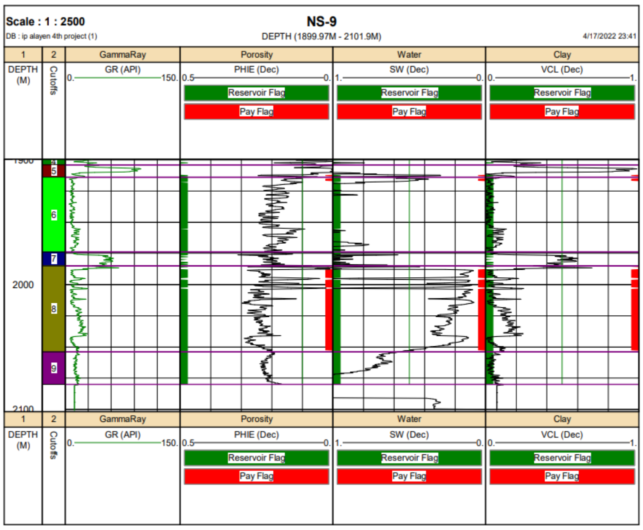
Well : NS-9
Date : 4/17/2022 11:33:42 PM

Reservoir SUMMARY

Zn #	Zone Name	Top	Bottom	Gross	Net	N/G	Av Phi	Av Sw	Av Vcl Ari	Phi*H	PhiSo*H
1	SADI	1550.00	1789.63	233.40	174.73	0.749	0.170	0.937	0.151	29.76	1.89
2	TANUMA	1789.63	1843.00	53.37	26.29	0.493	0.194	0.878	0.375	5.09	0.62
3	KHASIB	1843.00	1892.00	49.00	35.51	0.725	0.176	0.863	0.182	6.27	0.86
4	KIFIL	1892.00	1904.00	12.00	3.81	0.318	0.147	0.963	0.278	0.56	0.02
5	CR1	1904.00	1914.00	10.00	1.37	0.137	0.189	0.410	0.154	0.26	0.15
6	MA	1914.00	1974.00	60.00	59.32	0.989	0.184	0.963	0.036	10.91	0.41
7	CR2	1974.00	1985.00	11.00	6.67	0.606	0.203	0.891	0.325	1.35	0.15
8	MB1	1985.00	2054.00	69.00	64.34	0.932	0.233	0.220	0.093	14.97	11.68
9	MB2	2054.00	2080.00	26.00	26.00	1.000	0.214	0.806	0.047	5.58	1.08
	All Zones	**1550.00**	**2080.00**	**523.77**	**398.04**	**0.760**	**0.188**	**0.774**	**0.140**	**74.75**	**16.86**

Pay SUMMARY

Zn #	Zone Name	Top	Bottom	Gross	Net	N/G	Av Phi	Av Sw	Av Vcl Ari	Phi*H	PhiSo*H
1	SADI	1550.00	1789.63	233.40	3.20	0.014	0.410	0.025	0.009	1.31	1.28
2	TANUMA	1789.63	1843.00	53.37	0.00	0.000	---	---	---	---	---
3	KHASIB	1843.00	1892.00	49.00	3.66	0.075	0.217	0.313	0.053	0.80	0.55
4	KIFIL	1892.00	1904.00	12.00	0.00	0.000	---	---	---	---	---
5	CR1	1904.00	1914.00	10.00	0.91	0.091	0.220	0.325	0.095	0.20	0.14
6	MA	1914.00	1974.00	60.00	1.83	0.030	0.152	0.438	0.013	0.28	0.16
7	CR2	1974.00	1985.00	11.00	0.00	0.000	---	---	---	---	---
8	MB1	1985.00	2054.00	69.00	62.64	0.908	0.234	0.212	0.091	14.65	11.55
9	MB2	2054.00	2080.00	26.00	0.00	0.000	---	---	---	---	---
	All Zones	**1550.00**	**2080.00**	**523.77**	**72.24**	**0.138**	**0.239**	**0.207**	**0.083**	**17.24**	**13.67**



Average Reservoir Properties of Category 1 Reservoirs

Mishrif Formation

	Gross (m)	Net Reservoir (m)	Net Pay (m)	N/G (%)	PHIE (%)	SW (%)
Nasiriyah	172.0	152.9	55.4	32.2%	23.8%	34.3%

Conclusion

The wireline logging Interpretation for the newly drilled 4 wells in Nasiriya field were interpreted by utilized knowledge and the basic petrophyical analysis method and parameters for carbonate reservoirs . First RHOB logs was corrected to BH effect based on NPHI, DT and Lithology No Environmental corrections were applied due to lack of BH and logging parameters. No major problems observed with the logs data for the evaluation purpose In some intervals the log response was affected by borehole rugosity, primarily opposite the mudstone/shale Opposite the main reservoir intervals the hole is in gauge The depth discrepancies between all available curves were corrected using GR curve as a reference.

Log interpretation has been carried out for these wells drilled in the Nasiriya Field. • Target reservoirs were evaluated with comprehensive assessment using all the available information. As a result, fluid was identified for each reservoir and reservoir properties were calculated reasonably. The famous methodologies and parameters were applied to estimate the interpretation parameters i.e., Vcl, Porosity, Sw. The results were also verified by using the different other production data from mishrif reservoir The gamma ray log shows a gradual increase from the middle increased around the interval.. ¬ The average porosity and SW for the 4 wells are 19.6% and 29.9%, respectively. The values were consistent with the old previous five wells drilled in 1980's. ¬ The oil water contact (OWC) is defined for each wells. The average OWC is 2061.5m.TVDss which is 3.5m shallower than the old wells

Conduct the integrated reservoir study by incorporate with this study results and 3D seismic data top establish the optimum full field plan. ¬ Data gathering recommended to be perform by selecting the Key well(s) selection, in which full suite of logs, core and dynamic test to be conducted comprehensive study for understanding the reservoir. ¬ Perform the dynamic test such as well test and MDT to investigate the possible no-flow barrier for further optimizing the reservoir development.

Log interpretation still remain uncertainties in calculation of water saturation. It is caused by uncertain parameters (‘a’, ‘m’, ‘n’ and Rw) used in the Sw equation.
Reservoir properties from log interpretation will be utilized in the next petro physical evaluation like Fluid Contact model and Sw model, and in the Geological Model.

For more realistic log interpretation, rock type analysis using additional core samples is required. Therefore, it is essential to take additional samples during the field appraisal phase
. Oil Water Contact (OWC) The depth where water saturation calculated from logs becomes downward to 100 % in the oil-bearing reservoir. Oil-bearing reservoir is sealed vertically at the base by impermeable bed.

References

[1] Archie, G.E., 1942: The Electrical Resistivity log as an aid in determining some Reservoir characteristics: Journal of Petroleum Technology, 5. pp.54 -62.
[2] Doust, H., and Omatsola, M.E., 1990: Niger Delta, in Edwards J.D and Santogrossi, P.A eds. Divergent/Passive Margin Basins, AAPG Memoir 45. pp.239 -248. [3] Ekweozor, C.M and Daukoru, E.M (1994). Northern Delta Depobelt portion of the Akata-Agbada Petroleum System, Niger Delta, Nigeria in: Magoon, L.B, and Dow,W.G.(eds).The Petroleum system from source to Trap,AAPG Mem.,no.60,Tulsa,America
[4] Hilchie, D.W., 1978: Applied Open-hole Log Interpretation: Golden, Colorado, D.W. Hilchie Incorporated, p.309.
[5] Hospers, J., 1971: The Geology of Niger Delta. In: F.M., Delaney(Ed): The Geology of the East Atlantic Continental Margin: ICSU /SCOR Working Party (31) symp. – Cambridge Inst. Geol.Sci. Dept. pp.125 -127.
[6] Klett, T.R., Ahlbrandt., T.S., Schmoku., J.W, and Dolton., J.L., 1997: Ranking of the World`s Oil and Gas Provinces by known Petroleum Volumes. U.S. Geological Survey Open – file Report pp.97 - 4631. [7]
Kulke, H., 1995: Nigeria in Kulke. H, (eds).Regional Petroleum Geology of the World Part II: Africa, America, Australia and Antarctica. Berlin, Gebruder Bomtraeger, pp.143 -172.
[8] Larionov, V.V., 1969: Borehole Radiometry. Moscow, U.S.S.R. Nedra.
[9] Morris, R.L and Briggs, W.P (1967).Using Log-derived values of water saturation and porosity: SOC. Professional well log analysts, 8th Ann. Logging Smp. Trans., Paper.
[10] Schlumberger, 1972: Log Interpretation Manual/Principles, v.1: Houston. Schlumberger Well Services. Inc. p.31. [10]Schlumberger, 1985: Well Evaluation Conference, LagosNigeria. 3: p.47.
[11]Short, K.C., and Stauble A.J. (1967). Outline of Geology of Niger Delta. AAPG Bull., no 51, pp. 761-779.
[12]Wyllie, M .R.J and Rose, W.D., 1950:‘SomeTheoretical Considerations Related to the Qualitative Evaluations of the Physical Characteristics of Rock from Electric Log Data’. Journal of Petroleum Technology v.189, pp.105-11