

Well Logging Analyzing in Misan Province South of Iraq with Estimation of Logging Expenses

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Abstract--- Understandings of the log are the most significant part after the well is well drilled and the bit pills the well. The Amara oil field reservoir was studied. Software called (Interactive Petrophysics IP V3.5) has been used to interpret wireline log data, a software unleashed by the company Schlumberger. This interpretation recognizes the time and effort difference between the use of conventional old interpretation charts and modern software such as IP, thus the cost difference required to complete the interpretation process. Interpretation of logs by Interactive Petrophysics (IP) program which depends on the LAS files of the wells to determine the porosity by (sonic, neutron density) until the total porosity (ϕ_t) of the neutron and density logs, the secondary porosity index of the sonic and the total porosity is determined. Effective porosity (ϕ_e) has been determined and uninvasion zone resistivity (R_t) has to be found through the resistivity log. The water saturation resistivity (R_w) was also calculated from the water analysis or (R_{wa}) and determined Archie parameters such as (a , m , and n) from the cross plot. The variables of ϕ_e , R_t , R_w and Archie parameter must be entered in the Archie equation to saturate water (S_w) and thus determine the saturation of hydrocarbons. Formation lithology such as (limestone, sandstone and dolomite) by cross plot, also determined shale volume (V_{sh}) by different methods such as GR , neutron log and last caliper borehole diameter in comparison with bit diameter to know caving, fracture and magnification or mud cake that is useful for pumping cement volume. Cost control is an important part of good logging operations and must be the tool with the lowest cost and depends better on the performance of the tools. Many well logging companies have different prices for these tools and have taken samples of some companies to compare them, such as the Arab well log company (AWLCO), the oil service company and the national oil company (NPS). The (AWLCO) is the cheaper one.

Keywords--- Well Logging, Amara Oil Field, PetroPhysical Properties.

I. Nomenclature

CNL	Compensated Neutron Log.	CPI	Computer Processed Interpretation.
DIL	Deep Induction Latero log.	FDC	Formation Density Compensated.
MSFL	Micro Spherical Focused Log.	RLLD	Resistivity deep Latero log tool.
PHIT	Total porosity.	PHIE	Effective porosity.
R_{mf}	Resistivity of mud filtrate RMSFL.	R_o	Resistivity of the fully brine saturated rock.
R_t	True formation resistivity with water saturation.	R_w	Formation water resistivity.
Δt_{ma}	apparent matrix transit time $\mu\text{sec}/\text{ft}$.	Δt_f	fluid transit time $\mu\text{sec}/\text{ft}$.
ρ_b	bulk density log reading.	ρ_{mf}	mud filtrate density.
ϕ_D	density log porosity.	ϕ_{Dsh}	apparent density porosity in 100% shale.
ϕ_N	neutron log reading.	ϕ_{Nclay}	neutron log reading in 100% shale.
ϕ_t	total porosity.	ρ_g	grain density gm/cc.

II. Introduction

“Well logging” or “borehole logging”, can be described as the practice of complete recording of the geological formations entered by a well log [1] (See Figure 1). The log depends on two basic approaches: the visual inspection of surface samples called (geological logs); or the physical measurements with tools lowered into the hole named (geophysical logs) [2]. Few forms of geophysical well logs could be driven at any phase of the well description such as drilling, finishing, production or abandoning. Well logging is implemented in oil and gas fields, ground-water, mineral and geothermal exploration, geotechnical and environmental studies [3].

Well logging is a vital supplier for training assessments. The training assessment purposes contain evaluating the size of the reserve, supportive well-positioning and understanding the presentation of the reservoir throughout

development [4]. Well logging offers a limited bases from the well with valued materials. Training evidences can be attained via inspection the cuttings, core models and fluid characteristics of the drill. Supplementary data can be calculated with the tools in a well-logging [5]. Logging tools can be considered to determine the physical quantities such as electromagnetic and sonic wave signals during the formation part, and to notice the basic units produced by rock formation. Data are operated to approximate the formation features. The logging environment explains the reason behind of log combinations are used and discoursed log clarification performances and boundaries.

The major intention of this research is to employ the accessible data sets from the oil fields of Khasib, Mishrif and Nahr Umar Amara to define the petrophysical and lithological properties of each region. This study observes the pre-interpretation and core properties formation of Khasib, Mishrif and Nahr Umar formation. The current study consists of two parts, preparation and interpretation. Pre-interpretation includes finalizing the active porosity (shale effects), and completely the essential considerations during the interpretation procedures. The Interactive Petrophysics software v3.5 (an interactive program for interpreting and logging the borehole environment and the invasion effects) was used.

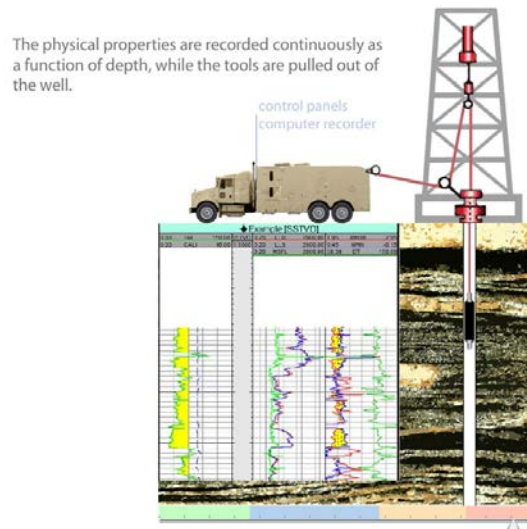


Fig. 1: “Well logging” or “borehole logging”

III. Methodology of Study

3.1. Area of Study

The Amara oil field was first discovered by seismic surveys conducted in the Misan province in the 1970s. It is 10 km southwest of the Amara town. This field, considered to be one of the newly discovered and developed fields, although W-E drawn-out slightly with the probability of a major fault in the center not yet confirmed [6], is approximately 16-km (west to west) and 5-km(south to north). The first well (AM-1) was drilled in 1980 and later ended with the start of the Iraq - Iran war. The Amara field is located in the unstable shelf in the Mesopotamian Basin. The primary production of recovery oil began in 2000. At present, there are 6 wells on the field.

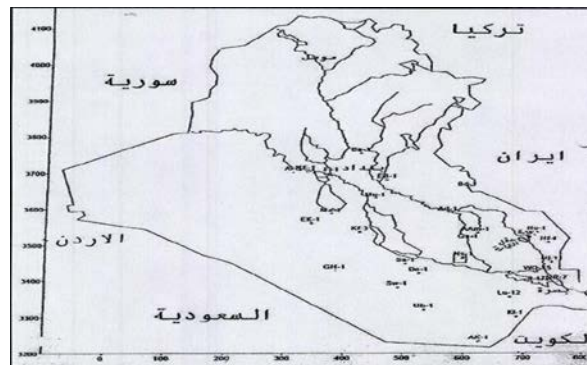


Fig. 2: Amara Oil Field Location

3.2. Description of the Reservoir

3.2.1. Khasib

The Khasib reservoir consists mainly of limestone rocks from the late Cretaceous period; this reservoir is divided into two main units without any conclusive evidence of vertical connectivity.

The total thickness of the reservoir is approximately 80 meters in total, porosity is described as poor to medium as seen in the cores and the open hole.

3.2.2. Mishrif

The Mishrif reservoir consists mainly of calcareous reservoir rocks from the Middle Cretan period, with moderate to good porosity both in the open hole and in the cores. The reservoir's thickness is over 400 meters in total.

This reservoir is made up of several subunits: MA, MB-11, MB-12, MB-13, MB-21, MC-1, MC-2 and MC-3 with barriers between these layers.

3.2.3. Nahr Umar

A Middle Cretaceous Sandstone reservoir, the Nahr Umar reservoir is made up of three sub-units with a total thickness of 240 metres. Measured porosity values from core samples acquired and open hole logs are good to excellent.

3.3. Basic Well Log Equipment

3.3.1. Logging Unit

A specialist truck installed with a complete data acquisition and processing computer system.

3.3.2. Logging Cable or Wire Line

An electromechanical cable attached to the truck and operated by the truck's hydraulics.

3.3.3. Tool for Logging

An electronic device consists of sensors, data acquisition and transmission processing circuits via a logging cable or wire-line is lowered to the well. The wire-line electrically attaches to the logging tool by the computer surface system[7].

The data acquired from the tool is conducted via the logging cable via digital telemetry to the surface system. The surface computer records, processes and tracks these data thoroughly and generates the so-called "log" or "good log". Normally this is called the wire-line logging technique.

3.4. Well Logging Cost Control

There are many types of well logging tools used to give physical and chemical rock properties such as (GR, density, neutron, caliper, resistivity and sonic logs), each type has two tool prices for each meter, the second price of each section hole such as hole 17.5-inch has a special price different from the other hole 12.25-inch or 8.25-inch without the number of meters in each hole.

The prices increase when the depth increases and differs from the company to another company, also depending on the type of well such as (vertical and directional (horizontal & deviated) when the well is horizontal, the conventional logs above the angle of 60 degrees cannot be used, but logging during drilling (LWD) can be used. Each company has a different price from year to year and is not constant and will take a sample of the Arab Well Logging Company (AWLCO), the Oil Field Services Company and the National Petroleum Company (NPS) which give the price tool for each meter.

Amara field (third stage) AWLCO ran the tools in the cased hole to match the open hole to give a perforation position and to prevent the perforate in the casing joint that was detected by the CCL.

These tools depend on lower costs and better tools (optimal tools), which helps control costs and this is very important in reducing or controlling costs.

Some types of tools run in an open hole of 8.25 inches to provide more information on formation, but these tools are very expensive, such as the nuclear magnetic resonance log (NMR), the modular dynamic tester (MDT), the side wall core (SWC) and the imaging of micro-resistivity.

Table 1: Company prices for some logs

AWLCO (Arab Well Logging Company)	
Tools	Price (\$/MT)
GR	4
SONIC	1
CALIPER	3
RESISITIVITY	5
NEUTRON	5.5
DENSITY	4.5
MSFL	3.5
OIL SERV	
Tools	Prize (\$/MT)
GR	10
SONIC	15
CALIPER	12
RESISITIVITY	20
NEUTRON	30
DENSITY	40
MSFL	25
National Petroleum Services	
Tools	Prize (\$/MT)
GR	12
SONIC	20
CALIPER	15
RESISITIVITY	30
NEUTRON	40
DENSITY	50
MSFL	35

3.5. Theoretical Approach

On the basis of measurements of the core data, two equations describing the resistivity behaviour of reservoir rocks were proposed[7].Equation (2) regulates the rocks resistivity filled with the water formation. The deformation factor (F) is stated as “the ratio of the rock resistivity to the water content (R_w)”, and the ratio was specified by the correlative porosity of the fractional rock powered by an exponent (m).The value of m increased whencombined sandstone was referred to the exponent of cementation, but appeared to reflect increased tortuosity in the pore network for generalized rock descriptors with a range of m values, after Archie introduced another constant (a) equation (1)[8].

$$F = \frac{R_o}{R_w} = \frac{a}{\phi_m} \quad (1)$$

archie described changes in resistivity due to the hydrocarbon saturation in a second equation (2). Archie defined a resistivity index, I , the ratio of measured rock resistivity (R_t) to its expected resistivity if completely saturated with water (R_o). [9]

$$I = \frac{R_t}{R_o} = \frac{1}{S_w^n} \quad (2)$$

Equations (1) and (2) can be combined into one equation, which is usually referred to as " Archie equation" (3)[10].

$$S_w^n = \frac{aR_w}{\phi^n R_t} \quad (3)$$

Installation of shales in the GR index oil volume by chart:

$$I_{GR} = GR_{log} - \frac{GR_{min}}{GR_{max}} - GR_{min} \quad (4)$$

Where; I_{GR} : index of gamma ray, GR_{log} : gamma ray reading from log, GR_{min} : minimum gamma ray reading, GR_{max} : maximum gamma ray reading.

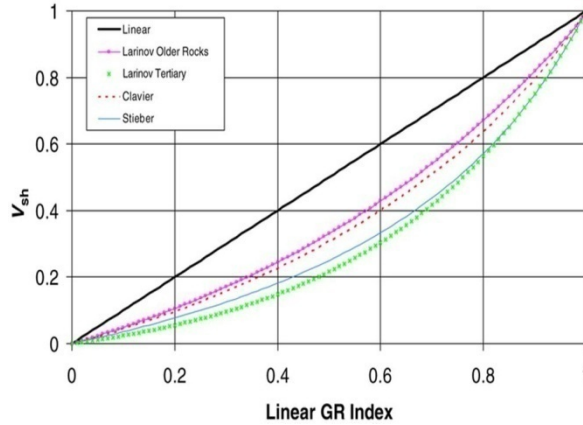


Fig. 3: Linear GR Index

Determination of the porosity of neutron log by shale volume[11]:

$$\phi_{N-correct} = \phi_N - V_{sh} \phi_{Nsh} \quad (5)$$

Where; $\phi_{N-correct}$: correct neutron porosity, ϕ_N : Neutron porosity from log, V_{sh} = Volume of the shale, ϕ_{Nsh} : Neutron porosity of shale.

Determining the porosity of the density log and the volume shale correction[12]:

$$\rho_b = \phi \rho_f + (1 - \phi) \rho_{ma} \quad (6)$$

Where; ρ_b : Formation's Bulk Density, ρ_f : Fluid Density (fresh water = 1, salt water = 1.1), ϕ : Porosity, ρ_{ma} = Grain (Matrix) Density.

Determination porosity from acoustic log by Wyllie-Time Average Equation [7]:

$$\phi_{sonic} = \frac{(\Delta t_{log} - \Delta t_{ma})}{(\Delta t_f - \Delta t_{ma})} \quad (7)$$

Where; ϕ_{sonic} : sonicporosity, Δt_{log} : travel time from the log ($\mu\text{sec}/\text{ft}$), Δt_{ma} : formation matrix travel time ($\mu\text{sec}/\text{ft}$), Δt_f : fluid travel time ($\mu\text{sec}/\text{ft}$) ($\Delta t_f = 189$).

Correction sonic porosity for shale volume [7]:

$$\phi_{S-correct} = \phi_S - V_{sh} \phi_{S-sh} \quad (8)$$

Correction sonic porosity for type of hydrocarbon [7]:

$$\phi_{sc} = \phi_s * 0.7, \text{ for gas.}$$

$$\phi_{sc} = \phi_s * 0.9, \text{ for oil.}$$

Resistivity (R) is the physical resistance measurement and is defined as electrical conductivity reciprocal (C) [7].

$$R = \frac{1000}{C} \quad (9)$$

R-log measures the resistivity of fluids applied in the rock around the electrical current. Oil and gas are electricity insulators. They do not perform the electrical flow and their resistivity is said to be endless. Water, however, drives electricity by salinity. The high dissolved solid water (NaCl) produces electricity much easier compared to fresh water. Then, salt water has a much minor resistivity than fresh water [9].

The induction log was designed to measure the resistivity of the formation of non-conductive fluids in boreholes. Bore hole with fresh water mud or oil - based mud offers excellent log environments. In fact, the induction log measures the training conductivity instead of resistivity [13]: $C = 1/R$

The dual induction log records three resistivity curves at three different degrees of investigation. A flushed zone resistivity, medium curve measurement and deep curve measurement of uncontaminated zone resistivity. Total neutron density and porosity[7]:

For oil zone:

$$\phi_t = \frac{\phi_N + \phi_D}{2} \quad (10)$$

For gas zone:

$$\phi_t^2 = \frac{\phi_N^2 + \phi_D^2}{2} \quad (11)$$

Effective porosity because of total porosity and shale volume[7]:

$$\phi_e = \phi_t(1 - V_{sh}) \quad (12)$$

Secondary index of porosity of total and sonic porosity[14]:

$$SPI = \phi_t - \phi_s \quad (13)$$

If the SPI is zero, the reservoir is not fractured, the reservoir is fractured if the SPI is less than one. Determine Archie equation water saturation[14]:

$$S_W = \sqrt[n]{\frac{R_O}{R_t}} \quad (14)$$

Archie's equation therefore becomes:

$$S_W = \sqrt[n]{\frac{aR_W}{\phi^m R_t}} \quad (15)$$

IV. Results and Discussion

4.1. Clay Parameter Determination

The M- N cross plot introduced by Schlumberger[14]A two- dimensional display of all three responses to porosity logs in complex reservoir rock. The cross plots of M-N are shown in Figure 3. It can be used to detect lithology, detect gas, classify clay minerals and SPI.

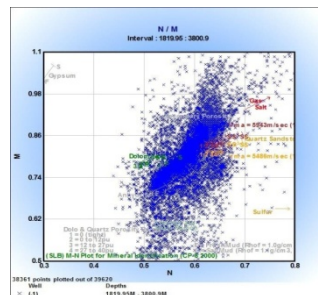


Fig.4: M vs N

4.2. Matrix Identification Plot

Clavier and Rust [14] introduced this technique. It determines the lithology as shown in Figure 4 by plot of the apparent lithology values (ρ_{ma}) versus (Δt_{ma}).

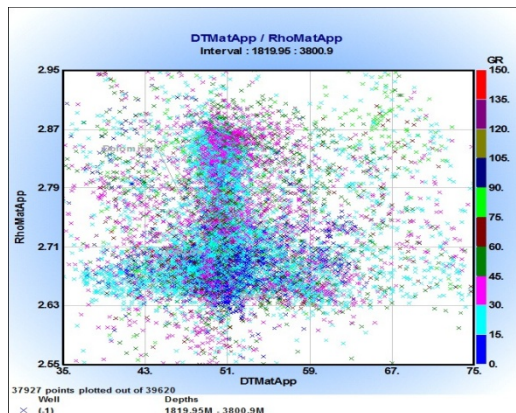


Fig.5: (ρ_{ma}) vs (Δt_{ma})

4.3. NPHI vs ROHP Matrix Identification

The matrix consists mainly of calcareous stone with some dolostone, as shown in Figures 6-10.

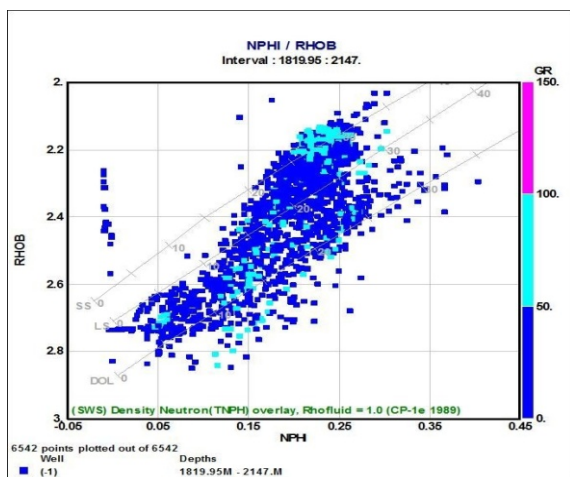


Fig.6:(1818.9M – 2147M)

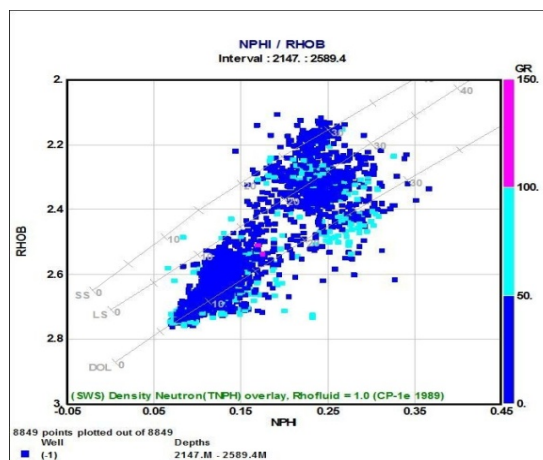


Fig.7:(1818.9M – 2147M)

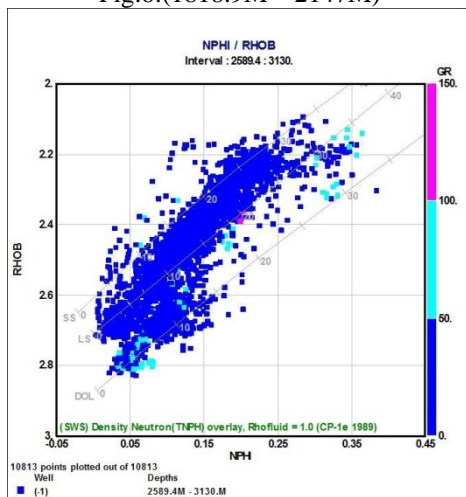


Fig.8:(2589.4M – 3130M)

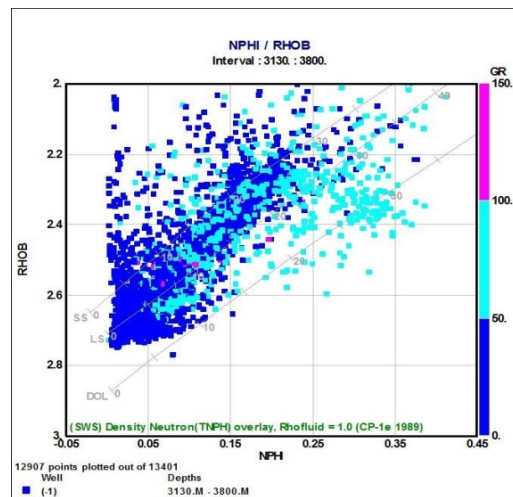


Fig.9:(3130M – 3800M)

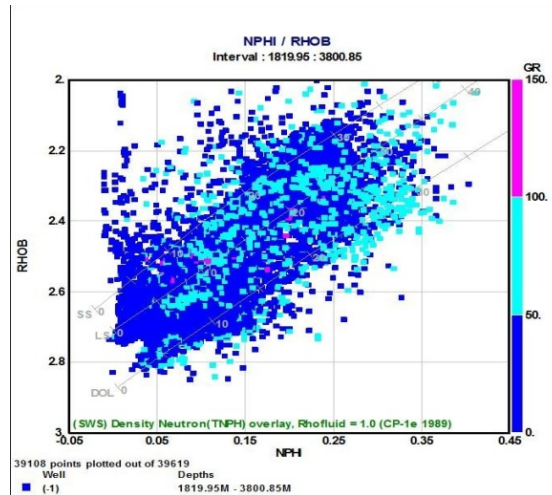


Fig.10: (1819.95 –3800.85)M

4.4. Archie Parameter Determination

Pickett presented resistivity- porosity cross plot and used the following equation to calculate m and a from well logs:

$$\log R_t = m \log \phi + \log a R_w \quad (16)$$

Equation (16) is a straight-line equation on log-log paper, where m is the slope and (aR_w) is the intercept at $R_t=1$; as R_w is calculated from water analysis and aR_w as shown in the Figure (11).

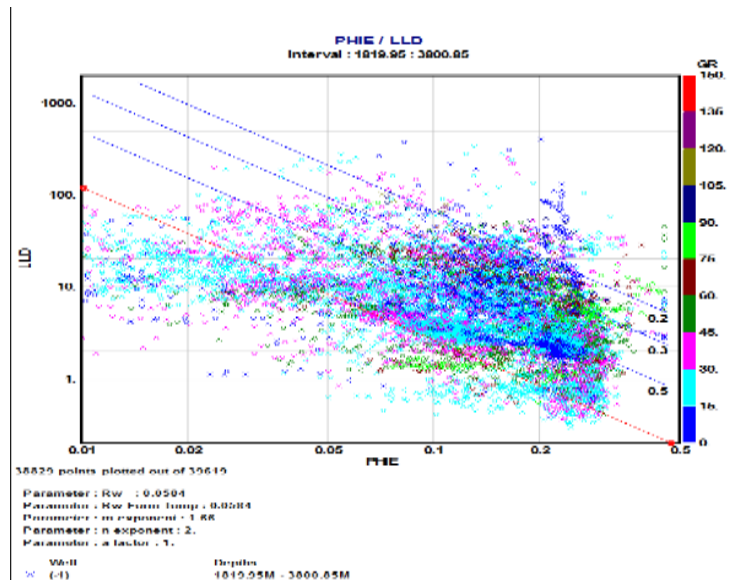


Fig. 11:LLD vs PHIE

4.5. Shale Volume Determination

The shale volume is determined using several methods as illustrated in Figure 12.

4.6. Computer process interpretation (CPI)

The CPI is calculate by using Archie equation as shown in the Figure 13.

4.7. Apparent resistivity method (R_{wa})

R_{wa} is the apparent water resistivityof the Archie equation forming, which assumes clean water- bearing formation. The following relationship is defined by R_{wa} :

$$R_{wa} = R_t/F \quad (17)$$

In clean water- bearing zones, R_{wa} is at least equivalent to R_w . Whereas the value is much higher in hydrocarbon-bearing zones (above three times R_w).

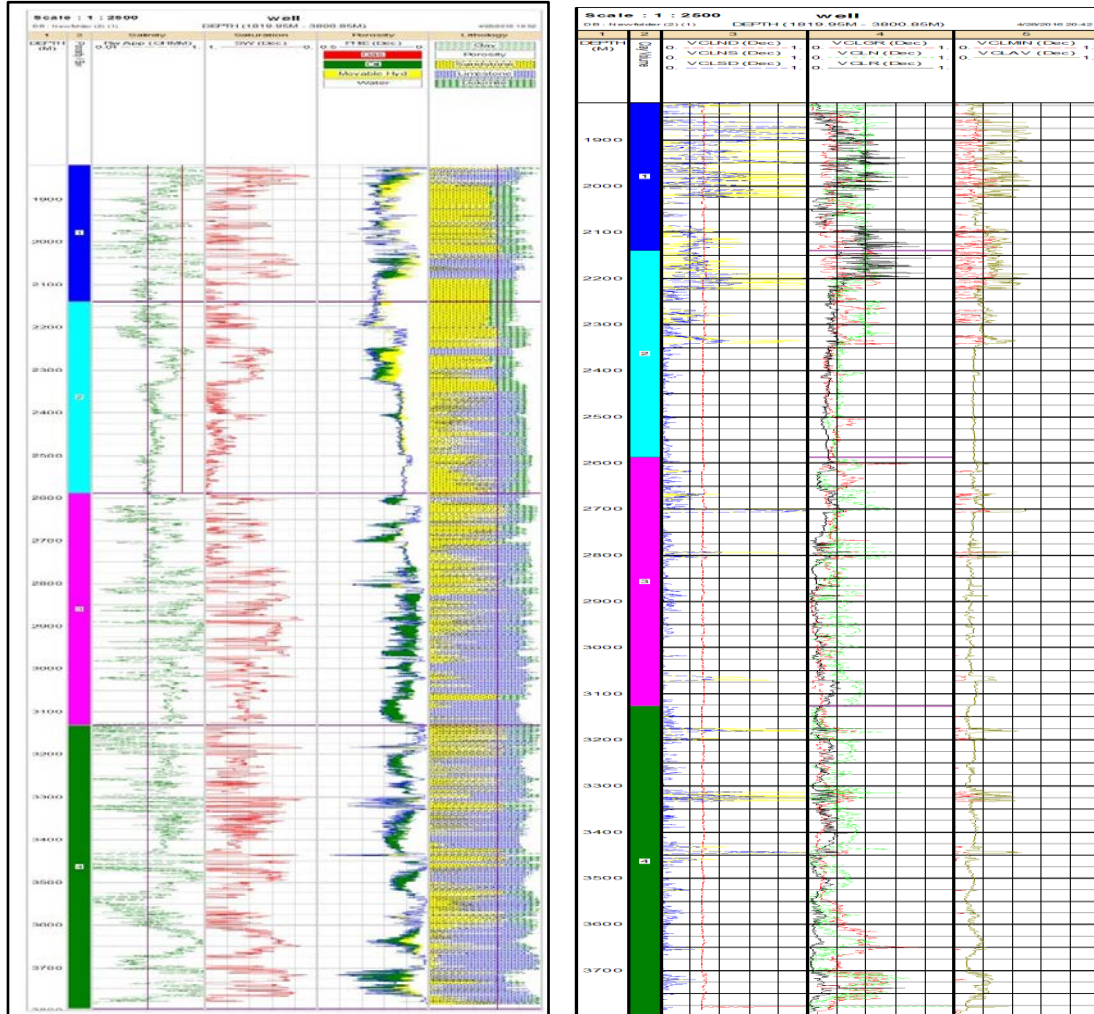


Fig. 12: Determine of Shale Volume Fig. 13: CPI

4.8. Perforation and percentage of shale

The Amara oil field is a prosperous field with a good multi-layer production, the mobile hydrocarbon represents a considerable amount. The formation contains a small amount of shale, but there are some feet with a high percentage of shale of 50%. The perforation from (1850–1925) m and (2250–2325) m should be in the zone.

V. Conclusions

The estimate of logging costs in the southern province of Misan in Iraq was considered in the current study. The data collected from the Amara oil field reservoir. The interactive software Petrophysics (IP) unleashed by Schlumberger was used for the interpretation of wireline log data. The results of this analysis are as follows.

1. The rock matrix was primarily made up of carbonate rock.
2. The shale volume determined by different methods is polluted by the small shale of the rocks.
3. Change in Archie parameters by plotting resistivity versus porosity (Pickett plot).
4. The well analyzed contains commercial amounts of hydrocarbon, as the CPI plot can be concluded.

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