Comprehensive Reservoir Characterization and Petrophysical Evaluation Utilizing Wireline and Core Data for Cretaceous Formation in Northern Iraqi Oil Field

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Abstract:

Evaluating the petrophysical properties is vital corner for any reservoir description study. Well logging and core analysis are the main source for evaluating the petrophysical parameters and studying the reservoir characterization of the Cretaceous formation.
The studied well in the reservoir is W-2 which has enough well logs and core data at the Interval depth (3025m-3189m) to execute the analysis.
The well logging analysis was carried out through the Interactive Petrophysics (IP) software which used to detect lithology, shale volume, the porosity, permeability, and water saturation were measured through the petrophysical analysis. Integrated results of reservoir characterization and petrophysical measurements and well logging analysis revealed that the Cretaceous formation is considered as decent reservoir rocks due to their high values of effective porosity and permeability also Cretaceous formation represent high potentiality for producing hydrocarbon based on hydrocarbon saturation analysis.

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Introduction

The accurate reservoir simulation and forecasting reservoir in addition to reservoir development is more need to a good petrophysical properties distribution by a quantitative model and how to known different scales of reservoir distribution and reservoir properties determination consider more a challenge and full uncertainty due to indirect measurements from well logging data. However, the core analysis which represents a direct determination of reservoir properties. Typically, core analysis can be obtained from few wells in a field whereas the well logging data can be got from most of the wells. Core analysis needs to a high cost and time associated with coring operation and for these reasons, various correlation can be implemented to determine reservoir properties especially porosity-permeability. However, a method was applied based on the porosity-permeability, in some wells where core data are not available, to determine the reservoir properties from wire-line logs data in the Cretaceous formation of a heterogeneous reservoir in Iraq. Cretaceous formation is one of three reservoirs in same field that located to North West of Kirkuk city in north of Iraq. See figure (1). In this study will be concentrated on determination of reservoir properties and prediction of average

properties of reservoir in addition to evaluate of reservoir quality.

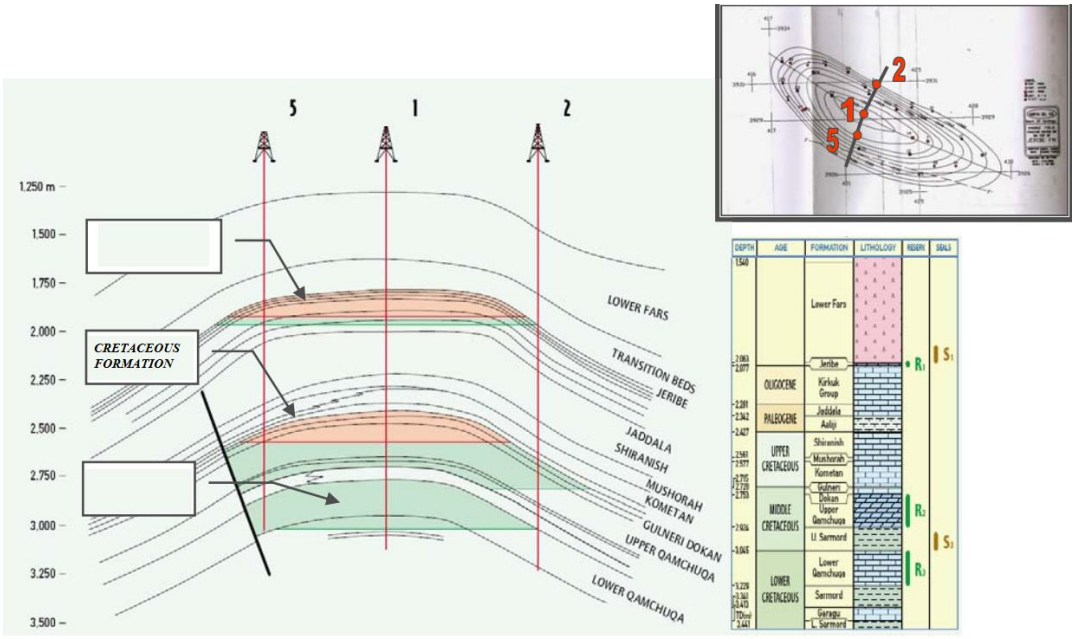

Figure (1): Field schematic cross section showing cretaceous formation. (Total Company,2008).

Data and methodology

2.1 Field data and Petrophysical Measurements

The well logging and core data has been given full set of well logging represent (resistivity, sonic, density, neutron, gamma ray, and caliper logs) in addition to 486 core sample from nine wells penetrated the cretaceous formation.

2.2 Methodology and Techniques

All measurements have been performed at ambient conditions on small plugs (1 inch diameter, 3-4 cm length) or large plugs (1.5 inch diameter, 4-6 cm length). In general, porosity and permeability properties from the laboratory measurements of core samples provide a direct measure of the Cretaceous formation.

Dakhanova (1977) and Ragab et.al (1985) described method to determine the bulk density (ρ_b) of each rock sample. The pycnometer method (Dortman, 1984) used to calculate the grain density (ρ_g) of each sample. Melcher technique (Dakhanova, 1977) introduced method to measure the rock porosity of each rock sample by the saturation method. Profile permeameter is used to measure the permeability of the rock sample .in addition to use NaCl solution of concentration for Cretaceous formation 140000 ppm to determine apparent electrical resistivity (R_o) of each sample according to the method described by Parkhomenko (1967).

Accordingly, formula (Archie, 1942) is used to determine the formation resistivity factor (F):

$$F = R_o / R_w \quad (1)$$

with other equation of (Archie, 1942) is applied to calculate the resistivity index (I) and water saturation (Sw) :-

$$I = R_t / R_o = S_w^n \quad (2)$$

2.3 Petrophysical Analysis

Different wireline logs are used to conduct petrophysical analysis such as: spontaneous potential sp, gamma ray gr, neutron ΦN, density ρb, deep

latrolog Rll, shallow laterlog Rlls, caliper Cal, sonic Δt. porosity, permeability, water saturation, hydrocarbon saturation (sh). In addition to lithology are marked and important on the petrophysical analysis through wireline logs.

Hydrocarbon potential of pay reservoir interval (Hussain et al. 2017; Dasgupta and Mukherjee 2019) based on petrophysical parameters. Gamma ray log is used to estimate of shale volume, high values of gr log indicate shale dominant formation while low gr log values represent clean formation. Dresser (1979) is introduced the formula to measure the gamma ray index (IGR):

$$IGR=\frac{GR_{log}-GR_{min}}{GR_{max}-GR_{min}} \quad (3)$$

Based on values of IGR , Larionov (1969), Stieber (1970) and Clavier (1984) are prepared to calculate shale volume and it is found that formation has shale volume from 20 to 25 %.

SP method is used to estimate water resistivity (Rw) which calculated by using IP program is 0.0286 ohm.m order to find out saturation of hydrocarbon with determine formation temperature by equation:

$$Tf = Ts + Df\ (BHT-TS)/TD \quad (4)$$

Temperature of formation is calculated of 207 F° at the surface temperature (60 F°) are picked from log header are used as references.

Reservoir porosity (ϕ) is one of the impotent property in the reservoir and define as storage capacity of hydrocarbon fluids. In this research total porosity can be calculated from average reading of neutron and density by given the equation (Schlumberger 1997)

$$\phi t=\frac{\phi_D+\phi_N}{2} \quad (5)$$

hallenging task in determine the other one of the important property that related to volume hydrocarbon fluid is the water saturation determination. Water saturation is calculated by using Archie's equation in this study for clean formation that used to estimate of hydrocarbon reserve by volumetric method:

$$Sw=\left(\frac{a}{\phi^m}\frac{R_w}{R_t}\right)^n \quad (6)$$

and finally, hydrocarbon saturation is determined by:

$$Sh=1-Sw \quad (7)$$

Furthermore, permeability is one the most property connects between dynamic and static modeling. Permeability measured in the laboratory by using core analysis but these values for few intervals in the well. However, coherent accurate method to estimate permeability from well logging consider more challenge in the petrophysical analysis. Abed A. and et.al (2011), Tawfeeq, Y. and et.al (2020), Abed A. and et.al.(2019) are used empirical relationship based on Timur equation but computed the coefficients (A, B, and C) of equation statistically by:

$$k= A\ \frac{\phi^B}{Swi^C} \quad (8)$$

Where;

A=52652, B=5.12, and C=1.132.

Results and Discussions

Reservoir characterization and petrophysical analysis in this study applied for Cretaceous formation by using IP program. In this study the formation evaluation results interpreted in different types of plots and of cross plots.

MID, M-N and $\rho_b - \Phi_N$ cross plots give a quick view about rock materials and the lithological constituents (shale, dolomite and limestone) in a qualitative way and parameters in a quantitative way.

The MID, and M-N cross plots showing in figures (2) and (3) for w-2 in Cretaceous formation in depth (3025m-3189m). These cross plots interpreted the formation is consisting from limestone with a minor occurrence of dolomite. However, there are many points downward refer to shale content and form cross plots reveal the porosity 15% approximately.

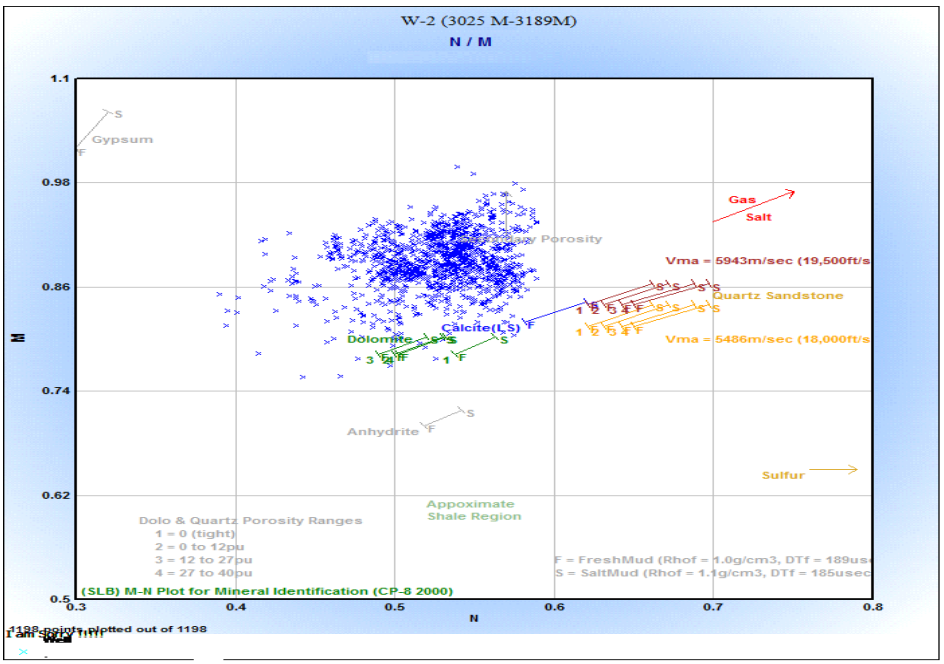

Figure (2): M-N plot for W-2 in Cretaceous Formation

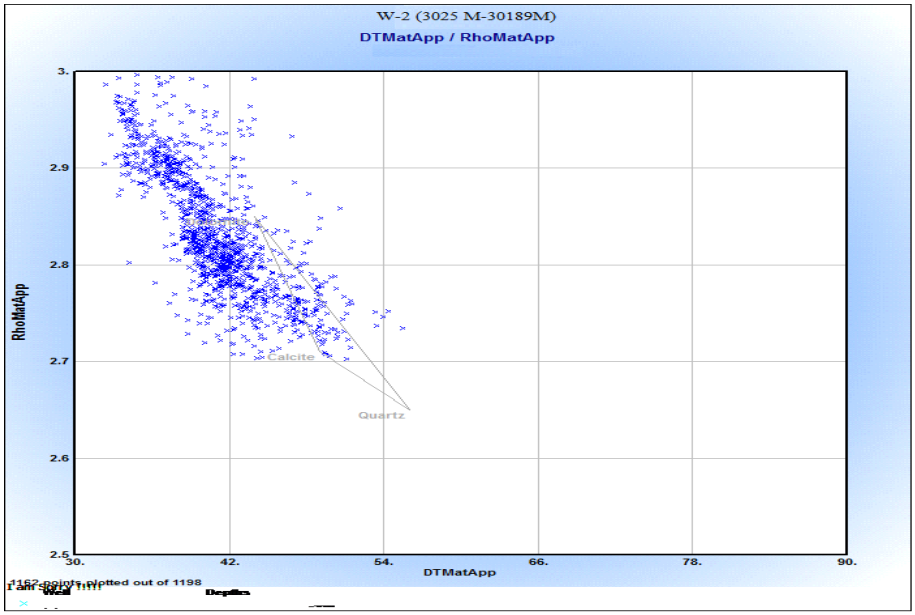

Figure (3): MID plot for w-2 in Cretaceous formation

From figure (4) represents the $\rho_b - \Phi_N$ cross plot that indicate entrance of high ratio from limestone allover section while many points refer to dolomite occupied the formation for w-2 in Cretaceous formation with interval 3025m-3189m.

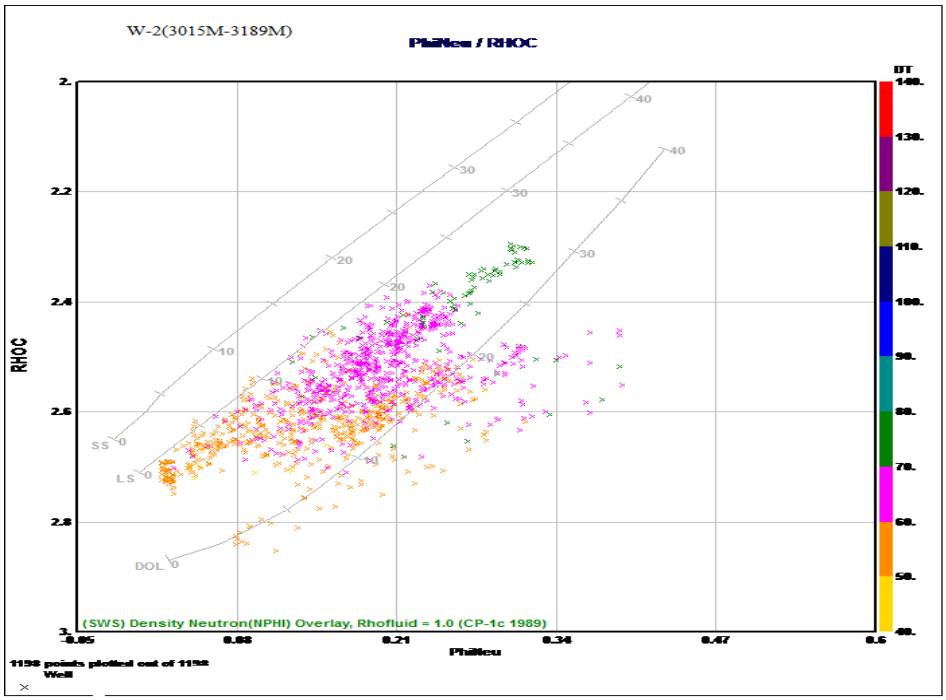

Figure (4): The $\rho_b - \Phi_N$ cross plot

Figure (5) explained the formation factor and porosity with water saturation. However, porosity value has weighted of (15%) which represent a good section for accumulation of water and hydrocarbon saturation. The figure (5) indicates the Cretaceous formation good potentiality for hydrocarbons because the water saturation is generally lower than hydrocarbon saturation.

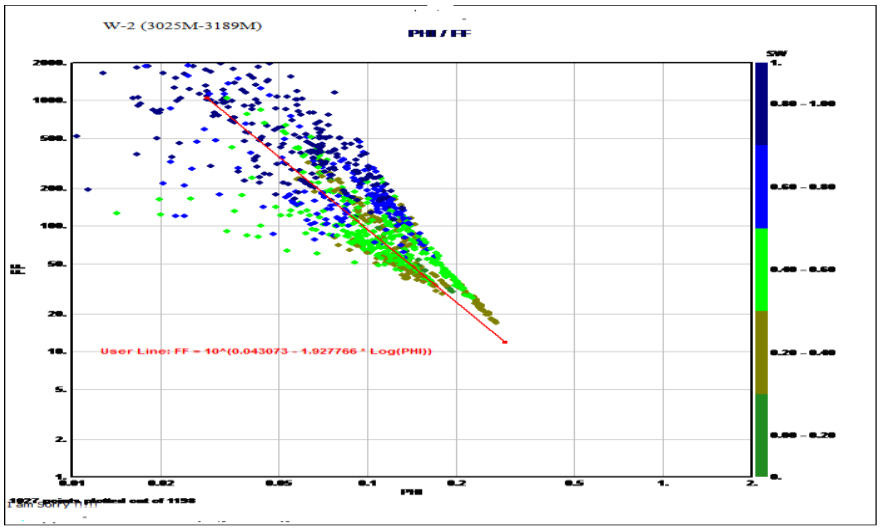

Figure (5): formation factor Vs. porosity with water saturation

Figure (6) shows the Archie's parameters (a,m and n) measured by using Pickett plot and displayed Rw equal to 0.0286 ohm.m which give m=1.88,n2.2 and a=1.05.

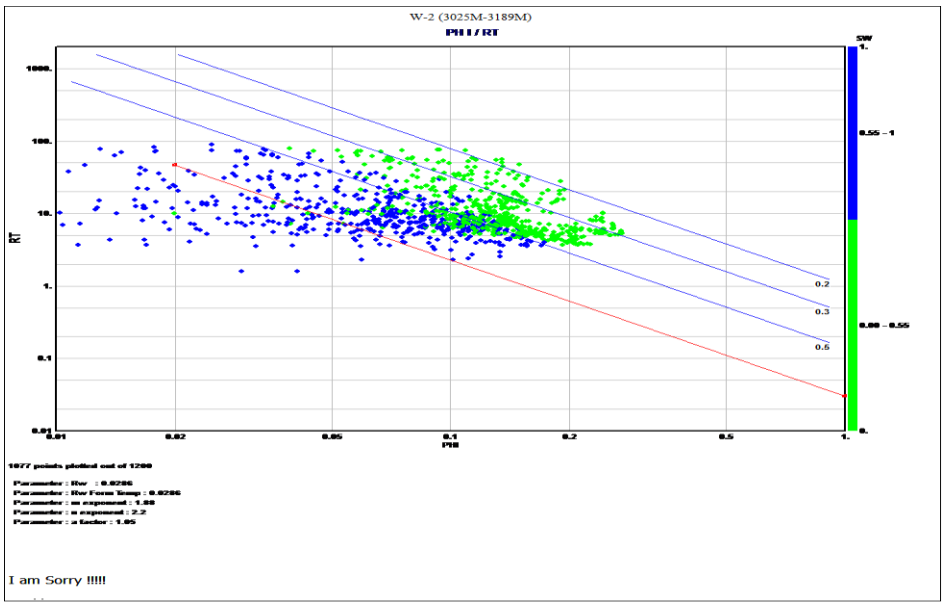

Figure (6): Pickett plot for determine m, n, and a

Figure (7), introduced the log tracks for Cretaceous formation showing all the input and derived petrophysical parameters in w-2 at the depth of 3025-3189m. It is shown the high accumulation of movable hydrocarbon which lies below 3100m in addition to high effective porosity with secondary porosity sections. Furthermore, the average shale volume is about 21 %, effective porosity about 16 %, saturation of water 32 % while hydrocarbon saturation 68% that is estimated through Schlumberger log chart along with several empirical formulae.

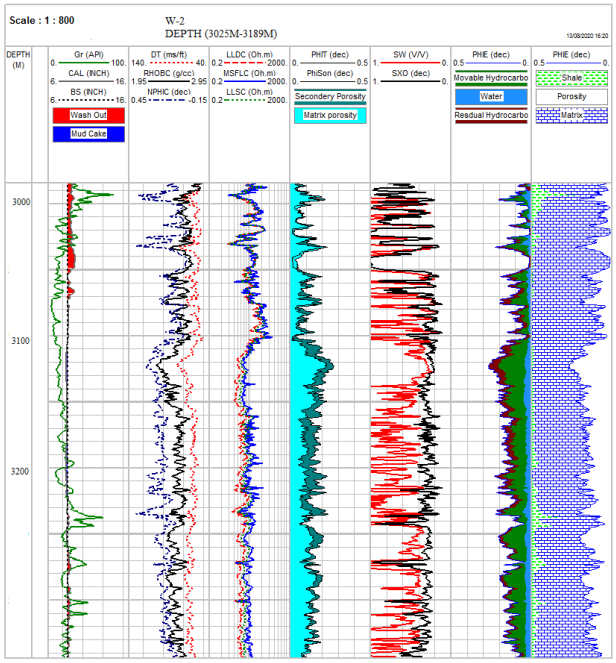

Figure (7): Results of petrophysical analysis.

Figure (8) represents the prediction of permeability from empirical relationship with Abed et.al (2011) statistical coefficients. However, there are a good matching between log-calculated permeability and core permeability. Permeability values from core located in the interval 3000m to 3100m and when use Schlumberger coefficient by using equation (8). The range permeability values range from 0.2 to 10 md through the section that good hydrocarbon potential.

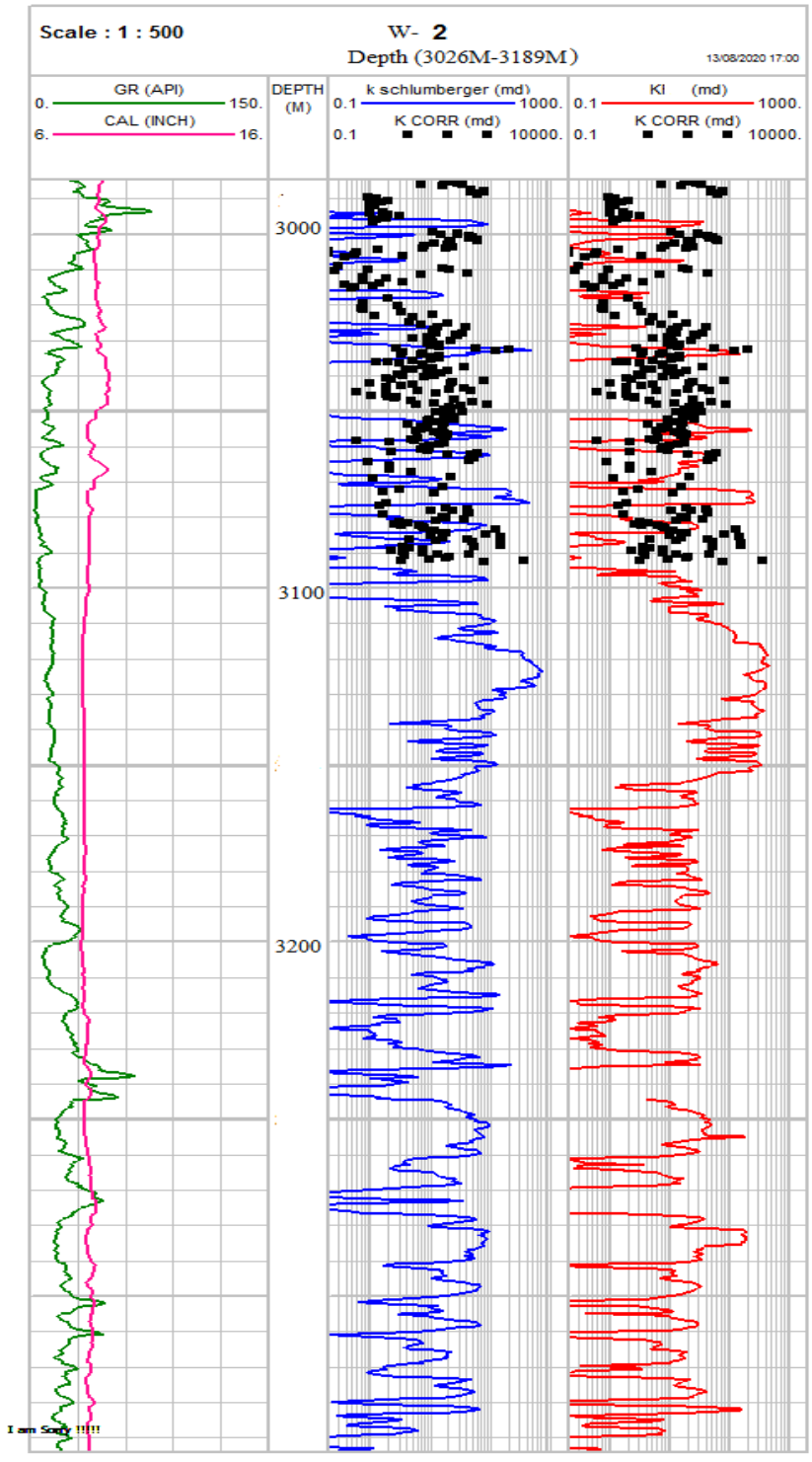

Figure (8): The prediction of permeability from empirical relationship

Conclusions

The current study depends on the petrophysical analysis and reservoir characterization that based on w-2 with full set data from well logging and core analysis and used IP program for interpretation we conclude the section interval 3000m-3100m has very good reservoir properties, porosity values range from 12 to 16%, permeability values average approximately 6-10 md, water saturation range reach to 38% but hydrocarbon saturation was 68 % in addition to shale volume was 21%.

Furth more. the Cretaceous formation consist from limestone and dolomite as shown and interpreted from cross plots and according to this integrated study, the Cretaceous formation is considered as good reservoir rocks due to their high values of effective porosity and permeability also Cretaceous formation represent high potentiality for producing hydrocarbon based on hydrocarbon saturation analysis.

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