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Permeability Prediction By Classical and Flow Zone Indictor (FZI) Methods for an Iraqi Gas Field

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Abstract

The permeability is the most important parameter that indicates how efficient the reservoir fluids flow through the rock pores to the wellbore. Well-log evaluation and core measurements techniques are typically used to estimate it. In this paper, the permeability has been predicted by using classical and Flow zone indicator methods. A comparison between the two methods shows the superiority of the FZI method correlations, these correlations can be used to estimate permeability in un-cored wells with a good approximation.

Key words: permeability, FZI method

Introduction

Rock permeability is a property of a porous medium that quantifies the capacity of a rock to transmit the fluids. In other word, It is a measure of fluid conductivity of a porous media. It is an important rock property and one of the most difficult of all petrophysical properties to predict and determine. An accurate estimate of permeability is essential because it is considered the key parameter that controls strategies of reservoir management, well completion and production.

Core analysis has been traditionally used to determine permeability. Kozeny (1927) and Archie (1942) were amongst the first few people to determine permeability based on electrical measurements made on core sample .

Frequently, core analysis data are not available because of the high cost of coring and due to the borehole condition. Thus, there are alternative methods can been made to predict and estimate permeability.one of the inexpensive and readily available sources of inferring permeability is from well logs. To achieve this goal, various models have been used and developed correlations to determine permeability based on well log measurements.

The studied field is Mansuriyah gas field at the east of Iraq Fig (1), and the studied reservoir of this field is Jeribe formation. Available core data for wells (Mn-1, Mn-2, Mn-3 , Mn-4) provide information for Jeribe formation that can be depended to predict permeability by two methods were chosen in this study.

Fig. 1, Al- Mansuriya field location

The two different methods of permeability-porosity relationships used to predict permeability are Classical and Flow Zone Indicator (FZI) method.

Classical Method for Permeability Prediction

In this method, permeability can be directly derived from porosity. By using empirical correlation between permeability and porosity that generated from core data, permeability can be predicted in un-cored well sections. The general form for the conventional permeability-porosity relationship is usually expressed as[1]:

$$Log\ (K) = a\emptyset + b \qquad \ldots (1)$$

k: permeability (md).
∅: Porosity (fraction) and
a and b : the constants to be fitted to the case study.

Available core samples data for four wells Mn-1, Mn-2, Mn-3 and Mn-4 collected together to generate empirical correlation of Permeability vs. porosity for Jirebe unit.

Figure (2) shows permeability vs. porosity plot that used to drive permeability model for Jeribe unit and the formula for the equation with correlation coefficient (R) . This low percent for (R) coefficient refers to high heterogeneity . The increase in permeability does not necessary lead to increase in porosity and the increase in porosity does not necessary lead to increase in permeability.

The limitation in the classical method that the porosity value is not the only parameter affecting permeability.

Table (1) shows the formula, correlation coefficient and sample number was used to generate permeability formula.

Table 1, classical permeability formula and correlation coefficient

Formation	Formula	Sample No.	Correlation Coefficient (R)
Jeribe	$K=0.063 \times e^{17.7770}$	451	0.4363

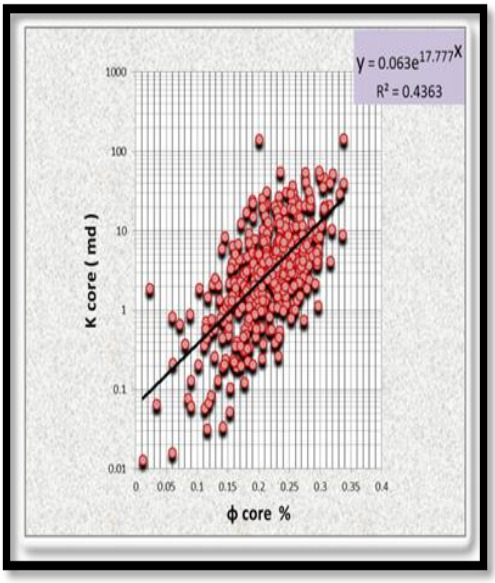

Fig. 2, core porosity and permeability for jeribe formation

Correlation between porosity and permeability applied for Jeribe formation. Figures (3) to (6) show predicted permeability for four wells , The figures show that predicted permeability doesn't strongly matched with the measured core permeability , due to the Permeability – Porosity classical correlation which is basic method where permeability depend on porosity only and does not cover all factors effect on permeability (pore scale and structure).

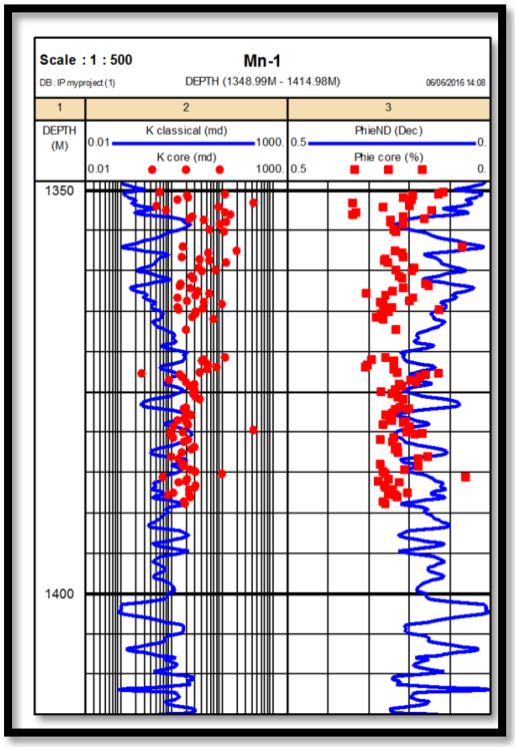

Fig. 3, predicted permeability for well Mn-1 by classical method

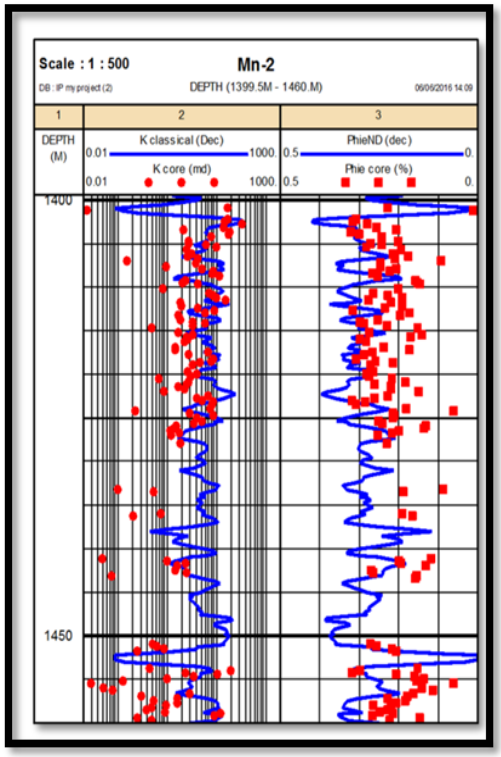

Fig. 4, predicted permeability for well Mn-2 by classical method

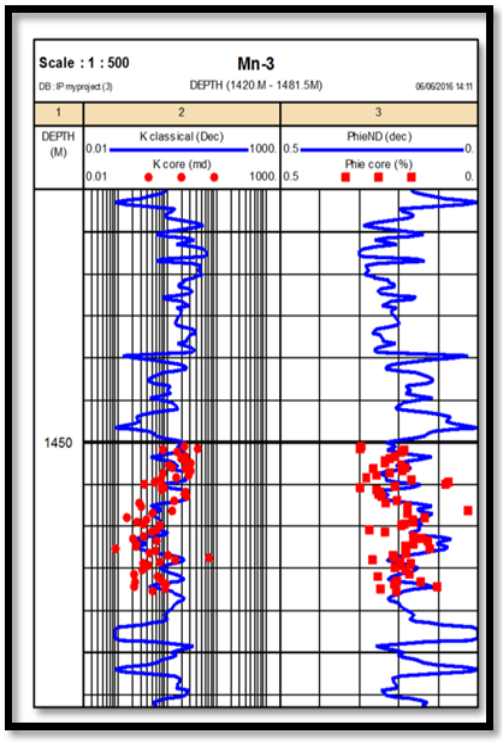

Fig. 5, predicted permeability for well Mn-3 by classical method

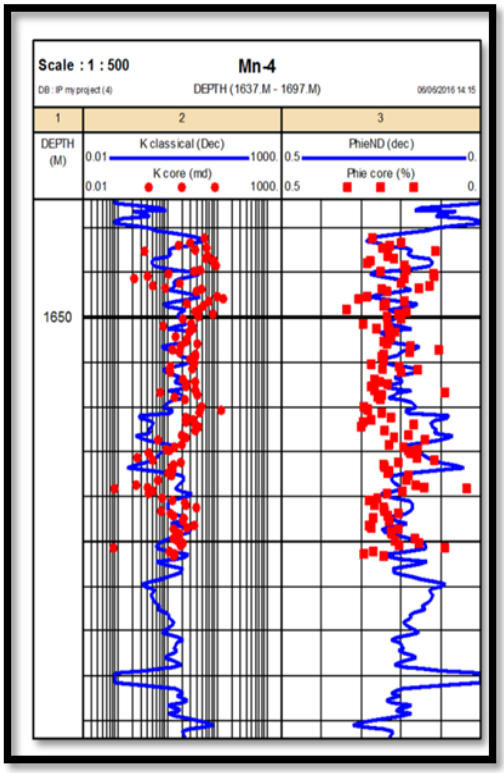

Fig. 6, predicted permeability for well Mn-4 by classical method

Flow Zone Indicator Method (FZI)[(2)(3)(4)]

Among the various quantitative rock-typing techniques were presented, the Hydraulic Flow Unit method (RQI/FZI) is more widely used. A hydraulic flow unit (HFU) is defined as the representative volume of total reservoir rock within which geological properties that control fluid flow are internally consistent and predictably different from properties of other rocks. This method is based on physics of flow in pore scale and geological parameters .The Flow Zone indicator (FZI) method for classifying core data into Hydraulic Units with specific FZI.

This approach provides accurate correlations between permeability and porosity if FZI of the reservoir rock is known. FZI is estimate from core data in the cored wells and it is usually applied to un-cored wells through correlations with log attributes.

In this approach, rock types are classified according to the following equations:

$$\mathrm{RQI} = 0.0314\sqrt{\frac{K}{\emptyset}} \quad \ldots (2)$$

$$\emptyset_z = \left(\frac{\emptyset}{1-\emptyset}\right) \quad \ldots (3)$$

By substitute RQI and Φz with FZI can be simplified as:

$$FZI = \frac{RQI}{\emptyset_z} \quad \ldots (4)$$

By taking the logarithm of both side of equation (4), the final approach can written as follow:

$$LogRQI = Log\emptyset(Z) + LogFZI \quad \ldots (5)$$

The above equation represents the straight line on log-log plot of RQI vs. Φz. The intercept of straight line at Φz=1 is the specific flow zone indicator of each group. Other FZI values of core samples will show on different lines. Points that lie on the each straight line got same pore throat description and, therefore, same a flow unit.

According to values of FZI four groups identified in permeability–porosity plot in figure (7) and permeability formula generated for each group. The generated permeability formulas applied in un-cored wells and intervals depending on porosity value from log.

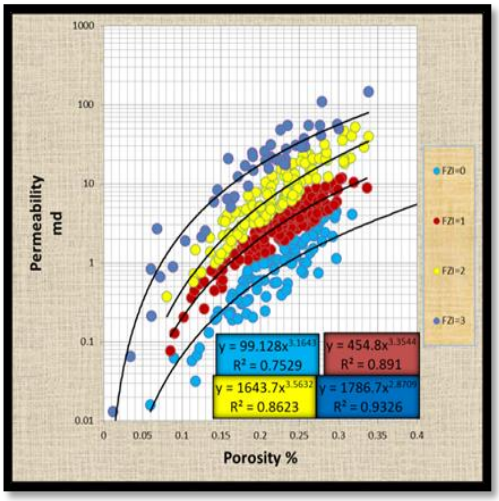

Fig. 7, cross plot log permeability vs. porosity for specific FZI Values for Jeribe formation

The generated permeability formulas tabulate in table (2) applied in cored well (Mn-1 , Mn-2, Mn-3 and Mn-4) to compere the predicted permeability values with measured core values as shown in figure form(8) to (11).

Table 2, FZI Permeability formula for Jeribe formation

FZI	Permeability Formula	R^2
FZI=0	$K=99.128x\Theta^{3.1643}$	0.7529
FZI=1	$K=454.8x\Theta^{3.3544}$	0.891
FZI=2	$K=1643.7x\Theta^{3.5632}$	0.8623
FZI=3	$K=1786x\Theta^{2.8709}$	0.9326

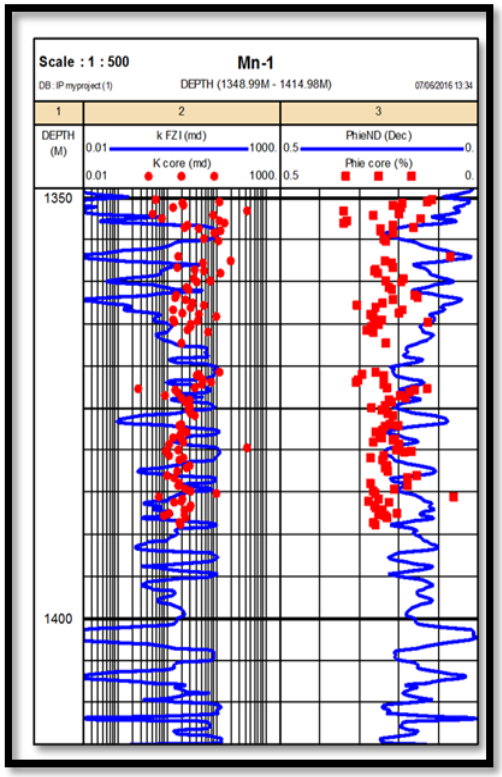

Fig. 8, predicted permeability for well Mn-1 by FZI method

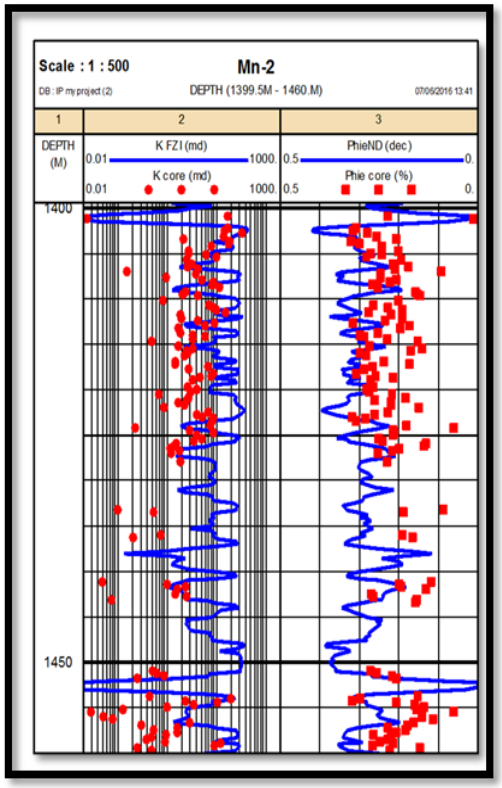

Fig. 9, predicted permeability for well Mn-2 by FZI method

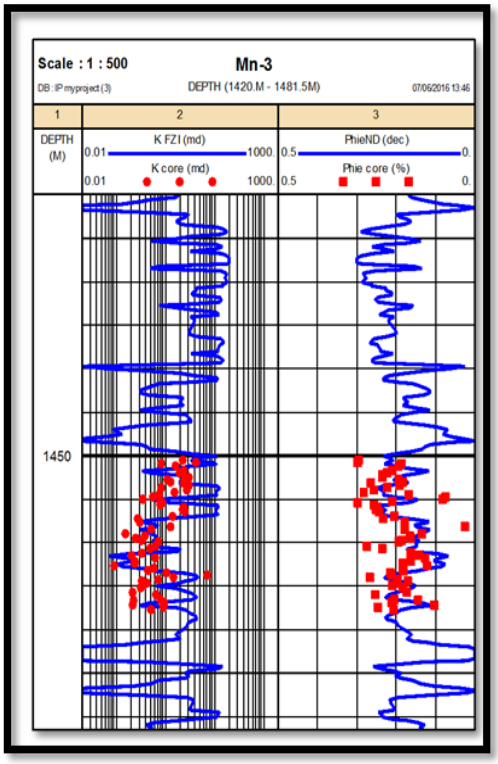

Fig. 10, predicted permeability for well Mn-3 by FZI method

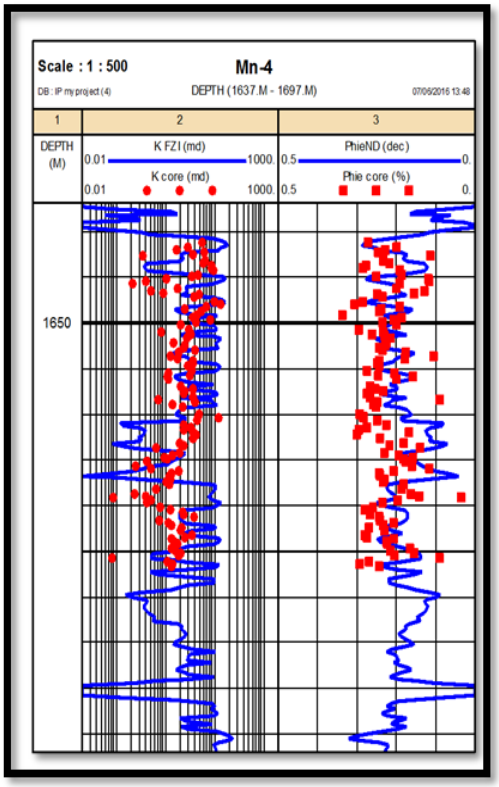

Fig. 11, predicted permeability for well Mn-4 by FZI method

Comparison between Permeability Methods for Estimating Best Method

Two permeability prediction methods (Classical and FZI) were used in this chapter that's covered the usefulness parameter that effect in permeability. To suggest the best method for this study, sample correlation made between measured and predicted permeability for two methods in order choose the method that gives the highest correlation coefficient.

From the Figures (12) and (13) shows that FZI method correlation gives the highest correction coefficient form classical method so it depended for permeability prediction in this study.

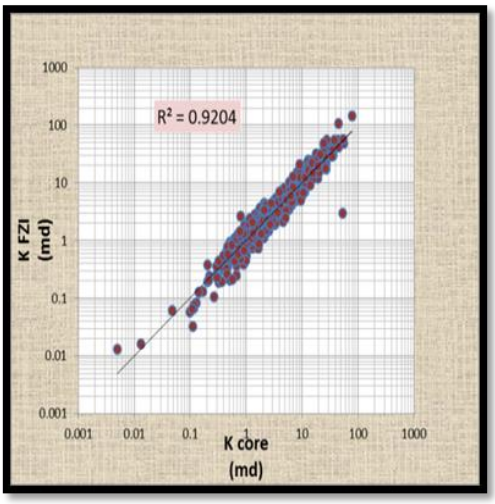

Fig. 12, accuracy of permeability prediction by FZI method

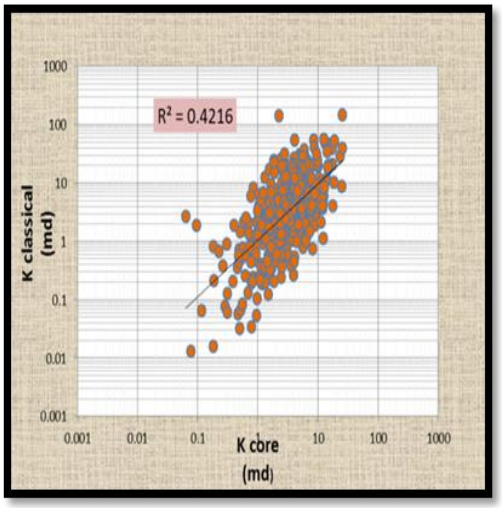

Fig. 13, accuracy of permeability predictions by classical method

Conclusions

1- The correlations developed to predict permeability using only porosity for Jeribe formation is found to be unsuccessful due to the heterogeneity of Jeribe Formation.
2- The estimated results of permeability using of FZI method is more accurate comparing with the classical method and greatly enhances the prediction of permeability.

Nomenclatures

1- Symbols

a , b : Constant are statistically determined.

Fs : Effective pore throat shape factor.

K: Permeability (md)

R^2: Correlation Coefficient (Dim.)

Ø :Porosity (Fraction)

2- Abbreviations

FZI : Flow Zone Indicator

HFU: Hydraulic Flow Unit

RQI: Reservoir Quality Index

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