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Comparing between permeability prediction by using classical and FZI methods/Tertiary Reservoir in Khabaz Oil Field / Northern Iraq

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Abstract

This study is developed to predict the permeability of Tertiary reservoir in Khabaz oil field northern of Iraq. Two methods are used , which are classical methods and FZI methods, the results show that the permeability estimated by core and classical method which depending on just the porosity are not close enough for the real values because it’s not toke in the considerations all effects parameters .

The FZI method is show more real values and provides best correlation coefficient in comparing with the classical methods.

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1. Introduction

Permeability prediction is most important factor to prepare a representative static model in addition to porosity, so the geological model or petrophysical model facing a dilemma and challenge in what its values represent and how close they are to reality. Because of the phenomenon of heterogeneity that characterizes the rocks **[1]**.

Generally permeability considers one of important property for reservoir rocks which mean the ability of reservoir rocks to transmit fluid through it. The accuracy and precision in prediction and estimation of permeability and porosity values were requested petroleum engineers to build up a good model to use it to make the right decision, because of permeability in charge of many operations for reservoir such as production, well completion, drilling and economic considerations **[2].**

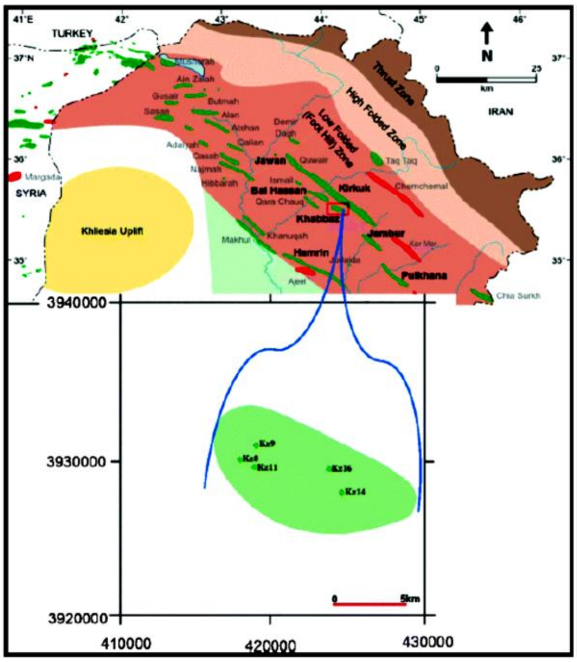
Permeability was defined by Darcy in (1856) as the ability of fluid to transmit through porous media. Darcy (D) or mille Darcy (md) are the units used for permeability **[3]**.

There are many of methods to predict permeability, generally the Routine Core Analysis (RCA) and Special Core Analysis (SCAL) are used to drive measurements of permeability, which are direct methods, Also log data can be used to predict permeability, in addition to classical method like using of hydraulic flow unit **[4, 5].** Recently the researchers have a wide use of Artificial Intelligent and other methods of neural network to product permeability.

This study aims to comparing between classical core and well log data methods, and FZI method to predict the permeability for tertiary reservoir in north of Iraq.

1.1 Area of Study

Khabaz oil field is represent one of the north Iraqi oil fields which have many pay zone contain great amount of oil and gas . Its located North West (NW) of Kirkuk city and (12 km) away from center of Kirkuk city. It's encircled by three oil fields Bai Hassan from North West and Baba dome exist in Kirkuk field from north east and Jumbour field from South east as shown in Figure (1). Structurally represents a single symmetrical anticline at subsurface consist of about (18 km) length and about (4 km) width. Now days (42 wells) were penetrated tertiary reservoir, more than half of wells were penetrated (cretaceous age), and less number of wells were reached Shu'aiba formation. Actually Seven wells (Kz-1, Kz-2, Kz-3, Kz-4, Kz-9, Kz-14, Kz-15) used for this study in Khabaz oil field. Generally the section direction from North West to south east and denoted by A (NW) – B (SE). First well for Khabaz oil field (Kz-1) was drilled in August (1976). Top of Jeribe formation is representing a structure contour map with 42 wells for Khabaz oil field and 4 faults explained in figure (2). Oligocene units are classified to Unit (A), Unit (A'), Unit (B), Unit (BE), and Unit (E) are explained in Figure (3) also clarified sequence of formation, lithology, hydrocarbon places and geological age of well (Kz-1) **[6]**.



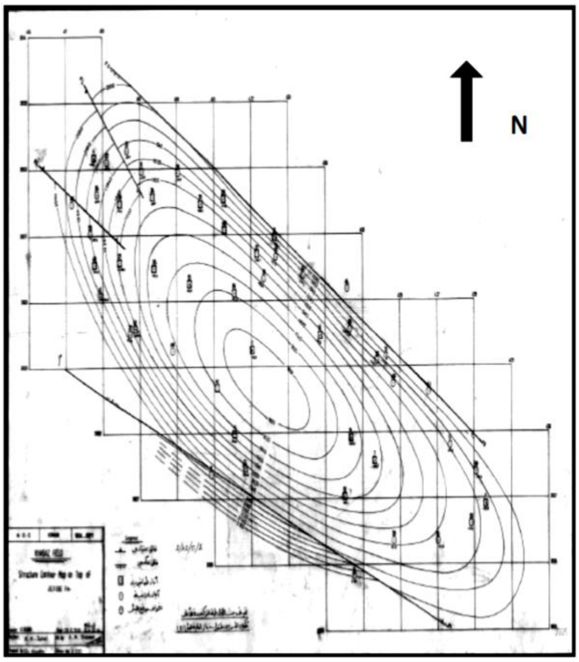
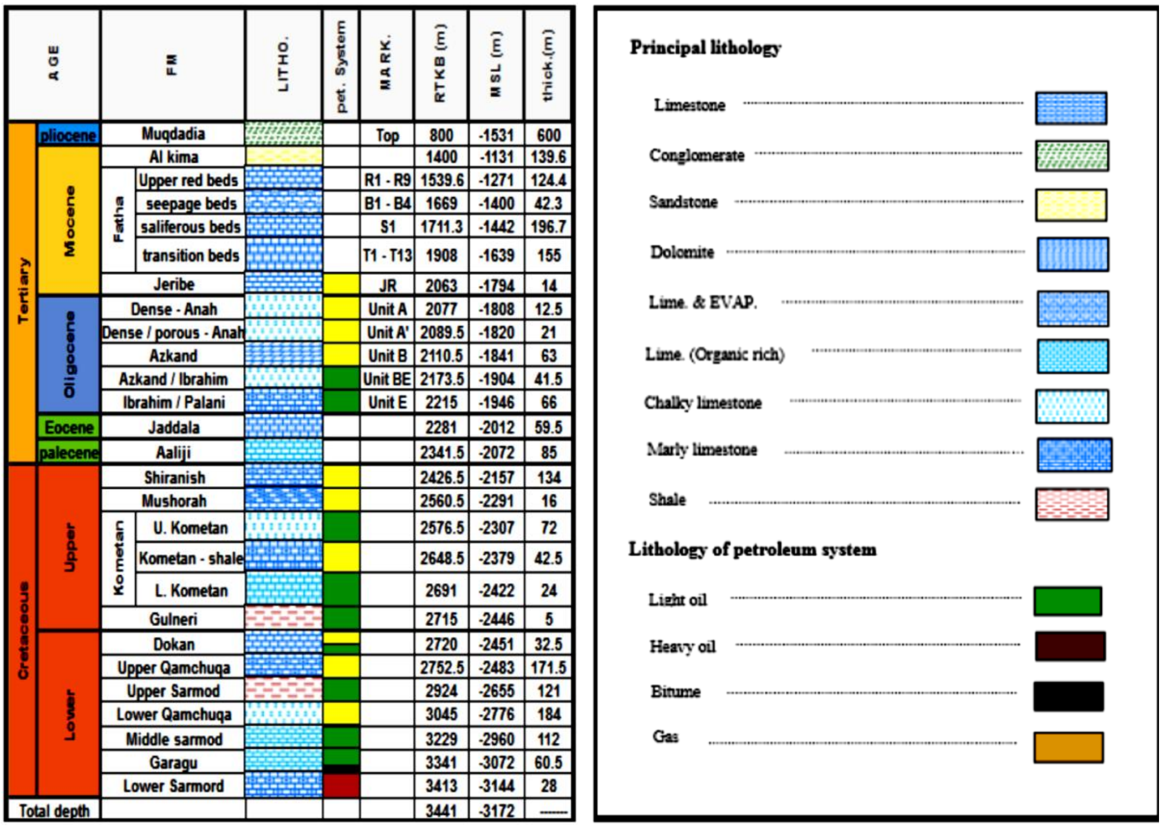


Figure (1): Location of khabaz oil field **[6]**.   **Figure (2):** Structure contour map on Jeribe formation **[7].**



AGE		FM		LITHO.	pet. System	MARK.	RTKB (m)	MSL (m)	thick.(m)
Tertiary	pliocene	Muqdadia				Top	800	-1531	600
	Mocene	Al kima					1400	-1131	139.6
		Fatha	Upper red beds			R1 - R9	1539.6	-1271	124.4
			seepage beds			B1 - B4	1669	-1400	42.3
			saliferous beds			S1	1711.3	-1442	196.7
			transition beds			T1 - T13	1908	-1639	155
		Jeribe				JR	2063	-1794	14
	Oligocene	Dense - Anah				Unit A	2077	-1808	12.5
		Dense / porous - Anah				Unit A'	2089.5	-1820	21
		Azkand				Unit B	2110.5	-1841	63
		Azkand / Ibrahim				Unit BE	2173.5	-1904	41.5
		Ibrahim / Palani				Unit E	2215	-1946	66
	Eocene	Jaddala					2281	-2012	59.5
	palecene	Aaliji					2341.5	-2072	85
Cretaceous	Upper	Shiranish					2426.5	-2157	134
		Mushorah					2560.5	-2291	16
		Kometan	U. Kometan				2576.5	-2307	72
			Kometan - shale				2648.5	-2379	42.5
			L. Kometan				2691	-2422	24
		Gulneri					2715	-2446	5
	Lower	Dokan					2720	-2451	32.5
		Upper Qamchuqa					2752.5	-2483	171.5
		Upper Sarmod					2924	-2655	121
		Lower Qamchuqa					3045	-2776	184
		Middle sarmod					3229	-2960	112
		Garagu					3341	-3072	60.5
		Lower Sarmord					3413	-3144	28
Total depth							3441	-3172	------

Figure (3): Sequence formation and legend of lithology and petroleum system of well (Kz-1) **[7] .**

1.2 Lithology Description of Tertiary Reservoir

A brief summary of formation, beds, and Units for tertiary reservoir for well (Kz-1) are given below:-

1. **Muqdadia formation: (800m – 1539.6m):** Typically includes sandstone alternating with marls and siltstone.
2. **Fatha formation: (1539.6m – 2063m):** The same lithology in Kirkuk and Bai-Hassan oil fields. It can be divided to many beds as given at the following:

   Upper red beds: (1539.6 m – 1669 m): Includes limestone, brown siltstone, and anhydrite.

Seepage beds: (1669 m – 1711.3 m): Includes anhydrite, grey-buff limestone.

Saliferous beds: (1711.3 m – 1908 m): Consists of thin limestone streaks, blue marls, anhydrite and salteuteotics.

Transition beds: (1908 m – 2063 m): Include limestone markers with alternating anhydrite.

3. **Jeribe formation: (2063 m – 2077m):** Mainly composed of cream limestone, some green marl and shaly bends that increasing at the bottom and streaks of dolomite.
4. **Oligocene system: (2077 m – 2281 m):** This system consists of many units and explains as brief of each unit a given as following:

Unit (A): (2077 m – 2089.5 m): This Unit includes cream poroellaneous limestone, calcite crystals, back reef facies and corals.

Unit (A'): (2089.5 m – 2110.5m): This unit includes white-cream limestone, sporadic anhydrite and calcite.

Unit (B): (2110.5 m-2173.5m): This unit includes recrystallized limestone, light brown-buff dolomite and vuggy.

Unit (BE): (2173.5 m – 2215 m): This unit includes fawn-light limestone and rare anhydrite.

Unit (E): (2215 m – 2281m): This unit includes fine marly limestone and locally dolomitized.

5. **Jaddala formation: (2281 m – 2341.5m):** This formation composed of cream marly limestone, rare chert nodules.
6. **Aaliji formation: (2341.5 m – 2425.5 m):** Includes light crystalline limestone and dolomite.

1.3 Aims of Study

This study aimed to estimate and prediction the permeability of tertiary reservoir by using:

1-core and classical methods

2-FZI method

3-comparing and correlated the results of the two methods.

2. Permeability estimation

There are many methods for predicting permeability, two main methods was used in this study, FZI and classical methods. Permeability could be controlled by size of pore space was connected in the formation. Good estimate permeability aid to know hydrocarbon content and how much can be produced from reservoir. **Wyllie and Rose:** suggested a method for predicting permeability relates to porosity (∅) and irreducible water saturation (Swi) **[8].**

$$K = a\left(\frac{\phi^b}{Swi^c}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(1)}$$

Kozeny, 1927 concluded one of the important formula to estimate permeability **[9]**.

$$K = a\left(\frac{\phi}{s}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(2)}$$

Carmen, 1937) changed Kozeny formula and introducing permeability in packs as uniform size **[10]**.

$$K = \left(\frac{1}{2\tau \times Svg^2}\right)\left(\frac{\emptyset^3}{(1-\emptyset)^2}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(3)}$$

Amaefule et. al., 1993) suggested two known methods to estimate permeability and indicate hydraulic units for un-cored well, first method is reservoir quality index (RQI) and second is flow zone indicator (FZI), where hydraulic unit will be introduced as a unit of reservoir rock which given a special relationship between porosity and permeability **[2]**. A lot of mathematical resolutions are applied on (3) to become as following form

$$\mathrm{RQI} = \sqrt{\frac{\mathrm{k}}{\phi\mathrm{e}}} = \left[\frac{1}{\sqrt{fs} \times \tau \times Svg}\right]\left[\frac{\emptyset}{1-\emptyset}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(4)}$$

Surface area, tortuosity and shape factor could be measured difficulty in reservoir so that term of Kozeny formula $\left(\frac{\mathbf{1}}{\boldsymbol{fs \times \tau^2 \times Svg^2}}\right)$ is assumed by the square root of FZI^2

RQI can be introduced as following term:

$$\mathrm{RQI} = 0.0314\sqrt{\frac{k}{\emptyset}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(5)}$$

And $\emptyset z$ can be normalized as following

$$\emptyset z = \frac{\emptyset}{1-\emptyset} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(6)}$$

Also, by simplified (FZI) in following term

$$FZI = \frac{RQI}{\emptyset z} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(7)}$$

After simplifying the equation (7) then (RQI vs. Øz) can be plotted on (log–log) paper, where similar FZI value of core sample will be appeared as a straight line, while various FZI value of core sample show on other parallel straight lines.

Core data available for all geological units except unit (E) are available wells (Kz-2) and (Kz-3). The following two methods were used to predict permeability for tertiary reservoir:

1- Classical method.

2- Flow zone indicator (FZI) method.

2.1 Classical Method

Permeability-porosity correlation in un-cored well can be determined from core data analysis. So in un-cored zones permeability can be estimated by log-derived porosity that explained in equation (6) at the below **[11]**.

$K = a \times e^{b\emptyset}$ …………………………………………..………………..………... **(8)**

The equation (8) could be performed for all geological units of tertiary reservoir in khabaz field.Core data analysis available for (Kz-2) and (Kz-3) wells, information given for all geological units of tertiary reservoir except unit (E). To generate the relation between porosity and permeability through plot that calculated value from core data by using semi-logarithmic paper where permeability at (y-axis) and porosity at (x-axis) **[12].**

Statistica 7 software helps to calculate values of empirical parameters (a and b) for all geological units of tertiary reservoir. The results were put as output file gives value for correlation coefficient (R^2).

Figure (4) show core permeability verses core porosity plots for all units except unit (E).

Correlations between porosity and permeability were performed for all units in tertiary reservoir. However, this method couldn't satisfactory because of variation of pore space and heterogeneity of reservoir. Most of common reservoir have rocks with similar porosity and different permeability.

Figures (4) and (5) illustrate predicted permeability for two wells (Kz-2) and (Kz-3) which contain core sample. Where Figures can be explained corresponding between predict permeability and core permeability (calculated) couldn't more strongly in some zones because of classical porosity and permeability are normally consider a basic method and then permeability depends on only porosity doesn't take considerations all factors which effects on the permeability.

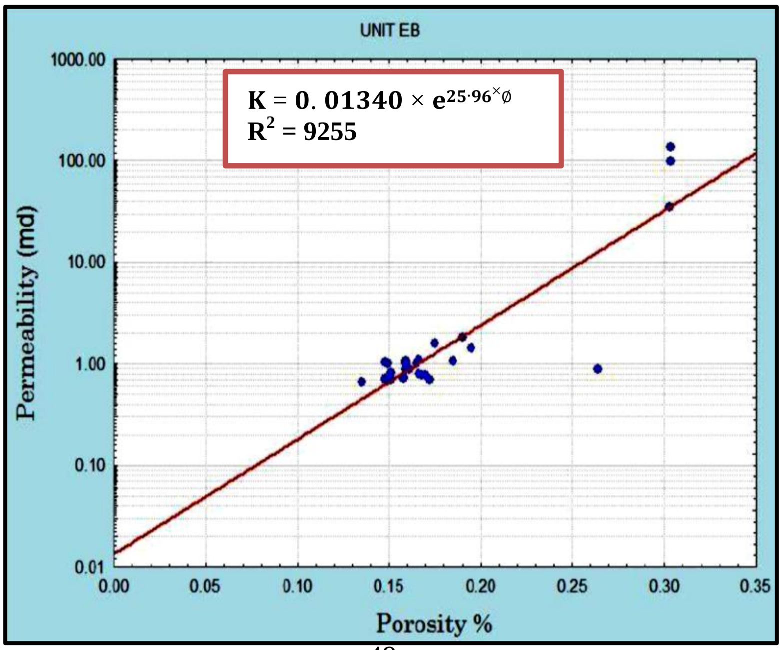
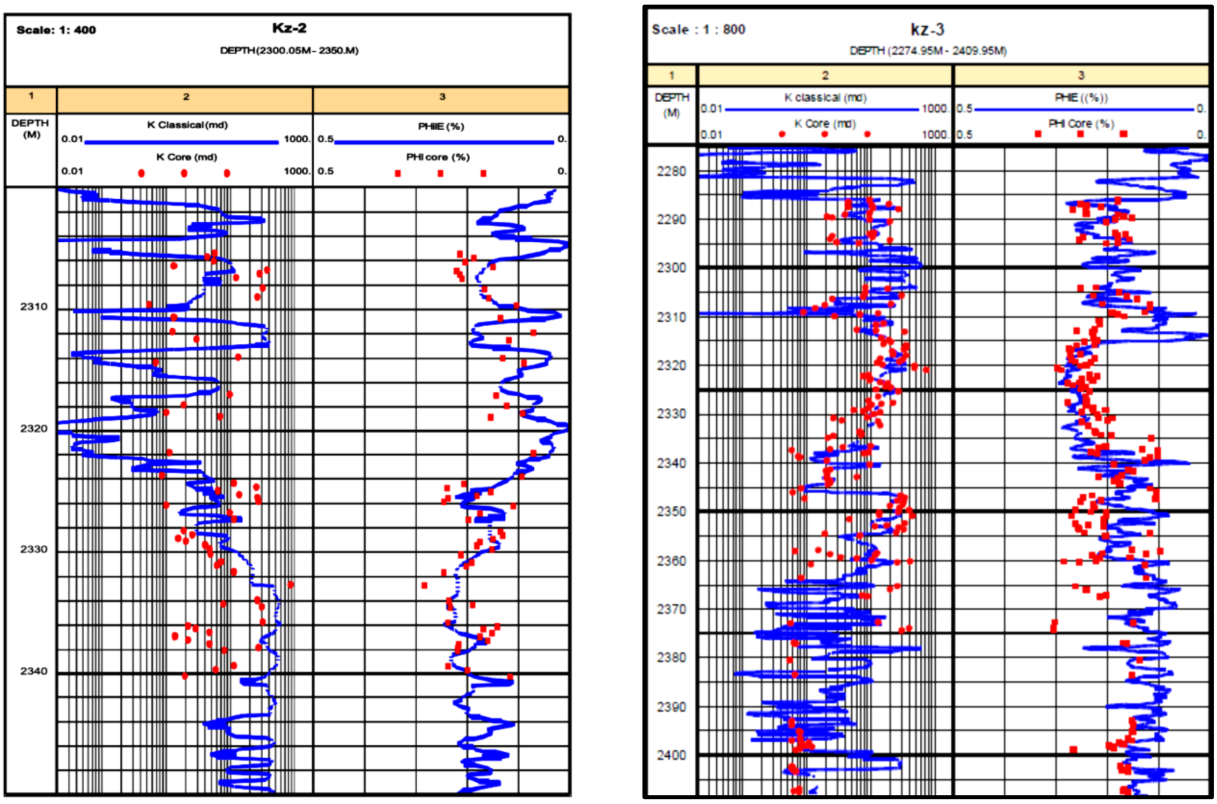


Figure (4): Core permeability and porosity for unit EB



(a) **(b)**

Figure (5): Predicted permeability by classical method (a) for well (Kz-2) (b) for well (Kz-3)**.**

2.2 Flow Zone Indicator (FZI) method

Generally statistical method can be used to correlate any information related well log data or reservoir property. This method used to describe or recognize zones in the reservoir in order to determined reservoir behavior. In a few years Hydraulic Flow Unit concept (HFU) was developed to predict permeability in un-cored zone. Where this concept was integrated with concept of Flow Zone Indicator (FZI), where two concepts are based on data if porosity and permeability which got from core. The key of parameter in these concepts are Reservoir Quality Index (RQI).

The FZI was performed to provide more accurate correlation between porosity and permeability if the value of FZI is known for reservoir rocks. The FZI was obtained from core data and commonly performed to un-cored intervals in the well so that provide best correlation with well log **[11]**. The general formula could be expressed by flowing equations:

$$\mathrm{RQI} = 0.0314\sqrt{\frac{\mathrm{k}}{\emptyset\mathrm{e}}} \quad \ldots\ldots \quad \mathbf{(9)}$$

$$\emptyset z = \frac{\emptyset e}{1-\emptyset e} \quad \ldots\ldots \quad \mathbf{(10)}$$

Kozeny equation by substitute (RQI) and (Øz) with FZI can be written as:

$$FZI = \frac{RQI}{\emptyset z} \quad \ldots\ldots \quad \mathbf{(11)}$$

The final approach can be simplified by taking logarithm for two side of equation (11) becomes:

Log (RQI) = log (Øz) + log (FZI) ……..………………..…….. **(12)**

In Figure (6) appeared that the equation (12) is represent as the straight line in the plot on the (log-log) paper between (RQI) verses (Øz).

Where intercept of the straight line (Øz = 1) with FZI for each type of rocks. All points are fall in the same straight line of (FZI) which can be regarded to obtain the same pore size throat and the same (hydraulic flow unit) controlling the path of flow. Where those points falls on the same straight line could be used to calculate permeability. Figure (6) shows four types of rocks or groups which can be determined from core data depending on particular value of FZI for each rock type by simple analysis for tertiary reservoir in khabaz field.

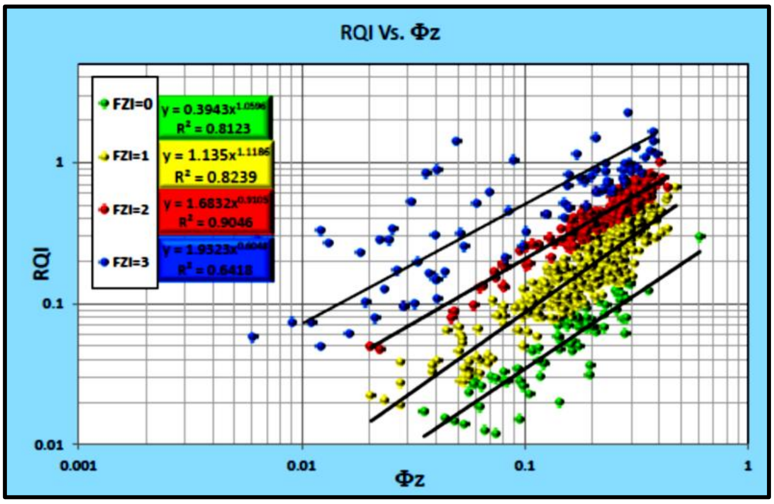


Figure (6): Cross plot between (RQI) and (Øz).

Depending on log permeability verses log porosity for particular value of FZI which can be generate for each group by using core permeability (K core) verses core porosity ($\emptyset\ core$) that shown in figure (7). The permeability – porosity correlations are performed in un-cored wells related to FZI values which estimated from well log data by statistical analysis.

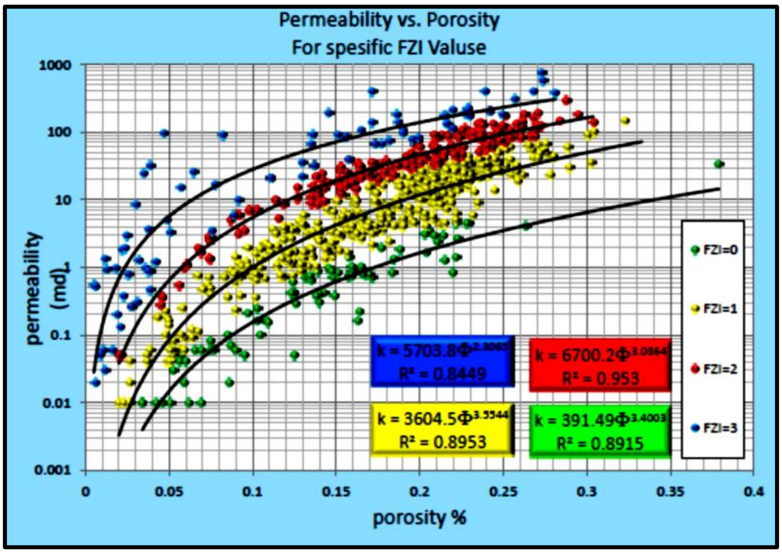
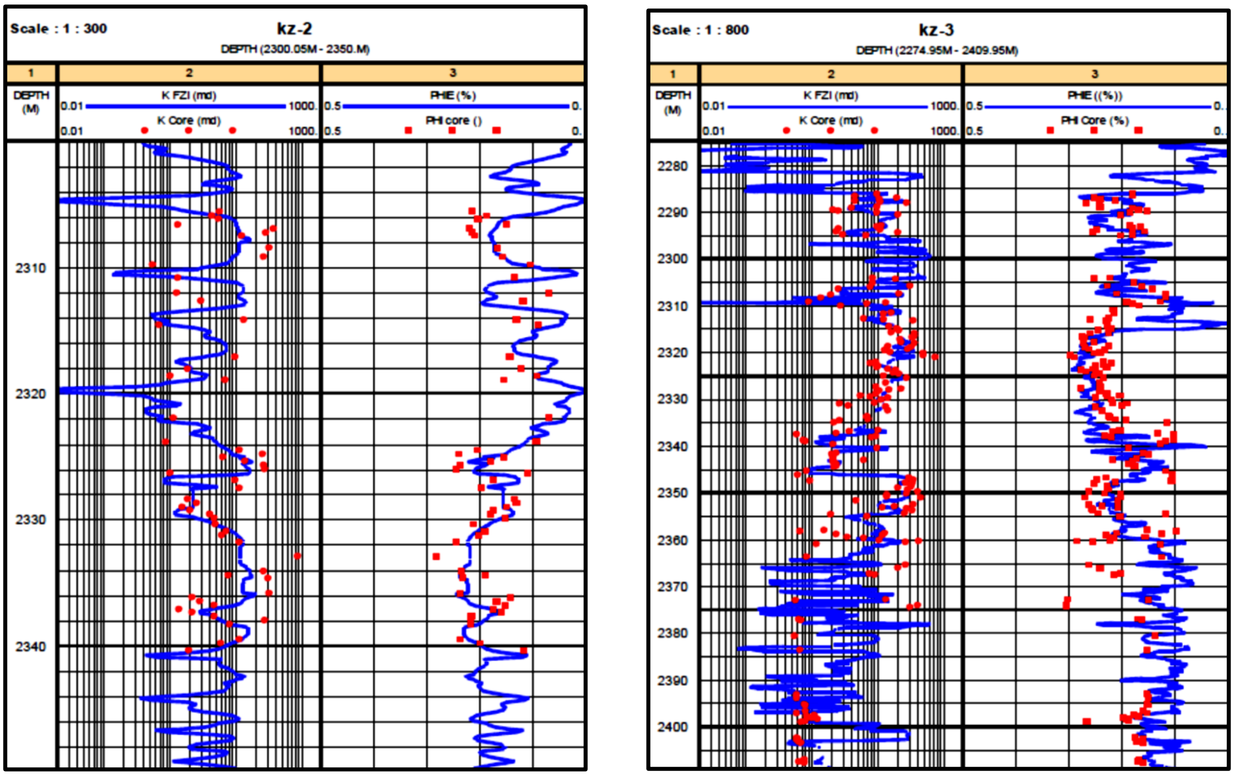


Figure (7): Cross plot of log permeability vs. porosity with FZI for tertiary reservoir.

Table (1): Provides four permeability formulas with their correlation coefficient (R^2).

FZI Values	Permeability formula	Correlation coefficient (R^2)
FZI = 0	$K = 391.49 \times \emptyset^{3.4003}$	0.89
FZI = 1	$K = 0.0450 \times \emptyset^{3.5544}$	0.89
FZI = 2	$K = 6700 \times \emptyset^{3.5544}$	0.95
FZI = 3	$K = 5703.8 \times \emptyset^{3.3065}$	0.84

Where that performed in cored wells for (Kz-2) and (Kz-3) in order to make comparison between measured permeability value and estimated permeability value that explained in Figures (8).



(a) (b)

Figure (8): Predicted Permeability by FZI method (a) for well (Kz-2) and (b) for well (Kz-3).

3. Comparison between Classical Method and FZI Method for Predicting Permeability

Permeability represents an essential property for rocks of formation. In carbonate rocks predict permeability from well log data is consider difficult task. Where correlation between porosity and permeability doesn't be generate, until after correlation was connected with all parameter of well log **[13].** Actually two methods are used to predict permeability and discussed in this study cover all parameter from core data analysis and well log data which effect on porosity and permeability, these methods are Classical and the FZI . To make simple correlation between measured and estimated permeability for two methods in order to select best method and this operation has been done by select method that provide greatest correlation coefficient for this study **[14]**.

Figures (9) and (10) explained that the FZI method provides best correlation coefficient as a compared with classical method. So can be depended for estimating permeability in this study.

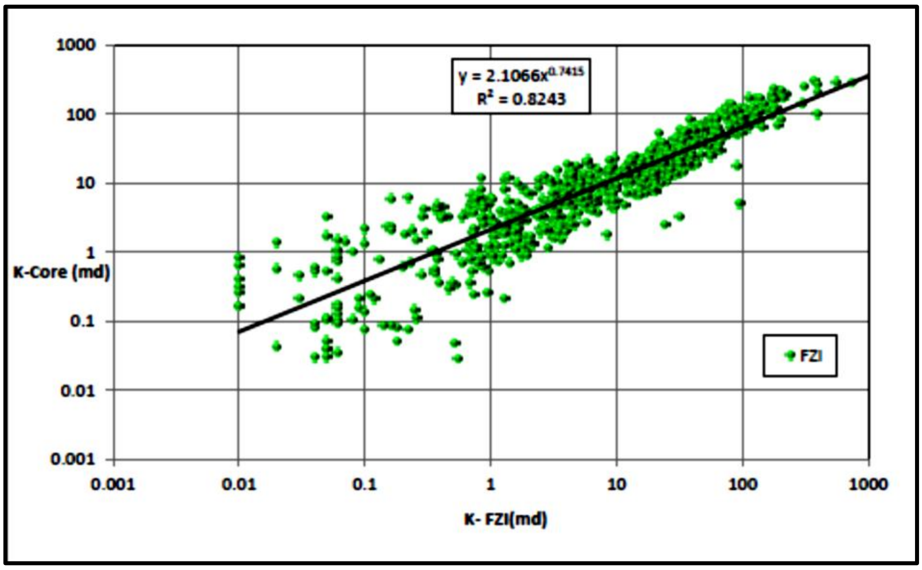


Figure (9): Accuracy of permeability predictions by FZI method.

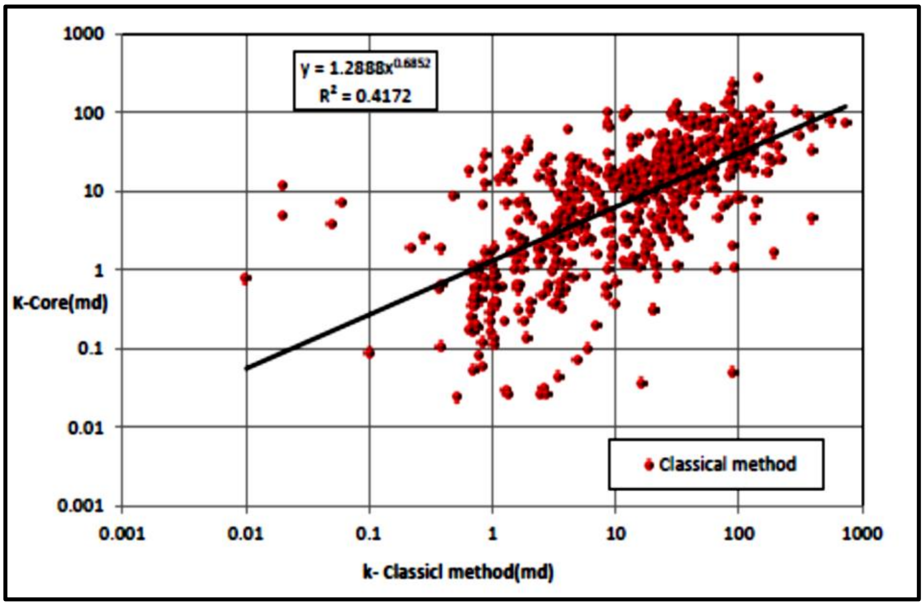


Figure (10): Accuracy of permeability predictions by Classical method.

4. Conclusions

The permeability estimation is a complex process, which have many parameters effect its value, so the classical methods depends on the values of porosity alone, when the FZI method had to take in the consideration many parameters. And that clear from the values of correlation coefficients (R^2) which reflect the values is more accurate.

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