Permeability Prediction for Nahr-Umr Reservoir / Subba field by Using FZI Method

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ABSTRACT

The permeability determination in the reservoirs that are anisotropic and heterogeneous is a complicated problem due to the limited number of wells that contain core samples and well test data. This paper presents hydraulic flow units and flow zone indicator for predicting permeability of rock mass from core for Nahr-Umr reservoir/ Subba field. The Permeability measurement is better found in the laboratory work on the cored rock that taken from the formation. Nahr-Umr Formation is the main lower cretaceous sandstone reservoir in southern of Iraq. This formation is made up mainly of sandstone. Nahr-Umr formation was deposited on a gradually rising basin floor. The digenesis of Nahr-Umr sediments is very important due to its direct relation to the porosity and permeability.

In this study permeability has been predicated by using the flow zone indicator methods. This method attempts to identify the flow zone indicator in un-cored wells using log records. Once the flow zone indicator is calculated from the core data, a relationship between this FZI value and the well logs can be obtained.

Three relationships have been found for Nahr-Umr reservoir/Subba field by FZI method.

By plotting the permeability of the core versus the permeability that is predicted by FZI method the parameter R^2 was found (0.905) which is very good for predict the permeability.

Key words: permeability, FZI

حساب النفاذيه لمكمن نهر عمر / حقل صبه باستخدام طريقة FZI

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الخلاصة

ان حساب النفاذيه في المكامن غير المتجانسه هي مسألة صعبه وذلك لان عينات اللباب وبيانات فحص الابار تكون قليله ومحدوده لعدد معين من الابار. في هذا البحث يتم استعراض (hydraulic flow units) و (flow zone indicator) لاستخدامها في حساب نفاذيه الصخور من خلال عينات اللباب الماخوذه من مكمن نهر عمر في حقل صبه. افضل نفاذيه هي النفاذيه المحسوبه في المختبر من عينات اللباب الماخوذه من الحقل. تكوين نهر عمر هو المكمن الرئيسي الاسفل في جنوب العراق وهو مكمن طباشيري. تكوين نهر عمر يتكون بصوره رأيسيه من حجر الرمل. تكوين نهر عمر ترسب بصوره تدريجيه في حوض نهري صاعد. تشخيص رواسب تكوين نهر عمر هي عمليه مهمه جدا وذلك لما للرواسب من تاثير مباشر على مساميه ونفاذيه المكمن.

في هذا البحث تم حساب النفاذيه لمكمن نهر عمر في حقل صبه باستخدام طريقة (Flow zone indicator) . هذه الطريقه تحاول حساب قيمه (Flow zone indicator) في الابار التي ليس بها عينات اللباب باستخدام المجسات. بعد حساب (Flow zone indicator) من بيانات اللباب المتوفره يتم ايجاد علاقه بين هذه القيمه المحسوبه (Flow zone indicator) ومجسات الابار .ثلاثه علاقات وجدت لمكمن نهر عمر/حقل صبه باستخدام طريقه FZI
بواسطه رسم نفاذيه اللباب ضد النفاذيه المستحصله بطريقه FZI فان المتغير R^2 قد وجد (0.905) حيث يتعبر قيمه جيدة لايجاد النفاذيه بطريقه FZI
الكلمات الرئيسيه : النفاذية , FZI

1. INTRODUCTION

One of the most important rock parameters for the evaluation of hydrocarbon reservoirs is permeability. Permeability was controlled by the size of the connecting passage between pores. Recovery of hydrocarbons from the reservoir is an important process in petroleum engineering and estimating permeability can aid in determining how much hydrocarbons can be produced from a reservoir.

Pasternak, 2009 stated that there is more one method to determine the permeability and porosity that are composed much of the technical literature in the industry of oil. There was no defined equation between the values of porosity and permeability. In many cases the relationship between porosity and permeability was qualitatively and in any way was not direct or indirect quantitatively. At all it was possible to find very high value of porosity without founding any permeability, as in the cases of pumice stones (where the permeability effective was approach to zero), clay and shale. The reverse might be true where the permeability was high and the porosity was low, like in micro fractured carbonate reservoirs. In spite of this fundamental lack of corresponding between the two properties, there were often can be find a good correlations between the porosity and permeability within one formation.

Tiab, and Donaldson, 2004 gave that the reservoir rock nature may contain oil dictated that the fluids quantities that were trapped within the pores of these rocks. The porosity may be defined as a measure of the void space of rock, and the permeability was the ability measurement of the rock to transmit fluid. Knowledge of the porosity and permeability was essentially before the questions concern the types of fluid, amount of fluid, rate of fluid flowing, and fluid recovery estimate could be answered.

2. FLOW UNITS

Bear, 1972, stated that the flow unit may be as the representative of the elementary volume of the total reservoir rock which the geologically and petro physical properties of the rock volume are the same.

Hear et al., 1984, defined the flow unit as a reservoir zone that was laterally and vertically continuous, and has similar permeability, porosity, and bedding characteristic.

Ebank, 1987, defined the hydraulic flowing units as portions of the reservoir which the geologically and petro physical properties that affects the flow of fluids were consistence and predictably different from the properties of other reservoir rocks volume.

Gunter, et al., 1997, showed that the flow units as continuous stratigraphic intervals of similar reservoir process that honor the geological frameworks and maintain the characteristically of the rock types. The hydraulic flow unit concept of hydraulic may be used to find the permeability.

3. DEVELOPMENT OF FLOW UNIT CONCEPT.

Amaefule, et al., 1993, considered the mean hydraulic radius role is in defining hydraulic flow units and correlation permeability from cores data. Their approach was essential based on the modified Kozeny-Carmen equation:

$$k = \left(\frac{1}{2\tau^2 \times S_{gv}{}^2}\right) \times \left(\frac{\emptyset_{eff}{}^3}{\left(1-\emptyset_{eff}\right)^2}\right) \quad (1)$$

The **Amaefule et al,**defined the mean hydraulic radius as follows:

$$rmh = \frac{Cross\ sectional\ Area}{Wetted\ perimeter} = \frac{r}{2} \quad (2)$$

Tiab, and Donaldson, 2004, considered the concept of subgrouping reservoir volume into the flowing unit, suggested that the term $2\tau^2$ in Eq. (1), which is classical referred to as Kozeny constant, is actually “variable constant”. That means that Kozeny constant may vary for different hydraulics units, but is constant for a specific unit. Based on that, **Tiab, and Donaldson, 2004,** introduced the “variable constant” k_τ referred to as the effective zoning factor:”

$$k = \left(\frac{1}{k_\tau \times S_{gv}{}^2}\right) \times \frac{\emptyset_{eff}{}^3}{\left(1-\emptyset_{eff}{}^2\right)} \quad (3)$$

Tiab, and Donaldson, (2004) proposed to estimate the effective zoning factor:

$$k_\tau = F_s \times \tau^2 \quad (4)$$

Carmen, 1937, ‘simulated a porous medium as a bundle of capillary tubes. They combined Darcy’s law for flow in a porous medium and Poiseuille’s law for flow in tubes. A tortuosity factor was also included, because for a realistic model of porous media the connected pore structure is not straight capillary tubes. **Carmen, 1937,** suggested the following relationship between porosity and permeability:

$$k = \frac{r^2 \times \varphi_{eff}}{8\tau^2} = \frac{\varphi_{eff}}{2\tau^2} \times \left(\frac{r}{2}\right)^2 = \frac{\varphi_{eff} \times r_{mh}{}^2}{2\tau^2} \quad (5)$$

Al –Ajmi, and Holditch, 2000, showed that the mean hydraulic radius can be related to the specific surface area per unit grain volume S_{gv}, and the effective porosity φ_{eff}, by the following equation:

$$S_{gv} = \frac{1}{r_{mh}} \times \left(\frac{\varphi_{eff}}{1-\varphi_{eff}}\right) \tag{6}$$

Combining Eqs. (5) and (6), gives the generalized Kozeny-Carmen equation:

$$k = \frac{{\varphi_{eff}}^3}{(1-\varphi_{eff})^2} \times \frac{1}{F_s \times \tau^2 \times {S_{gv}}^2} \tag{7}$$

The term ($F_s \times \tau^2$) is known as the Kozeny constant, which is usually between 5 and 100 in most reservoir rocks. The term ($F_s \times \tau^2 \times S_{gv}^2$) a function of geological characteristics of porous media and varies with changes in pore geometry. The determination of the ($F_s \times \tau^2 \times S_{gv}^2$) group is the focal point of the Hydraulic Flow Unit (HFU) classification technique.

4. IDENTIFICATION OF FLOW ZONE INDICATOR (FZI) AND RESERVOIR QUALITY INDEX (RQI)

Taslimi, 2008 showed that flow zone indicator depends on geological characteristics of the material and various pore geometry of a rock mass; hence, it is a good parameter for determining HFU. Flow zone indicator is a function of reservoir quality index and void ratio.

Amaefule, et al., 1993, addressed the variability of Kozeny's constant by dividing Eq.(1) by the effective porosity φ_{eff}, and taking the logarithm:"

$$\sqrt{\frac{k}{\varphi_{eff}}} = \frac{1}{0.0314} \times \left(\frac{\varphi_{eff}}{1-\varphi_{eff}}\right) \times \frac{1}{\tau\, S_{gv} \sqrt{F_s}} \tag{8}$$

Where, the constant 0.0314 is the permeability conversion factor from μm^2- md.

Al –Ajmi, and Holditch, 2000, defined the flow zone indictor FZI (μm) as:

$$FZI = \frac{1}{\tau\, S_{gv} \sqrt{F_s}} \tag{9}$$

Reservoir quality index RQI (μm) as:

$$RQI = 0.0314 \sqrt{\frac{K}{\varphi_{eff}}} \tag{10}$$

And normalized porosity φ_z (fraction) as:

$$\varphi_z = \frac{\varphi_{eff}}{1-\varphi_{eff}} \tag{11}$$

Substituting Eq. (9) and Eq. (10) in Eq. (8) gives the following equation:

$$RQI = FZI \times \varphi_z \tag{12}$$

Taking the logarithm of both sides of Eq. (12) yields:

$$\log RQI = \log FZI \times \log \varphi_z \tag{13}$$

Al –Ajmi, and Holditch, 2000, considered that in a Log-Log plot of RQI versus φ_z all the samples with similar FZI values lie on a straight line with a slope of one; and data samples with the same FZI values, but significantly different from the preceding one, will lie on another, parallel, unit-slope lines; and so on **Perez, 2003** samples that lie on the same straight line have similar pore throat attributes, and thereby constitute a unique HFU. Each line represents a HFU and the intercept of this line with φ_z=1is the mean FZI value for that HFU. Each flow unit is characterized by FZI. **Amaefule, et al.,1993,** determined the basis of HFU classification is to identify groups of data that form unit-slope straight lines on a Log-Log plot of RQI versus φ_z, as shown in **Fig.1**.

5. FZI CORRELATION WITH WELL LOGS DATA

FZI is then correlated with certain combinations of logging tool responses to predict permeability values in cored and un-cored intervals of wells. This method attempts to identify the flow zone indicator in un-cored wells using log records. Once the flow zone indicator is calculated from the core data, a relationship between this FZI value and the well logs can be obtained, **Pablo, 2008**.

Eqs. (10) through (12) are used to compute the functions for preparing a log-log plot of RQI versus φ_z for each reservoir unit of all the wells. The data that have similar FZI values fall on a straight line (of the same slope); and all the data on the same straight line can be considered to have similar pore throat attributes (the same hydraulic unit) governing the flow. The permeability can be computed for those points on the same straight line (with same FZI) where core permeability plotted versus core porosity as shown in **Fig.2**:

Using the Eq. (14) to calculate the permeability in the un-cored wells:

$$K = 1014 \times FZI^2 \times \frac{{\varphi_{eff}}^3}{(1-\varphi_{eff})^2} \tag{14}$$

The cross plot of the logarithm of permeability versus porosity data obtained from core analyses is shown in **Fig.1**. The cross plot of the logarithm of the reservoir quality index (RQI) versus the logarithm of the normalized porosity (Øz) for various values of the Flow Zone Indicator (FZI) are shown in Figure **Fig.2**. The cross plots of the K-predicated by FZI and K-core versus depth for each well are shown in **Figs .3** to **7**. A good agreement between the k-predicted and k-core values along most depth intervals of the units may be noticed from these figures. By plotting the permeability of the core versus the permeability that is predicted by FZI method for the cored wells the parameter R^2 was found (0.905) as in **Fig.8** and this value is considered good to find the values of permeability for Subba field /Nahr-Umr reservoir.

5. CONCLUSIONS

- FZI method is very accurate method in estimating permeability in un-cored well. Good agreement has been obtained between core permeability and calculated permeability by FZI method.
- FZI method gave three groups for Nahr-Umr reservoir, each group represent type of rocks, each type have the similar porosity and similar properties which can be used to divide the reservoir.

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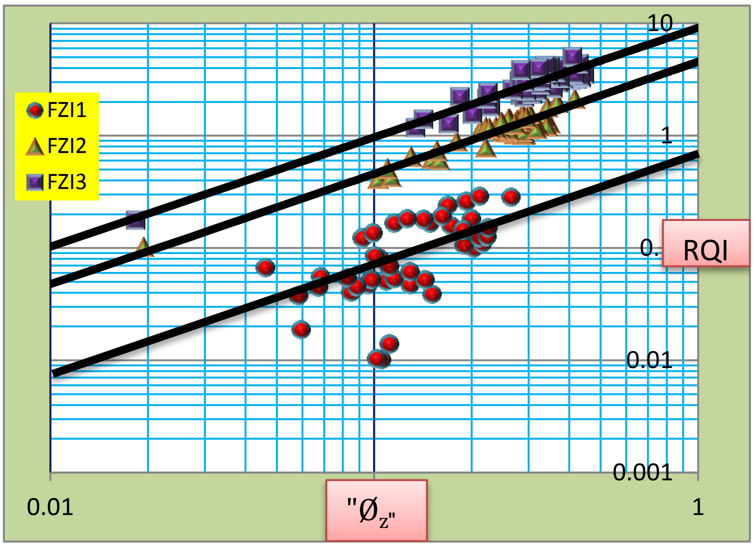

Figure1. Reservoir quality index (RQI) versus the normalized porosity (Øz) for Nahr-Umr formation**. Watten, 2015.**

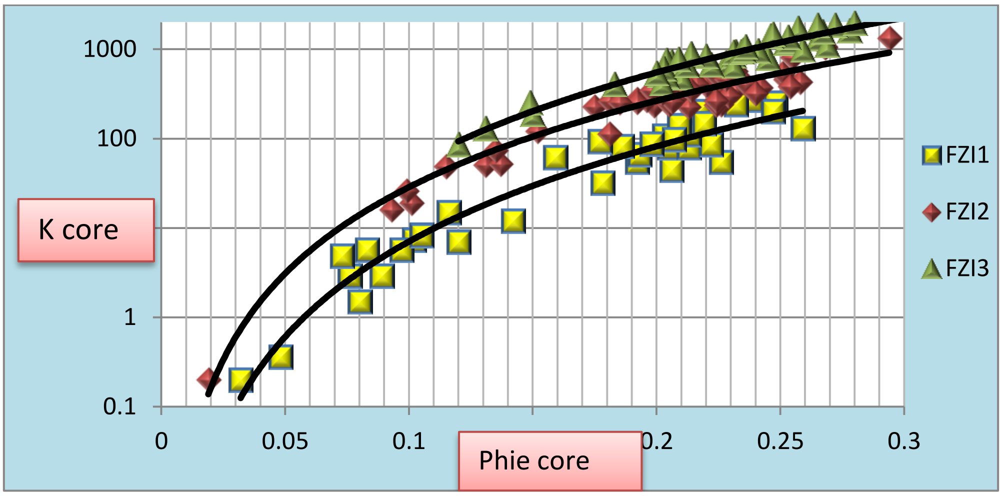

Figure 2. Core permeability versus core porosity for Nahr-Umr formation**. Watten, 2015.**

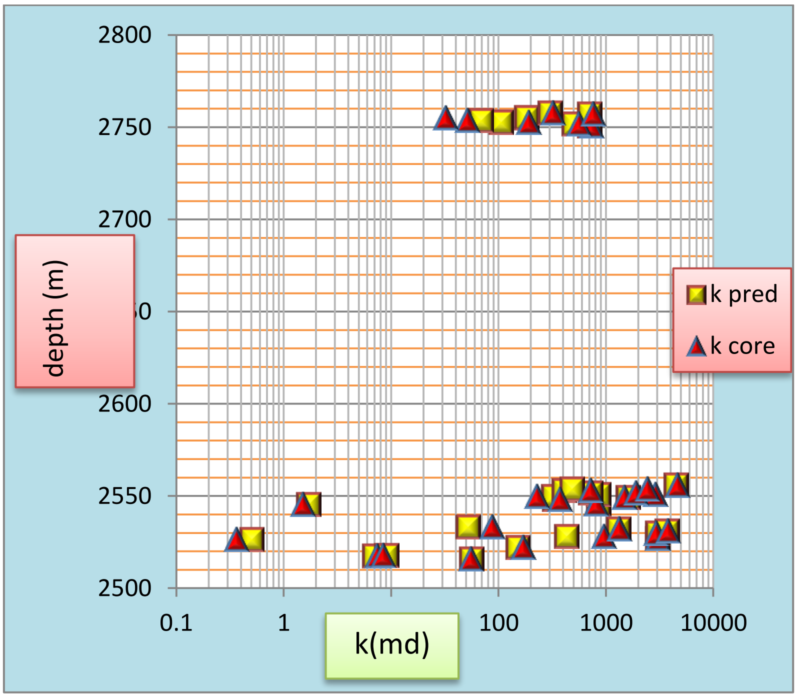

Figure 3. K- Predicted from FZI and K-Core versus depth for Nahr-Umr formation (well su-4). **Watten, 2015.**

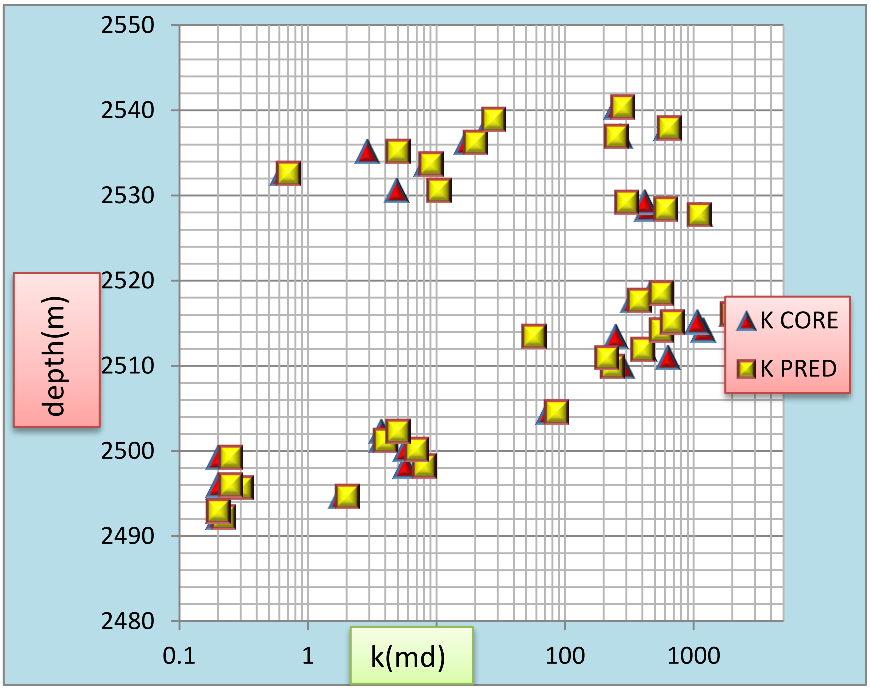

Figure 4. K- Predicted from FZI and K-core versus depth for Nahr-Umr formation (well su-5). **Watten, 2015.**

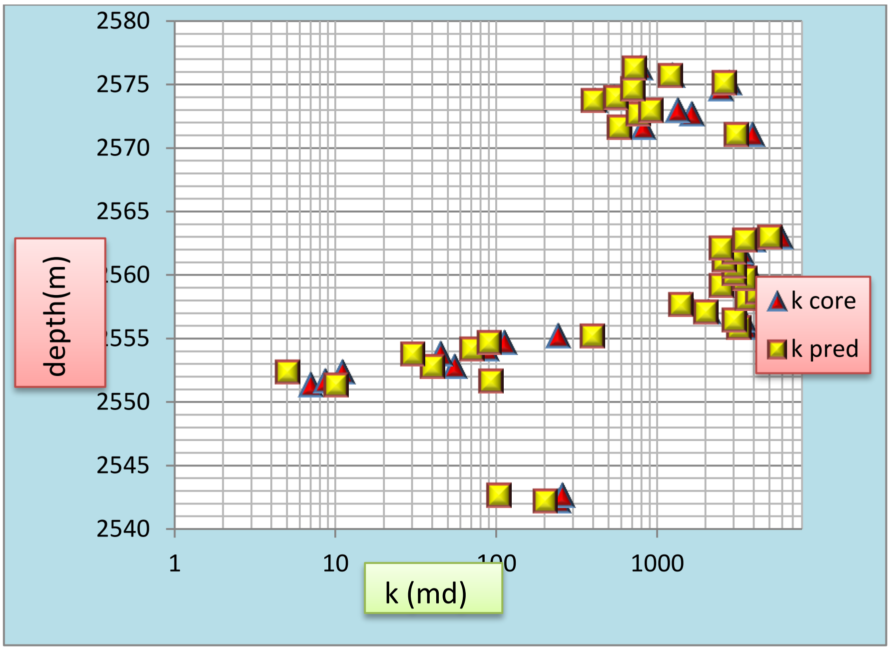

Figure 5. K- Predicted from FZI and K-Core versus depth for Nahr-Umr formation (well su-7). **Watten, 2015.**

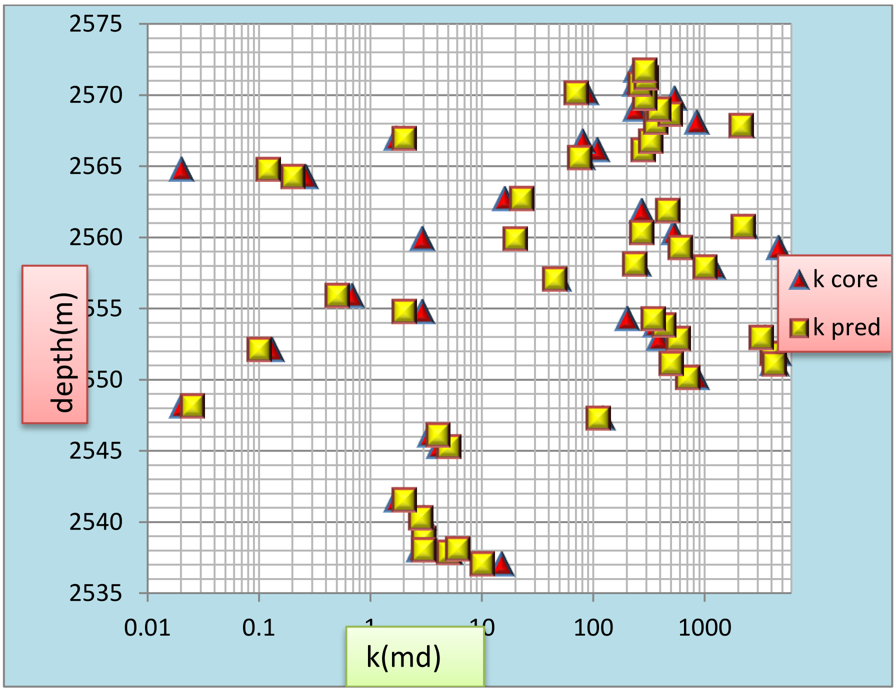

Figure 6. K- Predicted from FZI and K-core versus depth for Nahr-Umr formation (well su-9). **Watten, 2015.**

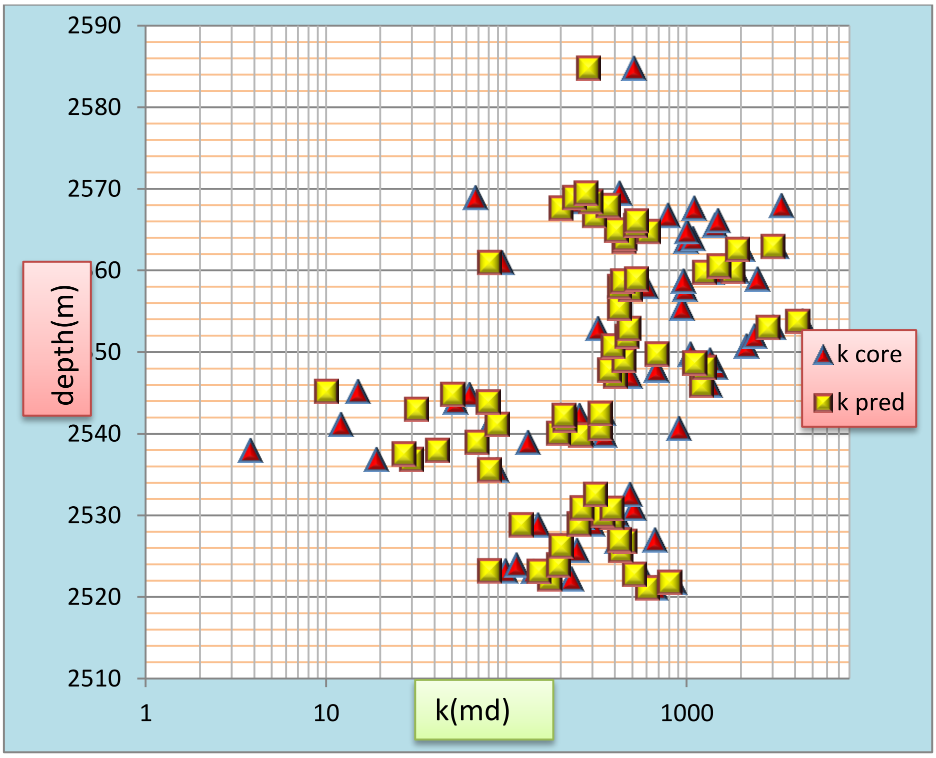

Figure 7. K- Predicted from FZI and K-core versus depth for Nahr-Umr formation (well su-14). **Watten, 2015.**

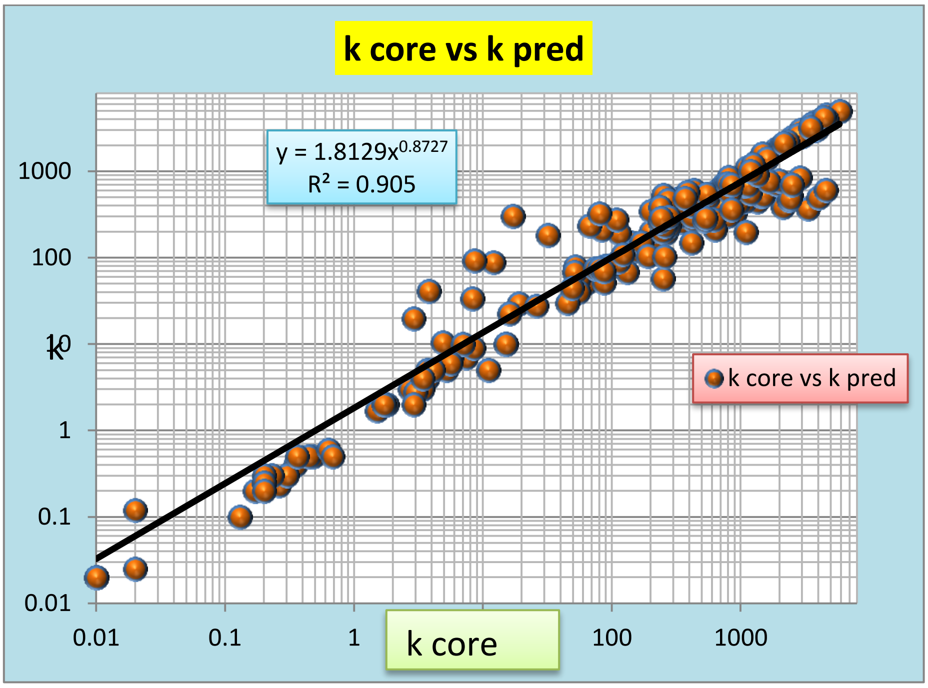

Figure 8: K- Predicted by FZI and K-core.

Table.1 Regression formulas with their correlation coefficient (R^2) by FZI method.

FZI	Formula	R2
FZI =1	$K=24483 *\phi eff^{3.5415}$	0.9437
FZI =2	$K=46612 *\phi eff^{3.211}$	0.9545
FZI =3	$K=14789 *\phi eff^{3.4757}$	0.9391

Symbol	Description	Unit
Fs	effective pore throat shape factor	(---)
K	permeability	md
K_τ	function of pore-pore throat size and geometries, tortuosity and cementation	(---)
r	pore throat radius	µm
rah	mean hydraulic radius	µm

S_{gv}	surface area of grains exposed to fluid per unit volume of solid material	cm2/cm3

NOMENCLATURE

Greek Symbols		
φ_{eff}	Effective porosity	fraction
φz	Normalized porosity	fraction
τ	Tortuosity	(---)

Abbreviations	
FZI	Flow Zone Indicator
HFU	Hydraulic Flow Unit
RQI	Reservoir Quality Index