3D Permeability Distribution Modeling from Porosity Wire Line Logs and Irreducible water saturation graph a Case Study on small giant Bai Hassan Oil Field-Northern Iraq

Fawzi Al-Beyati[1], Muhammed A. Ismail[2], Gasham Zeynalov[3]

[1] Kirkuk Technical College, Baghdad Street, Kirkuk 3600, Iraq
[2,3]Department of Petroleum Engineering, Khazar University, 41 Mehseti Street, Baku AZ1096, Azerbaijan

ABSTRACT

The main aim of this research is to determine nearest and acceptable predicted permeability value obtained from wire line logs compared with those values coming from core sample analysis within two wells belong to two domes from small giant Bai Hassan oil field, using irreducible water saturation graph method. This work consists of three main parts, the part one is well logs analysis, which involves determination of Archie petrophysical parameters, porosity corrected form volume of shale, water saturation and irreducible water saturation. The second part is predicting permeability using irreducible water saturation from well log analysis and compare the estimated values with the data of permeability that measured from core sample in BH-20 and BH-53 well. The last part was using SPSS statistic software to determine the factor that can give the very nearest and acceptable values, these values uses to estimate real permeability for another wells distributed on each dome of the small giant Bai Hassan oil field. Excellent correlation obtained (R^2 = 0.978 in BH-20 and R^2=0.9945 in BH-53) between estimated permeability values based on irreducible water saturation and permeability that got from core sample. The result of statistical method (SPSS software) is:

$K_{Core} = (K_{Predicted} * 1.040) - 3.363$ (BH-20) [Kithka Dome]

$K_{Core} = (K_{Predicted} * 1.030) - 3.359$ (BH-53) [Daoud Dome]

Keywords: 3D Permeability Modeling; Empirical method; irreducible water saturation.

INTRODUCTION

Reservoir management strategies are as realistic as the image of the spatial distribution of rock petrophysical properties. Permeability is the most difficult property to determine and predict. There are many methods for permeability estimation from logs from a practical point of view. Empirical methods are used in this study to estimate the permeability form wireline log by porosity and irreducible water saturation that well data is available.

In the last three years ago attention to the geostatic to 3D simulation the petrophysical properties like the (Amani et al .,2013) study from Bangstan oil field reservoir, also there are to other studies were done on the studied field recently by (Sadeq et al.,2015 a, b) in these two studies on cretaceous reservoir they revealed that the fractures and vugs were affected on the pore pressure and reservoir properties, also the tectonic were tacked the role in enhances the permeability of some parts Bai Hassan oil field. In 2016 Al-Jwani and Gayara also revealed the same results only the study was done Paleogene part in addition to the cretaceous part.

The purpose of this research is to get permeability value from porosity wireline logs to make screening and draw 3D model in a short time with more reliability from the compare between core and predicted permeability values using irreducible water saturation parameter of core sample in one well from each dome in each saddle of small giant Bai Hassan oil field (Kithka and Daoud Domes). For this reason, two wells were chosen BH-20 (Kithka Dome) and BH-53 (Daoud Dome). Permeability estimation from well log and core sample are used in SPSS statistic software to determine the factor that can give us the very nearest value, these factor value uses to estimate real permeability for another wells in the small giant Bai Hassan oil field. The importance of this idea is to make 3D model in available oil field in a short time with least cost, with available data in absence of seismic sections.

This work were done on dolomitic limestone and limestone rocks of Jeribe formation Early middle Miocene age (Jassim and Goff, 2006) which represent the main reservoirs rock of small giant Bai Hassan oil field .Bai Hassan oil field has extended previous mapping to include associated fault frameworks consisting of an imbricate front thrust and back thrust fault set within each of the two domes; in addition to, northeast-southwest trending tear faults are present within the Bai Hassan structure to accommodate differential fault movement on the separate and loosely coupled lateral thrust sheet segments comprising the front and back thrusts age (Bellen et al., 1959).

STUDY AREA

Bai Hassan small giant oil field is located geographically northwest of Kirkuk- northern Iraq with in the low folded zone according to (Dunnington, 1958) or zone of Hamren – Makhool according to (Buday and Jassim, 1987), which it is an Unstable Shelf Zone (Fig.1a). Structurally the oil field is asymmetrical elongated anticline extended for 40km in length and 13.5km in width in-between Kirkuk and Qarachoq anticlines.

The field contain from 2 domes (in SE – NW direction) Kithka Dome and Dauod Dome separated by a narrow saddle called Shahal saddle, Kithka dome is bigger in size and higher structurally by (335m) than Dauod dome(Fig. 1 b). The number of wells drilled to the time of the preparation this study reached 185 wells (Buday, 1980).

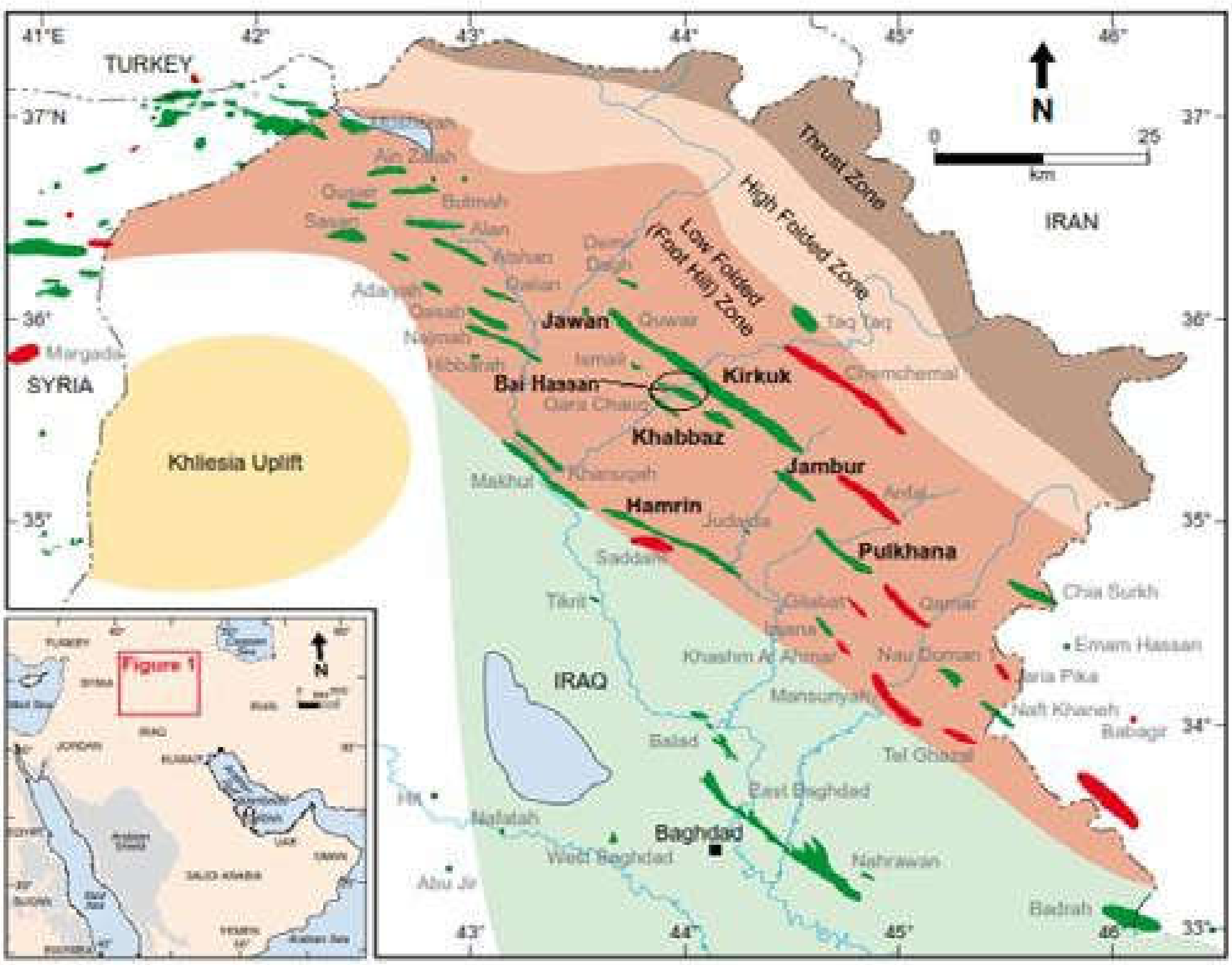


Fig.1a: Map of Northern Iraq Showing Location and structure of Bai Hassan Oil

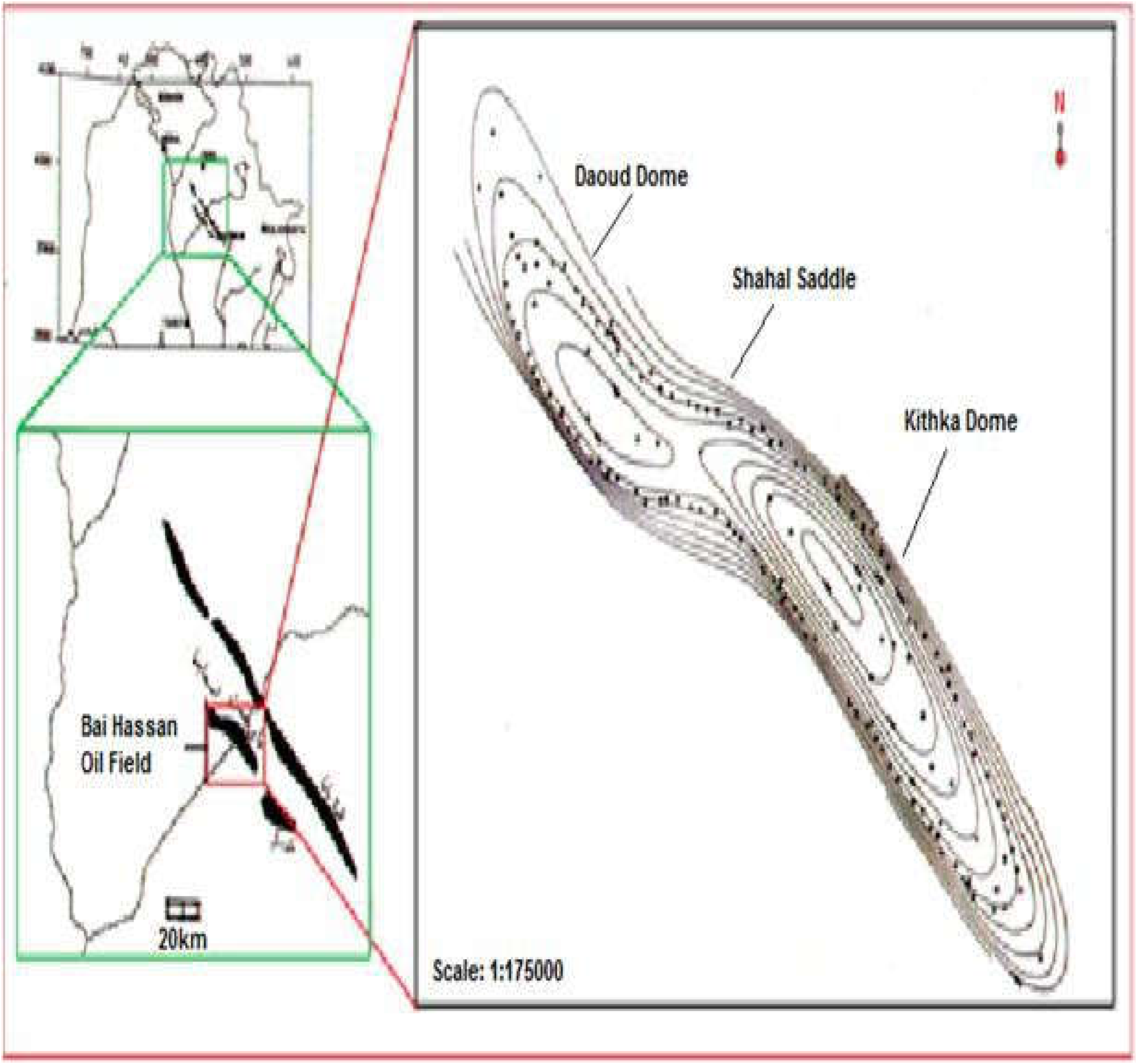


Fig.1b: Map of Northern Iraq Showing Location and structure of Bai Hassan Oil Field.

METHODOLOGY

1. Calculating K from Φ& Swir

In this step of the study, our goal was to develop a reliable model that could predict the permeability with only well log data for wells from which core data is not available. Calculating permeability (K) from porosity wireline log for both BH-20 and BH-53 wells using irreducible water saturation (Swir). Empirical methods are based on the correlation between permeability, porosity and irreducible water saturation. Log-derived permeability formulas are only valid for estimating permeability in formations at irreducible water saturation (Schlumberger, 1977 in Asquith and Krygowski, 2004).

Before calculating the permeability, we must do some steps, first well log digitized and corrected from the effect of shale volume, the second step was the determination of whether or not the target formation rock is at irreducible water saturation. The formation to be at irreducible water saturation depends upon bulk volume water values (BVW = S_{w*} Φ). When the bulk volume water values of the formation are constant, the zone is in irreducible water saturation case. If the values are not constant, a zone is not at irreducible water saturation (Fig.2), and this is mean that the estimated permeability values will be suspect (Asguith and Krygowski, 2004).

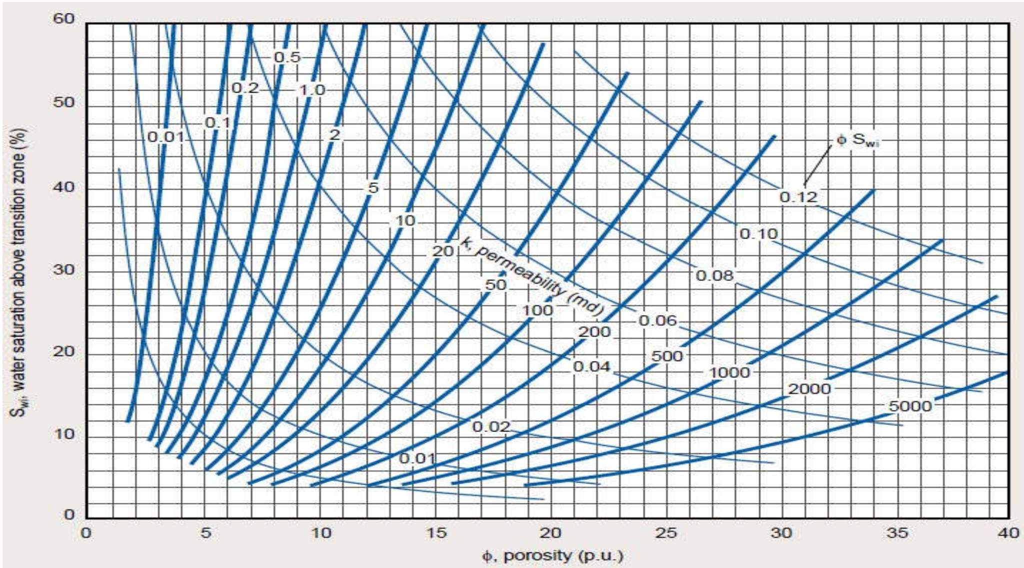


Fig. 2: Chart of porosity (Φ) versus irreducible water saturation (S_{wir}) (Schlumberger, 1998, Chart K-3)

1.1 Calculate Constant Value

The magnitude of the constant was shown to be related to rock type and indirectly to permeability. The lower value of the constant is referring to the better quality of the rock. Buckles (1965) suggested that the porosity and irreducible water saturation are related by the following formula

Porosity * Irreducible Water Saturation = Constant…...... 1

The importance of the constant was shown to be related to the rock type and indirectly to the permeability table (1), the lower value of the constant indicates to the better quality of the rock, higher porosity for any given value of porosity (Buckles, 1965; Morris and Biggs, 1967; Chilingar et al, 1967; Bond, 1978; Doveton, 1994).When data are representing on a log-log graph, points should align on a slope of (-1((Fig. 3).

Table 1: Ranges of constant according to the rock type

Rock Type	Range of the Constant
Sandstones	0.02 - 0.10
Intergranular Carbonates	0.01 - 0.06
Vuggy Carbonates	0.005 - 0.06

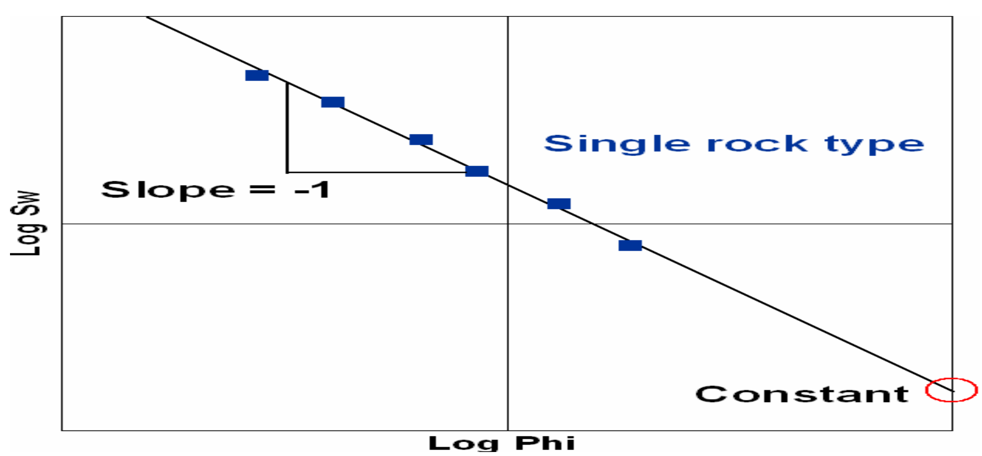


Fig. 3: Relation between Effective Porosity and Water Saturation

The relationship can be linearized to (Timur, 1968):

$$\textbf{Log } S_{wir} = \textbf{Log C} - \textbf{Log Phi} \quad \textbf{......... 2}$$
$$\textbf{K} = [79 * (Phi^3/S_{wir})]^2 \quad \textbf{........... 3}$$

S_{wir}= Irreducible water saturation
C = Constant
Phi = Porosity
K = Permeability

In the figures (4 and 5) the rock quality is shown between log porosity and log water saturation plots in BH-20 and BH-53 oil wells. Intercept value that read from the figure is (0.05 in BH-20 and 0.04 in BH-53) is representing the constant value that using to calculate Sw_{ir} and K.

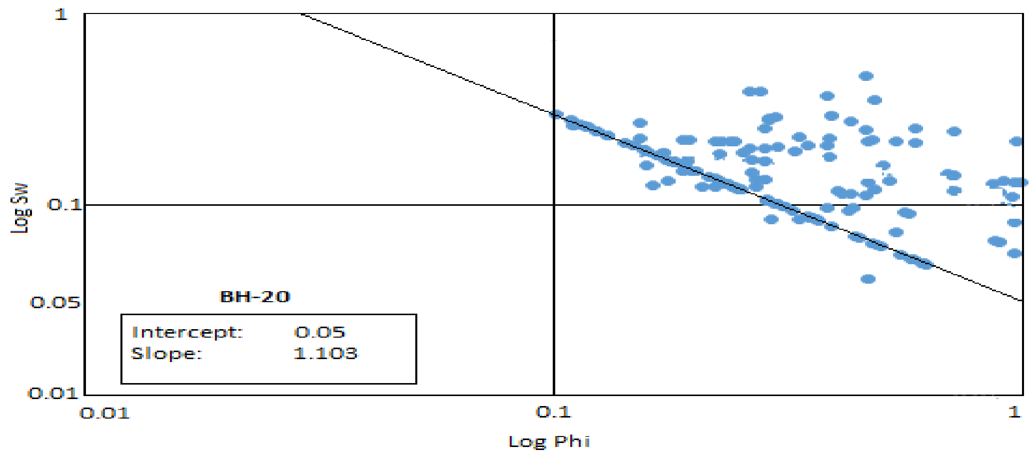


Fig. 4: Relation between Effective Porosity and Water Saturation in BH-20

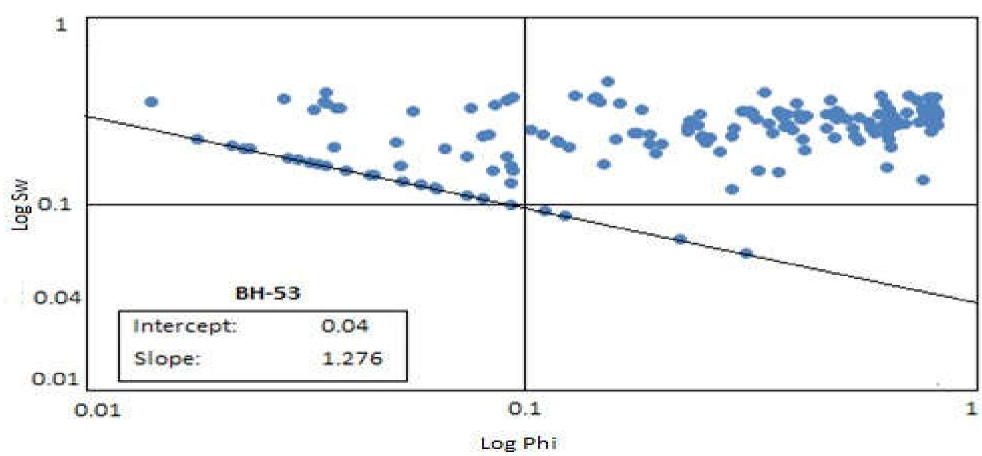


Fig. 5: Relation between Effective Porosity and Water Saturation in BH-53

2. Statistical processing

Using SPSS software program to calculate relationship between core and predicted permeability. This relation is representing by correlation coefficient R and build formula model between K that predicted from well log and K that measure from core sample for each saddle in small giant Bai Hassan oil field. In this study used BH-20 and BH-53 that cover each saddle and the core data is available.

2.1 BH-20 oil well

Data that used to import in the program is: depth, permeability that calculated from well log analysis and permeability measured from core sample. The goal of this processing is to get equation between permeability that calculated from wireline log and permeability measured from core sample.

According to the result that get from SPSS program is appear in equation (4) below. A result of calculated permeability versus core permeability with depth is shown in (Figure 6). It is observed in the (Figure 6) good correlation between the calculated permeability and core permeability. Good correlation coefficient (R2 = 0.9781) was obtained between permeability calculated based on empirical method and permeability of cores which is an index for accuracy of this method (figure 7).

$$K\ Core_{BH\text{-}20} = (K\ Predicted*1.040)-3.363 \ldots\ldots 4$$

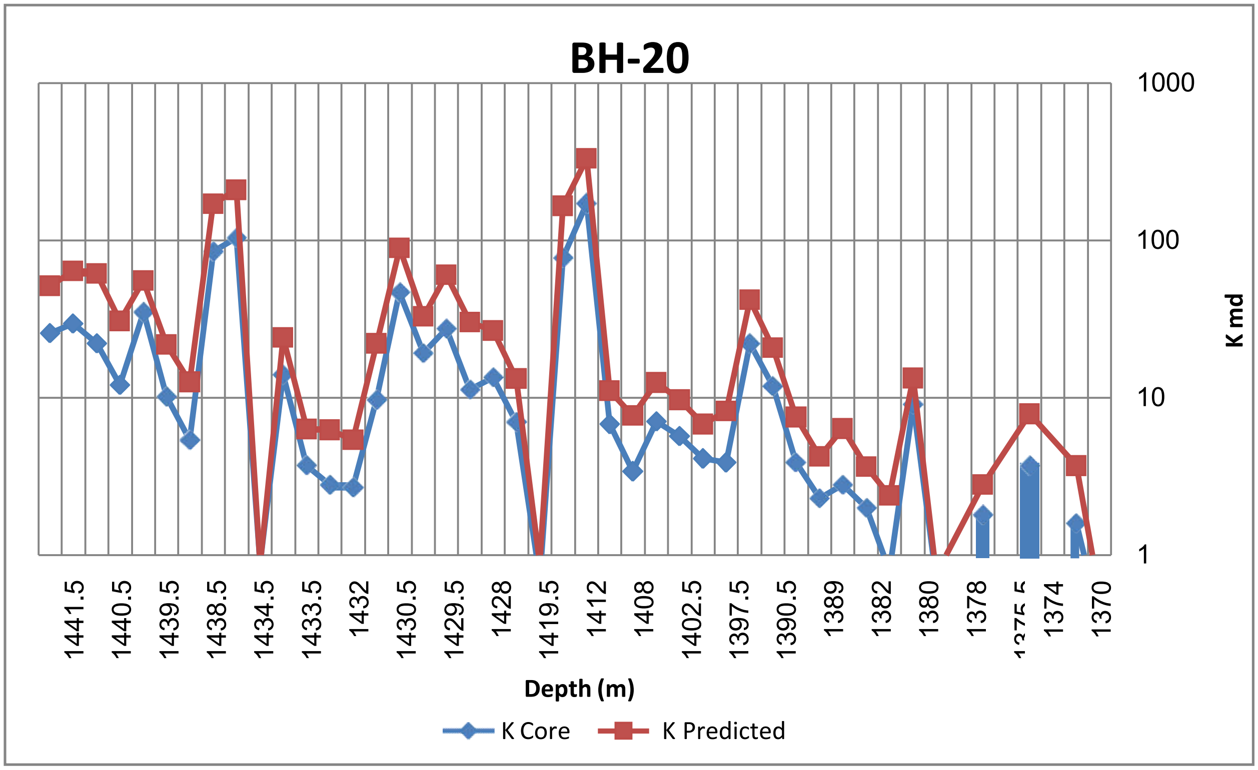
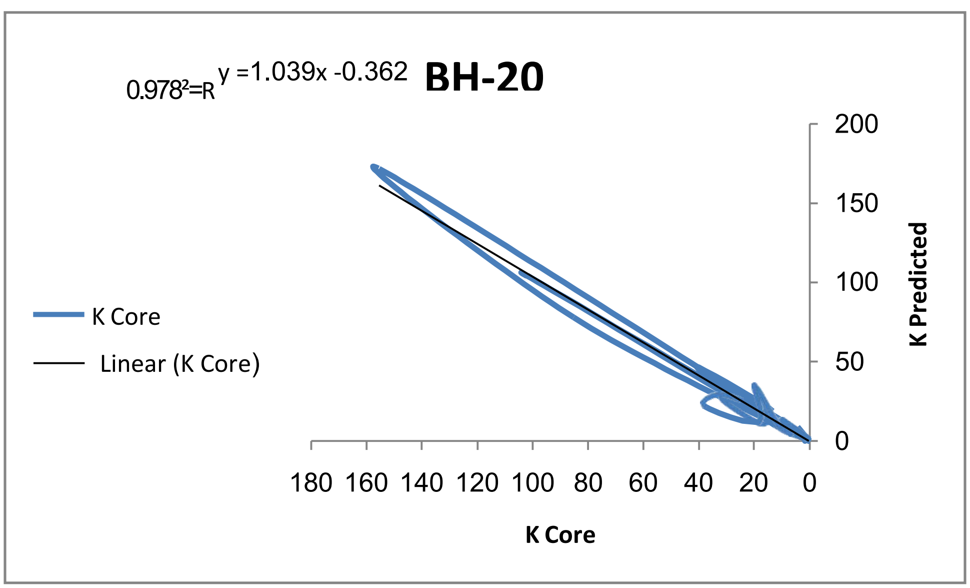


Fig. 6: Comparison of Continuous Predicted Permeability and Core Permeability in Well BH-20



2.2 BH-53 oil well

Data that used to import in the program is: depth, permeability that calculating from well log analysis and permeability measured from core sample that get from BH-53 oil well. The goal of this processing is to get equation between permeability that calculated from wireline log and permeability that measured from core sample.

According to the result that get from SPSS program is appear in equation (5) below. A result of calculated permeability versus core permeability with depth is shown in (Figure 8). It is observed in the (Figure 8) good correlation between the predicted permeability and core permeability. Good correlation coefficient (R2 = 0.9945) was obtained between permeability calculated based on empirical method and permeability of cores samples which is an index for accuracy of this method (figure 9).

$$\textbf{K Core}_{\textbf{BH-53}} \textbf{= (K Predicted*1.030)-3.359……5}$$

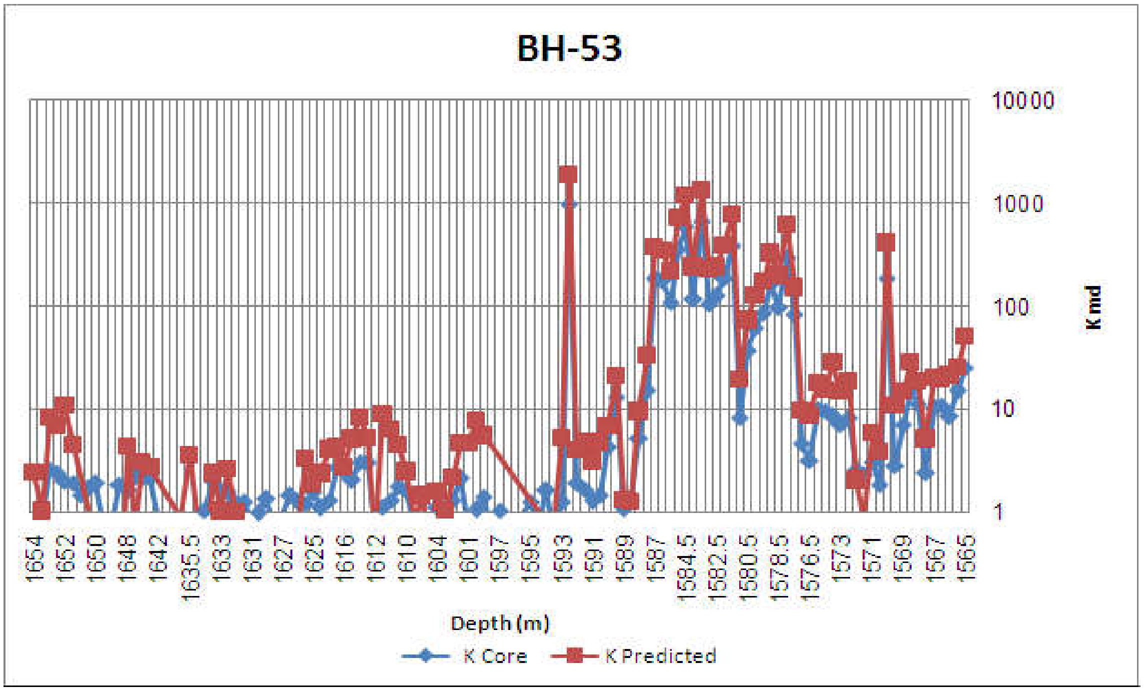
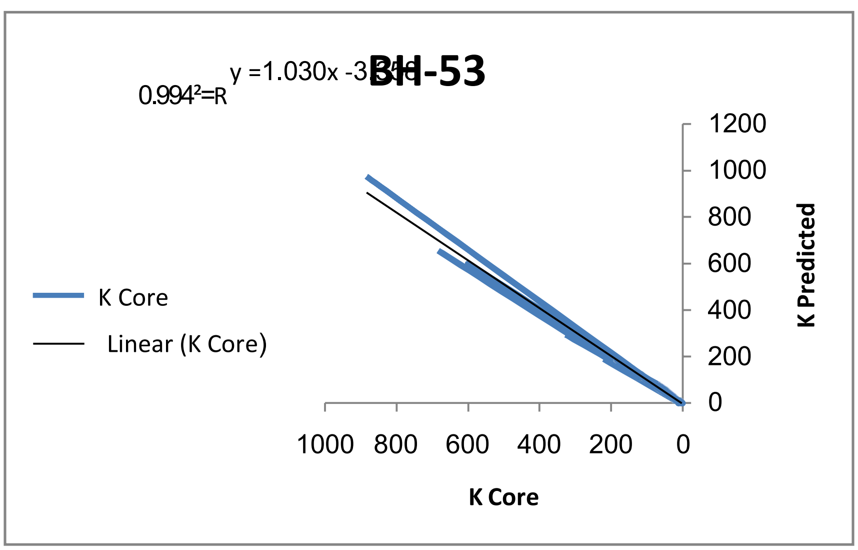


Fig. 8: Comparison of Continuous Predicted Permeability and Core Permeability in Well BH-53



RESULTS AND DISCUSSION

The overall results can be abbreviated by the following points:

1- The result of correlation between calculated permeability by using irreducible water saturation graph and permeability that measured from core sample is very good to excellent correlation in BH-20 and BH-53 that show in (Fig.6 and Fig.8).

2- The correlation coefficient ($R^2 = 0.978$ in BH-20 and $R^2=0.9945$ in BH-53) was obtained between permeability calculated based on irreducible water saturation and permeability of cores (Fig.7 and Fig.9).

3- The result of statistical method (SPSS software) is:

$$K_{Core}= (K_{Predicted}*1.040)-3.363 \text{ (BH-20) [Kithka Dome]}$$

$$K_{Core}= (K_{Predicted}*1.030)-3.359 \text{ (BH-53) [Daoud Dome]}$$

4- The reservoir 3D model simulation of the studied oil field reveal the heterogeneity according to spatial variability of permeability distribution(Fig.10) and this is arises the structural and sedimentological effect .The result concur with the actual existence condition of studied oil field, from this result the Kithka Dome is more prolific than the Daoud Dome, this is may be due to surface expression of Kithka dome (figure 11) ,this is due to structural development of Bai Hassan oilfield during Miocene compression and folding , these development of structure associated with the seated perpendicular axis extension faults (Bellen et al.,1959), which played as a conduit in addition to enhancement the fractures development within the formations rock at Kithka dome than the Daoud dome.

5- The sedimentlogical processes contributed to the enhancement the permeability distribution at the Kithka Dome than the other dome is the successive phase of dolomitization (Al-Hietee,2012, Sadeq et al.,2015) which influence and enhanced the reservoir character (Sadeq et al.,2015) therefore the dolomitic limestone is the main reservoir rock of Jeribe formation (Early middle Miocene) (Al-Ameri et al.,2011 , Sadeq et al.,2015), because this dolomitization lead to the influential by products porosities within the reservoir rocks like intercrystalline ,micro moldic and micro vugs (Sadeq et al .,2015).The all above idea can emphasize and give the best answer and interpretation to the different factors obtained for each dome of Bai Hassan oilfield.

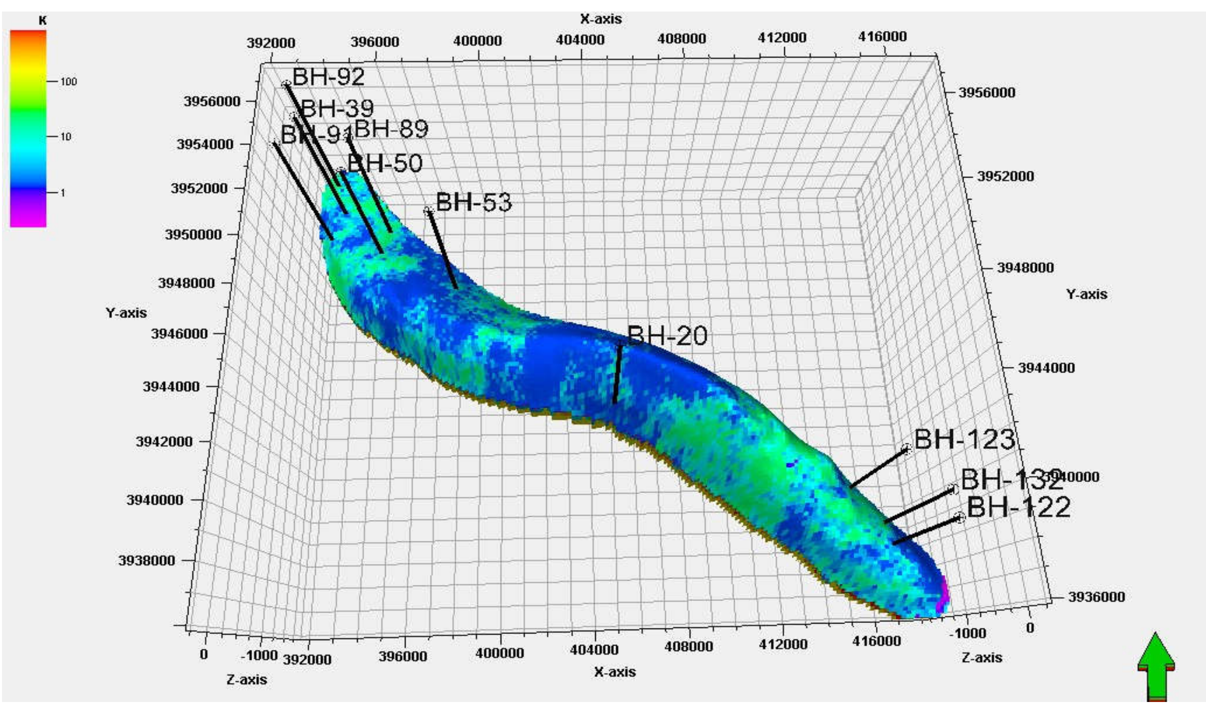


Fig. 10: 3D Model Showing Permeability Distribution in Bai Hassan Oil Field

6- The permeability distribution through Bai Hassan oil field is in (figure 10). It's clear that the permeability in general in this formation is good in some places (green area) for example in BH-132, BH-123, BH-89, BH-50 and BH-91 wells the permeability is represent in good area and the value is around about (10-100md).In the (blue area) it is clear that the permeability is not good and the wells BH-122, BH-20 , BH-53, BH-39 and BH-92 in this places. The value of permeability is around between (1-10md).

7- According to the result of this study we got an accurate model of a least cost and without need to the seismic sections that need to draw a three-dimensional model. This model is useful to throw a quick look at the field process to guide drilling of the field in the future as well as we can do direct drilling for the purposes of secondary production process within the distribution of the wells in the field for the purpose of secondary recovery.

Fig. 11: Satellite Image Reveal the Surface Expression at kithka Dome in Small Giant Bai Hassan Oil Field

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