Available online at http://ijcpe.uobaghdad.edu.iq and www.iasj.net
Iraqi Journal of Chemical and Petroleum Engineering
Vol. 24 No.2 (June 2023) 65 – 70
EISSN: 2618-0707, PISSN: 1997-4884
IJCPE

Prediction of Hydraulic Flow Units for Jeribe Reservoir in Jambour Oil Field Applying Flow Zone Indicator Method

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Abstract

The Jeribe reservoir in the Jambour Oil Field is a complex and heterogeneous carbonate reservoir characterized by a wide range of permeability variations. Due to limited availability of core plugs in most wells, it becomes crucial to establish correlations between cored wells and apply them to uncored wells for predicting permeability. In recent years, the Flow Zone Indicator (FZI) approach has gained significant applicability for predicting hydraulic flow units (HFUs) and identifying rock types within the reservoir units.

This paper aims to develop a permeability model based on the principles of the Flow Zone Indicator. Analysis of core permeability versus core porosity plot and Reservoir Quality Index (RQI) - Normalized porosity log-log plot reveals the presence of three distinct Hydraulic Flow Units and corresponding rock types within the Jeribe reservoir. These rock types can be identified if known. The reservoir can be divided into three groups of rock types, namely good, moderate, and bad quality. The bad rock type represents a restricted section within the reservoir, while the upper and lower parts predominantly consist of moderate-quality rock types. Conversely, the central section of the reservoir exhibits a good-quality rock type.

By utilizing the Flow Zone Indicator principles, this study provides valuable insights into the hydraulic flow behavior and rock types present in the Jeribe reservoir. The proposed permeability model derived from this method can aid in predicting permeability values for uncored wells, contributing to a better understanding of the reservoir's heterogeneity and facilitating reservoir characterization and management decisions.

Keywords: Jeribe reservoir, Flow Zone Indicator, Jambour oil field, Hydraulic Flow Units, Permeability Prediction.

Received on 03/10/2022, Received in Revised Form on 27/12/2022, Accepted on 03/01/2023, Published on 30/06/2023

https://doi.org/10.31699/IJCPE.2023.2.7

1- Introduction

When there is a lack of data, one of the most important problems in reservoir analysis is forecasting reservoir permeability [1]. To identify the formation evaluation and reservoir quality processes that are used in reservoir discovery, production, and improvement for the reservoir to evaluate if a potential oil field is economically feasible, the estimation of petrophysical properties such as permeability is quite important [2]. Identifying carbonate reservoirs is difficult due to their heterogeneity and propensity for tightness brought on by depositional and digenetic processes [3].

Jambour oil field is located northeast of Kirkuk governorate, and its production began in August 1959 [4]. The Jeribe Formation represents a heterogeneous formation originally described as organic detrital limestone. The formation was defined by Bellen in 1957 [5].

The permeability of a zone can be found in the well logs. By experimentally correlating the log response to core permeability data and the porosity, certain well logs and their outputs, such as porosity logs, can be applied to predict permeability [6]. Because permeability is a measure of the parameters of the formation, determining it from a well log is particularly difficult [7]. This is because the relationship between porosity and permeability may not be very accurate [8].

The hydraulic flow unit idea was put used by Amaefule et al. (1993) as a guiding principle for separating reservoirs into various rock types showing various pore-throat characteristics. To distinguish the rock types that form the basis of this reservoir characterization tool, the FZI (Flow Zone Indicator) serves as the main parameter in this approach [9].

In 2017, a study of the Jeribe reservoir in the Mansuriyah gas field estimated permeability to use both traditional and flow zone indicator methods to determine permeability using (451 samples) gathered from four wells. The research concluded that the classical method's correlation coefficient for the linear regression relationship between core permeability and porosity was (0.4363). As a result, the FZI approach was used to divide the reservoir into four zones with better correlation coefficients of more than 0.75 [10].

This study's goals are to determine the hydraulic flow units for the Jeribe reservoir in the Jambour oil field, contrast the permeability of the reservoir's core to that anticipated by the FZI permeability, and divide the reservoir vertically following the FZI results.

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2- Hydraulic Flow Units (HFU) Estimation

The traditional method of classifying rock types is dependent on an individual's subjective understanding of geology and an analytical correlation between permeability and porosity [11]. This traditional approach should be troublesome when considering such numerous flow units because the permeability of various locations within a particular rock may not limit to any certain porosity [12]. To solve this issue, the Kozeny-Carmen equation uses the Reservoir Quality Index (RQI) and Flow Zone Indicator (FZI) to characterize the hydraulic units inside mappable geological units (facies). RQI is used to calculate rock quality for heterogeneous reservoir conditions based on the non-linear relationship between permeability and porosity [13]. It also can be used to define the hydraulic unit's FZI. According to mineralogy and their geological texture, FZI is essentially a singular parameter that assists in the identification of distinctive pore geometrical facies [9].

Based on geological and physical factors at the pore size, the hydraulic flow unit (HFU) approach has been created to recognize and categorize different rock types. It can primarily be utilized to enhance the connections between well-to-well rock characteristics and permeability forecasting [14]. The geological and petrophysical reservoir rock parameters influence the hydraulic flow units. The petrophysical qualities include porosity and permeability, which are influenced by depositional facies and diagenetic processes, while the geological properties include rock texture and mineralogy, as well as sedimentary formations. A few HFU can exist within a single facies zone [15].

The correlation between the reservoir quality index (RQI), which describes the geometric distribution of pore space, and the normalized porosity (Z), is represented by the individual FZI for each reservoir flow unit.

$$RQI = 0.0314\sqrt{\frac{K}{\emptyset_e}} \quad (1)$$

Where: RQI is the Reservoir Quality index measured in (μm), $Ø_e$ is the effective porosity of the core in fraction, and K is the absolute permeability of the core in md.

$$\emptyset_Z = \frac{\emptyset_e}{1-\emptyset_e} \quad (2)$$

Where Øz is the normalized porosity or the ratio of pore volume to grain volume.

Finally, FZI (Flow Zone Indicator) in μm can be defined by the following:

$$FZI = \frac{RQI}{\emptyset_Z} \quad (3)$$

The logarithm of both sides of the equation Eq. 3 will lead to the final correlation, which is expressed as follows:

$$\log RQI = \log \emptyset_Z + \log FZI \quad (4)$$

Al-Ajmi and Holditch [16] stated that all samples with similar FZI values lie on a line with a slope of one in a Log-Log plot of RQI versus $Ø_Z$, while samples with equal FZI values but noticeably different from the earlier sample will lie on parallel lines with the same slope, as did Perez [17]. Samples parallel to one another have similar pore throat characteristics and make up a distinct HFU. Each line refers to a single HFU, and the intercept of each line, $Ø_Z$, indicates the mean FZI for each HFU. Each flow unit has a specific FZI [9].

3- Generating a Correlation between Core Porosity and Core Permeability

Depending on core measurements of porosity and permeability and a linear regression correlation between the log of core permeability and porosity, this classical equation has been established and explained in Eq. 5.

$$\log K = 16.129\emptyset - 1.984 \quad (5)$$

Only 29 plugs from five wells were gathered from the Jeribe reservoir because so few core samples were taken from this reservoir. Fig. 1 shows the Jeribe formation's core permeability and porosity's linear regression connection. The porosity-permeability relationship equation for the examined reservoir was created using the estimated relationship between porosity and permeability for the Jeribe reservoir, which had a Coefficient of Determination (R^2 = 0.519).

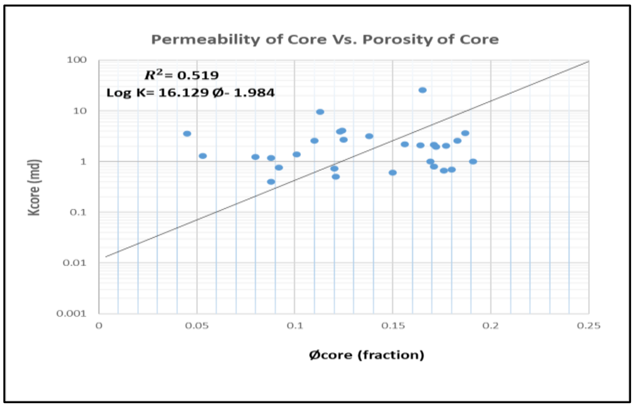

Fig. 1. Permeability of Core Vs. the Porosity of the Core for Jeribe Formation/ Jambour Oil Field

4- Determination of Hydraulic Flow Unit Numbers Appling FZI Technique

To generate a relation between porosity and permeability utilizing the FZI methodology from core data, one must first extend these correlations to uncored interval wells applying to well logging data [18]. Regression analysis is an important part of which these relationships are created [19]. After data screening with the use of (24 core plugs), this study generated the flow zone indicator (FZI) from core data and demonstrated the reservoir's flow unit magnitudes and distribution [9].

Eqs. 1, 2, and 3 are applied to porosity and permeability data collected from the core analysis where FZI will be obtained. Then they will be grouped according to the FZI, which resulted in three hydraulic flow units, as shown in Fig. 2.

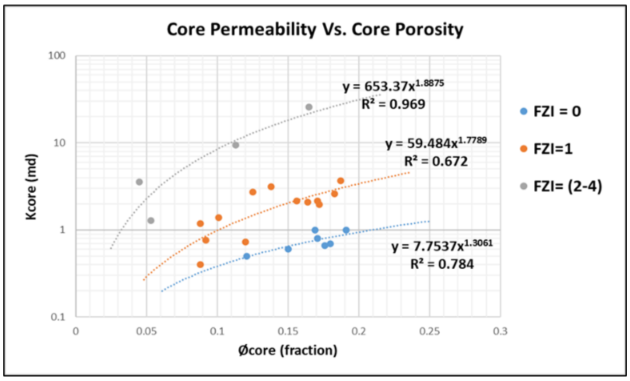

Fig. 2. Cross Plot of Core Perm-Porosity with FZI Values in Jeribe Reservoir / Jambour Oil Field

A simplified analysis of the core permeability-porosity data shows the permeability-porosity relationship for every grouping depending on different FZI values in Fig. 2. Given that there are three hydraulic units in the Jeribe reservoir, it's been shown that the application of generated permeability correlations in uncored wells depends on FZI values derived from the core subjected to statistical analysis. Table 1 summarizes the permeability formulas that were created.

Table 1. Permeability Formulas from FZI Values

FZI	Equation	R^2	Mean FZI
FZI=0	$K = 7.7537\ \emptyset^{1.3061}$	0.784	0.342
FZI=1	$K = 59.484\ \emptyset^{1.7789}$	0.672	0.75
FZI=2-4	$K = 653.37\ \emptyset^{1.8875}$	0.969	3.23

5- RQI Versus Øz Log-log Plot

Parallel lines can be seen in a plot of RQI vs z created using Eqs. 1, 2, and 3. Different core sample FZI values may show up on different lines [20]. As represented in Fig. 3 got the same pore throat description and, as a result, the same flow unit for points placed on each line. The mean FZI for each group will be obtained from (24 core plugs) The log permeability will be estimated using the following formula [9]:

$$K = 1014(FZI_{mean})^2 \frac{\emptyset_{e\,(log)}^3}{(1-\emptyset_{e\,(log)})^2} \tag{6}$$

The Jeribe reservoir was separated into three hydraulic flow units, according to the application of the FZI technique on the core samples, as shown by the three parallel lines in the generated RQI vs. $Ø_z$ plot in Fig. 3. Core samples with various FZI levels display entirely different lines. With the R^2 values given in Table 2, points that lie on each line had the same pore throat description and hence the same flow.

FZI predicted permeability values would be applied to well (W-33) to determine the applicability of FZI by comparing FZI permeability to core permeability, as explained in Fig. 4.

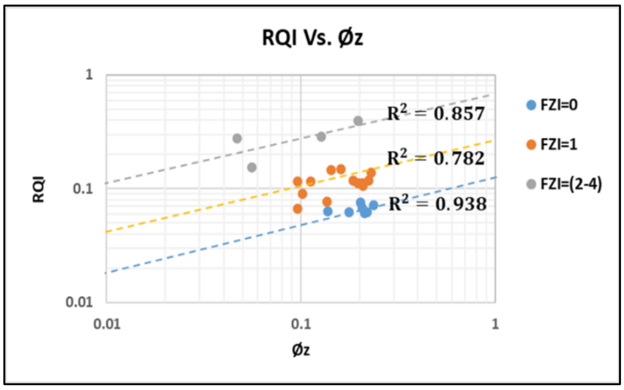

Fig. 3. Reservoir Quality Index Vs. Normalized Porosity Cross Plot for Jeribe Reservoir

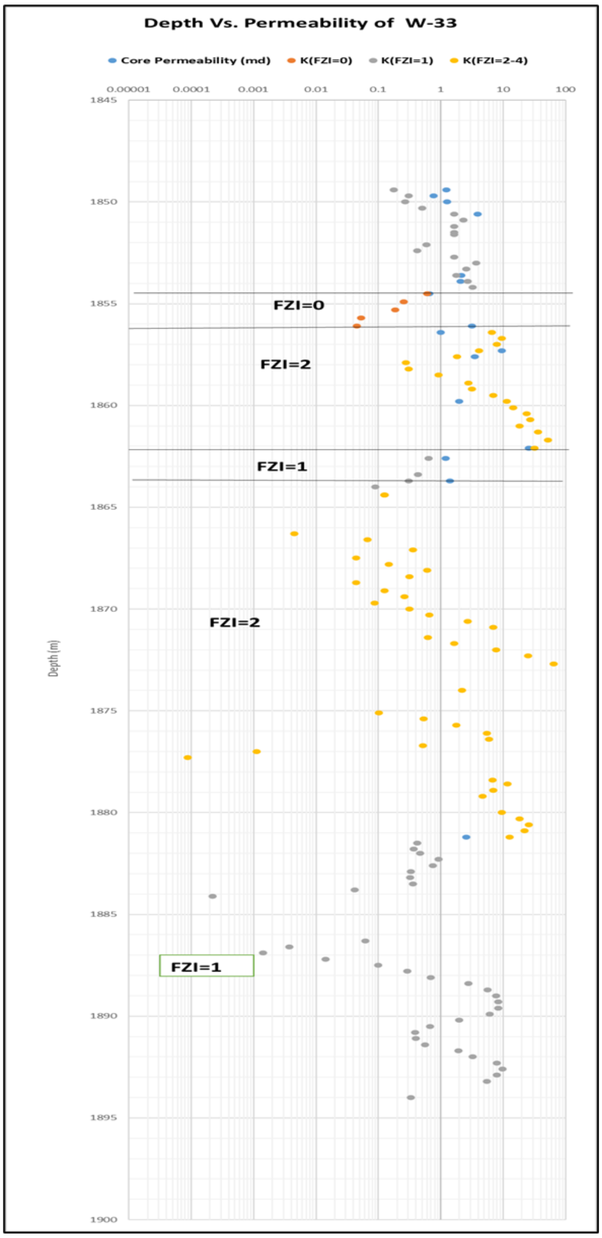

Fig. 4. Comparison between Core Permeability and Predicted Permeability by FZI

Table 2. Values of Correlation Coefficients Got from Reservoir Quality Index Vs. Normalized Porosity Relationship for each Hydraulic Flow Unit

FZI	R^2
FZI=0	0.938
FZI=1	0.782
FZI= (2-4)	0.857

6- Conclusions

The correlation coefficient (0.519) is a result of the classical method in permeability estimation which shows weak linear regression between core porosity and core permeability and deals with this reservoir as one unit; as a result, this method is not applied to predict permeability. Several hydraulic flow units are generated according to the application of the Flow Zone Indicator approach in spite of the available number of core samples was not enough to be of high certainty and accuracy degree because of the faults that intersect this reservoir and appear among the wells that are cored, but it shows a good result with correlation coefficients of (0.969, 0.672, 0.784). Jeribe reservoir is regarded as a reservoir with moderate-quality rock types in both the top and bottom units and a good-quality rock type in the middle unit. The small contrast of core permeability and predicted permeability by FZI demonstrates that the permeability equations obtained from FZI are suitable for use on uncored wells.

Nomenclature

Symbol	Description	Unit
FZI	Flow Zone Indicator	µm
FZI_{mean}	Mean Flow Zone Indicator	µm
HFU	Hydraulic Flow Unit	---
HFUs	Hydraulic Flow Units	---
RQI	Reservoir Quality Index	µm
$Ø_z$	Normalized Porosity	fraction
K	Permeability	md
Øe	Effective porosity	fraction
K_{core}	Core Permeability	md
$Ø_{core}$	Core Porosity	fraction
$Ø_{e(log)}$	Effective porosity measured by log	fraction

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تخمين وحدات التدفق لمكمن الجريبي في حقل جمبور النفطي بتطبيق طريقة مؤشر وحدات الجريان

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الخلاصة

يعد مكمن الجريبي من المكامن الكاربونية المعقدة والغير المتجانسة الذي يُظهر إختلافات وتغيرات عالية في النفاذية، واللباب الصخرية المتوفرة عليه محدودة وقليلة جداً مأخوذة من عدد ضئيل من الآبار مقارنة بالعدد الكلي للآبار الموجودة في حقل جمبور وبالتالي من أجل التنبؤ بالنفاذية لهذا التكوين تظهر الحاجة الى بناء علاقات الرياضية بالاعتماد على الآبار الماخوذة لها لباب صخرية، وتعميمها على الحقل من خلال تطبيقها على بقية الآبار. إحدى الطرق التي أظهرت إستخداماً واسعاً في الآونة الأخيرة هي طريقة مؤشر وحدات الجريان والتي من خلالها بالإمكان تقسيم المكمن المعني إلى عدد من وحدات التدفق في الإتجاه العمودي. هذه الدراسة تهدف الى بناء موديل للنفاذية مكمن الجريبي بالإعتماد على طريقة مؤشر وحدات الجريان.

من خلال رسم مخطط لكل من النفاذية والمسامية المقاسة مختبرياً عن طريق تحليل اللباب الصخرية ومخطط مؤشر جودة المكمن مع المسامية المحسّنة تم التوصل إلى إنه بالإمكان تقسيم مكمن الجريبي إلى ثلاث وحدات للتدفق وبالتالي فإنه يتكون من ثلاث أنواع مختلفة من الصخور(صخور ذات نوعية جيدة، متوسطة الجودة، رديئة الجودة). الصخور الرديئة الجودة تُمثل جزءاً محدوداً وقليلاً جداً مقارنة بالتكوين الكلي بينما الصخور المتوسطة الجودة تظهر بشكل واضح في كل من الجزء العلوي و السفلي من تكوين الجريبي أما الجزء الاوسط من المكمن تظهر فيه النوع الجيد من الصخور.

الكلمات الدالة: جريبي، مؤشر وحدات الجريان، جمبور، وحدات التدفق، التنبؤ بالنفاذية.