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Permeability Estimation of Yamama Formation in a Southern Iraqi Oil Field, Case Study

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Abstract: Permeability is one of the essential petrophysical properties of rocks, reflecting the rock's ability to pass fluids. It is considered the basis for building any model to predict well deliverability. Yamama formation carbonate rocks are distinguished by sedimentary cycles that separate formation into reservoir units and insulating layers , a very complex porous system caused by secondary porosity due to substitute and dissolution processes. Those factors create permeability variables and vary significantly. Three ways used for permeability calculation, the firstly was the classical method, which only related the permeability to the porosity, resulting in a weak relationship. Secondly, the flow zone indicator (FZI) was divided reservoir into two regions according to the bore throat and find correlation between them. Due to the lack of the core samples obtained in reservoir units, the correlations result were poor also. Thirdly, multilinear regression (MLR) was used to connect the logs and the variables that had the most significant influence on the calculated transmittance. It found the better match from other methods. Conclude that permeability was altering from very low in the insulator areas to medium in the reservoir units, which was characterized by cracks and fissures, which played an essential role in the permeability magintude. The importance of research is obtain permeability of wells in un-cored locations by used core data and well logs, which considered input for any geological and dynamic model.

Keywords:Permability, Yamama, oil, petrophysical properties.

INTRODUCTION

Permeability important factors in reservoir characterization. Core measurements are often used to gather this property. On the other hand, core findings may be limited in certain places, which is a challenging and costly activity. For estimate permeability using porosity or additional logging data, many approaches have been utilized in the oil industry[1] .Carbonate rocks are distinguished by petrophysical complexity and heterogeneity, Because of the variety of pore forms and the disposition environmets of carbonate rocks, which have (micro) fractures with widly range of permeability[2]. The carbonate rock is often expressed by multi-modal pore throat size distributions arising capillary pressure measurements, These dynamics make reliable permeability and saturation predictions

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difficult. And the resultant uncertainties in reservoir models reduce the accuracy of fluid storage and flow predictions [3].

The complete absence of general models acquired to permeability estimation due to, first the loss of core and breaking of many plugs are the primary reasons. Second, the reservoir is a carbonate rock, which is characterized by heterogeneity. Third, permeability is not only function of porosity; many other factors, such as void size and diameter, clay volume, facies and depositional environment are affect [4]. A methodologies were provided in many articles for identifying the link between Well logging and core permeability data. Data preparation and filter carried out using various datasets to detect outliers and assure the efficiency of permeability prediction. A heterogeneous reservoir approach was used to evaluate data behavior properly, and pretreatment results were compared to additional geological and geophysical data [5]. The calculation executed by Schlumberger Techlog(15.3) soft ware.

MATERIALS AND METHODS

Permeability Estimation Methods

Challenge to find a general relationship detrimine permeability in all reservoirs. However three methods discuss below for permeability estimate: FZI, MLR and Classical method.

Flow Zone Indicator (FZI)

The Flow Zone Indicater is a numerical tool for identifying and describing naturaily present areas in a reservoir that uses a multiple regression method to build a link for permeability estimates in cored and un-cored intervals of wells. Reservoir Qua1ity Index (RQI), an estimate of the average hydrau1ic radius in the reservoir rock, is the most critical parameter in this classification methodology [6].

Identifying geophysical features for the rocks, such as pore geometry and mineralogy, is linked to the determination of hydraulic flow units. These features influence fluid flow in the reservoir based on the connection between the pores across their throats and porosity. The mean hydraulics unit radius investigated the relationship between hydraulic flow unit(HFU) and porosity, permeability, and capillary pressure. By combining Darcy's and Poiseuille's laws for flow in tubes, the mean hydraulic unit radius concept was included in the Kozeny-Carman equation to replicate porous media through a bundle of capillary tube[7,8].

$$\mathrm{RQI} = 0.0314\sqrt{\frac{k}{\phi_Z}} \quad (1)$$

$$\phi_Z = \frac{\phi_{eff}}{1-\phi_{eff}} \quad (2)$$

$$\mathrm{RQI} = \mathrm{FZI} * \phi_Z \quad (3)$$

Take logarithm for both sides of the equation

$$\mathrm{Log(RQI.)} = \log(\phi_Z) + \mathrm{Log(FZI.)} \quad (4)$$

RQI: is the Reservoir quality index,

ϕZ: is a normalized porosity (pore volume to grain volume ratio) (fraction)

FZI: is a function of reservoir quality index and viod ratio and,

ϕeff: fraction of effective porosity.

The Flow Zone Index system, Based on permeability and porosity results, classify rocks into various categories and then produce log-transforms for permeability prediction; it's also limited by core data that should be covered almost interval.

Multi linear regression method (mlr)

Simple linear regression is a statistical function that allows an analyst or statistician to make expectations regarding one variable dependent on the knowledge of another variable. Linear regression is only applicable where two continuous variables are present, an independent and a dependent variable. The independent variable is the input function for calculating the dependent variable or result. But when more than one independent veriable effect numerous explanatory variables are used in a multiple regression model [1]. Multilinear regression(MLR) is a mathematical technique that combines several explanatory factors to predict an answer variable. The goal of MLR is to simulate the linear interaction between the independent explanatory factors and the response (dependent) variable.

In permeability prediction, multi-regression processing is widely used. For standardized and homogeneous formation, the traditional linear porosity-permeability trend can function well. This system, however, may not be suitable for highly heterogeneous reservoirs[9]. Due to the significant heterogeneity of the characteristics and many natural fractures, fissures, and vug[10]. We could not obtain a clear relationship between porosity and permeability by simple regression[11].

Classical Method

Permeability may be calculated directly from porosity measurements. Core analysis yields permeability-porosity correlations, which are then translated into well-log data. The standard permeability-porosity relationships are commonly represented as the equation(5) [9].

$$\log(K) = b + a\phi \quad (5)$$

k: permeability (md) ,ϕ: Porosity (fraction) and
a and b: the slope and intercept respective1y.

Calculation Methods

FZI

The core samp1es were divided into two groups, each representing a different pore throat diameter. It was discovered that the matching ratios are low; the first group has low permeability and porosity trend, the second group has good permeability and porosity trend. That means there are two rock types within this interval, See figure(1) represents the porosity-permeability relation.

A log-log plot of RQ1 vs ϕZ produces a straight 1ine with a unit s1ope, according to the equation(4). Knowing the intercept at the point ϕZ = 1 can be used to calculate the mean FZI for a group of similar samples. The wide variety in pore throat diameters within each rock type implies considerable differences in particle size and sorting, See figure (2)

Table (1) contains the formula and the correlation coefficient(R^2) for each hydraulic unit; this table indicates a good correlation, as seen by the high correlation coefficient values (R^2).

TABLE 1. Summarise correlation coefficient r and formula.

FZI	Formula	Correlation coefficient ($\mathbf{R^2}$)
FZI = 0	$K = 1471.5\phi^{4.1085}$	R^2 = 0.6243
FZI = 1	$K = 19414\phi^{4.0335}$	R^2 = 0.8083

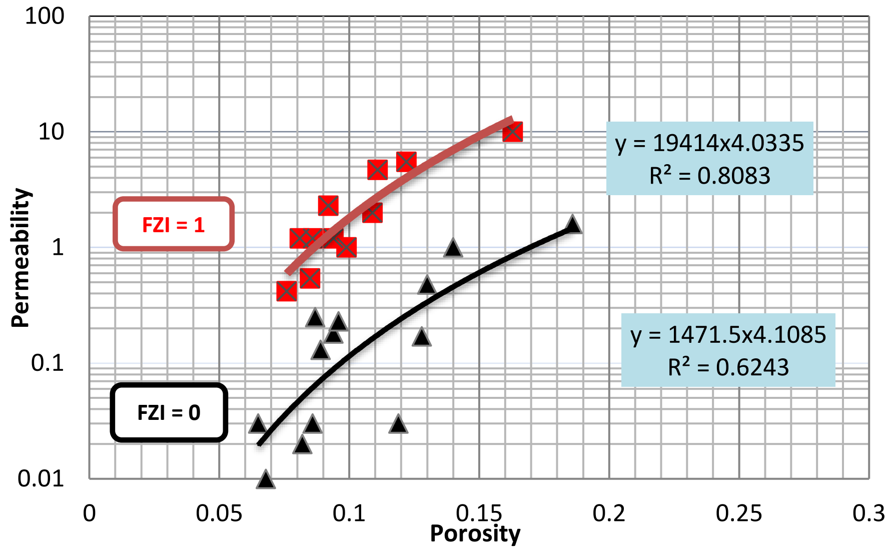

FIGURE 1. Permeability vs porosity for Yamama Formation.

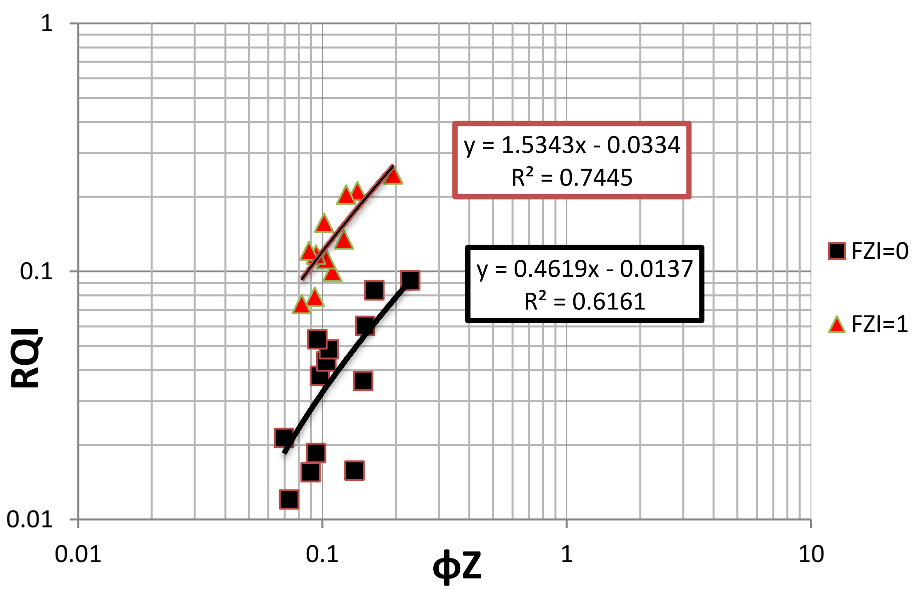

FIGURE 2. RQI vs ϕz for Yamama formation.

Multi Linear Regression

In this method, the data was evaluated to find which of them had the most impact on the results, and three inputs were selected (effective porosity, DT, and SP) for the following reasons:

1- As the variables were tested, it was discovered that they had a significant effect on the outcome.

2- The effective porosity of a porous medium is proportional to the size of the interconnected pores, indicating the fluid's direction during the passage across the porous medium.

3- DT is a proxy for the volume of secondary porosity, which is essential in carbonate rocks.
4- SP denotes the permeable region from the impermeable zone, and it was determined that it has a significant impact on the outcome. In contrast, the other log or variables have a negligible or tiny effect on permeability. See Figure (3) Sketch Of Multi-Linear Regression Parameters

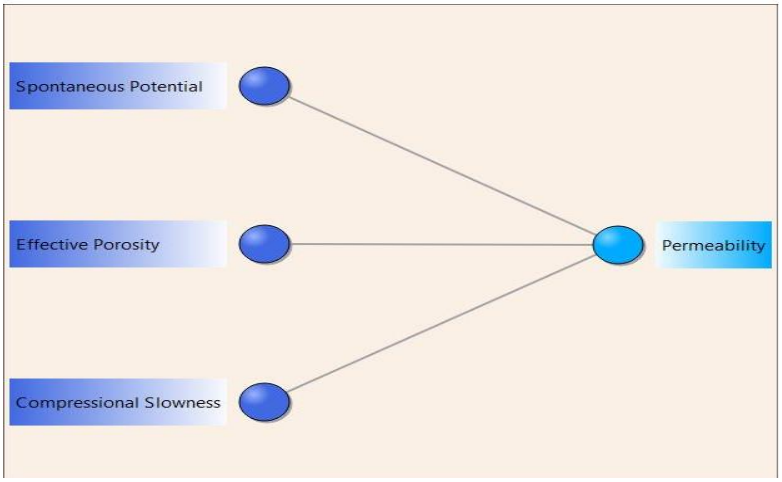

FIGURE 3. Sketch Of Multi-Linear Regression Parameters.

Classical Method

Thus, estimated permeability values are not strongly correlated with measured core permeability. Nevertheless, this is a fundamental method that generates permeability directly by porosity and neglected all other factors affecting permeability.

Comparison among permeability estimated methods

The result of the three methods above for permeability estimate is illustrated in figure(4). The multilinear regression method gives the best match with core permeability.

However, the obtained permeability provides only visual information and is not exact because it is based on a few core samples, all points from only one reservoir unit. Verify The results using some points of core samples collected from another well in the same units found the same trend of data result. Compare the result with The production test, and the permeability was approximately 30-26 md for some interval, Table (2) contains some well test data by used drill stem test(DST). The result showed greater than the obtained by regression, See figure(5). Although the permeability found from the Well test is the most accurate and reflects a longer interval, it is possible that the high productivity due to a fracture at a certain depth, not because of a high permeability on all units.

TABLE 2. Comparison between permeability of DST and MLR

Depth	Flow rate	K (DST)	K(MLR)
3903-3900 m	2000b/d	13 md	Average ~~ 10 md unit A
3947-3954 m	4600 b/d	26 md	Average ~~ 30 md unitB
4054-4061 m	3350 b/d	30 md	Averge ~~ 15 md unit E

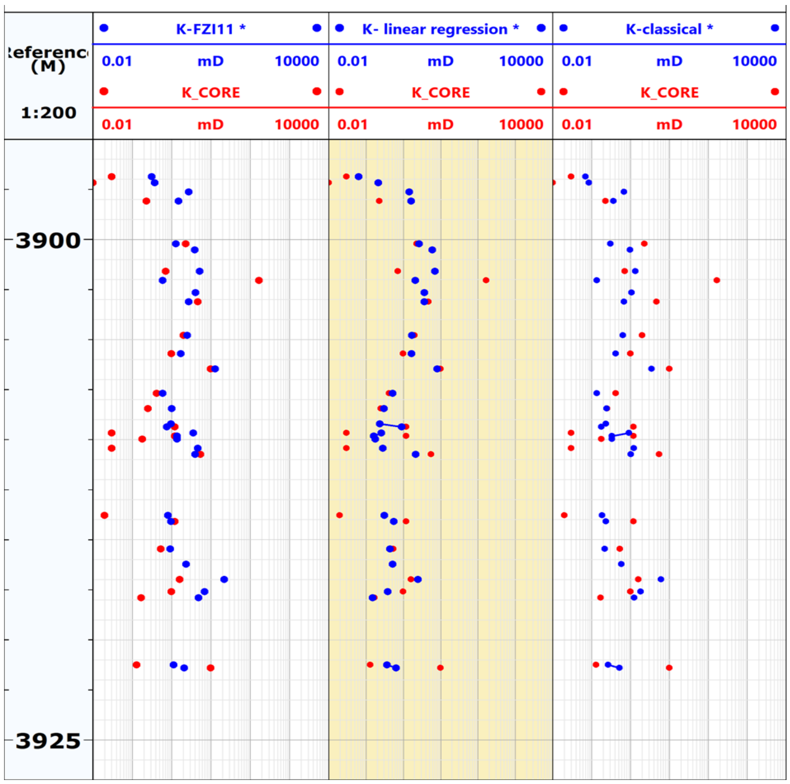

FIGURE 4. Permeability Prediction Methods (FZI, Linear regression and Classical).

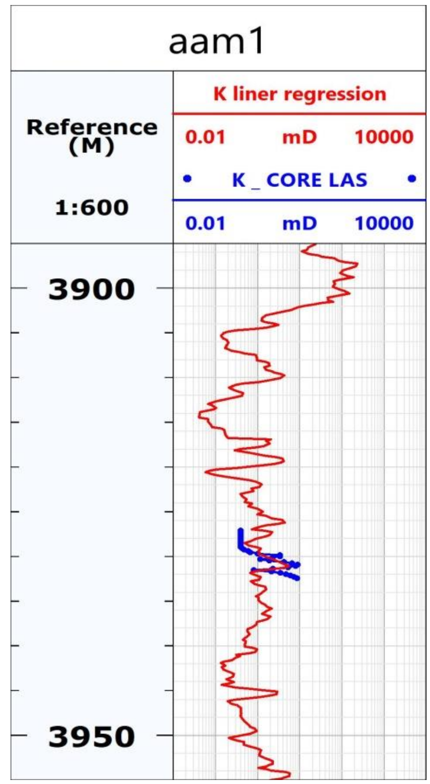

FIGURE 5. Compare the result of MLR with core data in well 1

RESULTS AND DISCUSSION

Three methods calculated the permeability, multilinear regression was selected for permeability calculation in the reservoir because it is the most consistent with the results of the core. Due to the formation's highly heterogeneous nature, the predicted permeability varies significantly, with some estimates being found to be near to 0 and others exceeding 128 md. After evaluating all of the sensors and attributes, the multilinear regression approach was used in the calculations, and (DT, SP, PHIE) was picked as the most influential on the results.

CONCLUSIONS

In conclusion, the findings of this study show that using a machine-learning algorithm to overcome the challenges of reservoir characterization and a lack of data. Permeability calculated by MLR can be used in build reservoir model and also in select perforation zone.

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