International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

Multiple Linear Regression Approach for the Permeability Calculation from Well Logs: A Case Study in Nahr Umr Formation - Subba Oil Field, Iraq

Ahmed Khalil Jaber[1], Muhannad Talib Shuker[2]

[1]Chief Assistant Reservoir Engineer in Southern Department Studies, Ministry of Oil, Iraq

[2]Ph.D, Associate Professor, at Universiti Teknologi PETRONAS

Abstract: ***The Subba oil field is a giant oil field located in south of Iraq about 110 km northwest Basra. Nahr Umr reservoir in Subba oil field is a heterogeneous clastic reservoir. The calculation of the permeability was based on rock types delineation from well logs data. The methods that have been used for the rock types classification are; the rock-quality-index (RQI), flow-zone-indicator (FZI), and Discrete-rock-typing (DRT). It has been recognized that excellent permeability-porosity relationships were obtained after conventional core data are grouped according to their rock types. Conventional core data analysis were first used to define the rock types for the cored intervals, the data analysis from 7 plugs taken from 7 wells in Subba oil field were used for this purpose. The wireline log measurements at the cored depths were extracted, normalized, and subsequently analyzed together with the calculated rock types. The resulted mathematical model can be used to predict the rock type in cored intervals and in uncored wells through (DRT) prediction. This allows the generation of a synthetic rock type log for all wells. The permeability model is constructed as a function of a number of wire line measurement–logs data (sonic, gamma ray, neutron porosity, deep indication, spontaneous potential, bulk density, porosity, and shale volume). The wells that chosen to apply this procedure that contains core data, and logs-data together. These wells cover a wide range area of the Subba field. The permeability function contains 9-parameters; the values of these parameters are calculated by employing multiple linear regressions for each rock type. High correlation coefficients were obtained for all resulted equations used for calculated permeability compared to the core permeability; the resulted equations enable to calculate permeability in non-cored intervals in all wells for each rock type.***

Keywords: Permeability, Nahr Umr Formation, Subba Oil field, Well log, Core data, multiple linear regressions, Shaly sand reservoir.

1. Introduction

Reservoir characterization is a very important domain of petroleum engineering. An effective management strategy can be applied only after obtaining a detailed of spatial distribution of rock properties. Among these, the most difficult to determine and predict is permeability. Frequently, the permeability is constructed on the basis of liner – least squares of the porosity versus log permeability plot. The best fit line which pass through large number of points for certain number of wells in the field, represent the final permeability equation, which can be adopted in field reservoir calculations, for which cores are not available. A great amount of work was done by several calculations [Archie (1942), Coats and Dumanoir (1974), Tixier (1949), Timur (1968), and Wylie and Rose (1950)] in an attempt to grasp the complexity of permeability function into a model with general applicability. All these studies relate factors calculated from well logs and with permeability such as porosity, water saturation, and formation resistivity factor, etc. These studies give a better understanding of the factors controlling permeability, but they also show that it is an illusion to generate a generic relation between permeability and other variables [Balan and Mohaghegh (1995)]. Many researcher address the rocks identification through hydraulic flow unit to predict permeability [Amaefule et al.(1993)], Fahad and Stephen (2000), Guo et al. (2005), Gunter et al (1997)]. Rock typing is a process of classifying reservoir rocks into distinct, each of which was deposited under similar geological conditions and undergone through similar diagenetic alterations [Gunter et al (1997)]. When properly classified, a given rock type is imprinted by a unique permeability-porosity relationship. As a result when properly applied, rock typing can lead to accurate estimation of formation permeability in uncored intervals and uncored wells subsequently, consistent and realistic simulation of a reservoir dynamic behavior and production performance. (RQI/FZI/DRT) technique used in this study for rock typing using the following equations:

$$RQI = 0.0314\sqrt{\frac{k}{\phi}} \qquad (1)$$

where k is permeability (md), ϕ_e is effective porosity (fraction), and RQI is Rock Quality Index (µm)

$$\phi_z = \left(\frac{\phi_e}{1-\phi_e}\right) \qquad (2)$$

where ϕ_z is normalized porosity index.

$$FZI = \left(\frac{RQI}{\phi_e}\right) \qquad (3)$$

where FZI is Flow Zone Indicator (µm). Core samples of the same rock type will have similar FZI values. Furthermore, on log-log plot of RQI versus ϕ_z , samples which lie on the same straight line constitute a hydraulic unit [Balan and Mohaghegh (1995)]. It was demonstrated that this technique is applicable to both carbonate and clastic reservoirs [Amaefule (1993)]. A continuous rock type variable (FZI) can be converted into a discrete one [Guo et al. (2005)] using the following equation.

$$DRT = Round.(2\ln(FZI) + 10.6)....................(4)$$

Once the FZI values are calculated for all core plugs, the wireline log measurements at the exact cored depths were extracted, normalized, and subsequently analyzed together with the calculated FZI to develop an explicit multivariate regression model for predicting FZI in uncored intervals and in uncored wells. This allows the generation of a synthetic rock type (FZI) log for all wells. In this paper, Conventional core data [Core measurements reports (1976-1980)] for 7 plugs have been taken from 7 wells in Subba oil field, were first used to define the rock types for the cored intervals, as shown in **Fig.1**, these wells were chosen to apply this procedure as it contains core data, and full set of wireline log measurements [Well logs for Nahr Umr reservoir (1973-1980)], since these wells cover wide range area of the Subba oil field as shown in **Fig.1**.

2. The Description of Nahr Umr Formation in the Subba Oil Field

The Subba oil field is located in the south of Iraq, (110 km) to the northwest Basra and (12 km) northwest of Luhais field [Geological study (1979)]. The dimensions of Subba oil field are about (30 km) long and (7 km) wide. Nahr Umr formation is considered as one of the main productive reservoirs in southern Iraqi fields that comprises an important place into the stratigraphic column of the Lower Cretaceous Albian Nahr Umr as shown in **Fig.2**. Nahr Umr formation has a double dome separated with shallow saddle, the larger one located in the south of the field and smaller one in the north field [Geological study (1979), Geological study (2001)] Strarigraphically Nahr Umr formation was divided into 4-layers, (A, B, C, and D) [Geological study (2001)] as shown in **Fig.3**, these layers consist mainly of sandstone, shale, and low ratio of siltstone [Geological study (1979), Geological study (2001)]. The siltstone in this reservoir consider non reservoir. There are two types of sandstone, Fluvial sand and Tidal sand. The formation has a heterogeneous permeability profile, including very high permeability sandstone facies and very low permeability for shale facies.

3. Rock Typing Delineations

The number of rock types or hydraulic flow units is identified for Nahr Umr formation depending on performing core analyses for 7 core plugs taken from 7 wells spread along wide area of the field. The results of these core measurements are shown in **Fig.4** were subsequently analyzed using RQI/FZI/DRT technique. The number of rock type were identified using graphical method of probability plot of the FZI based on cluster analysis [Fahad and Stephen (2000)] and the range of FZI for each rock type was identified by colored lines, since four rock types were identified for Nahr Umr formation as shown in **Fig.5.** The results of analyses are shown in **Fig.6.** The relation between permeability and porosity for each rock type was represented using power low model, high correlation coefficients were obtained for all rock types, then permeability can be accurately estimated from porosity for each rock type.

4. Parameter Estimation Approach

The more accurately prediction of permeability can be done depending on well logs by employing multiple linear regressions procedure. The range of FZI for each rock type was delineated previously from core data as shown in **Fig.5.** There are 7 wells were chosen for calculating FZI values and predict the final permeability model for each rock type, these wells have core data and set of wireline well logs measurements. The calculated FZI values from the core data are used as the anchor points for the rock typing. All logs are normalized using Equation (4) so that all log values will lie between zero and one and become dimensionless [Guo et al. (2005)].

$$N\delta = \frac{\delta - \delta_{min}}{\delta_{max} - \delta_{min}} ....(4)$$

where δ is any log, δ_{min} is the minimum reading of δ log, δ_{max} is the maximum reading of δ log, and $N\delta$ is the normalized δ log.

The values of the normalized logs are extracted at exactly the same depths as the core plugs. This will yield a matrix of the normalized logs and the calculated FZI values at all the core depths. A multivariate regression analysis is then performed to develop an explicit mathematical model for predicting FZI using the normalized logs. Equation (5) shows the final model.

$$FZI = \lambda_0 + \lambda_1 NDT + \lambda_2 NGR + \lambda_3 NRD + \lambda_4 NSP + \lambda_5 NRHO + \lambda_6 NPHI + \lambda_7 NSW + \lambda_8 NVC ....(5)$$

where NDT is normalized sonic, NGR is normalized gamma ray, NRD is normalized deep resistivity log, NSP is normalized spontaneous potential, $NRHO$ is normalized density, $NPHI$ is normalized porosity, NSW is normalized saturation, $NVCL$ is normalized clay volume and λ's are regression coefficients. The PHI, SW, and VCL are calculated from logs interpretation for each well. **Table 1** lists all the coefficient values for each rock type. High correlation coefficients were obtained for all rock types and much reliable equations were obtained to calculate permeability from wireline log measurements. The permeability calculated for each rock type using Equation (6) [Amaefule et al.(1993)].

$$k = 1014 FZI^2 \frac{\phi_e^{\,2}}{\left(1-\phi_e\right)^2} ....(6)$$

Fig.(7-12), show the comparisons between the calculated and core permeability for all rock types, the comparisons show highly correlation coefficients were obtained for all rock types.

5. Conclusions

This study demonstrate that rock typing using the RQI/FZI/DRT approach can be very effective in constructing consistent and reliable permeability which is necessary for geological and reservoir simulation modeling. When properly classified from conventional core measurements, and reasonably predicted in uncored intervals and uncored wells. The permeability results using this technique shows a better match to core permeability. This technique utilized 8 response logs to generate robust permeabilities models for each rock type.

6. Future Scope of Study

The future scope of this study is to find the most relevant parameters in the permeability model affect the calculated permeabilities values. This task can be achieved by utilizing different techniques of experimental designs (DoE).

7. Acknowledgments

My grateful to Iraqi Ministry of Oil for permission to publish this paper.

References

[1] Archie G. E., “The Electrical Resistivity Log as an Aid in Determining Some Reservoir Characteristics,” Trans. AIME, 1942, VOL. 146, No. 1 pp.54-62.

[2] All the Core Measurements Reports for Nahr Umr Formation-Subba Oil Field, Ministry of Oil, Baghdad, Iraq, 1976-1980.

[3] Amaefule J. O., Altunbay M., Tiab D., Kersey D., and Keelan D., “Enhanced Reservoir Description: Using Core and Log Data to identify Hydraulic (Flow) Units and Predict Permeability in Uncored Intervals/Wells,” Paper SPE 26436 presented at the Annual Technical Conference and Exhibition, Houston, Texas, 3-6 October 1993.

[4] Balan B., and Mohaghegh S., “State – of – The Art in Permeability Determination from Well Log Data: Part 1- Comparative Study, Model Development,” SPE 30978, Eastern Regional Conference & Exhibition, Morgantown, West Virginia, (September 1995).

[5] Coats G. R., and Dumanoir, J.L.,”A New Approach to Improved Log-Derived Permeability,” The Log Analyst, pp.17 , (January-February 1974).

[6] Fahad A. Al-Ajmi and Stephen A. Holditch, “Permeability Estimation Using Hydraulic Flow Units in a Central Arabia Reservoir,” Paper SPE 63254 presented at the Annual Technical Conference and Exhibition, Dallas, Texas, 1-4 October 2000.

[7] G. Guo, M. A. Diaz, F. Paz, J. Smalley, and E. A. Waninger, “Rock Typing as an Effective Tool For Permeability and Water-Saturation Modeling: A Case Study in a Clastic Reservoir In the Orienta Basin,” Paper SPE 97033 presented at the Annual Technical Conference and Exhibition, Dallas, Texas, 9-12 October 2005.

[8] Gunter G. W., Finneran J. M., Hartmann D. J., and Miller, J. D., “Early Determination of Reservoir Flow Unit Using an Integrated Petrophysical Method,” Paper SPE 38679 presented at the Annual Technical Conference and Exhibition, San Antonio, Texas, 5-8 October 1997.

[9] Geological and Evaluation Study for Subba Oil Field-Exploration Oil Company-Baghdad, August 1979.

[10] Tixier M.P., "Evaluation of permeability from Electric-Log Resistivity Gradients" Oil & Gas Journal, pp.113, (June1949).

[11] Timur, A, “An Investigation of permeability, Porosity, and Residual Water Saturation Relationship for Sandstone Reservoirs, “), The Log Analyst, pp.8, Vol.9, No.4, (July-August 1968).

[12] Well Logs for Nahr Umr Formation-Subba Oil Field. 1973-1980, South Oil Company, Basra, Iraq.

[13] Geological Study for Subba Oil Field-Ministry of Oil-Reservoir & Field Development Directorate, Baghdad, 2001.

[14] Wyllie M. R. J., and Rose W. D., "Some Theoretical Considerations Related to the Quantitative Evaluation of the physical characteristics of reservoir Rock from Electric Log Data, " Trans. AIME, pp.105, Vol. 189, (1950).

Authors Profile

Ahmed Khalil Jaber Currently he is a PhD candidate at Universiti Teknologi PETRONAS. He got scholarship from PETRONAS company. He holds B.Sc. and M.Sc. in Petroleum Engineering from Baghdad University in 1996 and 1999 respectively. He is working as a Chief Assistant Reservoir Engineer in Southern Department Studies / Ministry of Oil / Iraq. He has more than 13 years experience in Reservoir Simulation, Field Development Plans. He became SPE member in 2005.

Muhannad Talib Shuker Currently working as Associate Professor, at Universiti Teknologi PETRONAS. He holds B.Sc. from Baghdad University, M.Sc., from Colorado School of Mines, USA, and PhD in Petroleum Engineering. from Baghdad University. He has more than 30 years of diversified experience in Petroleum industry. His areas of expertise are EOR, Reservoir Engineering and Reservoir simulation. He is SPE member.

Table 1: Regression Coefficients for FZI Prediction Model for all Rock Types / Nahr Umr Reservoir

Rock Type-1									
Normalized Log Name		NXPHI	NXGR	NXVCL	NXRHO	NXRD	NXDT	NXNPHI	NXSP
Coefficient Name	γ_0	γ_1	γ_2	γ_3	γ_4	γ_5	γ_6	γ_7	γ_8
Coefficient Value	13.868	- 8.749	- 3.328	- 5.263	1.416	3.805	- 4.250	2.018	3.721
Rock Type-2									
Normalized Log Name		NXPHI	NXGR	NXVCL	NXRHO	NXRD	NXDT	NXNPHI	NXSP
Coefficient Name	γ_0	γ_1	γ_2	γ_3	γ_4	γ_5	γ_6	γ_7	γ_8
Coefficient Value	6.149	0.429	- 4.642	4.580	0.257	0.308	- 0.899	2.059	- 0.189
Rock Type-3									
Normalized Log Name		NXPHI	NXGR	NXVCL	NXRHO	NXRD	NXDT	NXNPHI	NXSP
Coefficient Name	γ_0	γ_1	γ_2	γ_3	γ_4	γ_5	γ_6	γ_7	γ_8
Coefficient Value	0.184	2.308	4.060	- 0.899	0.744	1.743	0.304	0.084	- 1.943
Rock Type-4									
Normalized Log Name		NXPHI	NXGR	NXVCL	NXRHO	NXRD	NXDT	NXNPHI	NXSP
Coefficient Value	γ_0	γ_1	γ_2	γ_3	γ_4	γ_5	γ_6	γ_7	γ_8
Coefficient Value	- 1.156	2.038	0.611	3.122	0.052	- 0.452	- 0.578	- 0.383	- 1.084

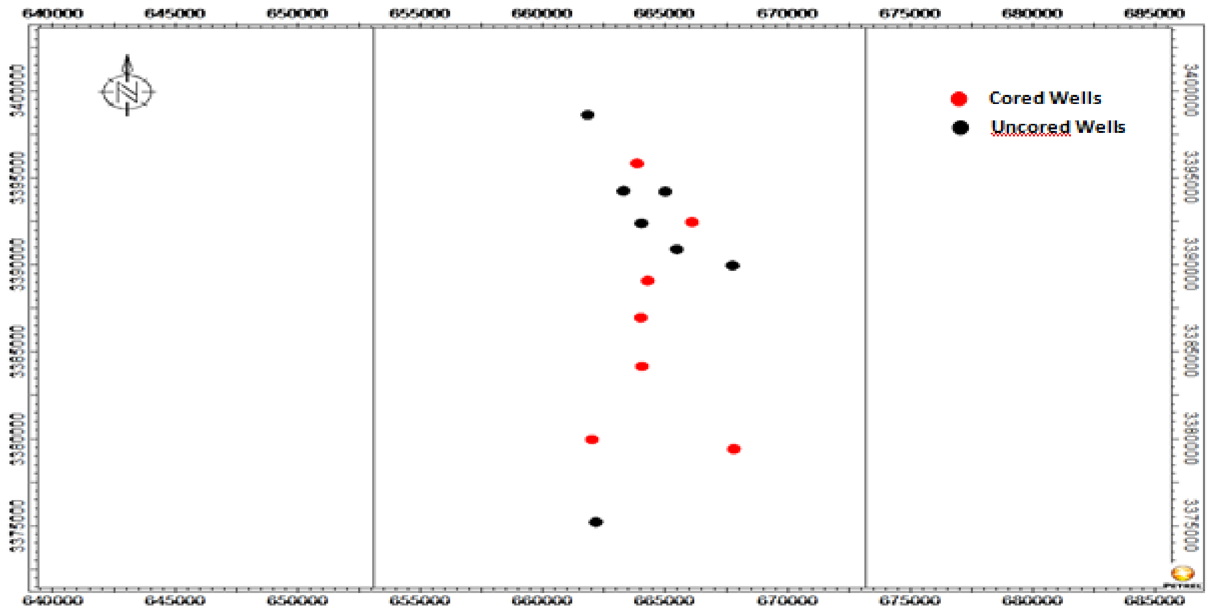

Figure 1: Well locations for Subba oil field

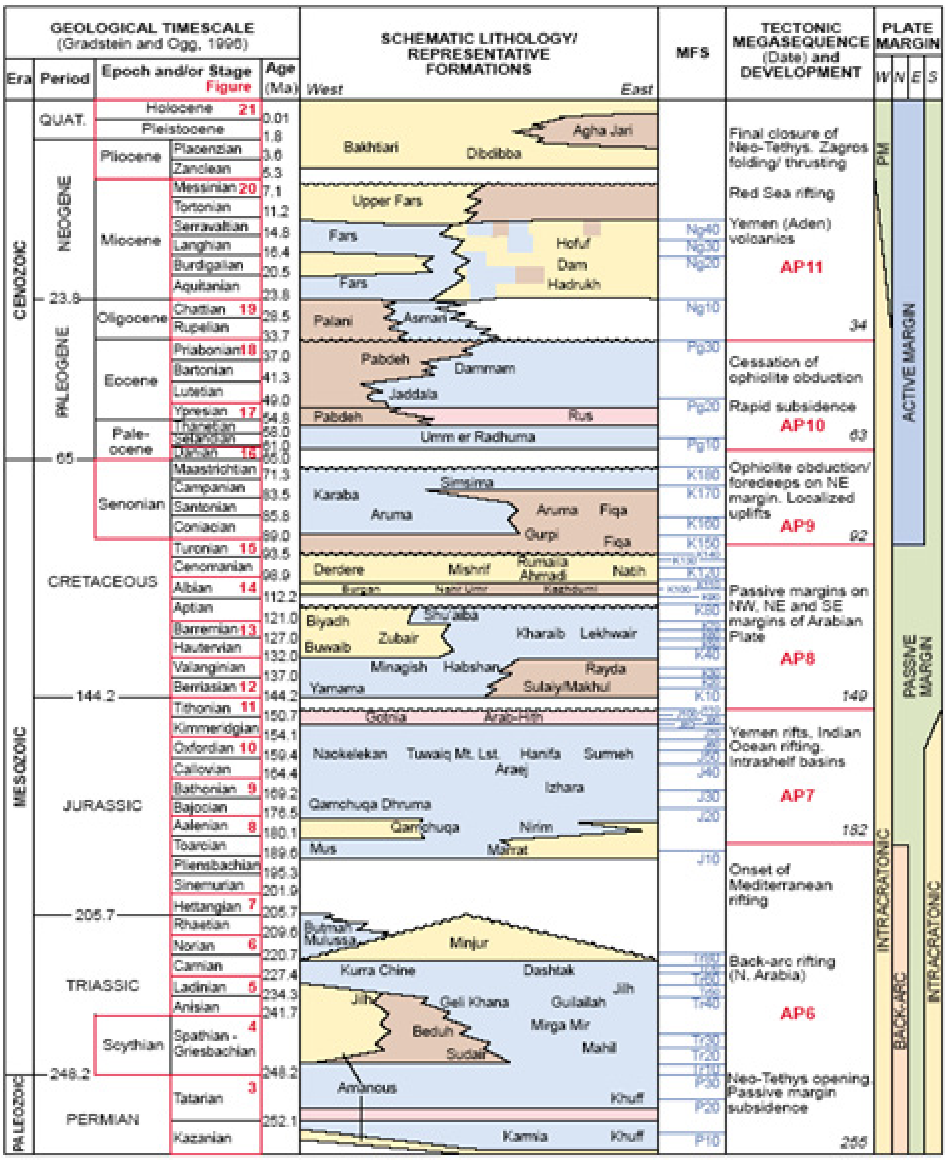

Figure 2: Stratigraphic Column for Iraq (Modified from Ziegler 2001)

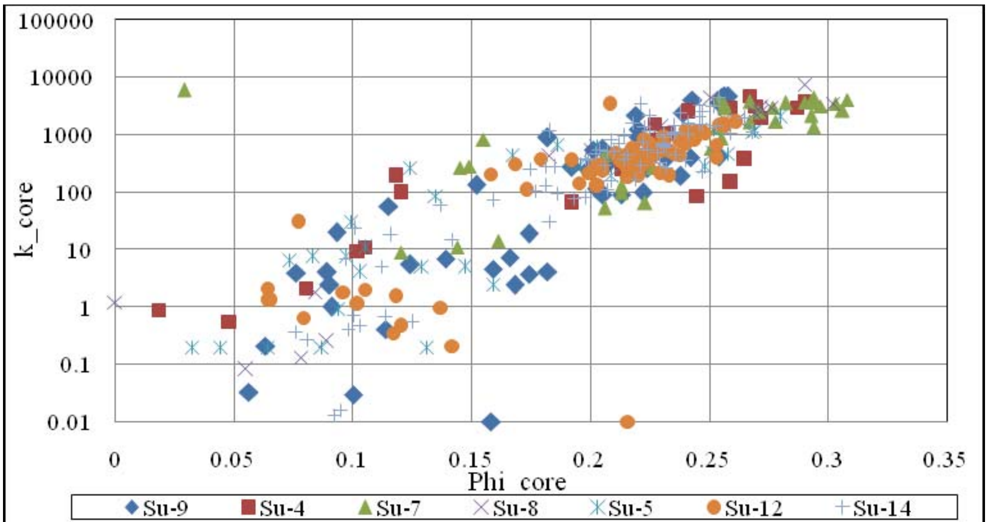

Fig.4-Porosity-Horizontial Permeabililty Relationship

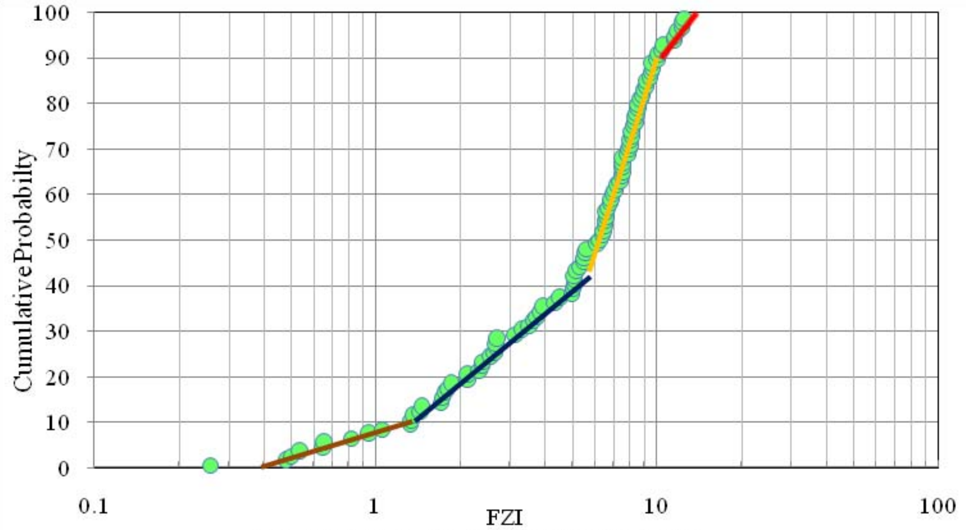

Fig.5-Normal probability plot for FZI

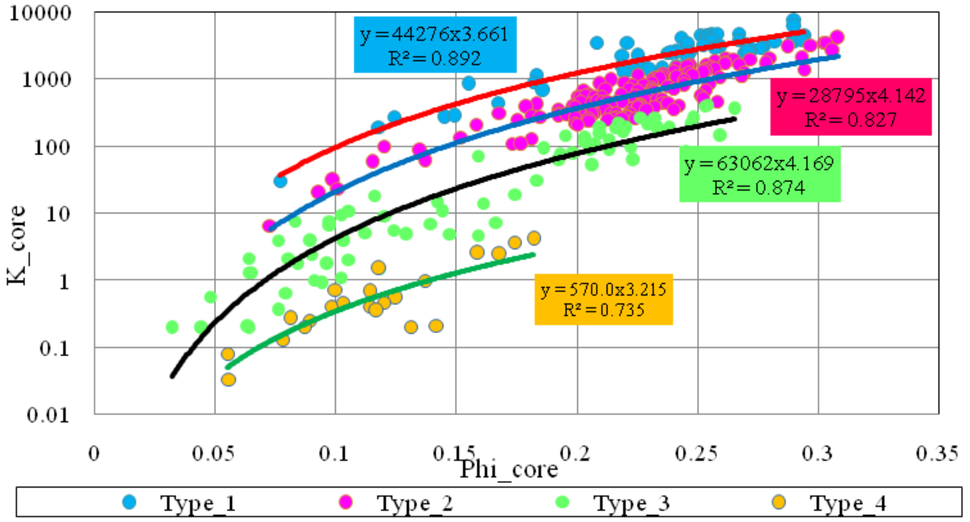

Fig.6-Core permeability vs. Core porosity for different rock types

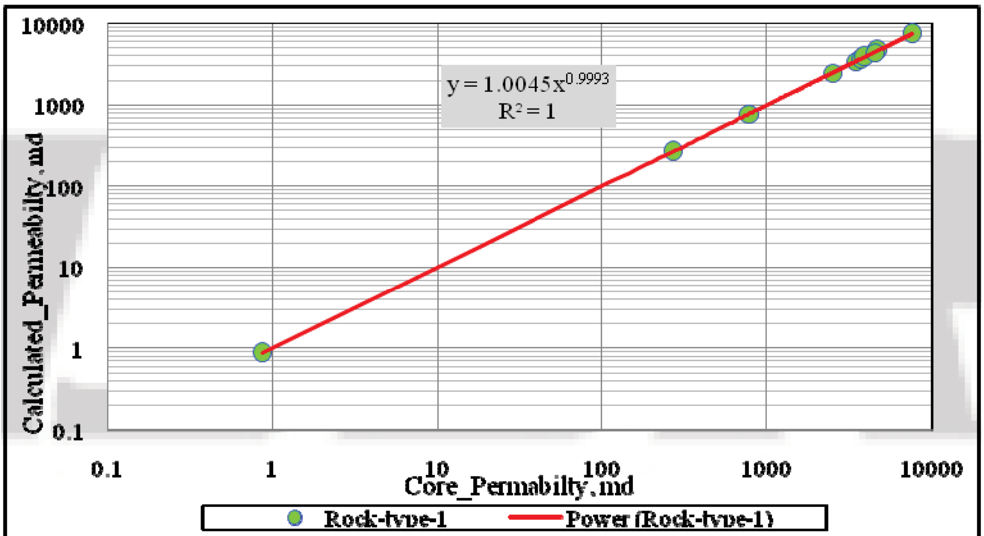

Fig.-7-Porosity-Permeabililty relationship for rock-type-1

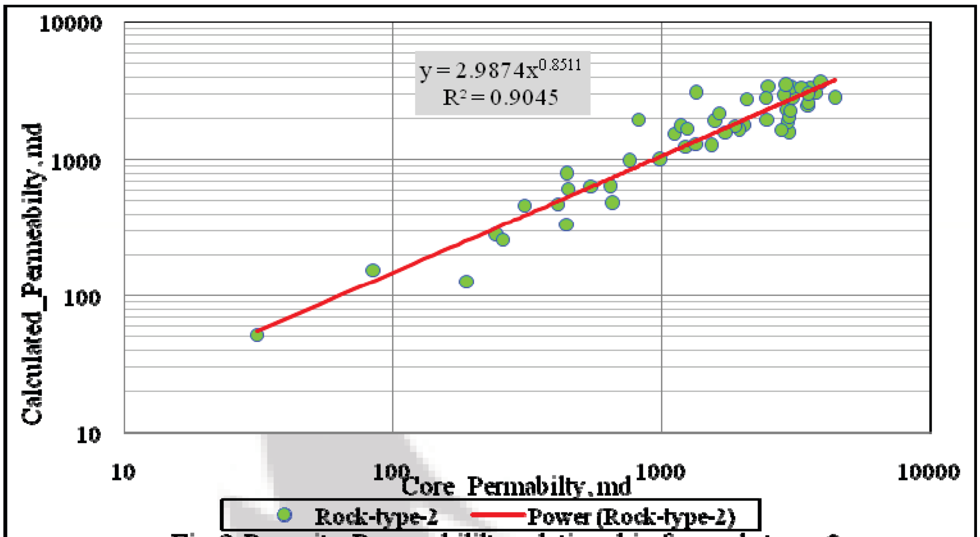

Fig.8-Porosity-Permeability relationship for rock-type-2

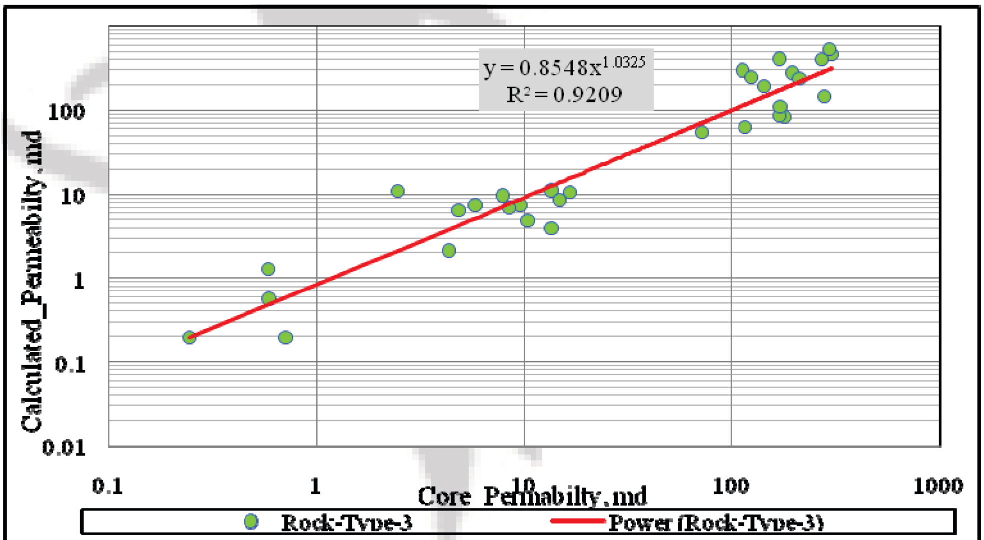

Fig.9-Porosity-Permeability relationship for rock-type-3

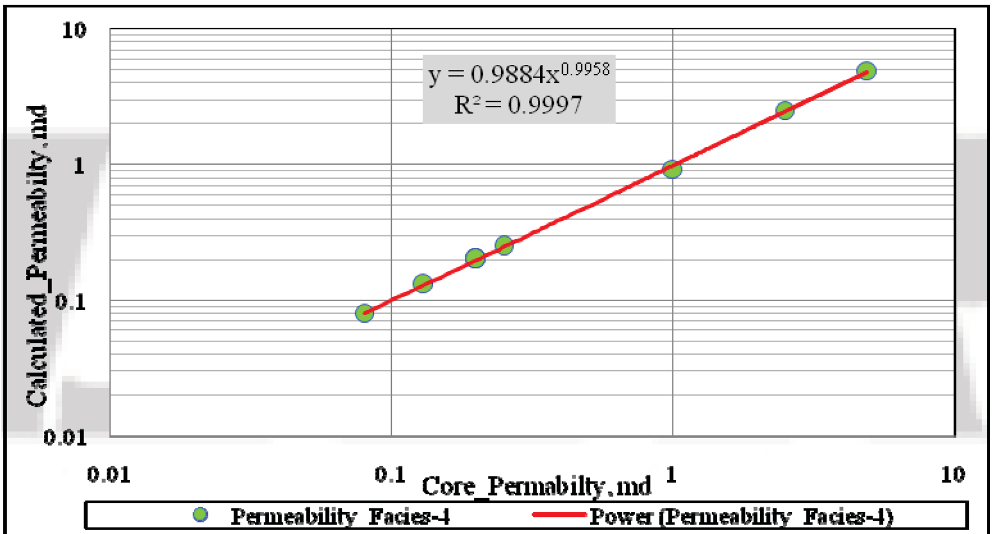

Fig.10-Porosity-Permeability relationship for rock-type-4

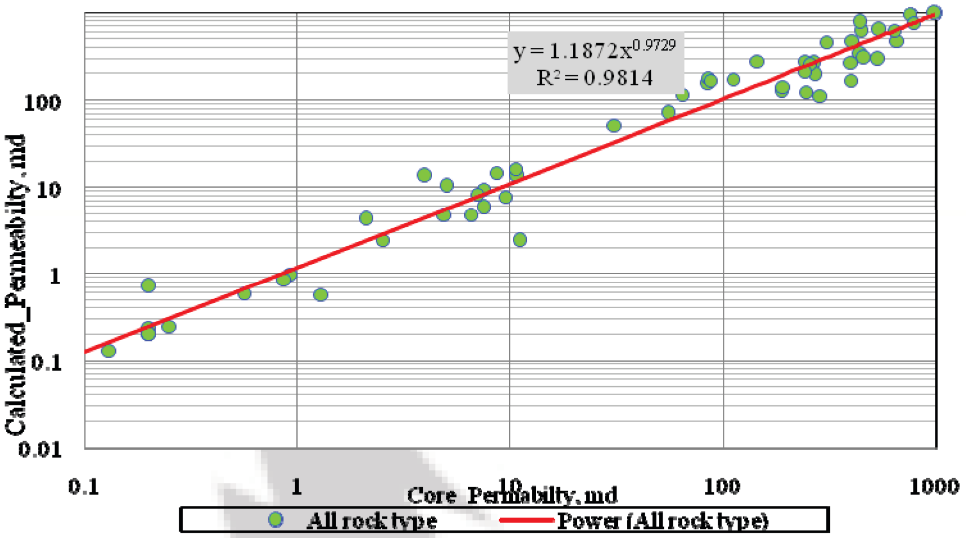

Fig. 11-Porosity-Permeabililty relationship for all rock-types

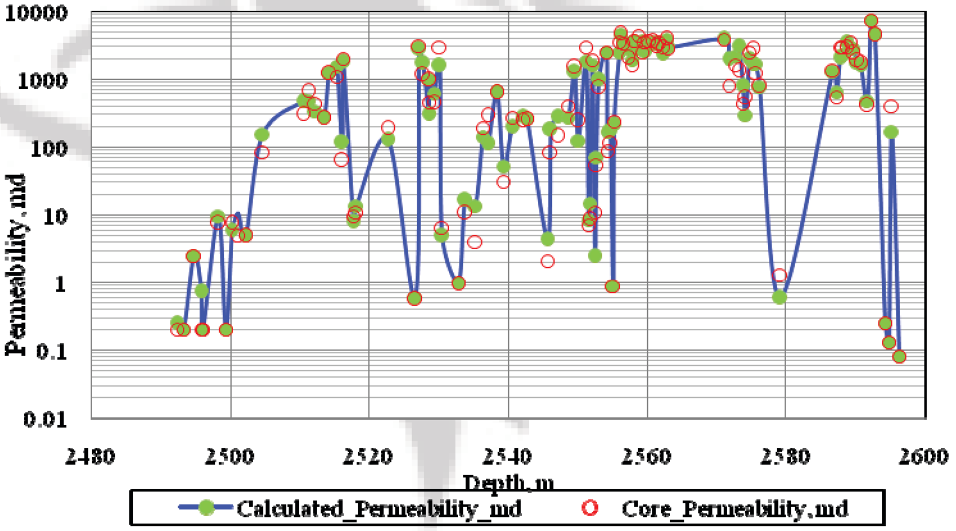

Fig. 12-Porosity-Permeabililty vs. Depth for all rock-types