EVALUATION OF PETROPHYSICAL PROPERTIES FOR RESERVOIR CHARACTERIZATION OF EOCENE AGE IN MEYAL FIELD, POTWAR BASIN – PAKISTAN

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ABSTRACT: *In this paper, the petrophysical properties of Eocene Age rocks of Meyal Field, Potwar Basin in Pakistan were evaluated with a view to understand their effects on the reservoirs and hydrocarbon production. A suite of geophysical wire-line logs comprising of gamma ray, resistivity, spontaneous potential, neutron, sonic and density logs for four wells from Meyal Field were analyzed to estimate properties such as volume of shale, average porosity, permeability, water saturation, hydrocarbon saturation, bulk volume of water, gross thickness, net thickness, net/gross ratio and net pay thickness of reservoirs. Results indicated two reservoirs i.e. Chorgali and Sakesar with the presence of hydrocarbon in both reservoirs. Calculated petrophysical properties of Chorgali reservoir gave average average porosity of 16.51%, permeability 85.94mD; water saturation 41.27%; and hydrocarbon saturation of 58.73%, while Sakesor reservoir gave average average porosity of 10.68%; permeability 38.36mD; water saturation 51.26%; and hydrocarbon saturation of 48.75%. Statistical analysis shows that Chorgali is good reservoir as compared to Sakeser reservoir of Eocene Age in Meyal Field.*

KEYWORDS: Petrophysical Properties, Meyal Field, Wire-Line Logs, Average Porosity, Permeability, Reservoir and Statistical Analysis.

INTRODUCTION

The general purpose of wireline logs analysis is to transform the raw log data into estimated quantities of oil, gas and water in a formation [1]. Geophysical logs help in defining the physical rock characteristics like lithology, porosity, pore geometry, and permeability in addition to their traditional use in Oil & Gas exploration [2].

According to [3], the Table 1 shows the criteria used of porosity and permeability for qualitative description of reservoirs.

This research has been performed in the Department of Geological Engineering, University of Engineering & Technology (UET) Lahore - Pakistan as a part of M.Sc. research work by principal author and partial results are being published here.

Objectives

The main objectives of the petrophysical evaluation for reservoir characterization of Eocene Age in Meyal Field include; lithology identification, volume of shale, average porosity, permeability, saturation of water, saturation of hydrocarbons, bulk volume of water, gross thickness, net thickness, net/gross ratio and net pay intervals of the reservoirs.

Location of the Study Area

Meyal Field is located in Attock district, near Pindi Gheb, in an active foreland and thrust belt in the Northern Potwar Deformed Zone (NPDZ), Potwar Basin of the Upper Indus Basin. It is one of the most important oil and gas producing fields in the Potwar Basin which was discovered by Pakistan Oilfields Limited in 1968 [4]. Location of wells, used in this study, is shown in Figure 1.

Geologic Settings

The Salt Range Potwar Foreland Basin (SRPFB) is bounded by the Salt Range Thrust (SRT), Main Boundary Thrust (MBT), Jehlum Fault (left lateral) and Kalabagh Fault (right lateral) in the south, north, east and west respectively. The sedimentary sequence of the Indian Plate is exposed in SRPFB of Eocambrian to Cenozoic age. Structurally, the SRPFB is divided into the Northern Potwar Deformed Zone (NPDZ) and the Southern Potwar Platform Zone (SPPZ) by the Soan Syncline. It is covered by the molasses sediments of Miocene to Pleistocene age. The Eocambrian to Tertiary sedimentary sequence in SRPFB is exposed along ranges in the south and are deformed during thin-skinned Himalayan tectonics (Figure 2). Because of this reason, the structural trap were formed for hydrocarbons and foreland basin is filled with thick sequence of the source, reservoir and seal rocks [5], [6], [7]. The thickness of overburden of fluvial sediments is about 1,980m to 3,050m which provide burial depth and optimum geothermal gradient favorable for the formation of hydrocarbon in the SRPFB [8].

Table 1: Criteria for qualitative description of reservoirs adapted from [3].

Qualitative Evaluation of Porosity	
Average Porosity (%)	Qualitative Description
0 - 5	Negligible
5 - 10	Poor
10 - 20	Good
20 - 30	Very Good
> 30	Excellent
Qualitative Evaluation of Permeability	
Average K Value (mD)	Qualitative Description
<10	Poor to Fair
10 - 50	Moderate
50 - 250	Good
250 - 1000	Very Good
>1000	Excellent

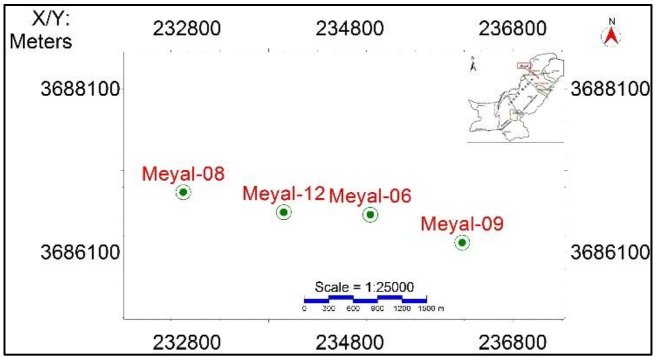

Figure 1: Map, showing the location of wells.

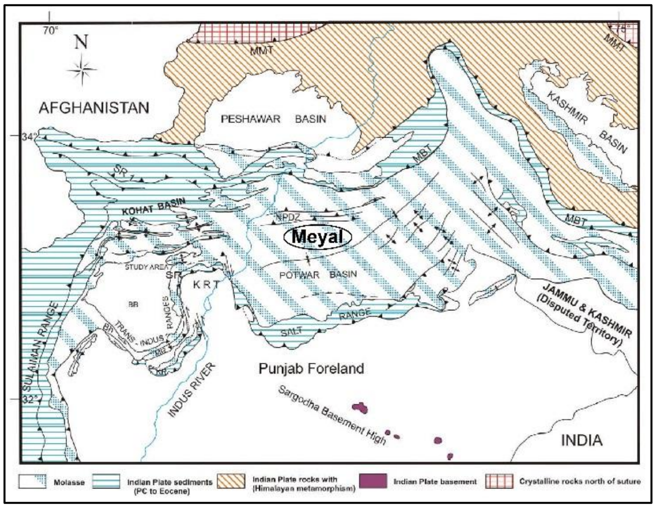

Figure 2: Tectonic map of North Pakistan, showing major tectonic features (Modified after [9]).

MATERIALS AND METHOD

Four wells, shown in Figure 1, have been selected for investigating the Eocene non-clastic reservoir rocks, to evaluate the hydrocarbon potentiality in the study area. Open-hole 1og data was provided by the Directorate General Petroleum Concessions (DGPC), Islamabad-Pakistan; including the Gamma Ray (GR), Spontaneous Potential (SP), Caliper (CALI), Resistivity logs (LLD, LLS and MSFL), Neutron (PHIN), Density (RHOB) and Sonic (DT).

Volume of Shale

According to [2] Gamma Ray Index is the first step to determine the volume of shale from a gamma ray log, shown in equation 1:

$$I_{GR}= (GR_{log}- GR_{min})/(GR_{max}- GR_{min}) \quad (1)$$

where:

I_{GR} = gamma ray index

GR_{log} = gamma ray reading of formation

GR_{min} = minimum gamma ray (clean sand or carbonate)

GR_{max} = maximum gamma ray (shale)

For a first-order estimation of shale volume, the linear response, where $V_{sh} = I_{GR}$, should be used. In nonlinear responses, following equation is used for Tertiary rocks, shown in equation 2:

$$V_{sh}=0.083*(2^{\wedge}(3.7.I_{GR})-1) \quad (2)$$

where:

V_{sh} = volume of shale.

I_{GR} = gamma ray index

Average Porosity

Average porosity is calculated using the sonic porosity and volume of shale, shown in Euation 3.

$$\emptyset_a = (\emptyset_d + \emptyset_n)/2 \quad (3)$$

where:

$\emptyset_a$ = average porosoty.

$\emptyset_d$ = density porosoty.

$\emptyset_n$ = neutron porosoty.

Permeability

Timur Permeability Equation is used to find out the permeability [2], shown in equation 4.

$$K= (93*\emptyset_a{}^{\wedge}2.2/S_{w\ irr})^{\wedge}2 \quad (4)$$

where:

K = permeability.

$\emptyset_a$ = average porosity.

$S_{w\ irr}$ = irreducible water saturation.

Water Saturation

Archie Equation is used to calculate the water saturation as shown in equation 5 [10].

$$S_w={}^n\sqrt{(a.R_w/\emptyset^m.R_t)} \quad (5)$$

where:

S_w = water saturation.

n = saturation exponent.

a = tortousity factor.

R_w = resirivity of formation water.

$\emptyset$ = porosity

m = cementation exponent.

R_t = resistivity of uninvaded zone.

Hydrocarbon Saturation

$$S_h=1- S_w \quad (6)$$

where:

S_w = hydrocarbon saturation.

S_w = water saturation.

Pay Reservoir and Net Pay

A porosity cut-off of 7% was used along with a shale volume cut-off of 40% to define the quality of the reservoir rock. Water saturation (S_w) cut-off value of 50% was used to define pay reservoir. The reservoirs were defined by the porosity greater than 7% and shale volume less than 40%. For the net pay, if the water saturation within the reservoir is less than 50%, it is considered to contain hydrocarbon.

Bulk Volume of Water (BVW)

BVW of the hydrocarbon-bearing zone is calculated using the equation 7 [11].

$$BVW= S_w*\emptyset_a \quad (7)$$

where:

BVW = bulk volume of water.

S_w = water saturation.

$\emptyset_a$ = average porosity.

RESULTS

The above methodology was used for the quantitative interpretation of the reservoirs in each well. Table 2 shows the results of some computed petrophysical parameters for Chorgali and Sakesar reservoirs. While the relationships of some of the calculated petrophysical parameters for both of the reservoirs across each well, with the help of chart, is shown in Figure 3.

Table 2: Some petrophysical parameters for reservoirs across all wells.

Parameters	Reservoirs							
	Meyal-06		Meyal-08		Meyal-09		Meyal-12	
	Chorgali	Sakesar	Chorgali	Sakesar	Chorgali	Sakesar	Chorgali	Sakesar
Depth Interval (m)	3699-3729	3772-3827	3715-3731	3818-3830	3732-3731	3818-3828	3710-3721	3733-3742
Gross (m)	14.88	23.01	14.88	11.00	12.88	10.13	07.13	08.12
Net (m)	06.63	20.88	12.75	09.25	07.75	09.00	07.13	01.25
Net/Gross (%)	44.56	90.74	85.69	84.09	60.17	88.85	100.00	15.39
Net Pay (m)	05.63	17.63	09.63	09.25	06.00	03.75	07.13	01.00
V_{sh} (%)	40.85	15.45	22.52	30.71	35.69	10.43	39.38	19.75
Øa (%)	15.39	16.39	28.08	08.90	10.43	09.99	12.14	07.45
K (mD)	90.36	137.66	249.85	00.63	01.34	07.73	02.21	07.40
BVW (%)	02.40	02.81	07.31	02.11	02.53	04.66	01.06	01.46
S_w (%)	62.45	28.62	47.62	34.56	40.45	58.27	14.57	83.57
S_h (%)	37.55	71.38	52.38	65.44	59.55	41.73	85.43	16.43

Table 3: The average petrophysical parameters of both reservoirs from all four wells of Meyal Oil Field

Reservoir	Well Name	Net/Gross (%)	Øa (%)	K (mD)	S_w (%)	S_h (%)
Chorgali	Meyal-06	44.56	15.39	90.36	62.45	37.55
	Meyal-08	85.69	28.08	249.85	47.62	52.38
	Meyal-09	60.17	10.43	01.34	40.45	59.55
	Meyal-12	100.00	12.14	02.21	14.57	85.43
	Average	72.60	16.51	85.94	41.27	58.73
Sakesar	Meyal-06	90.74	16.39	137.66	28.62	71.38
	Meyal-08	84.09	08.90	00.63	34.56	65.44
	Meyal-09	88.85	09.99	07.73	58.27	41.73
	Meyal-12	15.39	07.45	07.40	83.57	16.43
	Average	69.77	10.68	38.36	51.26	48.75

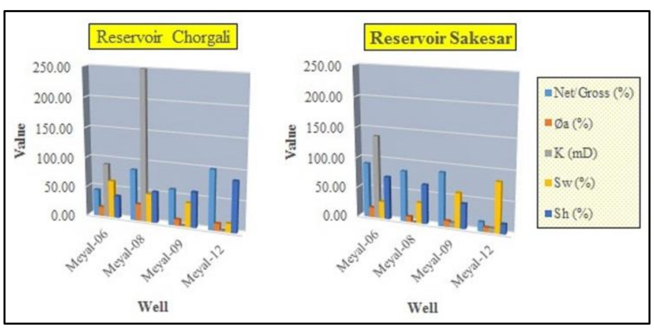

Figure 3: Chart showing relationship between percentage petrophysical parameters of reservoirs

The data used to determine reservoir quality is shown in Table 3. These parameters are subjected to statistical analysis by getting their average values across both the reservoirs in the all four wells (Figure 4).

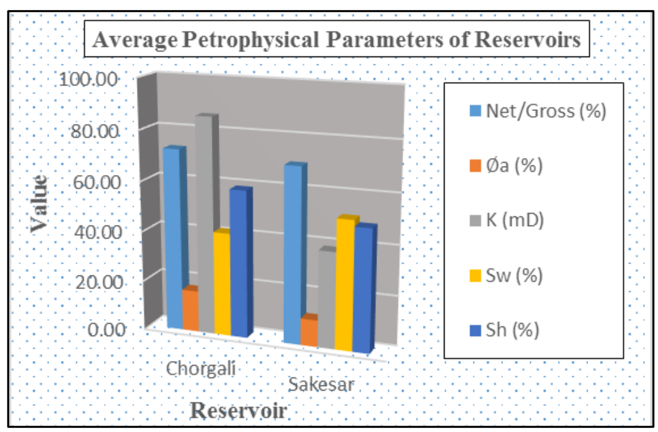

Figure 4: Relationship between average percentages of the parameters of reservoirs.

DISCUSSION

Net/gross ratio range from 47.54% to 100.00% indicate that these formations can act as a good reservoir except in one well, Meyal-12, where net/gross ratio was 15.39% which was confirmed when it was calculated that average porosity and net pay thickness was only 7.45% and 1.00 m respectively. While net pay thickness in other wells varies from 3.75 m to 17.63 m.

The average porosity and permeability range from 7.45% to 28.08% and 1.34mD to 249.85mD respectively. The maximum values of average porosity and permeability were recorded in Meyal-08 from the reservoir Chorgali which are qualitatively very good and good values, according to [3], respectively. Bulk volume of water ranges from 1.06% to 7.31 %. The hydrocarbon bearing reservoirs have hydrocarbon saturation (S_h) ranging from 37.55% to 85.43%, except one well (Meyal-12), indicate that the proportion of void spaces occupied by water is low consequently high hydrocarbon saturation and high hydrocarbon production,

From figure 4, it can be determined that Chorgali is good reservoir as compared to Sakessar because it have more average porosity, permeability, hydrocarbon saturation and net/gross ratio while lesser water saturation.

CONCLUSION

Petrophysical properties evaluation of Meyal Field for its reservoirs characterization was made possible by careful analysis and interpretation of its well logs. Average porosity ranging from 7.45% to 28.08% indicate a suitable reservoir quality, permeability values range from 1.34mD to 249.85mD and hydrocarbon saturation range from 37.55% to 85.43%; inferring high hydrocarbon production. Statistical analysis indicate that Chorgali Formation is good reservoir as compared to Sakeser Formation of Eocene Age in the Meyal Field.

ACKNOWLEDGMENT

Authors acknowledge the support of Director General of Petroleum Concessions (DGPC), Islamabad in data collection and the Department of Geological Engineering, University of Engineering & Technology (UET) Lahore in technical direction for this project.

REFERENCE

[1] Quijada, M. F. and Stewart, R. R., "Petrophysical analysis of well logs from Manitou Lake, Saskatchewan.," *CREWES Research Report*,**19**:(2007)

[2] Asquith, G. and Krygowski, D., “Basic Well Log Analysis, 2nd ed., *Tulsa, Oklahoma: American Association of Petroleum Geologists*,1-2, 31-32, 124(2004)

[3] Rider, M., "The Geological Interpretation of Well Logs," *Blackie*, *Glasgow*, 151-165(1986)

[4] Hasany, S. T. and Saleem, U., "An Integrated Subsurface Geological and Engineering Study of Meyal Field, Potwar Plateau, Pakistan," *Search and Discovery Article #20151*, (2012)

[5] Raza, H. A., Ahmed, R., Alam, S. and Ali, S. M., "Petroleum Zones of Pakistan," *Journal of Hydrocarbon Research*,**1**(2): 1-19(1989)

[6] Kadri, I. B., “Petroleum Geology of Pakistan,” *Karachi: Pakistan Petroleum Limited (PPL).*,275(1995)

[7] Shah, S. M. I., “Stratigraphy of Pakistan,” *Quetta: Geological Survey of Pakistan.***22**:381(2009)

[8] Ghazi, S, Ahmad. S. R. and Sharif, S., "Well Log Study and Petrophysical Properties of the Early Permian Warchha Sandstone, Potwar Basin, Pakistan.," *Pakistan Journal of Science*, **64**(3): 173-179(2012)

[9] Khan, A. A., Ahmad, S. and Khan, M. I., "Hydrocarbon Prospects of Karak anticline, NW Pakistan: Myths and Facts," *Pakistan Journal of Hydrocarbon Research*,**18**: 51-64(2008)

[10] Adaeze, I. U., Samuel, O. O. and Iwuagwu, C. J., "Petrophysical evaluation of uzek well using well log and core data, Offshore Depobelt, Niger Delta, Nigeria," *Advances in Applied Science Research*, **3**(5): 2966-2991(2012)

[11] Islam, A. R. M. T., Habib, M. A., Islam, M. T. and Mita, M. R., "Interpretation of wireline log data for reservoir characterization of the Rashidpur Gas Field, Bengal Basin, Bangladesh," *IOSR Journal of Applied Geology and Geophysics,* **1**(4): 47-54(2013)