Interpretation of wireline log data for reservoir characterization of the Rashidpur Gas Field, Bengal Basin, Bangladesh.

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Abstract: *The study was embodied with quantitative analysis of petrophysical parameters of the gas zone to characterize the reservoirs in the Rashidpur well-4 of the Rashipdur Gas Field, Bangladesh. 20 permeable zones were identified in the study. Among these, 4 zones were gas-bearing and the rest zones were water. Hydrocarbon type might be gas which was positively indicated comparatively high resistivity, low neutron and low density log responses in these zones than that of the water zones. Average porosity of these zones ranged from 18-27 %, water saturation 17-40 %, hydrocarbon saturation 60-82 % and permeability ranged from 50.94 mD to 363 mD. Hydrocarbon is moveable in the reservoir because all the value is less than 0.70 indicate by hydrocarbon moveavility index. Average bulk volume of water ranged from 0.04 to 0.13. All the calculated values support that lithology are fine to very fine-grained sandstone and is at irreducible water saturation. The zone-4 was shown comparatively highest thickness, porosity, hydrocarbon saturation and permeability than other zones. The study can be concluded that these hydrocarbon-bearing zones are potential for gas production and good reservoir bearing formation.*

Keywords*: Petrophysical parameter, Rashidpur Gas Field, Permeable zone, Hydrocarbon moveable and Reservoir potential*

I.   Introduction

Petrophysical parameters are the most useful characteristics of reservoir for development and production of the drill well and estimation of reserves in any gas field. Reservoir characterization is the process of mapping a reservoir's thickness, net to gross ratio, pore fluid, porosity, permeability and water saturation [1]. Different types of gamma ray (GR), spontaneous potential (SP), resistivity, neutron and density log are helped to define physical characteristics of the reservoirs such as porosity, saturation, hydrocarbon moveability and permeability [2]. These data are used to identify permeable zones for hydrocarbon with depth and thickness of the zones and to distinguish interfaces of oil, gas or water in a reservoir. All these are essential for estimation of hydrocarbon reserves. Islam et al., [3-6] were studied in shaly-sand reservoir of Bengal Basin, Bangladesh by petrophysical analysis. Rahman et al. [7] was carried out by in the reservoir sand of Titas-15 well, Bangladesh using wireline log interpretation. These earlier studies were motivated by the fact that gas-bearing reservoir of Bangladesh was taken special attention due to its economic interest.

In this regard, the present research work was focused on wireline log data to characterize the reservoir of the Rashidpur well-4. The outcome of this study is to characterize the reservoir using well logs and estimated petrophysical parameter of hydrocarbon-bearing zones of the Rashidpur Gas Field, Bangladesh. The Rashidpur Gas Field is situated in the south central part of the Sylhet Trough under Bahubal Upazila of Habiganj District and flanked by the Khowai syncline in the west and the Srimangal syncline in the east. The area is located in between the latitudes 24º 32" N to 24º 18" N and the longitudes 91º 30" E to 91º 43" E (Fig.1).

II.   Geologic Setting

Bengal Basin of Bangladesh is a young prolific hydrocarbon basin in the world [8]. The Rashidpur structure is situated in the south central part of the Sylhet Trough [9]. The Sylhet Trough is a major sub-basin of the Bengal Basin which situated in northeastern part of Bangladesh. The Sylhet Trough might have been formed at the late orogenic stage due to subsidence along the Dauki Fault system and Plio-pleistocene uplift of the Shillong Massif [10].The N-S trending Rashidpur structure is a narrow, elongated and compressed asymmetric anticline. As an asymmetrical anticline the eastern flanks of the structure is steeper (20º-25º) than the western flanks [10]. The eastern part of the structure is thrust faulted with a throw of about 500 m. The Lower to Middle Miocene Surma Group, consisting of the underlying Bhuban Formation and the overlying Boka Bil Formation were deposited during repeated transgression and regression phases of marine environment. This unit is well developed in the Eastern Folded Belts including Chittagong Hill Tracts and Sylhet Trough (Fig.2).
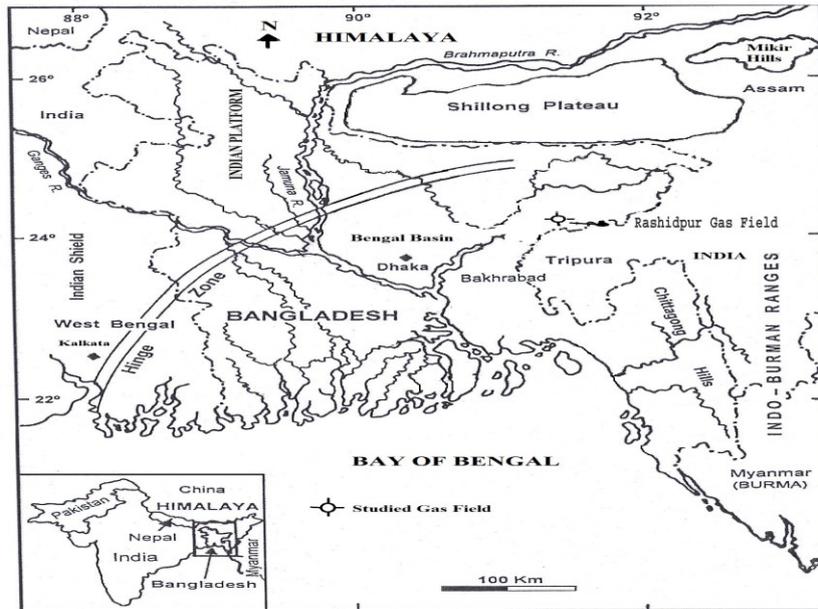
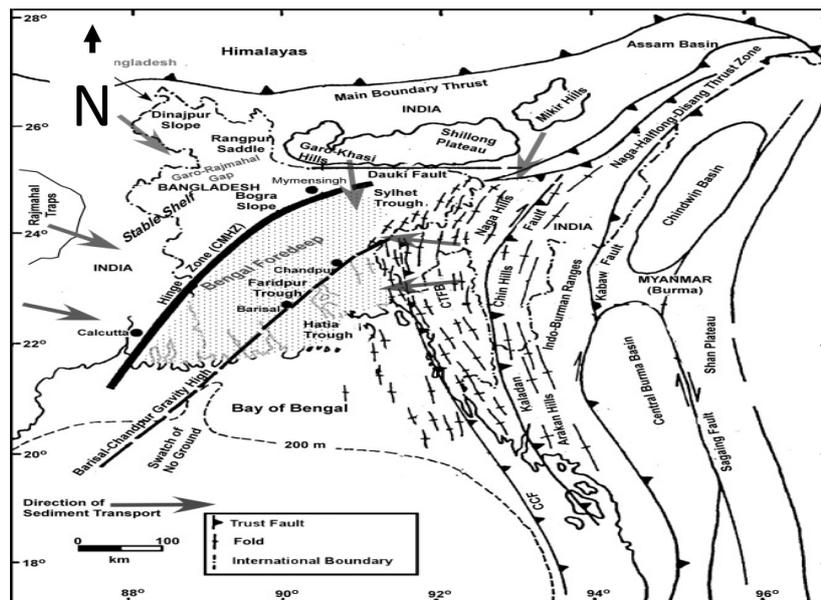Figure 1 Map showing the location of the Rashidpur Gas Field (After modified [8])

Figure 2 Map showing the regional tectonics elements of the Bengal Basin and surrounding areas (Modified from [8], [11])

III. Materials And Methods

Wireline log data for the study was collected from the Bangladesh Petroleum Exploration and Production Company Ltd. (BAPEX). Wireline logs (GR, SP, N, D, MSFL and ILD) of the Rashidpur well-4 have been regenerated from hard copies and calculated to determine the petrophysical parameters such as porosity, water and hydrocarbon saturation and permeability etc. Digitization of wireline log data was carried out by Excel software. The procedure for calculation of petrophysical parameters are as follows:

3.1 Volume of shale calculation: The primary step is required to determine the shale volume from a gamma ray (GR) log [12].

$$I_{GR} = \frac{GR_{log} - GR_{min}}{GR_{mix} - GR_{min}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(1)$$

Shale volume can be calculated from the gamma ray index (I_{GR}) for Tertiary rocks [13]. Calculate shale volume is written as:

$$V_{sh} = 0.083[2^{3.7 \times I_{GR}} - 1.0]$$ ....(2)

3.2 Porosity calculation: After calculation of the shale volume (V_{sh}), it is needed to correct the shale effect for porosity logs. To calculate porosity from neutron and density logs [13]:

$$\emptyset_{Den} = \left(\frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f}\right) - V_{sh}\left(\frac{\rho_{ma} - \rho_{sh}}{\rho_{ma} - \rho_f}\right)$$ ....(3)

$$\emptyset_{Ncorr} = \emptyset_N - [(\frac{\emptyset_{Ncl}}{0.45}) \times 0.30 \times V_{sh}]$$ ....(4)

Calculation of porosity value is also obtained from corrected Neutron-Density logs [12]

$$\emptyset_{Dcorr} = \emptyset_D - [(\frac{\emptyset_{Ncl}}{0.45}) \times 0.13 \times V_{sh}]$$ ....(5)

$$\emptyset_{N-D} = \sqrt{\frac{\emptyset_{Ncorr}^2 + \emptyset_{Dcorr}^2}{2.0}}$$ ....(6)

3.3 Saturation calculation: Water saturation has been calculated after porosity correction for shale effect. The following three equations of water saturation calculation are commonly used for gas reservoir:

$$S_w = \frac{\frac{V_{sh}}{R_{sh}} + \sqrt{\left(\frac{V_{sh}}{R_{sh}}\right)^2 + \frac{\emptyset^2}{0.2 \times R_W \times (1.0 - V_{sh}) \times R_t}}}{\frac{\emptyset^2}{0.4 \times R_W \times (1.0 - V_{sh}) \times R_t}}$$ ....(7)

Calculation of formation water resistivity of gas-bearing zone by the formula [14].

$$R_w = 10^{\left\{\frac{SSP}{K} + Log R_w\right\}}$$ ....(8)

3.4 Permeability calculation: Permeability value has been estimated from the following equation by [15]

$$k = \left(\frac{c \times \phi^{2w}}{W^4 \times (\frac{R_w}{R_{tirr}})}\right)^2$$ ....(9)

Where, $W = \left[(3.75 - \varphi) + \left\{\frac{\left[\log\left(\frac{R_w}{R_{tirr}}\right) + 2.2\right]^2}{2}\right\}\right]^{\frac{1}{2}}$

$c = 23 + 465\rho_h - 188\rho_h^2$

3.5 Hydrocarbon moveability index calculation: hydrocarbon moveability index is a ratio of the uninvaded zone and flushed zone which estimated by the following equation [16]:

$$\frac{S_w}{S_{xo}} = \left[\frac{R_{xo} \times R_w}{R_t \times R_{mf}}\right]^{1/2}$$ ....(10)

3.6 Bulk volume of water calculation: BVW of the hydrocarbon-bearing zone has been calculated using equation [17]:

$$BVW = S_w \times \emptyset$$ ....(11)

IV. Finding And Discussions

4.1 Permeable Zones Identification: Permeable zones were identified with the help of high SP and low GR log responses in the study well. But it was either water-bearing or hydrocarbon-bearing zone. Low resistivity, low SP, high GR log values were shown by water-bearing permeable zones. But high resistivity, high SP and low GR values were represented hydrocarbon-bearing permeable zones [2]. Four hydrocarbon-bearing zones were identified within the Miocene sequence of the Rashidpur well-4 and remaining was water-bearing (Table 1).

Table 1 Shows permeable zones of the Rashidpur well-4 in the Rashidpur Gas Field, Bangladesh.

Zone No.	Fluid Type	Depth Range (m)	Thickness (m)
1	Water-bearing	1374-1402	28
2	Hydrocarbon-bearing	1447-1523	76
3	Water-bearing	1534-1550	16
4	Water-bearing	1555-1565	10
5	Water-bearing	1575-1595	20
6	Water-bearing	1635-1670	35
7	Water-bearing	1718-1740	22
8	Water-bearing	1760-1780	20
9	Water-bearing	1795-1805	10
10	Water-bearing	1855-1885	30
11	Water-bearing	1930-1960	30
12	Water-bearing	1962-1985	23
13	Water-bearing	2060-2090	30
14	Water-bearing	2180-2190	10
15	Water-bearing	2215-2225	10
16	Water-bearing	2314-2335	21
17	Hydrocarbon-bearing	2337-2350	13
18	Water-bearing	2405-2440	35
19	Hydrocarbon-bearing	2466-2483	17
20	Hydrocarbon-bearing	2668-2732	64

4.2 Hydrocarbon-bearing Zones Identification: Hydrocarbon-bearing zones of the Rashidpur well-4 were identified by using conventional SP, GR, resistivity (MSFL; ILD), neutron and density logs. These zones were identified depending on the very high values of the resistivity logs comparing to water-bearing zones, high values of SP log and its deflection from the shale base line, low values of GR log, very low density and neutron log response [18] (Table 1; Figs. 4, 5, 6 and 7). Four hydrocarbon-bearing zones were identified from the depth ranged from 1447 m to 1523 m; 2337 m to 2350 m; 2466 m to 2483 m and 2668 m to 2732 m having average thickness of hydrocarbon-bearing zones were presented in the figure 3.
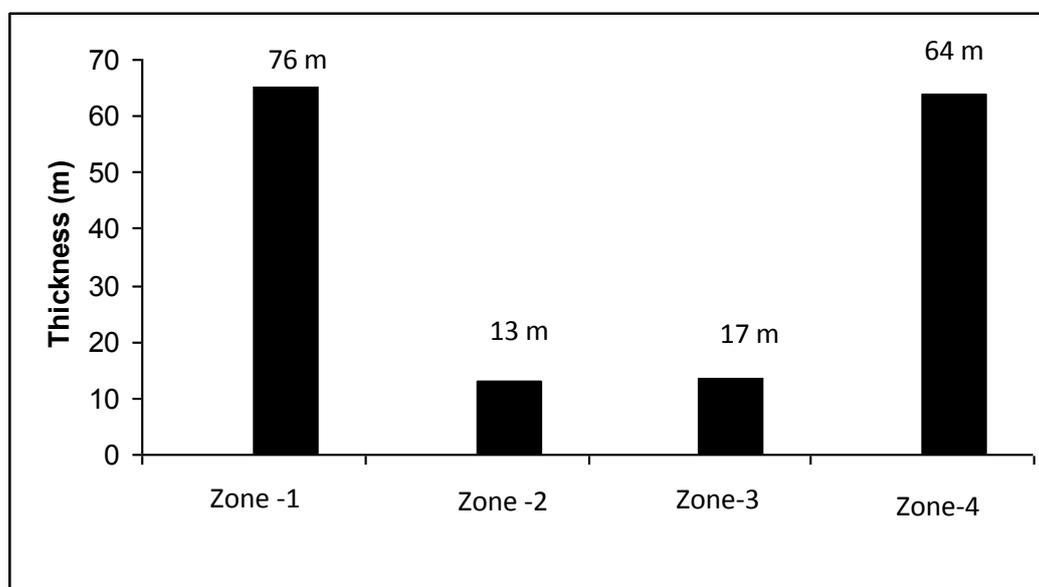

Figure 3 Average thickness distributions of hydrocarbon-bearing zone-1, 2, 3 and 4.
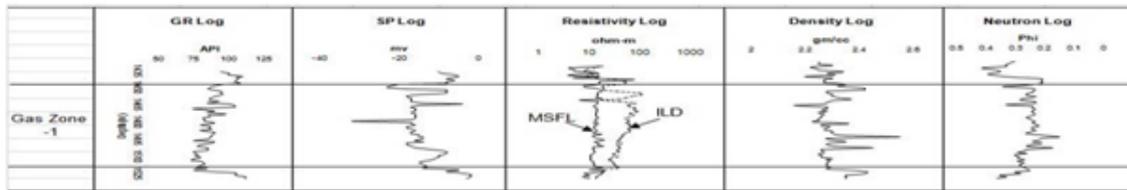
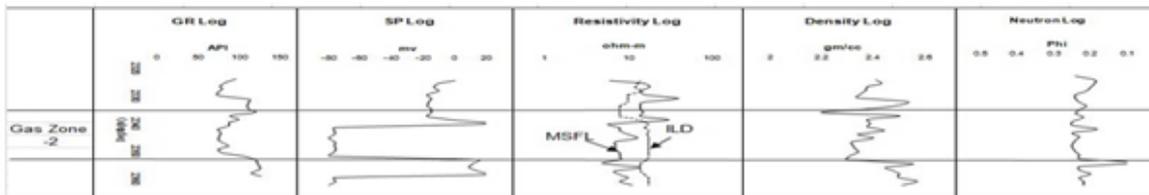Figure 4 Composite log response of the gas zone-1 of the Rashidpur well-4 in the Rashidpur Gas Field

Figure 5 Composite log response of the gas zone-2 of the Rashidpur well-4 in the Rashidpur Gas Field
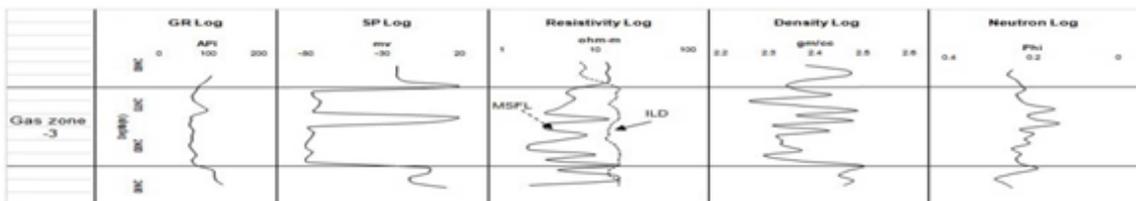

Figure 6 Composite log response of the gas zone-3 of the Rashidpur well-4 in the Rashidpur Gas Field
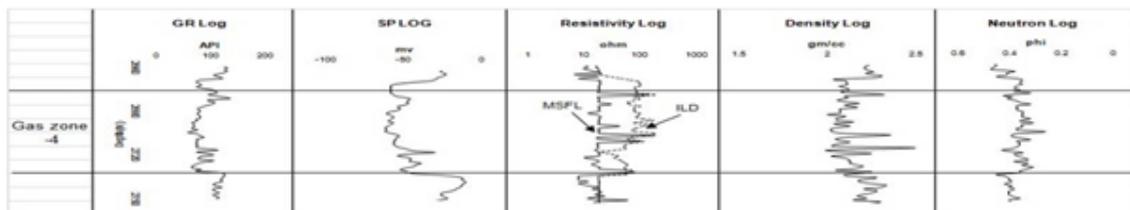

Figure 7 Composite log response of the gas zone-4 of the Rashidpur well-4 in the Rashidpur Gas Field
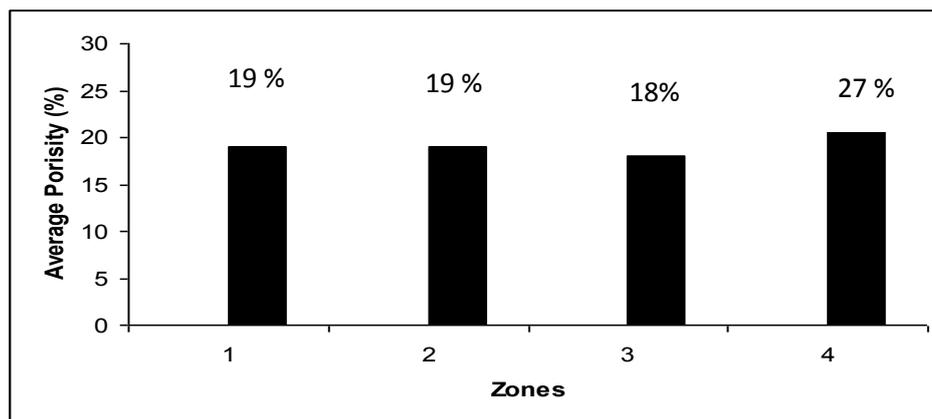

Figure 8 Average porosity values of the gas zone-1, 2, 3 and 4.

4.3 Volume of Shale of Hydrocarbon-bearing Zones: Volume of shale is used to characterize the shale distribution of a reservoir. Volume of shale is also indicating lithology of reservoir rock types. The volumes of shale values were low within the hydrocarbon- bearing zones which presented in the figures 9, 10, 11 and 12. Similar observation made by Islam et al., [3-4].

4.4 Porosity of Hydrocarbon-bearing Zones: The porosity calculation is a very important for determining fluid saturation in the reservoir evaluation [19]. The average porosity value of hydrocarbon-bearing zones-1, 2,

3 and 4 were presented in the figure 8. The porosity value of zone-4 was higher than other zones. The porosity values indicate that the hydrocarbon-bearing zones were good in categories (Figs. 9, 10, 11 and 12).

4.5 Saturation of Hydrocarbon-bearing Zones: Hydrocarbon-bearing zone has not been calculated using Archie (1942) equation because the equation is valid for clean sandstone. The average water saturation of hydrocarbon-bearing zones were calculated as ave. 27 %, ave. 37 %, ave. 44 % and ave. 17 % respectively and converted to the average hydrocarbon saturation estimated as ave. 72 %, ave. 62 %, ave. 60 % and ave. 82 % respectively (Fig. 9, 10, 11, 12 and 13). The hydrocarbon saturation value indicates that the reservoir is productive, when the value exceeds 60 % [2]. Islam *et al.,* [5-6] also got same result in the other gas field of Bengal Basin.

4.6 Hydrocarbon Moveability Index (S_w/S_{xo}): Hydrocarbon moveability index (S_w/S_{xo}) is the ratio between water saturation of uninvaded zone (S_w) to the water saturation of flushed zone (S_{xo}).The Sw/Sxo value is equal or greater than 1.0 indicates that hydrocarbon is not moveable, if the value is less than 0.7 indicate a moveable hydrocarbon condition [12]. Archie's [16] formula has been used for the calculation of hydrocarbon moveability index. All these values of hydrocarbon moveability of these zones are less than 0.7, which indicates that the hydrocarbon of these zones is moveable (Table 2).

4.7 Bulk Volume of Water of Hydrocarbon-bearing Zones: BVW indicate the formation is at irreducible water saturation or not. If the BVW ranges from 0.035 to 0.07, the grain size of the sand is fine to very fine-grained [18]. When value of BVW is constant or close to constant with some minor scattering, the formation becomes homogeneous and close to irreducible water saturation [20]. It also indicates that the grain size of the reservoir (Table 2).
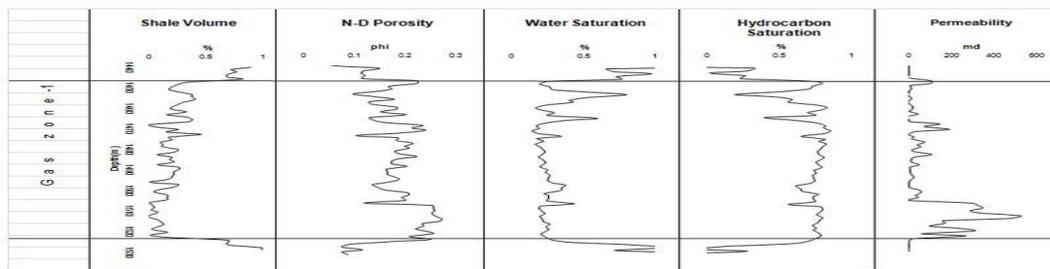

Figure 9 Graphical presentations of petrophysical parameter of the gas zone-1 of the Rashidpur well-4.
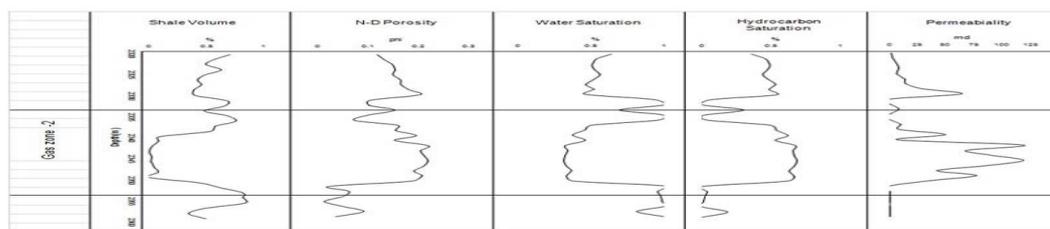

Figure 10 Graphical presentations of petrophysical parameter of the gas zone-2 of the Rashidpur well-4.
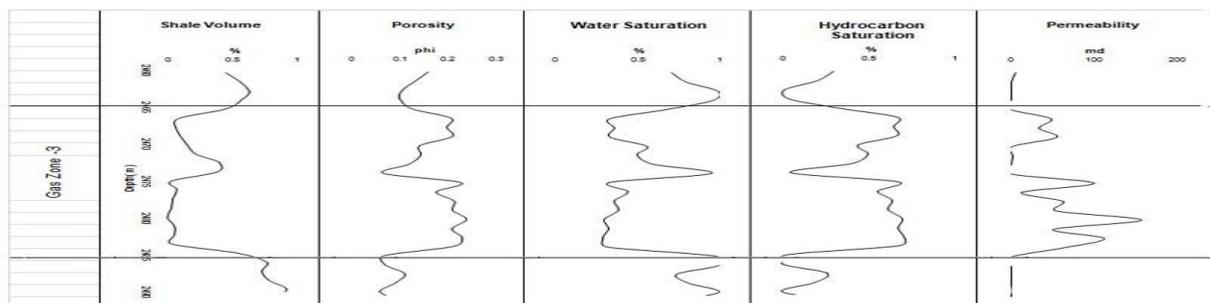

Figure 11 Graphical presentations of petrophysical parameter of the gas zone-3 of the Rashidpur well-4.
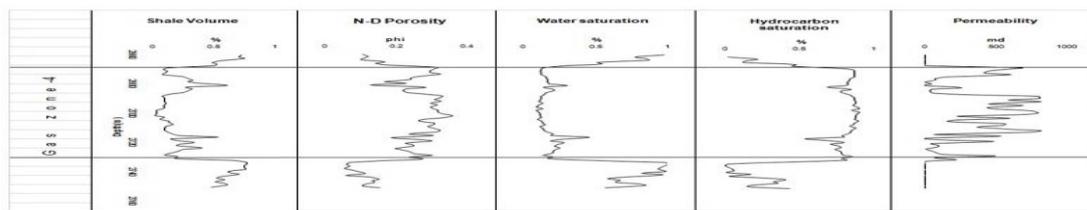
Figure 12 Graphical presentations of petrophysical parameter of the gas zone-4 of the Rashidpur well-4

4.8 Permeability of Hydrocarbon-bearing Zones: Permeability values of hydrocarbon-bearing zones were calculated using formula [15]. Permeability values of these zones ranged from 4.69-525 mD, 7.66-118 mD, 94-157 mD and 106-820 mD respectively. So, all calculated value of permeability indicated that good reservoirs potential according to observation made by [2] (Fig. 9, 10, 11, 12 and 14).
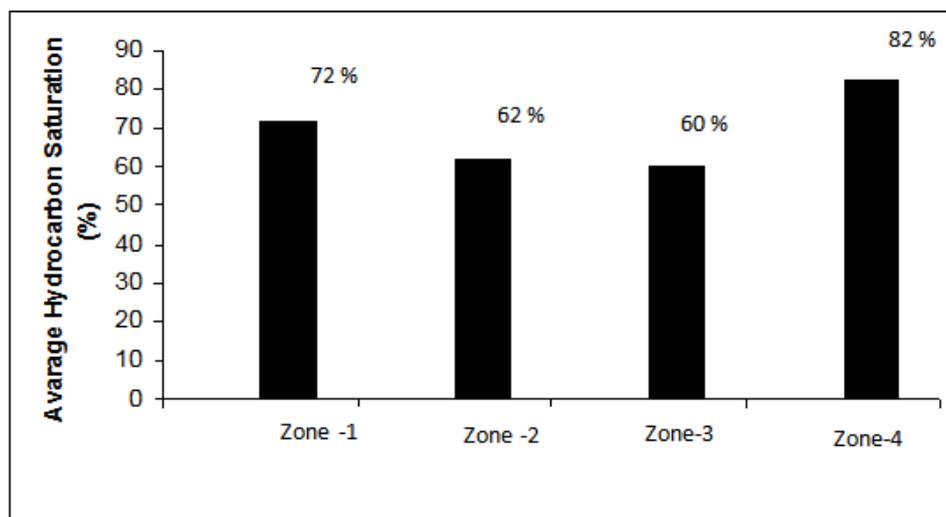

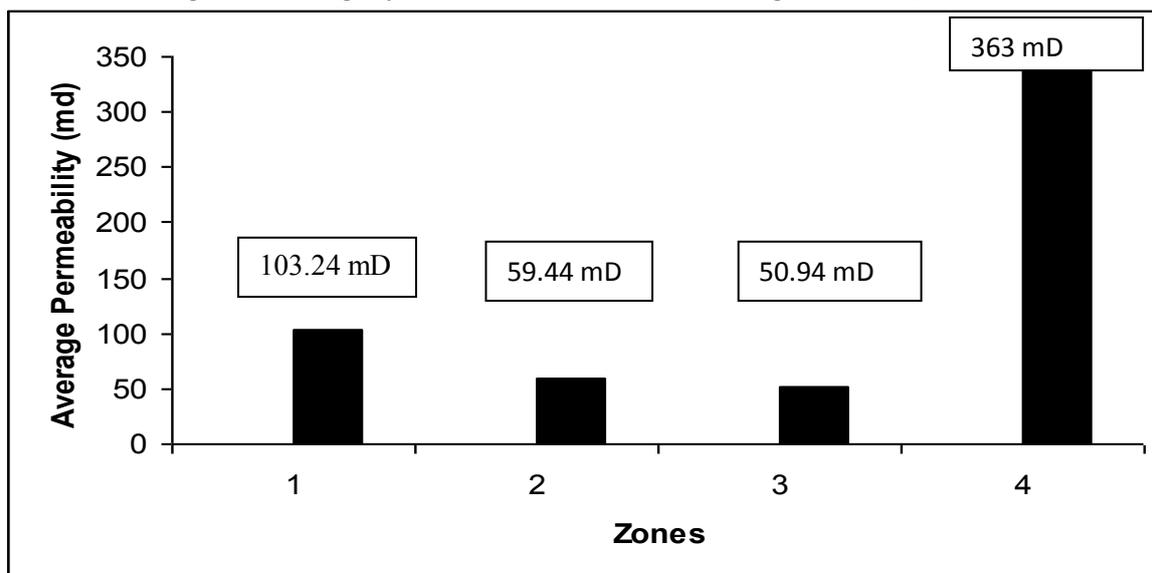Figure 13 Average hydrocarbon saturation values of the gas zone-1, 2, 3 and 4.

Figure 14 Average permeability values of the gas zone-1, 2, 3, and 4.

Table 2 presents the hydrocarbon moveability index and bulk volume of water of the gas zones in the Rashidpur well-4.

Zone No.	Depth Range (m)	Thickness (m)	Sw/Sxo Range	Average Sw/Sxo	BVW Range	Average BVW
1	1447-1523	76	0.09-0.38	0.14	0.065-0.266	0.13
2	2337-2350	13	0.13-0.25	0.17	0.056-0.09	0.067
3	2466-2483	17	0.08-0.22	0.14	0.049-0.145	0.081
4	2668-2732	64	0.11-0.44	0.20	0.027-0.088	0.04

V. Conclusion

The reservoir potentiality of the Rashidpur well-4 was studied using wireline logs. Based on the composite log response, 20 permeable zones were identified in the study well. Four zones were hydrocarbon bearing and the rest zones contained water. The low GR, high SP, high resistivity, low neutron and low density log responses indicated that hydrocarbon type was gas. Average porosity was calculated as 22 %. Average water saturation ranged from 17-40 % whereas average hydrocarbon saturation ranged from 60-82 %. Average BVW of these zones ranged from 0.081- 0.13. These values indicate that the lithologies of these zones are fine to very fine-grained sandstone and hydrocarbon is moveable in the Rashidpur well-4. Average permeability of gas-bearing zones was estimated at 207 mD. It reveals that all petrophysical parameters have been calculated to characterize the reservoir using wireline log data.The study also reveals that hydrocarbon-bearing reservoir are potential for gas production and accumulation and less effect of shale distribution.

Acknowledgement

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