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Petrophysical Properties of Gas Reservoirsin Well SB-02 of Shahbazpur Gasfield, Hatya Trough, Bengal Basin

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Abstract:
The present study reflect the petrophysical properties of gas reservoirs encountered in the well SB-02 ofthe Shahbazpur gasfield, Hatya Trough, Bengal Basin. Five gas-bearing reservoirs (Gas zones 01-05)are delineated in the Miocene sequence in thiswell.Off these, three gas-bearing zones (Gas zones 01, 02 and 04) are very promising good reservoirs.The reservoir of the gas zone-1 is consolidated to poorly consolidated sandstonehaving onaverage 21%V_{sh}, 63% S_h and, good effective porosity and permeability. The gas zone-2 is consolidated sandstone having 23.4 m net pay thickness. This reservoir has 23% V_{sh}, 15% effective porosity and 65% S_h. Its log derives permeability is 12 mD. The tight consolidated sandstone of the gas zone-4 has 8% V_{sh}, 14% effective porosity and 64% S_h. The consolidated sandstones of the gas zones 03 and 05 have high $V_{sh}$with low porosity, S_h and permeability, whichare not suitable for gas production.

Keywords: *Petrophysicalproperties, Well logs, Shahbazpur gasfield, Hatya Trough, Bengal Basin.*

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I. Introduction

The Shahbazpur gasfieldis the westernmost gasfield located in the middle of Bhola Island along the northern margin of the HatiyaTrough, Bengal Basin, Bangladesh (Figure 1). The Bangladesh Petroleum Exploration and Production Company Limited[3] discovered the gasfield in 1995where a total 5 wells have been drilled. The commercial productionfrom the Miocene sandstone reservoir of Shahbazpur Sequence-4 in the gasfield was stared in 2009.About 35 MMCFD gas have been produced from the 03 wells till to date.The main lithology of the Sequence-4 are sandstone, siltstone, and shale of marginal estuarine to marsh environments[23]. A study on the petrophysical characteristics of the shaley-sand encountered in the Shahbazpur well-1 have been done[20]. Several works related to depositional environment, geochemistry and seismic attributes of this gasfield have been done[17,18,19,27,28,30,31]. Petrophysical properties of the reservoir in the Shahbazpur well-02 has not been studied for characterization of the reservoir. The present research work aims to assess the reservoir, bothqualitative and quantitativelyto evaluate the petrophysical characteristics of the gas-bearing zones. The results would be helpful for enhanced production in the gasfield.

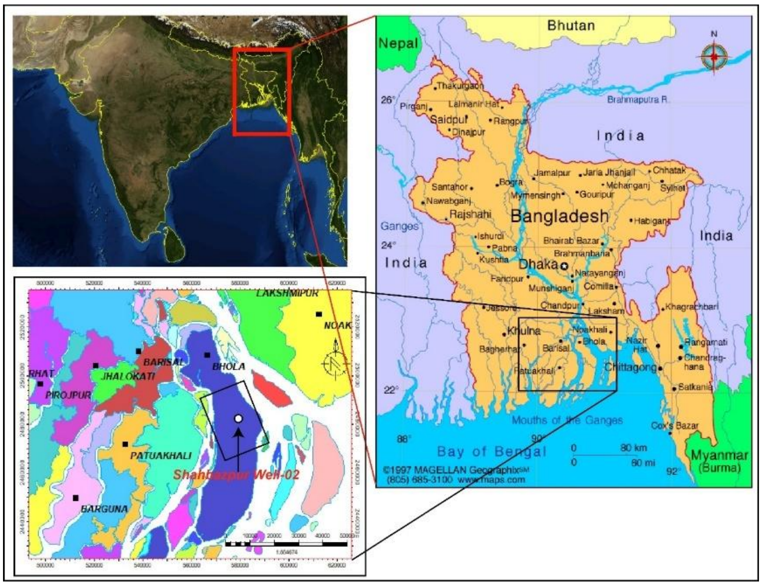

Figure 1. Location of the SB#02 in the Shahbazpur gasfield.

II. Geological Structure and Stratigraphy of the Gasfield

Regional geology, sedimentology, geochemistry, tectonics, source rock potentialityas well as evaluation of reservoir rocks of the gasfield have been described previously[1,2,8,9,10,11,12,13,14,16,21,22,30].The Shahbazpur gasfield is a sub-surface anticlinal structure situated in the northern margin of the Hatiya Trough. The NW-SE trending oval shaped Shahbazpur structure lies parallel to the Kutubdia in the Bay of Bengal. Itis bounded by the Chandpur-Barisal High in the northwest, and Chittagong-Tripura Fold Belt in the southeast, Muladi structure to the northwest and the Kutubdia structure to the southeast (Figure2).

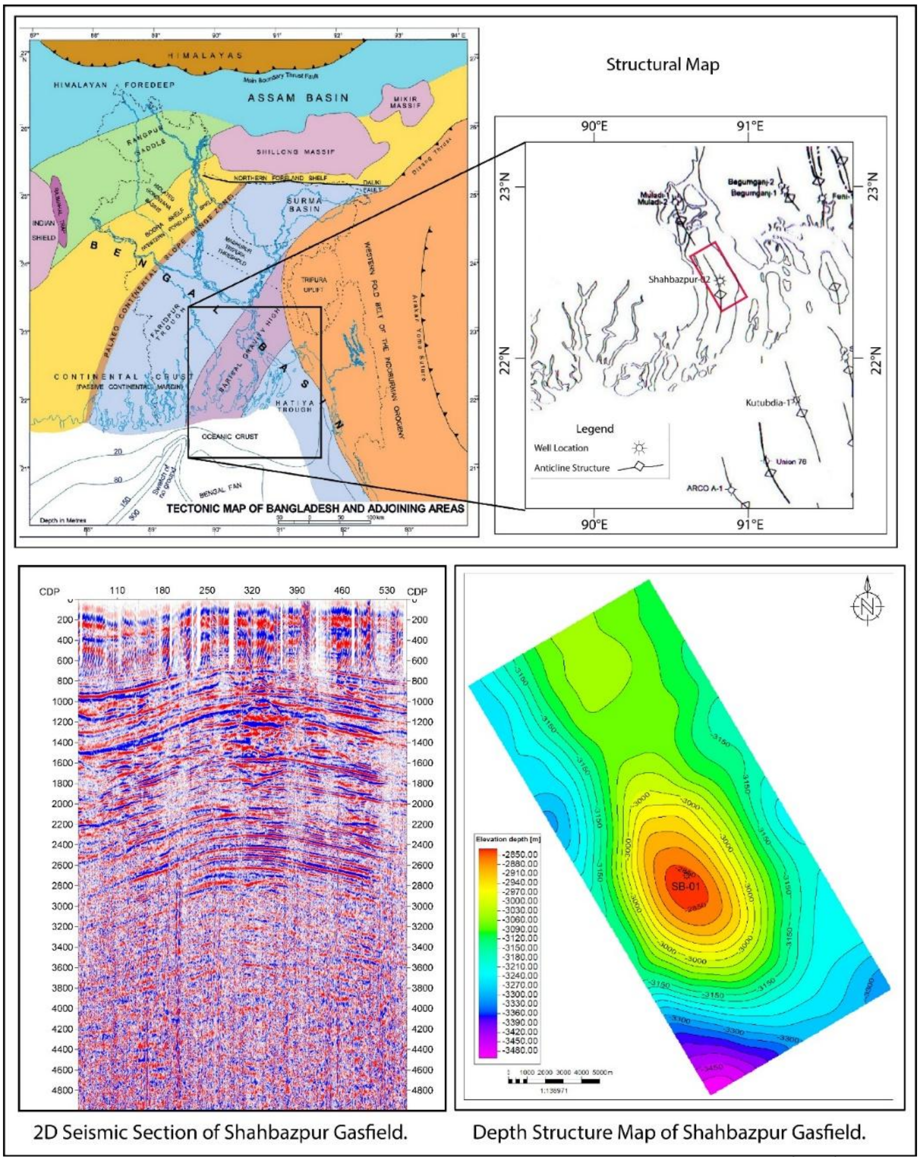

Figure 2. Tectonic framework and structure map of the study area [6,12,29].

The stratigraphy (Miocene to Recent) of the Shahbazpur structure was established based on the well SB#01, drilled in the middle part of the structure[3,23]. The stratigraphic succession of the structure is summarized in the Figure 3.

III. Materials and Methods

Wireline log data of Gamma Ray (GR), Spontaneous Potential (SP), Density (RHOB), Neutron (NPHI), Sonic (DT), Deep Laterolog Resistivity (ILD), Shallow Laterolog Resistivity (LLS) and Micro Spherical Focus Log (MSFL) of the SB#02 have been collected and analysed to determine the petrophysical parameters of reservoir zones. Collected digital log data have been processed with the help of the Techlog software to prepare composite logs and to identify the lithology and gas-bearing zone. The lithologies have been identified using NPHI-RHOB cross-plot and GR log. The resistivity of water (R_w) has been calculated using formation temperature and SP log data. The reservoir properties such as the shale volume (V_{sh}), porosity (φ), saturation (S_w, S_h) and permeability (k) have been determined using Techlog software. The standard cut-off value has been used to calculate the reservoir net pay zone values. The cut-off values of 50%, 10%, and 50% for the shale volume, porosity and water saturation respectively have been applied in the present study.

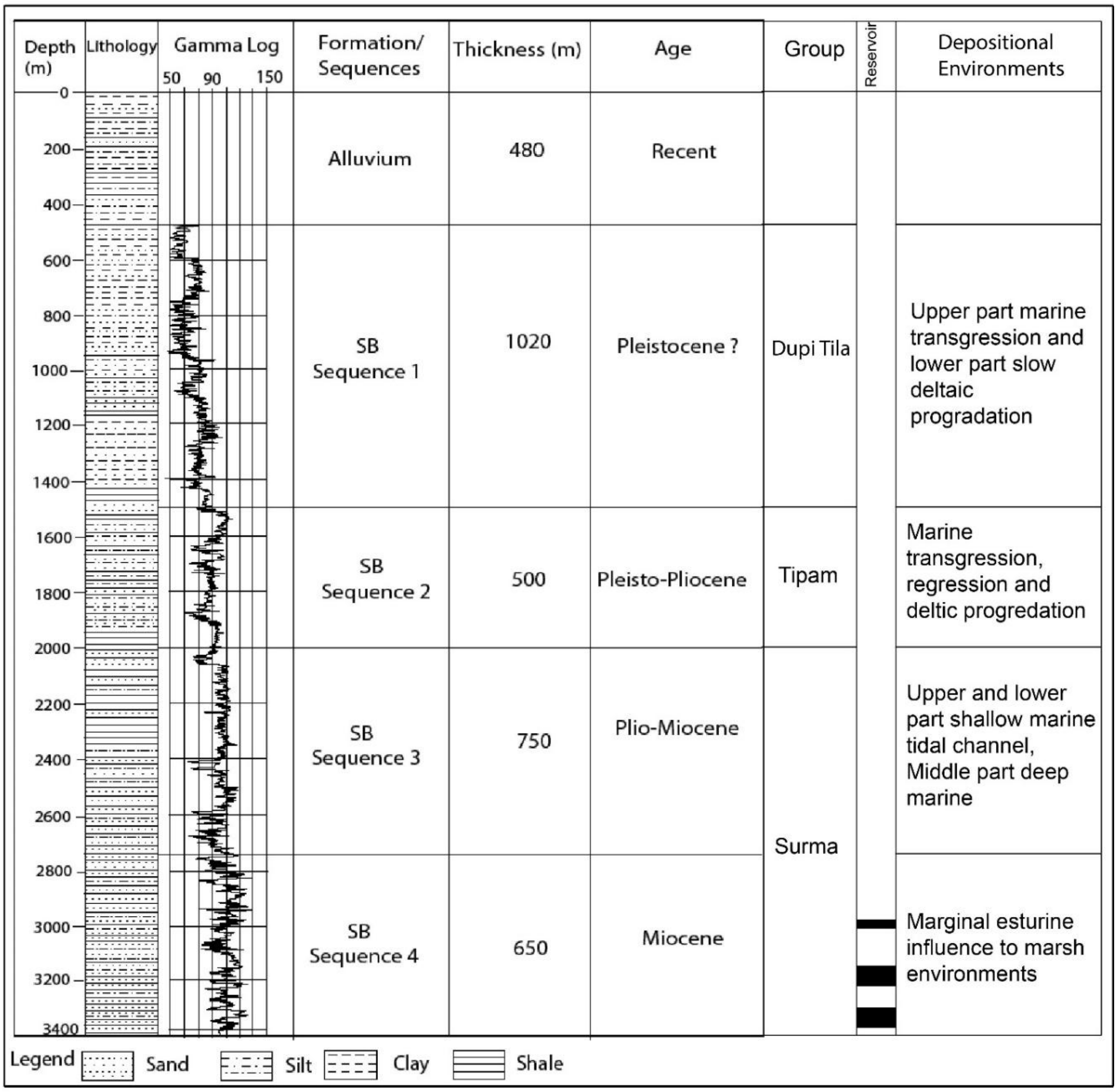

Figure3. Lithostratigraphy in the well SB#1 of the Shahbazpur structure along with interpreted depositional environments(modified after[3,23]).

IV. Results and Discussion

Identification of Lithology

The accurate identification of lithology is the first step to identify the hydrocarbon-bearing zone, which help to compute accurate petrophysical properties of reservoirs.Lithology of the subsurface sequence has been interpreted using the gamma ray response and neutron-density log cross-plot. The volumetric distribution of shale throughout the subsurface sequence along the well SB#02 hasalso been calculated. The neutron-density log cross-plot shows that the maximum points concentrated in sandstone and shale regions. But some points concentrated on limestone point which may indicates the calcareous shales and sandstones. On the basis log responses, there are three types of lithologies e.g., sandstone, shaley sandstone and shale have been identified(Figures4&5).

Identificationof Gas-bearing Zones

The gas-bearing zones in the Miocene reservoir have been identified from the GR, density, neutron and resistivity (MSFL, ILD) logs responses. In the gas-bearing zones, gamma ray log shows low response and it deflects from the shale baseline. The resistivity log response in these zones are very high. Normally in the gas-bearing zones, deep resistivity log (ILD) reading is higher than the shallow resistivity log (MSFL) reading. The negative separation between density and neutron responses are also the good indicator of gas-bearing zones and gas-water contact. On the basis of log responses, five gas-bearing zones (Gas zones -01 to 05) have been identified (Figures4&5).

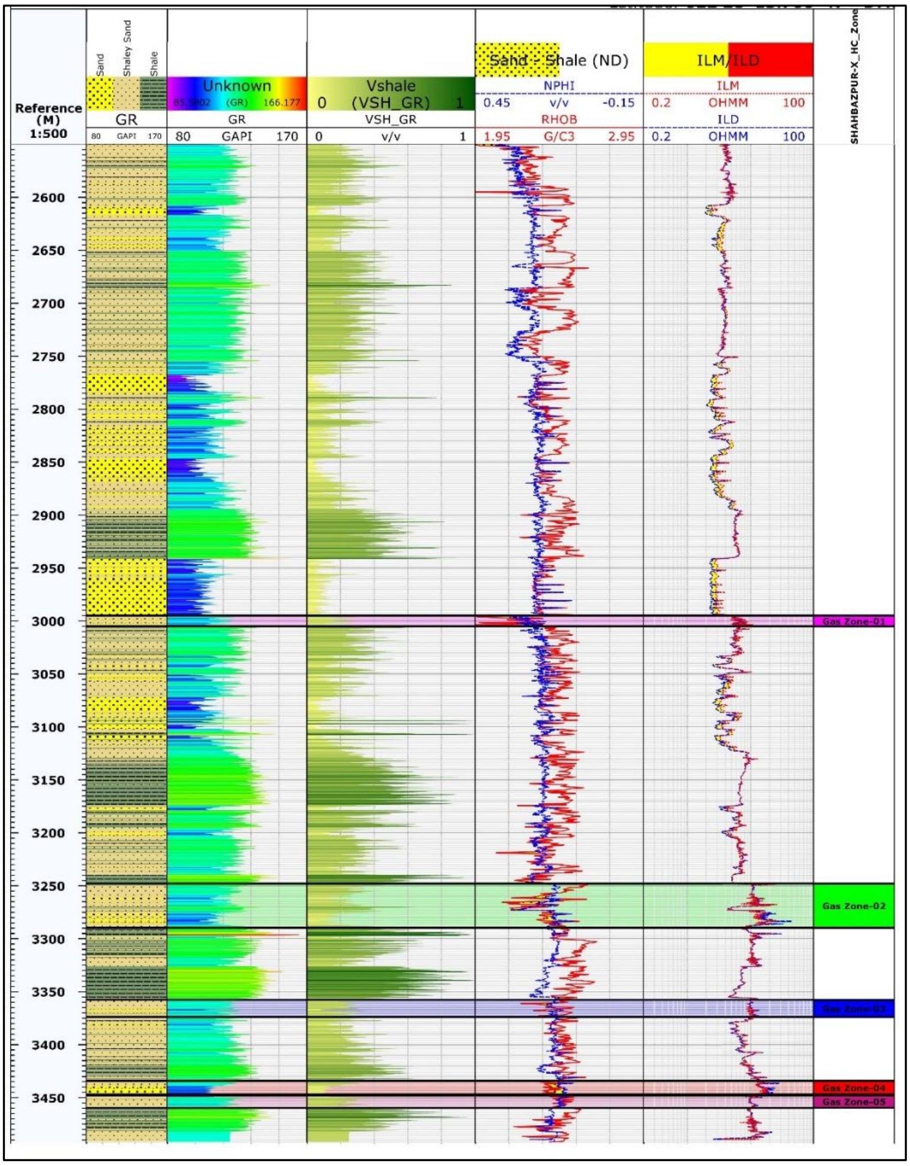

Figure 4. Identified lithologies and gas-bearing zones along with the log responses in the well SB#02, Shahbazpur, Hatya Trough, Bengal Basin.

Reservoir Properties

Shale Volume (V_{sh}):The shale content in the sandstone reservoir is very important for accurate assessment of reservoir property. Dominant presence of shale in the reservoir may alter the reservoir quality by modifying the petrophysical characteristics, like increaseof porosity values and decrease of resistivity[24]. In the present research work, the V_{sh} in the gas-bearing zones has been calculated using Dresser Atlas Methods[7] for unconsolidated Tertiary rocks. The V_{sh}value of the five gas zones are shown in the Table-1 and Figures 8-11. The average V_{sh}in the gross reservoir of the five gas zones are 26, 23, 40, 20 and 18% respectively. But in the net pay reservoir zones, these are 21, 16, 20, 8 and 6% respectively, which are lower than those of previous. The gas zones 04 and 05 show the lowest V_{sh} than those of the other zones.

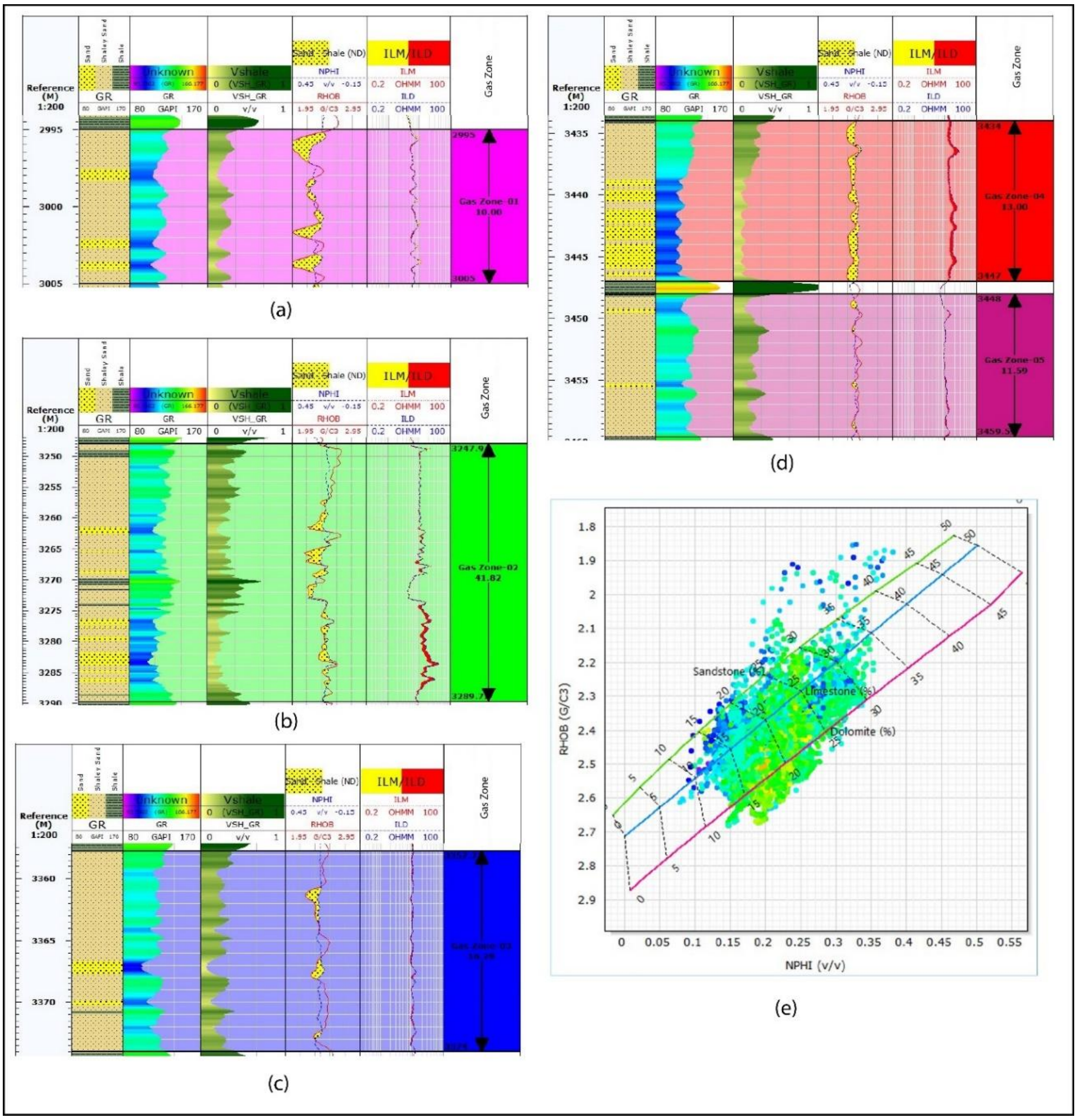

Figure5 (a-d). 'a-d' showing the lithologies and log responses of the gas zones-01to05 and 'e' showing the Neutron-Density log cross-plot of the well SB#02, Shahbazpur.

Effective Porosity (φ):Based on the porosity values, Bradley [4] classified sandstone reservoirs as the poor (5-10%), fair (10-15%), good (15-20%), very good (20-25%) and excellent (higher than 25%) categories. Effective porosity of these reservoirs have been calculated fromthe density (RHOB) and neutron (NPHI) logs using the Techlog software and the standard formula[7,32].The determined porosity of the five gas zones are shown in the Table 1 and Figures 8-11.

Water Saturation (S_w):Generally the water saturation (S_w)is calculated from the effective porosity and the resistivity log. Hydrocarbon saturation (S_h) is (1-S_w). The S_w has been calculated by the Simandoux[33], Indonesia[26]and Total Shale equations using the Techlog software.The S_w of the five gas-bearing zones are also shown in theTable 1 and Figures 8-11.

Permeability (K):The permeability may be ranked as the poor if it (<1mD), fair(1 to 10 mD), moderate (10 to 50 mD), good (50 to 250) and very good (>250 mD)[34]. Huang[15] has been classified as the tight sandstone reservoir on the basis of porosity and permeability as (1) high-quality tight sandstone reservoirs (ϕ=9%−12% and K=0.1−1.0 mD), (2) effective tight sandstone reservoirs (ϕ=6%−9%, and K=0.05−0.1) and (3) low-quality tight sandstone reservoirs (ϕ=4%−6% and K=0.01−0.05 mD).The average permeability (K) of gas-bearing zones in the well has been determined using Wyllie & Rose[35], and Coates & Dumanoir[5] formulas. The results are given inthe Table 1 and Figures8-11.

Table 1: Calculated petrophysical properties of the gas zones in the well SB#02,Shahbazpur, Hatya Trough, Bengal Basin.

Gas Zone	Gas Zone Name	Gas Zone-01	Gas Zone-02	Gas Zone-03	Gas Zone-04	Gas Zone-05
	Depth Range (m)	2995-3005	3247.90-3289.70	3357.70-3374	3434-3447	3448-3459.50
	Gross Thickness (m)	10	41.82	16.29	13	11.59
	Net Pay Thickness (m)	7	26	4	9	2
Shale Volume (%)	Range	8-70	1-60	007-95	007-60	0-55
	Average	26	23	40	20	18
	Average in net pay zone	21	16	20	8	6
Effective Porosity (%)	Range	0-35	0-24	0-17	0-16	0-15
	Average	21	12	7	11	10
	Average in net pay zone	21	15	14	14	14
Water Saturation (%)	Range	20-100	22-100	33-100	31-100	44-100
	Average	37	48	68	43	61
	Average in net pay zone	35	35	41	36	47
Permeability (mD)	Range	0-168	0-47	0-18	0-08	0-06
	Average	33	9	3	4	2
	Average in net pay zone	27	12	8	5	5

Cross-plot Analysis

The cross-plot is the most effective method to expose the petrophysical data. It can provides the hidden information more clearly than depth plot of logs. The Neutron-Density cross-plots have been produced for the five gas-bearing zones to interpret the lithology. The cross-plot of the well SB#02 shows that the reservoir is mainly sandstone (Figure6). The porosity-permeability cross-plots have been produced in this study and adopted with Petrowiki porosity-permeability cross-plots[25] (Figure7). The cross-plot shows that the gas zone-01 is consolidated to poorly consolidated sandstone whereas the other zones are consolidated sandstone reservoirs.

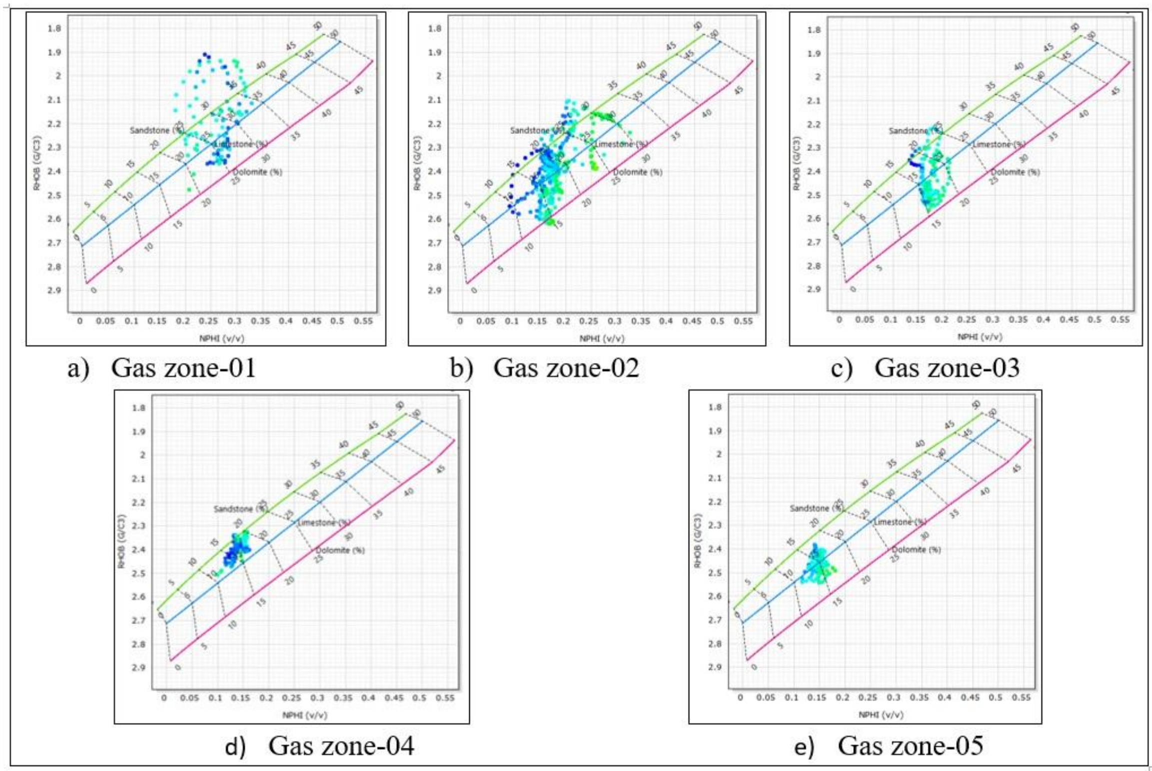

Figure 5. Neutron-Density cross-plots of the gas zones in the well SB#02, Shahbazpur, Hatya Trough, Bengal Basin.

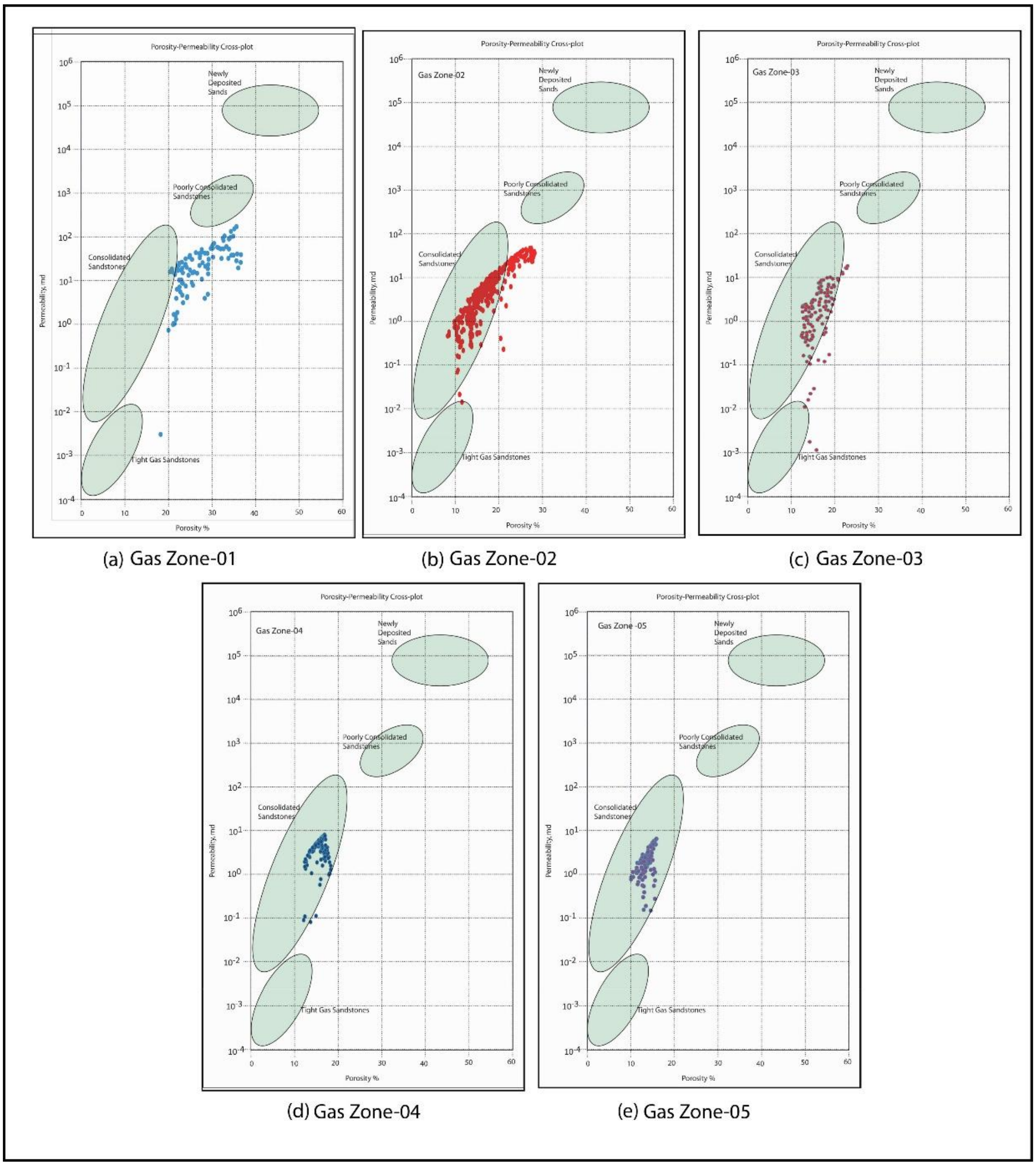

Figure 7. Porosity-Permeability cross-plots of the gas zones in the well SB#02, Shahbazpur, Hatya Trough, Bengal Basin.

Petrophysical Characterization ofReservoirs

Gas Zone -01: The quick look interpretation shows that the dominating lithology of the zone-01 is sandstone having low gamma ray values, clear negative separation of neutron-density overlay and Neutron-Density cross-plot. The medium separation of ILD and MSFL resistivity logs indicate the presence of gas in this zone. The gross reservoir thickness of the zone-01 is 10 m.The net reservoir pay thickness is 7 m but remaining 3 m is gas-bearing water. The $V_{sh}$of the gross reservoir and pay zone are 26% and 21% respectively. Its average effective porosity is 21% with average S_h of 63%. Its average permeability is 27 mD (Figure 8), which indicate that the zone isthe moderately permeable for gas production. The gas zone-01 is consolidated to poorly consolidate sandstone reservoir (Figure 7).

Gas Zone-02: The reservoir of the gas zone -02 is sandstone interbedded with shale layer. The V_{sh} in this reservoir ranges from 1 to 60%, with an average of 23% in the gross reservoir and 16% in the net pay zone. This V_{sh} in the reservoir is the main problem for the production of gas. Presence of shale in the reservoir reduced the porosity, permeability and hydrocarbon saturation. The gross thickness of the reservoir is 41.82 m, which reduces to 26.5 m in the net reservoir and 23.4 m in the net pay zone due to the presence of interbedded shale. Average effective porosity of gross reservoir and net pay zone are 12% and 15% respectively, which indicate it's fair to good quality with 65% S_h in the pay zone. Average permeability of the gross reservoir and pay zone are 9 mD and 12 mD respectively (Table 1 and Figure 9) which indicate its moderate permeability to produced gas. The porosity and permeability suggests it as consolidated sandstone reservoir (Figure 7).

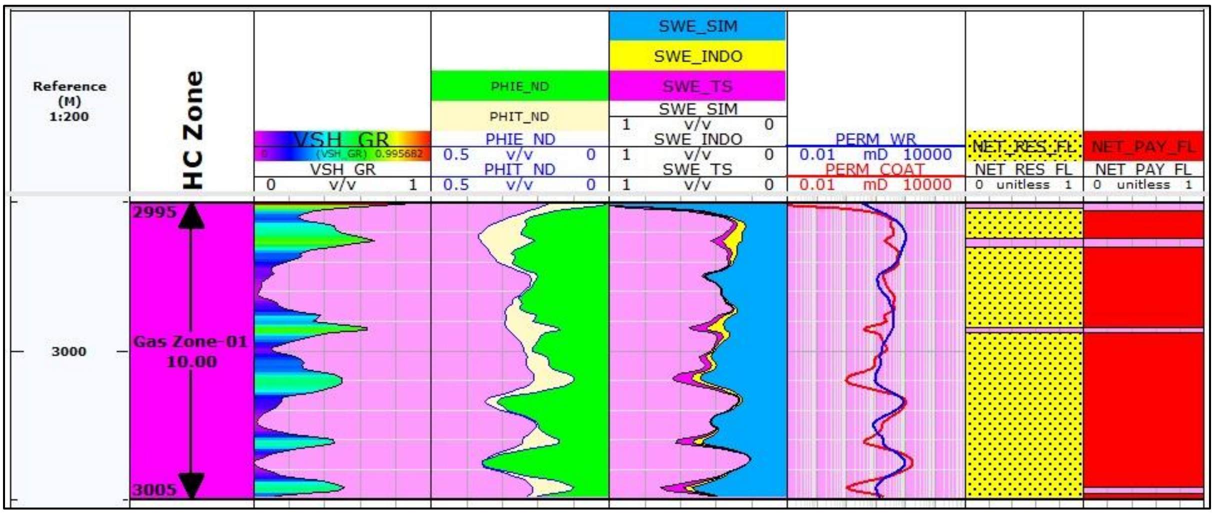

Figure 8. Petrophysical properties of the gas zone-01 of the well SB#02, Shahbazpur, Hatya Trough, Bengal Basin.

Gas Zone -03:Its gross and net reservoir, and net pay zone thickness are 16.29 m, 5.8 m and 4.0 m respectively. The average V_{sh}in the gross reservoir and pay zone are 40% and 20% respectively (Table 1 and Figure 10). The quality of the reservoir is poor and the thickness of pay zone reduces due to high shale content. The average effective porosity of the gross reservoir is 07% and that in the pay zone is 14%, which indicate fair quality porosity. The average permeability of the gross reservoir and pay zone are 03 mD and 8 mD respectively, which indicate fair permeability to produce gas. The porosity-permeability relation and quick look study shows that this zone is a consolidated sandstone reservoir. The pay zone has 59% $S_h$that indicates a moderate gas-bearing zone.

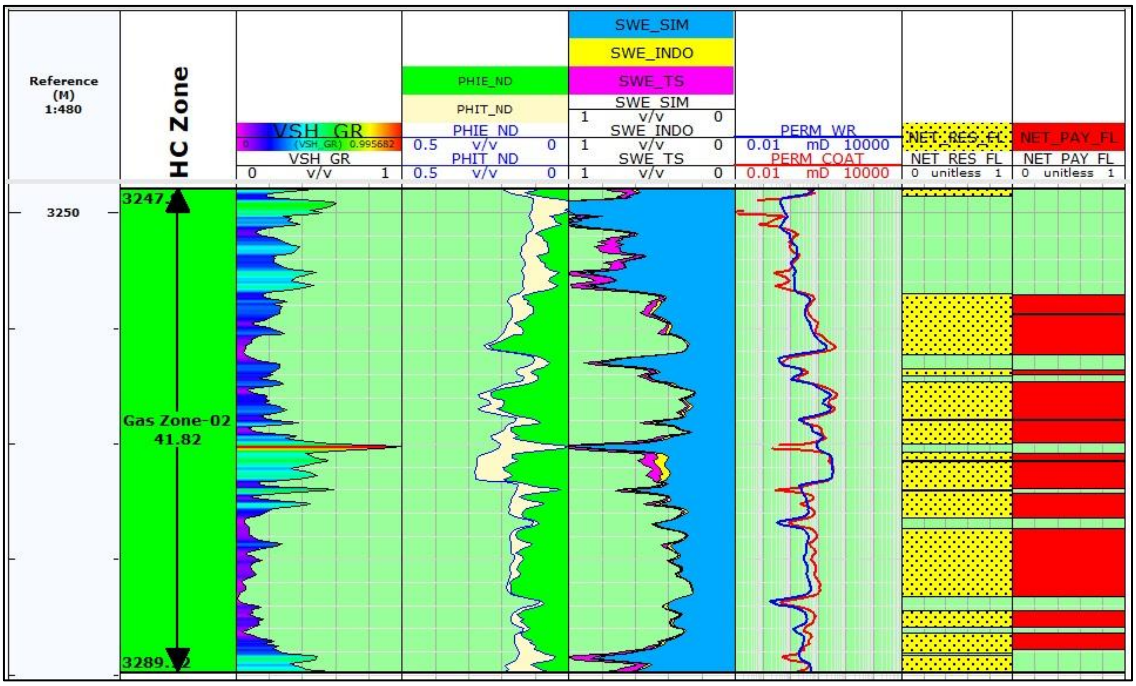

Figure 9. Petrophysical properties of the gas zone-02 of the well SB#02, Shahbazpur, Hatya Trough, Bengal Basin.

Gas Zone-04: Lithologically this zone is sandstone, which shows clear negative separation of the Neutron-Density overlay. Average V_{sh} is 20% in the gross reservoir whereas it is very low (8%) in net pay zone. The gross reservoir and net pay zone thickness are 13 m and 10.8 m respectively (Table 1 and Figure 11). This reservoir is consolidated sandstone with fair porosity (14%) and permeability (5 mD). This pay zone contains 64% hydrocarbon.

Gas Zone -05: Its gross reservoir and net pay thickness are 11.59 m and 1.8 m respectively. The V_{sh} in the gross reservoir is 18% whereas it is very low (6%) in the net pay zone. The average effective porosity in gross and net pay zone are 10% and 14% respectively. The S_h of these zone are 39% and 53% respectively (Table 1 and Figure 11). Its log drive permeability is very low in gross reservoir. The reservoir is consolidated shaley sandstone with fair porosity and permeability, which indicate its non-suitability for gas production.

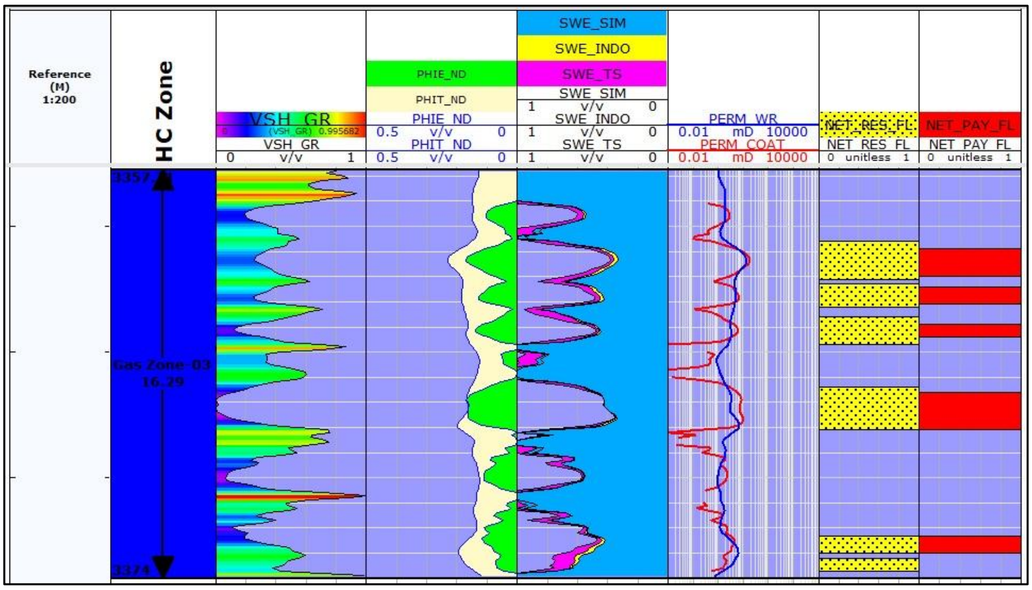

Figure 10. Petrophysical properties of the gas zone-03 of the well SB#02, Shahbazpur, Hatya Trough, Bengal Basin.

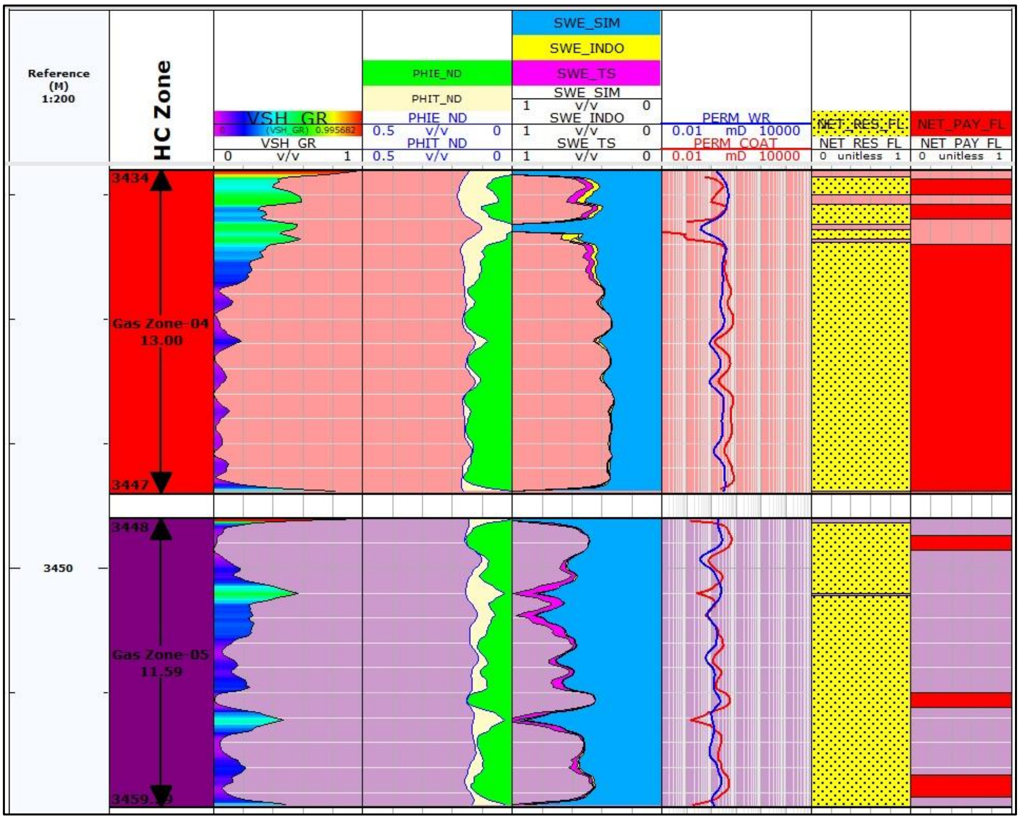

Figure 11. Petrophysical properties of the gas zones-04 and 05 of the well SB#02, Shahbazpur, Hatya Trough, Bengal Basin.

V. Conclusion

The Shahbazpur structure in the middle part of the Bhola Island is located in the northern margin of Hatya Trough, Bengal Basin. It is an SE-NW trending sub-surface oval shaped anticlinal structuretrending parallel to the Kutubdia structure. Reservoir quality and its hydrocarbon potentiality of Miocene sequence in the well SB#02 has been evaluated using well logs data. Five gas-bearing zones have been identified in the Miocene reservoirs. Among these, 3 reservoirs (Gas zones-01, 02 & 04) are good for gas production.The gas zone-01 is consolidated to poorly consolidated sandstone containing on average 21% shale having21% effective porosity, 63% hydrocarbon and 27 mD permeability. The reservoir of the gas zone-02 is the consolidated sandstone having 23% shale, 15% effective porosity, 65% hydrocarbon and 12 mD permeability. The gas zone-03 is only 4 m pay zone within16 m gross reservoir. It is consolidated sandstone with high V_{sh}, low porosity, and low S_h. The reservoir of the gas zone-04 is consolidated sandstone with fair porosity and permeability (14% and 5 mD). Its pay zone contains 64% hydrocarbon. This zone is comparatively tight sandstone reservoir than others. The gas zone-05 has only 1.8 mpay zone within the 11.59 m gross reservoir. The reservoir is consolidated sandstone with lowS_h and permeability. It is mainly gas-bearing water formation except for the pay zone.

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