Petroleum and Coal

Article **Open Access**

Prediction of Average Porosity of Sand Gas Reservoir in Bangladesh

Md. Sumon Chowdhury[1], Md. Shaheen Shah[2,3]*

[1] *Department of Petroleum and Mineral Resources Engineering, Bangladesh University of Engineering and Technology, BUET, Dhaka, Bangladesh*
[2] *Department of Oil and Gas Engineering, Memorial University of Newfoundland, Canada*
[3] *Department of Petroleum and Mining Engineering, Jashore University of Science and Technology, Jashore, Bangladesh*

Received July 25, 2019; Accepted November 3, 2020

Abstract

Porosity is one of the most important properties of reservoir rock which is essential for reserve estimation, formation evaluation and petrophysical properties analysis. This study focus on porosity estimation of three wells of Habiganj gas fields (HB-7, HB-9 and HB-10) in North-Eastern part of Bangladesh. The UGS zone of the reservoir is considered for this research. Two wireline logs (Neutron log and Density log) are used to calculate the porosity and average porosity by arithmetic means. The density log indicates a higher value of average porosity than neutron porosity for HB-7 and HB-10 but vice-versa for HB-9. The average porosity by neutron-density combined log is 29.29%, 32.82% and 35.76% for HB-7, HB-10 and HB-9 respectively. The effective porosity of Habiganj gas field ranges from 29 % to 36% which is good in quality for hydrocarbon potential evaluation.

Keywords: *Porosity; Neutron log; Density log; Surma basin; Bokabil-Bhuban formation.*

1. Introduction

Bangladesh is a densely populated country having 147570 sq kilometers area and 158.9 million inhabitants [1]. In spite of having coals, peats and heavy minerals in the coastal area, natural gas is the main source of energy in Bangladesh. There are 27 discovered gas fields in the greatest delta land, Bangladesh where most of them are in the fold belt zone [2]. Habiganj gas field is one of the most productive gas fields in this country. Total recoverable gas reserve is 2,787.00 bcf. Commercial gas production from this field was started in 1968 and till October 31, 2019 total 2479.750 bcf of reserves has been recovered which is 88.98% of reserves [3].

There are 11 wells in Habiganj gas field. According to BGFCL, gas production from HB-2, HB-8 and HB-9 was suspended due to excessive water and sand production. Among the 11 wells, this study is based on three wells which are HB-7, HB-9 and HB-10. Properties of reservoir rocks are very much important to analyze and characterize any reservoir. Porosity, permeability, saturation and such other rock and fluid properties provide an idea about the reservoir types and also about reservoir fluid types. Porosity is the capability of a rock to hold fluids in pore. It is the indicator of reservoir rock compactness. It is simply the void volume and total volume ratio of reservoir rock. A reservoir rock having a higher porosity may not be capable of production if there is no connection amongst the pore space. Effective porosity is that parameter which originally indicates whether a reservoir rock is good or not. It is the ratio of interconnected pore space volume to the total bulk volume of the rock.

Porosity in sandstone varies primarily with grain size distribution and grain shapes, packing arrangement, cementation and clay volume [4-5]. When the fluid and matrix effects are known or can be determined, the log record can be related to porosity [6]. It is the interconnected pore space of the reservoir rock. Generally sandstone, limestone and dolomite act as reservoir rock. Shale acts both as source rock and reservoir rock. Normally sandstone has higher porosity than limestone and dolomite. Shale has higher porosity than sandstone but it has little permeability than sandstone. This is the reason why sandstone is called good reservoir rock. Porosity of the reservoir rock can be determined by core analysis in the laboratory or by wire line log data analysis. Sonic log, density log, neutron log can be used to determined porosity of a formation. In this research, neutron log and density log are analyzed to estimate porosity of the defined wells.

Habiganj gas field has two production sand zone called UGS and LGS. The UGS of this field lies at depth of 1320 m to 1550 m which has an average permeability of 2 to 4 darcy. The LGS lies at a depth of 3000 m below the surface and has very little permeability of less than 100 md [7]. This research is on upper gas sands zone of Habiganj gas fields.

2. Study area and geological setting

Habiganj gas field is located at 24.3750°N and 91.4167°E. It lies in Madhabpur upazila which is under Habiganj district. This gas filed is 100 km away to the from capital city of Bangladesh, Dhaka to a direction of northern-east [3]. Total area of Habiganj gas field is 2,636.58sq km. and bounded by Sunamganj District to the north, Tripura of India and Maulvibazar District to the east, Balaganj upazila of Sylhet to the northeast, Brahmanbaria and Kishoreganj districts to the west. This field is located in Surma basin which is divided into Bokabil and Bhuban formations [8]. The study area is shown in Figure1.

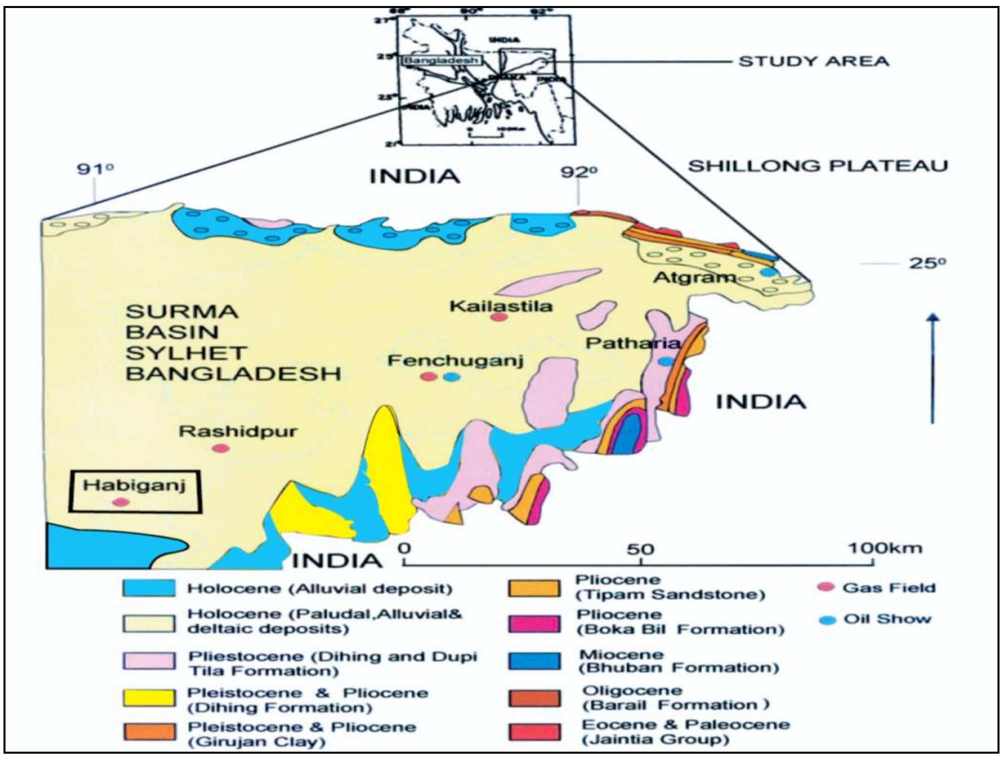

Figure1. Location map of the study area [8]

The thickness of Surma group varies from about 3500 m to 4000 m. Surma group is underlying by the Barail group and overlying by the Tipam group. Barail group is composed of predominantly sandstone, shale, and siltstone. The Surma group is composed of alternating sandstone, shale siltstone, conglomerate, and clay. The Sylhet succession is divided into six groups (Table1).

Table1. Stratigraphy of the Sylhet basin, Bangladesh [8-9]

Age	Group	Formation	Lithilogy	Depositional Environment
Recent	Alluvium	Alluvium	Sand,silt,clay	Fluvial
Late Pleistocene	Dihing	Dihing	sandstone,shale	Fluvial
Pliocene-Pleistocene	Dupitila	Dupitila	sandstone,shale	Fluvial
Late Miocene-Pliocene	Tipam	Girujan Clay	Clay,sandstone	Fluvial, lacustrine
		Tipam Sandstone	Sandstone,shale	Fluvial
Middle-Late Miocene	Surma	Bokabil	Sandstone,shale	Merine,deltic
		Bhuban	Sandstone,shale	
Late Eocene-early Miocene	Barail	Renji	Sandstone,shale	Shallow marine, deltic
		Jenam	Shale,sandstone	
Late Eocene	Jaintia	Kopili Shale	Shale, minor 1st	Shallow marine, deltic
Early-middle Eocene		Sylhet Limestone	Limestone	Shallow marine
Paleocene-early Eocene		Tura Sandstone	Quartz arenites	Shallow marine

3. Methodology

3.1. Necessary data and data collection

The necessary data for this study is wellbore log data. Among the 11 wells of Habiganj gas field, HB-7, HB-9 and HB-10 are selected for this research as log data of these fields is managed. Neutron and density log are used for porosity assessment. Wireline log data is collected from Petrobangla and some relevant data are taken from literature available.

3.2. Porosity assessment from density log

Porosity of a reservoir rock denotes the amount of porous space into the rock. It can be defined as the ratio of pore volume to bulk volume. Mathematically it can be expressed as:

$$\text{Ø}\ (\%) = \frac{(V_b - V_p)}{V_b} \times 100 \qquad (1)$$

where: Ø = Porosity in percentage; V_b = Bulk volume of the rock; V_p = Pore volume of the rock.

The density log provides the value of bulk density of the formation rock which is required to calculate density porosity. The density porosity can be calculated from the following formula [10]:

$$\text{Ø}_D\ (\%) = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f} \times 100 \qquad (2)$$

Where: Ø_D = Density porosity in percentage; ρ_{ma} = Matrix density of the rock, g/cc; ρ_b = Bulk density of the rock, g/cc; ρ_f = Formation fluid density, g/cc.

The bulk density is the average density of a unit of the formation. It can be expressed by the following equation [11]:

$$\rho_b = (\text{Ø} \times \rho_f) + (1{+}\text{Ø}) \times \rho_{ma} \qquad (3)$$

Matrix density varies with formation rock types. Sandstone, mudstone, shale, limestone and dolomite has individual matrix density range. The average matrix density for these rocks are shown in Table 2.

Table 2. Common matrix density of some formation rocks [11-12]

Rock Types	Matrix density (gm/cc)	Rock Types	Matrix density (gm/cc)
Sandstone	1.9 – 2.65	Clay	1.1 – 1.8
Limestone	2.2 – 2.71	Dolomite	2.3 – 2.87
Shale	2.4 – 2.8	Anhydrate	2.98

For this study, the sandstone matrix density is taken 2.65 gm/cc, shale matrix density 2.8 gm/cc. The formation fluid density depends on fluid types. Generally, the density value 0.9 gm/cc is for formation oil, 0.7 gm/cc for gas, 1.0 gm/cc for fresh water and 1.1 gm/cc for salty water. To conduct this research, the authors use 1.0 gm/cc of fresh water density as formation fluid. From previous research studies on Habiganj gas field, HB-7 is sandstone formation, HB-9 is shale formation up to 1350 m depth, sandstone from 1355 m to 1420 m depth and HB-10 is full of sandstone formation.

3.3. Porosity assessment from Neutron log

The neutron porosity is directly determined from neutron log. The log reading is fractional porosity value. The oil and gas presented in a formation gives high porosity value in neutron log. The Neutron log is primarily used to evaluate formation porosity, but actually it is a hydrogen detector.

3.4. Porosity assessment from Neutron - Density log

The average porosity of a formation is determined by the neutron-density combined log. It gives accurate value than neutron or density individual porosity results. The neutron-density porosity is determined by the following formula:

$$\emptyset_{N-D}\,(\%) = \sqrt{\left(\frac{\emptyset_D{}^2 + \emptyset_N{}^2}{2}\right)} \times 100 \qquad (4)$$

where: $\emptyset_N$ = Neutron porosity in percentage; $\emptyset_{N-D}$ = Neutron-density porosity in percentage

4. Results and discussion

The data quality of the studied well HB-7, HB-9 and HB-10 were good enough to read out from the log record. The formation for HB-7 and HB-10 is fully considered sandstone for this research where as shale formation is considered up to a certain depth for HB-9. The neutron porosity is directly taken from the neutron log. The bulk density of the formation is found from the density log. The neutron porosity of HB-7 varies from 16% to 40% in the depth of 1475 m and both 1340 m, 1435 m depth respectively. The average neutron porosity of the well HB-7 is found 25.14%. The density log shows a higher porosity than the neutron porosity. The lowest porosity in HB-7 from density log is determined at 1375 m depth and that is 24.24% where the higher porosity is found at 1340 m depth which is 39.39%. The bulk density is found 2.25 gm/cc for lowest porosity and 2.0 gm/cc for higher porosity. The average density porosity for HB-7 found in this research is 31.77% which is higher than neutron porosity. The combined neutron-density porosity gives the more appropriate value of porosity of any well. The neutron-density porosity of HB-7 lies from 24.23% to 36.82%. The average combined porosity is found 29.29% which is slightly less than density porosity. The porosity profile for HB-7 is shown in Figure 2 and Figure 3. The average porosity of HB-7 was determined 30%-35% according to Shofiqul *et al.* [13].

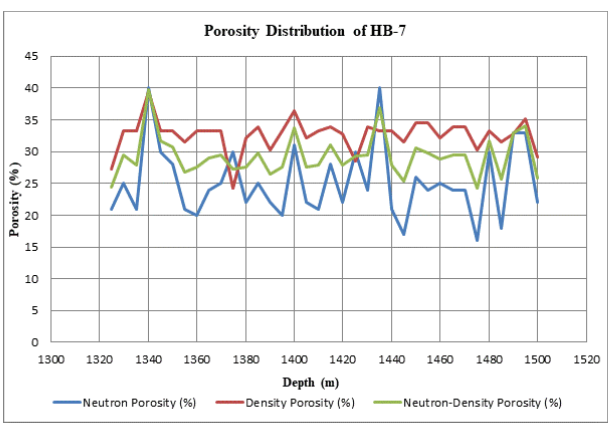

Figure 2. Porosity of HB-7 by various methods

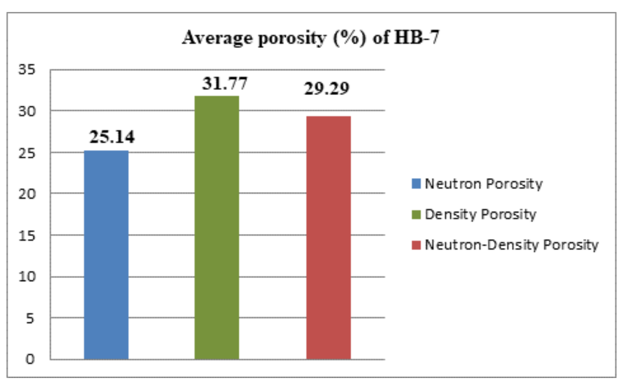

Figure 3. Average Porosity of HB-7

The formation of HB-10 is more porous than that of HB-7. The neutron porosity is determined from 13% to 28% for HB-10. The average neutron porosity is determined 18.57% for the same well. Density porosity is higher than neutron porosity. The average density porosity is found in this research is 41.92% for HB-10 where as the neutron-density porosity of HB - 10 ranges from 20.61% to 39.69% but the average porosity is 32.82%. The previous study determines average porosity of HB-10 is 30%-35%. The porosity profile for HB-10 is shown in Figure 4 and Figure 5.

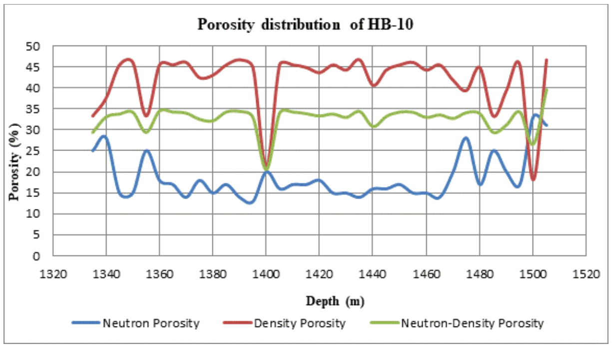

Figure 4. Porosity of HB-10 by various methods

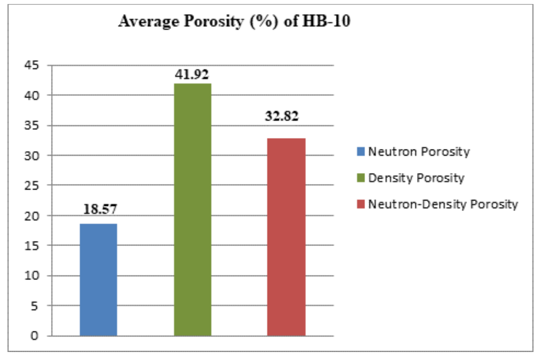

Figure 5. Average Porosity of HB-10

The neutron porosity of HB-9 varies from 35% to 43%. The average porosity determined from neutron log of HB-9 is 38.72% which is higher than that of HB-10. The density porosity shows a lower value than neutron porosity as the formation rock in HB-9 is shale from 1250 m to 1350 m depth. The density porosity ranges from 21.21% to 44.44 % where the average value is 32.43%. The combined neutron density porosity shows a higher value than the density porosity of HB-9. The average neutron density porosity of HB-9 is 35.76%. The porosity is almost fair up to 1350 m depth of HB-9 as it is shale formation but it is seen to decrease the porosity from 1355 m depth to the bottom of the well cause of sandstone formation. The porosity profile for HB-9 is shown in Figure 6 and Figure 7.

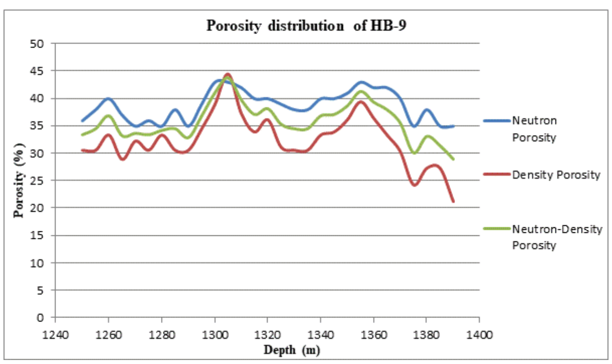

Figure 6. Porosity of HB-9 by various methods

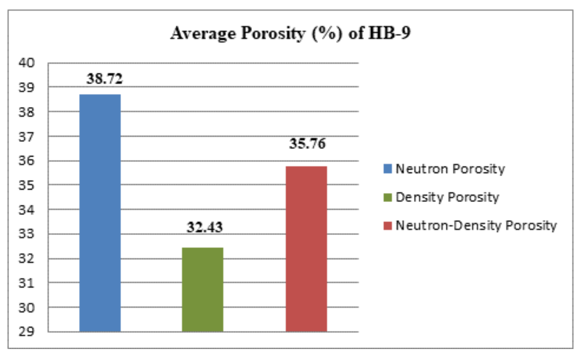

Figure 7. Average Porosity of HB-9

The authors find out that the effective porosity of Habiganj gas field ranges from 29 % to 36% which is near about the previous studied results. Imam [7] estimated the porosity of Habiganj gas field 30%. Shafiqul *et al.* [13] found porosity ranges from 30 % to 40 %. The result summary for porosity determination of Habiganj gas field is shown in table 2.

Table 2. Result summary of the research

Well		Average porosity	
	Ø_(N) (%)	Ø_D (%)	Ø_(N-D) (%)
HB-7	25.14	31.77	29.29
HB-10	18.57	41.92	32.82
HB-9	38.72	32.43	35.76

5. Conclusion

Porosity assessment from wire line log data is more accurate than core analysis in laboratory. The neutron density combined porosity is more accurate than individual density porosity, individual sonic porosity or neutron porosity. The density log showing a lower value and neutron log showing a higher value at the same depth indicates hydrocarbon bearing zone. This study denotes HB-9 is more porous than HB-7 and HB-10. The total porosity of Habiganj gas field is estimated 32.6 % by neutron density combined method based on HB-7, HB-9 and HB-10. The authors made their research on upper gas sand layers of Habiganj gas field. Accurate result depends on appropriate data which are read from wire line log record. However, the assessment results by this study are near about previous records.

Nomenclature and abbreviations

HB	*Habiganj gas field*	*BGFCL*	*Bangladesh Gas Field Company Limited*
UGS	*Upper Gas Sand*	*gm/cc*	*Gram per cubic centimeter*
LGS	*Lower Gas Sand*	*md*	*Milidarcy*

Appendix-1. Log data analysis for HB-9

Depth (m)	Density, ρ_b (gm/cc)	Neutron $Ø_N$ (%)	Depth (m)	Density, ρ_b (gm/cc)	Neutron $Ø_N$ (%)
1250	2.25	36	1325	2.24	39
1255	2.25	38	1330	2.25	38
1260	2.20	40	1335	2.25	38
1265	2.28	37	1340	2.20	40
1270	2.22	35	1345	2.19	40
1275	2.25	36	1350	2.15	41
1280	2.20	35	1355	2.00	43
1285	2.25	38	1360	2.05	42
1290	2.25	35	1365	2.10	42
1295	2.18	39	1370	2.15	40
1300	2.10	43	1375	2.25	35
1305	2.00	43	1380	2.20	38
1310	2.13	42	1385	2.20	35
1315	2.19	40	1390	2.30	35
1320	2.15	40	1325	2.24	39

Appendix-2. Log data analysis for HB-10

Depth (m)	Density, ρ_b (gm/cc)	Neutron $Ø_N$ (%)	Depth (m)	Density, ρ_b (gm/cc)	Neutron $Ø_N$ (%)
1335	2.10	25	1425	1.90	15
1340	2.03	28	1430	1.92	15
1345	1.90	15	1435	1.88	14
1350	1.89	15	1440	1.98	16
1355	2.10	25	1445	1.92	16
1360	1.90	18	1450	1.90	17
1365	1.90	17	1455	1.89	15
1370	1.89	14	1460	1.92	15
1375	1.95	18	1465	1.90	14
1380	1.94	15	1470	1.96	20
1385	1.90	17	1475	2.00	28
1390	1.88	14	1480	1.91	17
1395	1.91	13	1485	2.10	25
1400	2.30	20	1490	2.00	20
1405	1.90	16	1495	1.90	17
1410	1.90	17	1500	2.35	33
1415	1.91	17	1505	1.88	31
1420	1.93	18			

Appendix-3. Log data analysis for HB-7

Depth (m)	Density (ρ_b) (gm/cc)	Neutron, ØN (%)	Depth (m)	Density (ρ_b) (gm/cc)	Neutron, ØN (%)
1325	2.2	21	1420	2.11	22
1330	2.10	25	1425	2.18	30
1335	2.10	21	1430	2.09	24
1340	2.0	40	1435	2.10	40
1345	2.1	30	1440	2.10	21
1350	2.1	28	1445	2.13	17
1355	2.13	21	1450	2.08	26
1360	2.10	20	1455	2.08	24
1365	2.10	24	1460	2.12	25
1370	2.10	25	1465	2.09	24
1375	2.25	30	1470	2.09	24
1380	2.12	22	1475	2.15	16
1385	2.09	25	1480	2.10	30
1390	2.15	22	1485	2.13	18
1395	2.10	20	1490	2.11	33
1400	2.05	31	1495	2.07	33
1405	2.12	22	1500	2.17	22
1410	2.10	21			
1415	2.09	28			

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To whom correspondence should be addressed: Md. Sumon Chowdhury, Department of Petroleum and Mineral Resources Engineering, Bangladesh University of Engineering and Technology, BUET, Dhaka, Bangladesh E-mail: sumonpme12@gmail.com