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Reserve Estimation of Beani Bazar Gas Field, Bangladesh Using Wireline Log Data

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Abstract—Reserve estimation is very important part for determination of gas field's lifetime which is known as production duration of gas fields. Beani bazar gas field very rich in condensate has been discovered in October 1982. Although drilling was completed in May 1981, but in view of economic considerations the production testing of two potential gas sands detected from well logs were not conducted with the expensive parker rig at that time. But at last production testing of Beani bazar well was carried out by the same rig in August-September 1982 and the presence of commercial gas deposit with high content of condensate is confirmed. Beani bazar gas field is located about 30 km which is at the east of Sylhet town and 15 km east of Kailastila gas field. Reserve estimation of Beani bazar gas field has been done by volumetric reserve estimation method. This method's factors are estimated using wireline log data. In the preliminary reserve calculated earlier has shown in the total reserve of gas in place at 1.1 TCF and recoverable reserve at 0.8 TCF. According to estimation the total recoverable gas reserve comes at 0.243 TCF of which proven, probable and possible reserves are 0.098 TCF, 0.076 TCF and 0.069 TCF respectively. The recoverable condensate reserve is 3949000 BBLs.

Index Terms: Beani Bazar Gas Field, Reserve Estimation, Volumetric Method, Recoverable Reserve, Wireline Log Data, Condensate, Gas.

1 Introduction

Natural gas is the main origin of power and energy in Bangladesh which is the causes of development. Close to 2017, a total of 27 gas fields have been discovered in Bangladesh among them twenty five are onshore and two are offshore. The sandstone reservoir of gas field arises in Miocene-Pliocene age and the depths of about 1000 to 3500 m below the surface in Bangladesh [1]. Beani Bazar gas field is one of them among twenty five onshore gas fields. The location of study area as Beani Bazar gas field (Fig-1) is Beani Bazar upazila of Sylhet District in the division of Sylhet, Bangladesh where Beanibazar-1 is located at 92^{o}10′18″ N and 24^{o}97′33″ E and Beanibazar-2 is located at 92^{o}10′9.99″ N and 24^{o}48′24.99″ E [2]. The main targets of this study are to estimate the hydrocarbon reserve of the Beani Bazar gas field by using wireline log data. Wireline log data such as porosity, hydrocarbon saturation and water saturation are determined by different types of log method as gamma ray (GR), spontaneous potential (SP), resistivity, neutron and density log [3].

The structure of the Beani Bazar gas field is a symmetrical anticline with a dimension of about 12 km × 7 km. The structure is situated along the eastern flank of Surma basin. The well was spudded on November 20, 1980 and was terminated on May 12, 1981. The well was terminated at 3990 m (side tracked hole) i.e. 1039 m above target due to technical problems.

The Beani bazar structure is exposed on the surface, and only Dupitila formation is exposed. For this reason it did not attracted much attention for geological survey. Seismic survey over Beani bazar was first carried out by PSOC in 1959/1960. PSOC data confirmed the presence of the structure at depth. Since then there was no activity at Beani bazar. In 1979, Prakla was engaged for resurvey the area and 90 km of 12 fold coverage was shot. The quality of seismic data recorded was much better than the old one.

Two structural contour maps were prepared for selecting a location for deep exploratory well. Drilling started on 20 November, 1980 and was terminated at 3990 m (side tracked hole) on 12 May, 1981. In straight hole T.D. was 4111 m. After logging two potential gases sand was identified. In August & September 1982 these two zones were tested and presence of commercial gas was discovered.

2 Geological structure & gas potential of Beani Bazar gas field

Beani Bazar structure is situated within the folded flank of the Bengal fore deep. The structure lies on the Western margin of the Chittagong-Tripura folded belt in the south central part of the Surma Basin. On the surface the structure has a north south extension of about 12 km and 7 km wide. The dips of the flanks are symmetrical and the amplitude is gradually decreasing with increase of depth. In the upper horizon dips are low (2^0-3^0) but in the deeper horizon this increases slightly and amounts to (8^0-11^0). The northern pitch is steeper than the south. The top of the upper pay zone was delineated by contour line of 3200 m and the crest is found about 500 m NNW. The dimension of the structure on top of the upper pay zone is 11 km × 5 km (within closed contour 3400 m) and the amplitude is about 200 m. The dimension of the structure on top of the lower pay zone does not change much. But the crest of the lower zone is slightly shifted towards SSE and the well is almost on the top. No faults were observed from the 2D seismic data over the Beani Bazar structure or it's about. This is probably due to the low resolution of the variable quality 2D seismic data and probably more faults can be expected to be seen in a higher resolution 3D seismic data set.

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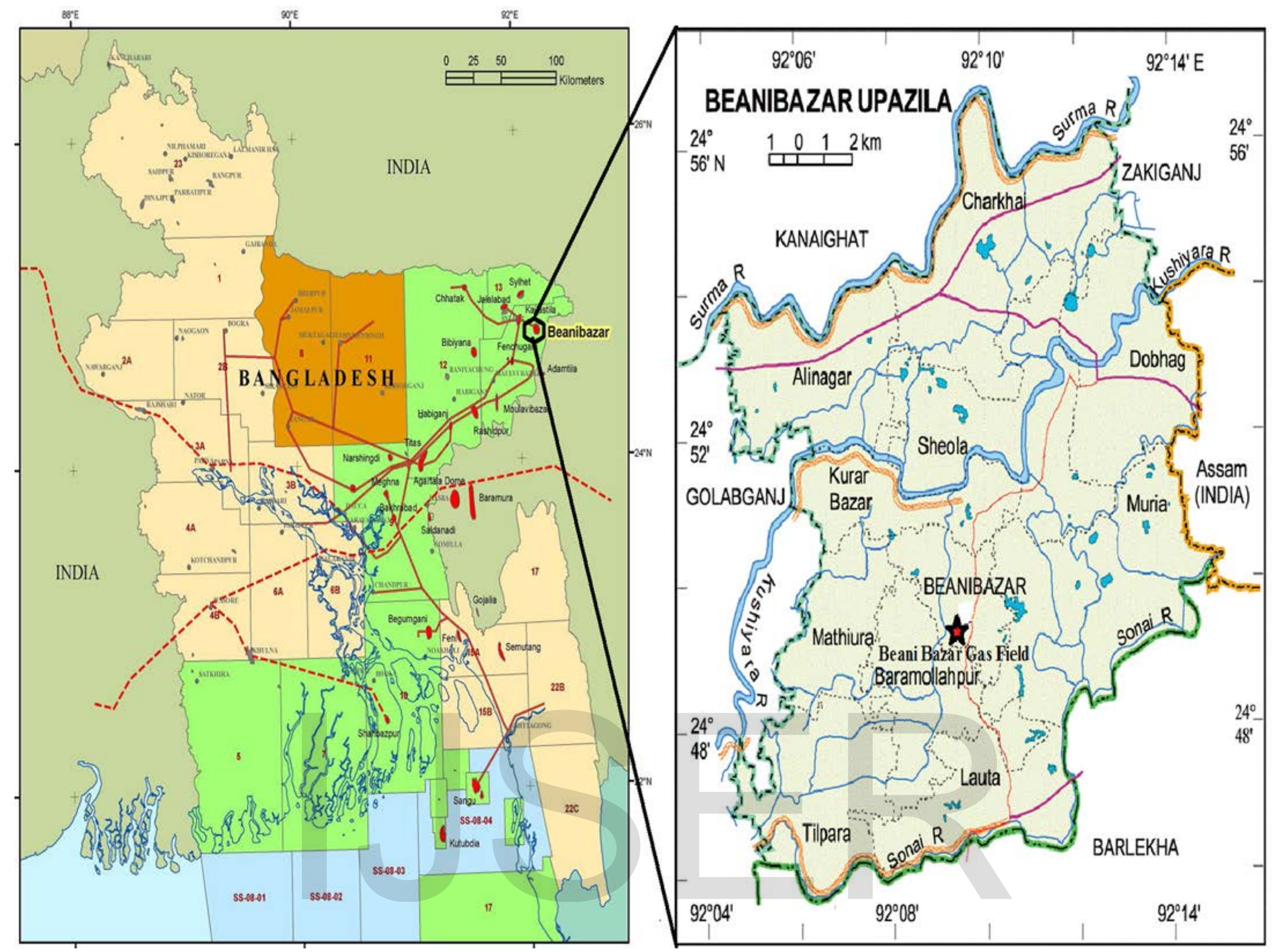

Fig-1: Location map of beani bazar gas field (Modified after RPS energy report, Petrobangla) [4].

The pay zones of Beani bazar gas field are from Surma group and probably from bhuban formation. The upper reservoir is sandstone horizon with thin bands of shales. In the well section it covers the interval 3205.3-3376.7 m. A 38 m thick shale unit is serving as cap rock. The porosity of sandstone ranges from 15% to 17% with an average of 16.3% for the gas saturated part. The gas saturated sandstone was encountered in the interval 3233-3280.6 m. The lower part of the reservoir is water saturated and GWC is located at -3252.90 m (BMSL). The seismic reflector corresponding to the top of the pay zone is quite prominent and can be traced to a considerable distance. This feature indicates lithological persistence of the pay zone across the area.

The gas pool is 47.6 m high at the crest and about 4.5 km long and 2.5 km wide. The lower zone is also a sandstone reservoir and in the well it covers the interval 3425.5-3439.8 m. The cap rock is a 50 m thick shale bed. The porosity of sandstone is within the range of 14% to 20%. The average porosity is 17% and porosity result from core gives a value of 17.15%. In the well the entire sandstone sequence is gas saturated. For this reason the position of GWC could not be determined. If we consider the percentage of filling in upper horizon then for the lower horizon GWC can be placed at -3500 m (BMSL). The seismic reflection which corresponds to the top of the pay zone can be traced easily in the southern part of the reservoir, but in the north it becomes indistinct about 1 km north of the crest. This might be due to some lithological variation. The gas pool of lower horizon is about 2.2 km long for confirmed GWC and 6.2 km for possible GWC. The width and height is 1 km and 14.3 m for the first case and 2.6 km and 60.2 m for the later case.

By the other gas fields of the region it can be assumed that at Beani bazar the reservoir drive mechanism will be a combined water drive and depletion one. All the other sandstone horizons of Beani bazar was found to be water bearing.

3 Materials & Methodolgy

Wireline log is too much essential because of estimating the reserve of a petroleum reservoir [5]. Reserve estimation is determined by different methods by using reserve estimation factor which be had of wireline logs. Reservoir properties such as porosity, water saturation, hydrocarbon saturation, permeability from wireline logging data which support to estimate the quantity of hydrocarbon reserve using volumetric reserve estimation method [6]. When available production data and development activities are few, volumetric reserve estimation methods are applied in early stage of the reservoir life which is least accurate [7]. But production data become available, volumetric reserve estimates are more accurate [1].

The study is mainly based on the petro physical properties of Beani Bazar gas field. The gas reserve of Beani bazar was determined by using the following relationship:

$$Q = A.h.\phi.S_g.\beta.f.k \qquad (1)$$

Where, Q = Recoverable gas reserve in Million M³, A = Gas bearing area in sq.km, h = Effective thickness in meter, ф = Effective porosity, S_g = Gas saturation, β = Pressure correction factor, f = Temperature correction factor and k = Gas recovery factor.

This system for estimation of gas reserve was followed while estimating reserves of Semutang, Titas, Feni, Hobigonj, Kamta and Begumgonj gas fields.

Gas Bearing Area: Gas is accumulated within the subsurface porous area is called gas bearing area. For determining gas bearing area two structural contour maps on top of upper and lower zones were prepared. Gas bearing area within reservoir and reservoir discontinuities such as pinch outs, faults, and/or gas-water contacts (GWC) are determined by using seismic depth structural maps and/or subsurface isopach maps [8,9].

Effective Thickness: Effective thickness is the vertical bore of a reservoir where petroleum can be outcome at a beneficial rate [10]. Well data from wireline log sheet are used for determining the effective thickness of a reservoir. This was determined after carefully studding the logs. With the help of log data and structural map one net sand isopach map was prepared.

Porosity: Porosity was taken from log evaluation results and was averaged for the entire pay zone. Using density-neutron logs (Schlumberger, 1979), porosity are estimated after determining the volume of shale.

The porosity equation [11] from density log can be given bellow:

$$\phi_d = \left(\frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f}\right) - V_{sh}\left(\frac{\rho_{ma} - \rho_{sh}}{\rho_{ma} - \rho_f}\right) \qquad (2)$$

Where, $\emptyset_d$ = The density porosity, ρ_{ma} = Matrix density (gm/cc), ρ_b = Bulk density, ρ_f = Fluid density and ρ_{sh} = Shale density.

The clay corrected Neutron porosity is measured by neutron log through following equation [11]:

$$\phi_{n-corr} = NPHI - (V_{sh} * NPHI_{sh}) + Lithology\ Correction \qquad (3)$$

Where, NPHI = Neutron logs value of zone of interest, $NPHI_{sh}$ = Average neutron log value of shale volume and Lithology correction=0.04.

By using two logs record different porosities for a zone to obtain correct porosities from density-neutron logs using Schlumberger [12], which are given bellow:

$$\phi = \sqrt{\left(\left(\phi_n^2 + \phi_d^2\right)/2\right)} \qquad (4)$$

Where, ∅ = The percent of porosity, $\emptyset_n$ = Neutron porosity and $\emptyset_d$ = Density porosity.

Gas Saturation: As before this was also taken from log and also averaged for the entire pay zone. The reservoirs are totally filled by gas known as gas saturation. The gas saturation determined after the water saturation can be measured.

According to Simandoux method, the water saturation equation [13] given bellow:

$$S_w = \left(\frac{0.4 \times R_w}{\phi^2}\right)\left[\frac{V_{sh}}{R_{sh}}\sqrt{\left(\frac{V_{sh}}{R_{sh}}\right)^2 + \frac{5\phi^2}{R_t \times R_w}}\right] \qquad (5)$$

Where, S_w = Water saturation, R_w = Formation water resistivity, ∅ = Porosity, V_{sh} = Shale volume, R_{sh} = Resistivity of shale volume and R_t = True resistivity.

Gas saturation of a reservoir [14] can be determined by the following equation:

$$S_{hc} = 100 - S_w \qquad (6)$$

Recovery Factor: The gas recovery factor was taken at 0.95 for the upper zone and 0.85 for the lower zone. As no detail study of the reservoir of the gas fields of this country was done the recovery factor is determined by using the widely accepted value and available information on the geological features of the concerned gas field. At Beani bazar the recovery factor for the lower zone is less because of possible deteriotion of reservoir properties north of the crest.

From the production test data gas condensate ratio was found to 112.4 cc/M³ for the upper zone and 89.9 cc/M³ for the lower zone. These values are used for calculating initial reserve of condensate.

Pressure and Temperature Correction Factor: The parameters so for determined will provide volume of gas under reservoir conditions. For calculating gas volume at standard condition (200°C & 1 ATM), essential formation pressure and temperature data were taken from the results of production testing (table-1). Final formation pressure and final correction factor for the deviation of gas from Boule-Mariotte's law was taken as 1.

For calculating the recoverable condensate reserve, the recovery factor is needed. For calculating recoverable condensate reserve the charts/monograms of F.A. Grishin (1975) cannot be used where condensate/gas ratio exceeds 30 gm/cc [15]. Moreover no laboratory data is available.

Under these circumstances the recoverable condensate reserve can be determined by the following formula [16]:

$$\omega = Q.N.C \qquad (7)$$

Where, ω = Recoverable condensate reserve, Q = Recoverable gas reserve in M³, N = Relative factor equal to the ratio of condensate recovery factor to the initial gas condensate factor and C = Value of the condensate recovery factor.

TABLE-1
PRODUCTION TESTING RESULTS OF BEANI BAZAR GAS FIELD

Pay Horizon	Depth Interval, M	Perforated Interval, M	Flow rates with different chokes, gas in thousand M³/day, condensate in M³/day				Absolute gas flow rate, thousand M³/day	Formation pressure, atm	Formation temperature, ⁰C	Condensate SPGR gr/CM³	Gas SPGR VS. air
			46/64"	38/64"	30/64"	24/64"					
Upper	3205.3-3376.7	3233.9-3251.3 3277.2-3280.6	617.5/ 61.7	538.3/ 57.1	408.9/ 45.1	298.9/ 28.0	3311.1	332.2	84.4	0.7826	0.600
Lower	3425.5-3439.8	3453.8-3458.1 3461.7-3467.8	543.4/ 47.9	461.3/ 39.2	339.6/ 26.1	205.7/ 9.2	3537.5	348.4	91.7	0.7949	0.604

4 RESULTS & DISCUSSIONS

Reserve estimation data such as area, thickness, porosity, gas saturation and so on are determined using the above equation where essential data (for estimating reserve estimation data) are collected from wireline log sheet (Fig-2) in Petrobangla.

Gas bearing area: The area was determining by planimetering using seismic depth structural maps and/or subsurface isopach maps which were given in table-2. For the upper pay zone the area within 1 km radius from the well was considered for estimating proven reserve and remaining part of the gas saturated area i.e. area within GWC line was taken for estimating probable reserve. In case of lower pay zone the area bounded by contour line 3439.8 m was taken for calculating proven reserve. The remaining area of the pay zone within the contour line 3500 m was considered for estimating possible reserve.

Effective thickness: The vertical thicknesses of a beani bazar gas field reservoir are determined from wireline log observation. These are given in table-2 and 3.

Porosity and Gas saturation: From wireline log sheet observation and using equation 2 to 6, the porosity and gas saturation of beani bazar gas field are determined which can be given in table-2 and 3.

TABLE-2
ESTIMATION OF GAS RESERVE DATA FROM WIRELINE LOG SHEET OBSERVATION WITH USING EQUATIONS

Zone	Reserve Categories	Gas Bearing Area, km²	Effective Gas Saturated Thickness, M	Porosity	Gas Saturation
Upper	Proven	3.14	25.1	0.163	0.74
	Probable	4.97	13.6	0.163	0.74
Lower	Proven	1.78	6.9	0.17	0.57
	Possible	11.50	7.7	0.17	0.57

TABLE-3
CALCULATION OF EFFECTIVE GAS SATURATED THICKNESS, POROSITY AND GAS SATURATION COEFFICIENTS FOR BEANI BAZAR FIELD

Depth Interval, M	Effective Gas Saturated Thickness, (h)	Porosity Coefficient, (M)	Multiplication Product of Porosity Coefficient by Effective Gas Saturated Thickness (h×M)	Gas Saturation Coefficient (S_{gc})	Multiplication Product of Gas Saturation by Effective Gas Saturated Thickness (h× S_{gc})
3233.0-3237.3	4.3	0.155	0.666	0.72	3.096
3237.9-3240.3	2.4	0.16	0.384	0.76	1.872
3242.1-3251.9	9.8	0.16	1.568	0.74	7.252
3255.0-3257.4	2.4	0.165	0.396	0.75	1.800
3258.0-3263.5	5.5	0.17	0.935	0.76	4.180
3264.7-3269.6	4.9	0.17	0.833	0.76	3.724
3269.6-3272.6	3.0	0.15	0.450	0.68	2.040
3278.1-3280.5	2.4	0.18	0.432	0.70	1.680
Total:	**34.7**	**0.163**	**5.664**	**0.74**	**25.644**
3453.2-3455.6	2.4	0.20	0.48	0.66	1.584
3455.6-3457.4	1.8	0.20	0.36	0.62	1.116
3460.5-3461.7	1.2	0.14	0.168	0.5	0.6
3461.7-3463.2	1.5	0.16	0.24	0.6	0.9
3463.2-3465.4	2.2	0.15	0.33	0.5	1.1
3466.3-3467.5	1.2	0.14	0.168	0.5	0.6
Total:	**10.3**	**0.170**	**1.746**	**0.57**	**5.9**

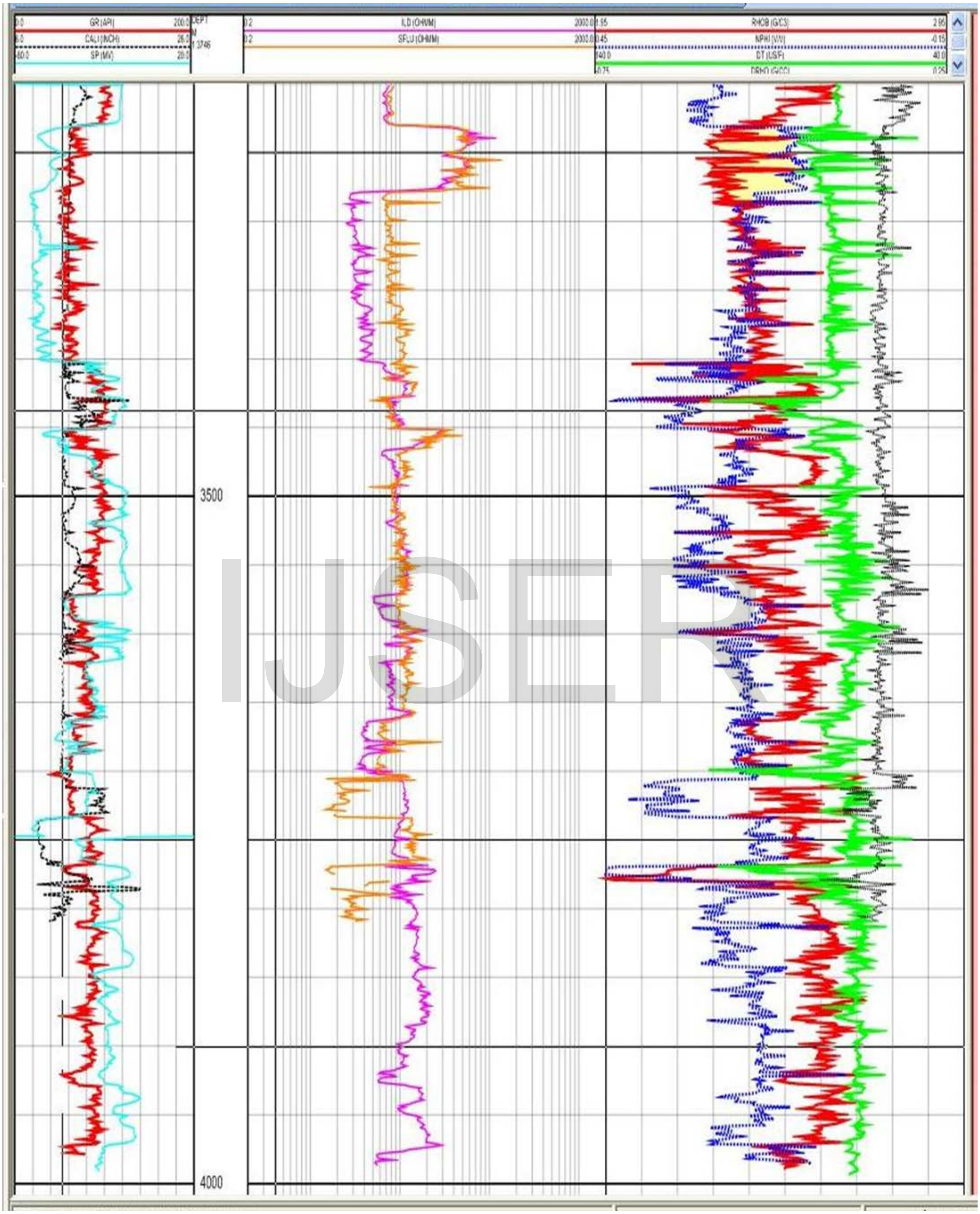

Fig-1: Wireline Log sheet of Beani Bazar Gas Field.

Estimation of gas reserve: Wireline log data such as gas bearing area, effective thickness, effective porosity, gas saturation, pressure correction factor, temperature correction factor and gas recovery factor are determined from subsurface isopach maps and log sheet. Gas reserves are estimated by putting this log data into the equation 1. These gas reserve data for estimation and the results are shown in table-4.

TABLE-4
GAS RESERVE CALCULATION DATA AND RESERVE OF BEANI BAZAR GAS FIELD

Pay Horizon	Reserve Category	Gas Bearing Area, km²	Effective Saturated Thickness, M	Porosity	Gas Saturation	Pressure Conversion Factor	Temperature Correction Factor	Gas Recovery Factor	Gas Reserve			
									Initial		Recoverable	
									mln m³	Tcf	mln m³	Tcf
Upper	Proven	3.14	25.1	0.163	0.74	337.8	0.82	0.95	2633	0.093	2502	0.088
	Probable	4.97	13.6	0.163	0.74	337.8	0.82	0.95	2258	0.080	2145	0.076
Total (Upper Horizon only)									**4891**	**0.173**	**4647**	**0.164**
Lower	Proven	1.78	6.9	0.17	0.57	336.9	0.80	0.85	321	0.011	273	0.010
	Possible	11.50	7.7	0.17	0.57	336.9	0.80	0.85	2313	0.082	1966	0.069
Total (Lower Horizon only)									**2634**	**0.093**	**2239**	**0.079**
Total for field	Proven								2954	0.104	2775	0.098
	Probable								2258	0.080	2145	0.076
	Possible								2313	0.082	1966	0.069
	Total								**7525**	**0.266**	**6886**	**0.243**

Estimation of Condensate Reserve: Wireline log data such as recoverable gas reserve, relative factor equal to the ratio of condensate recovery factor to the initial gas condensate factor and condensate recovery factor are putting into the equation 7 and then estimate the condensate reserve of beani bazar gas field. The parameters for calculating condensate recovery factor and recoverable condensate reserve are given in table-5 and 6.

TABLE-5
CONDENSATE RESERVE CALCULATION PARAMETERS AND CONDENSATE RESERVE OF BEANI BAZAR GAS FIELD

Pay Horizon	Reserve Category	Gas Reserve				Gas Condensate Factor	Initial Condensate Reserve		Condensate Recovery Factor	Recoverable Condensate Reserve	
		Initial		Recoverable							
		mln m³	Tcf	mln m³	Tcf		mln m³	Thousand bbl		mln m³	Thousands bbl
Upper	Proven	2633	0.093	2502	0.088	112.4	0.296	1862	0.81	0.240	1508
	Probable	2258	0.080	2145	0.076	112.4	0.254	1597	0.81	0.206	1294
Total (Upper Horizon only)		**4891**	**0.173**	**4647**	**0.164**		**0.550**	**3459**		**0.446**	**2802**
Lower	Proven	321	0.011	273	0.010	89.9	0.029	182	0.77	0.022	140
	Possible	2313	0.082	1966	0.069	89.9	0.208	1308	0.77	0.161	1007
Total (Lower Horizon only)		**2634**	**0.093**	**2239**	**0.079**		**0.237**	**1490**		**0.183**	**1147**
Total for field	Proven	2954	0.104	2775	0.098		0.325	2044		0.262	1648
	Probable	2258	0.080	2145	0.076		0.254	1597		0.206	1294
	Possible	2313	0.082	1966	0.069		0.208	1308		0.161	1007
	Total	**7525**	**0.266**	**6886**	**0.243**		**0.787**	**4949**		**0.629**	**3949**

TABLE-6
SUMMARY OF RECOVERABLE GAS AND CONDENSATE RESERVE OF BEANI BAZAR GAS FIELD

Zone	Category	Recoverable Gas Reserve (M³)	"N"	"C"	Condensate Reserve (M³)		Condensate Recoverable Factor
					Initial	Recoverable	
Upper	Proven	**2502.10^6**	9.6	1.003	296000	**240913**	0.81
	Probable	**2145.10^6**	9.6	1.003	254000	**206538**	0.81
Lower	Proven	**273.10^6**	8.2	1.003	29000	**22453**	0.77
	Possible	**1966.10^6**	8.2	1.003	208000	**161696**	0.77

It can be seen from the table that bulk of the recoverable gas reserve i.e. 67.5% is in the upper zone. The proven, probable and possible categories amounted to 40.3%, 31.1% and 28.6% respectively.

On significant characteristics of the Beani bazar field is the high condensate ratio and this accounts for the comparatively high recoverable condensate reserve of 3.949 million bbl (0.629 Million M^3). The recoverable condensate reserve of Titas and Habigonj are 3.421 million bbl (0.544 million M^3) and 0.657 million bbl (0.104 million M^3) respectively.

Considering the small area of Beani bazar gas field it is until an experiment to drill more wells to increase production. This will also help to clear the actual position of GWC in the lower horizon and estimate more confidently the reserve of the field. Within a total gas bearing area of upper gas sand respective as 8.11 km^2 around the well down to GWC usually proven reserves are calculated, the leftover area and volume respective down to the GWC are usually considered as probable reserves (to be usually discounted by 31.1%). Since no pay risk can be seen with respect to the lateral/vertical extent of the field, 0.088 TCF (2502 million M^3) and 1508 thousands bbl (0.240 million M^3) are considered as proven.

According to the ratio porosity/water saturation, the lower gas sand is close to the GWC. If the GWC would be expected to be much lower, and if there would be a considered pay risk seen, proven reserves within a cylindrical cone down to GWC (to be usually discounted by 3.97%) and possible reserves for the sand (usually to be discounted by 28.6%). Since no considerable pay risk can be seen, 0.010 TCF (273 million M^3) and 140 thousands bbl (0.022 million M^3) are considered as proven.

The condensate/gas ratio varies considerably from the choke size (this is usually the case). Without doubt, the upper gas sand has a higher condensate ratio. Under a realistic condensate/gas ratio of upper and lower gas sand, 1508 and 140 thousands bbl would be within the upper and lower gas sand respectively that is a total of about 1648 thousands bbl. About 0.243 TCF are supposed to be recoverable gas reserves in beani bazar gas field (recovery factor 0.90). It must be subject of a special reservoir study and production history to figure out the total recoverable condensate; due to pressure drop, the condensate/gas ratio certainly will change in the course of production. In beani bazar gas field, an average annual production of 350,000 barrels condensate could be achieved. An average annual production of 350,000 barrels condensate would be roughly equivalent to about 5% of the imported crude oil. USD annually provided, the Beani Bazar gas can be pipelined to consumers (which might be technically very costly).

5 CONCLUSIONS

Beani bazar well was drilled in 173 days to a depth of 4111 m (straight hole). Due to technical complication target depth could not be reached. Production testing was delayed by about 14 months. The reason be hid this delay was the decision to test the well with P-80 rig and release the expensive parker rig (TBA 2000). At that time 9.80 was engaged at Kailastila for work-over job. Unfortunately P-80 rig is not yet released from Kailastila. Final production testing was completed in August/September 1982 with the parker rig. The cost of drilling Beani bazar is 34 million taka in local currency and 12.90 million US $ in foreign exchange. The total expenditure is 317.80 million taka. The total reserve of recoverable gas reserve was estimated at 0.266 TCF and recoverable condensate at 3949000 bbl. In case of a production of 40 MMCFD gas about 800 barrels of condensate will be produced. The net revenue will be about 1.94 million taka/day. The estimate is based on market value of gas, motor spirit and diesel oil. The condensate of Beani bazar contains 80% motor spirit and 20% diesel oil. Considering the high condensate contain the Beani bazar field should be brought under production as early as possible.

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