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Reserve Estimation of Saldanadi Gas Field

Prokash Dey[1], Pulok Kanti Deb[2], Shireen Akhter[3], and Debotosh Dey[4]

[1]Bsc Student, Petroleum and Mining Engineering,
Shahjalal University of Science and Technology, Sylhet-3114, Bangladesh

[2]Assistant Professor, Petroleum and Mining Engineering,
Shahjalal University of Science and Technology, Sylhet-3114, Bangladesh

[3]Deputy Manager, Geological Division,
Bangladesh Petroleum Exploration and Production Company Limited, Dhaka-1215, Bangladesh

[4]Msc Student, Petroleum and Mineral Resources Engineering,
Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh

ABSTRACT: Estimation of gas-initially-in-place GIIP (2P) and remaining gas reserves are a matter of re-examination and very crucial for the oil/gas industry and for the national policy related to energy regulation. There are wide range of reserve estimation method in different sources over time, which has a different range of uncertainty. Reserve means the quantity of gas/oil that is commercially recoverable from known underground hydrocarbon deposit. An existing oil/gas industry needs to know the present reserve of the existing reservoir to take endeavor for further augmentation of field to increase oil/gas productivity. Among several types of reserve estimation method volumetric estimation is easier and done at the early stage of development based on formation factor, well log, fluid saturation and reservoir extent data. Accuracy of this method increases with production data. This project highlights the reserve estimation and remaining reserve calculation of Saldanadi Gas Field one of the prominent and vital gas field for geological situation as the underground reservoir rock is shared by both Bangladesh and India. To calculate reservoir volume using trapezoidal rule and area using planimeter, isopach maps have been created from contour map of both upper and lower gas sand. For greater accuracy production data from the well #1 and well #2 of the field has been used. It is found that total GIIP (2P) from both upper and lower gas sand is 501.186 Bcf among which 350.83 Bcf is recoverable with 70% recovery rate. In addition total remaining reserve is 282.95 Bcf.

KEYWORDS: Volumetric, Isopach, Planimeter, Trapezoidal, Hawkin's Formula.

1 INTRODUCTION

There Are Four Approaches of Reserve Estimation

Volumetric Estimate
Material Balance Estimate
Decline Curve Estimate
Reservoir Simulations Estimate

These different method need different kind of data and time of production to estimate reserve of relevant field. Among the above mentioned method volumetric formula requires no production and time dependent data and is used to fulfill the research objective. This method determine the areal extent of the reservoir, the rock pore volume, and the fluid content

within the pore volume. This provides an estimate of the amount of hydrocarbons-in-place. The ultimate recovery, then, can be estimated by using an appropriate recovery factor [1].

The objectives of this gas reserve estimation are:

- Calculating gas initially-in-place 2P (proved+probable) within the areal extent of each well
- Calculate the ultimately expected reserve for both gas sand upper and lower
- Measurement of the remaining reserve for production augmentation

Following assumptions have been made for this work:

- Homogenous isotropic reservoir
- No change of properties of fluid with pressure and time

2 STUDY AREA

Saldanadi Gas Field is located at the mid eastern part of Bangladesh and tectonically lies in the eastern fold belt at Kashba upazila of Brahmanbaria district. A channel named Saldanadi is flowing beside the gas field. The field is 50 km south-east of Brahmanbaria district and 40 km north of Comilla town. Saldanadi gas field lies on the northern part of greater Rokhia anticline. The northern and southern culminations of this structure have been named Shyampur dome and Jalangidome. This zone is characterized by low amplitude folding with a generalized NNW-SSE trend. This zone has undergone mild tectonic compression that left the structures relatively un-breached. Rokhia structure is about 40 km long and 6 km wide. Bangladesh Petroleum Exploration and Production Company Limited first drilled an exploratory well in 1996 and it was a gas deposit, the production of this well started on 28 March 1998.At present well #1 and well #2 are closed only well #3 is under production and well #4 is now under proposed.[5]

2.1 BACKGROUND OF THE RESEARCH

In 19th century the exploration was first started by Geological Survey of India, Burma Oil co. mapped the entire region. Systematic geological mapping of this area was carried out between 1911 and 1959. Petrobangla, Hydrocarbon Unit Bangladesh (HCU) / Norwegian Petroleum Directorate (NPD) and National Committee for Gas Demand and Reserve (NCGDR) made an estimation in three consecutive year and found the result, which has been shown in **Table-1**

Table 1.Comparison of different gas reserve (Proved+Probable) estimation [2]

Saldanadi Gas Field	Proved+Probable (Bcf)	Recovery Rate (%)	Total Recoverable Reserve(Bcf)
Petrobangla(2000)	200	70	140
HCU/NPD(2001)	200	70	140
NCGDR(2002)	380	65	247

After that in 2008 Khalid and Kazi re-estimate the gas reserve of Saldanadi Gas Field for both zone which are demonstrated in **Table-2**.

Table 2.Reserve estimation made by Khalid & Kazi [5]

Saldanadi Gas Field	Proved P1(Bcf)	Probable P2 (Bcf)	Recovery Rate (%)	Recoverable Reserve(P1+P2) (Bcf)
Upper Zone	48.00	284.40	70	232.68
Lower zone	14.72	95.44	70	77.11

Total Recoverable Reserve (2P) of Saldanadi Gas Field: 309.79 BCF

Technical information regarding well #1 and well #2 of Saldanadi Gas Field

Table 3 : Location, depth and type of Well #1 and Well #2

Well Name	Longitude	Latitude	Well Depth in m (msl)			Remark
			Target	TVD	MD	
Well # 1	91°10′14.8″	23°40′34.4″	2800	2511	-	Vertical Well
Well # 2	91°10′14.6″	23°40′33.6″	2500	2308.76	458	Deviated Well

Sub surface view of the well #1 and well #2 of Saldanadi Gas Field

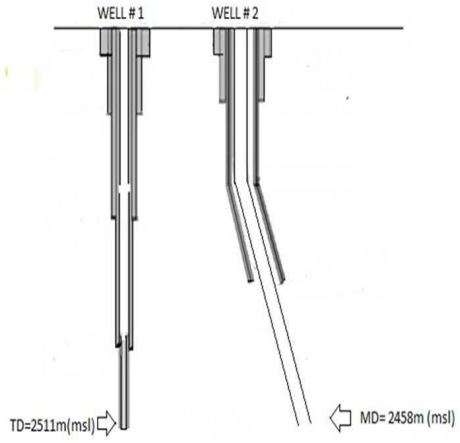


Fig 1 : Subsurface well view of Saldanadi Gas Field

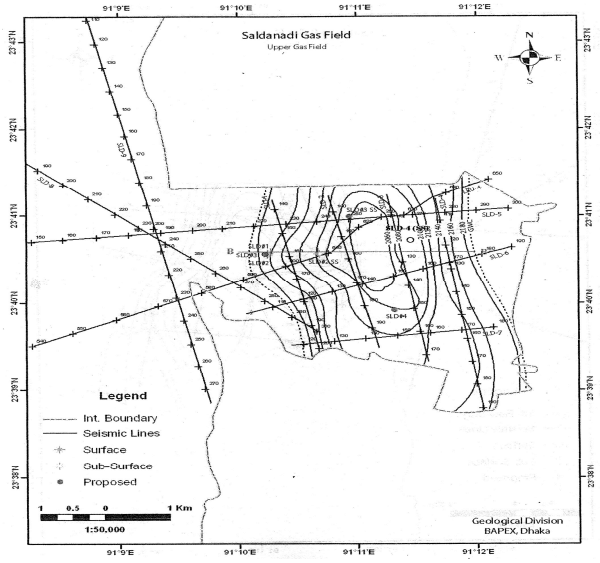


Fig 2: Contour map of upper gas sand

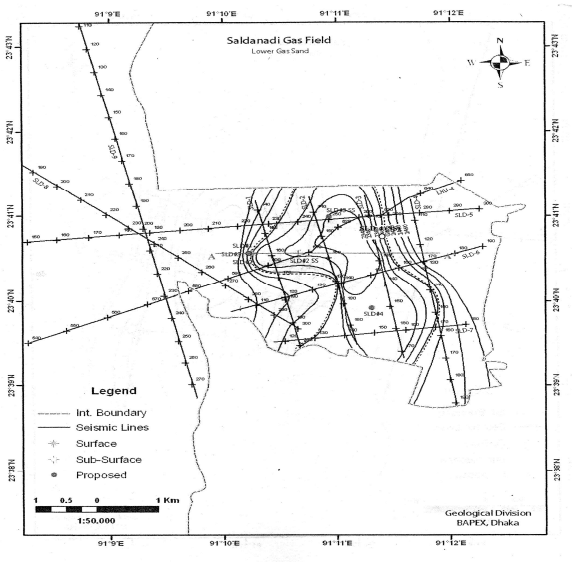


Fig 3: Contour map of lower gas sand

3 MATERIALS AND METHODS

3.1 DATA COLLECTION AND TREATMENT

Necessary data for this study had been provided by Bangladesh Petroleum Exploration and Production Company Limited (BAPEX). Collected data are reservoir data, contour map, fluid composition data, formation pressure and temperature, well log data, some annual reports of Petrobangla and Bapex. Structural contour maps have been revised for both Upper and Lower sand level. Among several types of planimeter, digital one is more accurate and very convenient to use.

Table 4 : Gas compressibility factor, Formation volume factor, Porosity & Gas Saturation of Saldanadi Gas Field

Saldanadi Gas Field	Gas Compressibility Factor	Formation Volume Factor	Porosity	Gas Saturation
Upper zone	0.895	0.00489	0.14	0.65
Lower zone	0.907	0.00464	0.18	0.70

It may be mentioned here that for depletion drive reservoir recovery factor was found to be ranging between (0.80-0.90) [2]. According to earlier report the FWHP/Z plot for lower Gas sand of Saldanadi Gas Field suggests a recovery factor that of 0.698 which may have been affected by high production rate. Considering this, recovery factor 0.70 has been adopted for both Upper and Lower Zone of Gas Field.

Table 5: Recovery factor of both Upper and Lower Gas Zone

Gas Zone	Recovery factor
Upper	0.70
Lower	0.70

Thickness of gas zone of Saldanadi Gas Field are shown in **Table 6**

Table 6: Total thickness of gas zone

Upper gas sand	2170- 2215 RKB 2142- 2187 MSL	Thickness : 45 m
Lower gas sand	2405- 2430 RKB 2376- 2401 MSL	Thickness : 25

RKB = Rotary Kelly Bushing
MSL = Mean Sea Level

Total thickness of the gas zone for both upper and lower sand has been divided into equal segment and considered this each segment as a height of the trapezoidal shape of reservoir.

3.2 ANALYSIS METHODS

Volumetric reserve estimation using isopach map, planimeter and trapezoidal volume rule have been used for this work. In volume calculation this volume is divided into trapezoidal segments. As the measured area ratio between two successive isopach lines is found greater than 0.50, the trapezoidal formula has been applied because of it's accuracy ([1], [3]).

3.3 METHODOLOGY

Rock volume has been determined from area and thickness of the reservoir which are constructed from subsurface contour map and subsurface isopach map. Contour maps are actually created with equal elevation line and depict the geologic structure beneath the surface of the earth and isopach maps are formed with equal lines of net gas-containing formation thickness. Isopachous maps are prepared from the contour maps when there exists a gas-water contact and the

contact line is assumed as a zero isopach line. The area of the reservoir is obtained by the planimeter from the isopach maps and thickness of the gas-bearing zone is enumerated from well logs and from the defined fluid contacts on the subsurface contour map.[3]

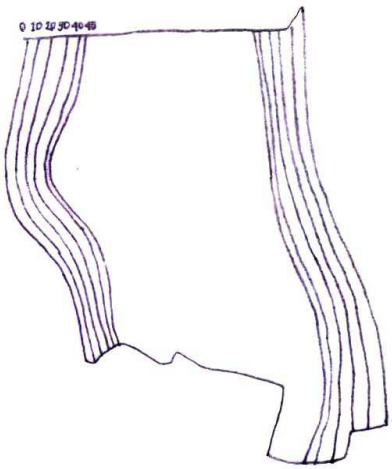
Trapezoidal volume of reservoir,

$$V = \frac{(A_1 + A_2)}{2} \times h \quad (1)$$

$$GIIP = V \times 10^6 \times 35.3147 \times \phi \times (1 - S_w) \times \frac{1}{B_g} \quad (2)$$

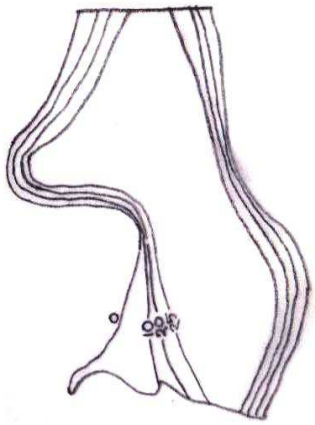
Where,
GIIP = Gas Initially In Place
A = Drainage area in square kilometers
h = Thickness in meters
ϕ = Porosity in %
S_w = Water saturation in %
B_g = Gas formation volume factor
1 square kilometer = 10^6 square meter
1 cubic meter = 35.3147 cubic feet

Isopach map for both upper and lower gas sand has been derived from the respective contour map and by planimetering area is calculated.



Scale = 1:50
Unit = Kilometer

Fig 4 : Isopach map of upper gas sand



Scale = 1:50
Unit = Kilometer

Fig 5: Isopach map of Lower gas sand

4 RESULTS AND DISCUSSIONS

4.1 RESULTS

In this section GIIP(2P) for both zone has been calculated by using equation (1) and (2) mentioned earlier.

Planimeter reading and contour interval for upper and lower gas sand of the field are in **Table-5** and **Table-6**

Table 5: Upper gas sand contour interval and planimeter reading

Contour Interval	Planimeter Reading
0	14
10	13
20	12.7
30	10.9
40	10.6
45	9.4

Table 6 : Lower gas sand contour interval and planimeter reading

Contour Interval	Planimeter reading
0	7.2
10	6.8
20	5
25	4.7

In this section GIIP(2P) for both zone has been calculated by using equation (1) and (2) mentioned earlier.

UPPER GAS SAND

Table-7: GIIP(2P) of upper gas sand of Saldanadi Gas Field

Contour Interval	Area km^2	Area Ratio	Shape	Thick-ness (m)	Rock Volume (km2*m)	Rock Volume (Bcf)	Effective porosity ϕ	Pore volume (Bcf)	Gas Saturation (1-Sw)	Gas Volume Bcf	Gas formation volume Bg	GIIP (2P) Bcf
0	14	0.928571	Trapezoidal	10	135	4.767484	.14	0.667447	0.65	0.4338410	0.0048	88.7200
10	13	0.976923	Trapezoidal	10	128.5	4.537938	.14	0.635311	0.65	0.4129524	0.0048	88.4483
20	12.7	0.858267	Trapezoidal	10	118	4.167134	.14	0.583398	0.65	0.3792092	0.0048	77.5479
30	10.9	0.972477	Trapezoidal	10	107.5	3.796330	.14	0.531486	0.65	0.3454660	0.0048	70.6474
40	10.6	0.886792	Trapezoidal	05	50	1.765735	.14	0.247202	0.65	0.1606818	0.0048	32.8592
45	9.4											Total = 354.223

LOWER GAS SAND

Table-8: GIIP(2P) of lower gas sand of Saldanadi Gas Field

Contour Interval	Area km^2	Area Ratio	Shape	Thickness (m)	Rock Volume (km2*m)	Rock Volume (Bcf)	Effective porosity ϕ	Pore volume (Bcf)	Gas Saturation (1-Sw)	Gas Volume (Bcf)	Gas formation volume Factor, Bg	GIIP (2P) (Bcf)
0	7.2	0.944	Trapezoidal	10	70	2.472029	.18	0.4449652	0.70	0.3114	0.00464	67.128
10	6.8	0.735	Trapezoidal	10	59	2.083567	.18	0.3750421	0.70	0.2625	0.00464	56.579
20	5	0.943	Trapezoidal	5	24.25	0.856381	.18	0.1541486	0.70	0.1079	0.00464	23.255
25	4.7											Total = 146.96

Table 9: Recoverable Reserve of Saldanadi Gas Field

Gas Zone	GIIP(2P) Bcf	Recovery factor	Recoverable Reserve Bcf
Upper gas sand	354.223	0.70	247.9561
Lower gas sand	146.96	0.70	102.872

Total GIIP = Upper zone GIIP + Lower zone GIIP
= 354.2231 Bcf + 146.963
= 501.186 Bcf

Total Recoverable Reserve = Upper zone recoverable reserve + Lower zone recoverable reserve
= 247.9561Bcf + 102.872 Bcf
=350.83 Bcf

4.2 DISCUSSIONS

Comparison between the estimated GIIP(2P) of this work and the previous estimation is shown on Table-10 below.

Table 10: Comparison between the estimation made by Khalid & Kazi and this analysis

Reserve Estimation Year	Estimated GIIP (BCF)	Recoverable Reserve (BCF)	Produced Gas (BCF)	Remaining Reserve (BCF)
2008	442.56	309.79	55.91	253.88
2015	501.186	350.83	67.88	282.95

Table-10 shows the augmentation of remaining reserve of about 29.07 Bcf between these two analysis. Saldanadi Gas Field plays the most important role in the sense that the reservoir is shared by both Bangladesh and India. India drilled 37 wells and we have drilled only 3 till date. Recent analysis and re-evaluation of seismic, geological and well data of SLD#1 and SLD#2 reveals that middle zone of SLD#2 has been considered as the Upper Zone and re-estimated the reserve accordingly. The Reservoir Volume Factor (Bg) and has been calculated newly where porosity, water saturation, recovery factor are remained same as the Reserve Estimation report of 2008 [5]. Revised contour maps have updated reservoir area 25.08 square kilometers while in earlier report it was 20.05 square kilometers. Considering this augmentation in reserve of my project work recently a proposal has been made to drill more development wells in Saldanadi Gas Field to enhance production that will certainly aid to meet the increasing gas demand of our country.

5 CONCLUSION

Reserve estimation is a vital activity for a gas field development. Based on the remaining reserve of a field necessary steps are taken for improvement. For the migration of gas from the reservoir rock total amount of reserve may change with time. Volumetric method is the easiest way to determine the amount of reserve accurately and this accuracy is augmented with the available of production and well log data from the reservoir.

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