Structural Modeling of Fenchuganj Gas Field, Sylhet, Bangladesh

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Abstract— In Bangladesh, most of the onshore part has been explored widely for natural gas, yet there is more possibility to explore the resource inland by remodeling and re-studying with modern techniques. Fenchuganj Gas Field is one of the producing gas fields located at northeastern part of Bangladesh. Five exploration wells (FNG-1, FNG-2, FNG-3, FNG-4 and FNG-5) have been drilled so far and two wells FNG-2 and FNG-3 are producing natural gas. Both the well FNG-1 and FNG-5 have been abandoned as dry wells. The well FNG-4 is still under evaluation. There are nine gas sands recognized are New Gas Sand IV (NGS IV), New Gas Sand III (NGS III), New Gas Sand V (NGS V), New Gas Sand II (NGS II), Upper Gas Sand (UGS), New Gas Sand I (NGS I), New Gas Sand VI (NGS VI), Middle Gas Sand (MGS) and Lower Gas Sand (LGS). Producing gas sands are UGS, MGS and LGS. Out of nine gas sands, seven have been modeled in this research work.

The structure of Fenchuganj Gas field has re-studied with petrel simulation software by incorporating seismic and wellline log data. The gas sand horizons were picked and 3D time contour map and depth structure map of each horizon were made. Fault models have been made for fault interpretation. Two major reverse faults have been identified trending NNE-SSW in the study area. These faults divided the study area into three segments which can be named as western part, eastern part and faulted zone. Maps and models showed that the structure of the Fenchuganj Gas Field is almost NNE-SSW trending asymmetric anticlinal fold. The eastern flank is steeper than the western flank.

The Fenchuganj structure is situated in the transition zone between the central Surma Basin and the folded belt in the east and is closest to the eastern margin of the central Surma Basin. The Surma basin was formed structurally by the contemporaneous interaction of two major tectonic elements, i.e. the emerging Shillong Massif to the north and the westward moving mobile Indo-Burma fold belt. The tectonic movement is considered to have occurred during Neogene to the present age with the strongest period of crustal disturbance during the middle Miocene.

I. INTRODUCTION

Energy resources have been the main driving force of human race since the beginning of civilization. Coal, Oil and Natural gas are the major nonrenewable energy sources. Natural gas has become the fastest growing energy source in the present world due to fatal impact of greenhouse gases to the atmosphere by burning coal and oil. Coal and oil were known as fuel of nineteenth and twentieth century respectively, natural gas became the prime fuel in the twenty first century due to its cleanliness and environmental friendly. At present, natural gas is playing very significant role in the economic and industrial development in Bangladesh. The country so far has discovered 26 gas fields including 2 offshore ones and searching for other prospects both on offshore and onshore area. The total initial gas reserve in the 26 gas fields has been estimated at 27.12 Tcf (Proved and Probable) and 20.08 TCF (recoverable) of natural gas sufficient to meet our demand of energy consumption till 2019 (Imam, B., 2005; Annual Report, Petrobangla, 2014). Fenchuganj is one of the most productive and prospective gas fields in Bangladesh and falls in gas block #14 (Fig. 1). Pakistan Petroleum Limited (PPL) delineated the subsurface geometry of the structure in 1957 on the basis of single fold analogue seismic data (Ganguly, S., 1997). Fenchuganj Gas Field was discovered in 1988. First well #FNG-1 was drilled in 1960 down to 2439 m and abandoned as a dry hole. Later on January 21st, 1985 drilling of the well #FNG-2 started and reached TD on November 4, 1986. After producing 24 BSCF gas, the well#2 was suspended due to excessive water and sand production and the well was recompleted at lower zone. But due to much amount of water and well head pressure down (1020 psi), well#2 shut on July 21, 2013. The well #FNG-3 started on February 6, 2004 and completed as production well on May 14, 2004. Drilling of the well #FNG-4 started on November 2010 and was completed on May 2011.
Right now FNG#3 and FNG#4 are the producing wells of this gas field. Producing gas zones are Upper Gas Sand and New Gas Sand VI (NGS VI). The development well FNG#5 was drilled to 3100 m and finally abandoned as no signs of existence of gas (Well Report on FNG#5, BAPEX, 2015).

The areal extent of the Fenchuganj Gas Field is about 65 sq km (Fenchuganj Geological Study for Petrobangla, 2009).

A. Study Area: The study area is located in Moulovibazar district, near the town of Fenchuganj (Map 2) about 40 km south of Sylhet and about 200 km northeast of Dhaka. The Fenchuganj Field is located in the south central part of the Surma Basin on the western margin of the Tripura high. Fenchuganj is a surface anticline and the area occupied by low hillocks and vegetation cover. It is about 30 km long, 8 km wide, located at longitude E 91°50’- 92° and latitude N 24°30’- 24°37’. It is situated in the folded belt in the east and is closest to the eastern part of central Surma Basin. The highest peak of this area is about 81m near the tea garden. The gas field is enclosed by Beani Bazar on the north east, Bibiyana on the west, Moulovibazar on the south west, Kailas Tila on the north and Rashidpur on the south.

B. Objectives: The main objectives of this research are as follows:

- 3D modeling to delineate subsurface structure.
- To identify the possible faults in the structure.
- To clarify the geology and tectonics of the area.
- To correlate wire-line logs and seismic data to delineate seismic horizons.

C. Stratigraphy: Stratigraphic succession of the Fenchuganj gas field is given in table-1.
The data used in this research work were acquired by BAPEX. Fifteen lines: FG-01, FG-02, FG-03, FG-04, FG-05, FG-06, FG-07, FG-08, FG-09, FG-10, FG-12, FG-14, FG-16, FG-18 and FG-57 were shot over the area during that time. The list of the Fenchuganj New 2D seismic lines are given in the table-2 and shown in the Fig. 3 (Fenchuganj Geophysical Study for Petrobangla, 2009).

II. DATA ACQUISITION

A. Seismic Data: Initially a single fold seismic data acquired by Geological Survey of India (GSI) in the area in 1959. The multi fold seismic survey that covers the entire Fenchuganj area was carried out by Prakla Seismos in 1979-81 and another regional line was acquired in 1982. Later, in 2011-2012 Seismic Survey was carried out again to attain precise information about the structure and prospects by BAPEX (Bangladesh Petroleum Exploration & Production Company Limited).
B. Wireline log data: The continuous recording of the geophysical parameter along a borehole produces a wireline log. The value of the measurement is plotted continuously against depth in the well. It is the most reliable source of information for determining the presence of hydrocarbon and subsurface lithology (Ridar M H, 2nd edition, 2002). Different types of logs are used in petroleum industry, such as Resistivity (R), Gamma ray (Gm), Sonic, Density, Caliper, Neutron, Self Potential (SP), etc. Geophysical log measures different properties of the rock, such as resistivity, natural gamma ray radiation, acoustic properties etc. and they are used for various geophysical or geological purposes. Among the logs mentioned above the Gamma ray log, Resistivity log, Sonic log and Density log were integrated with seismic data to delineate and model subsurface structure.

III. METHODOLOGY

Petrel Software is used in this research work to generate different types of structural model. Seismic data and Wireline log data have been integrated and reviewed. From preprocessed seismic data the reflectors of zone of interest have been selected.

A. Time to Depth Conversion using T-Z curve: To create T-Z curve for the thesis work, velocity data of well FG-03 is used. Average velocity of the well is used to convert the two-way time in to depth using the following equation.

\[ Z_i = Z_{i-1} + V \times (t_i - t_{i-1})/2 \]

This two-way time used to construct T-Z curve which is then used to convert two-way time to depth. This TWT used in seismic line interpretation.

B. Seismic Section Interpretation: Fourteen Seismic sections have been studied along the seismic lines by using Petrel Software. These seismic lines are FG-01, FG-02, FG-03, FG-04, FG-05, FG-06, FG-08, FG-09, FG-10, FG-12, FG-14, FG-16, FG-18 and FG-57. To create time contour maps, depth structure model and fault model as well as to interpret these seismic lines of Fenchuganj Gas Field, a project is created in the Petrel software. In this research work, 2D seismic data are used to interpret the structure of Fenchuganj gas field (Badley, E. M., 1985). The procedure of this works is described below:

Importing world co-ordinates:
Selecting the survey,
Naming the file,
Selecting “2D by dialog”,
Importing world co-ordinates

Importing seismic traces in SEG Y format (Fig. 6)
Importing SEG Y file into single 2D or 3D survey
Co-ordinates and shotpoint scaling action
Selecting seismic data volume name
Defining trace numbers for 2D import
Setting time data bounds
Advanced options override input file
Assigning 2D shotpoint to traces
Bulk importing 2D SEG Y traces
Assigning traces to shotpoint

Fig. 4: Work Flow Chart of the Research Work

Fig. 6: Loaded Seismic Section
Importing Well Data:
- Inserting New Wells
- Importing ASCII format of wire-line logs in each well
- Importing well Tops
- Well tie up with seismic section.
- Inserting deviation data for well #FNG-4

Picking fault lines (Fig. 7)
Discontinuity and absence of seismic reflections were considered to delineate fault line

Picking horizon (Fig. 8)
Well heads data have been used as input to correlate seismic reflections for picking horizons.
Continuity of seismic reflection is considered to pick horizon.

Contour map
- Selecting the Contour tab on Grid map
- Selecting the smoothing level
- Creating Contour map for Time Grid Map
- Creating Contour map for Depth Grid Map
- Naming the Time and Depth Contour Map

Fault Modeling
- Defining a New Model,
- Creating Faults from Fault Polygons,
- Editing Key Pillars,
- Building Key Pillars from Fault Polygons,
- Connecting Faults,
- Disconnecting Faults,
- Creating Branched and Crossing Faults,
- Creating Faults from Selected Fault Sticks,
- Creating Faults from All Fault Sticks,
- Automatic Generation of Faults,
- Automatic Connection of Faults,
- And Automatic Adjustment of Key Pillars

Making horizons:
Creating points from horizons
Making horizons with the help of created points.
Conformable horizons were made.

Velocity Model
To produce velocity model Vertical Seismic Profile (VSP) data has been used

IV. STRUCTURAL MODELING AND INTERPRETATION

A. Making upper and lower surface:
Top and bottom surface for each horizon has been created by depth attribute and wire-line log data which was converted by velocity model. Gamma ray log, density log, sonic log and resistivity log have been used. Depth of the surfaces may range from 1210 m to 2750 m. Graduated colors have been assigned to create horizons where higher elevations are colored as red and lowers are in magenta color. Surfaces are named from top to bottom (Fig. 9) as
- New Gas Sand IV Top and New Gas Sand IV Bottom
- New Gas Sand III Top and New Gas Sand III Bottom
- New Gas Sand V Top and New Gas Sand V Bottom
- Upper Gas Sand Top and Upper Gas Sand Bottom
- New Gas Sand VI Top and New Gas Sand VI Bottom
Middle Gas Sand Top and Middle Gas Sand Bottom
Lower Gas Sand Top and Lower Gas Sand Bottom

B. Making Gas Zones: Gas Zones have been made according to the surface generated by the software (Fig. 10). Zone between top and bottom surfaces have been considered as reservoir zone. Seven (07) reservoir zones have been created. Name of the reservoir zones are listed in the table-3.

Table 3:
Name of reservoir Zone with corresponding surfaces

<table>
<thead>
<tr>
<th>Zone Name</th>
<th>Surfaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone A</td>
<td>Between New Gas Sand IV Top and New Gas Sand IV Bottom</td>
</tr>
<tr>
<td>Zone B</td>
<td>Between New Gas Sand III Top and New Gas Sand III Bottom</td>
</tr>
<tr>
<td>Zone C</td>
<td>Between New Gas Sand V Top and New Gas Sand V Bottom</td>
</tr>
<tr>
<td>Zone D</td>
<td>Between Upper Gas Sand Top and Upper Gas Sand Bottom</td>
</tr>
<tr>
<td>Zone E</td>
<td>Between New Gas Sand VI Top and New Gas Sand VI Bottom</td>
</tr>
<tr>
<td>Zone F</td>
<td>Between Middle Gas Sand Top and Middle Gas Sand Bottom</td>
</tr>
<tr>
<td>Zone G</td>
<td>Between Lower Gas Sand Top and Lower Gas Sand Bottom</td>
</tr>
</tbody>
</table>

C. Interpretation of Seismic Sections: Fifteen seismic sections have been studied for this research work. Out of fifteen, six seismic sections have been presented here. The six sections have been interpreted by using PETREL software. The seismic lines along the seismic section are FG-02, FG-05, FG-06, FG-08, FG-12, and FG-16. The seismic lines FG-02 and FG-05 are NNE-SSW oriented along the strike of the structure (Fig. 11 and 12). All of the wells are located at the vicinity to seismic section FG-05. The reflection quality of the seismic section is very good. From top to bottom, the Seven gas zones Zone A, Zone B, Zone C, Zone D, Zone E, Zone F and Zone G have been found in this section. Remaining four seismic lines are WNW-ESE oriented along the dip of the structure. The reflection quality of the seismic sections is also good. Fault lines are striking along these seismic sections. Three gas zones Zone E, Zone F and Zone G encountered with the faults along the line FG-06 and all of the gas zones encountered the faults. All of the gas zones have also been found in these sections.
D. Interpretation of Time contour maps: Time contour maps of both upper and lower surface of the seven (7) gas zones have been made. Among those gas zones, time contour map of three producing gas zone (Zone D, Zone E and Zone G) have been presented in this research work.

Time contour map of upper and lower surface of Zone D: A flat peak is found in the centre of the upper surface of Zone D. The contour lines in eastern side are more closely spaced than that of the southern and western sides (Fig. 17). The structure of the upper surface of Zone D is gentler in the southern and western side than in the eastern side.

The contour lines in eastern side are abruptly changed and closely spaced due to faulting in the lower surface of Zone D. The contour lines in western side are widely spaced.

The structure is gentle in the western side and irregular in the eastern side (Fig. 18). The structure of the gas zone is almost NNE-SSW trending.

In lower surface of Zone E, the contour lines of the eastern side are more closely spaced than that of the western side (Fig. 20). The structure of the surface is gentle in the western side and irregular in the eastern side due to fault. The structure of the gas zone is almost NNE-SSW trending.
Time contour map of upper and lower surface of Zone G:

A flat elongated peak is found in the upper surface of Zone G. The contour lines of the eastern side of the studied area are more closely spaced than that of the southern and western sides (Fig. 21). The surface of the gas zone is gentle in the western side and steep in the eastern side.

The contour lines of the eastern side are more closely spaced than that of the western side in the lower surface of Zone G (Fig. 22). The structure of the gas zone is gentle in the western side and irregular in the eastern side. The structure is almost NNE-SSW trending.

Erosion, truncation of stratum or compression may have played a vital role during faulting. Probably, that is why some sediments layers are missing in the fault zone. More faults may found in the studied area but are not conspicuous probably due to the low resolution of seismic data.

Structural trend and shape of the remaining four gas zones more or less same to the mentioned three gas zones.

E. Fault Modeling: Discontinuity and absence of seismic reflections were considered for fault identification. Fault lines have been drawn and fault model have been created (Fig. 23 and Fig. 24) using the simulation software. From seismic profiles of Fenchuganj Gas Field, two major faults have been identified. From the model, the amount of dips in the eastern flank varies from 300-350 and in the western flank varies from 200-250. This fault can be compared with thrust fault and termed as reverse fault. No truncation of the two faults has been observed. These two faults run parallel to the main axis of the structure and divided the studied area into three segments. The segments of the studied area can be named as western part, eastern part and faulted zone. Segments of the area along with the faults are shown in Fig. 25. The trend of the faults is almost NNE-SSW. Fault Model including all zones both reservoir and non-reservoir (Fig. 26) shows some layer of sediments are missing in the fault zone.
Fig. 26: Fault Model showing all zones (reservoir and non-reservoir)

**F. Depth Structure Model**: The Depth Structure Model has been created after velocity model to get the thickness and depth of the gas zones. The depth structure map of both upper and lower surface of the seven (7) gas zones Zone A, Zone B, Zone C, Zone D, Zone E, Zone F and Zone G have been made. Among these gas zones, the Depth structure maps of three producing gas zones (Zone D, Zone E and Zone G) have been provided.

**Depth Structural Model of the upper and lower surfaces of Zone D**: The Depth Structure map (Fig. 27) shows the upper surface of Zone D at a depth of about 1946m in well FNG-1, 2014m in well FNG-2, and 1986m in well FNG-3 and 2020m in well FNG-4. The structure of the surface is gentle in southern and western part but steep in eastern part. It is almost NNE-SSW trending anticlinal structure.

The Depth Structure model (Fig. 28) illustrates the lower surface of Zone D at a depth of about 2001m in well FNG-1, 2044m in well FNG-2, 2067m in well FNG-3 and 2091m in well FNG-4. The structure of the surface is gentle in western part and steep faulted in eastern part. It is almost NNE-SSW trending anticlinal structure. The gas Zone D belongs to Lower Bokabil formation of Surma Group. It is 55m thick in well FNG-1, 30m thick in well FNG-2, 81m in well FNG-3 and 110m in well FNG-4.

**Depth Structural Model of the upper and lower surfaces of Zone E**: The Depth Structure map (Fig. 29) shows the upper surface of Zone E at a depth of about 2142m in well FNG-2, 2162m in well FNG-3 and 2169m in well FNG-4. Well FNG-1 did not reach the surface. The structure of the surface is gentle in southern and western part but steep in eastern part. It is almost NNE-SSW trending anticlinal structure. The Depth Structure map (Fig. 30) illustrates the lower surface of Zone D at a depth of about 2212m in well FNG-2, 2201m in well FNG-3 and 2225m in well FNG-4. Well FNG-1 had not reached the surface. The structure of the surface is gentle in western part and steep faulted in eastern part. It is almost NNE-SSW trending anticlinal structure. The gas Zone E belongs to Lower Bokabil formation of Surma Group. It is 70m thick in well FNG-2, 39m in well FNG-3 and 56m in well FNG-4.
**Depth Structure Model of the upper and lower surfaces of Zone G:** The Depth Structure map (Fig. 31) shows the upper surface of Zone E at a depth of about 2720m in well FNG-2, 2730m in well FNG-3 and 2694m in well FNG-4. Well FNG-1 did not reach the upper surface of Zone G. The structure of the surface is gentle in southern and western part but steep in eastern part. It is almost NNE-SSW trending anticlinal structure. The Depth Structure map (Fig. 32) illustrates the lower surface of Zone G at a depth of about 2733m in well FNG-2, 2735m in well FNG-3 and 2754m in well FNG-4. Well FNG-1 did not reach the surface lower surface of Zone G. The structure of the surface is gentle in western part and steep faulted in eastern part. It is almost NNE-SSW trending anticlinal structure. The gas Zone G belongs to Upper Bhurban formation of Surma Group. It is 13m thick in well FNG-2, 5m in well FNG-3 and 60m in well FNG-4.

**Table 4:**

<table>
<thead>
<tr>
<th>Gas Zones</th>
<th>Average Thickness (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone A</td>
<td>11.33</td>
</tr>
<tr>
<td>Zone B</td>
<td>35</td>
</tr>
<tr>
<td>Zone C</td>
<td>79.33</td>
</tr>
<tr>
<td>Zone D</td>
<td>59.25</td>
</tr>
<tr>
<td>Zone E</td>
<td>55</td>
</tr>
<tr>
<td>Zone F</td>
<td>122.67</td>
</tr>
<tr>
<td>Zone G</td>
<td>26</td>
</tr>
</tbody>
</table>

**G. Structural Interpretation:** The Surma basin is formed structurally by the contemporaneous interaction of two major tectonic elements, i.e. the emerging Shillong Massif to the north and the westward moving mobile Indo-Burma fold belt. The tectonic movement is considered to have occurred during Neogene to the present age with the strongest period of crustal disturbance during the middle Miocene. The primary result of this tectonics is a series of almost N-S oriented asymmetrical anticlines (Biswas, S. and Grasemann, B.; 2005). The Fenchuganj Gas field lies almost on the northeastern flank of the Surma Basin. The structure is a thrust faulted anticline with a dip and fault closure. The structural trend of the main axis is almost NNE-SSW and the major faults trend almost parallel to the axis and aligned in the eastern flank of the structure (Fig. 33). The structural dip at the Fenchuganj closure is quite steep, estimated to be about 20-30 degrees at the flank. Saddles separate the Fenchuganj structure from the surrounding anticline structures (Alam, M. M., Alam, M., Curray, J. R., Chawdhury, M. M. L. R. and Gani, M. R., 2003; Mandal, B. C. and Woobaid Ullah, A. S. M., 2006).

**V. Conclusion**

Fenchuganj Gas Field is one of the producing gas fields in Bangladesh. Five exploratory wells (FNG#1, FNG#2, FNG#3, FNG#4 and FNG#5) have been drilled in this gas field so far. Among these wells, FNG#1 and FNG#5 have been abandoned as dry well. Others two wells FNG#2 and FNG#3 are producing gas from this gas field. And, well #FNG-4 is still under evaluation. Producing gas zones are Upper Gas Sand, and Lower Gas Sand. Nine gas zones have been identified in this field so far. Time contour map, depth structure model, fault modeling, correlation among four wells showing reservoir zone of this area have been generated to get precise view about the structure. Petrel software of Schlumberger Inc. has been used to model this structure. The time contour map and depth structure model of the gas zones have revealed the structural trend of Fenchuganj structure is almost NNE-SSW trending. This structure is slightly asymmetric reversely faulted anticlinal fold. The eastern flank is steeper than the western flank. The structure has experienced major tectonic deformation and more potential for hydrocarbon accumulation (Guha, D. K., 1978). Two major reverse faults are found trending NNE-SSW in the study area. These faults divided the structure into three segments such as western part, eastern part and faulted zone. The structure is a thrust faulted anticline with a dip and fault closure. The Fenchuganj structure separated from the surrounding anticline structures by saddles.
Limitations: Limitations which are experienced during the research work are:

- Absence of well top data at the east side of faults.
- Insufficient vertical Seismic Profiling (VSP) data.
- Lack of neutron log data.
- Lack of gas-water contact for all New Gas Zones.
- Some log value showed enormous variations.

Recommendations: in order to get the better view of the structure, exploration well may be constructed in the eastern part of the fault zone and 3D seismic survey should be carried out.

REFERENCES


