API of Microgravity in Ashoknagar area, Bengal Basin

Abhinav Mittal, Madhab Hazowary, Sudhir Kumar and Sanjeev Sawai,*
Oil and Natural Gas Corporation Limited

Email: mittal_abhinav@ongc.co.in

Keywords

Bengal basin, Microgravity, Ashoknagar, Bouguer anomaly, Residual anomaly, Horizontal gradient, gravity model, basement configuration

Abstract

Bengal Basin is situated in the northeastern part of Indian sub-continent covering West Bengal state of India, Bangladesh and extended to the offshore region of Bay of Bengal.

Bengal Basin has attracted attention of Geoscientists after recent discovery of hydrocarbon in W-3 well (Fig. 5) from Pandua formation of Miocene age. The seismic data is not clear below the Eocene marker. Therefore, the project has been taken up with the objective to delineate low density zones, sedimentary thicknesses and Basement configuration of Ashoknagar area through Microgravity data analysis.

The project involves microgravity data acquisition, processing and interpretation. Accordingly, data has been acquired, processed as per the standard industry practices by applying various gravity corrections to generate Bouguer gravity anomaly and other attribute maps. The study based on gravity modelling infers that sedimentary thickness is increasing from northwest to southeast direction. The depth to the basement varies from ~12.5 km to ~13.8 km in Ashoknagar area. At wells W-3 and W-4, the basement depth is ~13.3 km and at the well W-2, it is ~12.9 km.

Introduction

Bengal basin is in the northeastern part of Indian Sub-continent, lies between Indian Shield to the west & north and Assam &Assam Arakan (A&AA) Fold belt to the east (Fig.1). Towards south, the basin extends into the offshore region of Bay of Bengal. The basin is a geological province spread over vast tracts of the Ganges and Brahmaputra-Meghna river valleys, lead to the largest fluvio-deltaic sedimentary system on Earth (Alam et al., 2003).

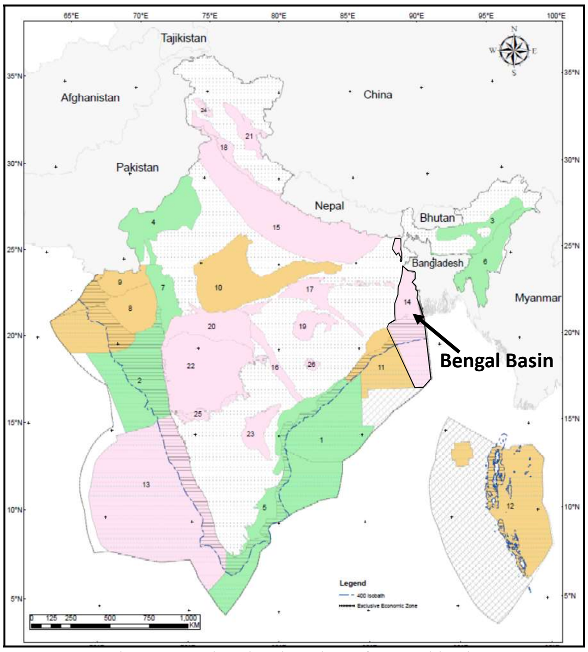

Fig. 1 Map showing location of Bengal basin

The basin has about 1–8 km of Permian to Holocene clastic sediments resting on the stable shelf in the western part of the basin (Imam and Shaw,1985) and as much as 16 km thick Tertiary to Quaternary alluvial sediments fill the foredeep of the basin at the mouth of the Ganges and Brahmaputra rivers (Allison,1998). A schematic cross section across the basin in east-west direction is given below. (Fig.2)

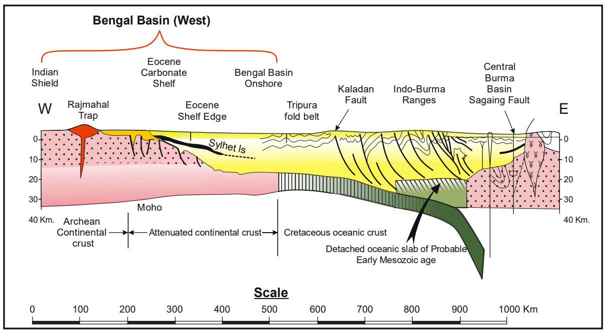

Fig. 2 Schematic east-west section across Bengal basin (After Alam et.al.2003)

The eastern part of basin (Hinge zone and Deep basin zone) is challenging as seen from the seismic section (Fig. 3), all the reflectors are dipping towards eastward direction. The shallow basement in western part (i.e. Basin margin zone and Stable Shelf zone) could be mapped with seismic where as in eastern part of the basin; no good reflector could be seen below the Eocene marker. Therefore, the project has been conceived with the objective to delineate low-density zones, sedimentary thicknesses and basement configuration in Ashoknagar area through Microgravity data analysis.

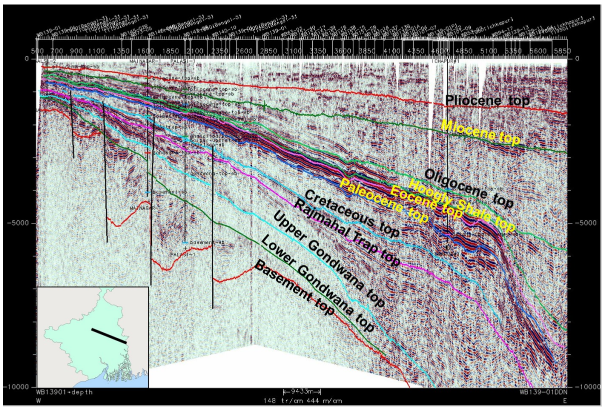

Fig. 3 Seismic section across the Bengal basin

The project involved data acquisition, processing and interpretation of Microgravity data comprising of 4125 stations with a study area of 251 km^2 in Ashoknagar area with station interval of 250 m.

Regional Geology

Bengal basin, a polycyclic basin, has evolved through two distinct tectonic episodes (Banerjee et al., 2013). It was initiated as an intra-cratonic rift basin within Gondwana land during Late Paleozoic-Mid Mesozoic time and received the continental Gondwana sediments (Krishnan, 1982). This phase of basin development ended with wide spread volcanism during which continental flood basalts (Rajmahal Trap) covered the Gondwana sediments. Second phase of basin formation took place when Indian Craton separated out completely from the Gondwana land and kept on moving northwards. During this journey of the Indian plate, the peri-cratonic part on the eastern margin (along with Gondwana sediments) continuously subsided and received colossal volume of sediments from Late Mesozoic through Tertiary to Recent times in a passive margin set-up. In its northern journey, the Indian plate collided with the Eurasian plate and caused folding and thrusting, forming the Himalayan Orogenic belt. Further movement of the Indian plate was in the northeasterly direction, northeastern end of Indian plate collided with the Burmese plate, the former subducting below the latter, and the sedimentary accretionary prism gave rise to the formation of Assam-Arakan thrust fold belt.

On the basis of NE-SW trending tectonic zones, the Bengal basin is sub-divided into four main tectonic and structural zones (Fig.4). These zones are as follows:

- Basin margin zone, characterized by shallow depth of Archaean rocks with basement and en echelon fault system.
- Shelf zone, where the Archaean basement maintains a uniform low gradient slope towards east and south-east.
- The Hinge zone (Shelf Break), characterized by sudden increase in the slope which is distinct at the level of Eocene limestone top (Kalighat limestone) as seen in seismic sections.
- Deep basin zone where basement is not identifiable due to thick sediment and basalt cover.

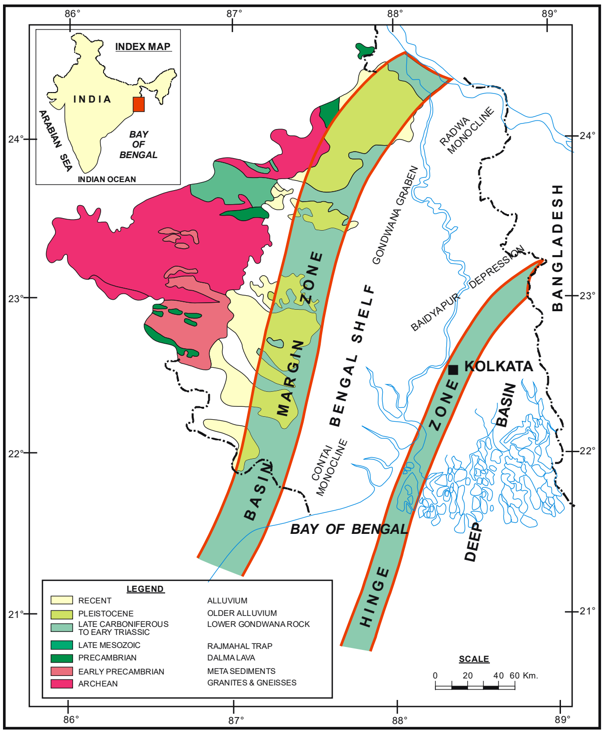

Fig. 4 Sub-divided into NE-SW trending tectonic zones of Bengal basin (Source: www.dghindia.com)

Methodology

CG-5 Autograv Gravity meters have been used for microgravity data acquisition with station interval of 250 m and obtain 3D topographical positioning (Latitude, Longitude and Elevation) of observation point by using Global Navigation Satellite System (GNSS).

The acquired microgravity data has been processed as per standard industry practices by applying standard gravity corrections to generate Bouguer anomaly map (Fig. 5).

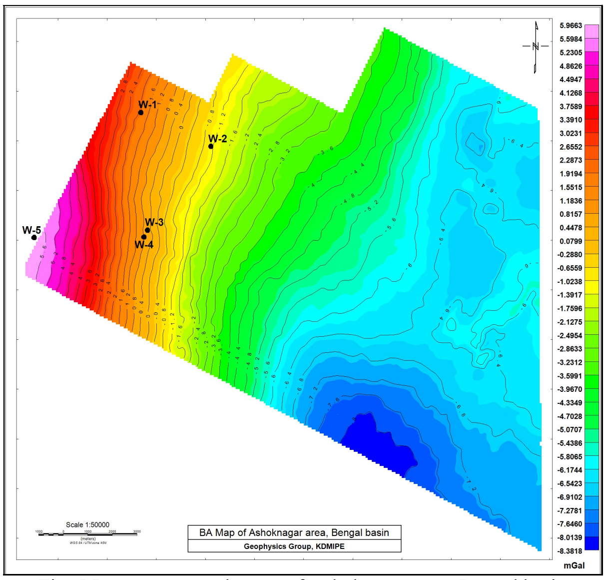

Fig. 5 Bouguer anomaly map of Ashoknagar area, Bengal basin

The Bouguer anomaly is continuously decreasing from northwest to southeast direction. Its value varies from 5.96 mGal to -8.40 mGal in the survey area (Fig.5). This may be due to the deepening of basement towards southeast direction.

The Bouguer anomaly comprise of both shallow as well as deeper causatives. To know the sediments' effect, the deeper information with wavelength longer than 21.0 km has been removed by mathematical filtering (High Pass) and residual anomaly map has been prepared (Fig.6). On this map, two isolated gravity lows have been seen that may be thicker sediments marked as L1 & L2.

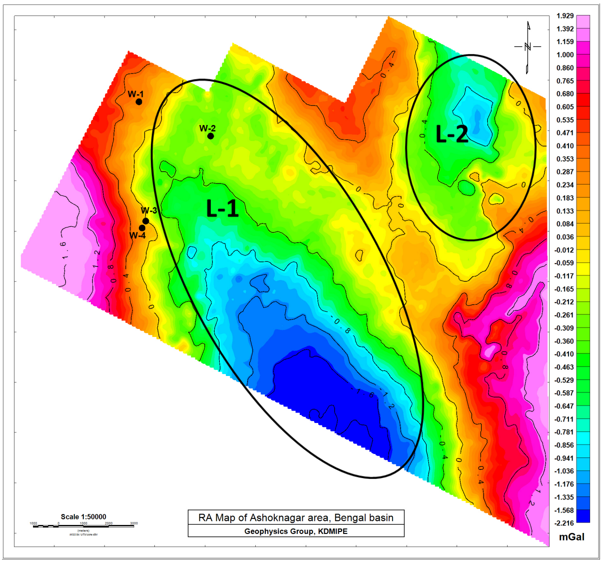

Fig. 6 Residual anomaly map of Ashoknagar area

The Horizontal Gravity Gradient is derived from Bouguer anomaly data. This attribute is combination of gravity derivative in horizontal direction (X and Y). The Horizontal Gravity Gradient maps reveal the anomaly texture and highlight anomaly-pattern discontinuities.

The Horizontal Gravity Gradient H(F) of an anomaly field F is calculated as the Pythagorean sum of the gradients in the orthogonal directions. Choosing the directions to be along the ones of the grids, the calculation becomes:

$$H(F) = (Gyz^2 + Gxz^2)^{1/2}$$

Thus, this is the absolute value of the Horizontal Gravity Gradient at X and Y direction.

The Horizontal Gravity Gradient is simply a measure of the lateral change in density of sediments. Its magnitude is dependent on the density contrast across the boundary, the vertical extent of the contrast, the dip of the boundary and its depth of burial. Two high Horizontal Gravity Gradients are marked as H1 and H2 on the Horizontal Gravity Gradient Map (Fig.7).

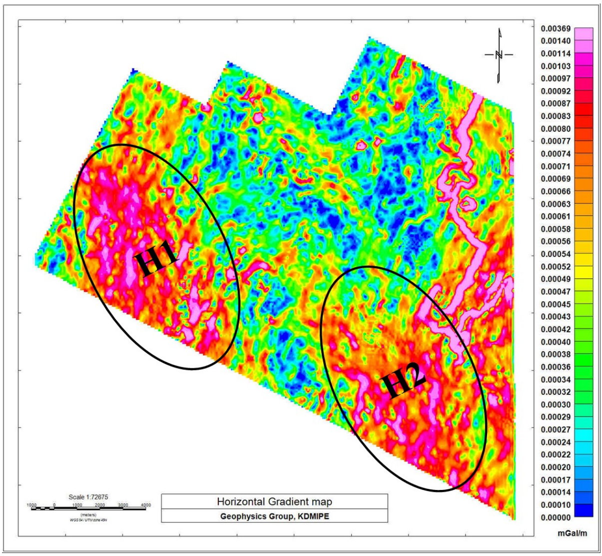

Fig. 7 Horizontal gradient map of Ashoknagar area

Gravity Modelling

The subsurface model derived from gravity modelling independently will not give unique solution. The uncertainty in the model is minimized by constraining the model with available seismic, wells and other G & G information.
Total ten profiles in Ashoknagar area have been identified for gravity modelling (Fig. 8) to generate sedimentary thickness and basement configuration.
Gravity data is constrained with well information (depth and density) and tied with seismic marker horizons and other G & G data to carry out gravity modelling. The modelling was done using GM-Sys software. The software calculates gravity response from modelled subsurface layers with given density and generates best fit observed and computed gravity anomalies.

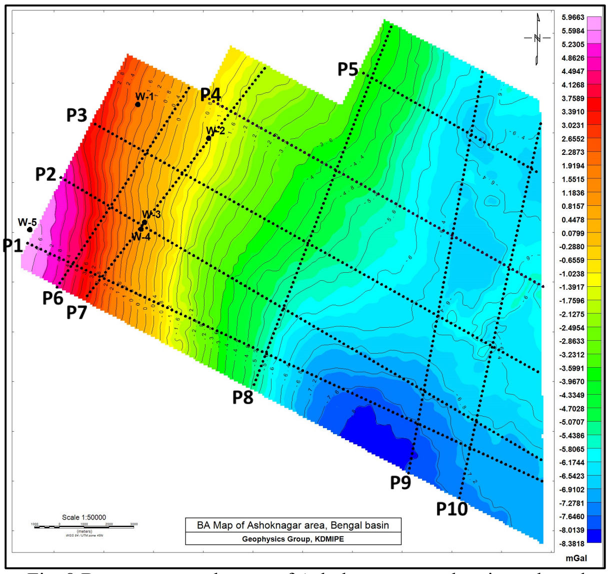

Fig. 8 Bouguer anomaly map of Ashoknagar area showing selected profiles for gravity modelling

The density of each formation has been determined with the help of RHOB log from the wells from nearby area A-1, A-2, A-3, A-4, A-5 and A-6 in the Bengal basin as no well had penetrated upto basement in the study area. The well density data were average for each formation. The density of Rajmahal Trap is slightly lower because of intra-trappean sediment present and it is confirmed from well A-4.
Average density and average interval velocity of different formations are in Table-1 below.

Well name	Recent to Oligocene	Eocene to Upper Cretaceous	Rajmahal Trap	Basement
	Density (g/cm^3)			
A-1	2.26	2.40	2.60	-
A-2	2.27	2.40	2.61	2.74
A-3	2.27	2.39	2.63	-
A-4	2.27	2.40	2.63	-
A-5	2.27	2.41	2.75	-
A-6	2.29	2.41	2.67	-
	2.27	**2.40**	**2.65**	**2.74**

Gravity modelling along ten profiles (P1, P2, P3, P4, P5, P6, P7, P8, P9 and P10) has been carried out (Fig. 8) using density information from the well data given in Table-1. The models have been constrained up to Eocene formation with seismic and well data as no well penetrated below Palaeocene formation. The Rajmahal trap and Basement are calculated by gravity modelling inversion after constraining Eocene top formations. Depth to Moho is nearly flat in the area at ~30 km based on vintage DSS survey (Kaila et al., 1992).

To determine basement configuration, the gravity model has been restricted to four layers viz. Sediments (surface to Oligocene bottom), Eocene (Eocene top to upper Cretaceous. bottom), Rajmahal trap (Rajmahal trap top to Basement top) and Basement (Fig. 8 to 10). From these gravity models, depth picks were gridded by Kriging method with cell size 250m X 250m and prepared depth to Basement map (Fig.11).

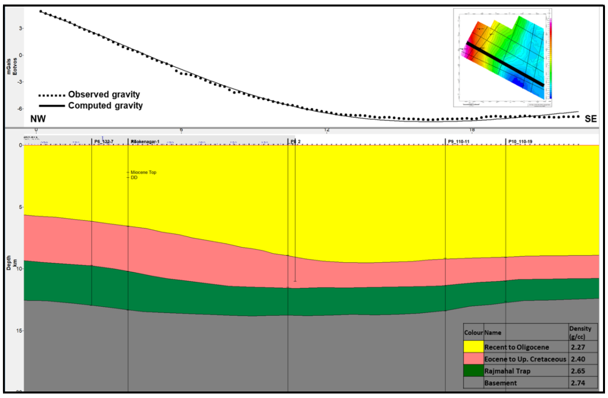

Fig. 8 Gravity modelling along profile P2

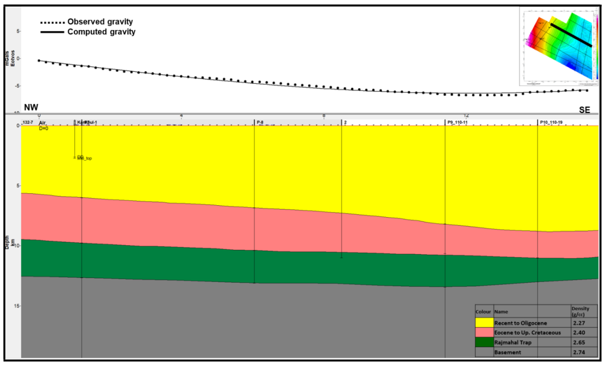

Fig. 9 Gravity modelling along profile P4

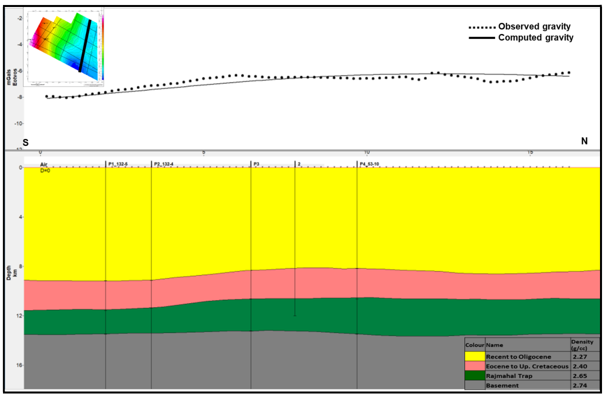

Fig. 10 Gravity modelling along profile P9

Depth to Basement

The depth to basement in the area varies from 12.5 km to 13.75 km (approx.). Its depth increasing from west (Hinge Zone) to east (Deep basin zone) direction. In the central part of the area, the maximum basement depth is observed of the order of ~13.75 km (Fig.11).

The depth to basement is ~12.90 km at well W-2 and ~13.30 km at wells W-3 & 4.

The similar trend of lows at mid-south and northeast part of study area seen in both depth to basement map (Fig. 11) and residual anomaly map (Fig. 6) corresponds to thick sediments deposits with deep basement in these two region. Also, the similar highs at eastern and western part of study area in both maps corresponds to thin sediment cover with relatively shallower basement.

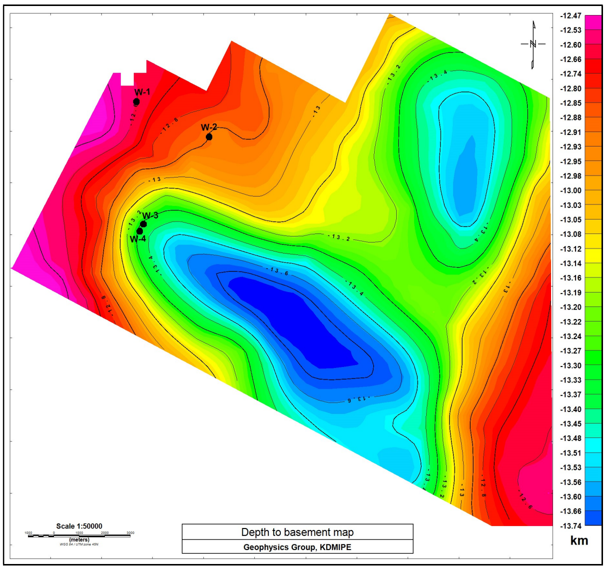

Fig. 11 Depth to Basement map of Ashoknagar area

Conclusion

The study infers that sedimentary thickness is continuously increasing from hinge zone to deep basin zone based on gravity modelling. The depth to the basement varies from 12.50 km to 13.75 km (approx.) in Ashoknagar area.

The depth to basement is ~12.90 km at well W-2 and ~13.30 km at wells W-3 & W-4.

The study will be helpful in formulating strategies for future exploration efforts in the study area.

Acknowledgements

The authors express thanks to ONGC for giving permission to publish this paper. Special thanks to Shri Nandan Verma, GGM-HoI, KDMIPE, ONGC for his guidance & suggestions. Thanks are also due to the members of Geophysics Group, KDMIPE for their encouragement and discussion.

References

1. Alam Mahmood , Alam M Mustafa, Curray Joseph R, Chowdhury M L Rahman, Gani M Royhan: An overview of the sedimentary geology of the Bengal Basin in relation to the regional tectonic framework and basin-fill history Sedimentary Geology 155 (2003), 179–208.
2. Allison M A: Geologic framework and environmental status of the Ganges–Brahmaputra delta. J. Coastal Res. 1998, 14 (3), 826–836.
3. Banerjee B, Marak I A and Biswas A K: Subcrop Gondwana of Bengal Basin and their Reservoir Characteristics, Journal Geological Society of India 2013, 81, 741-754.
4. Gulatee, B L: Interpretation of gravity anomalies in Raniganj area, Geol. Surv. India, Tech. Rep. for 1948-49, pp. 37-39, Calcutta.
5. Imam M B and Shaw H F: The diagenesis of Neogene clastic sediments from Bengal basin, Bangladesh. J. Sed. Petrol. 1985, 55, 665–671.
6. Kaila K L, Murthy P R K, Rao N M, Rao I B P, Rao K, Sridhar A R, Murthy A S N, Rao V V, Prasad B R: Structure of the crystalline basement in the West Bengal basin, India, as determined from DSS studies. Geophys. J. int. 1995, 124,175-188.
7. Kaila K L Reddy P R, Mall D M, Venkateswarlu N, Krishna V G, Prasad A S S S R S: Crustal structure of the west Bengal basin, India from deep seismic sounding investigations. Geophys. J. Int. 1992, 111, 45–66.
8. Krishnan M S: Geology of India and Burma. CBS Publishers and Distributors 1982, 239-291.
9. Lakra M N, Nabakumar Kh, Saha D, Hussain A, Prakash K: Integrated study of gravity and Seismic of Bengal Basin. SPG india 2013, P-038.
10. Palmowski D, Schenk O, Srivastav D K, etal: Understanding of petroleum systems of Gondowana and Paleogene sediments in Bengal Basin including Purnea. Report of KDMIPE 2011.
11. Sinha A K, Nambiar MV, Singh B, Chand S, Dubey P, Pandey Usha, Yadav Savitri: Integrated Geological Modeling of Bengal Basin including Petroleum System Modeling. Report of KDMIPE 201