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A review of Shale gas potentiality in Bangladesh

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Abstract: ***Shale gas is natural gas that is found trapped within shale formations, which act both as reservoir and cap. In the context of Bangladesh, there are many geological and exploring limitations to the development of shale gas in Bengal basin. The study carried out by taking store of the available information, review of the existing wells and their logs of potential area. The study provide the suggestion of shale plays and their lateral extents, and establish thickness and depth of the shale plays as well as geochemical data of the shale formations in Bengal basin. This initial study on shale gas potentiality in Bangladesh discloses that no effective shale gas plays occur in Bangladesh. Shale intervals in the Tertiary sediments greater than 20 m in thickness may occur in places within Kopili, Jenum and Tura Sandstone Formation, but they reach maturities at depths more than 5000 m, thus being not economic for extraction. In Gondwana basin, shale have reasonable maturity, but comprise only thin sequences. TOC is also a critical factor in these cases.***

Keywords: Shale gas, Potentiality, Bangladesh**.**

1. Introduction

Natural gas is an abundant indigenous energy resource in the People's Republic of Bangladesh. With almost 90% of the country's power plants being gas based, the power sector is the largest user of natural gas in Bangladesh. Bangladesh is currently producing gas from several gas fields located along its eastern border, all of which are conventional in character. Innovative invention of vast shale resources in the United States combined with dramatic advancing technology to extract shale gas have generated excitement among the energy community around the world (Ebinger et al. 2014). Bangladesh realizes that the supply of energy to the increasing population puts more and more strain on the energy resources. Hence, security of energy is very crucial in Bangladesh for different utilities. In addition, conventional energy resources are limited and depleting day by day.

Oligocene and Eocene carbonaceous marine shales are considered to be the potential source rocks of the Bengal basin. Early to Middle Miocene sandstones and siltstones of Surma and Tipam groups are the potential reservoir rocks in Bengal basin. Reservoir rocks in the Surma basin are chiefly Tertiary age sandstones of the Bokabil and Bhuban Formations (Miocene). Petroleum systems analysis of Basin area (Greater Bakhrabad) and Shelf area (Madarganj-Sariakandi) areas revealed hydrocarbon generation, expulsion and migration properties that are very encouraging in respect of prospect generation, prospect evaluation and hydrocarbon potential of the Bengal basin and may lead to new discoveries in future (Alam et al. 2006). Based on differences in tectonic style, basin evolution and sedimentation history, the Bangladesh part of the Bengal Basin can be divided into three petroleum provinces: (1) the Eastern Fold Belt, (2) the Central Foredeep, and (3) the NW Stable Shelf/Platform (Imam and Hussain, 2002).

Source rock studies have specified two primary areas that contain strata within the hydrocarbon generating window. They are Shillong Plateau and corresponds to the Surma Basin or Sylhet Trough and the south of the Tangail-Tripura High corresponding to the Hatia Trough (Curiale et al., 2002; Ismail and Shamsuddin, 1991; Shamsuddin and Khan, 1991). In these two "kitchen" areas the early mature gas generation window is in the lower portion of the Bokabil Formation. Western Bangladesh contains half-grabens located on the rifted margin of the India Plate that contain Gondwana strata that are mature for hydrocarbons. It is also foreseen the presence of mature oil windows in Paleocene through Eocene age strata along the Bogra Shelf.

Study of shale gas potentiality in Bangladesh is based on compiled literature, geochemical data (total organic content and maturity) and geophysical well logs. Based on many published literatures, the most important units that contain shale rich sequences (Kuchma and Paharpur Formations, Tura Sandstone and Kopili Shale, Jenum Shale, Bhuban and Boka Bil Formations). These units are frequently studding through different methodology for the determination shale gas potentiality. Most unfortunate thing is that there are very few wells penetrated to desired source rock depths.

2. General Geology and Tectonic Setting

The Bengal basin developed as a result of the collision of three plates – the Indian, Tibetan (Eurasian) and Burma (West Burma Block) (Alam et al., 2003). Oblique collision of the Indian and Burmese plates during the Eocene–Oligocene (Curray et al., 1974) resulted in obduction of the accretionary prism, forming the Indo-Burmese ranges (IBR). The basin is surrounded by the Himalayas and the Shillong massif to the north, Indian shield to the west and the Indo-Burman ranges to the east. To the south, the basin is sweeping to the Bay of Bengal. The geological evolution of the basin initiated in the late Mesozoic through the breakup of Gondwana and it is continuing (Alam, 1989). The Bengal basin, covering mainly shallow marine to continental clastic sedimentary rocks (mostly sandstone and shale of Tertiary age) and minor carbonates, forming a thick (±22 km) early Cretaceous to Holocene sedimentary succession (Alam et al., 2003).

Deposition in the Bengal basin accelerated with the arrival of clearly orogenic sediments from the Himalayas and Indo-Burman ranges during the earliest Miocene (Brunschweiler, 1980; Imam and Hussain, 2002). From at least the Miocene to the present, the Ganges–Brahmaputra and associated or ancestral rivers have been transporting clastic sediments to the Bengal basin (Uddin and Lundberg, 1999).
The deeper part of the Bengal basin is bounded by the hinge zone to the west and the fold belt to the east. The Bengal basin covers approximately 11,000 square kilometers, roughly half of which records deposition within offshore settings (Reimann, 1993). The width of the basin ranges from 200 km in the north to more than 500 km in the south where it extends into the Bay of Bengal.

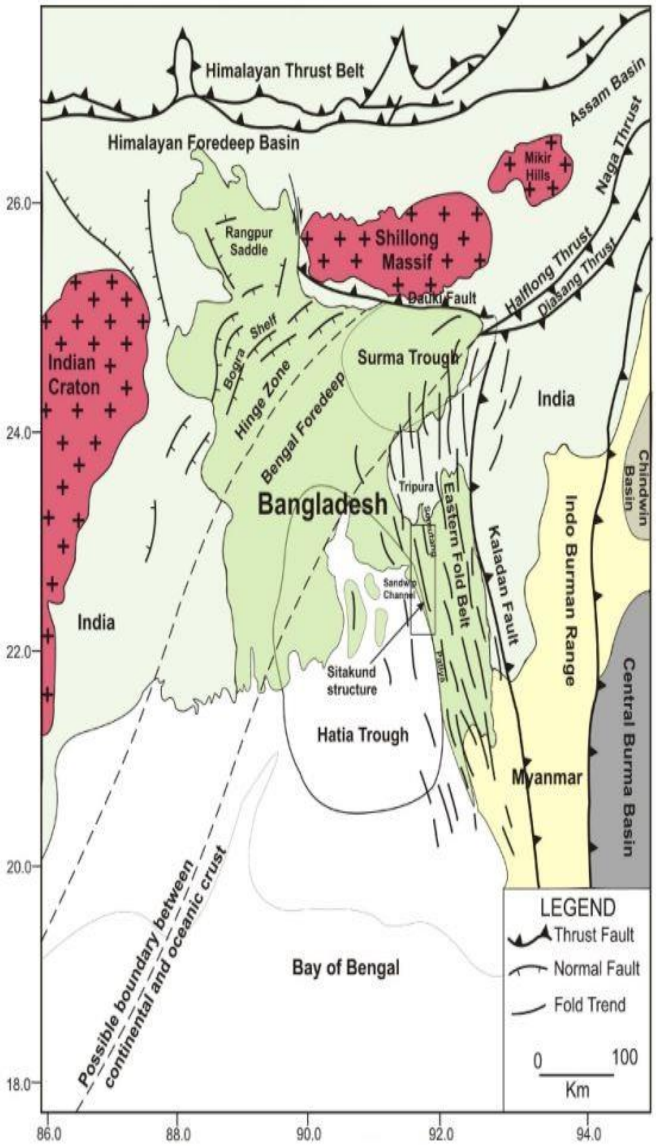

Fig. (1): Map of Bangladesh and adjoining areas showing the structural trends (modified after Mannan and Mirhamidov, 1981).

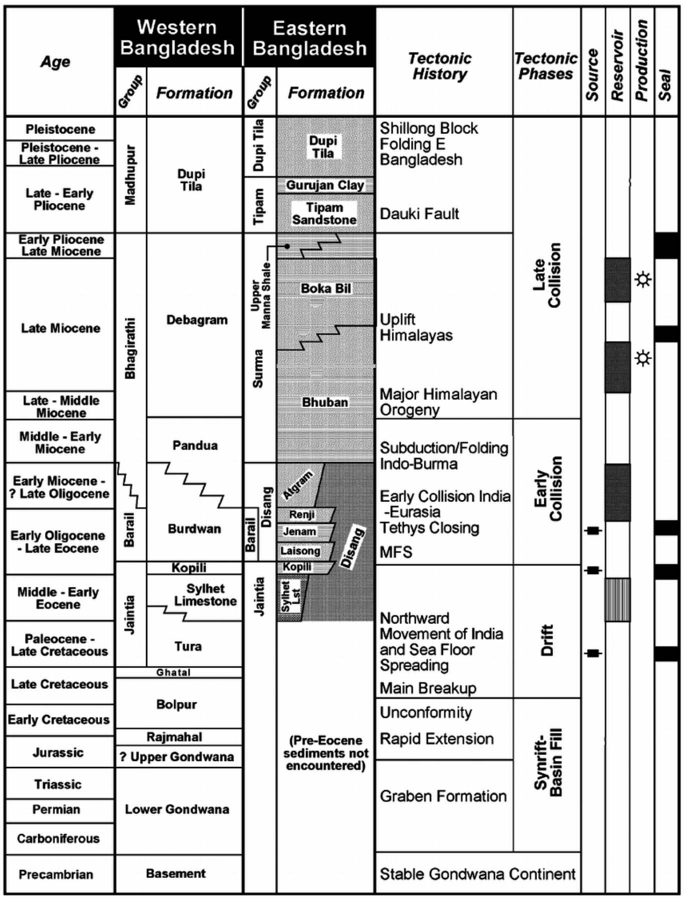

Fig. (2): Stratigraphic sections for eastern and western Bangladesh, showing tectonic history, phases and mega-sequences, and petroleum system elements (Curiale et al. 2002).

3. Material and Methodology

This study is the compilation of different literature concerning study issue without any field or laboratory works. Data have been collected from many published papers concentrating the petroleum habitats in Bangladesh including source and reservoir rock potentiality. It is the combined simulation of different well data so far drilled in Bangladesh. Findings from different studies those used the well data including the geochemical and other log data have considered here. General information and reports, borehole data and geophysical data were taken into consideration. For simple manipulation, Microsoft excel, spatial techniques (GIS) used frequently.
Data have been analyzed available by the Geological Survey, BAPEX, Petrobangla and HCU. However, for the purpose of this regional study the quality of the data is considered as appropriate.
1. General Information and Reports 2. Maps 3. Drill Hole Data 4. Geophysical Data

4. Result and Discussion

Present interpretation's mainly circled within historic data. Recent results of activities, including exploration data from international oil companies, were not available. Wells so far drilled in Bangladesh are highly spaced and scattered those are drilled focusing only the conventional reservoirs. A rigorous deep drilling project is necessary for this implementation because matured source rocks are approximately at greater depth more than 5000m.Accordint to the final updated report On Bangladesh Petroleum Potential and Resource Assessment 2010, total shale gas reserves 4007, 9392 and 18931 BCF consequently with P90, P50 and P10.

Table 1: key parameters with cutoff values (TNO, 2009)

Evaluation parameter of Shale Gas Plays (Key Parameters: 9,10,11,12)		
Seal	Porosity and permeability	
Structural Framework (fracture system, stress regime)	Burial depth	Cut off Value
Gas pressure	TOC	(>1 km and < 5 Km)
Water content and composition	Thickness	(> 20 m)
Modal composition of shale (qtz, clay, carb)	Type of Kerogen (OM)	(II)
Composition of clay mineral	Maturity (vitrinite reflectance)	(>0.8< 3.3 % R_0)

Lithological units with shale gas potential have been contemplated below:

1. Gondwana Group (Kuchma and Paharpur Formations)
2. Jaintia Group (Tura Sandstone and Kopili Shale)
3. Barail Group (Jenum Shale)
4. Surma Group (Bhuban and Boka Bil Formations)

Commonly unconsolidated soft clays and mudstones and immature for gas generation. Pliocene-Pleistocene and Holocene age Shaly interval were not focused on this study because it is too shallow for shale gas extraction.

Neogene sediments in the Foredeep are poor in organic content similar the fold belt, and are immature to somewhat mature. The TOC content of the shales in Muladi-1 well (Fig. 4) varies from 0.24% to 0.48% (Imam and Hussain, 2002).With the exception of few sapropelic intervals, the organic matter is principally humic Type III kerogen. Vitrinite reflectance values (Ro) range from 0.38% at a depth of 1,516m to 0.65% at 4,532m, indicating that the majority of the source rock is immature (this data is from an unpublished Petrobangla well Report, 1978). Ismail and Shamsuddin (1991). It is suggested that mature source beds for hydrocarbons in the Foredeep lie in generative depressions such as Hatia Trough at depths ranging from 5,400m to 10,000m. The source potential of Oligocene sediments in the Foredeep area is unknown because no wells have pierced the sequence, largely on account of an overpressured zone at depths ranging from about 3,500 to 4,500 (Table 2). Hydrocarbons migration in the Foredeep is generally vertical along fractures, and laterally up-dip along the palaeoslope to the west (Wandrey et al., 2000).

Table 2: Summary of some shale gas evaluation parameters in Bangladesh based on gross ideas combined with different data (Jamaluddin et al., 2001; Shamsuddin et al., 2004).

Parameters	Bogra Shelf	Surma Basin	Hatia Trough	Fold Belt
	Eocene Kopili Shale	Pre-Miocene Shales to Early Miocene	Pre-Miocene Shales	Pre-Miocene shales Jenam Shale Kopili Shale
Estimated area (km^2)	8,421	7,706	33,553	23,000
Depth	3,200	5,000	5,000	3,000 to 6,000
Gross Thickness (m)	120 to 350	240	90 to 240	240
TOC%	0.6	most 0.5 up to 1.5	0.5 up to 1.5	1.4 to 2.7
Geothermal Gradient	3°C/ 100m	3°C/ 100m	1.8°C/ 100m	1.8°C/ 100m

Shallow shale layers are commonly intercalated with sandstone. It can be expected that the shale layers are uniform with huge thickness at greater depth. Geothermal Gradient and TOC content are more or less considerable but the shale gross thickness are not enough in many areas to come up with production (Table 3). Depth is the major problem. It can be speculated that the potential shale gas are at greater depth. Thin layers of shale are not suitable for shale gas production with present technology available for Bangladesh.

Table 3: Formations petro-physicochemical parameters and possible limitations marked with red color (Farhaduzzaman et al., 2015; Imam 2005; Alam et al., 2003; Jamaluddin et al., 2001; Shamsuddin et al., 2004; Reimann, 1993).

Target Formation	Parameters Burial depth	Shale Thickness	TOC	Type of Kerogen (OM)	Maturity (vitrines reflectance)
Gondwana Group	**0.2 to > 5 km**	**4 m**	**0.9 – 9.9**	**II and III**	**0.89 -1.80**
Kopili Shale	**0.2 to > 5 km**	**36 m**	**0.6- 4.7**	**II**	**0.46-0.56**
Jenum Shale	**0.2 to > 5 km**	**Not eva-luated***	**0.8- 3.7**	**II**	**0.46-0.56**
Bhuban Formation	**0.2 to 4**	**Up to some 100 m**	**0.2 to 1.7**	**III and (II)**	**0.43 to 0.49**
Boka Bil Formation	**0.2 to 3.5**	**Up to some 230 m**	**0.1 to 0.9**	**III and (II)**	**0.38 to 0.65**
Tura sandstone	**0.2 to > 5 km**	**32 m**	**0.4- 4.3**	**III**	**0.43 – 0.47**

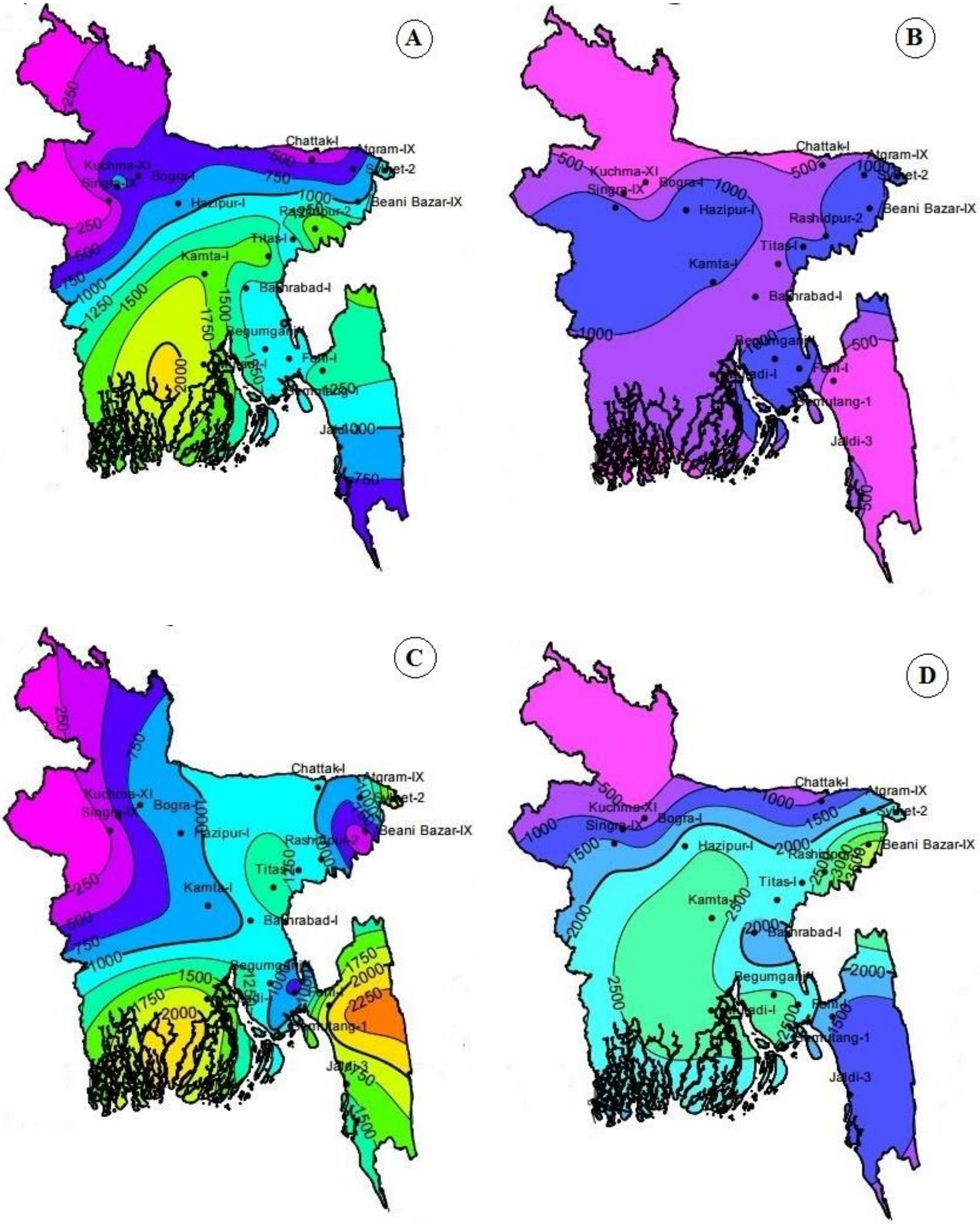

Fig. (3): A. Thickness map of the Boka Bil Formation
C. Thickness map of the Bhuban Formation

B. Depth map at Top Boka Bil Formation
D. Depth map at Top Bhuban Formation
(Data source: Uddin & Lundberg, 2004)

Available Gamma Ray logs, i.e. Kuchma-X1 for the Gondwana Group, Bogra-1 for the Tura Sandstone and the Kopili Shale used to delineate Values for shale thickness of unceasing shale intervals as based on quick-look assessments. No log ever found that cover was Jenum shale in Bengal basin to assign shale thickness accurately. Logs are available For the Boka Bil and Bhuban Formations because most of the reservoir are within these stratigraphic depth. Meanwhile, the TOC and Maturity had already shown unfavorable conditions that discouraged detailed evaluations to assign the shale thickness on a well to well basis (Table 3). Gamma Ray readings ranging up to some 100 m in thickness of shale interval in the Bhuban Formation. In places, where the Upper Marine Shale is present in the Boka Bil Formation it extents a thickness of some 230 m. In none of the geochemical samples down to 4877m (Jenum Shale in Atgram-1X) favorable maturity values greater than 0.8% have been reached (Fig. 4).

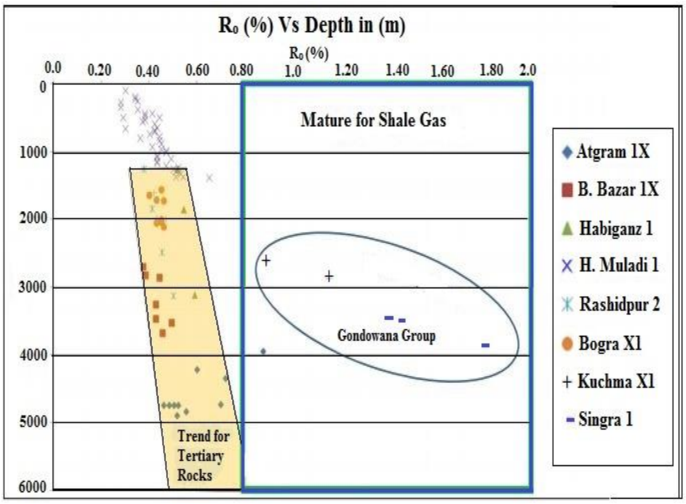

Fig. (4): Maturity vs. Depth trends for source rocks from existing data in Northwestern part of Bengal basin.

Only the Gondwana Group in the stable shelf region has reached favorable maturity compared to Tertiary shales. The reason for the greater maturity is the deep burial prior to the uplift between Middle Jurassic and Early Cretaceous (Frielingsdorf et al. 2008). In accordance with the mapping by (Islam & Eickhoff, 2001) the sub-basins of Singra-Kuchma and Sherpur are placed within the essential depth window. Threshold for Shale Gas Maturity 0.8% R_o.

Though, the Gamma Ray Log from Kuchma-X1 evidently specifies that the shale content stems from intercalated intervals which do not exceed 4 m in thickness. These thin layers do not permit adequate shale gas extraction. An additional constraint may ascend from the TOC distribution. Though one maximum TOC value of 9.88% has been noted, the remaining four samples are in a range of just 1.2 to 1.5%. Additionally, it should be noted that the Gondwana sediments in Kuchma-X1 were production confirmed by drill stem test without the presence of any hydrocarbon shows. From these outcomes it is decided that the Gondwana Group in the sub-basins of Singra, Kuchma and Sherpur does not offer a valid shale gas play.

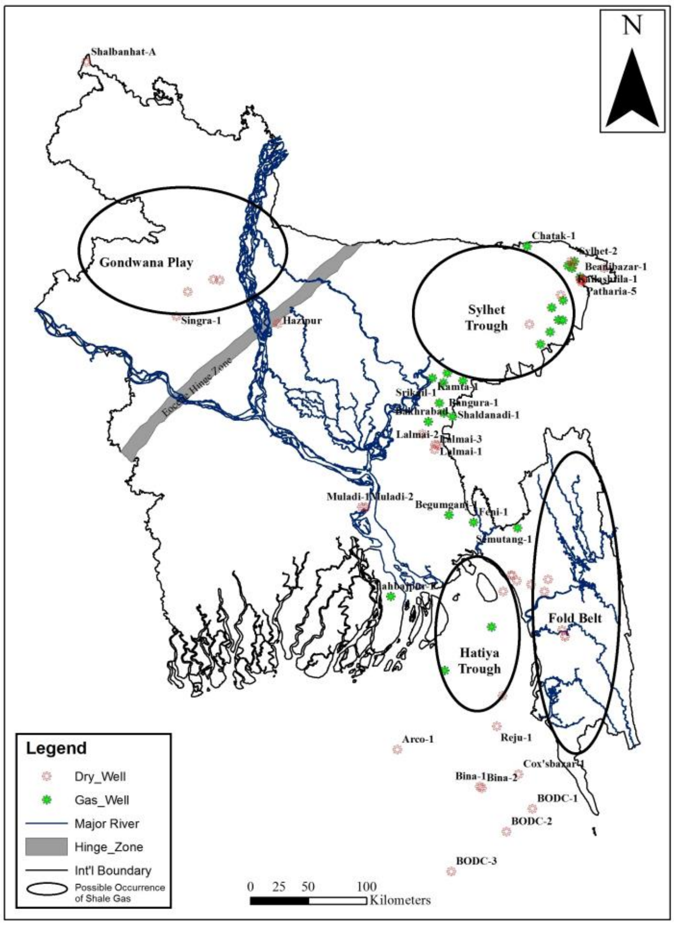

Fig. (5): Borehole location in Bengal basin and potential areas of shale gas occurrence.

5. Conclusion

The glimpse of the above data indicate that shale gas potentiality in Bangladesh reveals that no valid shale gas plays exist in Bangladesh. Shale intervals in the tertiary succession exceeding 20 m in thickness may present in zones of the Kopili, Jenum and Tura Sandstone Formation, unfortunately they approach maturities at depths deeper than 5000 m, so extraction of shale gas in Bangladesh would not be economical. From above evidences, the only favorable source rock existing in Gondwana plays but thickness of shales is the most concerning issue. Conclusion contradicts earlier estimations based on gross ideas that shows some possibility describing potential for shale gas and lists substantial volumes of contained gas in the basins. However, it did not combine all key factors affecting the potential of shale gas development.

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