Petroleum and Coal

Article **Open Access**

Occurrence, Distribution, and Origin of Shallow Biogenic Gas in Late Quaternary Unconsolidated Sand Deposit of Shahbazpur Structure, Southern Bangladesh

Morshedur Rahman[1], S.M. Mainul Kabir[1], Badrul Imam[1], AKM Eahsanul Haque[2], Md. Al Amin[1]*

[1] *Department of Geology, Faculty of Earth & Environmental Sciences, University of Dhaka, Dhaka-1000, Bangladesh*
[2] *Department of Physical and Geological Sciences, Universiti Brunei Darussalam, Gadong BE1410, Brunei Darussalam*

Received July 20, 2018; Accepted October 19, 2018

Abstract

Gas occurrences at shallow depths have been a common feature noticed in alluvial plain in shallow water well drillings in the southeastern part of Bangladesh. The gas occurs in recent (< 2 Mya) alluvial sediments at shallow depths and flows in a range of few hours to several days before being exhausted. The only exception is the shallow gas occurrence in Bhola Island, which flows from almost similar depth but have been consistently flowing for more than ten years. This shallow gas occurs within the recent deposit of Holocene age of Shahbazpur structure at a depth of 260m to 290m. These recent deposits are composed of unconsolidated sand with thin clay layers. The individual shallow gas pools are discontinuous and indicate that the shallow reservoir sand bodies have frequent facies change, which implies their lateral extensions are limited. Field data collected all over the Bhola island shows that the shallow gas accumulation is only located in Burhanuddin upozila. Entirely composed of methane, very high methane-ethane (+) (>1000) ratio and high dryness value (>0.99) of shallow gas is suggestive of its biogenic origin.

Keywords: *Shallow Gas; Biogenic origin; Shahbazpur structure; Southern Bangladesh.*

1. Introduction

Shallow gas is a well-known phenomenon, being accumulations of gas located in the upper sediments, close to the surface. It is trapped typically in shallow and immature sediments, indicating their formation in swamps, paddy fields, anoxic freshwater lakes, and sub littoral-marine bays, as well as glacial drifts and marine sediments beneath the anaerobic sulfate-reducing zone [1-2]. Though shallow gas is often known as drilling hazards, it has been used as commercial production of gas in some countries of the world and it's utilization is increasing day by day. Some countries recognized shallow gas as a natural resource such as Canada, Russia, and China [3-5]. A large accumulation of biogenic gas is known to occur in shallow (<1000) Cretaceous reservoirs of the Northern Great Plains (mainly Montana), USA and southeastern Alberta and southwestern Saskatchewan, Canada [6-7]. Such gas in shallow depths are typically rich in methane and are not associated with oils. Methane is the only hydrocarbon actually generated in significant volumes during the biogenic stage [1-8]. Occurrences of shallow gas during drilling of water well reported for many years in Bangladesh plain land. In recent years, the occurrences of shallow gas are more widely reported in Bangladesh because of the increasing number of tube Wells having sunk. The reported depths of biogenic gas occurrence ranges in different depths from 10 meters to 100 meters below the surface, but most of these occur at depths more than 30 meters [9]. All of these have been proved to be non-commercial and record gas flow for short intervals of a few days to a few weeks. However, the occurrence

of shallow gas in Bhola district in southern Bangladesh is the only exception in the sense that gas seepages have been continuing for as much as 10 years.

The shallow gas occurs in Quaternary sediments in Bhola Island at depth ranges from 200 to 300m meaning a deeper habitat compared to all other known Quaternary shallow gas in Bangladesh. Use of these shallow gas by local people through make shift crude technology (rubber tube and drum) have made the gas sub commercial. Although the subject have been reported in the news media for several years, no in-depth geological evaluation and research has been carried out on the gas seepages of Bhola. The present research aims at geological evaluation of the occurrences, distribution and origin of the shallow gas in the Bhola Island based on field studies and laboratory analyses. A comparison has also been made between the shallow gas as mentioned above and the deep reservoir gas of the Shahbazpur gas field that occurs in Miocene sediments at depth range in excess of 2500m [10].

2. Geological setting

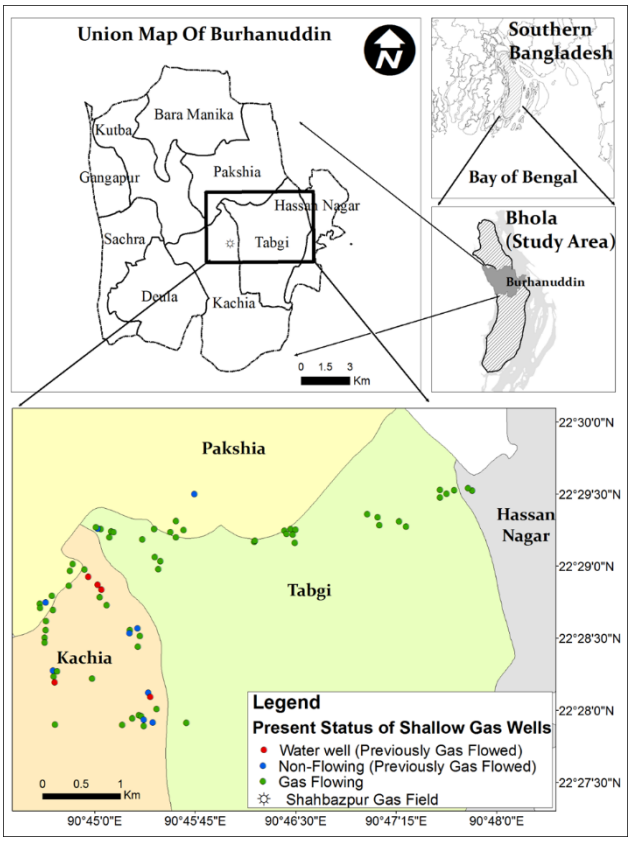

Fig.1. Location map of the study area and present status of shallow gas wells

Bhola, an island district of Bangladesh is located in Foredeep area of Bengal basin or can be said more precisely in the Hatia trough. The Foredeep part of the Bengal is at the west of eastern fold belt. Here the intensely folded sedimentary layers gradually become strata of mild folding or no folding at all. Therefore, the sedimentary layers are generally horizontal to sub horizontal and are free from major tectonic deformation in the Foredeep area. This unit covers the central part of the basin and is represented by river to delta plain topography at the surface [11]. The Shahbazpur structure is a subsurface anticlinal structure situated in the middle of the Bhola Island. There is no surface expression of the Shahbazpur subsurface anticline rather the surface is floored with recent alluvial plain deposits. Field survey has been carried out in almost all parts Bhola district. However, the shallow gas wells are found to be located only in Burhanuddin upozila. It covers the longitude range from 90^0 43'E to 90^0 50'E and latitude range from 22^0 24'N to 22^0 32'N (Fig. 1).

3. Stratigraphic sequence

The stratigraphy of Foredeep area of Bengal basin is characterized by an enormous thickness of Tertiary sedimentary succession. This succession is thicker in the southern part of the regions in the Faridpur and Hatia Troughs, but the stratigraphy is little known there [12]. The stratigraphy of the Shahbazpur area was established with the help of systematic lithological description of the drilled section, log data and from seismic data, and from correlation with neighboring well and is summarized in Table 1. It ranges from Miocene to Recent in age, although the base is not seen. The Shahbazpur-1 succession is divided into four sequences named Shahbazpur (SB) sequence -I, -II, -III and – IV [13]. These sequences have been assigned

to the traditional stratigraphic succession of Bangladesh, i.e. the Surma Group (SB sequence 3 and 4), the Tipam Group (SB sequence 2) and the Dupi Tila Group (SB sequence 1) [14].

Table 1. Stratigraphy and lithology in the Shahbazpur area [Modified after 13, 14].

Depth (m)	Age	Group	Sequence (m)	Lithology	Depositional Environment
0-480	Recent		Alluvium (480)	Loose unconsolidated sand with occasional clay	Fluvial Plain
480-1505	Pleistocene (?)	Dupi Tila (Tentative assignment)	SB sequence I(1025)	Shale with occasional occurrence of interbedded sandstone and calcareous siltstone	Deltaic to Fluvial plain
1505-2010	Pleistocene-Pliocene	Tipam	SB sequence II(505)	Shale and sandstone	
2010-2750	Plio-Miocene	Surma	SB sequence III (740)	Sandstone and shale	Deep sea to shallow marine
2750-3631	Miocene		SB sequence IV (881)	Sandstone and shale	

4. Materials and methods

4.1. Field Procedure and sampling

Field survey in the study area carried out twice during this study. First, a reconnaissance survey performed in winter (January 2015) to observe the status of the shallow gas wells. To get the general overview of the well location, suggestion of the local people taken. A hand held GPS was used to note down the well location. Another field visit was done in the beginning of rainy season (April 2015) to observe whether the flowing status of well are changed or not. At second visit period, gas samples were collected from several locations. Gas samples (Table 2) were collected by the water displacement method from each gas well. These samples immediately kept in glass bottles at the sampling sites and the bottles opened just before analysis in laboratory.

Table 2. Location of sampling wells

Area	Well	Depth (m)	Coordinates	
			Latitude (N)	Longitude (E)
Kachia	K-1	262	22°27'58.80"	90°45'19.93"
Kachia	K-22	259	22°28'31.26"	90°44'37.92"
Tabgi	T-15	259	22°28'59.70"	90°45'28.92"
Tabgi	T-23	290	22°29'17.52"	90°47'8.04"
Tabgi	T-26	262	22°29'15.30"	90°46'25.44"
Pakshia	P-2	259	22°29'15.90"	90°45'40.32"
Hassan Nagar	H-2	290	22°29'32.76"	90°47'47.76"

4.2. Analytical procedures

Hydrocarbon compositions of natural gases were analyzed by a gas chromatograph. The gas samples have been analyzed by Bruker 450 gas chromatograph fitted with a Hayesep 6'*1/8" column in parallel with a Molseive 13X 4'*1/8" column, both connected to Thermal Conductivity Detector (TCD) and a CP-Sil 5CB 60m * 0.25mm capillary column connected to Flame Ionization Detector (FID). Gas samples are passed through a 14-port valve to fill three individual loop of 250 µL and then it is injected to three columns separately by programmed valve switching. Temperature program was kept at 45^0 C for 6.5 min, then raised at a rate of

20^0 C/min up to 200^0 C and hold for 3.75 min. Helium was used as carrier gas. Hydrogen and oxygen (air) for FID. Presence of hydrogen sulfide (H_2S) in gas was tested with lead acetate.

5. Results and discussion

5.1. Subsurface occurrence and distribution of shallow gas

5.1.1. Occurrences: depth wise

A generalized stratigraphy established from the well tops information, which shows the position of the gas zones in stratigraphic sequence (Fig. 2a).

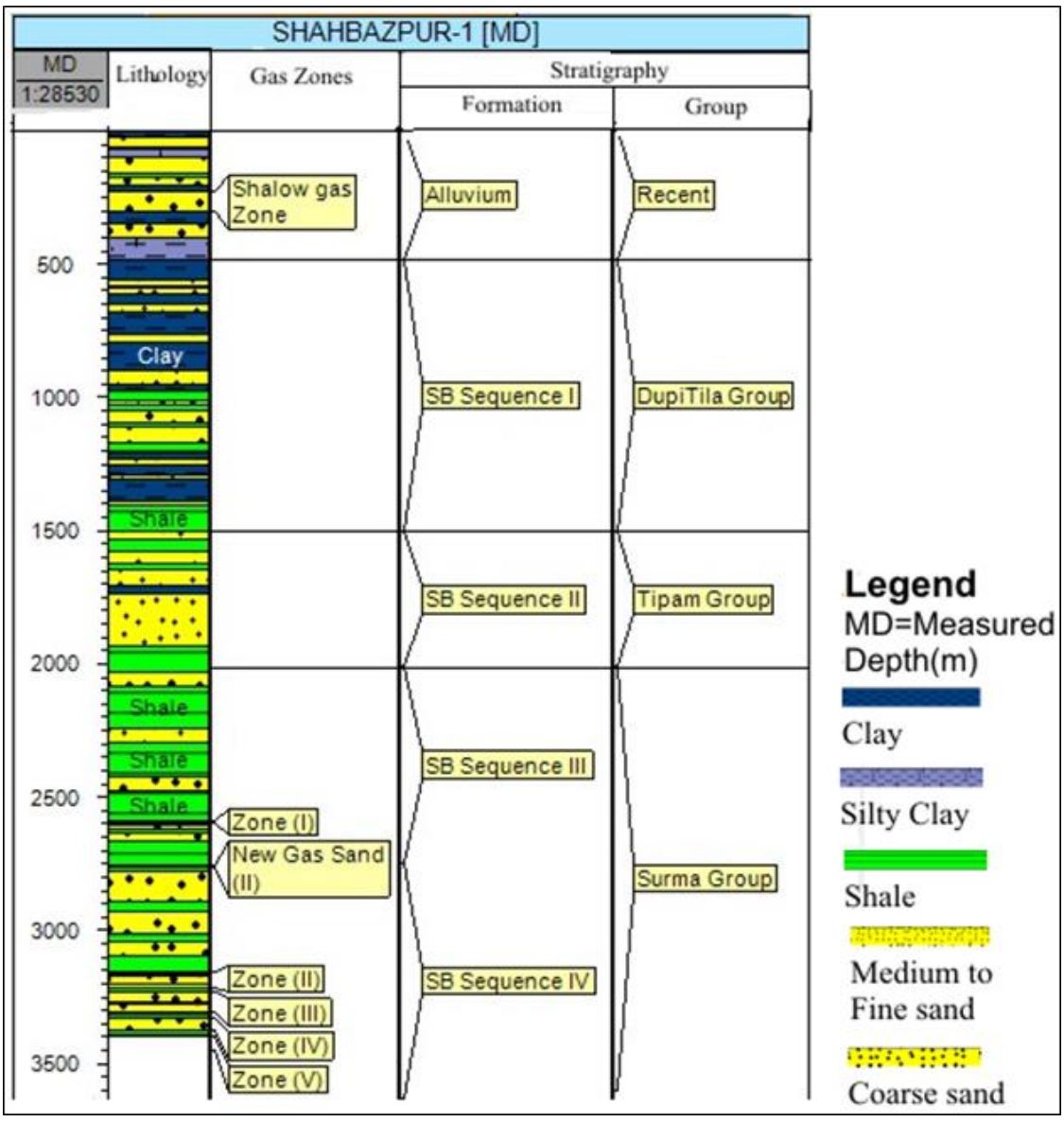

Fig. 2a. Occurrence of shallow gas in generalized stratigraphy (modified after [13])

From the figure, it can be noticed that the shallow gas zones occur in alluvial deposit of recent age where deep gas zone occurred in Surma group of Miocene-Pliocene age. A correlation has also been made between seismic stratigraphy of Shahbazpur gas field and Litholog made from Shah-bazpur-1 well (Fig. 2b) which shows that shallow gas zone occurred as delta top deposit of Megasequence 3, where most deep gas zones occurred as deep sea to shallow

marine deposits of Megase-quence 1. Two deep gas zo-nes occurred at the base of the incised valley fills of Mega-sequence 2 [15].
A cross-section (A-B) has been constructed along the shallow gas wells taking in reference Pakshia-1 well, which Litholog were made from available borehole data. From the Litholog it can be observed that the dominant lithology is unconsolidated sand with several thin to thick clay layers. A well correlation established along the cross-section based on top of the shallow gas zone where the base of the shallow gas zone was not known yet (Fig. 3). From the correlation of shallow gas wells, it can be found that the depth range of the top of the shallow gas zone is about 260m-290m.

A detail relation of seismic line with shallow gas wells shown in (Fig. 4). The relation between gas wells and seismic lines give a relationship between the occurrence of shallow gas wells and deep gas wells. The maximum distance from the seismic line to well is taken as 1000m that is, the wells that fall within this 1000m radius will show in the seismic line. It has been observed that the shallow gas wells have TWT (milliseconds) is about less than 500ms where the Shahbazpur gas wells have TWT is about 2500ms. The shallow gas wells clustered in the north of the Shahbazpur gas wells and there are no shallow gas wells in the south of Shahbazpur gas wells.

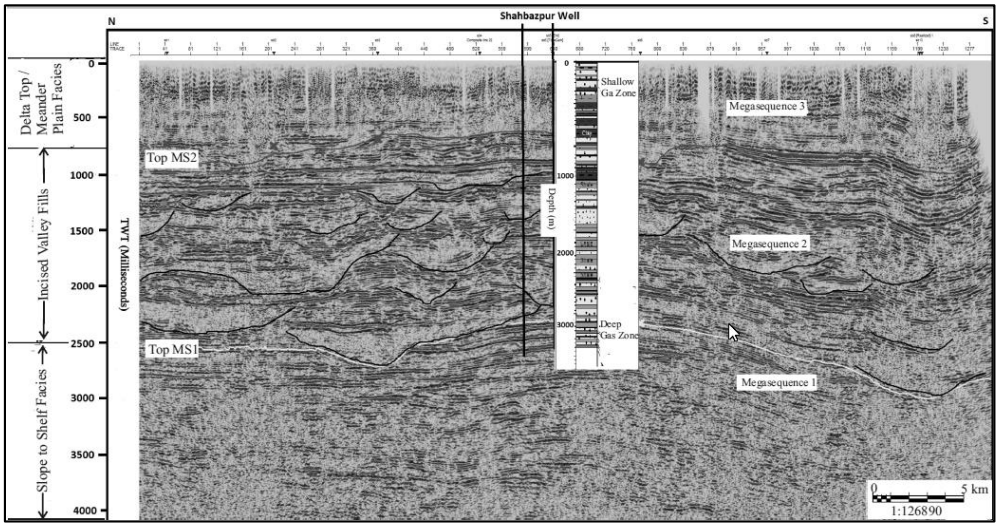

Fig. 2b. Occurrence of shallow gas in seismic stratigraphy (modified after [15])

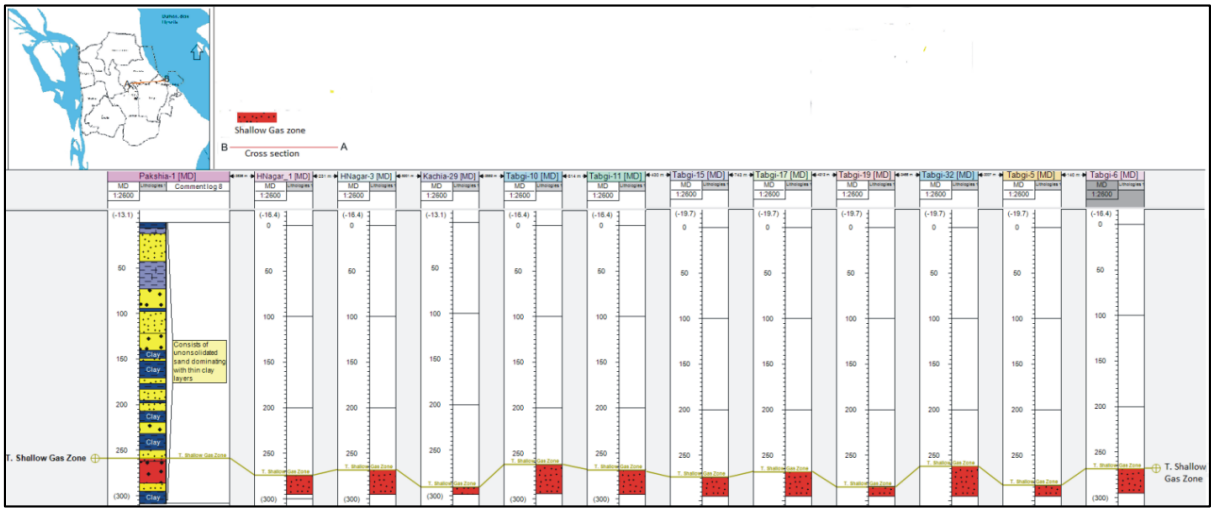

Fig. 3. Well correlation of shallow gas wells

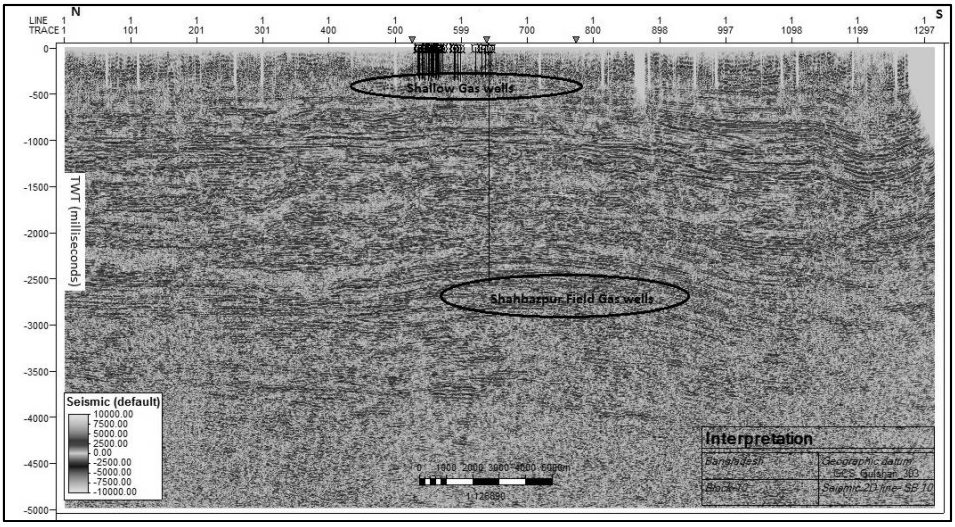

Fig. 4. Distribution of shallow gas wells in Shahbazpur seismic line

5.1.2. Distributions: area wise

Field survey has been carried out in all part of Bhola island, after that it has been confirmed that the shallow gas wells are located only in Burhanuddin upozila out of 7 upozila of Bhola district. The shallow gas wells are only present in four union of the upozila they are Kachia, Tabgi, and Pakshia and Hassan Nagar union (Fig. 1). No other union has reported of having such shallow gas wells. Most of the shallow gas wells are located in Kachia union, and they have a clustered distribution. The shallow gas wells located from Kachia to Tabgi to Hassan Nagar and some of the wells found in the bank of the Meghna River. According to local people, so many wells lost into the Meghna River. The shallow gas wells found from the north of the Shahbazpur gas field and no shallow gas wells found in the south of the Shahbazpur gas field. Some of the shallow wells are now used as water well; some are just abandoned because they are not flowing water or gas and most of them are still flowing gas, and new shallow gas wells are also exploited (Fig. 1). The pressure of the flowing gradually decreased with increasing age of wells. It has been observed that some wells stopped flowing or has lower flow rate gas during winter whether the rainy season they have full flow.

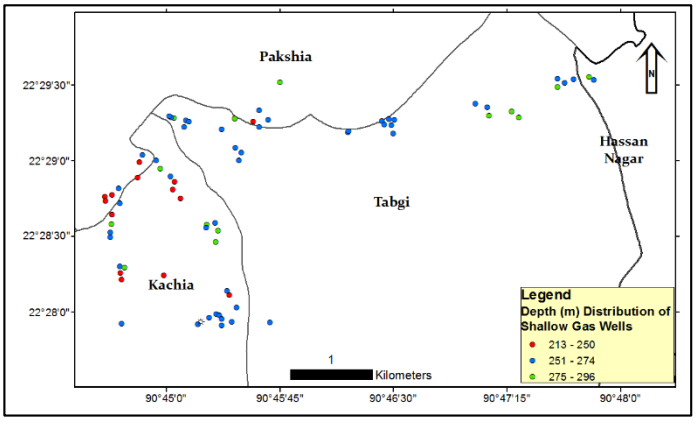

Fig. 5a. Depth distribution of shallow gas wells

The shallow gas wells in Kachia have higher flow rate than wells in Tabgi. When collecting gas samples, the less time required to fill the sample bottle in Kachia union than other unions. A depth distribution map was also made based on the depth information of shallow gas wells in the study area (Fig. 5a). The very shallow gas wells (213m-244m) are located in the west and North-west of the study area. All of the wells that are located in the in the northeastern part of the study area having depth range 250m-290m. When collecting data in the field, it has been observed that the average depth of shallow gas wells in Tabgi union is higher than the average depth of shallow gas wells in Kachia union. It has also been observed that the shallow gas wells are not clustered to the closure rather than they also distributed towards flanks of the structure (Fig. 5b).

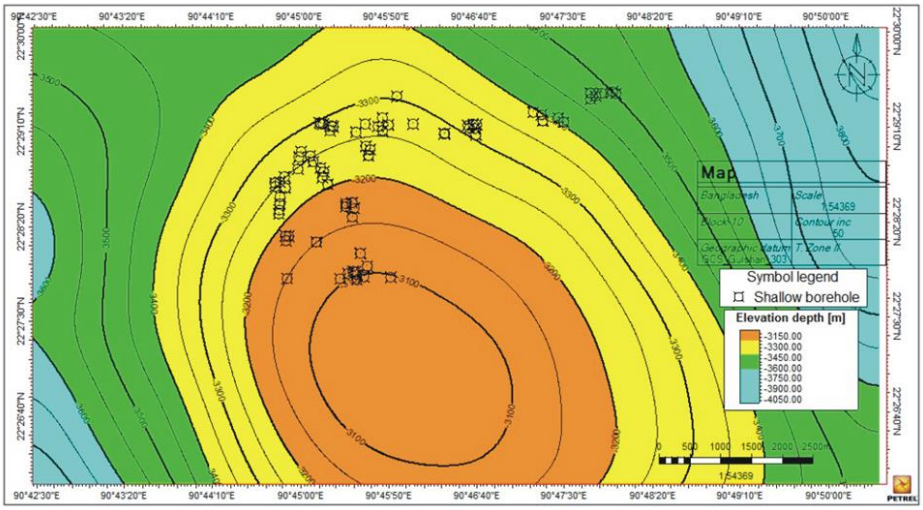

Fig. 5b. Showing distribution of shallow gas wells in Shahbazpur structure

5.2. The chemical composition of the shallow gas

Seven gas samples were analyzed for chemical composition. The analyses show that the samples are dominated by methane (as much as 90%), with minor C_{2+} hydrocarbons (<0.2%), N_2, and CO_2. The gas compositions of the shallow gas samples are shown in Table 3.

Table 3. Molecular composition of analyzed natural gases

Well	Molecular Composition (vol %)									
	CH_4	C_2H_6	C_3H_8	i-C_4	n-C_4	i-C_5	n-C_5	N_2	CO_2	H_2S
K-1	96.86	0.07	nd	nd	nd	nd	nd	2.51	0.56	nd
K-22	97.29	0.05	nd	nd	nd	nd	nd	2.18	0.48	nd
T-15	98.26	0.07	nd	nd	nd	nd	nd	0.83	0.84	nd
T-23	97.73	0.05	nd	nd	nd	nd	nd	1.11	1.11	nd
T-26	98.02	0.03	nd	nd	nd	nd	nd	0.94	1.01	nd
P-2	96.40	0.05	nd	nd	nd	nd	nd	2.72	0.83	nd
H-2	97.15	0.08	nd	nd	nd	nd	nd	1.89	0.89	nd

**nd=not detected*

For the gas samples collected from Kachia union, the ranges of hydrocarbon compositions are CH_4: 96.86 - 97.29%, C_2H_6: 0.05 – 0.07%, CO_2: 0.48 -0.56% and N_2: 2.18-2.51%. For the gas samples collected from Tabgi union, the ranges of hydrocarbon compositions are CH_4: 97.73 - 98.26%, C_2H_6: 0.03 – 0.07%, CO_2: 0.84 -1.11% and N_2: 0.83 -1.11%. For the gas, samples collected from Pakshia union the hydrocarbon compositions are CH_4: 96.40%, C_2H_6: 0.05%, CO_2: 0.83% and N_2: 2.72%. For the gas, samples collected from Hassan Nagar union the hydrocarbon compositions are CH_4: 97.15%, C_2H_6: 0.08%, CO_2: 0.89% and N_2: 1.89%. From the above observation, it can be said that the range of hydrocarbon compositions of shallow gas is CH_4: 96 – 98 %, C_2H_6: 0.03 – 0.08 %, CO_2: 0.5 -1% and N_2: 1-3%. The higher hydrocarbon constituent (>C_{2+}) were not present in the gas samples. It should be mentioned that the smell of hydrogen sulphide (H_2S) was found during collecting gas samples but was not found during lead acetate test in the laboratory.

5.3. Comparison of shallow gas with deep thermogenic gas

Comparison of two gases can be made by chemical and isotopic composition. As there is no facility available for isotope analysis in the country, only chemical analysis results by gas chromatography are used for comparison. For the deep thermogenic gases (>2 500m) of

Shahbazpur gas field the ranges of hydrocarbon compositions are CH_4: 89.82 - 94.9%, C_2H_6: 3.00 – 4.090%, C_3H_8: 0.55 – 1.12%, i-C_4: 0.15 -0.25%, n-C_4: 0.06 -0.11%, i-C_5: 0.02 -0.08%, n-C_5: 0.01 -0.05%, CO_2: 0.6 -0.9% and N_2: 0.4- 3.0%. Hydrogen sulphide was not present in the deep thermogenic gas.

The shallow gas does not have any higher hydrocarbon constituent (>C_2), it can be possible if the shallow gas were produced by bacterial biodegradation. However, a small amount of ethane can be present in the bacterial gas because ethane has high bacterial resistance [16]. Where the deep gas has higher hydrocarbon like propane, butane, pentane, and hexane. Therefore, from the composition of the shallow gas and deep gas, it can be said that the shallow gas is different from deep reservoir gas.

5.4. Origin of the shallow gas

To understand the resource-base, it is necessary to determine whether a gas accumulation is microbial, thermal or mixed. This is accomplished through an analysis of both molecular and isotope composition. However, isotope composition gives better result about the origin of the gas, but the molecular composition of the analysis can also give an indication of the origin of the gas. The values of C_1/C_{2+} greater than 1,000 indicated biogenic sources, whereas values less than 50 signaled thermogenic sources [17]. From the gas analysis of shallow gas and deep gas, it can be observed that the shallow gas have the range for C_1/C_{2+} ratio is about 1200-3500 where the deep gas has the range for C_1/C_{2+} ratio is about 20-35 (Fig. 6a).

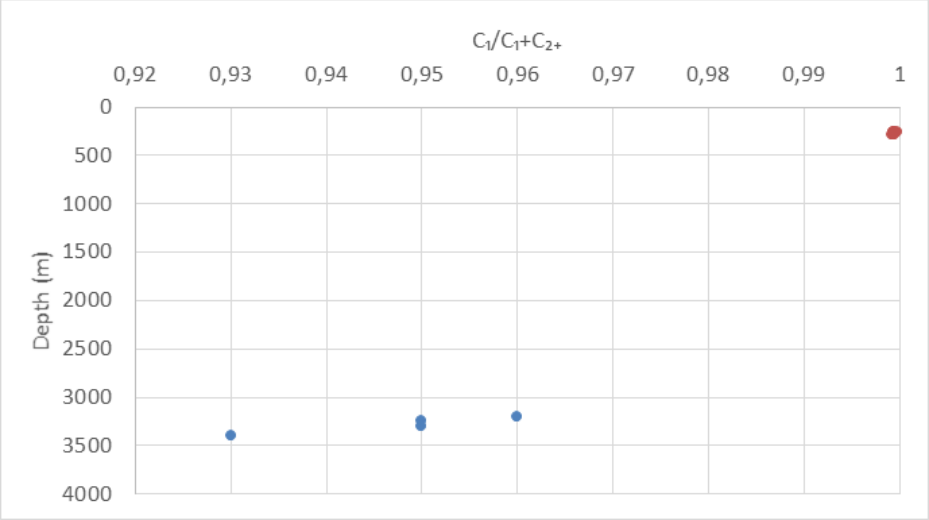

Fig. 6a. Dryness value of the shallow gas and deep gas

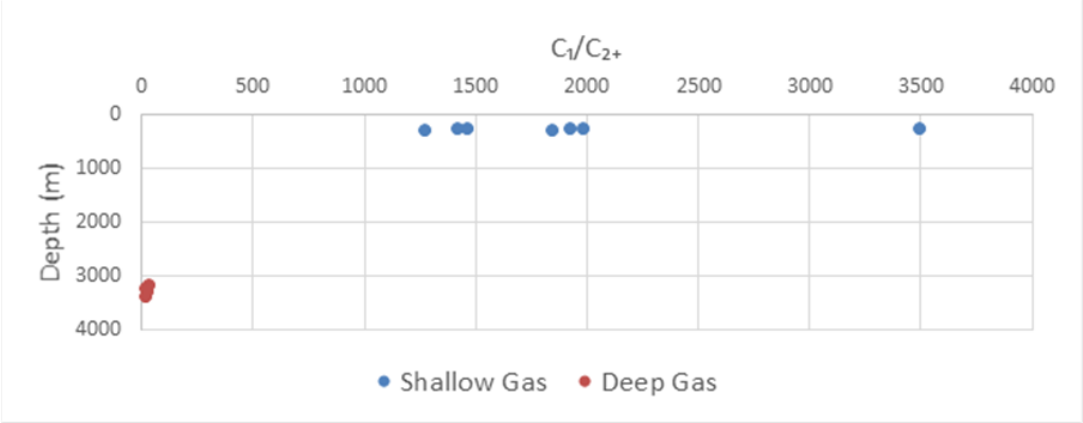

Fig. 6b. Showing the value of C_1/C_{2+} ratio in shallow gas and deep gas

Biogenic gases characteristically are composed almost entirely of methane ($C_1/(C_1+C_{2+})>0.98$) [5]. In other words, it can be said that the gas is very dry due to the dryness of methane. Generally, microbial gas is typically considered dry (i.e., depleted in C_{2+} components), but there is clear evidence that ethane and possibly propane may also form through microbial processes [16]. From the analyzed gas samples, the shallow gas has the range of the $C_1/(C_1+C_{2+})$ value is about 0.9992-0.9997 where the deep gas have the range of the $C_1/(C_1+C_{2+})$ value is about 0.93-0.96 (Fig. 6b).

Therefore, from the above observation discussed above it can be concluded that the shallow gas is quite different from conventional reservoir gas. The > 1000 C_1/C_{2+} ratio value and >0.98 $C_1/(C_1+C_{2+})$ value suggest the biogenic origin of the shallow gas, where the <50 C_1/C_{2+} ratio value and <0.98 $C_1/(C_1+C_{2+})$ value proved the thermogenic origin of the deep gas. Therefore, it can be summarized that the shallow reservoir gas in the study area is biogenic in origin though isotope analysis is needed for further confirmation.

5.5. Prospect of the shallow gas

During the field survey, it was observed that water is continuously drawing out from the tube well. The local people use a filter, which separates the water at the base and gas at the top (Fig. 7). The local people said that they are using this gas for about 30 years.

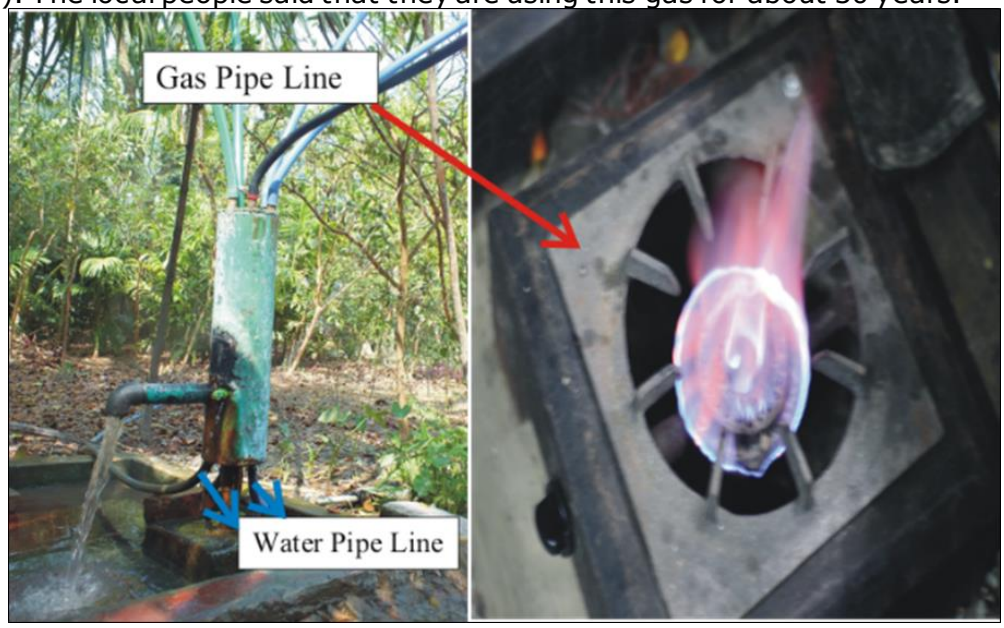

Fig. 7. Local filtering method for separating gas and using it for cooking purpose

It is true that all of the gas wells were not continually flowed from the beginning. Some of the gas wells flowed for 1 (one) year, some are for 5 (five) years, and some are still flowing (Fig. 8). There are some wells, which are flowed for more than 16 years, and there are two wells one in kachia and another in Pakshia, which flowed more than 30 years and they are still flowing.

There are on average 2-7 connections per well. Most of the gas wells having no connection with consumers are located in Kachia. The lack of connectivity is due to the absence of flow, but they flow previously. They had the connection like present flowing well when they flowed, but it is difficult to get the information on how many connections they had because no one has a clear idea about the connections. From the presently flowing gas wells, the wells from Tabgi and Hassan nagar union has more connection (Fig. 9).

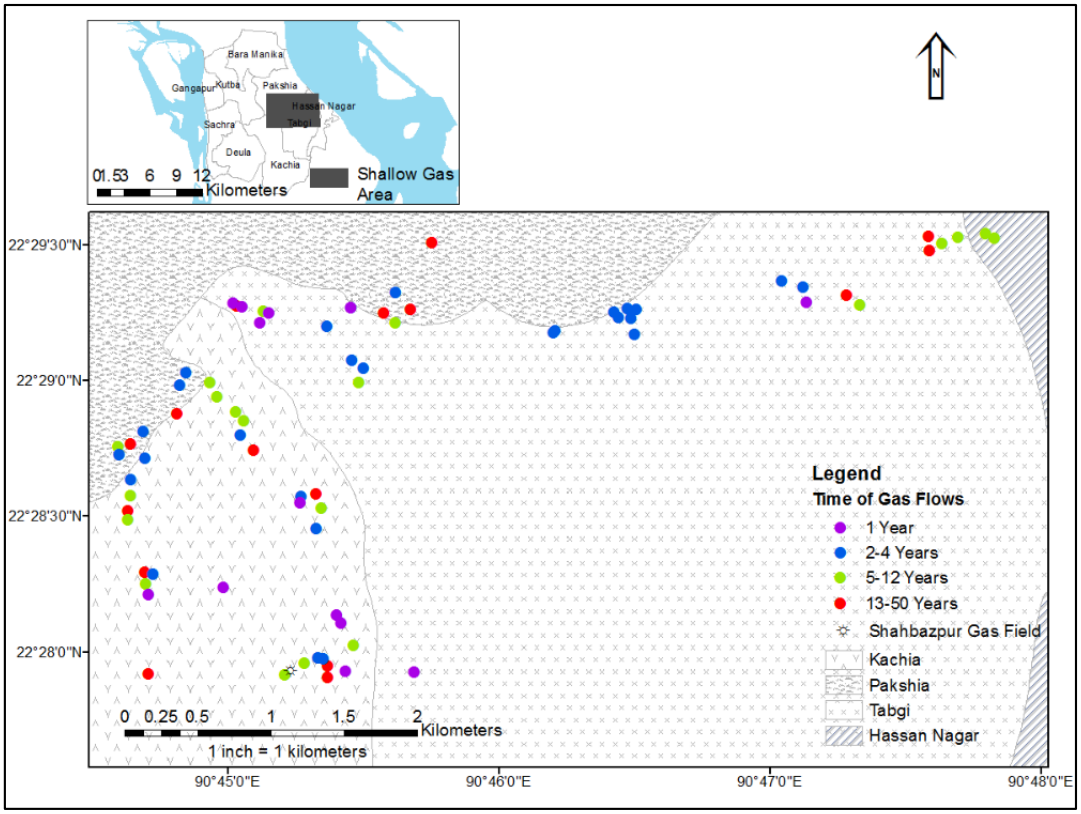

Fig. 8. Period of gas flow from shallow gas wells

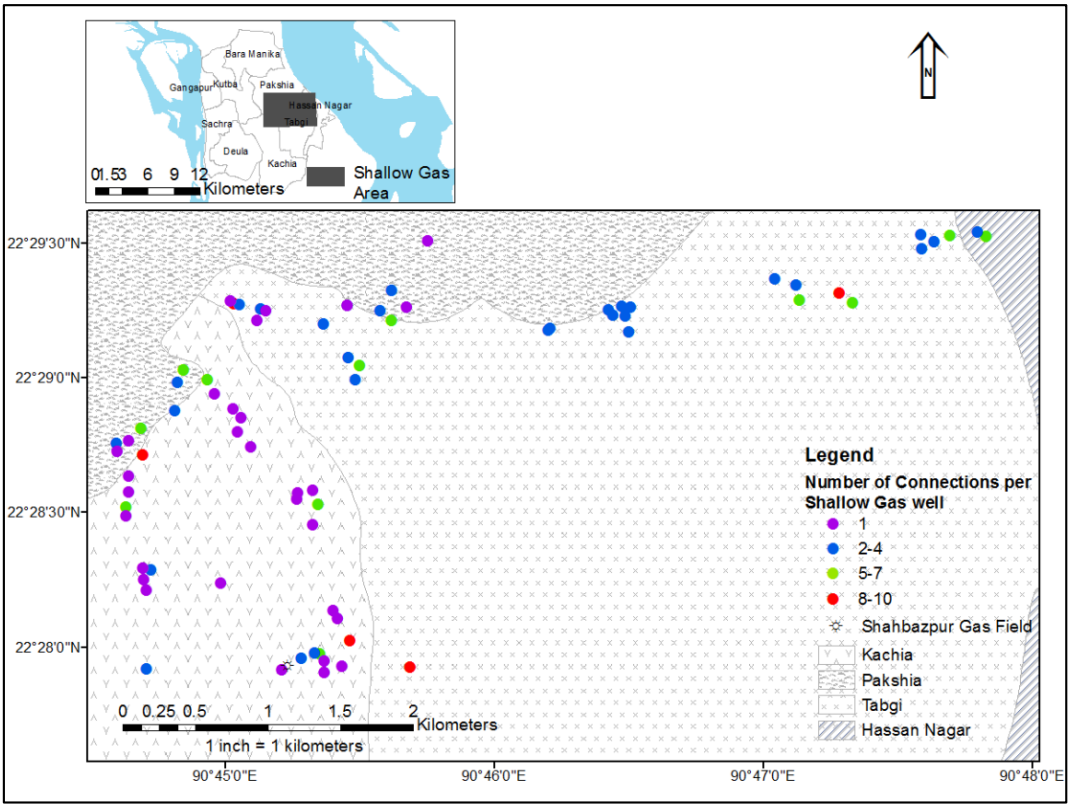

Fig. 9. Number of connections per shallow gas well

Therefore, from the above observation it cannot be said that the shallow gas has no prospect or no value, rather it can be marked that the gas has a moderate prospect or sub-commercial value, which is proved by its extreme utilization of local people.

6. Conclusions

The occurrence of shallow gas is restricted only to the Burhanuddin upozila in the central part of Bhola Island. The potential map has been produced to summarize the distribution of shallow gas wells. From that, it can be concluded that the shallow gas wells are only distributed within the four unions of Burhanuddin upozila. The other parts of the Burhanuddin upozila, as well as Bhola Island, do not have the shallow gas occurrence.

The shallow gas reservoir zones are consisted of fine to coarse sand which has an average porosity of 35%. The occurrence depth of the shallow gas reservoir is increasing towards the eastern part of the area. The shallow gas reservoir is sealed by a clay layer at the top. From the distribution of the shallow gas occurrence, it can be concluded that a localized stratigraphic trap exists in the area. The organic rich clay and shale that lie below the reservoir are the possible source of the shallow gas.

The chemical composition of shallow gas consists of entirely methane with less than 0.2% methane where the deep thermogenic gas consists of ethane as well as higher hydrocarbon like ethane, propane, butane, etc. The shallow gas has high methane-ethane (+) ratio (>1000) where the deep gas low methane-ethane (+) ratio (<50) and shallow gas has dryness value >0.99 (close to 1) where deep gas has dryness value >0.93.

The shallow gas is genetically different from the deep gas in being biogenic origin while the deep gas is the thermogenic origin. These two have a different generation, migration and accumulation pattern in their respective pools. Further study is needed including stable isotope geochemistry to conclude the origin of the gas.

Finally, it can be concluded that the shallow gas at recent deposit has a sub-commercial value which has been proved by the long term use of this gas in the community. Shallow gas is currently of little economic interest due to low-pressure drive to recovery at the surface. But it is of better potential for commercial interest in the future with the development of new and better technologies associated with biogenic gas. A country like Bangladesh that suffers from the long term energy crisis, the energy of this type can genuinely provide an aid to overcome the future energy crisis.

Acknowledgments

The authors are thankful to Managing Director of BAPEX for his support and permission of the research for the MS degree in Geology of University of Dhaka. The authors also want to express thanks to Mr. Md. Abul Kashem, Mr. Mohammad Asif Eqram Khan, Mr. Md. Masud Khan, Mr. Saman Uddin Ahmed, Ms. Rokshana Pervin and Mr. S.M. Mahtab-Ul-Alam for their support during the research work.

References

[1] Rice DD, Claypool GE. Generation, Accumulation, and Resource Potential of Biogenic Gas. American Association of Petroleum Geologists Bulletin, 1981; 65: 5–25.

[2] Lin CM, Gu LX, Li GY, Zha YY, Jiang WS. Geology and formation mechanism of late Quaternary shallow biogenic gas reservoirs in the Hangzhou Bay area, eastern China. American Association of Petroleum Geologists Bulletin, 2004; 88: 613–625.

[3] Hu Y, Li H, Xu J. Shallow gas accumulation in a small estuary and its implications: A case history from in and around Xiamen Bay. Geophysical Research Letters, 2012; 39.

[4] Lin CM, Li YL, Zhuo HC, Shurr GW, Ridgley JL, Zhang ZP, Xue T. Features and sealing mechanism of shallow biogenic gas in incised valley fills (the Qiantang River, eastern China): A case study. Marine and Petroleum Geology, 2010; 27: 909–922.

[5] Milkov AV. Methanogenic biodegradation of petroleum in the West Siberian Basin (Russia): Significance for formation of giant Cenomanian gas pools. American Association of Petroleum Geologists Bulletin, 2010; 94(10): 1485–1541.

[6] Ridgley JL, Hester TC, Condon SM, Cook T, Anna LO, Lillis PG, Rowan EL, Snyder GT. Assessment of Shallow Biogenic Gas Resources in Montana: CSPG Special Publications 2001. https://serc.carleton.edu/resources/13146.html
[7] Ridgley J. Regional Geochemical Study of the Upper Cretaceous Shallow Biogenic Gas System in Saskatchewan, Albert, and Montana - Application of Isotope and Compositional Systematics to Understanding the Distribution of Gas Resources. Saskatchewan Geological Survey 2002; 143–150.
[8] Floodgate GD, Judd AG. The origin of Shallow Gas. Continental Shelf Research. 1992; 12: 1145–1156.
[9] Ahmed KM, Hoque M, Hasan MK, Ravenscroft P, Chowdhury LR. Occurrence and Origin of Water Well Methane Gas in Bangladesh. Journal of Geological Society of India, 1998; 51: 697–708, 0016-7622198-51-5-697.
[10] Rahman M. Occurrence and Distribution of Shallow Gas in Southern Bangladesh: A Case Study on Bhola Island. M.S. Department of Geology, University of Dhaka, Ramna, Dhaka. August, 2015.
[11] Imam B. Energy resources of Bangladesh: natural gas, oil, coal: Dhaka, University Grants Commission of Bangladesh, 2nd ed.; University Grants Commission of Bangladesh, Dhaka, Bangladesh, 2013; 16-113, 984-809-020-1.
[12] Alam M, Alam MM, Curray JR, Chowdhury MR, Gani MR. An overview of the sedimentary geology of the Bengal Basin in relation to the regional tectonic framework and basin-fill history. Sedimentary Geology, 2003; 155: 179–208.
[13] Mondal D, Islam M, Islam A. Electrofacies Analysis of Neogene Sequence in the Well Shahbazpur-1, Bhola, Bengal Basin. The IUP Journal of Earth Sciences, 2009; 5: 57–74.
[14] Roy DK, Roser B. Geochemistry of Tertiary Sequence in Shahbajpur-1 Well, Hatia Trough, Bengal Basin, Bangladesh: Provenance, Source Weathering and Province Affinity. Journal of Life and Earth Science, 2012; 7: 1–13.
[15] Najman Y, Allen R, Willett EAF, Carter A, Barfod D, Garzanti E, Wijbrans J, Bickle MJ, Vezzoli G, Ando S, Oliver G, Uddin MJ. The record of Himalayan erosion preserved in the sedimentary rocks of the Hatia Trough of the Bengal Basin and the Chittagong Hill Tracts, Bangladesh. Basin Research, 2012; 24: 499–519.
[16] Katz BJ. Microbial Processes and Natural Gas Accumulations. The Open Geology Journal, 2011; 5: 75–83.
[17] Bernard B, Brooks J, Sackett W. Natural gas seepage in the Gulf of Mexico. Earth and Planetary Science Letters, 1976; 31: 48–54.

To whom correspondence should be addressed: AKM Eahsanul Haque, Department of Physical and Geological Sciences, Universiti Brunei Darussalam, Gadong BE1410, Brunei Darussalam