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Geology and Precambrian Banded Iron Formation formed at Rangpur Platform in Bangladesh

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ABSTRACT
The deposit was initially identified in the Precambrian basement complex at Alihat area of Hakimpur upazila of Dinajpur district in Bangladesh. Tectonically, the area is in Rangpur platform which is the eastern continuation of Indian Shield where more than 406 m thick overburden of Cenozoic sediments were found. Geological Survey of Bangladesh (GSB) confirmed that the existence of a significant iron ore deposit by four exploratory drilling programs which is the first ever iron ore discovery in Bangladesh. The Iron ore bearing body found as banded magnetite-silica, banded hematite-quartzite or banded magnetite- quartzite NE–SW trending bands. The iron formations are highly deformed and metamorphosed within the magnetic rock/amphibolite and to grunerite facies conditions and are composed of quartz–magnetite–siderite–hematite together with grunerite. Here we report the detailed core samples analysis and some geochemical characteristics of sixteen representative samples from the iron bearing layers that reveaedl a compositional variation with mainly Fe_2O_3 (51-78%) and SiO2 (22–43%), composed of Al_2O_3 (0.4-5%) and CaO (1-5%) as well as some trace valuable elements are also found (TiO_2, Cr_2O_3, MnO, NiO). All of the iron ore bearing collected core samples from four drilling holes have wavy microstructures and seems to be squeezed or pressurized. The core samples are light to dark colour and absent of mafic and ultramafic minerals. The chemical composition also suggested that less dominancy of TiO2 and rare earth minerals (Ni, Co, Mn, Cr, etc) of that deposit. The above results together with physical analysis of core samples, available geochronology of the associated lithology and geochemical characteristics suggested that the iron formations can be correlated to Algoma-type BIF within the Precambrian basement complex and first iron ore discovery in Bangladesh.

KEYWORDS: *Iron ore, Deposit, Precambrian, Mashidpur, Indian shield, Magnetite, Rangpur platform etc.*

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I. INTRODUCTION

Banded iron formation (BIF) represents one of the most distinctive types of rock that occurs widespread in space and time in the earlier part of the Precambrian in all the shield areas of the world (Roy, et.al, 2007). The Fe and Si were largely supplied by medium to high temperature sub-marine hydrothermal systems in Neoarchean and Neoproterozoic convergent margin settings (Yellappa, et. al, 2016). Superior-types represented by African and Arabian Shield Iron formations developed in Cryogenian and Ediacaran periods (Basta et al., 2011). Among these types are few other iron deposits of Clinton-type and the Minette-type which were described from South Africa, New Foundland, Europe and Canada. They constitute mainly hematite–siderite–chamosite beds with oolitic textures. These deposits represent only a minor part of the global iron formations and are commonly called Giant Iron-Formations (Gross, 1965, 1980). The Southern Granulite Terrane (SGT) of India preserves a prolonged history of Precambrian geological and tectonic events starting from Neoarchean to end Neoproterozoic (Santosh et al. 2015). There are many occurrences of iron formations of metamorphosed Banded Iron Formations (BIFs) and Banded Silica Formations (BSF) that are widely distributed in various parts of the Indian shield. The huge iron ore deposits of eastern India are part of the volcano-sedimentary basins containing iron and to some extent manganese deposits belonging to the Iron Ore Group of Precambrian age (Jones, 1934). The Precambrian iron ore of the Singhbhum-North Orissa region of eastern India occurs as part of the horses hoe-shaped broad synclinorium known as the Iron Ore Group (IOG) of rocks, which hosts the most important iron ore deposits in eastern India or near Bangladesh. The first discovery of iron ore bearing area in Bangladesh is the eastern continuation of the Indian Shield which is tectonically designated as Dinajpur slope of Rangpur platform/saddle (Alam, et al. 2003) (fig. 1). Several studies (4 numbers of exploratory geological drilling holes and 4 numbers of geophysical surveys) were taken in that region to identify the extension and reserve of iron ore deposit in the area by the Geological Survey of Bangladesh.

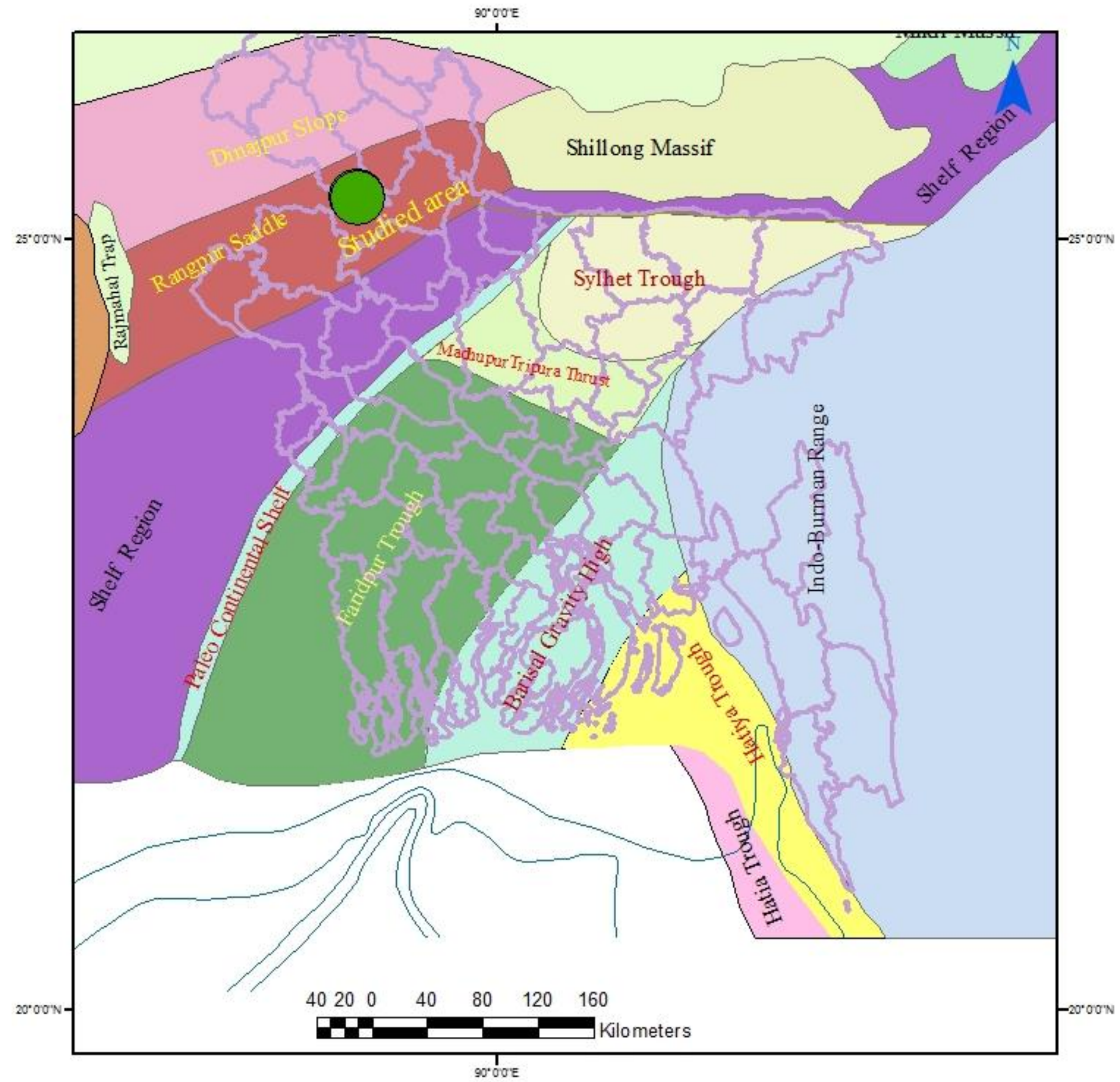

Fig.1. Figure showing geo-tectonic settings of Bangladesh part of Bengal basin and adjoining area as well as location point of the studied area. Modified Geological map of Bangladesh (2011) (http://en.banglapedia.org/index.php? title=Tectonic_Framework).

Namely, preliminary detail gravity and magnetic (total) profiling surveys was taken in that area (Hasan et.al, 2013). A seismic refraction survey was completed to delineate basement depth for the investigation of metallic minerals in that region (Haque, et.al, 2013). Another detailed seismic refraction survey was also done to delineate basement depth for the investigation of metallic minerals in the studied area (Haque, et.al, 2013). Detailed gravity and magnetic profiling surveys in Dighipara coal basin was completed which is adjacent of the studied area (Arefin et.al, 2005). A report (Rahman et. al, 2001) on digital processing and interpretation of gravity-magnetic data of Dinajpur area where also clearly mentioned that the Mashidpur magnetic body of the studied area (fig. 2).

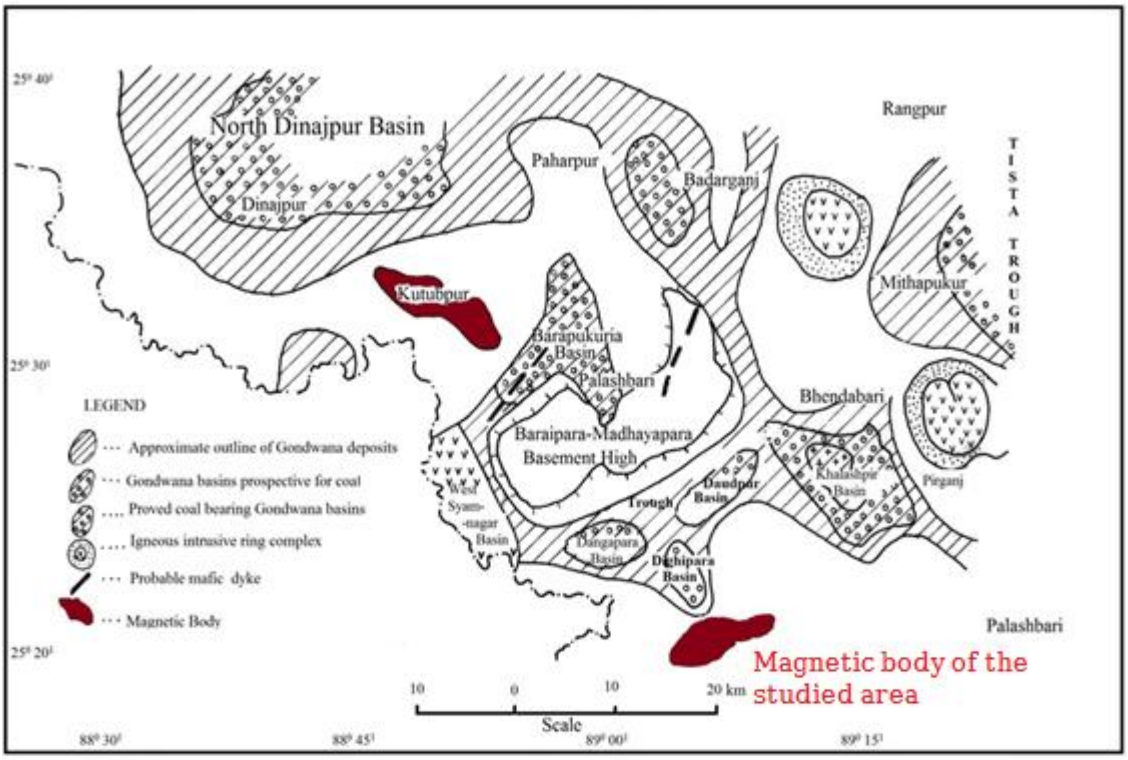

Fig. 2. Figure showing the high magnetic signatures at Dinajpur and Rangpur Area (modified from Rahman et.al. 2000).

Rahman et. al, 2001 were mentioned in their report that the prominent anomalies of Mashidpur magnetic body (peak to peak) is 850 Neno Tesla. Modeling of combined gravity and magnetic profile Cgm-Cgm and Dgm-Dgm clearly interpreted Mashidpur magnetic anomaly and Dighipara gravity low (fig. 3).

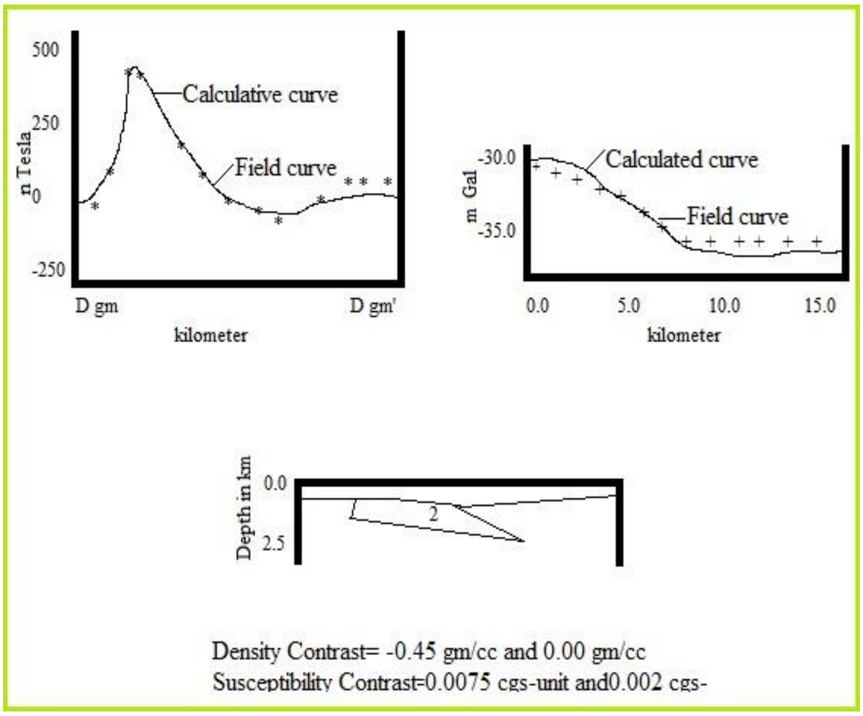

Fig. 3. Modeling of combined gravity and magnetic profile Cgm-Cgm and Dgm-Dgm Dinajpur and Rangpur Area (modified from Rahman et.al. 2000).

Geological Drill Hole (GDH-68/13) was completed (Sabuj et.al, 2014) in that region. Sequentially, GDH-73/19 and 75/20 (Masum et.al, 2019) as well as GDH-74/19 (Hoque et. al, 2019) were completed in that region. Based on the bore holes data and information as well as supporting geo-exploration data suggested that the presence of the first ever iron ore deposit in Bangladesh. Although some petrological and geochemical data of collected samples in the studied area also available but no detailed above studies in here. Crushing method and others strong subordinate analysis (XRF, magnetic susceptibility test by hand magnet and sonic logging) incorporated in here and tried to justify the deposition of iron ore deposit in the studied area. In this paper, we conducted detailed physical analysis of core samples and analyzed geochemical data from two important types of iron formations of the studied area: the Banded Iron Formations (BIFs) and Banded Silica Formations (BSF) which are distinguishable based on the variations in the dominance of silica (quartz) and Fe-magnetite (>55%). Some of the iron formations of Indian shield are associated with the recently reported Neo-Archean-Neo-Proterozoic oceanic remnants/ ophiolites and two pyroxene granulites/metagabbros, suggesting an accretionary sequence in a convergent margin setting (Shaji et al., 2014). The new results from the present study together with the regional tectonic position (study area is the eastern continuation of Indian shield) as well as few similarities with the BIF of China/ Brazil suggested that the iron formation belong to Algoma-type formed during two distinct events of Neo-Archean and Neo-Proterozoic periods.

II. GEOLOGICAL SETTINGS

The prospective iron ore bearing magnetic body has a susceptibility contrast of 0.0075 cgs unit and no apparent density contrast which appears to be a faulted step towards the north representing a flank of a basinal structure (Rahman et. a, 2000). A basinal half-graben such structure Dighipara (northern adjacent of Magnetic body) which contain coal-bearing Gondwana formations, occur over the basement in northwestern Bangladesh (i.e., the Platform unit).The high concentrated iron ore bearing area is around 5 km^2 which is lies in the Rangpur Platform (Dinajpur slope) and eastern continuation of Indian shield as well as part of the stable shelf zone in the northwestern Bangladesh part of Bengal Basin. The Bengal Basin has evolved tectonically from the collision of the Indian and the Asian plates (Alam et al., 2003). The Bengal Basin is one of the largest peripheral collisional foreland basins in South Asia (Mukherjee et al. 2019; DeCelles 2012) consisting of Permo-carboniferous to Mesozoic and Tertiary deposits covered by Recent alluvium. The geotectonic of the eastern part of the Indian Plate is dominantly influenced by its collision with the Eurasian Plate (Mukherjee et al. 2019) to the north and the Burmese Plate to the east, uplifting the Himalaya. The basin also occupied dominantly by the Ganges-Brahmaputra-Meghna (GBM) delta named after the Ganges Padma in Bangladesh), the Brahmaputra (Jamuna in Bangladesh) and the Meghna rivers, constituting the largest fluvio-deltaic to shallow marine sedimentary basin of the world (Hossain et. al, 2019). The location of the Bengal Basin is at the juncture of three interacting plates, viz., the Indian, Burma (Myanmar), and Tibetan (Eurasian) plates. The basin-fill history of these geotectonic provinces varied considerably (Jahan, 2016). The tectonic framework of Bangladesh can be broadly divided into two main units: the Platform and the Deep Basin (Uddin and Lundberg, 2004). The geology of the Platform unit is entirely different from that of the Deep Basin unit. The Bengal Basin traps and accumulates less than half of the total sediment budget through flexural subsidence over a broad area, in addition to faulting, folding and localized compaction (Goodbred and Kuehl 1998, 1999). This accumulated sediment has caused the entire Bengal Basin margin to programed more than 300 km since the Eocene (Najman et al. 2008). The Indo-Burman Ranges (IBR) in the north and east, respectively. The Himalayan mountain range started to form in the Mid-Late Eocene (Baxter et al. 2016), whereas the IBR began to form approximately in the Middle Miocene (Acharyya 2007). The Bengal Basin at the eastern part of the Indian Plate is tectonically active since the collision began (Eocene). Although the direction of subduction of the Indian Plate below the Eurasian Plate is *N-S, but below the Burmese Plate, it is NE–SW (Goodbred et al. 2003). In the north of the Bengal-Assam Basin, *E trending Himalaya takes a southward turn towards Myanmar and connects with the IBR (Hossain et al. 2019).The geodetic measurements show that the motion of the Indian Plate relative to the Burmese Plate is *36 mm/year (Socquet et al. 2006; Steckler et al. 2016) and the convergence between the Shillong Plateau and the Bengal Basin across the Dauki Fault varies from 3 mm/year in the west to >8 mm/year in the east (Socquet et al.2006; Vernant et al. 2014). Plate boundary deformation along these collisional belts is broadly distributed over a series of reverse and strike-slip structures, including the Dauki and Haflong-Disang Faults to the north and Chittagong-Teknaf, Kaladan and Sagaing Faults to the east of the Bengal Basin, respectively.The Bengal Basin rests on lithosphere that is transitional (along the paleo-continental slope also known as the Eocene Hinge Zone) between thick, buoyant Indian continental lithosphere in the west and north and dense Indian oceanic lithosphere in the east (Bender 1983; Curray 1991; Reimann 1993; Uddin and Lundberg 2004). Along its northern edge, it is subjected to continent-continent collision whereas along eastern and southeastern edge, it is subjected to ocean-continent subduction. According to Ingersoll et al. (1995), due to continued oblique subduction of the Indian Plate beneath the Burmese Plate to the SE, the Bengal Basin turned into a Remnant Ocean Basin at the beginning of the Miocene. Due to eastward component of subduction of the oceanic part of the Indian Plate, the thick pile of sediments of the Bengal Basin has been deformed into a fold belt and a huge flat accretionary prism (Alam et al. 2003; Steckler et al. 2008). In general, by considering the overall regional tectonic setting, the Bengal Basin as a remnant ocean basin can be divided into three major geotectonic provinces: (i) the stable shelf to the northwest—passive to extensional cratonic margin in the west, (ii) the deeper fore deep basin at the center remnant ocean basin, and (iii) fold belt to the east-the Chittagong Tripura Fold Belt (CTFB) (Bakhtine 1966; Alam 1972; Khan and Rahman 1992; Khan and Agarwal 1993; Reimann 1993; Shamsuddin and Abdullah 1997; Alam et al. 2003).(iii) fold belt to the east-the Chittagong Tripura Fold Belt (CTFB) (Bakhtine 1966; Alam 1972; Khan and Rahman 1992; Khan and Agarwal 1993; Reimann 1993; Shamsuddin and Abdullah 1997; Alam et al. 2003). The northwest Stable Shelf of the Bengal Basin consists of an easterly dipping shelf that is separated from the Precambrian Indian Shield to the west by a prominent fault zone (Basin Margin Fault Zone: more than 350 km in length and width is variable in hundreds of metres) with dislocation and cataclasis (Matin and Misra 2009; Roy 2014). To the southeast it is bounded by the Eocene Hinge Zone that forms the paleo-continental slope (Sengupta 1966; Guha 1978; Bender 1983; Reimann 1993; Uddin and Lundberg 2004). Only a few studies have been performed on the basement rocks and their possible origin in the Stable Shelf part of the Bengal Basin (Ameen et al. 2007). The western and southwestern parts of the Bengal Basin consist of an easterly inclined shelf, separated from the Singhbhum Craton of the northeastern part of the Indian Shield which may continued to the Rangpur platform of Bangladesh (Mukherjee et al. 2017) (fig. 4). The Masidpur magnetic body of Precambrian basement area is covered by Kopili, Jamalganj/ Undifferentiated Surma, Pleistocene and Holocene sediments. This is the part of stable platform, which occupies Rajshahi-Bogra-Rangpur-Dinajpur areas and is characterized by moderate thickness of sedimentary rocks above a Precambrian basement complex.

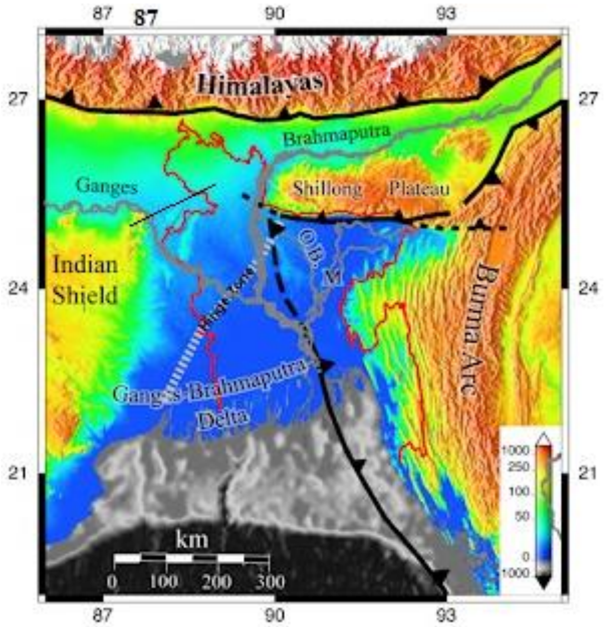

Fig. 4. Photograph showing regional tectonic position of the investigated area where clearly mentioned the study area is the eastern continuation of Indian shield (modified from Google image).

III. ABRIDGE DESCRIPTION OF THE STUDIED AREA

Around 5 km^2, the Iron ore deposit is the first ever discovery in Bangladesh which is located in the north-western part of the country very close to the Dighipara coal basin. The deposit was initially indicated by a high magnetic anomaly of Mashidpur area that is the eastern continuation of Indian Shield (Hunting geology and geophysics, 1981, Rahman, et. al, 2000 and Hasan et. al, 2013). Exploration for the deposit was conducted by the Geological Survey of Bangladesh (GSB) with four Geological Drill Holes (GDH) that confirmed the existence of a significant iron ore deposit. The deposit was formed as bands or thin layers within the crystalline rock at different depths in Precambrian basement complex which are unconformably overlain by Tertiary and Quaternary sediments (fig. 5). In all drill holes at varying thickness of bands of magnetic susceptible minerals or iron ore bearing layers are found. Four distinct iron ore bearing layers (1m to 80m) at GDH-68/13, 12 distinct iron ore bearing layers (2m to 61m) at GDH-73/19, 3 iron ore bearing layers (3m to 10m) at GDH-74/19 and 2 iron ore bearing layers (8m to 47m) at GDH-75/19 have been identified starting from depth 408 m to 632 m beneath the surface (fig, 4). High concentration of iron ore bearing bands/layers occurred within the depth of

426 m to 548 m with an average thickness is around 50 m. Physical properties of the collected core samples of iron ore exibit high magnetic susceptibility, high specific gravity and dark grey to grey colour both in solid and in crushing form.These iron bearing core samples contain more than 60% iron oxide which are tested by different kinds of analyses (microscopic analysis, chemical analysis/XRF, manual crushing test). These iron ore bearing layers also contain thin layers of quartzite/ amphibolite/ magnetic rock/seems to be highly metamorphosed rock within the Basement Complex. The iron ore bearing layers seem to be highly pressurized look like thin wavy structures and their streak form are grey to dark grey in coloured. The physical nature of the core samples are alternation of quartz or chert and iron ore where most of core samples are directly attracted by hand magnet and rest of them are attracted by hand magnet after crushing but not direct. The iron ore bearing Basement Complex is unconformably overlain by Tura Formation (alternation of loose water bearing sand and clay) of Early Eocene age. Middle Eocene of Sylhet Limestone formation and Barail/Bogra formation of Oligocene age is erosional rest of the formation started from Tura formation to Barind formation is successively present (Basement complex<Tura <Kopili <Jamalganj/ Undifferentiated Surma <Dupi Tila <Barind formation (fig, 5).

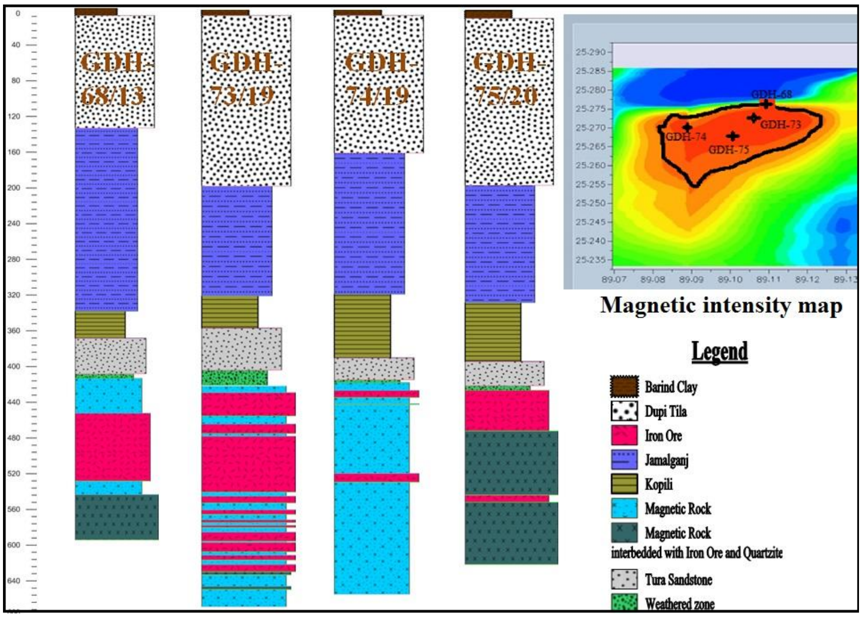

Fig. 5. Figure showing correlation of four drill hole logs and condition of iron ore layers and others lithological units, magnetic intensity map Alihat, Hakimpur, Dinajpur, Bangladesh.

IV. SAMPLING, PROCESS AND TECHNIQUE

Generally, Iron ore bearing core samples (core bearing tube) were collected (3 m interval) from the exploratory drilling activities by the over-shot (Wire line method). After collecting the samples, it was washed with fresh water and preserved in the core box. Detailed physical properties of core samples were closely examined by different tools (grain size chart, hand lens, portable microscope, colour chart and HCL) and written down in a note book. Iron ore bearing core samples were collected from different depth in a fixed interval for analyses (with the help of crushing method around 25 samples were analyzed, magnetic susceptibility test also completed of all collected core samples). Every 0.5 m interval crushing method was applied in the field during the exploration work. Collected all of undisturbed core samples were tested their magnetic susceptibility by the hand magnet in the field. Some mineralogical and chemical studies were also done of collected around 25 samples (in between the depth of 427 m to 457 m).

4.1. Core analysis: Iron ore bearing core samples of four drill holes were collected, washed it properly then closely examined with the help of 20 times magnifying glass if needed core samples were crushed (as much as possible) and analyzed their physical properties or all parameters. Some core samples were selected for laboratory analysis (both mineralogical and chemical).

4.2. Crushing method

Collected core samples (different depth) were crushed that converted into powdered form. Measured the mass of the total crushing of samples before the experiment their magnetic susceptibility with the help of magnet. The powdered samples have been subdivided into two parts by magnet, one part is magnetized (Iron Ore) and other part is non-magnetized. After finishing the separation, measured the mass of magnetized part which directly subtracted from the total powdered form of crushed samples and then calculated the iron ore percentage.

4.3. Magnetic susceptibility test by magnet

The collected Iron ore bearing core samples were tested thier magnetic susceptibility with help of hand magnet. In this test, Iron ore bearing core samples are directly attracted by hand magnet, a piece of core sample (more than 1.5 kg weight) directly attracted by hand magnet and keeping as hang. Most of the collected core samples were attracted by hand magnet, some collected core samples were not directly attracted by hand magnet but after crushing it attracted.

4.4. Mineralogy (optical and electron microscopy)

This analysis has been done in the laboratory of Economic Geology and Resources Assessment branch of GSB. But slide preparation was completed in the laboratory of Petrology and Mineralogy branch of GSB. In order to study mineralogical and textural properties of collected core samples and minerals under polarizing microscope rock slides must attain the standards thickness, which is believed to be 0.05 mm. A small slice of rock was cut from the specimen by using a diamond saw. The slice was ground flat and smoothens on both surface using progressively finer Carborandum powder. One side of the smoothen surface was cemented to a glass slide with Canada Balsam and the exposed surface polished again with the same grade of Carborundum powder until the required thickness of 0.05mm was achieved. The thickness was confirmed by observing the interferences color of some common minerals such quartz and feldspar. The slides were examined at the Geological Survey of Bangladesh with transmitted light (ZEISS Axio Scope.A1, Germany).

4.5. Geochemistry (XRF)

The chemical composition of the FA and BA samples were examined using XRF (PW 2400, Philips, Netherlands**)** technique in the laboratory of BCSIR, Joypurhat in Bangladesh. The oven dried milled samples (3 g) were placed in a porcelain crucible and thereafter were milled with binder (wax: sample, 1:3) and were then shaken for 2 h. The resulting mixture was spooned into an aluminum cap (30mm) that was sandwiched between two tungsten carbide pellets. Finally, the pellet was ready for analysis.

V. RESULTS AND FINDINGS

The collected samples are seems to be highly pressurized where thinly laminated of iron ore layers were squeezed (fig, 6).

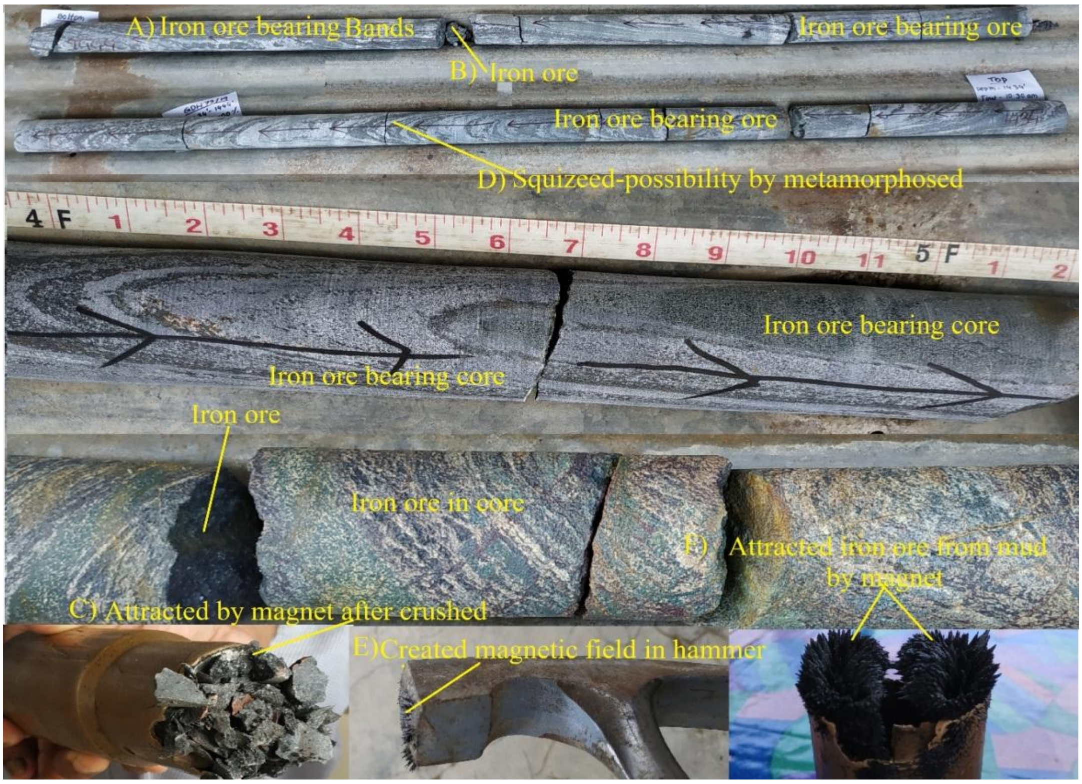

Fig. 6. Photograph showing the iron ore bearing core where clearly visible of A) iron bands, B) breaking surface ore concentration, C and F) crushing samples (by both hammer and drilling bit) attracted by magnet, E)

magnetic field created in hammer by streak samples. D) Squeezed iron ore in bands which may be the sign of metamorphosed, Alihat, Hakimpur, Dinajpur.

The powdered form of collected iron ore samples dark grey to medium grey and metallic luster. Some collected core samples within Precambrian basement complex composed of thickly to thinly layers which are look like as sedimentary layers. It is the indication of metamorphosed which is in sedimentary origin. Huge amount of foliation found in collected core samples of these holes which is another indication of sedimentary metamorphosed origin. Some core samples of this area are highly fractured and which are breaking along the bands or foliation. Huge gneissic structures or bands and some secondary mineralization were found throughout the core samples which is the another sign of metamorphism.

Some comparative discussions of core samples of studied area with the core samples of Brazil and China (Banded Iron Formation/BIF) were done. Generally, the core samples of the studied area composed of alternation of quartz and magnetite which are very similar to the core samples of China banded iron formation (fig, 7). Some gneissic structures found in the core samples Brazil banded iron formation where alternation of hematite and quartz which are seem to be the very similar with core samples of the studied area (fig, 7), the above similarities of core samples of banded iron formation of Brazil and China are the strong indication of Banded Iron Formation (BIF) of the area. Banded Quartzite-Magnetite and banded Hematite-Quartzite type of indication appeared in the banded iron formation of north Orissa carton (Nanda, et. al, 2020). Jasper is usually the characteristic mineral in banded iron formation around the world. Both of the bands (Banded Quartzite-Magnetite and banded Hematite-Quartzite) and Jasper present in the core samples of the studied area (eastern continuation of Orissa carton) (fig. 8).

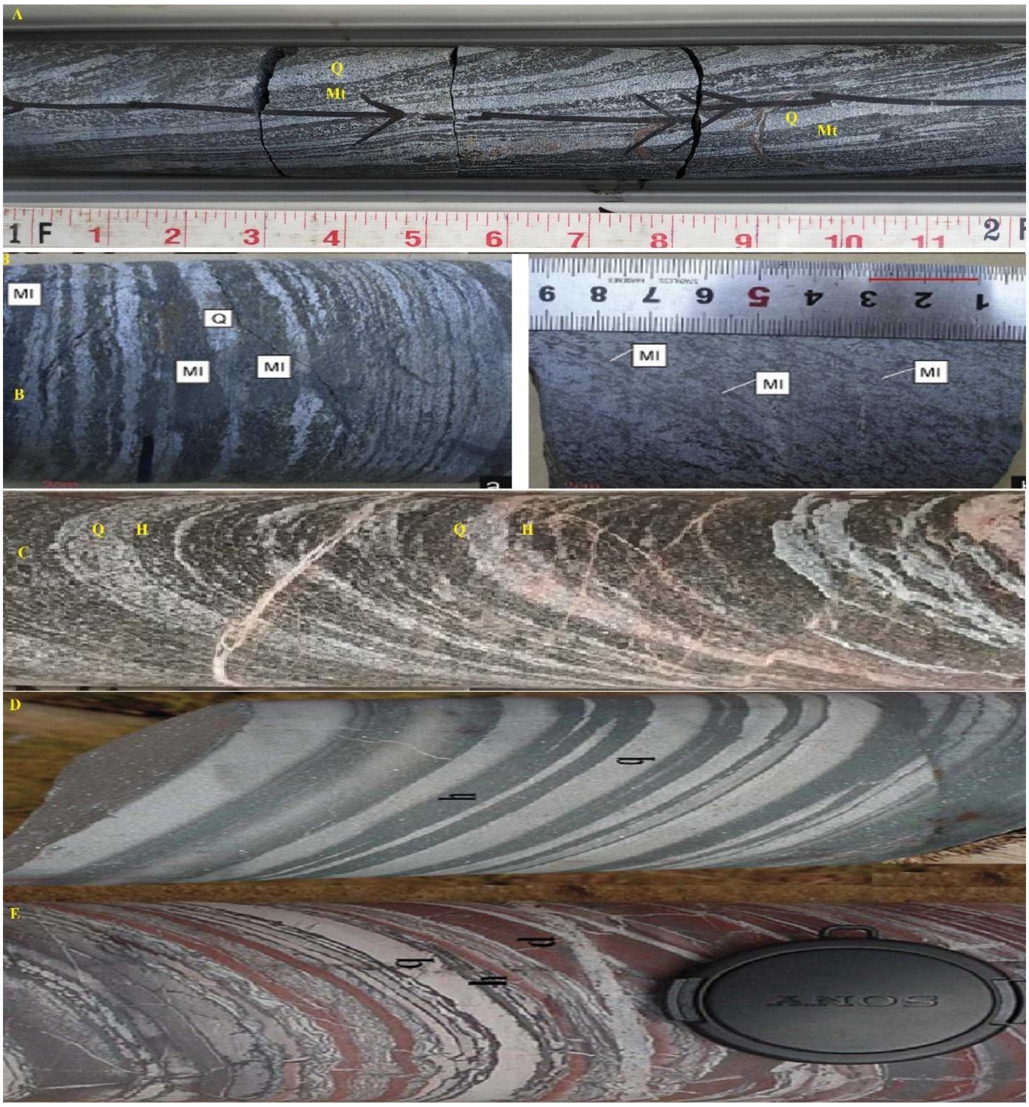

Fig. 7. Photograph showing the A) iron ore bearing core where alternation of quartz and magnetite like as B) those types of samples in China-BIF (Han, et.al, 2014). C) Sample of the study area where clearly visible

gneissic bands and alternation of quartz and hematite is similar to core samples D) and E Brazil (BIF)- (Spier et. al, 2007).

Fig.8. Photograph showing the A) alternation of quartzie and hematite, B) banded quartzie and hematite, C) hematite and jasper, D) banded quartzie and magnetite and E) core sample of jasper which are clear indication of BIF, Alihat, Hakimpur, Dinajpur, Bangladesh.

XRF analyses have been completed in the laboratory of BCSIR of Joypurhat district in Bangladesh. Actually in here, compound analysis of core samples (Iron ore bearing rock) were analyzed to know their chemical properties. 16 numbers of samples of 73/19 were analyzed and calculated their chemical properties. Fe_2O_3, SiO_2, P_2O_4, Al_2O_3, CaO, MnO, NiO Cr_2O_3, ZnO, Cr_2O_3 TiO_2 were found in that collected core samples where the percentage of Fe_2O_3 and SiO_2 is high (Fe_2O_3 is 51-79%) and SiO_2 or quartz (SiO_2 is 20-43%). In this analysis rare earth elements like Cr and Ni as well as few precious elements were also found as trace but dominant Iron oxide and quartz/silica (table. 1 a and 2). The geochemical result from XRF like iron oxide and silica dominant, trace amount of rare earth elements and TiO_2 (generally, TiO_2 percentage more than 14 and rare earth elements more than trace percentage in magmatic origin iron formation) (Mohanta, 2007) whose are supported that the iron formation might be BIF metamorphosed in sedimentary origin.

Table-1: Method: X-ray Fluorescence Spectrometer

Oxides (wt%)	S1- 428 m depth	S2- 430m depth	S3- 432m depth	S4- 437m depth	S5- 441m depth	S6- 443m depth	S7- 445m depth	S8- 450m depth	S9- 452m depth
Na_2O	0.67	0.09	0.08	0.04	0.13	0.29	0.03	0.03	0.02
MgO	3.39	2.03	0.42	0.25	1.86	1.81	0.74	0.42	0.34

Al_2O_3	5.88	1.27	1.21	0.41	1.13	2.25	0.75	0.40	0.46
SiO_2	24.94	26.32	43.61	30.19	32.93	40.37	35.63	22.92	40.88
P_2O_5	0.96	3.97	0.26	1.05	3.32	0.40	1.05	0.22	1.27
SO_2	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
Cl	0.01	0.10	0.01	0.05	0.05	0.01	0.04	0.01	0.02
K_2O	0.59	0.06	0.05	0.01	0.16	0.21	0.01	0.01	0.01
CaO	3.64	9.05	1.07	1.62	5.79	1.74	6.75	0.69	2.11
TiO_2	0.20	0.06	-	-	0.04	0.15	-	-	-
V_2O_5	0	-	-	-			-	-	-
Cr_2O_3	0.44	0.60	0.64	0.035	0.74	0.57	0.10	0.34	0.75
MnO	0.43	0.19	0.18	0.11	0.14	0.24	0.19	0.22	0.10
Fe_2O_3	58.76	56.07	52.42	65..65	53.56	51.94	54.33	74.68	53.96
Ca_2O_3	-	-	-	-	0.01		-	-	-
NiO	0.01	0.01	-	-	0.01	0.02	-	-	0.01
CuO	-	-	-	-	-		-	-	-
ZnO	0.04	0.01	-	-	-	0.01	-	-	-
Ga_2O_3	-	-	-	-	-		-	-	-
As_2O_3	0.01	0.15	0.02	0.06	0.43	0.01	0.01	0.01	0.07
Rb_2O	-	-	-	-	-		-	-	-
SrO	0.01	0.01	-	-	0.01	0.01	0.01	-	-
Y_2O_3	-	0.01	-	-	0.01		-	-	-
ZrO_2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Table-2: Method: X-ray Fluorescence Spectrometer

Oxides (wt%)	S10- 456m depth	S11- 460 m	S12- 463 m depth	S13- 466m depth	S14- 470m depth
Na_2O	0.05	0.02	0.07	0.04	0.05
MgO	0.60	0.75	0.77	0.50	1.26
Al_2O_3	0.96	0.81	1.93	0.67	0.99
SiO_2	38.10	30.75	20.62	17.65	33.60
P_2O_5	1.16	0.48	0.25	0.40	1.07
SO_3	0.02	0.01	0.07	0.01	0.01
Cl	0.03	0.03	0.02	0.01	0.04
K_2O	0.18	0.02	0.06	0.11	0.03
CaO	2.85	5.41	1.75	0.54	3.13
TiO_2	0.04	0.02	0.08	0.03	0.05
V_2O_5	-	-	-	-	-
Cr_2O_3	0.51	0.55	0.89	0.34	0.45
MnO	0.15	0.22	0.19	0.40	0.13
Fe_2O_3	55.23	60.89	73.15	78.57	59.12
NiO	0.01	0.01	0.02	-	0.01
CuO	-	-	-	-	-
ZnO	-	-	-	-	-
Ga_2O_3	-	-	-	-	-
As_2O_3	0.05	0.03	-	0.02	0.04
Rb_2O	-	-	-	-	-
SrO	0.01	-	0.02	-	-
Y_2O_3	-	-	-	-	-
ZrO_2	0.01	0.01	0.02	0.01	0.01
BaO	0.05	-	0.09	-	

All of petrographical views clearly shown the alternation of quartz and iron ore in both of grain slide and thin section slide, generally, all of the views are composed of mostly iron ore and rest of them are quartz grain. Most of the grains showing definite crystal structures within the crystalline basement rock whose are the indications of banded iron formation (fig. 9 and 10). All of the thin section and grain slide views were calculated and find out their average composition. The compositions of section slide calculated with the help of Ribbon counting method and grain slide calculated with the help of point counting method. Iron ore is dominant and quartz is in second highest and rest of them are amphibole pyroxene, mica, epidote, feldspar and others which are expressed by petrographic analysis. The petrographic views of all slides also indicated that the study area is similar to the BIF.

Around 25 core samples at different depth were crushed and analyzed where also clearly shown the high concentration of iron ore or magnetic minerals (fig.11).

The above results justified that the study area is rich in iron ore deposits which may be the ever first iron ore discovery in Bangladesh.

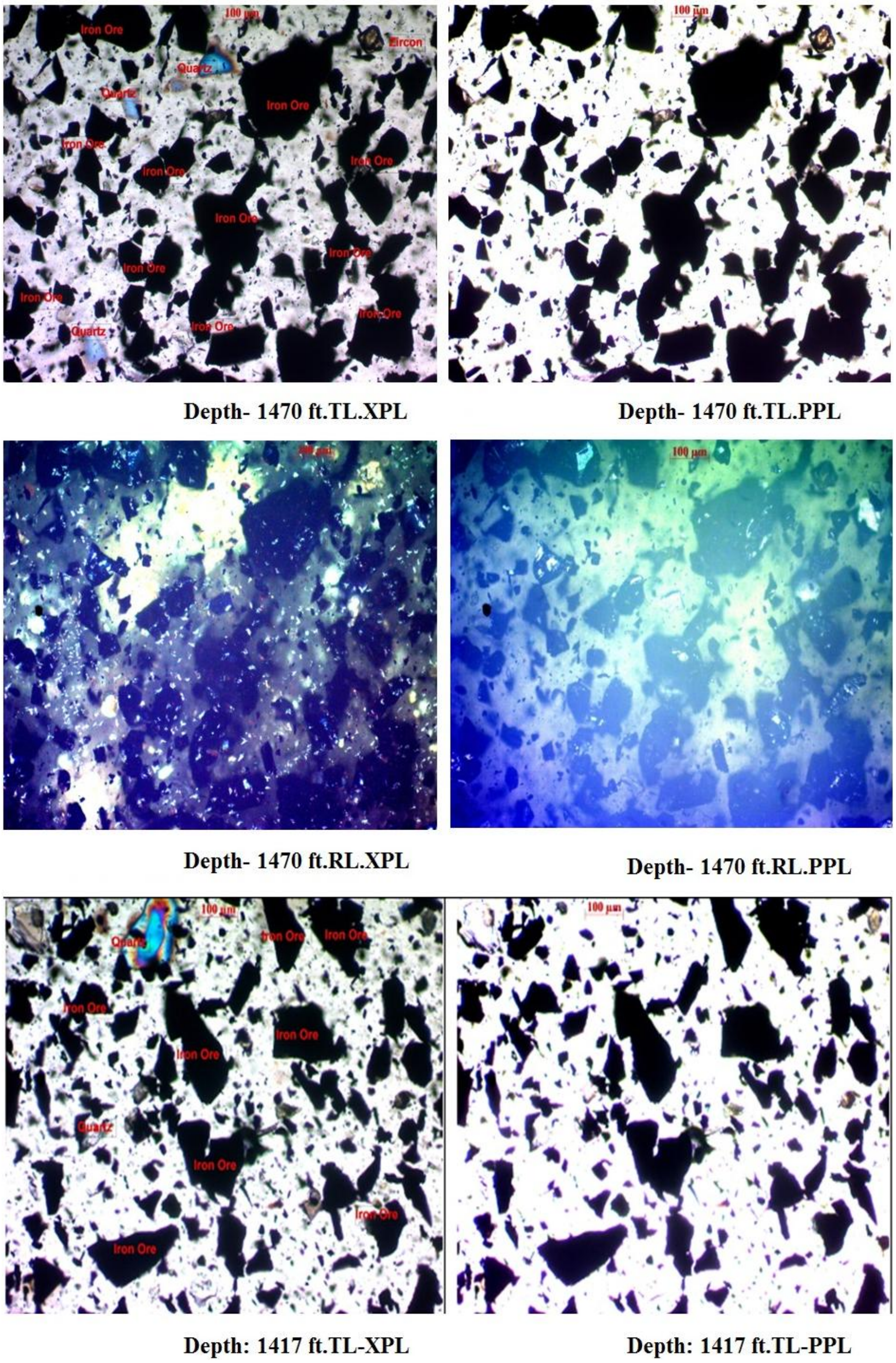

Fig. 9. Photograph showing the alternation of quartz and iron ore clearly visible in the grain slide view, all of the views are composed of mostly iron ore and rest of them are quartz grain which are clear indication of BIF, Alihat, Hakimpur, Dinajpur, Bangladesh.

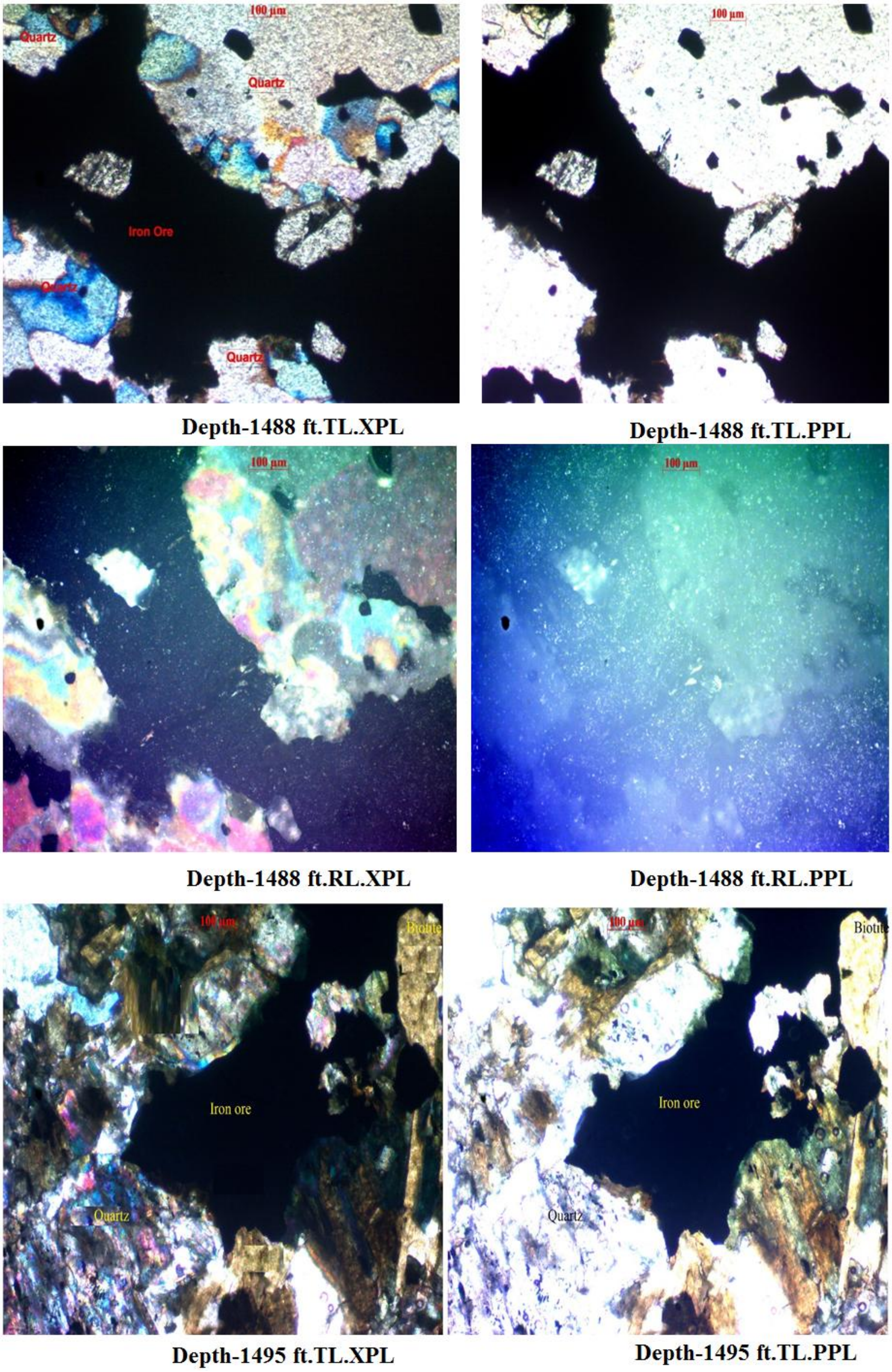

Fig. 10. Photograph showing the alternation of quartz and iron ore clearly visible in the thin section slide view, all of the views are composed of mostly iron ore and rest of them are quartz grain which are clear indication of BIF, Alihat, Hakimpur, Dinajpur, Bangladesh.

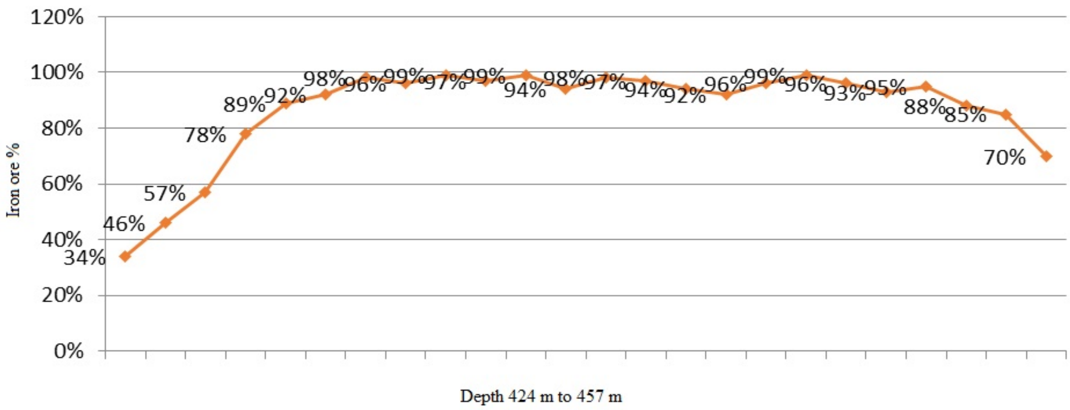

Fig. 11. Photograph showing the compositional variations of crushing test results or analysis in the field where shown high concentration of iron ore or magnetic minerals (34% - 99%) at Alihat, Hakimpur, Dinajpur, Bangladesh.

VI. CONCLUSION

The area of Mashidpur magnetic body is delinated by the geo-exploration study (gravity and magnetic interpretation) where four drill holes have been completed by GSB. With the view of four geological drilling programs suggested that the area riched in iron ore bearing basement rock which is oldest one that encountered at shallow depth in that region. The collected samples are seem to be highly pressurized where thinly lamination of iron ore layers were squeezed like as gneissic bands and analytical results (both geochemical and petrological as well as all field test) supported that the first ever iron ore deposit of studied area is similar to the sedimentary metamorphosed banded iron formation type (Algoma-type) found in Precambrian rock.

REFERENCES

[1]. Acharyya, S. K., 1994. Accretion of Indo-Australian Gondwanic blocks along Peri-Indian collision margins. 9th International Gondwana Symposium, Hyderabad, India, 029– 1049.
[2]. Acharyya, S. K., 1998. Break-up of the greater Indo-Australian continentand accretion of blocks framing south and east Asia. J.Geodyn. 26, 149– 170.
[3]. Acharyya, S. K., 2007. Collisional emplacement history of the Naga-Andaman ophiolites and the position of the eastern Indian suture. Journal of Asian Earth Sciences, 29(2-3), 229-242.
[4]. Alam, M., 1972. Tectonic classification of Bengal basin. Geological Society of America Bulletin, 83(2), 519-522.
[5]. Alam, M., Alam, M.M., Curray, J., Chowdhury, R.M.L.R., Gani, M.R., 2003. An oerview of the sedimentary geology of the Bengal Basin in relation to the regional tectonic framework and basin-fill history. Sedimentary Geology 155, 179–208.
[6]. Ameen, S. M., Wilde, S. A., Kabir, M. Z., Akon, E., Chowdhury, K. R., Khan, M. S. H. 2007. Paleoproterozoic granitoids in the basement of Bangladesh: A piece of the Indian shield or an exotic fragment of the Gondwana jigsaw?. Gondwana Research, 12(4), 380-387.
[7]. Arefin Dr. K.M .S., Rahman K.A.H.M.S., Shahjahan, M., 2005. Report on detailed gravity and magnetic profiling surveys in Dighipara coal basin area of Nawabgonj Upzila Dinajpur district.
[8]. Bakhtine, M. I., 1966. Major tectonic features in Pakistan, part II, Eastern Province. Science and Industry, 4(2), 89-100.
[9]. Bakr, M. A., Rahman, Q. M. A., Islam, M. M., Islam, M. K., Uddin, M. N., Resan, S. A., Anam, A. N. M. H., 1996. Geology and coal deposits of Barapukuria Basin, Dinajpur district, Bangladesh. Records of Geological Survey of Bangladesh, 8(pt 1).
[10]. Basta, F.F., Ayman, E., Maurice, A.E., Fontbote, L., Favarger, P.Y., 2011. Petrology and geochemistry of the banded iron formation (BIF) of Wadi Karim and Um Anab, Eastern.
[11]. Baxter III, C. O., Bedi, J. J. 2016. U.S. Patent No. 9,326,771. Washington, DC: U.S. Patent and Trademark Office
[12]. Bender, F., Bannert, D. 1983. Geology of Burma.
[13]. Berthet, T., 2014. Clockwise rotation of the Brahmaputra Valley relative to India: Tectonic convergence in the eastern Himalaya, Naga Hills, and Shillong Plateau. Journal of Geophysical Research: Solid Earth, 119(8), 6558-6571.
[14]. Bustin, R.M., Clarkson, C.R., 1998. Geological controls on coalbed methane reservoir capacity and gas content. International Journal of Coal Geology 38, 3–26.
[15]. Bustin, M.M.A., Bustin, R.M., 2008. Coal reservoir saturation: Impact of temperature and pressure. AAPG Bulletin 92, 77–86.
[16]. Close, J.C., 1993. Natural fractures in coal. AAPG Studies in Geology 38, 119–132.
[17]. Creedy, D.P.,1988. Geological controls on the formation and distribution of gas in British coal measure strata. International Journal of Coal Geology 10, 1–31.
[18]. Curray, J. R., 1991(a). Geological history of the Bengal geosyncline. J. Assoc. Explor. Geophys. XII, 209–219.
[19]. DeCelles, P. G., 2012. Foreland basin systems revisited: Variations in response to tectonic settings. Tectonics of sedimentary basins: Recent advances, 405-426.
[20]. Desert., Egypt: implications for the origin of Neoproterozoic BIF. Precambrian Res. 187, 277–292.
[21]. Desikacher, S.V., 1974. A review of the tectonic and geological history of eastern India interms of plate tectonic theory. Journal of the Geological Society of India 15,134–149.
[22]. Diamond, W.P., Schatzel, S.J., 1998. Measuring the gas content of coal: a review.
[23]. International Journal of Coal Geology 35, 311–331.

[24]. Drobniak, A., Mastalerz, M., Rupp, J., Eaton, N., 2004. Evaluation of coalbed gas potential of the Seelyville Coal Member, Indiana, USA. International Journal of Geological map of Bangladesh 2011. https:// commons. wikimedia. org/wiki/ File: Geological_map_of_Bangladesh.PNG

[25]. Goodbred Jr, S. L., Kuehl, S. A., 1999. Holocene and modern sediment budgets for the Ganges-Brahmaputra river system: Evidence for highstand dispersal to flood-plain, shelf, and deep-sea depocenters. Geology, 27(6), 559-562.

[26]. Goodbred Jr, S. L., 2003: Response of the Ganges dispersal system to climate change: a source-to-sink view since the last interstade. Sedimentary Geology, 162(1-2), 83-104.

[27]. Gross, G.A., 1965. Principal types of iron-formation and derived ores. Annual General Meeting, Toronto Transactions. vol. LXIX, pp. 41–44.

[28]. Gross, G.A., 1980. A classification of iron formations based on depositional environments. Can. Mineral. 18, 215–222.

[29]. Guha., D. K., 1978. Tectonic framework and oil and gas prospects of Bangladesh. In Proc. 4th Annu. Conf., Bangladesh Geol. Soc., Dhaka (pp. 65-76).

[30]. Haque, M. E., Reza. M. S., Uddin, M. Z., 2013. Report on Seismic Refraction Survey to delineate Basement depth for the investigation of Meallic Minerals in Chakurpara- Masidpur areas of Dinajpur District, Bangladesh. (GSB Unpublished).

[31]. Han, C., Xiao, W., Su, B., Chen, Z., Zhang, X., Ao, S., Wang, Z. 2014. Neoarchean Algoma-type banded iron formations from Eastern Hebei, North China Craton: SHRIMP U-Pb age, origin and tectonic setting. *Precambrian Research*, *251*, 212-231.

[32]. Hasan, M.N., Rahman, K.A.H.M. S., Shahjahan., 2013. Preliminary Report on Detail Gravity and Magnetic (total) Profiling Surveys in the Chakurpara-Masidpur area of Dinajpur District, Bangladesh. (GSB Unpublished).

[33]. Hoque, M.N, Masum. M., Mahmud, M., Amin, M., 2020. Report on Iron Ore Deposits and Geology on the Basis of Drilling Program (GDH- 74/19) at Alihat Area of Hakimpur Upazila, Dinajpur District, Bangladesh(GSB Unpublished).

[34]. Hossain, M. S., Khan, M. S. H., Chowdhury, K. R., Abdullah, R., 2019. Synthesis of the tectonic and structural elements of the Bengal Basin and its surroundings. In Tectonics and Structural Geology: Indian Context (pp. 135-218). Springer, Cham.

[35]. Hunting geology and geophysics Ltd, England, 198. Interpretation and operations report of an aeromagnetic survey of Bangladesh, Petrobangla and Geological survey of Bangladesh, Government of the people's republic of Bangladesh.

[36]. Ingersoll, R. N., Graham, S. A., Dickinson, W. R., 1995. Remnant ocean basins. In: Busby, C.J., Ingersoll, R. V. (Eds.), Tectonics of Sedimentary Basins. Blackwell, Oxford, pp. 363–391.

[37]. Islam, M.S., Ali, M.W., Choudhury, M.E.A., Mannan, K.M., Anam, A.N.M.H., 1996.

[38]. Geology and coal deposits of Barapukuria Basin,DinajpurDistrict, Bangladesh. Records of Geological Survey of Bangladesh, vol. 8. pt 1.

[39]. Islam, M.R., Islam, M.S., 2005. Water inrush Hazard in Barapukuria Coal Mine, Dinajpur District, Bangladesh. Bangladesh Journal of Geology 24, 1–17.

[40]. Jones, H, C., 1934. The iron ore deposits of Bihar and Orissa. Geol Surv India Memoir, 63:1098-1109.

[41]. Kim, A.G., 1977. Estimating methane content of bituminous coal beds from adsorption data. Report of Investigations, U.S. Bureau of Mines RI 8245, p. 22.

[42]. Khan, F.H., 1991. Geology of Bangladesh, Willey Eastern Limited, 4835/24 Ansari Road, Daryaganj, New Delhi 110002, India, pp. 33–40.

[43]. Khan, A. A., Rahman, T., 1992. An analysis of the gravity field and tectonic evaluation of the northwestern part of Bangladesh. Tectonophysics, 206(3-4), 351-364.

[44]. Khan, A. A., Agarwal, B, N, P., 1993. The crustal structure of western Bangladesh from gravity data. Tectonophysics, 219(4), 341-353.

[45]. Khan, A.A., Chouhan, R.K.S., 1996. The crustal dynamics and the tectonic trends in the Bengal basin. Journal of Geodynamics 22, 267–286.

[46]. Matin, A., Mishra, S., 2009. Repeated cataclasis in a reactivated fault zone–an example from Bengal Basin Margin Fault, Jharkhand, India. J. Virtual Explor.

[47]. Masum, M., Mahmud, M., Amin. M. A., Razzaque, A,B., Rana. M. S., 2019. Report on Iron Ore Deposits and Geology on the Basis of Drilling Program (GDH- 73/19) at Alihat Area of Hakimpur Upazila, Dinajpur District, Bangladesh (GSB Unpublished).

[48]. Mohanta, M. K., 2007. Geochemistry of iron ores.

[49]. Mukherjee, A., Kundu, M., Basu, B., Sinha, B., Chatterjee, M., Bairagya, M. D. Sarkar, S., 2017. Arsenic load in rice ecosystem and its mitigation through deficit irrigation. Journal of environmental management, 197, 89-95.

[50]. Mukherjee, S., 2019. Introduction to tectonics and structural geology: Indian context. In Tectonics and Structural Geology: Indian Context (pp. 1-5). Springer, Cham.

[51]. Najman, Y., Bickle, M., BouDagher-Fadel, M., Carter, A., Garzanti, E., Paul, M., Vezzoli, G., 2008. The Paleogene record of Himalayan erosion: Bengal Basin, Bangladesh. Earth and Planetary Science Letters, 273(1-2), 1-14.

[52]. Nanda, S. K., Pani, S., Beura, D., 2020. Recovery of Iron values through conventional beneficiation techniques from Banded Hematite Jasper of Eastern India with special reference to mineralogical and chemical characterization. *Indian Journal of Science and Technology*, *13*(38), 3960-3969.

[53]. Rahman. M.A., Idris M., Blank, H.R., 2000. Digital Processing and Interpretation of Gravity and Magnetic Data, Rangpur-Dinajpur Area, Bangladesh, Record of the Geological Survey of Bangladesh, Vol-10,part-1.

[54]. Reimann, K. U., Hiller, K., 1993. Geology of Bangladesh.

[55]. Roy, S., Das, A., Mohanty, M K., 2006. Feasibility to producing pellet grade concentrate by beneficiation of iron ore slimes in India, Communicated for publication in Separation Sci and Tech.

[56]. Roy, S., Das, A., Venkatesh, A. S., 2007(August). Characterization of Iron Ore from the Jilling Area of Eastern India with a view to Beneficiation, In. In Proc. Iron Ore Conf., Perth, Australia (pp. 179-186).

[57]. Roy, D. P., Wulder, M. A., Loveland, T. R., Woodcock, C. E., Allen, R. G., Anderson, M. C., Zhu, Z., 2014. Landsat-8: Science and product vision for terrestrial global change research. Remote sensing of Environment, 145, 154-172.

[58]. Sabuj, M.N., Sayem. M A., Rana. M. S., 2013. Report on the Drilling Program (GDH-68/13) at Masidpur Area of Hakimpur Upazila, Dinajpur District, Bangladesh(GSB Unpublished).

[59]. Santosh, M., Yang, Q.Y., Shaji, E., Tsunogae, T., Ram, M., Satyanarayanan, M., 2015. An exotic Mesoarchean microcontinent: the Coorg Bock, southern India. Gondwana Res. 27, 165–195.

[60]. Scott, S., Anderson, B., Crosdale, P., Dingwall, J., Leblang, G., 2007. Coal petrology and coal seam gas contents of the Walloon Subgroup — Surat Basin, Queensland, Australia. International Journal of Coal Geology 70, 209–222.

[61]. Sengupta, S., 1966. Geological and geophysical studies in western part of Bengal basin, India. AAPG Bulletin, 50(5), 1001-1017.

[62]. Shaji, E., Santosh, M., He, Xiao-Fang, Fan, Hong-Rui, Dhanil Dev, S.G., Yang, Kui-Feng.,Thangal., Mifthah K., Pradeepkumar, A.P., 2014. Convergent margin processes during Archean–Proterozoic transition in southern India: geochemistry and zircon U–Pb

geochronology of gold-bearing amphibolites, associated metagabbros, and TTG gneisses from Nilambur. Precambrian Res. 250, 68–96.
[63]. Shamsuddin, A. H. M., Abdullah, S. K. M., 1997. Geologic evolution of the Bengal Basin and its implication in hydrocarbon exploration in Bangladesh. Indian Journal of Geology, 69, 93-121.
[64]. Shu, T., Yan, W., Dai, Z., 2007. A comprehensive appraisal on the characteristics of coalbed methane reservoir in Tupan–Hami Basin, China. Journal of China University of Mining & Technology 17, 521–725.
[65]. Socquet, A., Vigny, C., Chamot-Rooke, N., Simons, W., Rangin, C., Ambrosius, B., 2006. India and Sunda plates motion and deformation along their boundary in Myanmar determined by GPS. Journal of Geophysical Research: Solid Earth, 111(B5).
[66]. Spier, C. A., de Oliveira, S. M., Sial, A. N., Rios, F. J., 2007. Geochemistry and genesis of the banded iron formations of the Cauê Formation, Quadrilátero Ferrífero, Minas Gerais, Brazil. *Precambrian Research*, *152*(3-4), 170-206.
[67]. Steckler, M. S., Akhter, S. H., Seeber, L., 2008. Collision of the Ganges–Brahmaputra Delta with the Burma Arc: implications for earthquake hazard. Earth and Planetary Science Letters, 273(3-4), 367-378.
[68]. Steckler, M. S., Mondal, D. R., Akhter, S. H., Seeber, L., Feng, L., Gale, J., Howe, M., 2016. Locked and loading megathrust linked to active subduction beneath the Indo-Burman Ranges. Nature Geoscience, 9(8), 615-618.
[69]. Stricker, G.D., Flores, R.M., 2002. Coalbed methane content in the Powder River Basin, Wyoming: saturation by coal rank and depth. The 19th Annual International Pittsburgh Coal Conference. University of Pittsburgh, Pittsburgh, Pa, pp. 1–15.
[70]. Uddin, M.N., Islam, M.S.,1992. Gondwana basins and their coal resources in Bangladesh. Proceedings of the First South Asian Geological Congress, Pakistan. Geology in South Asia-1, pp. 224–230.
[71]. Uddin, A., Lundberg, N., 2004. Miocene sedimentation and subsidence during continent–continent collision, Bengal basin, Bangladesh. Sedimentary Geology, 164(1-2), 131-146.
[72]. Vernant, P., Bilham, R., Szeliga, W., Drupka, D., Kalita, S., Bhattacharyya, A. K., Berthet., T. 2014. Clockwise rotation of the Brahmaputra Valley relative to India: Tectonic convergence in the eastern Himalaya, Naga Hills, and Shillong Plateau. Journal of Geophysical Research: Solid Earth, 119(8), 6558-6571.
[73]. Wardell A., 1991. Techno-Economic Feasibility Study of Barapukuria Coal Project (unpubl.), Dinajpur, Bangladesh.
[74]. Yellappa, T., Chetty, T. R. K., Santosh., M. 2016. Precambrian iron formations from the Cauvery Suture Zone, Southern India: implications for sub-marine hydrothermal origin in Neoarchean and Neoproterozoic convergent margin settings. Ore Geology Reviews, 72, 1177-1196.

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