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Mineral Resources Assessment (Final)

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Last but not least, we would like to sincerely thank all the participants of the Workshops held on October 05, 2011, September 04, 2012, June 18, 2013 and August 26, 2013, to capture views of several stakeholders in Bangladesh Mineral Sector and Academicians from Universities on suitable Mineral Resource Classification System for Bangladesh.

PricewaterhouseCoopers Pvt. Ltd.

Place: Hyderabad

Date: 15 December 2013

Table of Abbreviations	
AEC	Asia Energy Corporation
BCMCL	Barapukuria Coal Mining Company Limited
BCMP	Barapukuria Coal Mining Project
BMD	Bureau of Mineral Development
BMEDC	Bangladesh Mineral Development Corporation
BOGMC	Bangladesh Oil, Gas and Mineral Corporation
BTU	British Thermal Unit
CIDA	Canadian International Development Agency
CMC	Chinese National Machinery Import & Export Corporation
CRIRSCO	Committee for Mineral Reserves International Reporting Standards
DAF	Dry Ash Free
DG	Director General (HCU)
EIA	Environmental Impact Assessment
EMRD	Energy and Mineral Resources Division
GSB	Geological Survey of Bangladesh
HCU	Hydrocarbon Unit, EMRD
HRSS	High Resolution Seismic Survey
IAEA	International Atomic Energy Agency
ICMM	International Council on Mining and Metals
IMC	International Mining Consultants
JORC	Joint Ore Reserves Committee
LDT	Lower Dupi Tila
MGMCL	Maddhapara Granite Mining Company Ltd
MSL	Mean Sea Level
Mt	Million Tonnes
NPV	Net Present Value
ROM	Run of Mine
RRI	Robertson Research International
TEFS	Techno Economic Feasibility Study
UDT	Upper Dupi Tila
UNDP	United Nations Development Programme
UNFC	United Nations Framework Classification

Table of Contents

1. Executive Summary

1.1.1. The present report, Mineral Resources Assessment (Final), is prepared as a part of the Mines and Minerals Development Project (Package#07), Hydrocarbon Unit, Energy and Mineral Resources Division, Bangladesh incorporating comments from HCU and other stakeholders (as forwarded by HCU) on report on Mineral Resources Assessment (Draft).

1.1.2. This report aims at assessing and classifying the mineral resources of Bangladesh (Coal including Peat and Hard Rock resources) detailing the in-place and recoverable resources, discovered and potential remaining resources.

1.1.3. The mineral resource of Bangladesh has been assessed in accordance with the guidelines provided in the UNFC System for Mineral Resources Classification, which was selected for classifying and reporting the mineral resources of Bangladesh based on the discussion with key stakeholders held during the workshop on Mineral Resource Classification and Reporting at Dhaka on October 5, 2011, September 04, 2012, June 18, 2013 and August 26, 2013.

1.1.4. The UNFC System of Classification uses three basic criteria (affecting their recoverability) for classification of the mineral resources:

- Economic and commercial viability (E).
- Field project status and feasibility (F).
- Geological knowledge (G).

The three criteria are easily visualized in three dimensions as shown in the figure below:

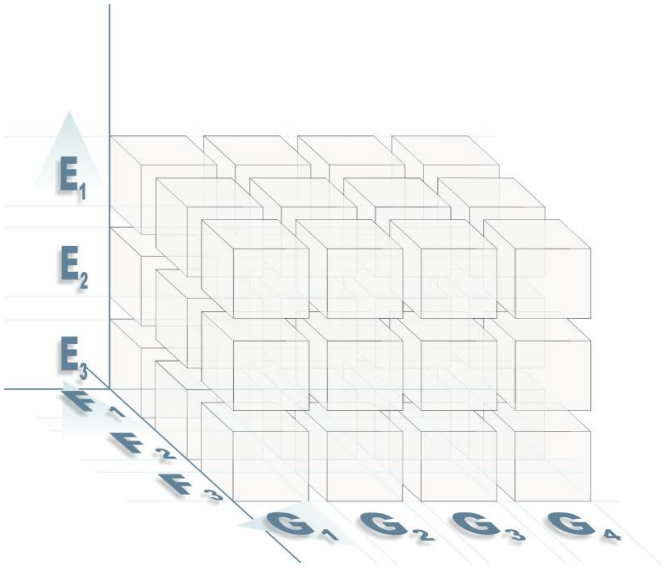


Figure 1: Criteria used by UNFC System for Mineral Resources classification

1.1.5. The UNFC System of classification in the matrix form is presented below:

UN International Framework		Detailed Exploration	General Exploration	Prospecting	Reconnaissance
Economic Viability					
Feasibility Study and/ or Mining Report	**1**	(111)	**USUALLY**		
	2	(211)			
Prefeasibility Study	**1**	(121)	(122)	**NOT**	**RELEVANT**
	2	(221)	(222)		
Geological Study	**3**	(331)	(332)	(333)	(334)

Economic Viability Categories:

1: Economic **3: Intrinsically Economic**

2: Potentially Economic

Table 1: UNFC System of Classification in Matrix form

1.1.6. The present report on Mineral Resources Assessment is based on the data and information received by Consultant from Hydrocarbon Unit, Energy and Mineral Resources Division, Bangladesh. No exploratory study or geological work has been conducted by Consultant. Thus the mineral resources (Coal including Peat and Hard Rock resources) are assessed based on the data available from past exploration done by different agencies and reports received from HCU and reclassified as per the UNFC system of Mineral Resources Classification.

1.1.7. The summary of Mineral Resources Assessment of Coal resources of Bangladesh as per the UNFC System of classification is provided in the table below:

Resources	Deposit	Code 111	Code 112	Code 221	Code 222	Code 332		Code 333		Code 334		Code 3.2;1;1	Code 3.2;1;2	Code 3.2;2;1	Code 3.2;2;2
Coal	Barapukuria	26.13	38.67	9.9	6.76	Code 3.1;3;2	40.24	Code 3.1;3;3	21.06	Code 3.1;3;4	43-64	32.24	53.19	46.05	72.47
						Code 3.2;3;2	-	Code 3.2;3;3	-	Code 3.2;3;4	-				
						Sub Total	40.24	Sub Total	21.06	Sub Total	43-64				
	Phulbari	243.7	191.3					Code 3.1;3;3	58			44.3	34.7		
								Code 3.2;3;3	-						
								Sub Total	58						
	Khalashpir				297.57			225.92							
	Jamalgunj							1053.9							
	Dighipara					105				495					
Total		**269.83**	**229.97**	**9.9**	**304.33**	**145.24**		**1358.88**		**538-559**		**76.54**	**87.89**	**46.05**	**72.47**

(3.1) – Virgin reserve of intrinsic economic interest based on geological study.. (3.2) – Unrecoverable reserves due to design loss and mining loss based on feasibility study/pre-feasibility study.

Note: Table 1 shows the UNFC in matrix form excluding the codes which are usually not relevant (as shown in Figure 1). In Barapukuria and Phulbari deposits, a part of reserves (229.97 Mt as shown in Table 2) have been classified under code 112 as these reserves are economically viable (code 1 in Economic axis) and included within the mineable reserves in the feasibility reports /Basic Mine Design document /Life of Mine report (code 1 in Feasibility axis) but the geology of these reserves are yet to be firmed up (hence considered under code 2 in Geology axis). Usually, reserves for which geology is not firmed up are considered in Pre-feasibility reports (i.e., under code 2 of Feasibility axis) and not in the formulation of Feasibility report; whereas such reserves have been included in the Feasibility reports (i.e., under code 1 of Feasibility axis) of Barapukuria and Phulbari deposits. Therefore, these reserves have been classified under code 112 instead of code 122, in the present case and have been treated as Probable Mineral Reserves along with reserves considered under codes 121 and 122.

Table 2: Summary of UNFC type classification of Coal resources of Bangladesh (Figures in Million Tonnes)

1.1.8. The summary of Mineral Resources Assessment of Peat resources of Bangladesh as per the UNFC System of classification is given in the table below:

Resources	Code 331	Code 334
Peat (Dry)	38*	95**

* Comprises 30 million tonnes (Mt) (dry) of Faridpur deposit and 8 Mt (dry) of Kola Mouza deposit
** Comprises dry peat resource of Faridpur deposit only

Table 3: Summary of UNFC type classification of Peat resources of Bangladesh (Figures in Million Tonnes)

1.1.9. The summary of Mineral Resources Assessment of Hard Rock resources of Bangladesh as per the UNFC System of classification is given in the table below:

Resources	Deposit	Code 111	Code 121	Code 232	Code 333
Hard Rock	Maddhapara	125.15*	792.65**	1521.90	1201.50

*125.15 - Mineable reserve up to 270 m
** 792.65 – Extractable reserve between 160 m and 350 m depths.

Table 4: Summary of UNFC type classification of Hard Rock resources of Bangladesh (Figures in Million Tonnes)

1.1.10. The comparison of classes in CRIRSCO code with UNFC System of Classification of Coal, Peat, Hard Rock resources of Bangladesh is given below:

Class	Code	Coal (Mt)	Peat (Mt)	Hard Rock (Mt)
Proved Mineral Reserves	code 111	269.83		125.15
Probable Mineral Reserves	codes 121 + 122	229.97#		792.65
Pre-Feasibility Mineral Resources*	codes 221+222	314.23		
Measured Mineral Resources	code 331		38	
Indicated Mineral Resources	code 332	145.24		
Inferred Mineral Resources	code 333	1358.88		1201.50
Reconnaissance Mineral Resources	code 334	538-559	95	
-	Code 3.2;1;1	76.54		
-	Code 3.2;1;2	87.89		
-	Code 3.2;2;1	46.05		
-	Code 3.2;2;1	72.47		
-	Code 232			1521.90
Total		**3139.10 – 3160.10**	**133**	**3641.20**

#Refer note under Table 2
*Additional Classes in UNFC System

Table 5: Comparison of classes in CRIRSCO code with UNFC System of Classification of Coal, Peat, Hard Rock resources of Bangladesh

2. Introduction

2.1. Background

2.1.1. The mineral resources of a country are vital component of its natural wealth. The knowledge of the location, quantity and quality of such resources, including the resources yet to be explored fully, is an essential element in formulation of mineral resource policies, land access, land usage pattern and conservation of the same. The results of mineral resources assessment also help in setting priorities for exploration and determining the economic potential of a mineral deposit and associated investment risks.

2.1.2. With the economy of Bangladesh presently growing at a rate of around 6% per annum, the country will need to augment its energy sector may fold to sustain this growth rate through the next few decades. Considering the dwindling resources of natural gas, Bangladesh need to focus on proving new coal basins and on developing the existing ones to diversify the sources of primary energy.

2.1.3. Gondwana coals are found at depth beneath Tertiary sediments in the North-western region of Bangladesh (Plate 1). Occurrence of coal was first observed near Bogra town in 1959 where one of the wells of the Standard Vacuum Oil Company intersected 52 m of superior quality Bituminous coal at a depth of about 2713 m. Subsequent exploration proved the existence of Gondwana coal at Jamalganj (1965), Barapukuria (1985), Khalaspir (1989), Dighipara (1995) and Phulbari (1997). Locations of these five coal basins and of Madhyapara Hard Rock deposit have been shown in Plate 2.

2.1.4. The geological setting of coal deposits in Bangladesh, as revealed by exploratory drilling and geophysical surveys carried out in the coal basins till date, is complex. There are multiple coal horizons which mostly occur at great depths in synclinal basins. The seams often show a tendency of splitting and merging. Some of the coal horizons are quite thick and their full recovery will be difficult by underground mining. Also, presence of highly water bearing aquifers in close proximity above the coal seams poses additional problem in extraction of these reserves.

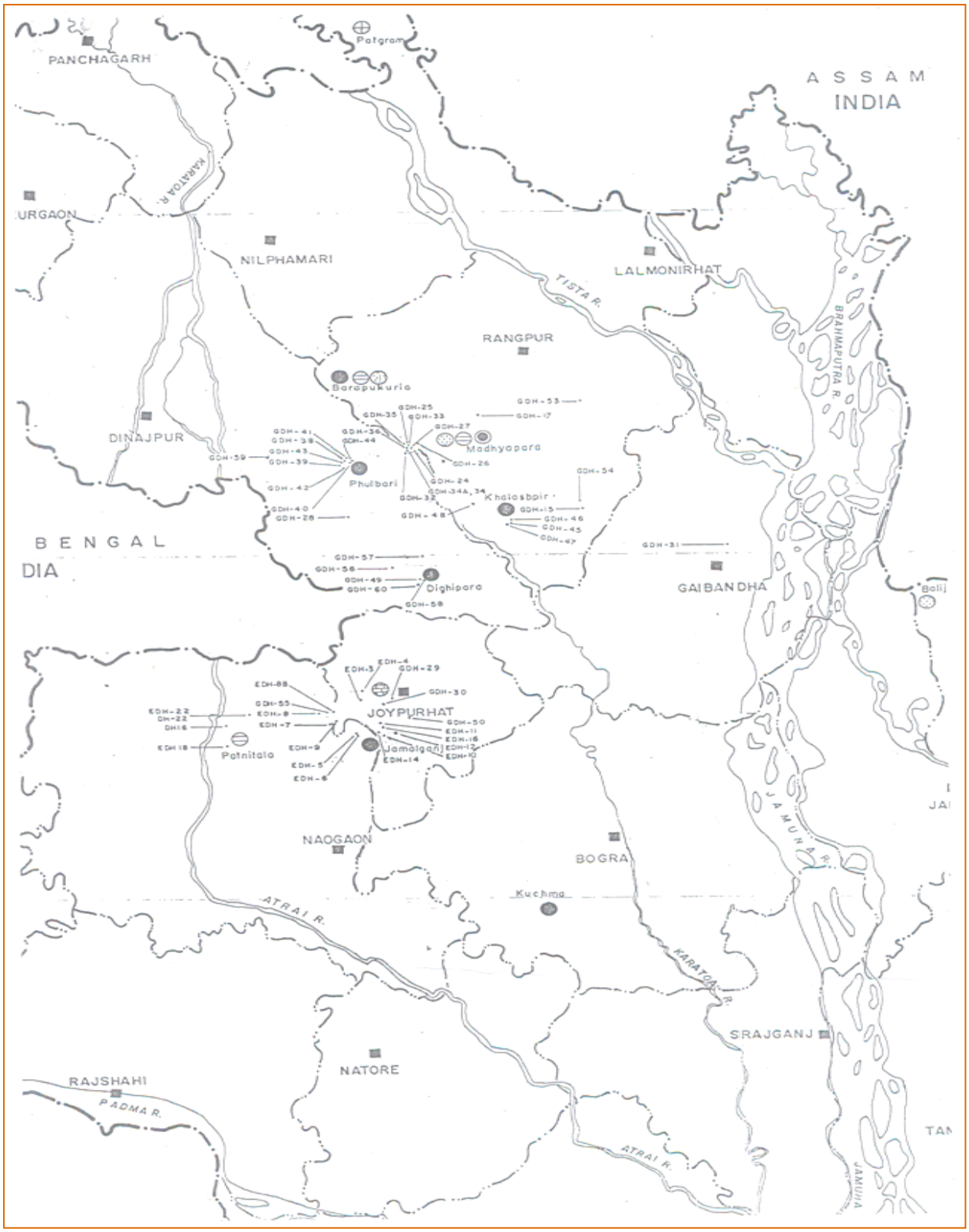
2.1.5. As a part of the Mines and Minerals Development Project (Package #07), a report titled 'Report on Mineral Resource Classification Systems – Suitability and Selection' was submitted by PwC to Hydrocarbon Unit, Energy and Mineral Resources Division (EMRD), Bangladesh.

2.1.6. In the report on Mineral Classification Systems – Suitability and Selection, a review of various mineral resources classification and reporting systems which are prevalent globally was presented and a suitable classification system for Bangladesh was selected in consultation with stakeholders.

2.1.7. The suitable classification system was selected after conducting a 'Workshop on Mineral Classification Systems' held in Dhaka on October 5, 2011, where consultations were held with various stakeholders of Bangladesh mineral sector and based on the consultations in the workshop it was unanimously decided to adopt the UNFC system of classification for mineral resources of Bangladesh.

Note: Map not to scale

Plate 1: Map Existing and Potential Coal Zone



Note: Map not to scale

Plate 2: Locations of Coal Basins and Maddhapara Hard Rock Deposit

2.1.8. Detailed Techno-Economic Feasibility Studies together with Environmental Impact Assessment Studies have been carried out for Barapukuria, Khalashpir and Phulbari coal basins as well as for Maddhapara Hard Rock deposit and therefore, estimates of recoverable reserves and of unrecoverable reserves that will be lost due to various technological factors have been assessed for these deposits with fair degrees of accuracy in respect of major part of resources occurring in these basins/deposits.

2.1.9. The resources of other coal basins and also of peat deposits have been established with varying degrees of confidence through exploratory efforts ranging from detailed exploration to reconnaissance. Therefore, the resources of the five coal basins, the peat basins and of the hard rock deposit of Bangladesh, present a myriad of situations that have to be appropriately addressed in the UNFC classification matrix. Accordingly, an effort has been made in this report to classify the mineral resources of Bangladesh as per UNFC system.

2.2. TOR for this Report

2.2.1. Mineral resources assessment of Coal, Peat and Hard rock resources of Bangladesh and classify them in accordance with the UNFC system of classification.

2.3. Scope of Report

2.3.1. The scope of this report is as follows:

- To collect the available geological reports, exploratory study reports and feasibility study reports related to the Coal, Peat and Hard rock resources of Bangladesh.
- To study the geology of the Coal, Peat and Hard rock bearing areas of Bangladesh and understand the level of geological confidence of these areas based on the study of exploration study reports and feasibility study reports.
- To analyse and classify the available resource and reserve data relating to Coal, Peat and Hard rock deposits as per the UNFC System of classification.
- To carry out mineral resources assessment of the Coal, Peat, Hard rock deposits of Bangladesh where resource data are available and classify them as per the UNFC System of Classification.

3. Classification of Coal Resources in different basins of Bangladesh

3.1. Barapukuria Coal Deposit

3.1.1. The Barapukuria Coal Deposit is located in the north-western part of Bangladesh, between 25° 21' 00" N & 25° 34' 00" N and 88° 57' 00" E & 88° 59' 00" E, about 50 km southeast of the district headquarters of Dinajpur and about 20 km east of the border with India.

3.1.2. The main north-south broad gauge railway line passes to the immediate west of the project area and the towns and railway stations of Phulbari and Parbatipur are located 6 km to the south and 20 km to the north respectively. The Maddhapara hard rock project site is about 10 km to the east.

3.1.3. The mine field is a part of alluvial plain formed between River Ganges and River Jamuna. Relief of the area is flat with surface elevation varying between +29 m and +32 m. The surface gently slopes from north to south.

3.1.4. The Barapukuria coal deposit is presently being worked by underground mining method for a rated production of 1 Mtpa by Barapukuria Coal Mining Company Ltd. (BCMCL), a subsidiary of Petrobangla. The mine is being operated by China National Machinery Import & Export Corporation (CMC) on contract basis. Presently only the thick VI seam is being worked in the mine by mechanized longwall technology with caving.

Geological Description

Introduction

3.1.5. The Barapukuria coal field is an asymmetrical half-graben basin with axis roughly along N-S which is truncated in the east by a major fault. The basin is of Gondwana coal bearing formation of Permian period and is preserved in a graben structure. It overlies unconformably on basement Archaean rocks.

3.1.6. The important geological features of Barapukuria coal basin as have been deciphered by the works of different agencies like GSB (1985-87), Wardell Armstrong (1990) and CMC (1994) are summarized below.

History of Exploration

3.1.7. Geological Survey of Bangladesh (GSB) carried out gravimetric and magnetic surveys in April, 1985 and submitted a report in April 1986 titled 'A Preliminary Report on the Gravity and Magnetic Profiling Survey over Barapukuria – Phulbari Coal Deposit Area, Dinajpur' which outlined the structure of the basin. One borehole (GDH 26) was also drilled but the location or any detail of this borehole was not available for the study.

3.1.8. Between 1985 to 1987, GSB selected the low gravity geophysical anomaly district at Barapukuria as the first exploration area and drilled 7 boreholes (GDH-38, 39, 40, 41, 42, 43 & 44) with total depth of 2901.10 m. Coal was encountered in all the boreholes at varying depths between 129.57 m and 506.55 m below the surface, except in GDH-44.

3.1.9. On the basis of these boreholes, GSB approximately outlined the basin boundary and determined the extent, thickness and reserves of coal seam and submitted two reports in 1986 and 1987. Seven coal bearing horizons namely, from bottom upwards, seams VII, VI, V, IV, III, II and I were identified. Total coal reserves were estimated at 235.29 Mt over an area of 2.98 km^2. Out of this total reserve, 101.56 Mt was calculated as Proved reserve and the balance 133.73 Mt as Probable reserve.

3.1.10. Between, November 1987 to February 1988 Wardell Armstrong carried out pre-feasibility studies of Barapukuria mine based on information generated by GSB. Sampling and testing of coal seams obtained from two boreholes (GDH-38 and 41) was carried out and stage 1 Pre-feasibility Study of the Barapukuria Coal Deposit, Dinajpur was submitted.

3.1.11. Between April and May 1988, British Horizon Exploration Company carried out HRSS along 18 practical seismic survey lines with a total length of 61.4 km covering an area of 27 km^2 and submitted a report in August 1988.

3.1.12. In October 1988, Wardell Armstrong submitted the report 'Stage 1, Final Pre-feasibility Study of Barapukuria Coal Deposit, Dinajpur' based on all existing information at that time.

3.1.13. Between December 1989 and April 1990 Wardell Armstrong carried out drilling of 28 borehole totalling a drilling depth of 5775.95 m as follows:

- Two (2) pumping test boreholes totalling a drilling depth of 405 m.
- Thirteen (13) shallow boreholes for geotechnical and hydro geological observation totalling a drilling depth of 1488.36m.
- Thirteen (13) geological boreholes totalling a drilling depth of 3882.59 m.

3.1.14. Out of the above 13 geological boreholes of DOB series (DOB-1 to DOB-13), the details of DOB-3 is not available. All other 12 boreholes intersected Upper DupiTila and Lower DupiTila formations and all seams up to seam VI. The exploration report was delivered in May 1990.

3.1.15. Wardell Armstrong completed the Techno-economic Feasibility Study (TEFS) of Barapukuria coal project on the basis of 7 boreholes done by GSB (GDH series), 61 km of HRSS data and data from 28 boreholes as mentioned above. The TEFS furnished the details of structure, stratigraphy, coal seams, reserves, hydrogeology and other technical details along with mining plan and economics.

3.1.16. In February 1994, a contract of Barapukuria Coal Mine Development Project (BMCP-77) was signed between CMC and Bangladesh Oil, Gas and Mineral Corporation (BOGMC). A Supplementary Geological Exploration in Barapukuria was taken up as a part of contract No. - BMCP-77 for generation of necessary data for coal mine construction. The main objectives of the Supplementary Exploration were:

- To further ascertain the structure of the deposit, particularly the faults in the first mine area, nature of strata around the faults and how mining will be influenced by these faults,
- To ascertain distribution and variation of LDT formation and to find out hydraulic relationship of LDT and UDT formations with the roof and floor strata of VI seam,
- To estimate the gas content in the VI seam as well as explosibility of coal dust of VI seam and
- To determine temperature and geothermal gradient of the deposit and to identify isotherm zones.

3.1.17. Thirteen (13) boreholes totalling a drilling depth of 4060m were drilled for the supplementary exploration as follows:

- Five (5) Special Hydro geological borehole (CSE series) totalling a drilling depth of 1390m

- Six (6) Pumping test borehole (CSE series) totalling a drilling depth of 2050 m
- Two (2) Shaft inspection borehole (MSOB & ASOB) 620 m

3.1.18. The above drilling was conducted between 27.6.1994 and 15.9.1994 by deploying five drilling rigs. The exploration was done by Jiangsu Coal Geology Exploration under supervision of CMC. Manpower and all equipment and consumables (except oil, cement and sand) were transported from China.

3.1.19. The findings of the explorations are available in two un-named volumes (without the volume containing Figures). The date of publication of these volumes is not known. Some information regarding the geology of Barapukuria basin is also contained in the report of 'Basic Design of Barapukuria Coal Mine' (Vol. – I) submitted by CMC in May 1995. The drawings contained in volume – I and also volume – II of the report are not available.

3.1.20. Another report on 'Modification of Basic Design for Barapukuria Coal Mine Project (Revision)' submitted by CMC in April 2000 also contain information on geology of the deposit wherein certain basic data on structure of the deposit has been significantly altered.

Lithostratigraphy

3.1.21. In the absence of any paleontological evidence, the stratigraphical sequence from top to bottom has been divided on purely lithological grounds into following groups as shown in the table below:

Stratigraphy Sequence (Top downwards)	Formation	Thickness		
		Max.	Min.	Mean
	Barind Clay	15	3	9
	Upper Dupi Tila	126	94	107
	Lower Dupi Tila	81	0	25
	Gondwana – Upper Coal Sequence	179	0	N/A
	Gondwana – Seam VI Sandstone Sequence	124	0	N/A
	Seam VI	42	29	36
	Gondwana – Lower Sandstone Sequence	100	55	85
	Tillites	65	35	55
	Basement	-	-	-

Table 6: Lithostratigraphic Sequence of Barapukuria Coal Deposit

i. Barind Clay

This aquiclude is thick in the west-north and thin in the east-south, and mainly consists of brown yellow sandy clay horizons, which plasticity indexes vary from 10.4 to 46, inter bedded with dark grey silt and fine sand horizons in the lower part and bluish grey silty clays occasionally, grey clayey silt beds at the bottom.

ii. Upper Dupi Tila Formation

It has a thickness between 90.70 and 126.82 m, average of 104.41 m, and depth of the floor varies from 102.70 to 136.20 m. It is thin in the south and north while thick and deep in the centre eastwards and mainly consists of medium sand beds inter bedded with fine sand, pebbly grit and thin clay horizons. The content of clay increases with the depth.

The aquifer constitutes the major groundwater reservoir of Bangladesh. Hydraulic gradients vary from 0.0004 to 0.0006. Average transmissivity is 1200 m^2/d and permeability varies from 15 to 20 m/d. Groundwater movement is from the north-east to south-west, and velocities are on average 0.02 m/d. The rate of lateral flow is about 7 l/s/km width of aquifer.

iii. Lower Dupi Tila Formation

It is an aquiclude and distributed in the south of the boreholes linking DOB1, CSE6, CSE4 and CSE8 but absent in the north forming an 'open window' of 1.41 km^2 area. Lithology of it is light grey and greyish white mudstone, silty mudstone and quartz sandstone, and inter bedded with 1 to 2 lignite seams. Rocks in the formation are poorly consolidated and easy to smash.

Thickness of the formation is from 0 to 80.14 m with an average of 28.88 m. The depth of its floor varies from 115.09 m to 118.45 m. It is generally less than 15 m in the middle of the minefield. Rock is loose due to weathering after deposition of Lower DupiTila strata.

iv. Gondwana Group (Permian)

Only the middle and lower part of the Gondwana group is present in the mine field. The maximum depth drilled is 475.40 m. CMC in its report on Basic Design of Barapukuria Coal Mines, May 1995 divided the Gondwana group into four members from top downwards namely, Upper Coal-bearing member, the Middle Coal-bearing members, the Lower Sandstone and Moraine.

These are named in TEFS by Wardell Armstrong as Gondwana - Upper Coals sequence, Gondwana – Seam VI Sandstone Sequence, Gondwana - Lower Sandstone Sequence and the Tillites respectively.

Seam VI, the main seam is in between Gondwana – Seam VI Sandstone Sequence and Gondwana - Lower Sandstone Sequence These sub-divisions of Gondwana group are described below:

- **Gondwana - "Upper Coals sequence":** The Gondwana - "Upper Coals sequence" consists of fine to medium grained sandstone, siltstone, mudstone, carbonaceous mudstone and coal seams. It contains five coal seams namely from bottom upwards seams V, IV, III, II & I.

  The coal seams II and IV are more consistent, varying in thickness between about 6m and 15m, whilst seams III and V are laterally variable and discontinuous. Seam I is only present in one borehole in the deepest area. These seams are not being mined temporarily due to the influence of overlying strong aquifer.

- **Gondwana –"Seam VI Sandstone Sequence":** The "Seam VI Sandstone Sequence" varies between about 75m and 125m thick, and is a sequence of relatively homogenous and massive light grey and white medium to coarse grained sandstones, grit stones and conglomerates. Other lithologies, including coal, mudstone and siltstone are virtually absent. All of the sandstones in the Gondwana sequence contain occasional high angle joints. These are generally tight or in filled, again limiting the sandstone's secondary permeability.

- **Seam VI:** Seam VI is the thickest seam (average 36m thick) and apart from some thin impersistent bands of coal below, it is the basal coal seam in the sequence. It contains the bulk of the Barapukuria coal reserves. Seam VI is generally overlain and underlain directly by sandstone, with a frequent thin parting of mudstone at the roof contact.

- **Gondwana - "Lower Sandstone Sequence":** The sequence below Seam VI is substantially different from the Gondwana sequence above. It consists of a fairly rapidly inter banded sequence of sandstones, siltstones and mudstones with occasional thin coal bands. Most of the sandstones above Seam VI are to some extent weathered and moderately weak, with slight to complete decomposition of the feldspars to kaolinitic clay, the sandstones below Seam VI are mostly un-weathered, less feldspathic and moderately

strong. There are frequent units of fluviatile sandstones and inter banded sandstone/siltstone sequences with occasional thin bands of coals and isolated fossil plants.

- **The Tillites:** The tillites of glacial origin form the lowest member of the Gondwana sedimentary sequence and are generally considered to be of Upper Carboniferous age. They consist of variable thickness of boulder-bed tillites containing clasts of unsorted sedimentary, igneous and metamorphic rocks, inter banded with occasional units of mudstone, siltstone and coal indicative of periods of interglacial sedimentation and occasional minor peat accumulations.

v. Pre-Cambrian Archaean basement

The Archaean basement complex has been contacted in two of the recent deep exploration boreholes and in six of the earlier GSB boreholes. The basement consists of various veined gneissic metamorphic and meta-igneous rocks, the details of which are not pertinent to this report. There is some weathering in the top part (5m to 10m), but below this is the rocks are very strong and fresh, which the Maddhapara hard rock studies have considered eminently suitable for a wide range of uses as industrial aggregates.

Geological Structure

3.1.22. The basic structure of Barapukuria basin, established by all the agencies, is of an asymmetrical syncline which has been truncated by a fault along the eastern boundary of the basin. However, the number and location of faults in the basin have changed as more exploratory boreholes and geophysical surveying were conducted in the basin area by different agencies.

3.1.23. The report of Wardell Armstrong identified only three faults including the great eastern boundary fault while the report of CMC identified nine faults including the eastern boundary fault. Plate 3 shows these faults along with locations of boreholes of GDH series (done by GSB), of DOB series (done by Wardell Armstrong) and of CSE series (done by CMC). The CMC report greatly deciphered the structure of the basin.

3.1.24. However, in a subsequent report 'Modification of Basic Design for Barapukuria Coal Mine Project (Revision)' submitted by CMC in April 2000, the number of faults in the basin has been mentioned as Thirty Six (36). Out of these thirty six (36) faults, one (1) fault has a throw of more than 200 m, two (2) faults have throw between 30-50 m, eight (8) faults have throw between 10-30 m, eighteen (18) faults have throw between 5-10 m and seven (7) faults have throw of 5 m. However, map showing locations of these faults are not available.

3.1.25. Wardell Armstrong identified occurrence of seam VI towards the south of the NW – SE trending fault marking the boundary of the main basin in the south where only one borehole (GDH-42 done by GSB) is available. The extension of seam VI in this area has not been ascertained by any agency including CMC during their subsequent exploration in 1994.

Coal Seam Development

3.1.26. The exploration by GSB identified presence of seven coal horizons, namely from top to bottom, Seam I to Seam VII. Wardell Armstrong did not identify Seam VII separately and reported occurrence of Seam I to Seam VI.

3.1.27. The CMC report confirmed presence of Seven (7) seams from Seam I to Seam VII. The details of the coal seams as per the CMC report are given in table below:

Name of coal seam	Thickness (m)			No. of holes passing through the seam horizon	No. of holes intersected the seam horizon	Average thickness of parting with upper seam (m)	Remarks
	Min.	Max.	Average				
I	-	-	4.57	1	1		Intersected in 3 holes, thickness in 2 holes 0.46 m each.
II	13.95	15.24	14.44	4	4	54.27	Persistent. Area of spread 1.02 km².
III-1	0.72	2.60	1.59	5	5	9.87	Moderately persistent. Area of spread 1.26 km².
III-2	0	1.16	0.65	5	4	2.55	Not persistent.
IV-1	0	0.46	0.27	8	6	19.24	Not persistent.
IV-2	3.12	10.58	8.82	11	11	16.3	Persistent. Area of cover 1.89 km².
V-1	0	0.63	0.33	13	12	106.95	Not persistent.
V-2	1.74	10.37	4.78	14	14	N.A.	Persistent. Area covered 2.40 km².
V-3	0	2.74	1.27	14	8	N.A.	Not persistent.
VI	29.40	40.52	36.14	30	30	106.95	Highly persistent. Area covered 5.8 km².
VII	0	4.42	1.55	29	19	0.90	Not persistent.

Table 7: Thicknesses of coal seams and partings in Barapukuria Coal Basin (As per Geological Report submitted to BCMCL, Prepared by CMC)

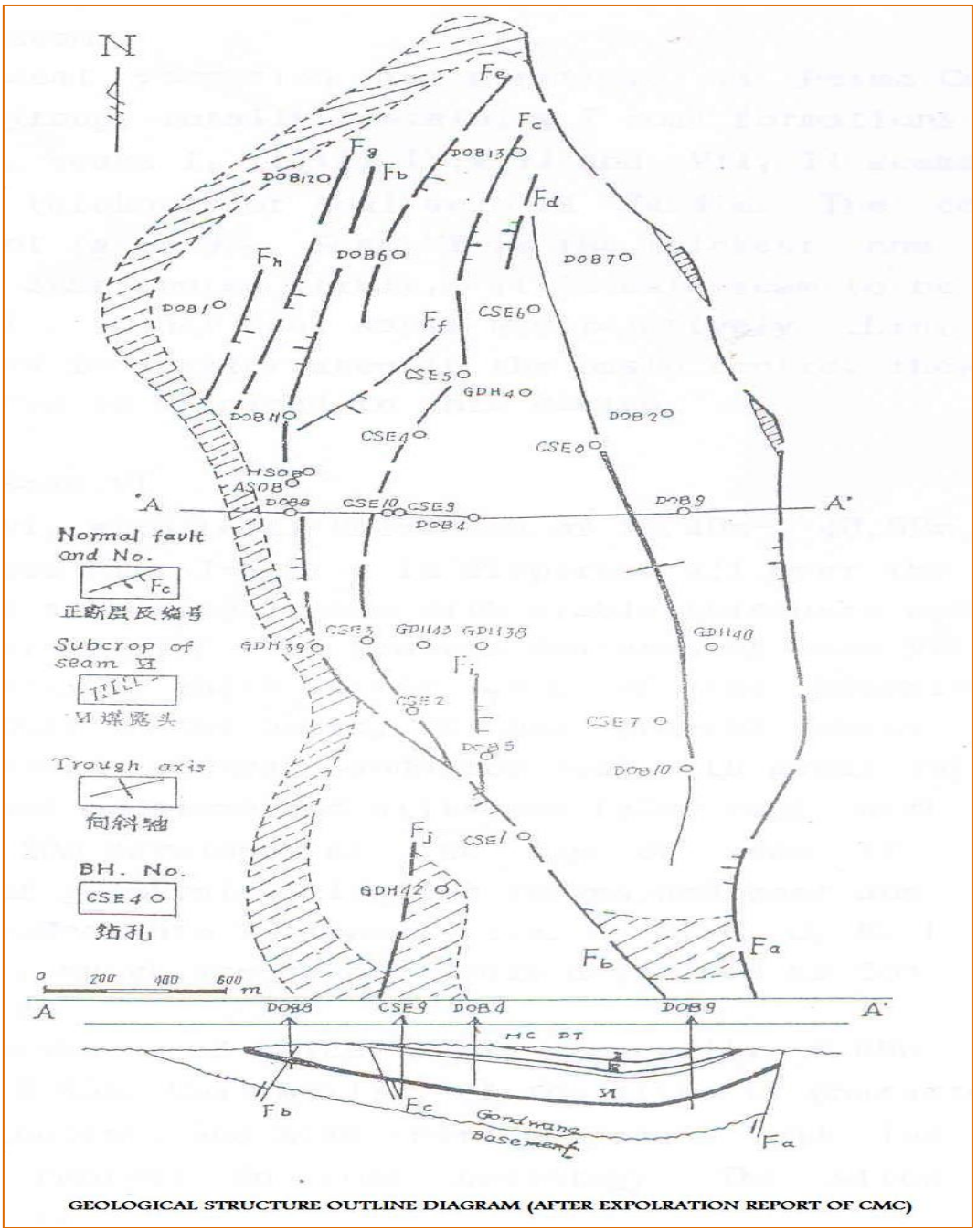
Seam VI

3.1.28. Seam VI which is the main seam of the basin has been vertically divided into seven zones namely, A to G from top downwards. This division has been made primarily on the basis of coal quality. The thickness variations of each zone are as under:

Zone	Thickness (m)			Remarks
	Minimum	Maximum	Average	
Zone A	4.66	7.97	6.63	Characterized by high ash content
Zone B	2.96	7.58	5.60	Relatively low ash content
Zone C	4.03	6.39	4.81	Contains two dirt bands
Zone D	3.08	5.19	3.77	Ash content is lower, good coal quality

Zone E	3.47	7.86	4.72	Low ash, good quality coal
Zone F	2.68	7.20	5.21	Contains 1-3 carbonaceous bands
Zone G	2.85	7.52	5.40	Quality is better than zone F

Table 8: Thickness variations of Zones in Barapukuria Coal Basin (As per Geological Report submitted to BCMCL, Prepared by CMC)



GEOLOGICAL STRUCTURE OUTLINE DIAGRAM (AFTER EXPOLRATION REPORT OF CMC)

Map not to scale

Plate 3: Geological structure outline diagram of Barapukuria (After exploration report of CMC)

3.1.29. In the area to the south west of the mine field (in the vicinity and to the south of borehole GDH-42), a secondary syncline has developed. According to Wardell Armstrong the area of seam VI in this zone ranges from 1-1.5 km2 and the seam is in close proximity below the Dupi Tila formations over a considerable area. Extra drilling will be required to get a clear picture of the seam in this area.

Upper DupiTila and Lower DupiTila Formation (UDT and LDT)

3.1.30. The extent and thickness of UDT and LDT formations have been studied in details in the course of supplementary exploration conducted under CMC in 1994.The results of the exploration indicate that hydrogeology of the coalfield is much more complicated than what was perceived earlier.

3.1.31. The overlying highly water bearing aquifer UDT serves as the main source of water for the coal formation. In addition, seam VI also contains water. Together, these sources combine to make the normal water inflow to the mine of about 1200 m^3/hr in contrast to 368 m^3/ hr considered in the original mine design. The maximum water inflow in seam VI has been now estimated at approximately 1800 m^3/hr.

3.1.32. It has been found that LDT is absent in the north of line linking DOB-1, CSE-6, CSE-4 and CSE-8 forming an 'open window' of 1.41 km^2 where seam VI come in direct contact with the highly water bearing UDT formation. According to the modified mine design prepared by CMC, this area will be worked later after development of suitable method to tackle the UDT aquifer.

Reserves

3.1.33. Reserve of seam VI occurring in the main basin (excluding reserves in the secondary syncline lying in the south west of the main basin area) has only been considered by both Wardell Armstrong and by CMC in their report of Supplementary Exploration.

Reserves of Seam VI as per TEFS of Wardell Armstrong

3.1.34. The total in-situ geological reserve of all the coal seams and also including the reserves of Seam VI in the secondary syncline area in the south west of the main basin as estimated by Wardell Armstrong is given below:

Seam	Demonstrated (Measured & Indicated) (Mt)	Inferred (Mt)
Seam I	-	1
Seam II	14	-
Seam III	-	4
Seam IV	18	-
Seam V	-	17
Seam VI	271	43-64*
Total	**303**	**65-86**

*In second syncline towards SW of main basin

Table 9: Total In-situ Geological Reserves for all Seams Barapukuria (Source- Wardell Armstrong TEFS on Barapukuria Coal Project)

3.1.35. Inferred and indicated reserves given above could be more accurately assessed and promoted to higher classifications by further drilling.

3.1.36. The in-situ geological reserve of seam VI (main basin area) as computed by Wardell Armstrong is presented below:

Class	Area (km²)	Average thickness (m)	Average density (t/m³)	Reserve (Mt)
Measured reserve	5.163	36.45	1.417	266.6
Indicated reserve	0.076	36.00	1.42	3.9
Total	**5.239**			**270.9**

Table 10: Total In-situ Geological Reserves for Seam VI Barapukuria (Source- Wardell Armstrong TEFS on Barapukuria Coal Project)

3.1.37. Wardell Armstrong considered that seam VI is unsuitable for mining in the part where the vertical distance from the base of DupiTila formations to the seam roof is less than 45m and also left a barrier of 105m from the eastern boundary fault. Also the area of steep inclination in the eastern limb of syncline was not considered for mining.

3.1.38. Thus, the mineable reserve (termed as 'Base reserves' in the TEFS of Wardell Armstrong) was estimated at 201.7 Mt as given below:

Class	Area (km²)	Average thickness (m)	Average density (t/m³)	Reserve (Mt)
Measured reserve	3.883	36.65	1.412	201.0
Indicated reserve	0.014	36.00	1.42	0.7
Total	**3.897**			**201.7**

Table 11: Mineable Reserves (Base Reserves) of Seam VI Barapukuria (Source- Wardell Armstrong TEFS on Barapukuria Coal Project)

Reserves as per Supplementary Exploration Report of CMC

3.1.39. As per the report of Supplementary Exploration submitted by CMC in 1994/1995, only the reserves of seam VI in the main basin area (i.e., excluding the reserves of seam VI in the SW of fault F_b) has been considered. The bases of estimation of reserve taken in this report are as under:

- The boundary considered for reserve estimation is as under:
  - East – Fault F_a
  - South west – Fault F_b
  - South and west, North West and north – Vertical depth of 18m from VI seam sub crop (i.e., weathered zone of sub crop excluded.)
  - The area of seam VI on the above basis has been estimated as 5.47 km².
- Single dirt band thickness of greater than 0.5m has been excluded from seam thickness while dirt bands of less than 0.5m thickness have been included in seam thickness.
- Coal with less than 40% of ash and with gross calorific value greater than 12.5 MJ/kg has been included in the reserve estimate.
- Specific gravity of VI seam coal has been taken as 1.43t/m³ on the basis of weighted average ash content of 16.5%. An equation relating coal density and ash content data of 349 nos. of ex-band coal samples of seam VI is derived from regression analysis.

- A coal barrier of 50m – 100m has been left on both sides of the faults F_a and F_b. For other faults no barrier has been left.
- Coal reserves have been classified as Rank A, Rank B and Rank C in the Supplementary Exploration report prepared by CMC on the basis of confidence level of geological interpretation of available exploration data. The criteria for Rank A, Rank B and Rank C are as follows :-

Criteria	Rank A	Rank B	Rank C
Engineering arrangement density	500m x 500m	1000m x 1000m	2000m x 2000m
Coal seam horizon, thickness, coal seam occurrence.	Ascertained.	Basically ascertained.	Coal seam horizon basically ascertained. Thickness variation preliminarily ascertained.
Structure and its variation, seam contours and faults.	Structure and its variation ascertained, seam contours controlled, faults > 20m throw ascertained.	Structure and its variation basically ascertained. Seam floor contours also basically controlled, faults > 50m throw ascertained.	Structure preliminarily ascertained.
Coal seam correlation	Reliable	Reliable	Reliable
Coal quality and its variation.	Ascertained	Basically ascertained.	Preliminarily ascertained.

Table 12: Criteria for Rank of Coal in Barapukuria (Source - Supplementary Exploration report prepared by CMC)

- Coal reserves under areas of influence of GDH series boreholes (done by GSB) has been treated by CMC as Rank C reserve due to absence of geophysical logging, reliable borehole coordinates, coal analysis data and coal recovery data. Reserves of barriers against fault have also been considered as Rank C reserve in CMC report.
- Coal reserves falling under 'open window' area i.e., area towards the north where Lower DupiTila aquiclude is absent, has been considered as temporarily unusable reserve in the CMC report. These reserves, according to the CMC report, can be partly converted to utilizable reserve when special study (for extraction of seam VI under UDT aquifer) is completed and the pit limit in this area determined. The balance reserve of VI seam in the areas where LDT aquiclude is present has been considered as utilizable reserves except the reserves occurring in fault barriers.

3.1.40. **Geological Reserves:** Based on the above principles and method of calculation of reserves, the Geological Reserves of the coal seams have been estimated by CMC as under:

Seam	Available Reserve (Mt)						Reserves not currently available (Mt)			
							North area with LDT absent			Fault Pillars
	A	B	C	A+B	A+B+C	(A+B)/ (A+B+C) (%)	B	C	B+C	C
VI	6.55	51.82	86.41	58.36	144.77	40	55.95	38.23	94.18	46.46
V	-	-	9.95	-	9.95	-	-	-	-	6.45
Total	6.55	51.82	96.36	58.36	154.72	36	55.95	38.23	94.18	52.91

Table 13: Geological Reserves estimated by CMC

3.1.41. **Mine Design Reserves:** Mine design reserves has been calculated by CMC after deducting from the above geological reserves, the reserves lost in barriers against faults, barriers against aquifer and in un extracted portion of coal seam thickness. The table below shows the Mine design reserves:

Seam	Geological Reserves (Mt)	Loss from Permanent Pillars (Mt)				Design Reserves (Mt)
		Fault Pillars	Water Barriers	Mining Thickness Loss	Sub-total	
VI (open window area)	135.18	40.58	15.47	54.23	110.29	24.89
VI (non-open window area)	150.23	5.88	10.05	42.54	58.46	91.77
VI Total	285.41	46.46	25.52	96.77	168.75	116.66
V	16.40	0.64	3.24	7.40	11.29	5.11
Total	301.81	47.10	28.76	104.17	180.04	121.77

Table 14: Mine Design Reserves estimated by CMC

3.1.42. **Recoverable Reserves:** The recoverable reserves have been calculated by CMC after deduction of coal loss in site pillars and due to mining loss from the design reserves estimated above. The table below gives the estimation of mine recoverable reserves:

Seam	Design Reserves (Mt)	Mine site pillar and mining loss			Recoverable Reserves (Mt)
		Site Pillar	Mining Loss	Sub-total	
VI (open window area)	24.89	4.07	4.16	8.23	16.66
VI (non-open window area)	91.77	10.76	16.20	26.96	64.81
VI Total	116.66	14.83	20.36	35.19	81.47
V	5.11	-	2.56	2.56	2.55

Total	121.77	14.83	22.92	37.75	84.02

Table 15: Recoverable Reserves estimated by CMC

Reserve of Seam VI in second syncline towards SW of main basin

3.1.43. This area has been intersected by 1 borehole (GDH-42) done by GSB. No further drilling has been done since then by any agency in this area. Wardell Armstrong has approximately assessed the reserve of seam VI in this area (1-1.5 km²) as 43-64 Mt considering an average thickness of 30m and a specific gravity of 1.42 t/ m³. Supplementary exploration done by CMC has not appraised reserve of this area.

Reserves of Upper Seams

3.1.44. The reserves of the upper seams, namely, seams I, II, III, IV & V have been considered under indicated/inferred category by Wardell Armstrong and CMC as presented in the table below:

Seam	According to Wardell Armstrong (1990)		CMC Report (1994)	Remarks
	Indicated Reserve	Inferred Reserve	Inferred Reserve	
Seam I	-	0.8	1.63	Developed in only 1 borehole of GSB. No quality data and too close to UDT.
Seam II	14.1	-	21.06	Intersected by 4 boreholes in an area of spread of 1.02 km² and close to UDT. More exploration data required.
Seam III	-	3.9	2.86	Low thickness of the split sections and also wide variations in thickness.
Seam IV	17.9	-	23.84	Lower split has good thickness and quite persistent. Intersected by 11 boreholes in an area of spread of 1.89 km². Has potential for economic exploitation.
Seam V	-	17.2	16.40	Split into 3 sections – middle section is persistent with wide variation of thickness. Intersected by 14 boreholes in an area of spread of 2.40 km².
Total	32.0	21.9	65.79	-

Table 16: Reserves of Upper Seams - Barapukuria

Estimation and classification of resources

Analysis of Reserve

3.1.45. For the purpose of classification of coal resources of Barapukuria coal basin, the above coal resource/reserve data falling under 'open window' and 'non-open window' resources/reserves of seam VI have to be further sub-divided into Rank A, Rank B and Rank C reserves. Resource/reserve of seam V comes entirely under Rank C.

3.1.46. Accordingly, the distribution of Geological and Recoverable reserves as estimated above by CMC has been re-arranged as under:

Seam	Geological Reserves (Mt)	Distribution of Geological Reserves in Rank A, Rank B & Rank C (Mt)					
		A	B	C	C (Fault Pillar)	Total A+B	Total C
VI (open window area)	135.18	--	55.95	38.23	41.00	55.95 (41.39%)	79.23 (58.61%)
VI (non-open window area)	150.23	6.55	51.82	86.41	5.45	58.37 (38.85%)	91.86 (61.15%)
VI Total	285.41	6.55	107.77	124.64	46.45	114.32	171.09
V	16.40	--	--	9.95	6.45	--	16.40
Total	301.81	6.55	107.77	134.59	52.90	114.32	187.49

Table 17: Distribution of Geological Reserves

3.1.47. The recoverable reserves as estimated by CMC have been proportionately distributed under Rank A+B and Rank C in the table given below:

Seam	Recoverable Reserves	Distribution of Recoverable Reserves	
		Total A+B	Total C
VI (open window area)	16.66	6.90	9.76
VI (non-open window area)	64.80	25.18	39.62
VI Total	81.46	32.08	49.38
V	2.56	--	2.56
Total	84.02	32.08	51.94

Table 18: Distribution of Recoverable Reserves

3.1.48. The reserves in the upper seams have been included under indicated/inferred category by Wardell Armstrong and fully under inferred category by CMC. Considerable reserves have been estimated in seams II, IV and V by both Wardell Armstrong and CMC.

3.1.49. The CMC report has also made an effort to draw isopach lines of the persistent sections of seam IV and seam V. Also, the borehole density in seam IV and seam V works out to around 5.8 boreholes/ km^2. Therefore, these two seams can be said to have been covered by general exploration (as per UNFC nomenclature).

3.1.50. However, further exploration is needed in these two seams to ascertain the variation in thickness and quality parameters before taking up any mine planning. Seam II has been intersected by only 4 boreholes and further boreholes are necessary to ascertain the continuity, variation in thickness and quality parameters of the seam.

3.1.51. With the present level of information, seam II can be said to have been covered by prospecting operation (as per UNFC nomenclature). The meagre reserves of seam I and seam III do not merit serious consideration.

Classification of Resources as Per UNFC System

3.1.52. The distribution of coal resources of different seams in Barapukuria is mainly based on the latest report of Supplementary Exploration submitted by CMC and on Techno-economic Feasibility Study submitted by Wardell Armstrong.

3.1.53. Based on the above information available, the coal resources of different seams in Barapukuria basin can be categorized in the UNFC matrix as under.

Seam	Resource (Mt)		Economic	Feasibility	Geology	Remarks
Seam VI (open area) ***These are non-utilizable resource at present. The resources*** *may be* ***utilizable in future subject to further study regarding development of mining system under highly water bearing UDT.***	**Recoverable Resource:**	Rank (A+B) - 9.90	2	2	1	Assessment of mining potentiality done requires further study. Potentially economic.
		Rank (C) - 6.76	2	2	2	Same as above but geological confidence level is lower (Rank C).
		Sub Total (a) - 16.66				
	Remaining Resource:	Rank (A+B) – 46.05	3	2	1	Unrecoverable reserve under design loss and mining loss. Mining potentiality assessed.
		Rank (C) – 72.47	3	2	2	Unrecoverable reserve under design loss and mining loss. Also, lower geological confidence (Rank C). Mining potentiality assessed.
		Sub Total (b) - 118.52				
	Total (a + b) - 135.18					
Seam VI (non-open area) ***These are utilizable resources and are proposed to be worked first. Resources of this area have been covered in mine planning and design.***	**Recoverable Resource:**	Rank: (A+B) – 26.13	1	1	1	Proved reserve.
		Rank: C – 38.67	1	1	2	Probable reserve.
		Sub Total (a) - 64.80				
	Remaining Resource:	Rank (A+B) – 32.24	3	1	1	Unrecoverable reserve under design loss and mining loss. Mine planning done.
		Rank: C – 53.19	3	1	2	Unrecoverable reserve with lower geological confidence and coming under design loss and mining loss. Mine planning done
		Sub Total (b) - 85.43				
	Total (a + b) - 150.23					

Seam VI (second syncline area to the SW of main basin area)	43-64	3	3	4	Reconnaissance resource, data available from only one borehole in an area of spread of 1-1.5 km².
Seam V	16.40	3	3	2	Explored with borehole density of 5.8boreholes/km². Structure and thickness variation ascertained preliminarily. Can be classified as indicated resource. Mine planning not done.
Seam IV	23.84	3	3	2	Explored with borehole density of 5.8boreholes/km². Structure and thickness variation ascertained preliminarily. Can be classified as indicated resource. Mine planning not done.
Seam II	21.06	3	3	3	Inferred resource. Borehole density around 4boreholes/km². More exploration required.

Table 19: Distribution of Coal Resources of different Seams under UNFC Code

Codification of Barapukuria coal resources

3.1.54. Based on the above seam wise classification of resources/reserves, the total geological resources of Barapukuria coal deposit has been codified in standard UNFC codes in table below.

3.1.55. However, an additional code under Economic Axis had to be created to account unrecoverable coal reserves which are lost as design loss (in fault barriers, water barriers and thickness loss) and mining loss.

3.1.56. It is considered that introduction of an additional code (3.2) under Economic Axis to account for unrecoverable reserves as mentioned above is justified to distinguish this class of reserve from virgin reserves which are considered to be of intrinsic economic interest based on geological study. In fact, in the UNFC classification system for Petroleum resources, there is a provision to account for unrecoverable resource under Economic Axis (E 3.3).

Economic Axis (E)		Feasibility Axis (F)	Geological Axis (G)			
			Detailed Exploration (1)	General Exploration (2)	Prospecting (3)	Reconnaissance Study (4)
Economic (1)		Feasibility study (1)	26.13	38.67		
		Pre-feasibility study (2)				
		Geological study (3)				
Potentially Economic (2)		Feasibility study (1)				
		Pre-feasibility study (2)	9.90	6.76		
		Geological study (3)				
Intrinsically Economic	(3.1)	Feasibility study (1)				
		Pre-feasibility study (2)				
		Geological study (3)		40.24	21.06	43-64
	(3.2) Unrecoverable	Feasibility study (1)	32.24	53.19		
		Pre-feasibility study (2)	46.05	72.47		
		Geological study (3)				

Note: (3.1) – Virgin reserve of intrinsic economic interest based on geological study.

(3.2) – Unrecoverable reserves due to design loss and mining loss based on feasibility study/pre-feasibility study.

Table 20: UNFC Type Codification of Barapukuria Coal Resources (Figures in Mt)

3.1.57. The coal tonnages of different seams considered in the above classification have been taken from the Supplementary Exploration report submitted by CMC. The same tonnage figures have been adopted in the report titled "Modification of Basic Design for Barapukuria Coal Mine Project" submitted by CMC in April 2000.

3.1.58. However, there are certain differences in the geological data between the above two reports, particularly in respect of the area of seam VI and the structure of seam VI (number of faults have increased to 36 in the report on 'Modification of Basic Design' from 9 faults envisaged in the 'Supplementary Exploration' report).

3.1.59. Also, the Volumes containing Drawings of the reports of 'Supplementary Exploration' and 'Modification of Basic Design' are not available and hence the design and mining losses envisaged in the reports could not be appraised properly.

3.2. Phulbari Coal Deposit

3.2.1. Phulbari coal project is located in the Dinajpur district in North Western part of Bangladesh. The project is at a distance of approximately 240 km from Dhaka and about 10 km from the border with India. Barapukuria coal project is lying towards the immediate north of Phulbari.

3.2.2. The main north-south broad gauge railway line passes over the western part of the project area and Phulbari railway station is located on this line. The Phulbari town with a population of over 30,000 is located on the Phulbari coal basin. The regional airport at Saidpur is reasonably close to the project.

3.2.3. The mine site is generally a flat plateau with elevations ranging from 28 m to 35 m above MSL and being on a plateau, the area is not prone to frequent major flooding. The little Jamuna river and the Khari Pul river flow through the site.

3.2.4. A detailed geological report, life of mine plan for a 15 Million tonnes per year (Mty) capacity opencast mine and a detailed environmental impact assessment (EIA) plan are available for the Phulbari coal project. However, the project activities are yet to start.

Geological Description

Introduction

3.2.5. The Phulbari coal deposit is situated in an elongated asymmetric north-west trending half-graben basin filled with coal bearing sediments of Permian age. Within the basin, the Permian sequence forms a synclinal structure. The basin sediments are overlain unconformably by flat lying Tertiary sediments. The important geological features of Phulbari coal basin are summarized below.

History of Exploration

3.2.6. Exploration activities carried out by Geological Survey of Pakistan during 1960 provided initial indications of presence of coal within Permian basin at Barapukuria to the north of Phulbari. Subsequent regional geophysical surveys (seismic and gravity), open hole drilling and limited coring carried out by BHP during 1994-1997 confirmed the presence of the Permian coal sequence to the south of Barapukuria which was called Phulbari basin.

3.2.7. In 1998, BHP assigned their rights to Asia Energy Corporation (Bangladesh) Pty Ltd (AEC), the company formed specifically for the purpose of exploring and developing the project. Since then, Asia Energy embarked on significant exploration and drilling programme to develop a full scale feasibility study of the Phulbari basin through commissioning of international consultants from various fields of expertise.

3.2.8. AEC drilled 6 open holes which provided information regarding east west extension of the deposit and about Upper Dupi Tila aquifer formation present in the basin. Subsequently a detailed exploration and geological modeling of the deposit was done by GHD Pty Ltd (GHD) using MineScape geology software.

3.2.9. This model was provided by GHD to MineConsult in July 2005 and MineConsult transformed the geological model into Minex software for estimation of in-situ and mineable quantities of coal and waste and also as the basis for mine planning.

3.2.10. Presently, Asia Energy Corporation holds the title of two exploration licenses (area B and area H) and a mining lease (Plate 4). License area G can be used for relocation of rivers and other infrastructures and license areas ‘I’, ‘T’ and ‘U’ can be utilized for project facilities, mine batters and waste dumps.

3.2.11. A total of 118 boreholes have been completed in the basin area. Out of these, 104 are specifically for resource assessment and stratigraphic purpose and the balance 14 are for aquifer pump testing purposes (4 nos. for pump installation and 10 nos. for monitoring near the pumps).

3.2.12. The coal quality assessment has been done for 52 boreholes. The boreholes were planned in a 500 m x 500 m grid but this pattern could not be followed strictly because of surface constraints in locating the boreholes. However, an average borehole density of nearly 4 boreholes/ km² is reported to have been achieved.

Stratigraphy

3.2.13. The stratigraphic sequence of the basin is given in table below:

Stratigraphy Sequence (Top downwards)	Formation	Age	Brief Description
	River Sediments	Quaternary	Surface alluvial sands and gravels
	Barind Clay		Silty to sandy high plasticity clay
	Upper Dupi Tila	Tertiary	Micaceous sands and gravels, cobbly basal unit
	Middle Dupi Tila		Clays, often kaolinitic and ferruginous
	Lower Dupi Tila		Quartz sand
	Weathered Permian	Permian Gondwana Group	Residual soil – weathered mudstone, coal
	Un – Weathered Permian		Mudstones, siltstones, sandstones
	Top Coal Seam (2 leaves)		Intermittent coal, 5-10m thick
	Upper Coal Seam		Persistent coal seam, up to 16m thick
	Main Coal Seam		Most persistent coal seam 20-35m thick
	Lower Coal Seam (2 leaves)		Intermittent coal, 4-8m thick
	Base Coal Seam (2 leaves)		Intermittent coal, 2-4m thick
	Lower Permian		Mudstones, siltstones, sandstones
	Archaean	Archaean	Diorite basement

Note: The five coal seams shown in table are all separated by un-weathered Permian inter burden.

Table 21: Stratigraphic Sequence in Phulbari Coal Basin

Geological Structure

3.2.14. The Phulbari coal deposit lies in a NNW-SSE elongated basin which forms a half-graben structure over an Archaean basement complex. The basin is cut off in the east by a major boundary fault and the sub crop zone in the west (Plate 5). The Permian sediments are unconformably overlain by more than 100 m thick flat Tertiary sediments.

3.2.15. Geophysical information (gravity and some seismic) suggests that the eastern limit of the Phulbari basin is defined by basement faults trending north-northwest. The southern area of the Phulbari basin may be characterized by occurrences of northerly trending faults and basement highs.

3.2.16. These fault structures as basement highs may interrupt the coal bearing sequence and additional drilling with geophysical study will be required to clarify the eastern limit of the southern margin. Also, additional drilling will be required to confirm the southern extent of the coal basin. At this stage the basin remains open with suggestion from the gravity surveys and geological modeling that it does extend further southward.

3.2.17. The western boundary of the Phulbari basin is defined by the sub crop of the Permian half-graben structure beneath the overlying Tertiary formations. On the northern boundary of the Phulbari basin, the coal either sub crops and possibly extends into the Barapukuria basin or is truncated beneath the overlying Tertiary sediments.

3.2.18. The basin and coal strata deepen from west to east and the depth of coal appears to be highest in the central part of the basin. Drilling in the basin has revealed cores continuing evidence of faulting particularly in the boreholes of southern area and supports faulting indicated by seismic observations along three lines in the basin.

Coal Seams

3.2.19. There are five major coal horizons in the basin, namely from top downwards, Top seam, Upper seam, Main seam, Lower seam and Base seam. Main seam is having four splits named as Main A, Main B, Main C and Main D from top downwards. A major part of coal resources occur in Upper and Main seams. The range of depths, thicknesses and quality variations of these seams are given in table below:

Seam	Range / Average	Depth to Top (m)	Thickness (m)	Moisture Air dried (%)	Ash Air dried (%)	Volatile Matter Air dried (%)	Fixed Carbon Air dried (%)	Relative Density In Situ	Specific Energy Air dried (MJ/kg)	Sulphur Air dried (%)
Top	Range	170-195	1.14-5.26	2.8-3.0	13.2-15.4	31.4-32.9	50.1-51.9	1.37-1.41	27.3-28.4	1.03-1.24
	Average	180	3.36	2.9	14.1	32.1	50.8	1.38	27.9	1.10
Upper	Range	144-328	2.56-11.62	2.1-4.2	11.9-24.6	15.9-32.0	48.1-64.7	1.36-1.44	25.8-28.6	0.58-2.77
	Average	230	10.59	2.6	16.5	29.4	51.5	1.40	27.3	1.09
Main A	Range	143-300	3.0-17.3	1.7-3.4	9.5-21.2	26.8-31.8	48.9-56.0	1.33-1.45	25.76-29.0	0.55-2.48
	Average	232	7.31	2.5	15.2	29.4	53.0	1.39	27.7	1.02
Main B	Range	145-317	2.56-10.15	1.8-3.2	9.6-23.9	26.9-32.4	47.1-56.1	1.35-1.46	24.1-30.4	0.45-2.47
	Average	229	5.83	2.4	14.2	30.5	53.0	1.38	28.3	0.97
Main C	Range	142-323	1.32-10.30	1.6-3.0	10.6-25.1	25.6-32.4	45.9-55.6	1.35-1.46	24.1-30.1	0.40-2.64
	Average	230	4.83	2.3	16.2	30.1	51.5	1.40	27.6	0.81
Main D	Range	144-328	2.56-11.62	1.6-3.2	11.4-32.0	24.5-31.5	40.8-55.5	1.35-1.56	21.29-29.36	0.37-1.94
	Average	235	4.66	2.3	18.3	28.9	50.5	1.42	26.6	0.78
Lower	Range	180-306	1.0-12.6	1.7-2.5	19.6-36.8	23.6-28.8	42.0-50.1	1.43-1.61	19.3-26.8	0.47-1.38
	Average	248	4.67	2.0	27.4	26.1	44.7	1.51	26.1	0.77
Base	Range	243-318	7.45-13.10	1.6-4.0	21.3-31.0	25.8-28.3	41.4-50.5	1.45-1.55	21.6-25.7	0.56-1.04
	Average	293	11.20	2.4	27.4	24.8	45.4	1.51	24.8	0.58

Table 22: Seam-Wise variation of depths, thickness and quality

UDT Formation

3.2.20. The Upper Dupi Tila (UDT) is a major formation within the Tertiary sediments. The UDT is laterally consistent and is having a thickness of 90-100 m usually. UDT is a major aquifer horizon and is confined by the overlying Barind Clay and the underlying clays of Lower Dupi Tila. Extensive de-watering of this formation will be required during mining.

Estimation and classification of resources

Estimation of resources

3.2.21. The resource estimate of this basin as reported by Asia Energy Corporation (Bangladesh) Pty Ltd in its feasibility study report (2005) have been done in accordance with the 2004 edition of JORC Code by competent persons as defined in the JORC Code and were employed by GHD Pty Ltd.

3.2.22. The resource estimates was made through Mincom Minescape software and was found to compare well with resource tonnage obtained by simple multiplication of areas, average seam thicknesses and relative densities. The assumption has been made that the deposit will be worked by surface mining method and the following criteria have been used:

- Coal with less than (<40%) ash is included; if the ash content is greater than (>40%) the material is not considered as coal.
- Stone bands with thickness greater than (>0.5m) are considered removable by mining and have been excluded. Thinner stone bands are included if coal on either side is greater than (>1m).
- Minimum coal thickness of the upper and main seams for inclusion in the resources is 5 m in the weathered zone.
- Lower and Base seams thicker than 1 m are included provided the ratio of inter burden plus band thickness with coal thickness is less than 5:1.
- Coal beyond the line of intersection of major boundary fault with main seam has been excluded.
- The tonnage generated by this process have been adjusted downwards by 5%, 10% and 15% respectively for measured, indicated and inferred categories of resources.

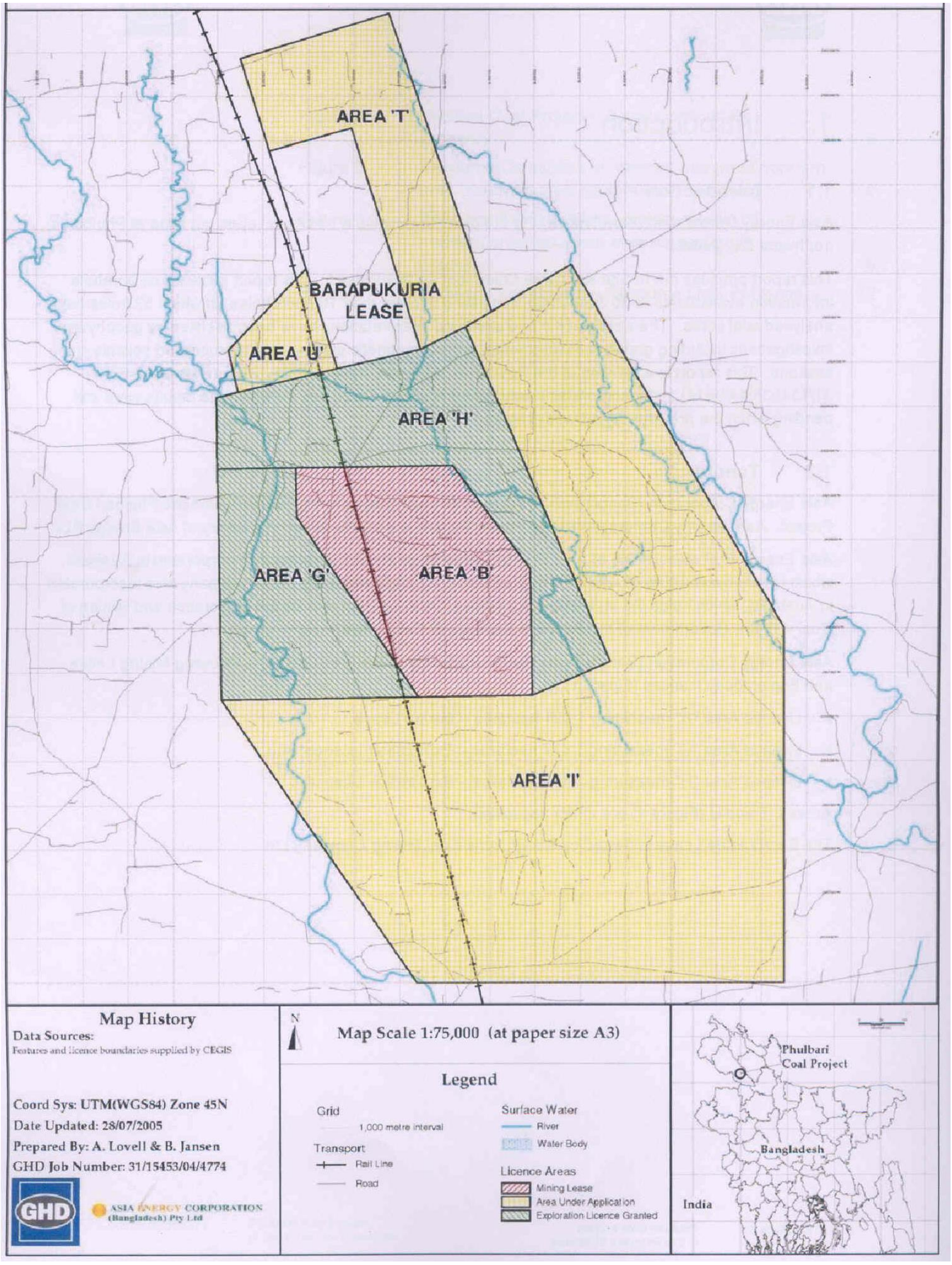


Plate 4: Phulbari Coal Project - Licence Boundaries (After AEC Report)

Map not to scale

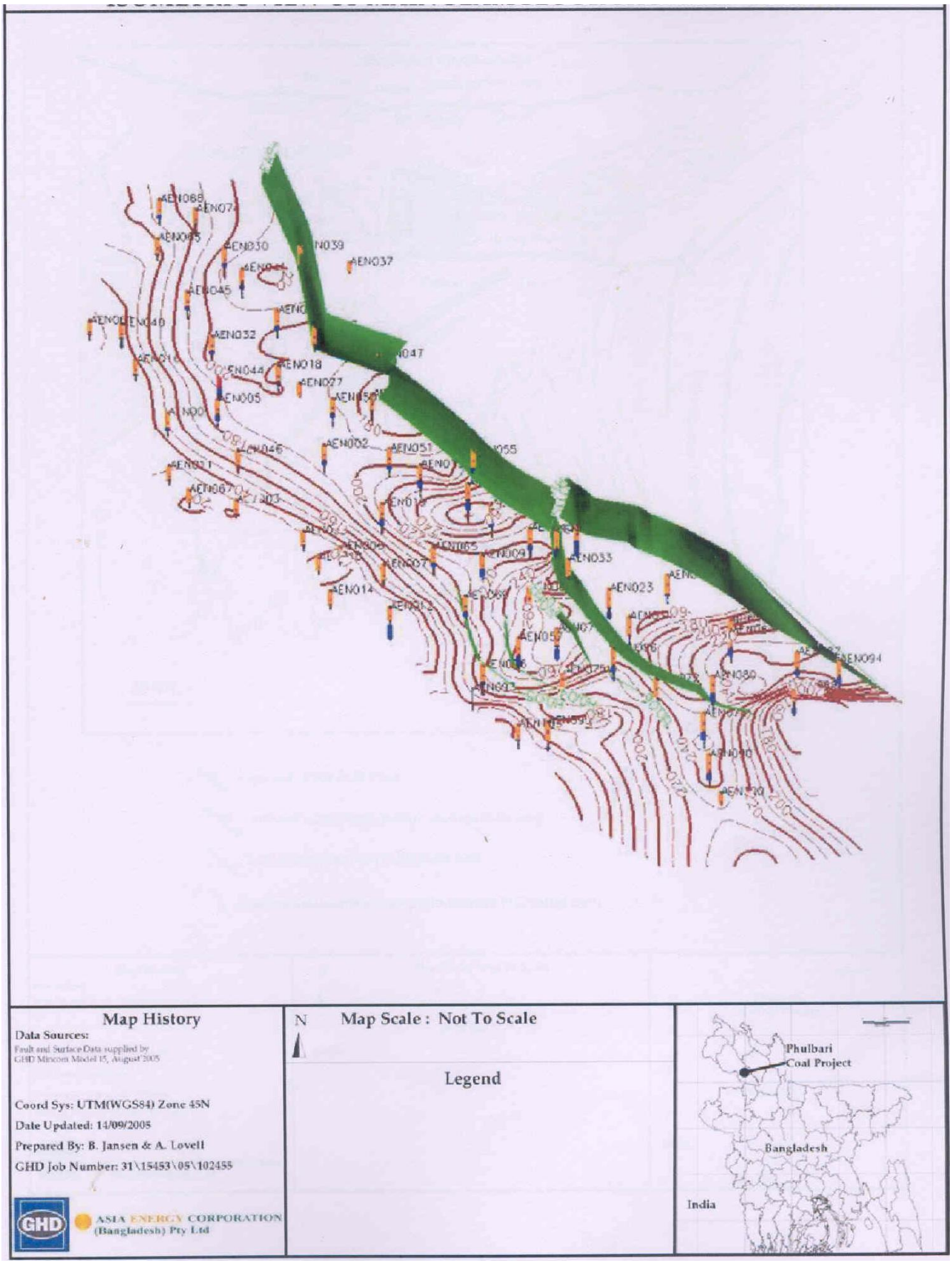


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Plate 5: Phulbari Coal Project Main Seam Floor Showing Faults (After AEC Report)

3.2.23. On an average, a borehole density of about 4 boreholes/ km² was achieved over most of the Resource area. The deposit has been divided into northern area with a relatively simple structure and southern area where more frequent evidence of structural disturbance was observed (Plate 6). Accordingly the northern resources have been assigned a higher category (of confidence level) than the southern resources.

Northern Area Measured Resources

3.2.24. The resources occurring in upper and main seams within the northern portion has been considered as measured resources. However, a zone of 100 m width against the main boundary fault in the east has been excluded from the measured resources. A reduction of 5% has been made for unforeseen geological disturbances like faults and intrusions.

Northern Area Indicated Resources

3.2.25. A zone of partially weathered upper and main seams, but thicker than 5 m of fresh coal and coal in the 100 m zone against the fault have been considered as indicated resource.

3.2.26. The northern development of upper seam has also been included in the indicated resource, in the portion where the seam thins out from a thickness of more than 10 m to a very high ash level in the next borehole.

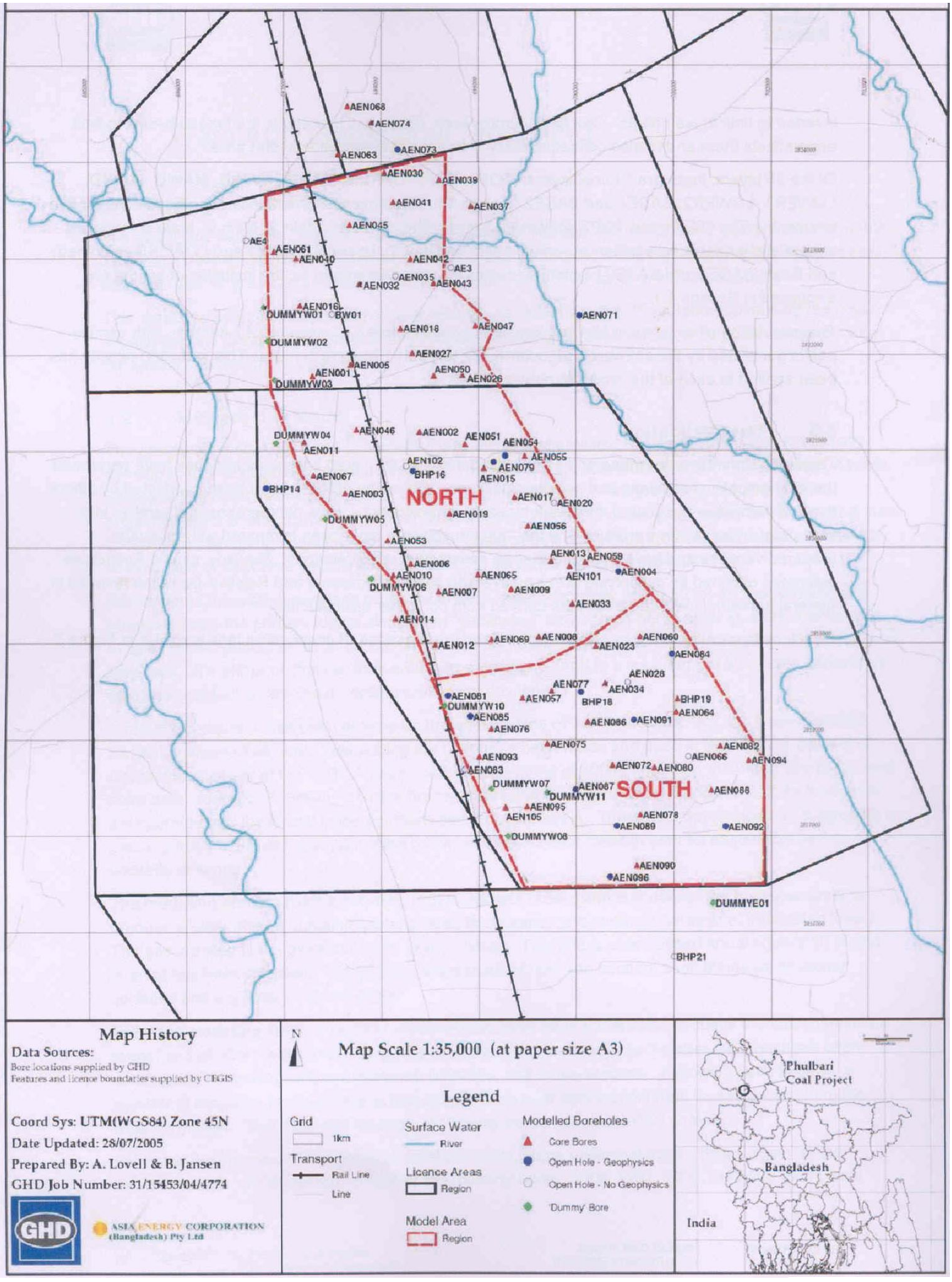
3.2.27. The resource of lower seam in the northern area has been considered in the indicated category as the pattern of splitting has not been definitely established, although boreholes are at 500 m interval.

3.2.28. A reduction of 10% has been made from all indicated resource mentioned above to account for unforeseen geological disturbances.

Southern Area Indicated Resources

3.2.29. The full upper and main seam in the southern portion of the deposit has been categorized as indicated resource despite presence of boreholes in 500 m grid because 1/3rd of the boreholes are not analyzed and there is frequent evidence of faulting/irregular seam levels.

3.2.30. The indicated resources are limited by the line approximately 250 m distant from boreholes with analyzed cores. The resource in the zone of 100 m width of coal against the eastern boundary fault has not been included in the indicated category.



Map not to scale

Plate 6: Phulbari Coal Project Northern and Southern Areas and Borehole Locations (After AEC Report)

3.2.31. The thickest developments of the Top, Lower and Base seams in the southern area are also included in the indicated category subject to the basic premise of the seams occurring within 5:1 ratio of inter burden plus band thickness : coal thickness. The resources in these seams have been considered up to the limit in the east vertically below the line of intersection of base of main seam with a distance of 100 m to the west of main eastern boundary fault.

3.2.32. A deduction of 10% has been made from all indicated resource mentioned above to account for unforeseen geological disturbances.

Southern Area Inferred Resources

3.2.33. Inferred resources for Upper and Main seams occur in the sub crop zone adjacent to the southern Upper and Main seams with indicated resources but limited by the 5 m isopachs. Where the Southern, Upper and Main seams are cut off by the major fault, inferred resources are assigned to the 100 m wide zone west of the fault.

3.2.34. Near the southern boundary of the license area, the deposit is open ended and the inferred resources are limited by the line approximately 500 m distant from boreholes with analyzed cores.

3.2.35. A deduction of 15% has been made from all indicated resource mentioned above to account for unforeseen geological disturbances.

3.2.36. Based on the above criteria, the seam wise measured, indicated and inferred resources have been summarized in table below:

Seam	Measured (Mt)	Indicated (Mt)	Inferred (Mt)	Total (Mt)
Top	-	1	-	1
Upper	51	61	12	124
Main	237	124	28	389
Lower	-	39	-	39
Base	-	19	-	19
Total	**288**	**244**	**40**	**572**

Table 23: Summarised In Situ Resources of Phulbari coal field

3.2.37. The detailed seam wise resources with break-up of measured, indicated and inferred categories are given in table below:

Seam	Measured			Indicated			Inferred			Total
	Resources (Mt)	Area (ha)	Thick (m)	Resources (Mt)	Area (m)	Thick. (m)	Resources (Mt)	Area (ha)	Thick. (m)	In Situ Resources (Mt)
Top	-	-	-	1.0	23	3.36	-	-	-	**1.0**
Upper North	50.8	348	10.91	13.6	134	8.58	-	-	-	**64.4**
Upper South	-	-	-	47.3	338	11.2	11.9	92	10.96	**59.2**
Main A North	75.5	747	7.61	7.4	90	7.21	-	-	-	**82.9**

Main A South	-	-	-	30.1	359	6.78	7.9	104	6.48	**38.0**
Main B North	61.1	747	6.22	8.3	124	5.49	-	-	-	**69.4**
Main B South	-	-	-	23.0	358	5.2	6.3	115	4.78	**29.3**
Main C North	49.6	747	4.99	8.9	152	4.74	-	-	-	**58.5**
Main C South	-	-	-	20.1	354	4.49	7.1	125	4.81	**27.2**
Main D North	50.5	747	5.03	9.4	155	4.83	-	-	-	**59.9**
Main D South	-	-	-	16.6	355	3.58	6.5	126	4.25	**23.1**
Lower North	-	-	-	9.8	204	3.5	-	-	-	**9.8**
Lower Central	-	-	-	20.5	305	4.89	-	-	-	**20.5**
Lower South	-	-	-	9.0	125	5.45	-	-	-	**9.0**
Base	-	-	-	19.3	126	11.2	-	-	-	**19.3**
Total	**287.5**			**244.3**			**39.7**			**571.5**

Table 24: Seam-wise In-Situ Resources of Phulbari coal field

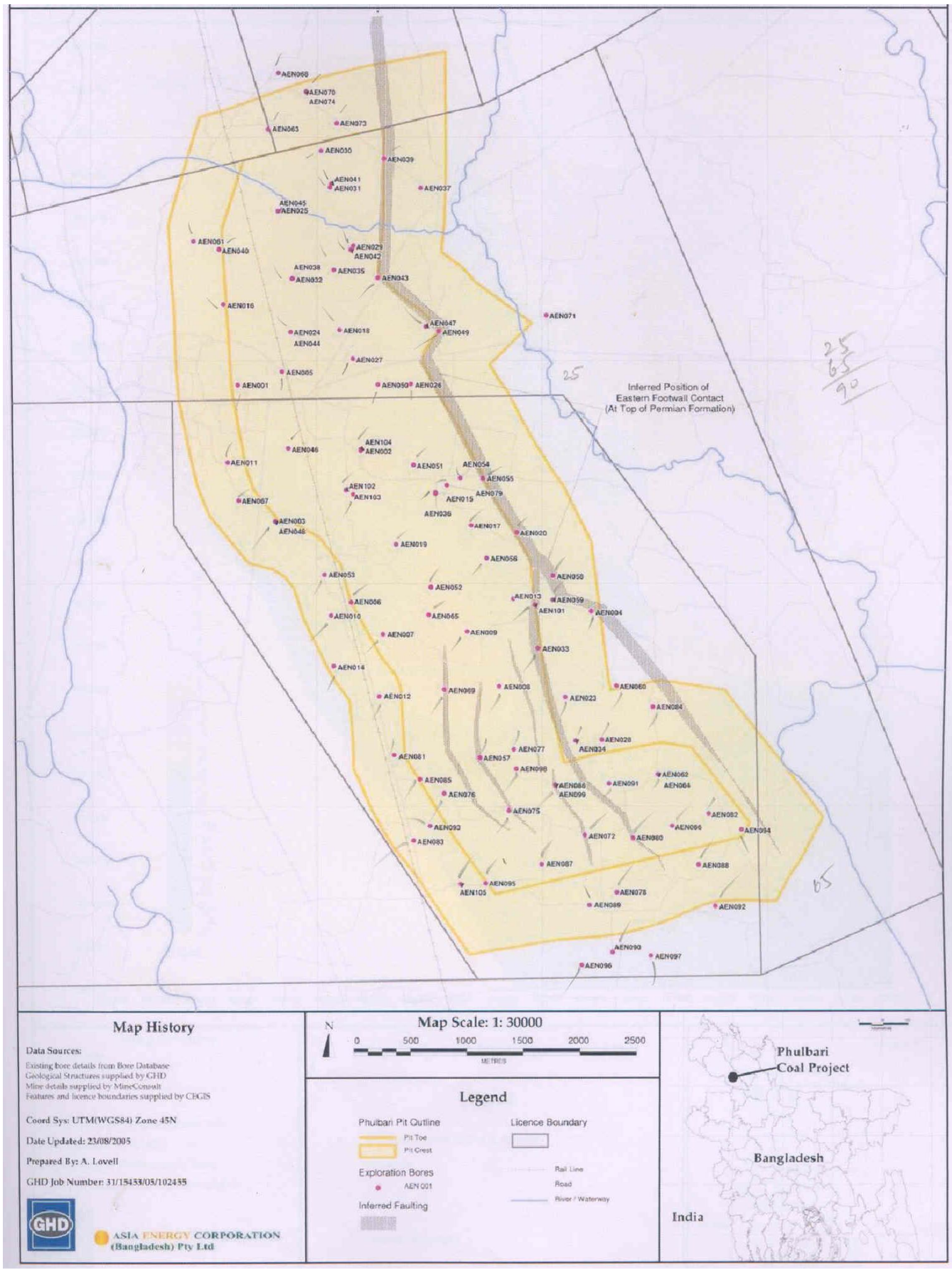
3.2.38. The extractable ROM coal of Phulbari Open Cast mine (ref. Plate 7 for opencast boundary) as estimated in the Draft 'Life of Mine Plan' of Phulbari Coal Project submitted by Asia Energy Corporation (Bangladesh) Pty Ltd in October, 2005 is 475 Mt within the pit limits.

3.2.39. It may be mentioned here that the open cast mine plan has considered the in-situ resources of Top seam, Upper seam and Main seam only. Out of 475 Mt of extractable reserve, the marketable coal product has been estimated in the mine plan as 435 Mt after washing as given in the table below.

Materials	Tonnage (Mt)
Low ash metallurgical coal	88
High quality thermal coal	257
High ash domestic coal	69
Marketable impacted coal*	21
Total Product Coal	435

* ROM coal not washed

Table 25: Coal Products from Phulbari coal field



Map not to scale

Plate 7: Phulbari Coal Project – Opencast Boundaries Showing Faults and Boreholes (After AEC Report)

Classification of Resources as per UNFC System

3.2.40. The codification of resources/reserves of Phulbari coal project in the UNFC matrix has been worked out based on the above estimation of in-situ coal resources of Phulbari mine area and study of the following reports available:

- 'Coal geology and Resource Assessment' report prepared as per JORC code and submitted by Asia Energy Corporation (Bangladesh) Pty Ltd
- Extractable coal reserves and marketable coal product as assessed in the 'Life of Mine Plan' of Phulbari Coal Project submitted by Asia Energy Corporation (Bangladesh) Pty Ltd in October, 2005.

3.2.41. The total in-situ coal resources of Phulbari mine area has been estimated as 572 Million tonnes including 288 Million tonnes of measured resources, 244 Million tonnes of indicated resources and 40 Million tonnes of inferred resources.

3.2.42. Out of the total in-situ resource of 572 Million tonnes, only an in-situ resource of 514 Million tonnes occurring in Top, Upper and Main seams within the opencast pit limits have been considered in the 'Life of Mine Plan' of Phulbari opencast project, excluding a resource of 58 Million tonnes occurring in Lower and Base seams which have not been included within the scope of opencast mining in the 'Life of Mine Plan'.

3.2.43. Out of 514 Million tonnes of in-situ resources within the opencast pit limits, total recoverable ROM coal has been worked out as 475 Million tonnes, and marketable coal product has been worked out as 435 Million tonnes after washing the entire ROM coal except 21 Million tonnes of ROM coal designated as 'impacted coal' in the 'Life of Mine Plan'.

3.2.44. The 'impacted coal' which is coal from weathered zone near sub crop of the seams, is not proposed to be washed as per the 'Life of Mine Plan'.

3.2.45. The 514 Million tonnes of in-situ resources considered for opencast mining include 288 Million tonnes of measured resources, 186 Million tonnes of indicated resources and 40 Million tonnes of inferred resources as per the 'Coal Geology and Resource Assessment' report prepared as per JORC code and also as per 'Life of Mine Plan' by Asia Energy Corporation (Bangladesh) Pty Ltd.

3.2.46. In the 'Life of Mine Plan' of Phulbari opencast coal mine, the estimate of recoverable ROM coal (i.e. 475 Mt) considers measured, indicated and inferred resources within the opencast pit limit indicating a loss of 39 Million Tonnes of in-situ coal during mining. Further, the 'Life of Mine Plan' envisages a marketable coal product of 435 Million tonnes indicating a loss of 40 Million tonnes of ROM coal as rejects in the coal washery.

3.2.47. From the above discussions, it is apparent that the recoverable ROM coal (475 Mt) of Phulbari opencast coal project as has been estimated by the 'Life of Mine Plan' is more than the measured resource of 288 Million tonnes reported in the Coal Geology and Resource Assessment report prepared as per JORC code.

3.2.48. Obviously, for obtaining the balance recoverable ROM coal, extraction of indicated and inferred resources (totalling 226 Mt) of the target coal seams within the opencast pit limit have been considered in the 'Life of Mine Plan'.

3.2.49. Therefore, the total in-situ resources of 514 Million tonnes has been proportionately distributed between column 1 (G.1) and column 2 (G.2) of geological axes in the UNFC matrix presented in the table. Consequently, the marketable coals (435 Mt) as well as the losses due to mining and coal washing (totalling 79 Mt) have also been proportionately distributed under G.1 and G.2 columns. However, the entire marketable coal of 435 Million tonnes has been included in the feasibility axis 1 considering the following:

- 'Life of Mine Plan' can be taken as equivalent to a feasibility study as this includes all details and calculations of a feasibility study including economics of the project and is also supported by a separate detailed Environmental Impact Assessment study for the project.
- Opencast mining, unlike underground mining, provides extreme flexibility of extraction of coal deposits occurring even under complex structural set up, though estimates of coal and overburden volumes may vary from the projections depending on the degree of structural deviation from the stage of geological assessment.
- The entire mine area has been prospected with a borehole density of around 4 boreholes/km² (i.e. conforming to an average of 500m x 500m grid pattern of boreholes) which has been considered adequate for measured resources by the competent persons under JORC code.
- Adequate margins for geological uncertainties in respect of calculation of different categories of coal resources have been provided for in the geological assessment report (5%, 10% and 15% deduction have been made from gross estimates of measured, indicated and inferred in-situ resources respectively, for arriving at the reported values under these categories).
- Most of the indicated and inferred resources occur in the southern side of the property which will be worked during the later part of the life of mine. Therefore, ample time is available for generating geological information to meet the present data gaps relating to coal quality and structure of the deposit in the south side.

3.2.50. So far as distribution of 79 Million tonnes of unrecoverable coal resources is concerned, it is imperative that an additional code under Economic Axis be created to account for such unrecoverable coal resources which are envisaged to be lost during mining (39 Mt) and in the process of washing of ROM coal as rejects (40 Mt).

3.2.51. Thus, an additional code (3.2) under Economic Axis has been created to account for the unrecoverable resources as mentioned above to distinguish this class of resource from virgin resource which are considered to be of intrinsic economic interest based on geological study. In fact, in the UNFC classification system for Petroleum resources, there is a provision to account for unrecoverable resource under Economic Axis (E 3.3).

3.2.52. The in-situ geological resources of 58 Million tonnes occurring in the Lower and Base seams have been considered under 3.1-3-3 category as the pattern of splitting of these seams have not yet been conclusively established and also because these seams have been excluded from the scope of opencast mining in the 'Life of Mine Plan'.

Economic Axis (E)	Feasibility Axis (F)	Geological Axis (G)			
		Detailed Exploration (1)	General Exploration (2)	Prospecting (3)	Reconnai-ssance Study (4)
Economic (1)	Feasibility study (1)	243.7	191.3		
	Pre-feasibility study (2)				
	Geological study (3)				
Potentially Economic (2)	Feasibility study (1)				
	Pre-feasibility study (2)				

		Geological study (3)				
Intrinsically Economic	(3.1)	Feasibility study (1)				
		Pre-feasibility study (2)				
		Geological study (3)			58	
	(3.2) Unrecoverable	Feasibility study (1)	44.3	34.7		
		Pre-feasibility study (2)				
		Geological study (3)				

Note: (3.1) – Virgin reserve of intrinsic economic interest based on geological study. (Figures in Mt)

(3.2) – Unrecoverable resources due to loss in mining and washing based on 'Life of Mine Plan'

Table 26: UNFC Type Codification of Phulbari Coal Resources

3.3. Khalashpir Coal Deposit

3.3.1. Khalashpir coal deposit is located in the north western part of Bangladesh in Pirganj Upazila of Rangpur District between 25° 23' 14" N & 25° 30' 0" N and 89° 09' 12" E & 89° 15' 0"E, at a distance of about 48 km towards south from Rangpur town, the district headquarter.

3.3.2. Khalashpir is connected to Pirganj 13 km east by a fair weather motor able road. Pirganj is on Rangpur-Dhaka National Highway. The nearest railway station from Khalashpir is Rangpur and Phulbari. The coal basin area can also be accessed by good metalled road from Saidpur airport (60 km).

3.3.3. The Khalashpir coal basin has been explored by Geological Survey of Bangladesh (GSB) in 1989 and by Hosaf International in 2004. A Techno-economic Feasibility Study of Khalashpir Coal Mine Project was prepared by China Jinan Mining Development Corporation in 2006. However, the coal basin is virgin and no mine construction work is being done at present.

Geological description

Introduction

3.3.4. Khalashpir basin is a NW-SE elongated fault bounded synclinal basin of 25 sq. km. The sedimentary sequences of Gondwana group (Permian), Jamalganj Formation (Miocene), DupiTila Formation (Pliocene), Barind Clay (Pleistocene) and Alluvian (Holocene) have been preserved in this basin. The base of Gondwana group has not yet been proved.

History of Exploration

3.3.5. Geological Survey of Bangladesh (GSB) had undertaken programmes for intensive investigation for coal and other economic minerals in the inferred shallow basins (areas of low gravity anomalies) and discovered coal in Barapukuria basin (1985) and in Khalashpir basin (1989).

3.3.6. GSB started core drilling in Khalashpir on March, 1989 and 4 holes, namely GDH-45, GDH-46, GDH-47 and GDH-48 were drilled during 1989-90. Commercially viable coal deposits was encountered in 3 out of these 4 boreholes (GDH-45, GDH-46 and GDH-47) at varying depths ranging from 23.29 m to 284.95 m below the surface. However, in one borehole (GDH-48), only small patches of coal were found.

3.3.7. The drilling data revealed the existence of one prominent fault (near GDH-46) with NNW-SSE alignment. The throw of this fault could not be calculated but was estimated to be of about 150 m from correlation of conglomerate beds between the holes GDH-46 and GDH-48.

3.3.8. The total basin area was estimated to be more than 25 km^2 and the coal bearing area as about 12.26 km^2, out of which the proved area was 2.52 km^2. The exploration proved existence of 8 coal horizons. Coal quality was analyzed for all the three holes. No geophysical logging of the boreholes was carried out.

3.3.9. In 2004, Hosaf International Ltd was awarded the exploration licence for Khalashpir prospect. Hosaf International, in turn, contracted Geo-tech India to undertake additional cored drilling. Geo-tech India completed 14 more boreholes and thus the total number of boreholes in the prospect is 18 (including GDH-48 where coal was not properly developed). No geophysical logging was done in these boreholes to validate the borehole data. Also coal analysis was done for only one borehole.

3.3.10. In 2005, a contract was awarded to Geo-Mineral Engineering Co. Ltd (Shandong China) to undertake 2D and 3D surface seismic surveys. The 2D seismic survey was done in an area of 12.26 km² bounded by an irregular polygon. The 3D seismic survey was done in an area of 3 km² within a rectangle limited by GDH-45, GDH-46 and GDH-47. The seismic survey was done mainly to decipher the structure and to study the splitting of coal horizons. The study revealed existence of 7 faults of varying throws from 5 m to more than 50 m.

Stratigraphy

3.3.11. The Khalashpir basin area is more or less plain land covered by Barind clay residuum and Alluvium. On the basis of drill hole data, the stratigraphic sequences of the area are divided into four major divisions which are correlated with four groups/formations of India and Bangladesh

3.3.12. These are Gondwana Group, Jamalganj Formation, DupiTila Formation, Barind clay residuum and Alluvium of Permian, Miocene, Pilocene, Pleistocene and Holocene ages respectively. The generalised stratigraphic sequence succession of Khalashpir basin from top downwards is shown below:

Stratigraphy Sequence (Top downwards)	Formation	Age	Max. Thickness (m)
	Alluvium	Holocene	4.26m
	Barind clay residuum	Pleistocene	6.10m
	DupiTila Formation	Pliocene	162.12m
	Jamalganj Formation	Miocene	184.14m
	Gondwana Group	Permian	814.93m + (Base not seen)

Table 27: Stratigraphic Sequence of Khalashpir Coal Basin (Source – Geology of the Khalashpir Coal Basin, Pirganj, Rangpur, Bangladesh, GSB, 1992)

i. Alluvium

The alluvium is not present in the main basin area, rather it is present in the relatively low lying areas. Thickness of the formation is variable (14 m in GDH-48). It is mainly composed of grey silty micaceous sand and clay.

ii. Barind Clay

The thickness of Barind Clay (known as red clay) is variable. Generally its thickness varies from 4.5 m to 6 m. In some part of the basin it is absent or thinner. The clay is sticky, plastic and hard on drying. This clay has low permeability.

iii. Dupi Tila Formation

The maximum thickness of the formation is 162 m and the average thickness is 125 m. This formation is composed of fine to coarse grained poorly consolidated sandstone and pebbly sandstone with bluish grey mudstone patches.

This formation is the main aquifer zone of this basin. The ground water level during wet seasons is observed to be near surface and around 6 m below the surface during dry season. The recharge of aquifer is by rainfall, stream/canal flow and irrigation returns. The ground water flow is north-west to south-east.

The hydraulic gradient of the aquifer is 0.1%, the permeability varies from 32.10 – 42.40 m/day, the transmissivity varies from 4916 – 5996 m^2/day and the water inflow rate is 644–846 m^3/day/m.

iv. Jamalganj Formation

Sandstone and mudstone are found in the Jamalganj Formation in alternate sequence. The maximum thickness of mudstone is 70 m in the central part of the basin and it may change laterally into sandstone.

The sandstone is present in the north eastern side of the basin and is absent in the central part. Maximum thickness of sandstone is 119 m. The sandstone is usually medium to fine grained, at places it is coarse grained.

Pumping test was carried out in the Jamalganj Formation. The permeability was found to be 0.02 m/day and transmissivity was 0.64 – 1.63 m^2/day. The unit filtration rate was 0.51 – 0.63 m^3/day/m. The low permeability of the Jamalganj Formation will prevent infiltration of Dupi Tila water to the coal bearing zone.

v. Gondwana Group

The Gondwana sequences starts from 227.60 m to 1097.50 m below the surface. These sequences are composed of carbonaceous and feldspathic sandstone, pebbly sandstone and conglomerates, siltstone, shale and coal beds.

The coal seams occur in the upper part (top 183 m) of Gondwana strata. 8 coal zones have been encountered from a level of 257.16 m below MSL to 582.93 m below MSL. The maximum thickness of coal bearing sequences has been found in the central part of the basin (GDH-45).

The average composite thickness of coal zones is around 50 m. The top of the coal bearing sequence is an erosion surface. Each coal zone contains a number of beds with parting/lenses of sandstone. The lower part of Gondwana does not contain coal seams.

Geological Structure

3.3.13. From the Bouger anomaly contour map of Dinajpur and part of Rangpur Districts, it is found that the Khalashpir basin is more or less elongated basin with the largest axis in the northwest-southeast direction. This basic structure of the basin was confirmed by subsequent drilling of GSB.

3.3.14. However, GSB could detect existence of only one NNW-SSE trending fault of about 150 m throw. Subsequent seismic survey conducted in 2005 revealed existence of seven faults (Plate 8) as follows:

Throw of Faults	Faults
Greater than 50 m throw (>50m)	F1, F3 & F8 (3 faults)
Greater than 20 m but less than 50 m throw 20<Throw<50)	F5 (1 fault)
Greater than 10 m but less than 20 m throw (10 m < Throw <20)	F2 & F4 (2 faults)
Greater than 5 m but less than 10 m throw (5 m < Throw <10)	F7 (1 fault)

Table 28: Faults in the Khalashpir Coal Basin (Source – TEFS of Khalashpir Coal Mine Project, China Jinan Mining Development Corporation, July, 2006)

Coal Seams

3.3.15. The thicknesses of the 8 coal zones as interpreted by GSB on the basis of borehole data and analyses of coal obtained from GDH-45, GDH-46 & GDH-47 are presented in table below :

Zones	Depth Ranges of Zones in Boreholes	No. of Beds	Thickness (m) as observed in boreholes		
			GDH-45	GDH-46	GDH-47
Zone I	284.95m to 321.11m in GDH-45. 318.60m to 332.0m in GDH-46. 257.15m to 263.18m in GDH-47.	1	1.53	7.31	6.02
		2	0.38	5.48	-
		3	13.82	-	-
		4	0.34	-	-
		5	15.13	-	-
		6	0.64	-	-
Zone II	284.95m to 321.11m in GDH-45. 341.46m to 355.67m in GDH-46. 269.51m to 277.58m in GDH-47.	1	12.27	1.60	1.78
		2	-	0.82	0.31
		3	-	0.61	4.72
		4	-	2.54	-
		5	-	4.33	-
		6	-	0.58	-
Zone III	369.0m to 369.81m in GDH-45. 364.02m to 364.94m in GDH-46. 281.10m to 183.0m in GDH-47.	1	0.81	0.92	1.90
Zone IV	415.70m to 425.12m in GDH-45. 367.98m to 378.20m in GDH-46. 288.49m to 294.51m in GDH-47.	1	2.53	0.31	1.19
		2	0.31	0.64	0.40
		3	0.43	7.77	2.51
		4	2.07	-	-
		5	1.57	-	-
Zone V	436.96m to 438.49m in GDH-45. 379.65m to 384.15m in GDH-46. 310.67m to 314.00m in GDH-47.	1	1.53	3.12	0.61
		2	-	0.31	0.66
		3	-	-	0.61
Zone VI	449.28m to 450.88m in GDH-45. 398.40m to 404.88m in GDH-46. 317.15m to 319.66m in GDH-47.	1	0.31	1.65	0.74
		2	1.04	0.36	0.46
		3	-	3.62	-
Zone VII	461.89m to 464.33m in GDH-45. 407.32m to 414.17m in GDH-46. 322.40m to 324.69m in GDH-47.	1	2.44	1.27	0.31
		2	-	0.71	0.96
Zone VIII	481.09m to 482.93m in GDH-45. 425.30m to 427.76m in GDH-46.	1	0.92	0.31	0.31
		2	0.62	0.31	-

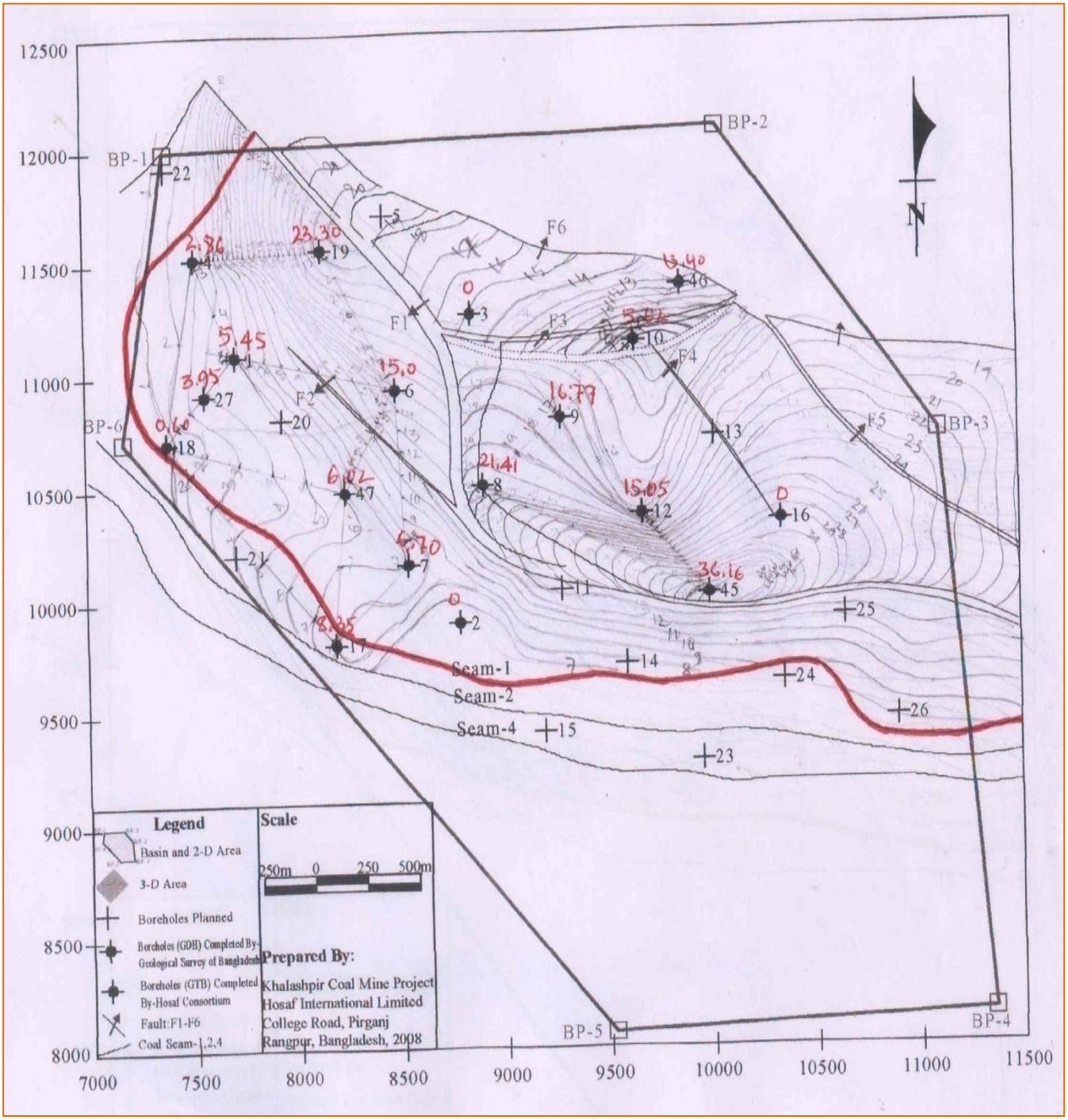
	378.20m to 378.51m in GDH-47.	3	-	1.50	-

Table 29: Thickness of coal zones in boreholes of GSB at Khalashpir Coal Basin (Source – TEFS of Khalashpir Coal Mine Project, China Jinan Mining Development Corporation, July, 2006)

3.3.16. The seam wise thickness of coal as observed by drill holes of Hosaf International Ltd and its consortium are given in table below:

Borehole No.	Seam thickness in meters							
	Seam I	Seam II	Seam III	Seam IV	Seam V	Seam VI	Seam VII	Seam VIII
GTB-1	5.45	8.42	0.68	9.98	0.40	0.55	0.35	0.15
GTB-2	6.03	11.22	2.01	7.00	-	-	-	-
GTB-3	5.51	7.07	2.16	15.64	3.06	3.18	0.54	0.31
GTB-4	5.80	5.13	2.02	3.95	1.75	0.94	1.20	1.20
GTB-6	15.00	16.53	3.64	4.01	1.16	6.88	4.35	0.88
GTB-8	22.28	19.07	1.46	13.86	3.66	0.64	1.13	0.36
GTB-9	13.04	2.35	0.20	29.10				
GTB-10	5.62	7.61	0.88	24.43	1.22	9.97	1.43	1.20
GTB-12	14.60	36.52	0.50	15.89	11.00	4.83	11.82	6.85
GTB-16	4.36	3.70	7.22	15.23	-	-	-	-
GTB-18	4.32	4.35	1.91	4.82	-	-	-	-
GTB-19	5.26	4.26	1.80	2.92	-	-	-	-
GTB-20	4.50	5.66	1.45	6.75	-	-	-	-
GTB-21	4.48	5.00	2.08	5.13	-	-	-	-

Table 30: Seam-wise thickness of coal at different drill holes of Hosaf International and its consortium (Source – TEFS of Khalashpir Coal Mine Project, China Jinan Mining Development Corporation, July, 2006)



Map not to scale

Plate 8: Khalashpir Coal Basin – Isopach Map of Seam-I Showing Faults (After TEFS of Khalashpir Project, China Jinan Mining Development Corporation, July 2006 Report)

Description and Continuity of coal seams

3.3.17. Seam I, II and IV are the main coal seams in the coal basin. Thicknesses of these seams are not uniform and are separated by medium hard to hard feldspathic sandstone, carbonaceous sandstone and carbonaceous shale. In GDH-45, Seam I has direct contact with the overlying Jamalganj Formation.

3.3.18. The continuity of the coal seams are determined from the drill hole and seismic data. The coal seams in the Khalashpir coal field are present in three major blocks created by the faults in the region. Due to the asymmetric nature of the blocks some edges of the seams are eroded. In general, the coal beds have gentle dipping and are wavy in nature.

Reserves

3.3.19. GSB estimated the coal resources of Khalashpir basin on the basis of the data obtained in three boreholes drilled by them (GDH-45, GDH-46 & GDH-47). The minimum coal thickness considered in the reserve was 0.3 m. The specific gravity of coal was taken as 1.32.

3.3.20. The resources within the triangular area obtained by joining the above three boreholes (2.52 km^2) was estimated at 142 Mt which was considered as proved resource. The resource within the basin area of 12.26 km^2 was estimated at 685 Mt which was considered as probable resource. The coal resources as calculated by GSB is presented in table below:

Number of zones	Area		Average thickness of coal zones	Proved reserves		Probable reserves
	Proved	Probable		Each zone	Total	
I	2.52 sq.km	12.26 sq.km	16.95m	56.38x10^6	142.92x10^6 Tons	685x10^6 Tons
II			9.93m	33.03x10^6		
III			1.22m	4.05x10^6		
IV			6.96m	23.15x10^6		
V			2.77m	7.55x10^6		
VI			2.67m	8.88x10^6		
VII			1.66m	5.52x10^6		
VIII			1.31m	4.35x10^6		

Table 31: Coal reserves of Khalashpir basin according to GSB (1992)

3.3.21. The Techno-economic Feasibility Study of Khalashpir Coal Mine Project prepared by China Jinan Mining Development Corporation in July 2006 considered the surveyed area of 7.5 km^2 for calculation of the coal resources.

3.3.22. The total coal resources were estimated at 451.09 Mt out of which measured resource was 277.11 Mt and indicated resource was 173.98 Mt. The seam wise resources considered in TEFS (July 2006) is given below:

	I	II	III	IV	V	VI	VII	VIII	Total
Measured (Mt)	90.31	90.40	-	96.40	-	-	-	-	277.11
Indicated (Mt)	41.68	34.35	8.66	23.81	11.25	23.94	23.99	6.30	173.98
Resource Reserve (Demonstrated) (Mt)	131.99	124.75	8.66	120.21	11.25	23.94	23.99	6.30	451.09

Table 32: Seam-wise resource reserves of Khalashpir Coal Basin (Source – TEFS of Khalashpir Coal Mine Project (Vol. – 1), Prepared by China Jinan Mining Development Corporation, July 2006)

3.3.23. In August 2006 the above resource figures were marginally modified in Supplementary Information on Techno-Economic Feasibility Study of Khalashpir Coal Mine Project submitted by Jinan Mining Development Corporation.

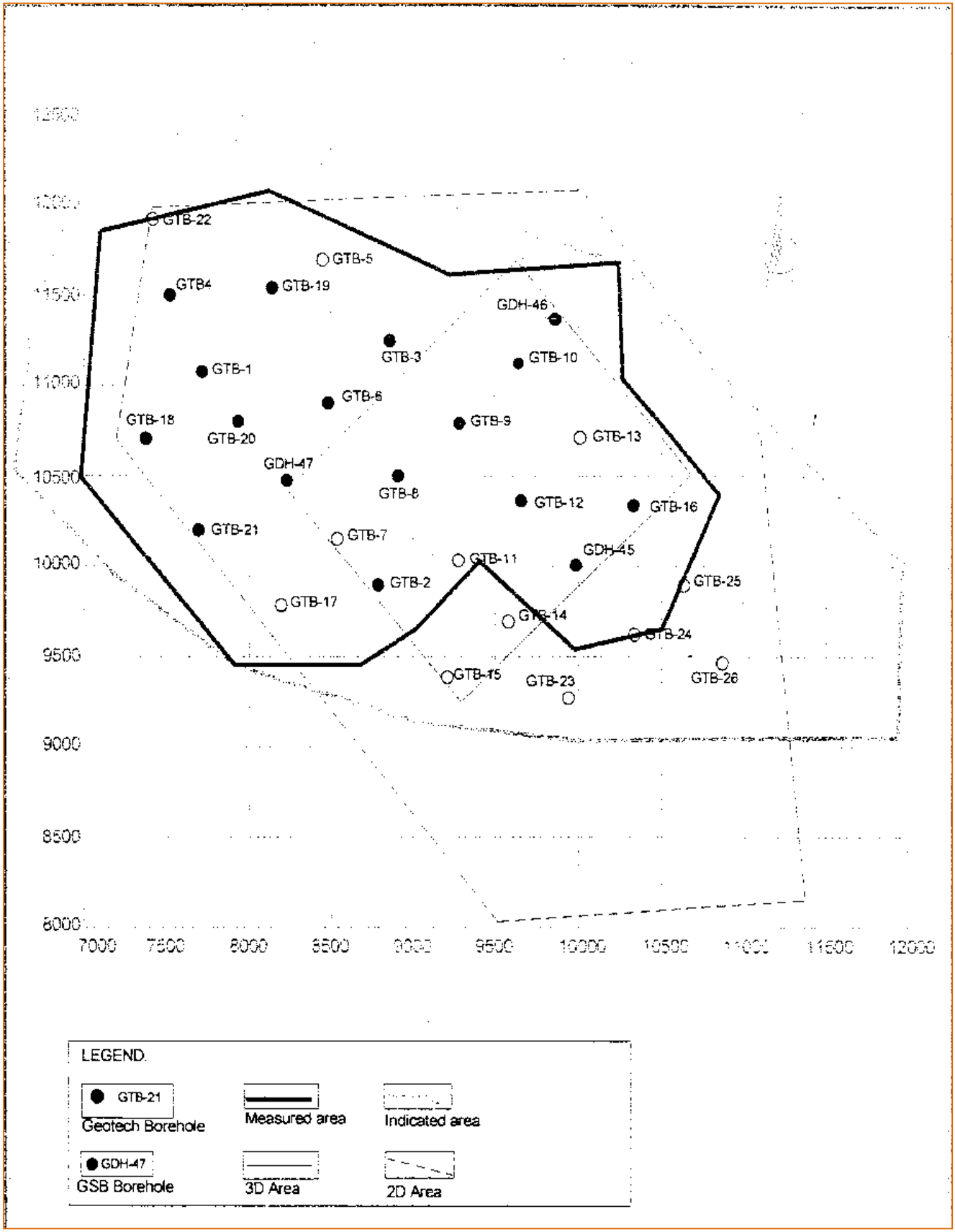
3.3.24. The seam wise measured resources as per this report was determined in the surveyed area of 7.5 km² and the indicated resources was calculated in an area of 10 km² (Plate 9). The measured resources were calculated on the basis of 17 drill hole data and seismic data.

3.3.25. The indicated reserves were calculated on the basis of seismic data beyond the drilled area. Table below shows the coal resources calculated from seismic and drilling data.

Coal bed	I	II	III	IV	V	VI	VII	VIII	Total
Measured Reserves (7.5 km² area) (Mt)	96.97	97.06	-	103.54	-	-	-	-	297.57
Indicated reserves (Mt)	32.25	32.30	24.55	34.40	22.57	48.44	19.93	11.48	225.92
Resource reserve (10 km² area) (Demonstrated) (Mt)	129.22	129.36	24.55	137.94	22.57	48.44	19.93	11.48	523.49

Table 33: Coal resource calculated from seismic and drilling data (Source – Supplementary Information on Techno-Economic Feasibility Study of Khalashpir Coal Mine Project, August, 2006)

3.3.26. The total in-situ resource of coal in 8 seams of the 7.5 km² surveyed area has been calculated in this report (Supplementary Information on Techno-Economic Feasibility Study of Khalashpir Coal Mine Project, August 2006) as 393 Mt based on average seam thicknesses of 17 drill hole data. The area is calculated covering 500 m offset from the peripheral drill holes.



Map not to scale

Plate 9: Khalashpir Coal Basin – Boundaries of Measured Resource Area (7.5 Sq. Km) and Indicated Resource Area (10 Sq. Km)
(After TEFS of Khalashpir Project, China Jinan Mining Development Corporation, July 2006 Report)

3.3.27. The table below shows the In-situ resources based on average seam thickness:

Seam No.	Area (km²)	Av. Thickness of coal (m)	Reserves in Mt	Remarks
I	7.5	9.79	96.97	Specific gravity of the coal is 1.32
II		9.80	97.02	
III		1.86	18.43	
IV		10.45	103.45	
V		1.71	16.93	
VI		3.67	36.39	
VII		1.51	15.02	
VIII		0.87	8.66	
Total			392.87	

Table 34: In-situ resources based on average seam thickness (Supplementary Information on Techno-Economic Feasibility Study of Khalashpir Coal Mine Project, August 2006

3.3.28. IMC Group Consulting Ltd reviewed the TEFS of Khalashpir mine (July 2006) prepared by China Jinan Mining Development Corporation and submitted its report on "Review of Techno-Economic Feasibility Study", Khalashpir Coal Mine, in June 2009. In this review report, IMC expressed serious concern over the following aspects of the TEFS.

- Absence of geophysical logging data for any borehole (of GDH or GTB series) to validate drilling data.
- Very limited proximate analysis of coal seams (available for only 3 boreholes of GDH series and 1 borehole of GTB series). This adversely affects accuracy in correlation of coal seams.
- The pattern of splitting and merging of various sections/leaves of individual coal zones (named as coal zone I to coal zone VIII by GSB) has not been detailed out and hence correlation of different coal seams and splits have not been established thus lowering confidence in reported coal seam continuity and their thicknesses.
- The presence of poorly consolidated DupiTila Formation close to the surface over the entire Khalashpir mine area is likely to adversely affect the data quality and resolution obtained in the 2D and 3D seismic surveys conducted under the auspices of Hosaf International Ltd. This will adversely affect the confidence level of the interpretation of faults.

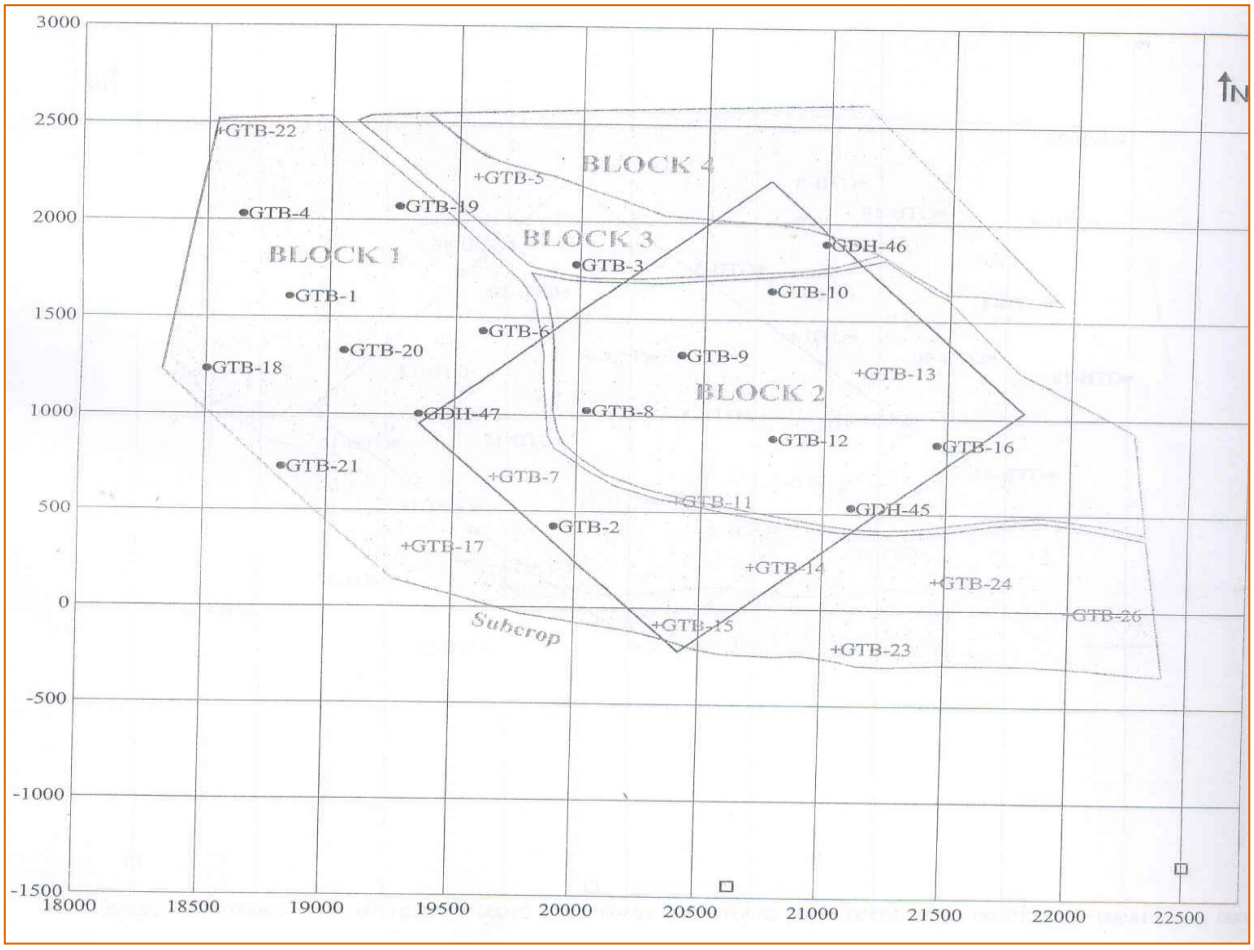
3.3.29. It is apparent that the reviewing authority i.e., IMC Group Consulting Ltd was not at all satisfied with the level of geological studies done in the project till date. They have therefore, opined that the term 'reserves' used in the TEFS of Khalashpir mine should be more appropriately termed as 'resources' in view of the uncertainties involved in the basic geological data and also undemonstrated economic extractability.

3.3.30. However, based on the available data, IMC has generated certain geological models and calculated the resources of seam I, II & IV as given in the table below:

Resource Block	Seam I			Seam II			Seam IV		
	Area (hectares)	Av. coal thickness (m)	In-situ resource (Mt)	Area (hectares)	Av. coal thickness (m)	In-situ resource (Mt)	Area (hectares)	Av. coal thickness (m)	In-situ resource (Mt)
1	335.99	4.00	17.74	410.77	12.00	65.07	449.15	6.00	35.57
2	247.85	14.00	45.80	248.13	18.00	58.96	247.89	18.00	58.90
3	63.25	5.00	4.17	56.63	6.00	4.49	63.53	12.00	10.06
4	112.99	6.00	8.95	117.99	8.00	12.46	114.62	10.00	15.13
Total	**760.08**		**76.67**	**833.52**		**140.97**	**875.19**		**119.66**
Total Resources of Seams I, II & IV = 337.30									

Table 35: Preliminary Resource Estimate, Seams I, II & IV by IMC Group Consulting Ltd (Source – Review of TEFS Khalashpir Coal Mine Project, June, 2009)

3.3.31. Plate 10 shows the area considered by IMC for calculation of coal resource of seam IV demarcating areas of resource blocks 1, 2, 3 & 4 mentioned in the table above. IMC has given the plans showing areas of resource blocks for seams I and II also but Plate 10 showing the resource area of seam IV has been presented as this covers the maximum area.



Map not to scale

Plate 10: Khalashpir Coal Basin – Resource Blocks
(After IMC Group Consulting Ltd (Source – Review of TEFS Khalashpir Coal Mine Project, June, 2009)

3.3.32. Hydrogeological studies of Khalashpir coal field was conducted by Hosaf International and its consortium and the report was prepared by the hydrogeologist, Dr. Om Kil Yong. Pumping tests were carried out to study the hydrogeological characteristics of DupiTila formation, Jamalganj Formation and Gondwana group.

Estimation and classification of resources

Analyses of Resources

3.3.33. The proved/measured and indicated/probable resources of Khalashpir basin have been calculated by different agencies as under:

Agency & date of assessment	Seams considered	Proved/Measured resource		Indicated/probable resource		Total resource (Mt) [Area (km²)]	Remarks
		Area (km²)	Resource (Mt)	Area (km²)	Resource (Mt)		
GSB (Geological report, 1992)	I to VIII (all seams)	2.52	142.92	12.26	685.00	685.00 [12.26]	Based on 3 boreholes done by GSB
TEFS by China Jinan Mining Dev. Corpn. (July 2006)	I, II & IV	7.50	277.11	2.5	99.84	451.09 [10]	Based on 18 boreholes (3 of GSB and 15 of Hosaf Intl) and geophysical survey by Hosaf Intl.
	III, V, VI, VII & VIII	-	-	10	74.14 [173.98]		
TEFS by China Jinan Mining Dev. Corpn. (August 2006)	I, II & IV	7.50	297.57	2.5	98.95	523.49 [10]	Based on 18 boreholes (3 of GSB and 15 of Hosaf Intl) and geophysical survey by Hosaf Intl
	III, V, VI, VII & VIII	-	-	10	126.97 [225.92]		
TEFS by China Jinan Mining Dev. Corpn. (August 2006)	I, II & IV	7.50	297.44	---	---	392.87 [7.5]	Based on average Seam thickness of each seam estimated from 17 nos. of borehole data.
	III, V, VI, VII & VIII	-	-	7.50	95.43		
IMC Review Report (June 2009)	I, II & IV	8.75	337.30	N.A.	N.A.	337.30 [8.75]	Based on geological model

	Other seams	-	-				prepared by IMC based on all available data till 2009 for seams I, II & IV only. Other seams not considered.

Table 36: Summary of Resource Estimates in Khalashpir Mine by Different Agencies

3.3.34. It is apparent from the above data that several resource figures of Khalashpir coal prospect have emerged based on the same set of geological and geophysical data/information which are as under:

- Borehole data from 3 boreholes done by GSB and coal quality data of seams obtained from these boreholes.
- Additional borehole data from 15 boreholes done by Geo-Tech India and considered in the TEFS of Khalashpir mine.
- Data obtained from 2D and 3D seismic surveys conducted by Geo-Mineral Engineering Co., China, in the mine area.
- Pumping test data for Dupi Tila, Jamalganj Formation and Gondwana Group aquifers.

3.3.35. The geology of the Khalashpir coal mine having an area of 7.5 km² (i.e. area arrived after setting off 500m from the peripheral boreholes drilled) has been deciphered based on 18 boreholes. This gives a borehole density of 2.4 boreholes/km² for the upper seams (up to seam IV), and further less for lower seams which have not been intercepted by some boreholes.

3.3.36. This borehole density is considered highly inadequate for a deposit with 8 coal zones each containing several splits which show tendency of erratic merging and splitting in a structurally complex set up having several faults. Further, the existing boreholes provide incomplete data as coal seams in most of the boreholes have not been analyzed.

3.3.37. The basis of estimation of coal resources have also not been clearly spelt out in respect of minimum thickness of coal seam splits/leaves and of dirt bands considered for inclusion/exclusion in the resources.

3.3.38. Also the coal quality in terms of maximum ash percent that will be excluded from the reserve estimation has not been spelt out. In absence of all these information, the basis of determining specific gravity of coal as 1.32 is not clear and appears to be on the lower side.

3.3.39. TEFS of Khalashpir mine mentions the recoverable reserves of the mine as 120 Mt. However, the basis of estimation of recoverable reserve has not been given in the TEFS, neither the details of design loss and mining loss of coal in seams I, II & IV which are proposed to be mined have been indicated.

3.3.40. Considering the above, the coal resources of I, II & IV seams cannot be categorized under proved or measured category as the level of confidence of the basic geological information is not adequate for taking up mine planning for investment decision.

Estimated Recoverable Reserve

3.3.41. It has been indicated in the TEFS of Khalashpir mine prepared by China Jinan Mining Development Corporation that 30-35% of proved/measured resources will be actually recoverable.

3.3.42. No details have been presented in the TEFS regarding method of estimation of recoverable reserve. However, from the production schedule given it has been estimated that about 120 Mt of coal will be recovered during the life of the mine.

Economics

3.3.43. An economic analysis of the mining operation has been presented in Vol. 2 of TEFS which indicate that the financial IRR of the project will be 27.24% and NPV at 15% discount rate will be around 15.6 billion taka (base date of estimate – July 2006). The selling price of coal was taken as US$ 50/t. It shall be noted that the assumptions taken in the TEFS for the analysis were based on current context i.e., bank rate, global traded coal prices, costs etc., which change from time to time; and hence analysis will need to be updated at the time of its use for any decision making.

Classification of Resources as Per UNFC System

3.3.44. Based on the above discussions, the 'measured reserve' of 297.57 Mt occurring in seams I, II & IV within an area of 7.5 km² as estimated in the Supplementary Information on TEFS of Khalashpir mine (August 2006) submitted by China Jinan Mining Development Corporation, has been taken as probable resource and the balance resource of I, II & IV seams along with the resource of other seams as estimated in the above report as 225.92 Mt, has been considered as indicated mineral resource.

3.3.45. The TEFS of Khalashpir mine has indicated a recoverable reserve of 120 Mt from seams I, II & IV. The basis of such estimation has not been given in the TEFS. Therefore, this recoverable reserve has not been considered to be very much reliable due to the following reasons:

- The basic geological premise of the deposit as brought out in the TEFS lacks adequate confidence level due to the reasons mentioned earlier (3.3.36 – 3.3.41)
- The details of mining plan have not been given along with basis of estimation of design and mining loss.

3.3.46. Therefore, the TEFS of Khalashpir mine has been considered as a pre-feasibility study only (i.e. under category 2 in the feasibility axis of UNFC matrix).

3.3.47. Volume 2 of TEFS of Khalashpir mine has estimated the capital cost and profitability of the project. However, the break-up of various items under capital cost and the break-up of operating cost estimates along with the norms that have been followed for such estimation have not been given.

3.3.48. The cost estimates are also five years old and need to be updated to arrive at the present economics of the project. Furthermore, there is need to provide for adequate capital for further exploration, further geo-technical and hydro-geological studies relating to the impact of mining on Dupi Tila aquifer and for social and environmental control measures including mine closure etc. However, as the financial IRR was quite high at 27.24% with old selling price of $50/t, the deposit is expected to remain potentially economic with the present selling price of coal of around $100/t (i.e. under category 2 in the economic axis of UNFC matrix).

3.3.49. Considering the above, no reserve has been shown in the UNFC matrix under 111 categories. The 'measured reserve' of 297.57 Mt occurring in seams I, II & IV as per TEFS has been considered as 'probable resource' and placed under category 2 in the geological axis of UNFC matrix thereby indicating that detailed exploration will be required and only general exploration has been done at present.

3.3.50. The balance 'indicated reserve' of 225.92 Mt has been treated as 'indicated mineral resource' and has been placed under category 3 in the geological axis of UNFC matrix thereby indicating that considerable exploration need to be done for this category of resource to upgrade the same for use in mine planning purpose.

3.3.51. The following table shows the UNFC type codification of the coal resources of Khalashpir coal basin:

Economic Axis (E)	Feasibility Axis (F)	Geological Axis (G)			
		Detailed Exploration (1)	General Exploration (2)	Prospecting (3)	Reconnai-ssance Study (4)
Economic (1)	Feasibility study (1)				
	Pre-feasibility study (2)				
	Geological study (3)				
Potentially Economic (2)	Feasibility study (1)				
	Pre-feasibility study (2)		297.57		
	Geological study (3)				
Intrinsically Economic (3)	Feasibility study (1)				
	Pre-feasibility study (2)				
	Geological study (3)			225.92	

Table 37: UNFC Type Codification of Khalashpir Coal Resources (Figures in Mt)

3.4. Jamalganj Coal Deposit

3.4.1. The Jamalganj coal field is located in Jaipurhat district in the vicinity of Jamalganj town and to the west of the north-south broad-gauge railway line.

3.4.2. The area of Jamalganj is flat with elevation of 17 m – 19 m above MSL. The local railway line runs along an embankment at a height of 19.3 m above MSL. Roads and tracks also run along embankments which are generally slightly higher than 1 m above the surrounding ground. Unsurfaced roads are generally narrow and can be reached only during dry season.

Geological description

Introduction

3.4.3. Coal in the Jamalganj deposit belongs to the Gondwana group. They lie unconformably on basement archaean rocks and in turn overlain unconformably by tertiary to recent sedimentary succession. The base of the Gondwana group was not reached by drilling in this area, but a thickness of 577 m was proved by the EDH-6 borehole (Refer page no.8 of Technical Report WC/95/59R of British Geological Survey)

History of Exploration

3.4.4. The Jamalganj area was explored by Geological Survey of Pakistan who drilled 11 boreholes. This includes borehole GDH-14 which is shaft site drill. There is no data base at present because the cores from all the boreholes were stored in West Pakistan before independence of Bangladesh and have been lost except possibly one coal sample from Jamalganj which has been kept in the museum of Geological Survey of Bangladesh in Dhaka.

3.4.5. A second specimen is also possibly kept at the Petro Bangla Site Manager's office at Jaipurhat. Seismic surveys have also been conducted across the area (Kappelmeyer, 1965) and (Farah and Anwaruddin, 1992) but these data are also not available.

3.4.6. Subsequently mine development feasibility studies were also done by Fried Krupp Rohstoffe, 1966; Powell Duffryn Technical Services Limited, 1969; Robertson Research International (RRI), 1976; N V Kempense Seenkolenmijnen, 1980 etc.

Stratigraphy

3.4.7. The stratigraphic sequence in Jamalganj basin from top downwards is given below:

Stratigraphy Sequence (Top downwards)	Group	Formation	Thickness (m)	Depth (m)
		Alluvium	59.5	0 – 59.5
		DupiTila	42.7	59.5 – 102.2
		Jamalganj	400	102.2 – 502.2
	Jaintia	Kopili Shale	33.8	502.2 – 536.0
		Sylhet Lime stone	27.2	536.0 – 563.2
		Cherra Sandstone	61.3	563.2 – 624.5
	Gondwana	Paharpur & Kuchma	About 1200	624.5 – 1850

Table 38: Stratigraphic sequence of Jamalganj coal field (Source – Jamalganj Coal Project-Development and Mining Scheme Feasibility - Find Report, Second Phase, submitted by M/s Fried Krupp Rohstoffe, December 1966)

i. Alluvium

Alluvium is the top most layer of stratigraphy. It has a thickness of 59.5 m. The line separating the Alluvium and Dupitila could not be defined accurately as the two formations were petrographically very similar.

ii. Dupi Tila formation

Under the recent to sub-recent alluvium of the Jamalganj area lies the Pliocene Dupi Tila formation. This formation consists of weakly consolidated pebble beds with fine to coarse sand and minor amounts of mudstone.

iii. Jamalganj Formation

The Lower Miocene to Upper Oligocene Jamalganj Formation consists of siltstones with fine sandstones and represents an abrupt facies change from the overlying Dupi Tila Formation. Some impure coal seams occur towards the base of the formation. It is bounded above and below by unconformities.

iv. Kopili shale formation

The Kopili shale formation is Upper Eocene in age and is composed of interbedded sandstones and claystones with some glauconite. It represents a fresh water facies.

v. Sylhet Limestone formation

Underlying the Kopili shale formation is the massive, white to light grey fossiliferous Sylhet Limestone Formation. The upper part of the formation is sandy but the sand content of the limestone decreases downwards while clay content of the limestone increases downwards. The Sylhet Limestone is also Eocene in age.

vi. Cherra Sandstone formation

The Palaeocene to Middle Eocene Cherra Sandstone Formation directly underlies the Sylhet Limestone and is composed of thick, unconsolidated sands in the upper part and mudstone and sandstone in the lower part. Rocks of Upper Triassic, Jurassic and Cretaceous age are absent from the Jamalganj area.

vii. Gondwana Group

In the Jamalganj area the Gondwana group is sub-divided into Upper Gondwana and Lower Gondwana Groups.

Upper Gondwana: The Upper Gondwana Group believed to be of Lower Triassic age consists of approximately 250 m of medium to coarse grained feldspathic sandstones interbedded with conglomerates and siltstones.

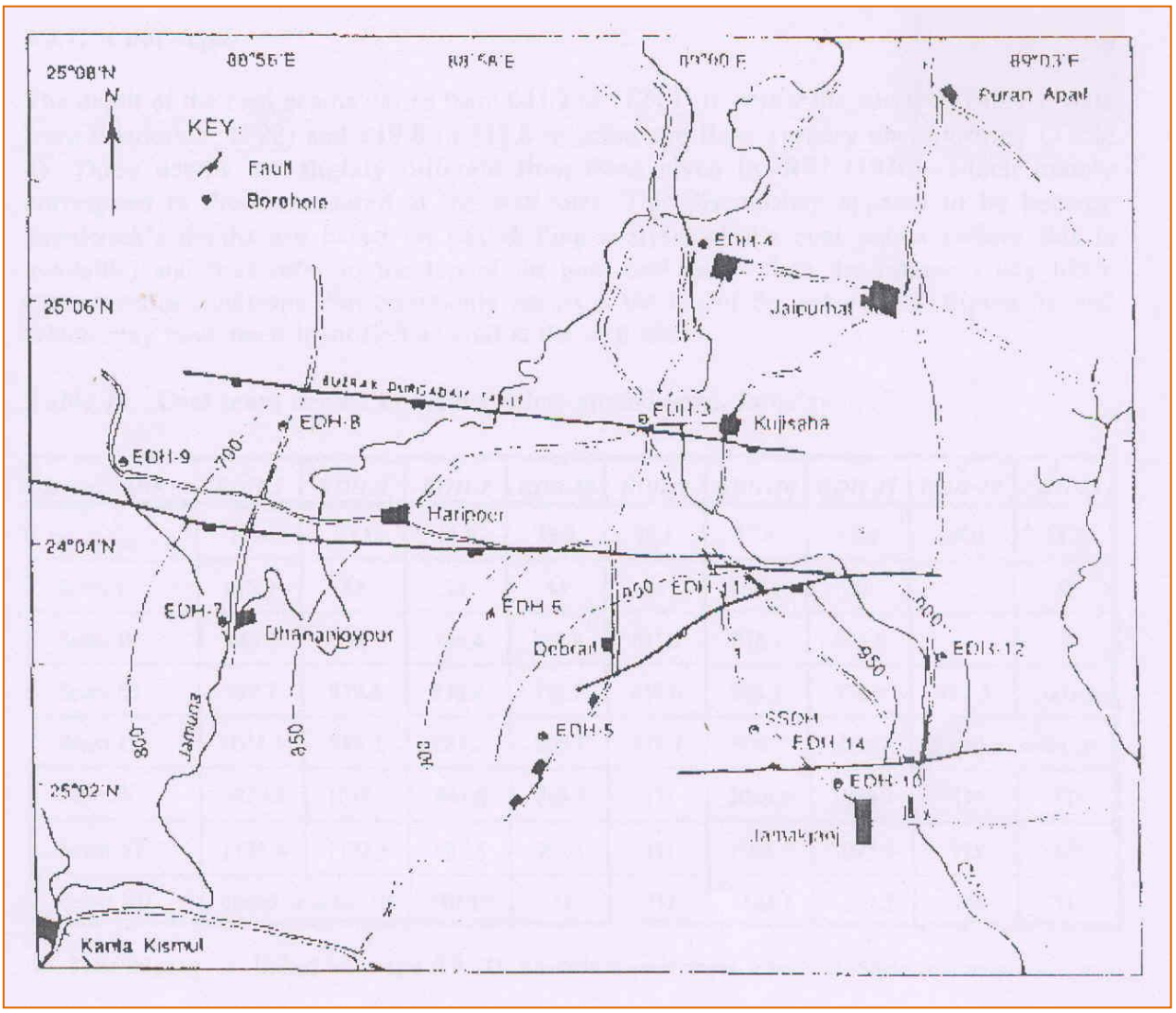
Lower Gondwana: The Lower Gondwana Group is believed to be equivalent to Raniganj coal measures of India and is at least 305 m thick. However, some researchers suggest that the Lower Gondwana Group is equivalent to Barakar coal measures of India because of the great thickness of the seams at Jamalganj.

Seven (7) coal seams occur in a predominantly sandstone succession with some dark grey siltstone layers. The base of Lower Gondwana Group was not penetrated by drilling so there is possibility of more seams at greater depth.

The coal seams at Jamalganj contain variable numbers of non-coal partings ranging from a few centimetres to a few meters thick. Thus they could perhaps be more correctly described as coal zones comprising several leaves of coal in each zone. These leaves also show rapid thickness variations and thus they vary in quality both laterally and vertically.

Geological Structure

3.4.8. The coal deposit of Jamalganj basin is bounded in the north by an east-west trending fault or set of faults which was mainly active prior to Tertiary times, but which also cuts Tertiary strata. This fault is named the Buzrak-Durgadah boundary fault (Rahman & Zaheer, 1980). Further down to the south, fault or set of faults is interpreted to occur between boreholes EDH-9 and EDH-11. A fault is also present towards south east between boreholes EDH-10 and EDH-14 (Plate 11).



Map not to scale

Plate 11: Jamalganj Coal Basin – Geological Structure Showing Contours in Meters on the top of Seam III (Source – Prepared by Robertson Research Int. in 1976. Published by M.M. Rahman and M.A. Zaher in 1980

3.4.9. Kappelmeyer (1965) is quoted by RRI as stating that there are numerous faults on the seismic survey, but very little evidence of folding. The core records show that the Gondwana Group generally have dips of 5-10°, but dips can sometimes be as high as 15°. In EDH-10 and EDH-11 dips are generally between 2° and 5°. The horizons mapped from seismic reflection data indicate a regional south west dip.

Coal Seams

3.4.10. Borehole-wise depths of coal seams in Jamalganj coal field are given in table below :-

Jamalganj	EDH-5	EDH-6	EDH-7	EDH-8b	EDH-9	EDH-10	EDH-11	EDH-12	EDH-14
Elevation	17.4	20.1	16.8	19.2	20.3	17.4	18.9	18.0	18.3
Seam I	912.9	M	M	M	M	867.1	M		S
Seam II	940.0	+	786.4	698.9	641.2	876.1	892.2		S
Seam III	999.7	929.8	838.4	725.1	659.6	908.7	976.9	922.3	1032.1
Seam IV	1037.5	995.2	882.7	806.7	679.4	966.7	1005.6	++	
Seam V	1070.3	1018.0	941.8	865.9	TD	1024.6	1036.2	TD	TD
Seam VI	1126.4	1102.5	981.6	902.5	TD	1108.7	1093.6	TD	TD
Seam VII	+++		1013.9	M	TD	1124.1	1101.2	TD	TD

M Seam missing, +++ United with Seam VI (Figures In meter)

+ United with seam II TD Borehole stopped above seam,

++ United with Seam III, S Shaly coal only,

Table 39: Coal Seam Depths below Ground Level, Jamalganj (After Friederich, 1992)

3.4.11. There are seven (7) seams (actually these are coal zones referred to as coal seams) in the Jamalganj deposit. The seam thicknesses are given in the table below. These data are quoted by Friederich (1992), mainly from analytical data collected by Krupp Rohstoffe (1966).

Jamalganj	EDH-5	EDH-6	EDH-7	EDH-8b	EDH-9	EDH-10	EDH-11	EDH-12	EDH-14
Seam I	0.30	M	M	M	M	0.72	M	-	S
Seam II	0.35	+	(1.06)	4.18	0.26	(2.07)	-	-	S
Seam III	13.16	11.17	4.63	12.83	(2.47)	(24.84)	27.32	26.212	> 5.012
Seam IV	(8.69)	5.17	4.16	-	-	11.281	9.31	++	
Seam V	(2.14)	1.15	4.42	3.25	TD	1.82	3.81	TD	TD
Seam VI	6.001	4.88	4.11	0.92	TD	6.01	4.47	TD	TD
Seam VII	+++		7.42	M	TD	10.10	14.67	TD	TD
Net coal	24.64	22.37	25.80	21.18		47.74	42.51		

Figures in brackets estimated without analytical data. (Figures in meter)

1 Not estimated by Friederich (1992). Here estimated from graphic 1

2 Borehole terminates in seam

Legends:

M Seam missing, +++ United with Seam VI

+ United with seam II TD Borehole stopped above seam.

++ United with Seam III S Shaly coal only

Table 40: Thickness of Coal Seams in Jamalganj (Adapted from Friederich, 1992)

Coal Quality

3.4.12. A summary of the chemical analysis of the Jamalganj coal by several authors is presented in the table below. The ash content of thicker areas of seam III may be somewhat lower than the average – perhaps around 17% (Friederich, 1992).

Jamalganj	Ahmed & Zaheer 1965	Krupp Rohstoffe 1964, 1966	RRI 1976
Proximate analysis			
Ash content	22.4% (10.60%)	25.70% (DAF)	24.25%
Volatile matter (dry basis)	30-40%	40.60%	36.92%
Fixed Carbon (dry basis)	47% (33-54%)	-	36.72%
Moisture (air dried)	-	-	3.58%
Calorific value (clean coal)	12 100 BTU/lb	11 870 BTU/lb	11 878 BTU/lb
Calorific value (20-25% ash)	11 000 BTU/lb	-	-
Ultimate analysis (DAF)			
Carbon	79.00%	80.25%	80.10%
Hydrogen	5.40%	5.34%	5.39%
Nitrogen	1.81%	1.87%	1.83%
Sulphur	0.65%	-	-
Oxygen	12.50%	11.80%	12.02%
Chlorine	0.04%	-	-

Table 41: Summary of the chemical analysis of the Jamalganj coal

Reserve

Area of the deposit

3.4.13. The western, eastern and southern limits of the Jamalganj coal deposit are poorly known. Towards the north, the deposit is limited by a major fault. However, it seems the coal measures may well continue beyond the drilling area towards the east and west and perhaps at greater depth towards south.

3.4.14. On the basis of borehole information, the area of the coal deposit (limited by boreholes EDH-8b, EDH-12, EDH-10, EDH-5, EDH-7 and EDH-9) has been estimated by Rahman and Zaher (1980) to be approximately 14.39 sq. miles (37.3 km^2).

3.4.15. Fried. Krupp Rohstoffe in its report (Find Report, Second Phase, 1966) on Jamalganj coal Project submitted to East Pakistan Industrial Development Corporation has mentioned that the deposit has been explored by 9 successful drill holes.

3.4.16. The drill hole EDH-8 had struck the major fault occurring in the north and another hole EDH-9 had to be discontinued before reaching coal seams. Therefore, the reserves occurring inside the line drawn between EDH-5, EDH-10, EDH-12, EDH-11, EDH-6 and EDH-5 can only be regarded as proven according to this report of Fried. Krupp Rohstoffe. The area bounded by this line was calculated as 11.7 km^2.

3.4.17. Fried. Krupp Rohstoffe in its report (Find Report, Second Phase, 1966) had considered an area of 11.5 km^2 and had assumed (assumed the thickness of the seams as found in drill hole EDH-10 to be an average value. The report also ignored the reserves of seam I, which is 0.7 m thick divided into two layers as this seam would not be mineable.

3.4.18. The average specific gravity of coal was assumed as 1.4 g/cm^3. Accordingly, the reserve of Jamalganj basin had been worked out as 1053.9 Mt. Seam wise reserve as calculated in the report is presented in table below:

Seam	Reserves (Mt)
II	39.05
III	526.8
IV	32.4
V	30.0
VI	50.8
VII	374.4
Total	1053.9

Table 42: Seam wise Reserves of Jamalgunj coal field

3.4.19. Hoque (1988) suggested the reserves in Jamalganj to be around 1000 Mt. As no mining plan or feasibility report has been prepared for Jamalganj coal deposit, the recoverable reserves from the deposit has not yet been assessed.

Estimation and classification of resources

Analysis of Resources

3.4.20. The boundary of the Jamalganj coal basin has not yet been firmed up. Presently an area of around 11.7 km^2 within the basin has been prospected by putting only 11 boreholes thus giving a borehole density of around 1 borehole/km^2 for the area.

3.4.21. Therefore, the deposit has to be explored in great details to firm up the extent of the coal seams, the pattern of splitting and merging of different layers within the seam, the thickness variation and contours of the seams, their split sections, analysis of all coal sections and their co-relation. The structure of the deposit is tentatively known at present and this has to be firmed up.

3.4.22. With the present level of available exploration data the ‘proved reserve’ of 11.7 km^2 area has been estimated as 1053.9 Mt assuming the thickness of coal seams obtained in one borehole (EDH-10) where all the seams have been well developed, as average thickness of these seams for the entire area of 11.7 km^2. The specific gravity has been assumed as 1.4 t/ m^3. Thus the ‘proved reserve’ mentioned above can be considered as ‘Inferred Resource’ only.

3.4.23. As no mining plan or feasibility study has been done, the recoverable tonnage of coal could not be assessed. However, certain very old assessment of production potentiality, capital investment and profitability (cost per tonne) are available but these figures cannot be relied upon due to absence of detailed break up and also as methodology for such estimation have not been spelled out in any report.

Classification of Resources as per UNFC System

3.4.24. As already mentioned above, the Jamalganj coal deposit needs further detailed exploration to establish the geology with high level of confidence and feasibility study need be carried out based on the firmed up geological report to assess the recoverable coal reserve of the deposit. Presently only inferred resources of 11.7 km² area is available as 1053.9 Mt. On this basis the UNFC classification of the resources of Jamalganj coal deposit has been shown in the table below :-

Economic Axis (E)	Feasibility Axis (F)	Geological Axis (G)			
		Detailed Exploration (1)	General Exploration (2)	Prospecting (3)	Reconnai-ssance Study (4)
Economic (1)	Feasibility study (1)				
	Pre-feasibility study (2)				
	Geological study (3)				
Potentially Economic (2)	Feasibility study (1)				
	Pre-feasibility study (2)				
	Geological study (3)				
Intrinsically Economic (3)	Feasibility study (1)				
	Pre-feasibility study (2)				
	Geological study (3)			1053.90	

(Figures in Mt)

Table 43: UNFC Type Codification of Jamalganj Coal Resources

3.5. Dighipara Coal Deposit

3.5.1. Dighipara coal basin is located in Nawabganj Upazila of Dinajpur District. The area is lying towards SSE of Barapukuria coal project. Dighipara area can be accessed by both road and rail.

Geological Description

Stratigraphy

3.5.2. The Dighipara basin was discovered by Geological Survey of Bangladesh (GSB) in 1995 by one borehole. Subsequently three more boreholes were done in 2001, 2003 and 2004. The basic stratigraphic sequence of the basin area as established by 4 boreholes, namely GDH-49, GDH-58, GDH-60 & GDH-61 (Plate 12), done by GSB is given below :

Stratigraphy Sequence (Top downwards)	Group	Formation	Max. Thickness (m)	Remarks
		Alluvium	0.9	0 – 59.5
		Barind Clay	7.62	59.5 – 102.2
		Dupi Tila Formation	320.00	102.2 – 502.2
	Jaintia	Kopili Shale	60.95	502.2 – 536.0
		Tura Sandstone	60.95	536.0 – 563.2
	Gondwana	Paharpur & Kuchma	167.33	563.2 – 624.5
	Precambrian Crystalline Basement		41.15	624.5 – 1850
	Base not seen			

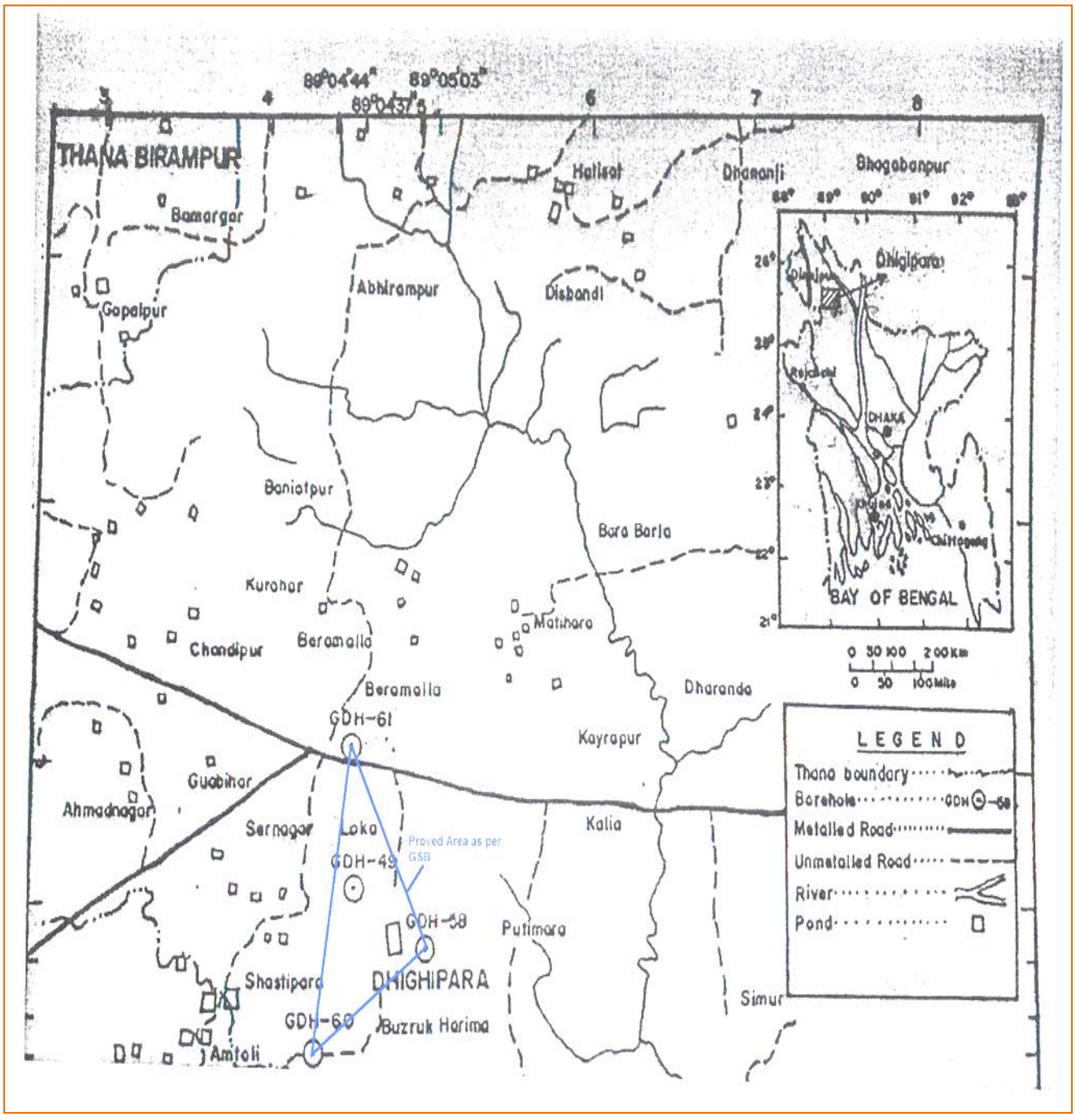
Table 44: Stratigraphic Succession as Established from 4 Boreholes in Dighipara

Coal seams

3.5.3. Seven coal seams have been intersected in the 4 boreholes drilled by GSB. The depth and thickness of different coal seams as observed in the 4 boreholes are shown in table below :

Seam No.	GDH-49/1995	GDH-58/2001	GDH-60/2003	GDH-61/2004
I	17.07	16.98	9.91	19.81
II	33.83	35.30	33.99	36.58
III	7.01	1.22	0.52	6.71
IV	2.44	10.27	2.90	3.35
V	1.60	-	-	0.91
VI	0.30	-	-	0.81
VII	-	-	-	2.90
Total Thickness	62.25 metres	63.76 metres	47.32 metres	71.07 metres

Table 45: Depth Range and Thickness of Coal Seams in the Boreholes (Figures in meter)



Map not to scale

Plate 12: Dighipara Coal Basin – Location of Boreholes GDH 49, 58,60 and 61
(Source – GSB)

Coal Quality

3.5.4. All the boreholes were analyzed and the results of proximate analysis are given in table below.

Seam	Moisture %			Volatile matter %			Ash %			Fixed Carbon %			Total sulfur %			Calorific value BTU/lb		
	Max	Min	Av	Max	Min	Av	Max	Min	Av	Max	Min	Av	Max	Min	Av	Max	Min	Av
I	4.73	0.49	3.2	38.23	14.74	30.89	38.57	2.53	9.18	73.15	35.04	56.29	1.29	0.33	0.65	14981	9110	12836
II	4.71	0.32	2.67	39.56	13.42	32.08	37.56	1.34	8.17	79.9	37.69	57.13	0.91	0.4	0.67	14250	9220	12983
III	3.59	2.11	2.71	33.59	20.36	28.46	30.2	4.6	12.50	62.85	45.32	56.33	0.86	0.37	0.58	14600	9250	12497
IV	2.68	0.41	1.88	29.65	22.85	25.12	34.9	12.33	20.62	56.57	41.44	52.38	1.01	0.4	0.56	12200	9100	10650
V	2.1	1.38	1.74	29.97	26.24	27.64	32.23	11.85	22.47	56.08	40.12	50.08	1.03	0.44	0.86	12350	9100	10480
VI	1.58	1.58	1.58	32.94	32.94	32.94	14.71	14.71	14.71	50.77	50.77	50.77	0.89	0.89	0.89	12170	12170	12170
VII	3.15	3.15	3.15	27.57	27.57	27.57	9.66	9.66	9.66	59.62	59.62	59.62	0.50	0.50	0.50	13200	13200	13200

Table 46: Results of seam wise proximate analysis of the boreholes

Reserves

Area of Dighipara Basin

3.5.5. The gravity data and geological conditions of the basin suggest that the Dighipara basin may be extended to an area of about 15 km². However, coal reserve of Dighipara deposit has been estimated by GSB in its geological report of Dighipara coal basin (July 2005) in a triangular area of 1.25 km² formed by joining GDH-61, GDH-58 and GDH-60.

3.5.6. The borehole GDH-49 is within the triangle. The average thickness of coal in this area has been considered as 61 m and the average specific gravity of coal has been considered as 1.375 t/ m³. Accordingly the coal reserve in this 1.25 km2 area has been calculated as 105 Mt and this has been termed as proved reserve in the above geological report of Dighipara.

3.5.7. The speculated reserve of coal considering the basin area as 15 km² has been worked out as 600 Mt by GSB considering an average thickness of coal as 30 m (half of the average composite thickness).

Estimation and classification of resources

Analysis of Resources

3.5.8. The geological report of Dighipara (July 2005) is based on only 4 boreholes. This gives a borehole density of 3.2 boreholes/ km² considering an area of 1.25 km² for which 'proved reserve' has been calculated as 105 Mt.

3.5.9. More detailed exploration is necessary for firming up the thickness and quality variations of the seams, pattern of splitting and merging of individual seams, thickness and quality of each split, correlation of the seams and the split sections and also the structure of the deposit.

3.5.10. Each borehole data also need to be validated by geophysical logging. Therefore, the reserves of 1.25 km² area can be considered at present as 'indicated/probable resource' and not as 'proved reserve'.

3.5.11. The extent of Dighipara basin area has not yet been established. The speculated reserve of 600 Mt estimated for a basin area of 15 km² includes 105 Mt of indicated/probable reserve. Therefore, the balance 495 Mt can be considered as reconnaissance resource based on the geological confidence level of exploration.

3.5.12. No mining plan or feasibility study has yet been undertaken for the Dighipara basin.

Classification of Resources as Per UNFC System

3.5.13. Based on the above discussions, the resources of Dighipara basin falling within an area of 1.25 km² bounded by 3 boreholes with an additional central borehole can be classified under category 2 of the geological axis in the UNFC matrix. The reconnaissance resource of 495 Mt can be classified under category 4 of geological axis in the UNFC system.

3.5.14. Accordingly, the coal resources of Dighipara have been coded as per UNFC system as given in the table below :

Economic Axis (E)	Feasibility Axis (F)	Geological Axis (G)			
		Detailed Exploration (1)	General Exploration (2)	Prospecting (3)	Reconnai-ssance Study (4)
Economic (1)	Feasibility study (1)				
	Pre-feasibility study (2)				
	Geological study (3)				
Potentially Economic (2)	Feasibility study (1)				
	Pre-feasibility study (2)				
	Geological study (3)				
Intrinsically Economic (3)	Feasibility study (1)				
	Pre-feasibility study (2)				
	Geological study (3)		105		495

Table 47: UNFC Type Codification of Dighipara Coal Resources (Figures in Mt)

4. Classification of Peat deposits of Bangladesh

4.1. Scope of Present Report

4.1.1. The present report is based on the following information as presently available:

- Investigations of Peat in the Faridpur District, East Pakistan, by F H Khan, Bureau of Mineral Resources, Geological Survey, Government of Pakistan (June 1957).
- Interim Geological Report No. 2, Peat Deposit of Kola Mouza, Khulna, East Pakistan by M A Zaher, Ministry of Industries, Natural Resources and Works, Mineral Exploration and Development Program, Government of Pakistan (October, 1962).
- Peat Mining By Petrobangla (1992-1994), Report of Engr. A K M Shamsuddin, (e-mail communication).
- An Overview of Mineral Resources and Mineral Reserves Classification System: Bangladesh Perspective, Sept., 2011 by Md. Mosharraf Hussain (e-mail communication).

4.1.2. It appears that further information regarding occurrence of different peat deposits of Bangladesh as contained in different reports mentioned under status of exploration (Para 4.3.6 to 4.3.9) are required for proper classification of peat resources under UNFC system.

4.2. Peat Deposits

Peat Deposit of Faridpur

4.2.1. Peat was discovered in Faridpur district of the then East Pakistan by the Geological Survey of Pakistan in December, 1953. Scout drilling in 1954 & 1955 indicated that these deposit extends over an area of more than 200 sq. miles (over 500 sq. km) in the Baghia and Chanda beels (Plate 13).

4.2.2. Exploration of these deposits by drilling with 990 ft. (about 300 m) centres with hand augers was carried out during 1955-56 and 1956-57 and about 1/5th of the total area believed to be under lain by peat had been explored. The average peat thickness was about 1.8 m and the overburden thickness varied from nil to 3.6 m with an average of 1.5 m.

4.2.3. The average analytical result of 50 samples of Faridpur peat (air dried for one week) is as follows:

Analysis	Percentage
Fixed Carbon	24 %
Ash	16.6%
Moisture	17.1%
Volatile Matter	42.3%

Table 48: Analytical result of 50 Samples of Faridpur peat (air dried for one week)

4.2.4. The peat is soft when wet and becomes fairly hard when dry. It can be moulded into briquettes that adhere without the addition of a binder.

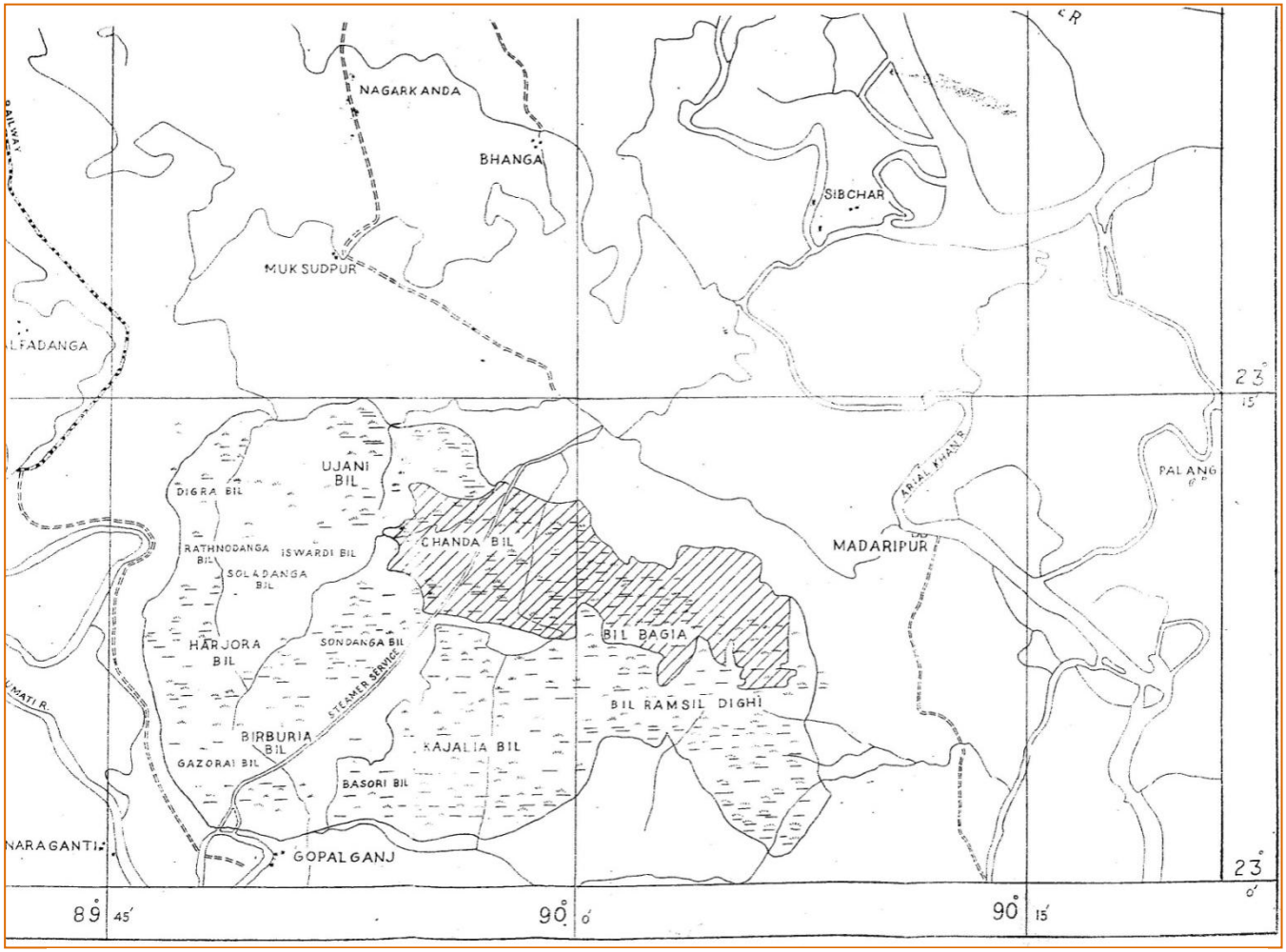


Plate 13: Peat Deposit of Faridpur District
(Source: Investigation Peat in the Faridpur District, June 1957, Geological Survey of Pakistan

4.2.5. For about six months during the monsoon season each year, most of the areas underlain by peat in the Faridpur district are covered by about 2.4 m to 3.6 m of water. Even in dry seasons some parts of the peat deposit remain below water.

4.2.6. Also most of the surface areas over peat deposits are used for growth of rice during the wet season and vegetables during the dry season.

Peat Deposit of Kola Mouza, Khulna

4.2.7. Peat fields were discovered in the Kola-Barasat area near Khulna of the then East Pakistan by Mr. M A Zaher of Geological Survey of Pakistan in March, 1960. Because of the close proximity of Kola Mouza to Khulna (Plate 14) a detailed geological survey of the mouza was started immediately after this discovery and was completed in May, 1960.

4.2.8. Kola (between longitudes 89°34'15" and 89°38'45", latitudes 22°51'and 22°55'45") and Barasat (between longitudes 89°37'20" and 89°38'20", latitudes 22°57' and 22°54'30") are two important mouzas under the Terakhada police station in the district of Khulna.

4.2.9. These and other adjoining mouzas form a big swampy area called Kola-Barasat depression. The Kola mouza peat field lies in the southern part of the Kola-Barasat depression which is surrounded by the natural levees of Atai River on the west, Bhairab River on the south, Atharabanki on the east and Chitra on the north. There are many canals in this depression to drain its stagnant water through the levees into the rivers.

4.2.10. The alluvium in Kola mouza consists of a sequence of clay and peat. The succession established in most parts of the area is as follows:

Clay	Range of thickness (m)	Average thickness (m)
Gray clay	0.15 – 1.35	0.42
Peaty clay	0.05 – 0.6	0.22
Peat	0.08 – 3.82	1.5
Bluish clay	-	-

Table 49: Succession in alluvium in Kola mouza

4.2.11. Bluish clay is the most conspicuous and wide spread formation on the sequence. It invariably underlies the peat. The contact between the bluish clay and the overlying peat is rarely sharp. The top portion of the bluish clay is mostly brown due to embedded plant materials.

4.2.12. Prospecting of the peat was carried out by hand augur (7.5 cm diameter) in a grid pattern with spacing of 270m. The peat is found throughout the prospected area but greater concentration has been put in the central portion of the mouza where thickness ranges from 1.5m to 2.7m. It is 0.6m to 2.7m thick in the north, south and west side and 1.5m to 2.13m in the east. Average thickness of the peat is 1.5m.

4.2.13. The analyses of dry peat samples from Kola mouza is summarized below :

Analysis	Percentage (%)
Fixed Carbon	21.10 – 29.20
Ash	9.50 – 30.10
Moisture	12.3 – 31.3
Volatile Matter	32.00 – 47.10

Table 50: Analysis of dry peat samples from Kola mouza

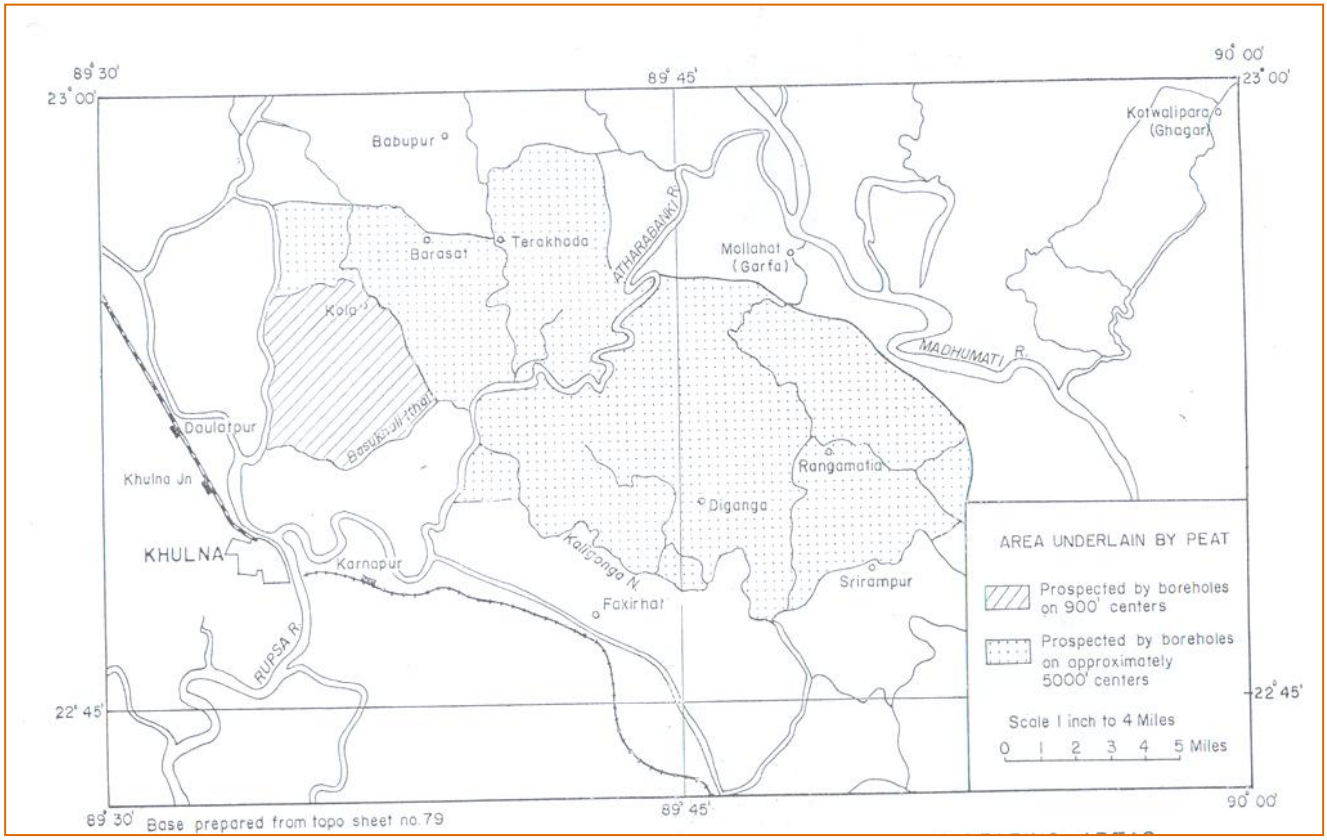


Plate 14: Kola Mouza Peat Field and Adjoining Peat Bearing Areas Khulna District
(Source – Interim GR No. 2 of Peat Deposit of Kola Mouza, Khulna, Geological Survey of Pakistan, 1962)

4.3. Peat Resources

Peat Deposit of Faridpur

4.3.1. As per the 1957 report of Peat Deposit of Faridpur by Mr. F H Khan of Geological Survey of Pakistan, the peat resources were as follows:

Level of Prospecting	Area (Sq. miles)	Wet Peat (Mt)	Dry Peat (Mt)
Detailed proving and analysis done	45	210	30
Scout drilling done (entire Faridpur deposit)	200	875	125

Table 51: Peat Resources of Faridpur (Figures in Mt)

4.3.2. The calorific value of Faridpur dry peat is estimated at 6,000 BTU/lb on an average (considering 14% ash).

Peat Deposit of Kola Mouza

4.3.3. The peat deposit of Kola mouza extends over an area of 15 sq. miles. The thickness range of the peat varies from .075m to 3.83m with an average of 1.5m. Assuming a specific gravity of wet peat as 1 and that of dry peat as 1/7, the estimated reserves of wet peat is 56 Million tonnes and that of dry peat is about 8 Million tonnes. The details of the peat resources of entire Kola-Barasat depression area of Khulna district are not available.

4.3.4. The calorific value of Kola mouza dry peat is likely to be lesser than 6,000 BTU/lb on an average as the ash percentage is rarely less than 14%.

Status of exploration

4.3.5. Peat is found to occur in the marshy areas of north eastern, middle and south western regions of Bangladesh.

4.3.6. In 1957 the then Geological Survey of Pakistan discovered peat in greater Khulna and Faridpur districts during exploration work covering an area of 500 km².

4.3.7. In 1979-80, the then BMEDC in collaboration with Geological Survey of Bangladesh (GSB) carried out a Feasibility Study on peat deposits in Kola Mouza, Khulna. The study advocated using peat for domestic and brick-burning purposes.

4.3.8. In 1983-84, a survey and investigation sponsored by UNDP reveals that a reserve of 400 million tons of peat exist in various parts of Bangladesh.

4.3.9. In 1986, Petrobangla conducted a detail study on peat with CIDA assistance in Madaripur, Khulna and Gopalganj region. The study located 61.26 million tons of peat covering an area of 205 km².

4.3.10. The peat usually occurs as a near surface deposit and has been excavated under a pilot project titled 'Peat Development and Demonstration Project' during 1992-94 in an area of 15 acres at Barabahadurpur Mouza of Kendua Union under Madaripur Sadar Thana where the peat thickness varied from 1.7 m to 4.25 m and the thickness of overburden varied from 0.25 m to 1.35 m. Till June, 1994 about 1800 tons of wet peat had been extracted. It was established that peat can be used in brick fields and in other commercial and domestic sectors. However, the cost of production of peat was Taka 2000 per ton which was considered high.

4.4. UNFC Classification of Peat Resources

4.4.1. Based on the above available data, the dry peat resources of Bangladesh have been placed in the UNFC matrix as shown in the table below assuming that the peat resources are intrinsically economic.

Economic Axis (E)	Feasibility Axis (F)	Geological Axis (G)			
		Detailed Exploration (1)	General Exploration (2)	Prospecting (3)	Reconnai-ssance Study (4)
Economic (1)	Feasibility study (1)				
	Pre-feasibility study (2)				
	Geological study (3)				
Potentially Economic (2)	Feasibility study (1)				
	Pre-feasibility study (2)				
	Geological study (3)				
Intrinsically Economic (3)	Feasibility study (1)				
	Pre-feasibility study (2)				
	Geological study (3)	38*			95**

* Comprises 30 Mt (dry) of Faridpur deposit and 8 Mt (dry) of Kola Mouza deposit

** Comprises dry peat resource of Faridpur deposit only

Table 52: UNFC Type Codification of Dry Peat Resources of Bangladesh (Figures in Mt)

5. Classification of Hard Rock deposits of Bangladesh

5.1. Maddhapara Hard Rock deposit

Geological description

Introduction

5.1.1. Maddhapara Hard Rock Mine is located at Maddhapara village, under Parbatipur Thana of Dinajpur district in the Rajshahi division. It lies between Longitudes 89° 03' 30" E to 89° 04' 53" E and Latitudes 25° 33' 15" N to Latitude 25° 34' 15" N.

5.1.2. The mining area is well connected with capital Dhaka and other parts of the country by rail and road. Topography of the mine area is almost flat and forms more or less a table land and the altitude ranges between 29.1 m and 30.9 m above mean sea level (MSL).

5.1.3. Slope of the mine area is about 0.45 m per km whereas slope of the outside of the industrial area of the mine is 0.70 m per km.

History of Exploration

5.1.4. In 1974, Geological Survey of Bangladesh (GSB) discovered fresh Hard Rock (Granite, Granodiorite and Gneiss) at a depth ranging from 136m to 160m below the surface at Maddhapara, Dinajpur District by drilling six boreholes during the period 1974 – 1976 (GDH-23, GDH-23A, GDH-24, GDH-25, GDH-26, GDH-27). Six other boreholes (GDH-32, GDH-33, GDH-34, GDH-34A, GDH-35 and GDH-36) were drilled in the area in 1983.

5.1.5. M/S SNC Inc. conducted feasibility study on Maddhapara Hard Rock Deposit in 1975-77. M/S SNC Ltd. recommended developing underground mine at Maddhapara for extraction of Hard Rock.

5.1.6. Executive Committee of National Economic Council (ECNEC), Govt. of Bangladesh, approved the Project Performa of Hard Rock Mining Project in 1978. A contract was signed in March 1994 between Petrobangla and NAMNAM (Korea South – South Cooperation Corporation, DPR of Korea) to develop Maddhapara Hard Rock Mine. M/S Kopex S. A. of Poland was appointed as Supervisory Consultant to supervise the work of the project.

5.1.7. The objective of the project was to produce 1.65 million tons of hard rock annually to meet the growing demand of boulders, crushed stone, concrete blocks and stone dust for usage in the river embankments, railways, construction of high rise and multi-storeyed buildings, roads and highways, etc.

5.1.8. The life of the mine was considered 70 years. Size of mining concession taken was 2.0 km in the strike direction and 1.25 km in the dip direction. Its area is 2.5 sq. km. Indicated and measured reserves of stone amounts to approximately 400 Million Tons, when mining thickness is considered to be 60m.

Stratigraphy

5.1.9. The stratigraphic succession is based on the data of six boreholes (GDH-23, GDH-23A, GDH-24, GDH-25, GDH-26 and GDH-27) drilled from 1974 to 1976 and six other boreholes (GDH-32, GDH-33, GDH-34, GDH-34A, GDH-35 and GDH-36) were drilled in the area during 1983.

Stratigraphy Sequence (Top downwards)	Group	Formation	Age
	-	Alluvium	Recent
	-	Barind Clay	Pleistocene
	-	Dupi Tila Formation	Pliocene
	Jaintia	Tura Sandstone	Eoecene
	Gondwana	Paharpur and Kuchma	Permian
	Precambrian Crystalline Basement		Archean

Table 53: Stratigraphic succession of Maddhapara Hard Rock area (Source – Geology of Maddhapara area, Dinajpur District, Bangladesh)

i. Alluvium

The alluvium is the top most layer.

ii. Barind Clay

Clay is the main component while silty clay are found in the lower part. It is sticky and its thickness ranges from 3.5m to 18m in thickness.

iii. DupiTila Formation

Dupi Tila formation comprises of sandstone in the upper part and pebbly sandstone, pebble bed and silty sand stone in the lower part. The thickness ranges from 94-120m.

iv. Tura Sandstone Formation

Tura Sandstone Formation consists of silty clay weathered from tertiary sandstone and argillite which seldom appears in the lower part. Tura Sandstone Formation is overlying the Kaolinized rock in all boreholes, except GSB borehole GDH-26, where it is overlying the Gondwana Group. In all the boreholes, Tura Sandstone Formation is covered with DupiTila formation. The thickness of the formation ranges from 16.2m to 33m.

v. Gondwana Group

Gondwana Group lies between basement and Tura Sandstone Formation in unconformity at a depth of 165m. Its thickness is more than 170m. It mostly contains conglomerate, sandstone, and feldspathic rocks).

Geological Structure

5.1.10. Bangladesh is tectonically divided into four main units/divisions:

i. Sub-Himalayan Foredeep

ii. Platform Area

iii. Bengal Foredeep

iv. Arakan-Yoma-Mega-Anticlinorium

5.1.11. Maddhapara Hard Rock deposit lies in the shallowest part of Rangpur Saddle of platform area. The Rangpur Saddle extends approximately 100 km in width and is a possible sub-surface connection between Indian Platform and Shillong Massif.

5.1.12. Geological structure in Maddhapara and its surroundings were revealed by geophysical prospecting and exploratory drilling. The basement rock has been found at a depth ranging from 128m to 326m at Maddhapara and surrounding areas.

5.1.13. Osmanpur graben lies on the east surrounding the area of basement. Stratigraphical succession of hard rock deposit lies on the Pre-Cambrian basement complex (granodiorite and others) and subsequently Tura Sandstone Formation, Dupi Tila formation, Barind clay and Alluvium from bottom to top.

5.1.14. From the geological data obtained in the GSB borehole GDH-26, Gondwana Group is found at a depth of 165m to the east of the mine. The analysis of the samples confirmed that the basement belongs to Pre-Cambrian age.

Lithologically, the basement consists of two parts:

i. Upper part of weathered rock,

ii. Lower part of fresh rock.

5.1.15. The fresh basement consists of,

i. **Granodiorite:** It is light grey in colour with green spots and medium to coarse grained equigranular rock. The composition of granodiorite is shown in the table below:

Component	Percentage
Quartz	25%
Plagioclase	45%
Hornblende	20%
Pyroxene & others	10%

Table 54: Composition of Granodiorite

ii. **Quartz diorite:** It is light green with dirty white and green spots and medium to fine grained. It is composed of quartz, plagioclase, hornblende and pyroxene.

iii. **Gneiss:** It appears as a banded structure with pegmatite and quartz vein. Its colour is white, pink and greenish grey – grey with green band and spots. It is fine to medium and sometimes coarse grained. It is equidimensional and has the gneissic texture. Main components are quartz, plagioclase, amphibole, pyroxene, biotite, chlorite, and a few grains of K-feldspar, while accessory minerals are epidote, garnet, zircon, rutile, and pyrite.

Estimation and classification of resources

Analysis of Resource/ Reserve

5.1.16. Large number holes have been drilled by GSB at various points of time to prove the occurrence of hard rock deposit in the Maddhapara area. However, the estimation for the rock reserves has been done based on the area delineated by a system of ten investigatory boreholes. The depth used for calculation is from the fresh basement at 160m depth (-130 m level) to the bottom of the boreholes at 350 m depth (-320 m level).

5.1.17. The data obtained from the exploration drillings showed that basement in the mine area lies almost at the same depth from surface. The subsurface configuration of basement in the area was obtained from exploratory drilling and geophysical survey data. The basement has a slope of 2 to 3 degrees towards the borehole GDH-25 that is, 1,250 m north of skip shaft. The basement encountered at 1,050 m west of cage shaft, is restricted to 1,100 m distance to the east of skip shaft by the NW-SE trending major fault.

5.1.18. The rock deposit extends as far as 4 km further to the South-East (GDH-24).of the mine area and therefore southern direction has more recovery prospect (Ref. Fig 2 Layout of Maddhapara Granite Mine). As such, below 350 m depth the rock resource is unlimited.

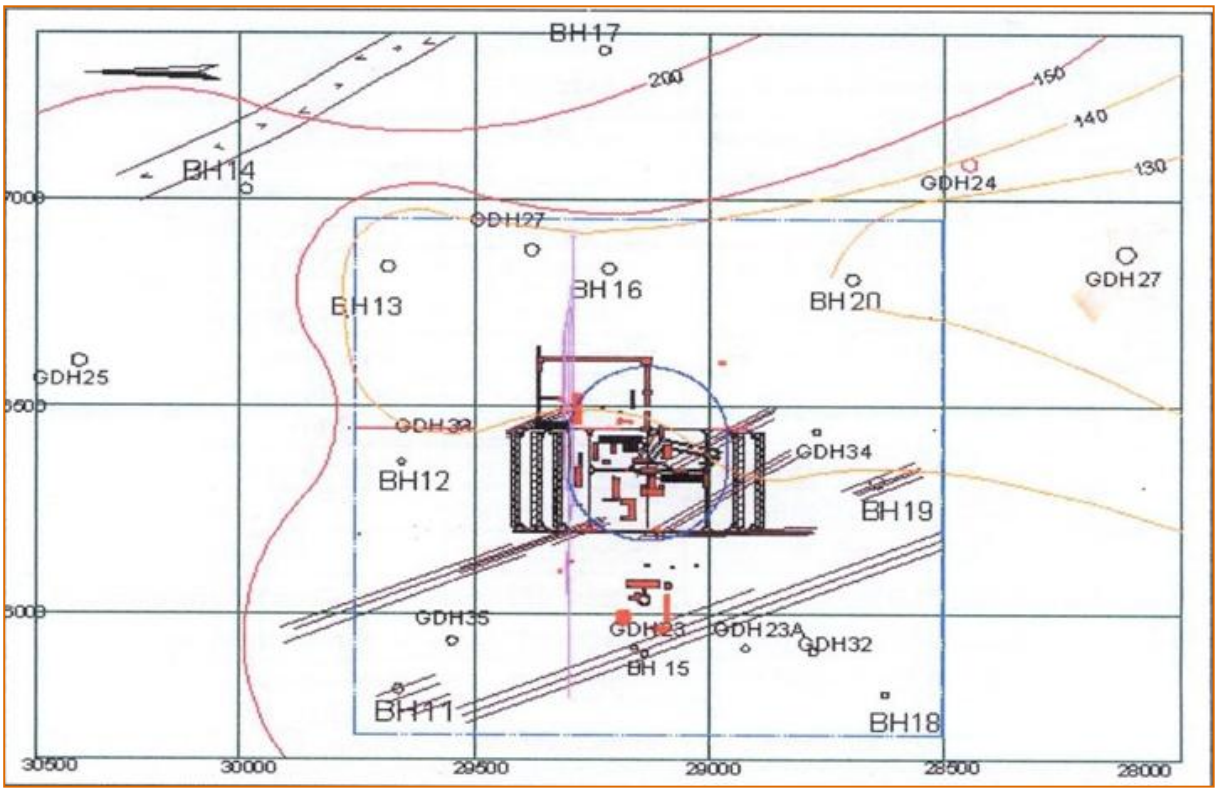


Figure 2: Layout of Maddhapara Granite Mine

5.1.19. Under above circumstances the contour for the calculation of prospecting/geological reserves of the mine area could be determined as a rectangle of 2,000 m south of borehole BH-14 and 1,500 m west of GDH-24.

Parameter	Measurement
Length in N-S direction	2,000 m
Length in E-W direction	1,500 m
Thickness (Depth)	190 m (160 m to 350 m)
Tonnage factor	2.67 tonnes/m^3
Total Resource	1,521.90 million tonnes

Table 55: Parameters for calculation of Prospecting/ Geological Resource

5.1.20. Mining of fresh basement rock has been planned for meeting the construction material requirement of Bangladesh. Therefore, it has to be extracted by low cost mining methods such as room and pillar method and/or sublevel open stoping method because of the fact that other mass mining methods may not be economically feasible.

5.1.21. With an increase in depth, stress in the ground increases which lead to instability of open rooms and pillars left after extraction of the rock. Further, we cannot allow caving of the strata after mining of the rooms as there are two active aquifers above fresh rock basement complex.

5.1.22. One aquifer is immediately above the basement rock complex and second one is near the surface. Therefore, pillars left after mining of the rooms have to remain stable for quite long time in the future and have to be designed accordingly. In addition to it, the designed pillars have to be of larger size and thus, the percentage extraction shall decrease.

5.1.23. With further increase in depth, the rock mass surrounding the rooms becomes highly stressed and may lead to failure. In view of this, open stoping is generally done up to a depth of 500m. Therefore, the underground mining of fresh basement rock has to be limited to a depth 500m only, from the surface.

5.1.24. Thus the basement rock between 350 m and 500 m can be considered as rock resource which can be mined in future, if required. This provides the basis for the calculation of the Total Rock Resource which sums up as per the table below:

Additional rock resource	1,201.50 million tonnes
Total Rock Resource	2,723.40 million tonnes

Table 56: Additional and Total Hard Rock Resource of Maddhapara Hard Rock Project

5.1.25. **Extractable Reserve** within the contour area of 1.25 km x 1.25 km is given in the following table:

Parameter	Measurement
Length in N-S direction	1,250 m
Length in E-W direction	1,250 m
Thickness (Depth)	190 m (160 m to 350 m)
Tonnage factor	2.67 tonnes/m^3
Extractable Reserve	792.65 million tonnes

Table 57: Parameters for calculation of Extractable Reserve

5.1.26. **Minable Reserve** between 210 m (-180 m level) and 270 m (-240 m level) depths (leaving a 50 m fresh rock pillar above the stoping area) with 50% recovery, within the contour area 1.25 km x 1.25 km, by sublevel open stoping is given in the table below

Parameter	Measurement
Length in N-S direction	1,250 m
Length in E-W direction	1,250 m

Recovery	50%
Thickness (Depth)	60 m
Tonnage factor	2.67 tonnes/m3
Minable Reserve	**125.15 million tonnes**

Table 58: Parameters for Measurement of Mineable Reserve

Classification of Resources as per UNFC System of Classification

5.1.27. The classification of resources as per UNFC System of Classification of Maddhapara Hard Rock is given as per table below:

Economic Axis (E)	Feasibility Axis (F)	Geological Axis (G)			
		Detailed Exploration (1)	General Exploration (2)	Prospecting (3)	Reconnai-ssance Study (4)
Economic (1)	Feasibility study (1)	*125.15			
	Pre-feasibility study (2)	**792.65			
	Geological study (3)				
Potentially Economic (2)	Feasibility study (1)				
	Pre-feasibility study (2)				
	Geological study (3)		1521.90		
Intrinsically Economic (3)	Feasibility study (1)				
	Pre-feasibility study (2)				
	Geological study (3)			1201.50	

*125.15 - Mineable reserve upto 270m
** 792.65 – Extractable reserve between 160m and 350m depths.

Table 59: UNFC Type Codification of Hard Rock Resources of Maddhapara Hard rock deposit (Figures in Mt)

6. Recommendations and Conclusions

6.1. Barapukuria Coal Deposit

6.1.1. In Barapukuria basin, out of a geological resource of 285.41 Mt of VI Seam in the main syncline, only 81.46 Mt (i.e. 28.54%) would be recoverable. The rest of the resources of VI Seam, which is the main seam of Barapukuria deposit, will be lost due to different design loses and mining loss. Out of this 81.46 Mt of recoverable reserve, 64.80 Mt has been classified as proved reserve (111) and probable reserve (112). The balance 16.66 Mt has been classified as pre-feasibility resource (221 and 222).

6.1.2. In addition to the above, Barapukuria basin contains 40.24 Mt of indicated resource (332), 21.06 Mt of inferred resource (333) and 43 to 64 Mt of reconnaissance resource (334).

6.1.3. An appropriate mining technology need to be developed to exploit the resource of VI seam in the 'open area' in the northern part of Barapukuria mine so that the estimates of recoverable reserve in this area can be firmed up.

6.2. Phulbari Coal Deposit

6.2.1. In Phulbari basin, out of a total geological resource of 572 Mt, 288 Mt is measured resource and the balance 244 Mt is indicated and inferred resource. The basin is proposed to be worked by Opencast Mining for which a feasibility report has already been prepared. Out of 572 Mt, an in-situ resource of 514 Mt occurring in top, upper and main seams will be excavated by opencast mining leaving a resource of 58 Mt in lower seams. According to the feasibility report, the recoverable ROM coal will be 475 Mt. Out of this 475 Mt, 435 Mt will be marketable coal after washing. Out of above 435 Mt, 243.7 Mt has been classified as proved reserve (111) and 191.3 Mt has been classified as probable reserve (112). A reserve of 79 Mt will be lost in the process of opencast mining and coal washing.

6.2.2. Slope stability studies should be taken up for determining the final highwall pit slopes and ultimate internal dump slope so that the recoverable reserves of the mine and the volume of internal dump can be firmed up.

6.3. Khalashpir Coal Deposit

6.3.1. In Khalashpir basin, out of total resource of 523.49 Mt, 279.57 Mt has been classified as pre-feasibility resource (222) and the balance 225.92 Mt has been classified as inferred resource (333). A techno-economic feasibility study (TEFS) of Khalashpir mine was prepared considering seams I, II and IV only. However, this TEFS has been considered as a pre-feasibility study as the report does not contain adequate details.

6.4. Jamalganj Coal Deposit

6.4.1. In Jamalganj basin an area of 11.7 Sq. Km has been prospected by putting only 11 boreholes thus giving borehole density of around 1 borehole / Sq. Km. With this level of exploration, the geological resource of 11.7 Sq. Km area of Jamalganj basin has been estimated as 1054 Mt which has been classified inferred resource (333).

6.5. Dighipara Coal Deposit

6.5.1. In Dighipara basin, only 4 boreholes have been drilled by GSB in an area of 1.25 Sq. Km. The resource in this area has been estimated as 105 Mt by GSB. This resource has been classified as indicated resource (332) in this report. GSB has also estimated that about 600 Mt of resource will be available in an area of 15 Sq. Km (including the above 1.25 Sq. Km) in the basin. Therefore, the balance 495 Mt of resource has been classified as reconnaissance resource (334) in this report.

6.6. Peat Deposits

6.6.1. Assessment reports of Peat deposits occurring in Kola Mouza in Khulna District and in Baghia and Chanda Beels of Faridpur District are only available at present. On the basis of the available information, 38 Mt of dry Peat resource has been classified as measured resource (331) and 95 Mt of dry Peat resource has been classified as reconnaissance resource (334) in this report.

6.7. Maddhapara Hard Rock deposit

6.7.1. In Maddhapara Hard Rock deposit, out of the total rock resource of 2723.40 Mt, currently extractable reserve within an area of 1.25 km x 1.25 km is 792.65 Mt. However, the mineable reserve within the same area up to depth of 270 m, is 125.25 Mt.

6.8. General Observations

6.8.1. From the above classification of coal, peat and hard rock resources of Bangladesh, it can be concluded that intensive exploration work is necessary in all the basins except in Barapukuria and Phulbari basin to upgrade the resource base to measured category.

6.8.2. Even for Barapukuria and Phulbari basin, further exploration are required to firm up and upgrade the resources of seams which have not been included in the scope of mining as per the feasibility study reports of the coal mine projects planned in these basins.

6.8.3. In order to coordinate the significant exploration and mine planning activities that are to be taken up in near future, Bangladesh would require to strengthen the relevant organisations in terms of internal capacity and skill development, adequate human resources, and computational tools.