कार्यकारी सारांश

वित्त वर्ष 2024–2025 के दौरान असम के दीमा हसाओ जिले स्थित उत्तर-पश्चिम बोरोलखींदोंग ब्लॉक में चूना पत्थर की प्रारंभिक खोज (G-3) की गई, जिसका उद्देश्य विभिन्न ग्रेड के चूना पत्थर संसाधनों का मूल्यांकन करना था। यह ब्लॉक टोपोशीट संख्या 83C/11 का हिस्सा है, जो लगभग 4.82 वर्ग किमी क्षेत्र को आच्छादित करता है। खोज कार्यों में विस्तृत भूवैज्ञानिक मानचित्रण (1:4000 के स्केल पर) 2 मीटर के कंटूर अंतराल के साथ, DGPS सर्वेक्षण यंत्र की सहायता से किया गया। साथ ही 800 मीटर के अंतरिक्ष में पाँच बोरहोल्स में कुल 500 मीटर की ड्रिलिंग की गई। इन बोरहोल्स से 50 संख्याओं में बेडरॉक नमूनों का संग्रहण किया गया तथा 5 कोर और बेडरॉक नमूनों को पेट्रोलॉजिकल अध्ययन हेतु एकत्र किया गया। खोज के दौरान एकत्र किए गए 451 कोर नमूनों का रासायनिक विश्लेषण NABL मान्यता प्राप्त शिवा एनालिटिकल प्रयोगशाला में किया गया तथा इनका 10% बाहरी परीक्षण NABL मान्यता प्राप्त SGS इंडिया लिमिटेड में करवाया गया। प्राप्त आंकड़ों के आधार पर विभिन्न ग्रेड के चूना पत्थर का वर्गीकरण और संसाधन मूल्यांकन किया गया।

भूवैज्ञानिक दृष्टिकोण से इस ब्लॉक का लगभग 60% क्षेत्र शेला समूह की ऊपरी सिलहट चूना पत्थर इकाई से आच्छादित है, जबकि कोपिली निर्माण ब्लॉक के उत्तर-पूर्वी, दक्षिण-पश्चिमी एवं कुछ दक्षिण-पूर्वी भागों में प्रमुखता से प्रकट होता है। ऊपरी सिलहट चूना पत्थर कोपिली निर्माण द्वारा अधिरोपित है और यह प्रमुख चूना पत्थर इकाई है, जिसमें कठोर, महीन से मध्यम दानेदार, जीवाश्म युक्त चूना पत्थर पाया जाता है, जिसमें कुछ स्थानों पर शेल की अंतःस्तरित परतें भी विद्यमान हैं। कोपिली निर्माण मुख्यतः सफेद से पीले-भूरे रंग का, अच्छी तरह से छँटा हुआ, महीन से मध्यम दानेदार बलुआ पत्थर, ग्रे से हल्के ग्रे रंग का शेल तथा कुछ स्थानों पर जीवाश्म युक्त चूना पत्थर की पतली परतों से बना है। ये शैल इकाइयाँ क्षैतिज से उप-क्षैतिज अवस्था में हैं, जिनकी स्ट्राइक दिशा NNE–SSW से NE–SW के मध्य बदलती है और इनकी ढाल 2–3 डिग्री दक्षिण-पूर्व की ओर है। प्राथमिक संरचनाओं में परतबद्धता और लेमिनेशन प्रमुख हैं, जबकि द्वितीयक संरचनाओं में स्टायलोलाइट्स, घुलन संरचनाएँ, गह्वर भराव, भ्रंश, सिंकहोल्स और भूमिगत गुफाएं पाई जाती हैं, जो चूना पत्थर क्षेत्रों में सामान्य रूप से देखी जाती हैं।

बोरहोलों में चूना पत्थर की मोटाई में महत्वपूर्ण भिन्नता देखी गई है, जो PBH-01 में 4.00 मीटर से 82.76 मीटर, PBH-02 में 4.40 मीटर से 100.00 मीटर, PBH-03 में 15.78 मीटर से 100.00 मीटर, PBH-04 में 15.80 मीटर से 100.00 मीटर तथा PBH-05 में 16.14 मीटर से 100.00 मीटर तक पाई गई है। इन पाँचों बोरहोलों में दर्ज चूना पत्थर की मोटाइयों के आधार पर औसत मोटाई 85.32 मीटर आंकी गई है।। उपसतही अवलोकनों से यह ज्ञात हुआ कि चूना पत्थर का ऊपरी भाग फेरूजिनस, बफ रंग का है, जिसमें Discocyclina sp., Asterocyclina sp. और Nummulite sp. जैसे मेगाफॉसिल्स पाए गए। मध्य भाग में हल्के से गहरे ग्रे रंग का, ठोस, मध्यम दानेदार, अत्यधिक जीवाश्म युक्त चूना पत्थर पाया गया, जबकि निचले भाग में यह शेल के साथ अंतःस्तरित रूप में उपस्थित है। इसमें पाए जाने वाले प्रमुख फोरामिनिफेरा प्रजातियाँ Nummulites sp., Discocyclina sp., Assilina sp., Alveolina sp. और Asterocyclina sp. हैं, जो इस चूना पत्थर को मध्य से उत्तर इओसीन काल

(Middle to Late Eocene) का दर्शक बनाती हैं।

कोर नमूनों के रासायनिक विश्लेषण से प्राप्त परिणाम इस प्रकार हैं: CaO – 34.14% से 52.93%, MgO – 0.67% से 4.58%, SiO_2 – 1.49% से 15.83%, Al_2O_3 – 0.93% से 6.44% तथा Fe_2O_3 – 0.75% से 19.78%। प्राप्त आंकड़ों के आधार पर बहुभुज विधि (Polygonal Method) और ठोस मॉडलिंग तकनीक का उपयोग करते हुए विभिन्न ग्रेडों में संसाधन मूल्यांकन किया गया। UNFC वर्गीकरण के अनुसार 333 श्रेणी के अंतर्गत इस ब्लॉक में कुल 498.96 मिलियन टन चूना पत्थर संसाधनों का अनुमान लगाया गया है, जिनमें ग्रेडवार वितरण इस प्रकार है: 195.29 मिलियन टन – पोर्टलैंड सीमेंट ग्रेड, 144.40 मिलियन टन – ब्लेंडेबल/बेनिफिशिएबल सीमेंट ग्रेड, 155.68 मिलियन टन – एसएमएस (OH) ग्रेड, और 3.58 मिलियन टन – अन्य/अवर्गीकृत श्रेणी।

EXECUTIVE SUMMARY

The preliminary exploration for limestone in Northwest of Boro Lakhindong Block, Dima Hasao district, Assam (G-3) was carried out during F.Y.2024-2025 to assess the resources of different grades of limestone. Northwest of Boro Lakhindong Block is part of toposheet no. 83C/11, covering an area of 4.82 sq. km.

The various work components of the preliminary exploration in the block including detailed geological mapping (on 1:4000 scale) with contour interval of 2m with aid of DGPS surveying instrument, drilling of five boreholes placed at space of 800m respectively, with collection of 50 nos. of bedrock samples, and 5 nos. of core & bedrock samples for petrological study and to classify the different grades of limestone. Total drilling of 500m in 5 boreholes was carried out during this exploration and 451 nos. of core samples were analyzed at NABL accredited Shiva Analytical laboratory and 10% external check samples of core were analyzed at NABL accredited SGS laboratory, India Ltd.

Geologically, the 60% of the block is covered with Upper Sylhet limestone of Shella Formation. Kopilli Formation is exposed mostly on the north-eastern, south-western and some part in the south-eastern of the block. Upper Sylhet limestone is overlain by Kopili Formation. Upper Sylhet limestone of Shella Formation is the most important limestone horizon and it comprises hard, fine-medium grained fossiliferous limestone with occasional shale intercalation in some places. Kopili Formation consists of fine to medium grained, whitish to brownish yellow, well sorted, less compact sandstone, grey to light grey shale and occasionally it is also interbedded with fossiliferous limestone. These lithological units are horizontal to sub-horizontal in attitude with strike varying from NNE-SSW to NE-SW dipping at 2-3°southeasternly. Primary structures such as bedding and laminations are common. The secondary structures, observed in the area, are stylolite. Stylolite, a solution structure, cavity fillings, fracture zone, sinkholes and underground caverns are common in the limestone.

The thickness of limestone varies significantly across the boreholes, ranging from 4.00 m to 82.76 m in PBH-01, 4.40 m to 100.00 m in PBH-02, 15.78 m to 100.00 m in PBH-03, 15.80 m to 100.00 m in PBH-04, and 16.14 m to 100.00 m in PBH-05. Based on the limestone thicknesses recorded in all five boreholes, the average thickness has been calculated to be 85.32 m. From the sub surface data, it is observed that the upper part of the limestone is ferruginous, buff colour with mega fossil of Discocyclina sp., Asterocylina sp., and Nummulite sp.

In the middle part, light greyish to dark greyish colour, massive, medium grained, hard and compact, highly fossiliferous limestone variant are observed and at the bottom part, limestone is dark greyish in colour and it is intercalated with shale. The common species of foraminifera present in the Upper Sylhet Limestone are Nummilites sp., Discocylina sp., Assilina sp., Alveolina sp. and Asterocyclina sp. This assemblage of fossils indicates Middle to Late Eocene age.

Chemical analysis results of 451 numbers of core samples of limestone show 34.14 to 52.93% CaO, 0.67 to 4.58% MgO, 1.49 to 15.83% SiO_2, 0.93 to 6.44% Al_2O_3 and 0.75 to 19.78% Fe_2O_3. A total 498.96 million tonnes of limestone resource (categorized under 333 of UNFC classification) is estimated from Northwest of Boro Lakhindong Block. Further, Grade wise resources are estimated. 195.29 million tonnes of Cement (Portland) grade, 144.40 million tonnes of Cement (Blendable / Beneficiable) grade, 155.68 million tonnes of SMS (OH) grade and 3.58 million tonnes of Unclassified or Others category.

CHAPTER 1

INTRODUCTION

The present work entitled "Preliminary Exploration for Limestone in Northwest of Boro Lakhindong Block, Dima Hasao district Assam" was taken up for G-3 stage exploration during FY 2024-2025 with F.No. 23/444/2023-NMET/599. The UNFC guideline of G-3 Stage of exploration was initially followed to accomplish the preliminary exploration of limestone. It is located in Dima Hasao district of Assam, India near Assam-Meghalaya border in toposheet no 83C/11. In the study area, the Kopili River flows all along Southwestern corner of the Block. Exposed limestone in the area belongs to the Upper Sylhet Limestone member of the Shella Formation of the Jaintia Group of Eocene age (~34Ma). The limestone occurs as thick bedded sequence, suggested to have been deposited over platform areas under stable shelf conditions along the southern fringe of Meghalaya plateau, further extending easterly toward the Dima Hasao district of Assam.

1.1 INVESTIGATION AGENCY

The exploration Block (Northwest of Boro Lakhindong) is investigated by M/S. Maheswari Mining Pvt. Ltd, **Notified Private Exploration Agency (NPEA) under** second provison to sub section (1) of section-4 of the Mines and Minerals (Development and Regulation) Act, 1957 (67 of 1957) and consequent upon accreditation provided by the National Accreditation Board for Education and Training of the Quality Council of India (QCI-NABET), the Central Government hereby notifies the M/s. Maheshwari Mining Private Limited under 'Category A Exploration Agencies' as specified in the guidelines for notification of accredited private exploration agencies issued by the Government of India in the Ministry of Mines vide order No. M.VI-16/15/2021-Mines VI, dated the 12th August, 2021. The notification has been annexed to this report **(Annexure-VIII)**.

1.2 PRESENT WORK

The various work components of the preliminary exploration in the block include detailed geological mapping (on 1:4000 scale) with contour interval of 2m with aid of DGPS surveying instrument, systematic drilling of 500m of 5 boreholes placed at space of 800m respectively, collection of 50nos of bedrock samples, and 5 nos of petrological study of core & bedrock samples to classify the different grade of limestone. The quantity of the work component has been given in the **Table.1.1.**

Table 1.1: Nature, quantum of work & achievement during FY 2024-2025				
Sr No	**Toposheet No**	**Nature of Work**	**Total workload envisaged**	**Total Achievement**
1	83C11	1.Geological Survey a. Detailed Mapping on 1:4000 scale (sq. km)	4.82	4.82
2	83C11	2. Technological Survey a. Subsurface exploration i.e. Drilling (m)	500	500
3	83C11	3. Sampling (in number) a.Core Sample (CS)	500	451
4	83C11	b. Bedrock Sample (BRS)	50	50
5	83C11	4. Petrological/Mineralogical Studies (number) a. Petrographical Study (PS)	5	5
6	83C11	5. Petrochemical Analysis (number)	10	10

1.3 OBJECTIVE OF INVESTIGATION

To assess the block potentiality with estimation of resource (under 333 category) of different grades of Upper Sylhet Limestone member of Shella Formation.

1.4 PERSONNEL ASSOCIATED WITH THE INVESTIGATION

Table 1.2: Overall Supervision and Geological Report Preparation	
Responsibility	**Name**
Overall Coordination	Mr. Ambika Prasad Samantaray, President & CEO Exploration Mr. Pradipta Tarafdar, Advisor Geology Dr. Suman Krishnan Sit, Vice President Exploration Mr. Sourabh Sarkar, DGM Geology
Headquarter Coordination	Mr. Balkrishan Vishawakarma, Manager (Geology) Mrs. Moulipriya Bhakta, Deputy Manager (Geology) Mr. Promit Roy (Geologist)
Geological field report preparation and documentation	Mr. Sudev Mahato, Geologist Mr. Souvik Duya, Geologist Mr. Padamata Sai Chandu, Geologist
Field Geologist & Field Coordinator	Mr. Sudev Mahato, Geologist Mr. Souvik Duya, Geologist
Petrographic Study	Ms. Medha Sarkar, Geologist Mr. Sudev Mahato, Geologist
ArcGIS	Mr. Saswat Subedit, Deputy Manager, Geology Mr. Sudev Mahato, Geologist
Resource Modelling	Mr. Saswat Subedit, Deputy Manager, Geology
Draughtsman	Mrs. Susmita Dolai, Ms. Gargi Roy Chowdhury
Peer Reviewer	Shri Bharat Kumar Gazarasan, Ex GM (Geology), CMPDIL
Site In-charge (Drilling Unit)	Mr. Gobinda Dasgupta, Drilling Unit In-charge

1.5 MODE OF OPERATIONS OF DIFFERENT WORK COMPONENTS AND ASSOCIATED AGENCIES:

Detailed geological mapping on 1:4,000 scale in G3 stage, surface and subsurface sampling, drilling, DGPS survey, and petrographic studies were conducted by Maheshwari Mining Private Limited. Core cutting and sample preparations were done by in-house resources and samples analysed from different NABL laboratories shown in **Table 1.3**.

Table 1.3: Analysis of samples at different NABL laboratories

Agency	Methodology	Quantum of work	
		Nature of samples	No. of samples
M/s Shiva Analyticals	XRF	Core samples	451
M/s Shiva Analyticals	XRF	Bedrock samples	50
M/s Shiva Analyticals	XRF	Petrochemical Studies	10
M/s SGS India Ltd	XRF	Check samples	50

1.6 ACKNOWLEDGEMENT

The authors express their sincere gratitude to the National Mineral Exploration Trust (NMET), Ministry of Mines, Government of India for approving the project and funding it. The Directorate of Geology and Mining (DGM, Assam) is thankfully acknowledged for monitoring the program.

During the execution of the project constant support from Mr. Sanjiv Ganeriwala, Joint MD of Maheshwari Mining Private Limited and Mr. Ambika Prasad Samantaray, President & CEO, Head of Geology Division, Maheshwari Mining Private Limited, is gratefully acknowledged.

In addition, relentless support from seniors & colleagues of Maheshwari Mining Private Limited is being acknowledged humbly.

Support by the local administration/authorities of Dima Hasao district, Assam, and relentless support of the North Cachar Hills Autonomous Council are being thankfully acknowledged. Thanks are due to the local authorities for their cooperation for accomplishment of the project.

CHAPTER 2

PROPERTY DESCRIPTION

The land of Northwest of Boro Lakhindong block is owned by people of Boro Lakhingdong and Choto Lakhindong village under the administration and jurisdiction of Deputy Commiossioner, Dima Hasao District and Chief Executive Member, North Cachar Hill Autonomous Council, Haflong, Dima Hasao. The land is either privately owned or community owned. The required description in detail is given below.

2.1 DETAILS OF THE AREA

2.1.1 VILLAGE NAME, DISTRICT, STATE

Village: Boro Lakhindong and Choto Lakhindong

District: Dima Hasao

State: Assam

2.1.2 SURVEY OF INDIA TOPOSHEET NO.

Survey of India Toposheet No: 83C/11

2.1.3 CO-ORDINATES OF ALL CARDINAL POINTS OF THE INVESTIGATED BLOCK

Boundary co-ordinates are surveyed through DGPS. The details of the Cardinal Points of the block are given below in Table 2.1.

Table 2.1: Cardinal Points of the Investigated Block

Point ID	DMS		UTM (ZONE 46)	
	Latitude	Longitude	Easting (X)	Northing (Y)
A	25°28’45.23’’	92°35’37.65’’	459169.8	2818076
B	25°28’41.67’’	92°37’40.45’’	462598.3	2817957
C	25°27’52.98’’	92°37’41.15’’	462613.6	2816459

Point ID	DMS		UTM (ZONE 46)	
	Latitude	Longitude	Easting (X)	Northing (Y)
D	25°27’57.37’’	92°36’00.95’’	459816	2816602
E	25°28’12.31’’	92°35’51.37’’	459549.9	2817062
F	25°28’16.26’’	92°35’36.92’’	459146.7	2817185

2.1.4 CADASTRAL DETAILS OF THE AREA WITH LAND USE/COVER

The exploration block under investigation is primarily owned by private parties, particularly from Boro Lakhingdong and Choto Lakhindong. It falls within the administrative jurisdiction of the North Cachar Hills Autonomous Council, Haflong. The region is characterized by dense vegetation cover, with Jhum cultivation, also known as shifting or slash-and-burn agriculture, is a traditional agricultural practice widely practiced in many parts of Northeast India, including the block near the Kopili River.

Despite its traditional significance, the Jhum cultivation has raised environmental concerns, particularly regarding soil erosion, loss of biodiversity, and the long-term sustainability of the land.

2.1.5 FREEHOLD/ LEASEHOLD. IF LEASE HOLD, GIVE THE STATUS

At present, the land of the investigation block is leasehold and the leasehold premise eventually belongs to the North Cachar Hills Autonomous Council, Haflong.

2.1.6 LOCATION AND ACCESSIBILITY

The area of investigation is about 34 km southwest of the Umrongso town. The area is located in Dima Hasao district of Assam, India near Assam-Meghalaya border in toposheet no. 83C/11 **(Fig.2.1).** Nearest railway station is Lanka railway station. The Umrangso area can be reached from Lanka town by Lanka-Umrangso Road (NH 627 or SH20) which is at a distance of 77km. Bus services are available from Umrangso town to Lanka and to Guwahati. Nearest airport is LGB international airport, Guwahati.

2.1.7 CLIMATE

The region has a tropical monsoon climate, characterized by high humidity and distinct seasonal changes. The average annual rainfall ranges 220 to 300 cm, making it a region with substantial precipitation. The rainy season lasts from mid-May to September, bringing heavy downpours and contributing to the lush vegetation in the area. October and November are relatively cooler, offering a brief respite from the intense rains. However, during the winter months, from December to February, the climate becomes significantly colder, with temperatures ranging from 2°C to 10°C, making it quite chilly. During the summer times, the temperature ranges from 24° to 30°C (*Source from https://mausam.imd.gov.in/*).

2.1.8 FLORA AND FAUNA

The area is densely vegetated, with pine (Pinus), bamboo (Bambusoideae), banana (Paradisiaca), and various bushes forming the main plant life. Notable tree species include Gmelina arborea, Phyllanthus emblica, Sterculia villosa, and Monoon longifolium, while the forest floor hosts a variety of ferns and orchids. Fauna includes a range of insects, birds, and reptiles, though wild animals are rare. Occasionally, wild cats (Felissilvestris), snakes (Serpentes), and leeches (Hirudinea) may be spotted, especially during the rainy season.

2.2 INFRA-STRUCTURE & ENVIRONMENT

The local population near the investigation block relies on natural resources, agriculture, lumbering, and fishing for their livelihoods. The area faces poverty, with limited access to basic amenities such as roads, sewage systems, and drinking water. The Kopili River serves as the primary source for drinking water, transportation, fishing, and recreation.

The area is accessible from Lanka town via a 72 km long road shown in **Fig.2.2**. The Dalmia Cement factory is located near Umrangso town, and a reservoir nearby supplies water to the NEEPCO (Northeastern Electric Power Corporation) for electricity production. Education levels are generally low due to the absence of good, affordable schools. High rainfall supports abundant forest growth in the region. All residents of the Boro Lakhindong village belong to Scheduled Tribe (Karbi). There is only one government primary school in the village. The nearest secondary school is in Umrangso. The nearest Community Health Centres or Primary Health Centres is in Umrangso. The telephonic coverage for communication is very poor to non-existent. There are no archaeological or historical sites in the area; however certain caves hold religious significance for the people.

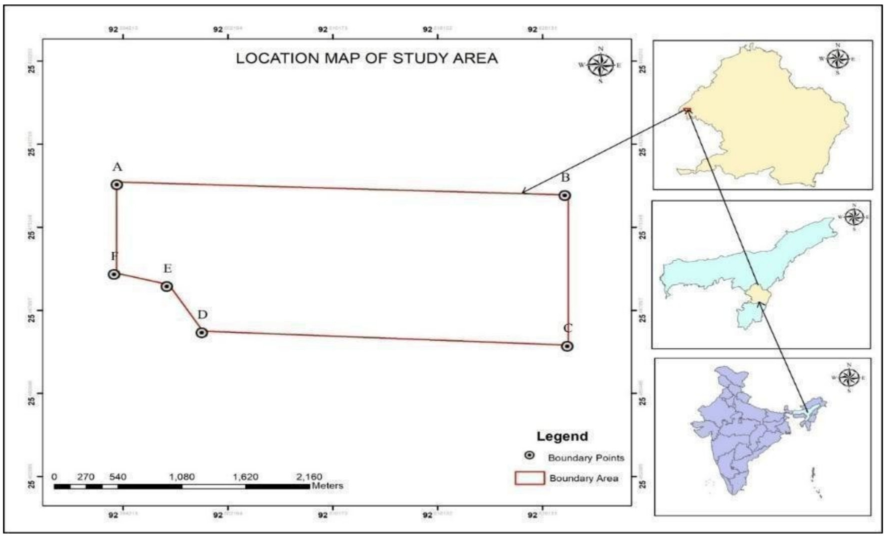

Fig 2.1: Location of the Northwest of Boro Lakhindong Block in Dima Hasao district, Assam

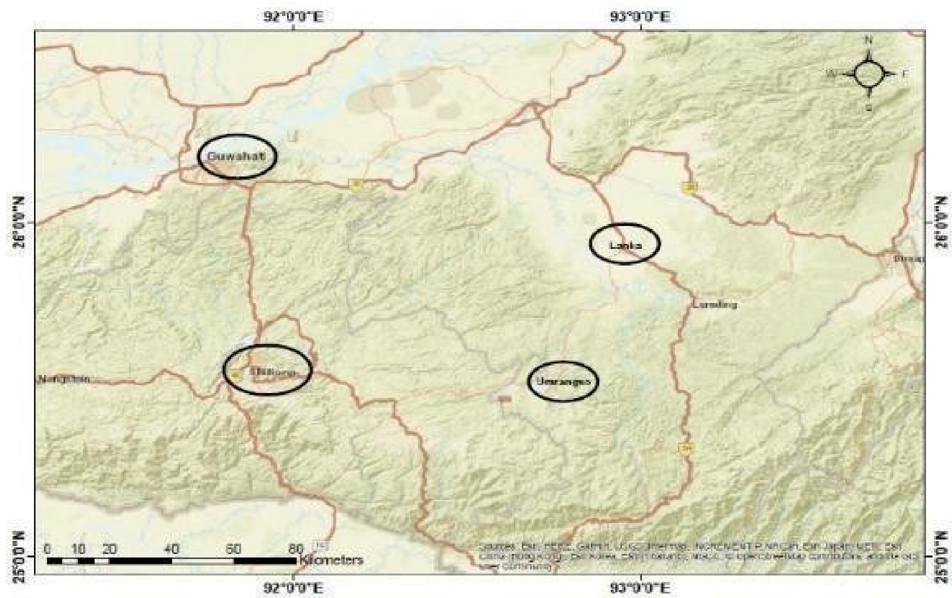

Fig 2.2: Location and accessibility map of the Northwest of Boro Lakhindong Block, Dima Hasao district, Assam

CHAPTER 3

PREVIOUS EXPLORATION WORK

3.1 PREVIOUS EXPLORATION/INVESTIGATION

The earliest geological work in Jaintia Hills dates back to the 19th century, starting with Oldham (1859) and followed up by Medlicot (1869), who contributed to establish the stratigraphy of the area. Evans (1932) divided the Jaintia series into three stages: Therria, Sylhet Limestone, and Kopili in ascending order. Later on, Wilson and Metre (1953) revised Evans' classification, subdividing the Sylhet Limestone into various stages like Lakadong Limestone, Lakadong Sandstone, Umlatdoh limestone, Narpuh sandstone and Prang limestone in ascending order. The lower sandstone and limestone bands of Therria ghat section is designated as Upper Therria substage and Lower Therria substage by them.

Limestone exploration has been done in several periods in Jaintia Hills by GSI, particularly in Litang Valley. Later Duara & Burman (1966-67) mapped a 0.35 sq. km area in the west of Nongkhlieh Ridge and estimated limestone resorce of 16 million tonnes. Deb Adhikari (1969-70) reported a 60m-thick limestone deposit near Umkyrpong village, situated in north-eastern flank of Jaintia Hills. Murthy et al. (1976) introduced the Shella Formation to replace the Sylhet Limestone stages. The Therria Sandstone below the Lakadong Limestone in Therriaghat section was included as part of Shella Formation and the underlying fourth band of limestone and shale were grouped as Langpar Formation. They also introduced new terms like 'Sylhet Sandstone' and reorganized the stratigraphy. The term Lakadong, Umlatdoh and Narpuh were replaced by the names Lower, Middle and Upper Sylhet Sandstone, Limestone respectively.

A detailed geological survey was conducted by Chawade et al. (1990) on 1:50,000 scale around Litang Valley, identifying limestone over 100 sq. km. Based on this, Thiruvengadam et al. (1989-93) estimated a potential resource of 2,265 million tonnes of limestone over all grades with an area of 16 sq. km in the western part of the Litang river as per E-1 stage investigation. Exploration for limestone under E-II stage commenced during FS 1992-93. Thereafter exploration in different stages has been done and estimated a resource of approximately 9,915 million tonnes (Sumar, 2018).

In Assam, different cement grade limestone blocks have been explored by State D.G.M. in Garampani and Umrangso area of Dima Hasao district. The estimated resource of the limestone blocks are estimated to be 4.6 million tonnes in Tumbung area, 26.7 million tonnes and 105.6 million tonnes in 16 KM and 21 KM posts, respectively, on the Garampani-Lanka Road and 44.14 million tonnes in New Umrangshu (Kakati and Kalita, 1974 and Kakati et al., 1982).

During FS 2019-20, two adjacent limestone blocks were explored by GSI under G-3 stage in Dima Hasao district of Assam, namely North Boro Hundong Block and South Boro Hundong Block. About 474.78 million tonnes & 592.63 million tonnes of limestone resource (categorized under 333 class of UNFC classification) is estimated for North Boro Hundong Block and South Boro Hundong Block, respectively.

3.2 DETAILS OF EARLIER AEROGEOPHYSICAL AND GEOPHYSICAL MAPPING

No Aerogeophysical and geophysical mapping was carried out in the study area.

CHAPTER 4

GEOLOGY OF THE AREA

4.1 REGIONAL GEOLOGY

The Assam-Meghalaya Granites and Gneisses, dating to the Archean-Proterozoic, form the basement of the region. Overlying these are the Proterozoic Shillong Group rocks, intruded by Neo-Proterozoic to Early Paleozoic granites, followed by Gondwana sediments, which are intruded by Cretaceous Sylhet Traps and alkaline rocks. The Shella Formation (Paleocene-Eocene) directly overlies the granitic basement and consists of alternating sandstone and limestone sequences, with the Upper Sylhet Limestone at its top. The Kopili Formation, which sharply overlays the Upper Sylhet Limestone, contains greyish shale, sandstone, black shale, and fossiliferous limestone. The region is tectonically active, with the Kopili Fault marking a NW-SE trending strike-slip fault, alongside other thrust and minor faults resulting from the subduction of the Indian plate beneath the Eurasian plate. The regional geology of the area is shown in **Fig.4.1** and the regional stratigraphy table is shown in **Table 4.1**.

4.2 ASSAM-MEGHALAYA GNEISSIC COMPLEX

The Assam-Meghalaya Gneissic Complex, located to the north, forms the basement beneath the unconformably overlying Shella Formation of the Jaintia Group. Comprising para- and ortho-gneiss, migmatites, and metasedimentary layers, it is intruded by amphibolites, metadolerites, and metapyroxenites. Biotite-bearing quartzo-feldspathic gneisses are the most common. This complex has undergone multiple deformation and metamorphic events (GSI, 2009) and is considered an extension of the Peninsular India (Evans, 1932), with the Dawki Fault separating the Shillong Plateau from the Indian shield. It is widespread across central Assam and found in isolated inselbergs in the western Brahmaputra plains (GSI, 2019).

4.3 JAINTIA GROUP

4.3.1 Langpar Formation

The Cretaceous-Eocene sequence exposed in the southern and southeastern margin of the Shillong Plateau consists of Mahadek Formation overlain by Langpar Formation.

Langpar Formation is exposed in Meghalaya and comprises a 200 m thick succession of impure sandy limestones and shales containing molluscan shells of Danian age. The micro-faunal assemblage of the Langpar Formation includes Angulogerina, Anomalina, Cibicides, Coleites, Globigerina, Trifarina, and Veginulina. The faunal assemblages of Mahadek and Langpar Formations indicate shallow water open sea environments of deposition.

4.3.2 Shella Formation

The Jaintia Group that conformably overlies the Langpar Formation has been subdivided into two formations. It is well-developed, consisting of three limestone bands intercalated with three clastic sandstone units. The basal Theria-Cherra Sandstone Member has been reclassified as the Lower Sylhet Sandstone Member. The Upper Sylhet Limestone Member has been traced north-eastward from the Jaintia Hills into the North Cachar and Mikir Hills (GSI, 2019).

In the Garampani area, a single limestone horizon is underlain by sandstone, marking the base of the formation. The limestone, referred to as the Sylhet Limestone Member in Meghalaya, corresponds to the Upper Sylhet Limestone Member found along the southern scarp of Meghalaya. The underlying Lower Sylhet Sandstone Member in Assam represents a facies variant of the limestone and sandstone units exposed along the southern scarp of the Meghalaya Plateau. The Lower Sylhet Sandstone in Garampani unconformably rests over the Precambrian basement and includes thick sandstone beds interbedded with shale, carbonaceous shale, and thin coal seams. In some areas, the sandstone is quartzitic in nature (GSI, 2019).

The overlying Upper Sylhet Limestone in Garampani consists of thick beds of foraminiferal limestone with minor shale and marl bands. The limestone is hard and compact, with several sets of vertical joints, which have created karst topography and solution channels. Fossils such as *Nummulites bagelensis*, *Assilina spira*, *Coperculina sp.*, and *Alveolina elliptica* in the Upper Sylhet Limestone indicate a Middle to Upper Eocene age (GSI, 2019).

4.3.3 Kopili Formation

The Shella Formation is conformably overlain by the Kopili Formation, which consists mainly of greyish, ferruginous, splintery shales interbedded with sandstone and calcareous marl of variable thickness. It follows a similar conformable trend to the underlying Shella

Formation. The Kopili sequence includes white sandstone, calcareous or grey shales, sandy shales, ferruginous shales, and coaly material (GSI, 2019).

The Kopili Formation has a gradational contact with the Shella Formation, marked by a highly fossiliferous limestone layer, rich in mega fossils of *Nummulites*, *Discocylina*, and shell fragments. The lower part of the Kopili Formation, predominantly dark brown to dark grey shale, contains abundant phosphatic nodules. Fossils such as *Nummulites Pengaroensis* and *Globigerina semi Involuta* found in the Kopili Formation indicate an Upper Eocene age (GSI, 2019).

4.4 METAMORPHISM AND STRUCTURAL FABRIC OF THE AREA

The area is mostly covered by Tertiary sediments, with no regional metamorphism occurring. The bedding in the Tertiary Group rocks trends NNE-SSW to NE-SW with a moderate dip southeast. The Assam-Meghalaya Gneissic Complex (AMGC) is rarely exposed but has undergone regional metamorphism, ranging from amphibolite to granulite facies. The structural framework of the complex is complex, showing evidence of polyphase deformation and intrusion. At least two folding phases are recognized: one along an E-W axis and another along a NE-SW axis, with a third phase indicated by N-S upwarps and tight synforms.

4.5 SURFACE INDICATION OF MINERALISATION

The fossiliferous upper sylhet limestone of the Shella Formation covers 60% of the block. This limestone forms gentle undulations in the landscape, creating a relatively smooth and rolling topography. The beds of limestone are generally horizontal or sub-horizontal, and they appear at the surface as outcrops. These outcrops often develop karst topography, which is characterized by features like sinkholes, caves, and other erosion-related landforms. The limestone is also exposed along nalas (small streams or seasonal watercourses) and other areas like sinkholes, further indicating its presence across the region.

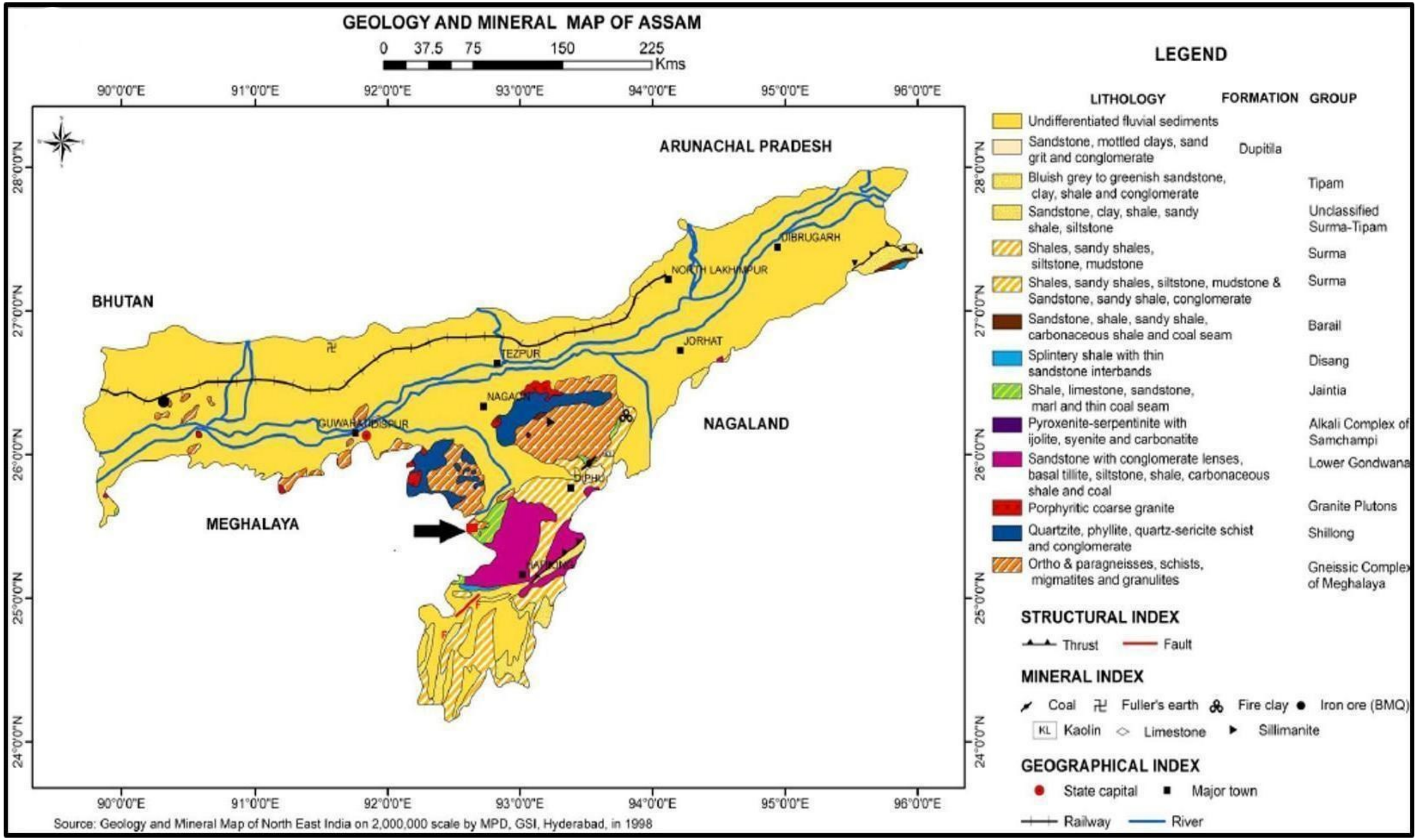

Fig. 4.1 Regional Geological Map of Assam

Table-4.1: Regional stratigraphy of the Meghalaya and adjoining areas of Assam

Sr No	Toposheet No	AGE	GROUP	FORMATION/ROCK TYPE
1	83C11	Holocene	Newer Alluvium	Sand, Silt and Clay
2	83C11	Pleistocene	Older Alluvium	Sand, Clay, Pebble, Gravel & Boulder deposits
3	83C11	Pliocene- Pleistocene	Dupitila	Dupitila- Siltstones, clays, conglomerates
4	83C11	Mio -Pliocene	Garo Group	Chengapara/Barengapara/Boldamgiri/Angortoli- Siltstones, clay and minor calcareous bands
5	83C11	Miocene		Baghmara Formation/Dalu- Siltstones, conglomerates& minor sandstones
6	83C11	Eocene- Oligocene		Simsang Formation/Chokpotgiri Formation (Khasi Hills) - Siltstones & mudstone
7	83C11	Palaeocene- Eocene	Jaintia Group	Kopili Formation- Shale & minor sandstones, Shella Formation- Sandstone & minor coal, Langpar Formation - Calcareous sandstones
8	83C11	Late Cretaceous-Early Tertiary	Sung (Khasi Hills) Alkaline complex	Pyroxenite, ijolite, syenite & carbonatite
9	83C11	Late Cretaceous	Khasi Group	Mahadek Formation- sandstone, Bottom Conglomerate – conglomerate, Jadukata Formation- sandstone
10	83C11	Jurassic- Cretaceous	Sylhet Trap	Basic Volcanics
11	83C11	Late Carboniferous- Permian	Lower Gondwana (Garo Hills)	Karharbari Sandstone and minor coal Talchir Formation
12	83C11	Neoproterozoic -	Kyrdem, Nongpoh,	Pink and grey porphyritic granitoids with mafic (boninite plutonic equivalents),
13	83C11	Early Paleozoic	Mylliem granite, South Khasi Batholith, Seindhuli	diorite, granodiorite or mangerite/gabbroic, anorthositic, early differentiates.
14	83C11	Mesoproterozoic(?) (1450&1462 Ma)	Basic Intrusives	Norite, noritic gabbro and diorite
15	83C11	Meso- Proterozoic (<2500 M.a.)	Shillong Group	Quartzite, phyllite, with minor meta rhyolite, tuffs and conglomerates
16	83C11	Paleo to Meso-Proterozoic (1150to 1714 + 44 Ma)	Meghalaya- Assam Gneissic Complex	Pink granite & augen gneisses, charnockitic gneiss and charnockites
17	83C11	Paleo-MesoProterozoic(?)	Umsning Schist Belt	Quartz mica schist, micaceous quartzite, black biotite-quartzite and carbonaceous phyllite/graphitic schist, quartz-hornblende biotite schist with sillimanite, sillimanite rock, etc.
18	83C11	Archaean- Early Proterozoic (?)	Older Gneisses (2230+13 to 2637+55 Ma)	Grey dioritic gneiss & tonalitic granulite
19	83C11		Older Basic Intrusives	Basic granulite occasionally associated with magnetite& cordierite- spinel-sphene granulite; anthophyllite-sapphirine & tremolite-actinolite with hornblende rocks
20	83C11		Riangdo or Sonapahar High-Grade Metasedimentaries	Sillimanite-corundum rocks, sapphirine spinel bearing rocks, sillimanite-quartzite, garnet-sillimanite quartzo-feldspathic rock, sillimanite ferruginous schist (Khondalite?), BMQ, calc-granulite & chert (occurring as caught up patches and enclaves in gneisses).
	- Basement unknown -			

CHAPTER 5

GEOSCIENCE INVESTIGATION

5.1 DETAILED GEOLOGICAL MAPPING

An area of 4.82 sq. km was mapped on 1:4,000 scale with a contour interval of 2m using DGPS. The contour plan is shown in the **Fig.5.1**. A Differential Global Positioning System (DGPS) survey (**Fig.5.2)** was conducted over the entire block to generate accurate topographic contours. High-precision DGPS equipment, supported by a fixed base station, was used to collect precise elevation data. This data was processed using GIS and CAD software to develop detailed contour maps for surface modeling and resource estimation. The NW of Boro Lakhindong block is exposed with the sedimentary rocks comprising of Shella and Kopili Formations of Jaintia Group of Eocene age. The upper sylhet limestone member of the Shella Formation is exposed in approximately 60% of the block area. The remaining area is covered by Kopili Formation, exposed mainly in the north-eastern, south- eastern and south-western part of the given block **(Plate-II)**. The Litho-stratigraphy succession in the area is given in **Table 5.1**.

Table 5.1 Litho-stratigraphy of the study area

Age	Group	Formation	Member	Lithology
Paleocene-Eocene	Jaintia Group	Kopili Formation	-	Greyish shale, marl & reddish-brown sandstone. Lower part has phosphatic nodules
		Shella Formation	Upper Sylhet Limestone	Light grey to dark grey, highly fossiliferous, compact limestone
			Upper Sylhet Sandstone**	Medium-grained grey sandstone with coal streaks, dark shale and specks of pyrites

**Not exposed but intersected in boreholes (PBH-01). The RL of PBH-01 is 731.00m and Upper Sylhet Sandstone member of Shella Fm. is encountered at 82.76m depth in that borehole.

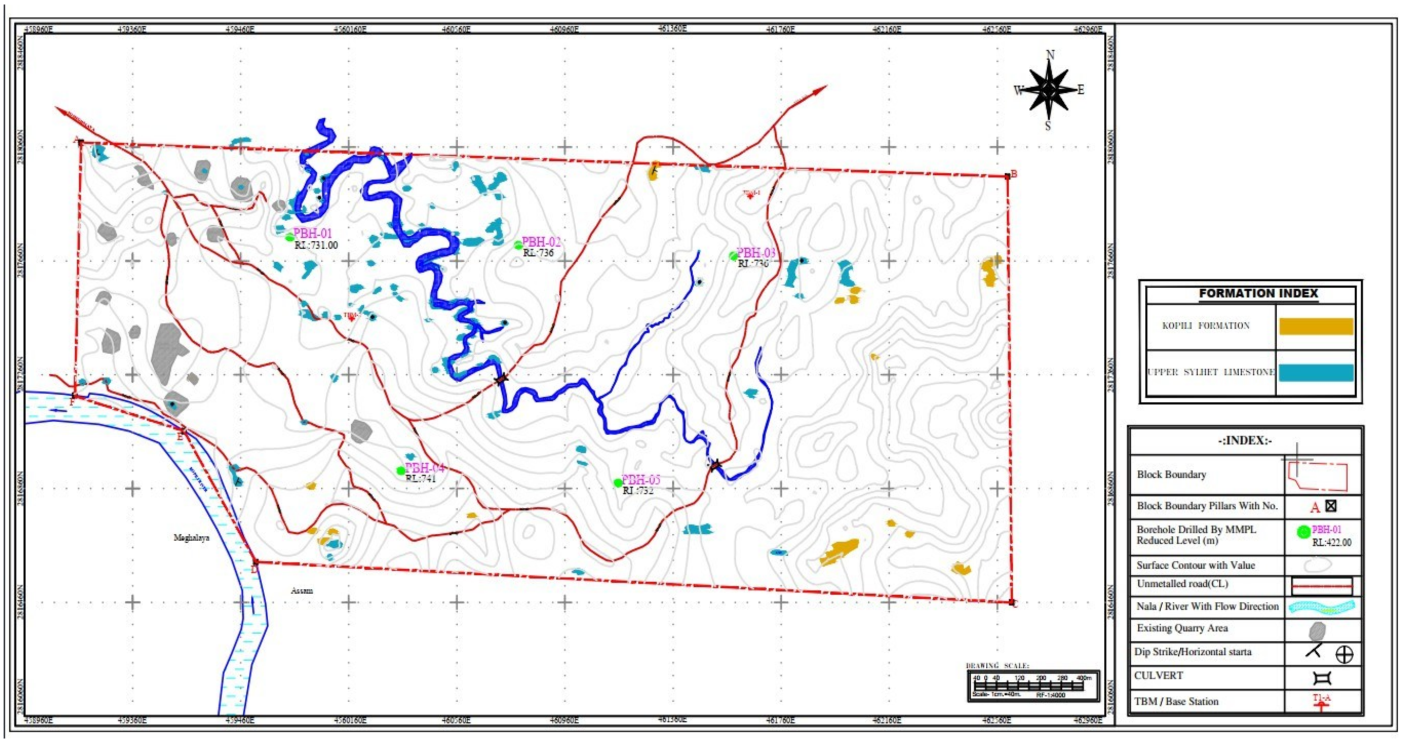

Fig. 5.1 Topographical map of Northwest of Boro Lakhindong showing contours and proposed borehole locations.

Fig.5.2: Topographical survey done by DGPS

5.2 DESCRIPTION OF LITHOLOGY

The various litho-units are exposed in the block as well as those which are encountered in the boreholes are described below.

The Shella Formation is divided into two members: the lower Upper Sylhet Sandstone and the topmost Upper Sylhet Limestone. The Upper Sylhet Sandstone is not exposed in the area but it is encountered only in one borehole. Around 60% of the block is covered with the Upper Sylhet Limestone of the Shella Formation.

Upper Sylhet Sandstone, the contact between the Upper Sylhet Sandstone and the overlying Upper Sylhet Limestone is gradational in nature (**Fig.5.3)**. It comprises of medium to coarse grained, grey coloured sandstone and laminations of black shale. Streaks and patches of coal are also found in this member. The Upper Sylhet Sandstone is not exposed on the surface but is encountered in the core of borehole PBH-01(**Fig.5.4)**. It mainly consists of alternating layers of sandstone and black shale. The contact between the Upper Sylhet Limestone and Upper Sylhet Sandstone is indicated by subsurface drilling data (**Fig.5.3)**.

Upper Sylhet Limestone, The Upper Sylhet Limestone occupies the central and north-western part of the block area. This comprises thickly bedded, light to dark grey, mostly medium grained, fossiliferous (**Fig.5.5 & 5.6)** and compact limestone. On surface, it is often exposed as a stacked body of rock & bedded deposits. Bedded limestone deposits are observed on the banks of Kopili River and in the nearby nala sections of the block (**Fig.5.8)**. Due to the extensive dissolution of limestone, it has led to the development of Karst topography (**Fig.5.7)** in the area. Small caves and gully like features are seen in this area.

Fig 5.3. Photograph of core showing contact between Upper Sylhet Limestone & Upper Sylhet Sandstone member.

Fig 5.4. Photograph of core showing intercalation of shale and sandstone of Upper Sylhet Sandstone member

The thickness of limestone varies significantly across the boreholes, ranging from 4.00 m to 82.76 m in PBH-01, 4.40 m to 100.00 m in PBH-02, 15.78 m to 100.00 m in PBH-03, 15.80 m to 100.00 m in PBH-04, and 16.14 m to 100.00 m in PBH-05 as it is evident from **Table 7.1**. Based on the limestone thicknesses recorded in all five boreholes, the average thickness has been calculated to be 85.32 m. This average represents the mean value of limestone thickness across the boreholes, highlighting the substantial and relatively consistent presence of limestone in the area. Shale intercalations are common in the upper part of Upper Sylhet Limestone due to its gradational nature of contact with the overlying Kopili Formation (Fig.5.14). These intercalations of shale which are recorded in all boreholes except in borehole (PBH-01), situated in the north-western part of the area. These intercalations may be the reason for the grade fall of limestone in the upper part of the Upper Sylhet Limestone. The strike of the limestone beds is N10°E-S10°W, dipping towards south-east and the dipping of the limestone beds are sub-horizontal to horizontal in nature **(Fig.5.8)**.

In cores, bedding parallel stylolites and mud partings are observed (Fig.5.11). The Upper Sylhet Limestone has well preserved fossils of Nummulite sp., Assilina sp., Discocyclina sp., Alveolina sp., etc. **(Fig.5.9)**.

Fig 5.5. Field Photograph of Upper Sylhet Limestone showing Nummulite sp. and Alveolina sp. fossils.

Fig 5.6. Field photograph of Upper Sylhet Limestone showing Nummulites fossils in abundance.

Fig 5.7. Field photograph showing a karst feature outcrop of Upper Sylhet Limestone.

Fig 5.8. Field photograph showing thickly bedded outcrop of Upper Sylhet Limestone.

Fig 5.9. Photograph of core of brownish cherry red fossiliferous limestone showing Discocyclina sp and Alveolina sp fossils (PBH-02).

Fig 5.10. Photograph of core of highly fossiliferous limestone of Upper Sylhet Limestone encountered in borehole PBH-01 (15.92m to 19.93m depth)

Fig 5.11. Photograph of core of Upper Sylhet Limestone showing Stylolite.

Kopili Formation, The Kopili Formation overlies the Upper Sylhet Limestone Member of Shella Formations having a gradational contact (**Fig.5.14**). Around 40% of the area is covered by rocks of Kopili Formation.

It consists of grey-coloured shale (**Fig.5.13)** and fine to medium grained, reddish-brown sandstone (**Fig.5.12)**. The shale of Kopili Formation is encountered in boreholes in all the boreholes except PBH-01.

Fig 5.12. Field Phototograph of Sandstone of Kopili Formation.

Fig 5.13. Field Phototograph of Shale & Sandstone of Kopili Formation.

Fig 5.14. Photograph of core showing contact between Kopili Formation and Upper Sylhet Limestone (PBH-03).

5.3 PETROLOGICAL STUDIES

Petrographic examination of thin sections of 2 bedrock samples and 3 borehole core samples from Northwest of Boro Lakhingdong Block, Assam has been conducted. This study was aimed at elucidating the mineralogical and textural variations in the samples.

PETROGRAPHIC STUDY OF LIMESTONE SAMPLES:

5.3.1 SAMPLE ID: BLD 37 (BEDROCK SAMPLE)

The bedrock comprises fossiliferous limestone classified as biomicrite, dominated by microcrystalline calcite (micrite) forming a dense matrix as shown in **Fig.5.15**. The allochemical fraction primarily consists of foraminiferal fossils, including Nummulites, Assilina, Alveolina, and Discocyclina sp., with occasional bivalve fragments.

Fossil shells and quartz grains exhibit partial to complete calcite replacement, while sparry calcite infills pore spaces and fossil chambers. Intraclasts appear as fine-grained, dark grey fragments, whereas oolites and peloids are rare. The presence of micritic lime mud suggests a low-energy depositional setting, while polysynthetic twinning in calcite grains indicates diagenetic overprinting.

Fig 5.15: Photomicrograph from BLD37 showing *Nummulites and Alveolina* foraminifera in a micritic cement (in PPL)

5.3.2 SAMPLE ID: BLD/C1 (CORE SAMPLE)
BOREHOLE NO.: PBH-01
DEPTH OF SAMPLE: 18.30 m

This sample consists of a fine to medium-grained limestone matrix dominated by microcrystalline calcite and lime mud (micrite), characteristic of the Upper Sylhet Limestone. It contains an abundance of Discocyclina sp., with megafossils distinctly visible. Fossil cores exhibit partial to complete replacement by microcrystalline calcite, while the matrix remains micritic, embedding terrigenous components. The presence of lime mud and calcitic infillings in fossil chambers suggests a low-energy, shallow marine depositional setting. Photomicrographs shown in **Fig.5.16**.

5.3.3 SAMPLE ID: BLD/C2(CORE SAMPLE)
BOREHOLE No.: PBH-02
DEPTH OF SAMPLE: 96.70 m

This limestone sample is dominated by Nummulites sp., which are almost entirely replaced by granular calcite. The matrix consists of sparry calcite cement, filling pore spaces and fossil chambers, indicating post-depositional recrystallization. Other completely calcified fossil fragments are embedded within the calcite groundmass, with occasional intraclasts present as fine-grained, dark grey fragments. The reduced presence of micrite compared of other samples and increase of sparry cement suggest a higher-energy setting with significant diagenetic overprinting. Photomicrographs shown in **Fig.5.17**.

5.3.4 SAMPLE ID: BLD/C3(CORE SAMPLE)
BOREHOLE No.: PBH-04
DEPTH OF SAMPLE: 62.50 m

This sample is primarily composed of microcrystalline calcite, forming a dense micritic groundmass. Nummulites sp. dominates the allochemical fraction, with Discocyclina also present in notable amounts. Some fossil shells show partial calcite replacement, while others retain well-preserved structures. The presence of fine-grained lime mud, coupled with embedded allochems, indicates a low-energy depositional environment, characteristic of the Upper Sylhet Limestone. Photomicrographs shown in **Fig.5.18**.

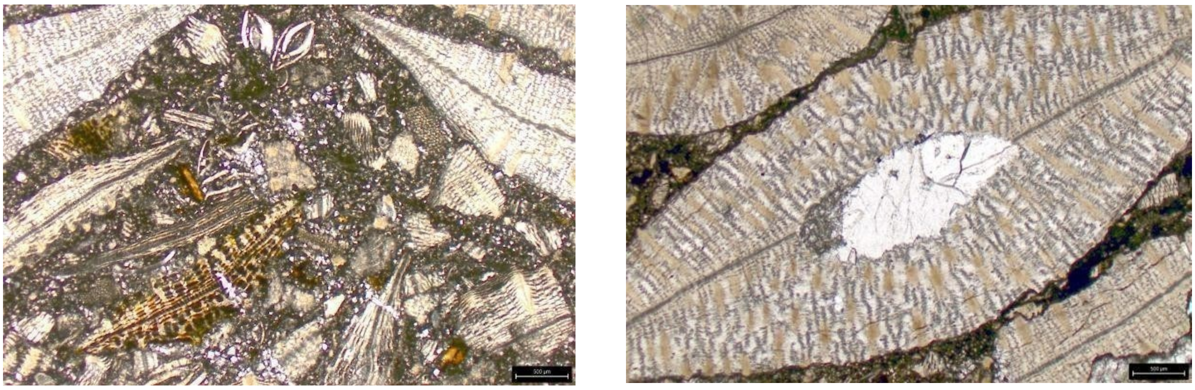

Fig 5.16: Photomicrograph from BLD/C1 showing Discocyclina sp foraminifera in PPL embedded in micritic cement and some fossil cores being altered to calcite grains.

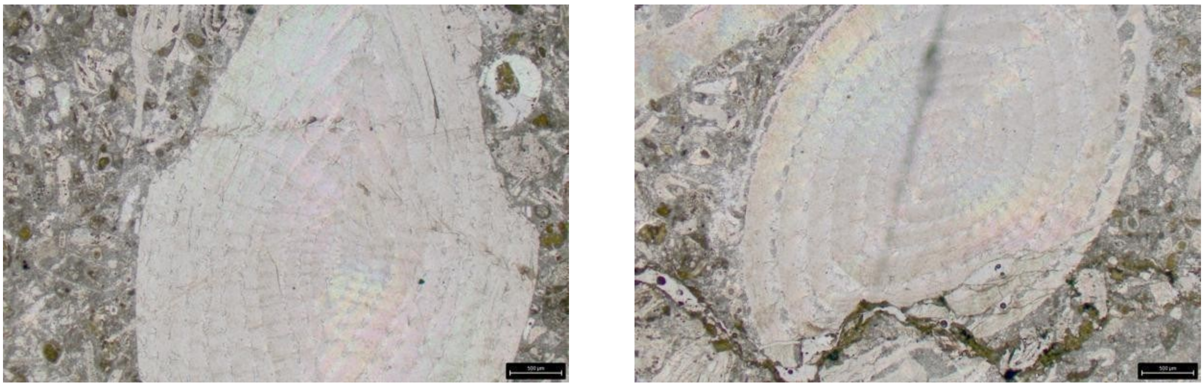

Fig 5.17: Photomicrograph from BLD/C2 showing calcified fossils within spary cement

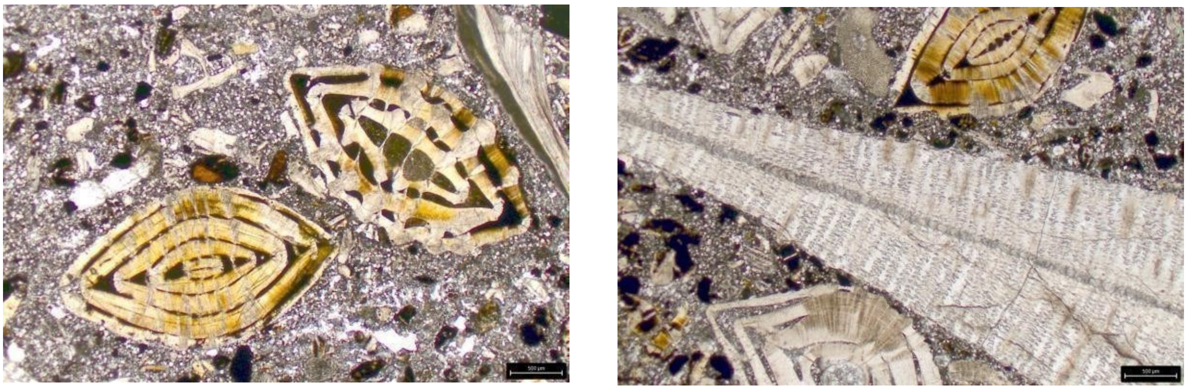

Fig 5.18: Photomicrograph from BLD/C3 showing *Nummulites and some Discocyclina sp* foraminifera in micritic cement (in PPL)

OVERVIEW OF THE OBSERVATIONS:

MEGASCOPIC DESCRIPTION

The limestones in the study area exhibit a color range from light greyish- white to dark grey and are predominantly fine- to medium-grained.

MICROSCOPIC DESCRIPTION

Petrographic examination reveals that the limestones are primarily composed of microcrystalline calcite, classifying them within the orthochemical group. Fossils form the dominant allochemical component, primarily composed of Nummulites sp., along with other foraminifera such as Assilina sp., Alvelina sp. and Discocyclina sp. The detailed petrographic observations are described below.

(a) Mineralogical Composition

- **Orthochemical Constituents**

The matrix of the limestone is composed of microcrystalline calcite and lime mud (micrite). These micritic calcium carbonate muds play a crucial role in the formation of the Upper Sylhet Limestone. The terrigenous components and allochemical constituents are embedded within a fine-grained calcite groundmass. In some cases, fossil shells and quartz grains exhibit partial to complete replacement by microcrystalline calcite. Certain samples display a matrix composed entirely of micrite, with occasional polysynthetic twinning observed in calcite grains. The microcrystalline calcite also occupies pore spaces within fossil chambers and sometimes replaces quartz.

- **Allochemical Constituents**

Allochems are chemically or biochemically precipitated materials that have undergone limited transportation within the depositional basin. The allochemical fraction in the Upper Sylhet Limestone predominantly comprises fossil allochems, constituting >50% of the rock. The foraminiferal assemblage includes Nummulites sp., Assilina sp., Alveolina sp., and Discocyclina sp. **(Fig. 5.16–5.19)**, forming the major allochemical components. Broken skeletal fragments are also prevalent. There are some bivalve fossils also present within these samples. In most cases, these fossils are composed of calcite, with granular calcitic material infilling their internal cavities. Oolites and pellets are rarely observed, while intraclasts appear as fine-grained, dark grey fragments.

Based on Folk's (1959) classification, the fossiliferous limestone of the Upper Sylhet Limestone is categorized as a biomicrite.

Identifying Properties of Limestone in this thin section

i. Optical Properties

- **PPL:** Light to dark brown (micrite) or colorless (pure calcite).
- **XPL:** Low to high birefringence, depending on grain size.
- **Relief:** Low.

ii. Mineralogy

- **Dominant:** Microcrystalline calcite (micrite) or sparry calcite.
- **Secondary:** Quartz (undulatory extinction), clay.

iii. Texture & Fabric

- **Micrite Matrix:** Fine-grained, dense groundmass.
- **Sparry Calcite:** Coarser cement filling pore spaces.
- **Fossils:** *Nummulites*, Discocyclina, *Assilina*, *Alveolina* sp., often well-preserved.
- **Ooids/Peloids:** Rare, but some in some places indicating high- energy settings.

iv. Diagenetic Features

- **Recrystallization:** Micrite transforming into sparry calcite.
- **Stylolites:** Wavy pressure-solution seams.
- **Compaction Effects:** Fossil compression under burial stress.

Classification

- **Micrite-Dominated:** Low-energy settings (lagoon, deep marine).
- **Fossiliferous:** High biogenic productivity.

Feature	Micritic Limestone
Grain Size	<4 μm (fine)
Birefringence	Low
Texture	Dense, compact
Fossil Content	High
Cement Type	Calcitic cement

The presence of Nummulites sp., Assilina sp., Alveolina sp., and Discocyclina sp. confirms the Eocene age (Lutetian–Bartonian) of the deposit, aligning with the known fossil assemblage of the Upper Sylhet Limestone. This validates the formation classification and its deposition in a shallow marine setting.

The following photomicrographs visually depict the discussed fossil assemblage and micritic groundmass, confirming the petrographic characteristics of the Upper Sylhet Limestone **(Fig.5.19-5.48)**.

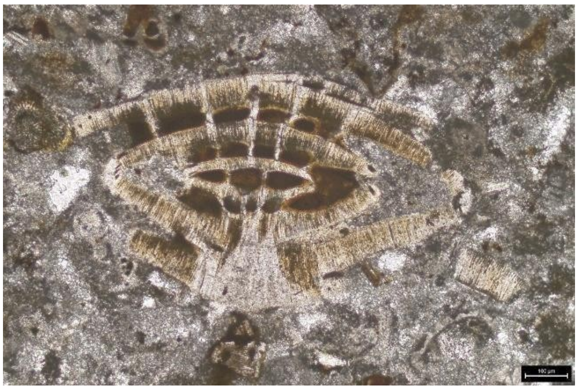

Fig 5.19: Photomicrograph showing *Nummulitesattacius* foraminifera (in PPL)

Fig 5.20: Photomicrograph showing bivalve fossil under PPL

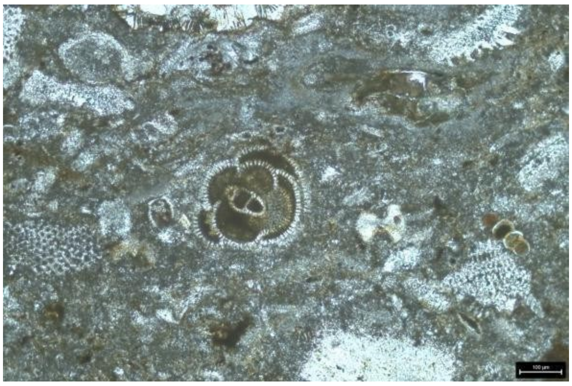

Fig 5.21: Photomicrograph showing rotalida foraminifera in PPL

Fig 5.22: Photomicrograph showing Nummulitessp. foraminifera (in PPL)

Fig 5.23: Photomicrograph showing broken skeletal fragments

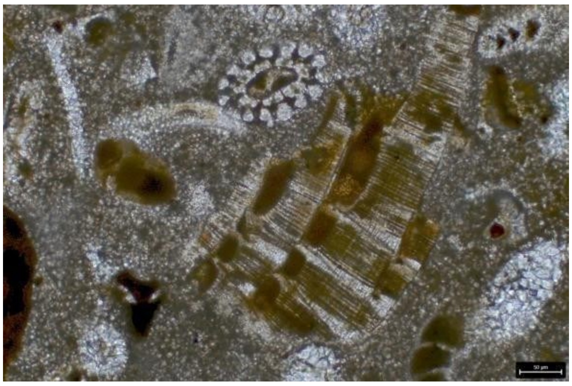

Fig 5.24: Photomicrograph showing broken shell of Nummulites atacicus Foraminifera and a small echinoderm (in PPL)

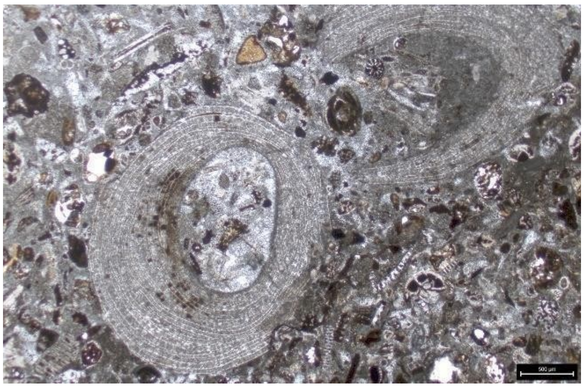

Fig 5.25: Photomicrograph showing ooid with concentric rings of numulites and a central core replaced by calcite (in PPL)

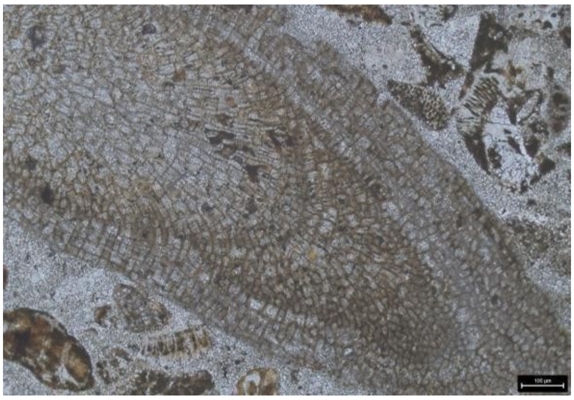

Fig 5.26: Photomicrograph showing Nummulitessp. foraminifera (in PPL)

Fig 5.27: Photomicrograph showing Nummulitessp. foraminifera (in PPL)

Fig 5.28: Photomicrograph showing Rotalida foraminifera in PPL

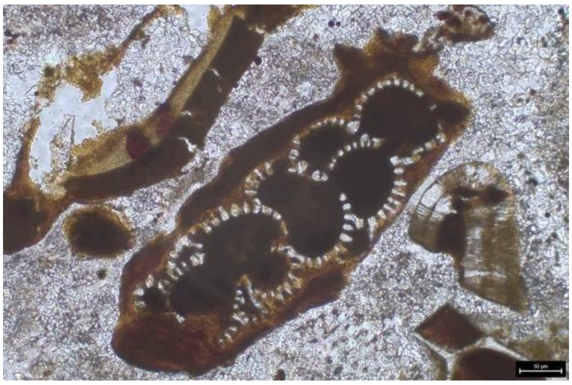

Fig 5.29: Photomicrograph showing Nummulitessp. Foraminifera in PPL

Fig 5.30: Photomicrograph showing Nummulitessp. Foraminifera in PPL

Fig 5.31: Photomicrograph showing Assilina spinosa foraminifera (in PPL)

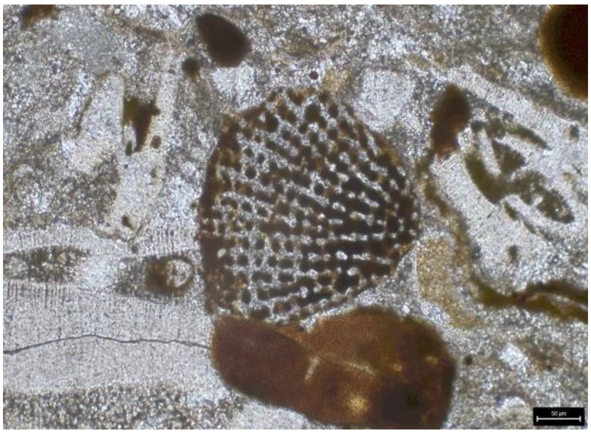

Fig 5.32: Photomicrograph showing Cuneolina in PPL

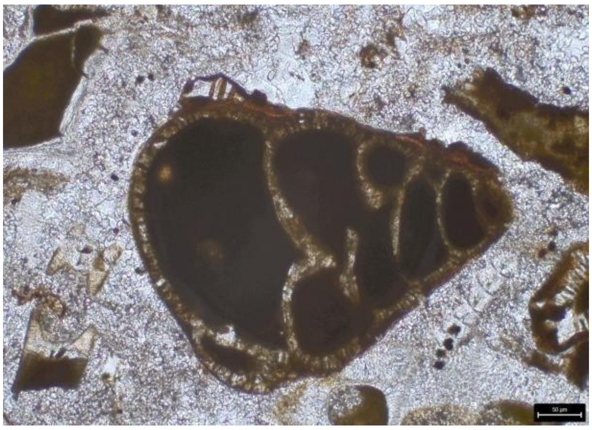

Fig 5.33: Photomicrograph showing Praechrysalidina sp. Longitudinal sections (in PPL)

Fig 5.34: Photomicrograph showing bivalve fossil in PPL

Fig 5.35: Photomicrograph showing Alveolina oblonga (in PPL).

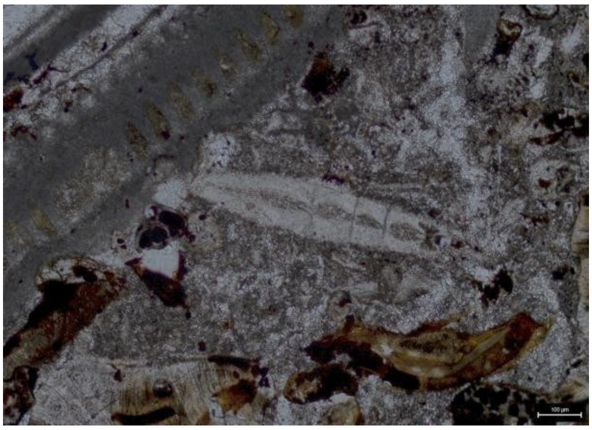

Fig 5.36: Photomicrograph showing Assilina sp. Foraminifera (in PPL)

Fig 5.37: Photomicrograph showing broken part of Alveolina nuttalli. (in PPL).

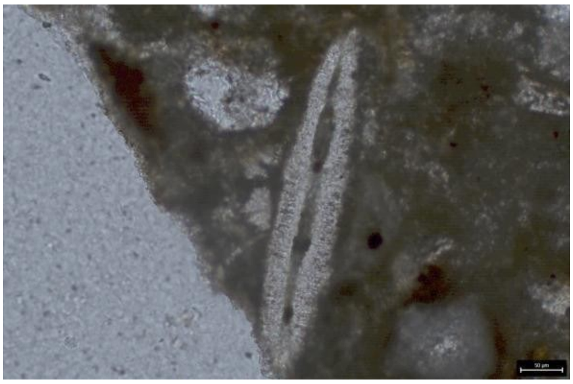

Fig 5.38: Photomicrograph showing Assilina sp. Foraminifera (in PPL)

Fig 5.39: Photomicrograph showing Nummulitessp. Foraminifera (in PPL)

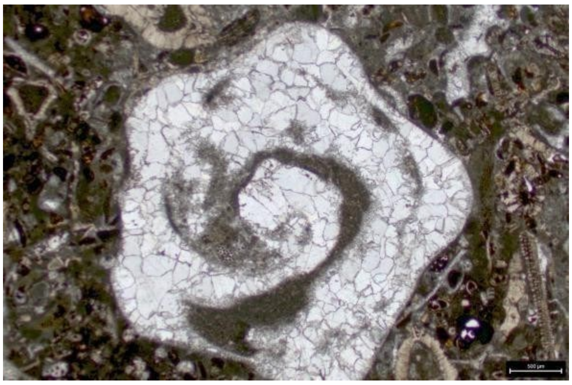

Fig 5.40: Photomicrograph showing Asterocyclinasp. Completelyalteredby calcite

Fig 5.41: Photomicrograph showing benthic foraminifera lepidocylina sp. (Dicyclina cf. schlumbergeri) in PPL

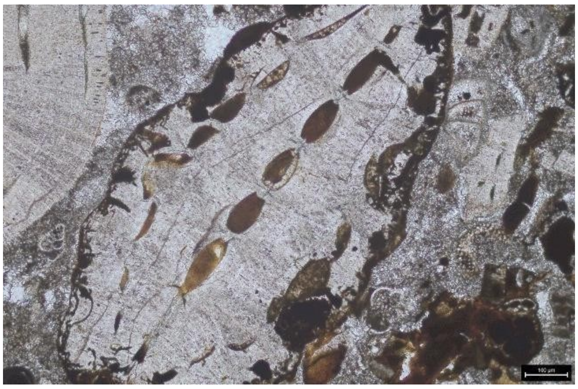

Fig 5.42: Photomicrograph showing Nummulites sp. Foraminifera of age Miocene (in PPL)

Fig 5.43: Photomicrograph showing Assilina spinosa foraminifera (in PPL)

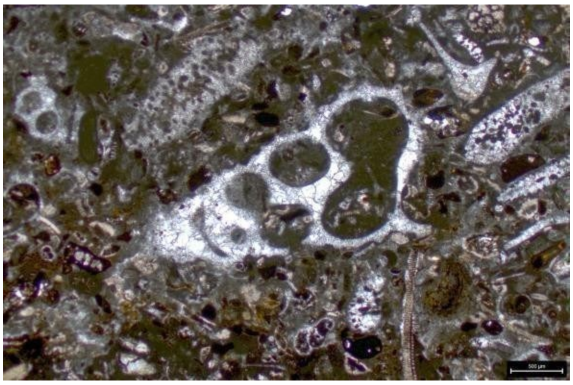

Fig 5.44: Photomicrograph showing Praechrysalidina sp. Longitudinal sections (in PPL)

Fig 5.45: Photomicrograph showing of broken parts of lepidocylina sp. in PPL

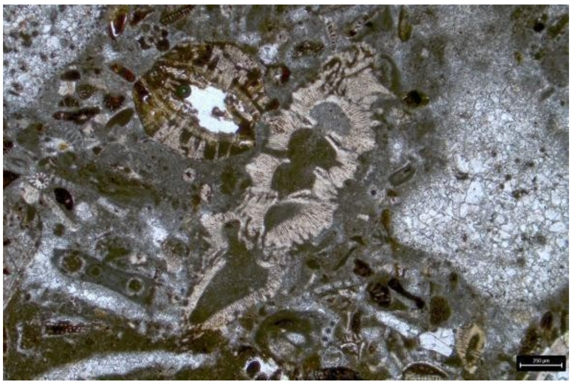

Fig 5.46: Photomicrograph showing Assilina spinosa foraminifera (in PPL)

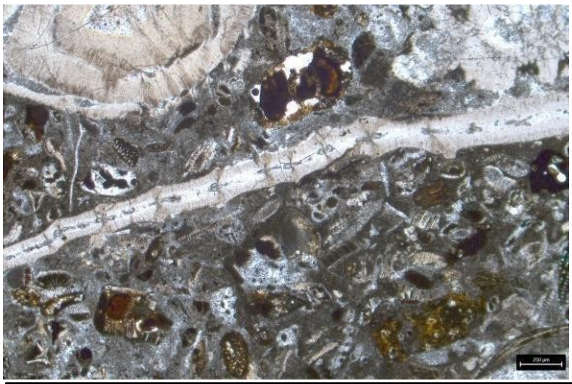

Fig 5.47: Photomicrograph showing Operculina sp. foraminifera (in PPL).

Fig 5.48: Photomicrograph showing Nummulitessp. Foraminifera (in PPL)

PETROGRAPHIC STUDY OF OTHER LITHOLOGICAL SAMPLES:

SAMPLE ID: BLD 41(BEDROCK SAMPLE)

The thin section reveals a composition primarily of quartz and feldspar grains, bound by a ferruginous cement. Lithic fragments are also present. Quartz grains are medium to fine-grained, sub-angular to sub-rounded, and exhibit moderate sphericity **(Fig.5.49)**. Both monocrystalline and polycrystalline quartz, the latter displaying undulose extinction, are observed. Grain contacts are predominantly long-contact, though concavo-convex contacts are also noted. In some instances, three or more grains are in direct contact. Heavy minerals are present in minor amounts.Modal analysis indicates quartz content exceeding 95%, with a matrix proportion of less than 15%. Based on this composition, the sandstone is classified as quartz arenite.

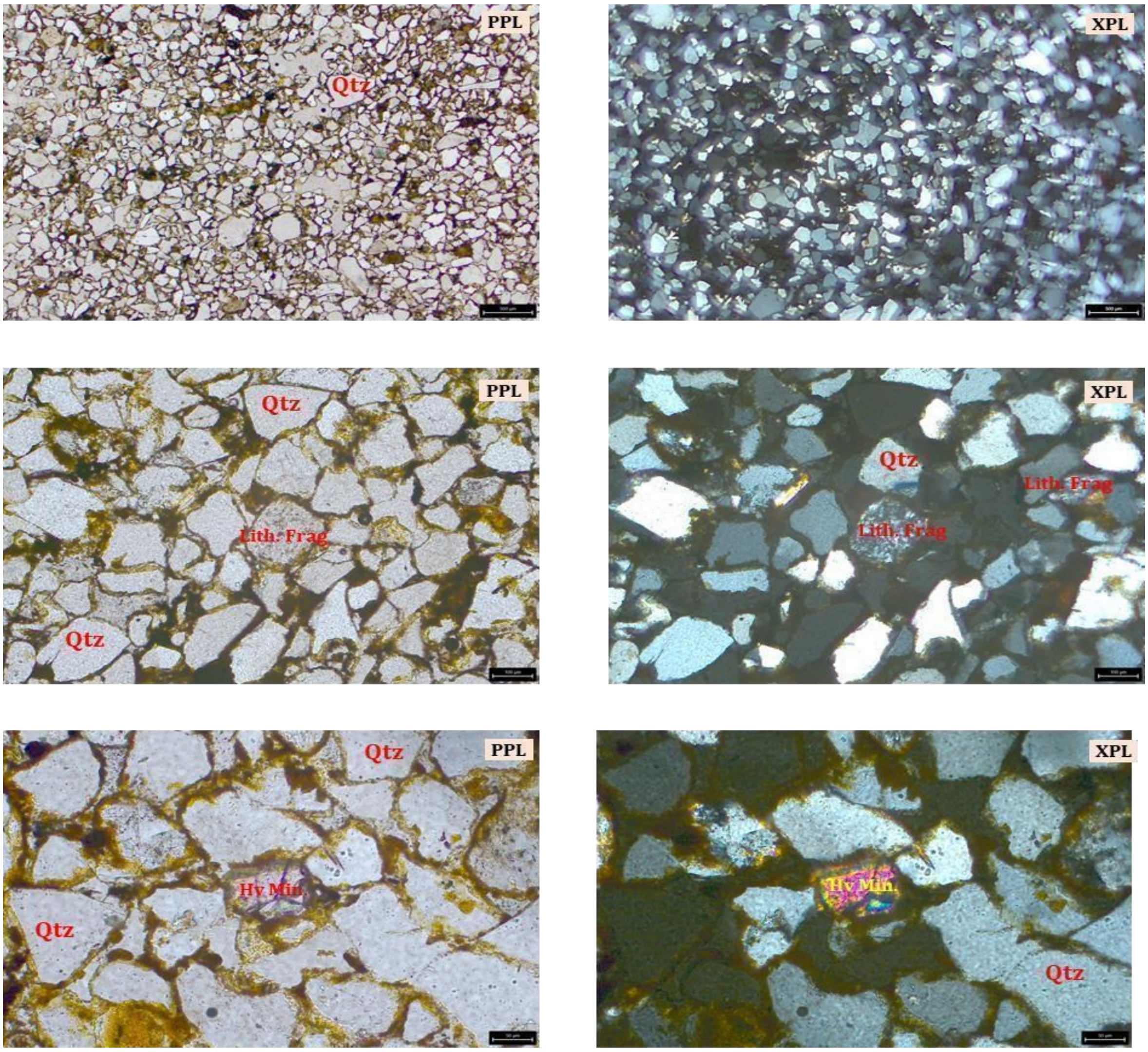

Fig 5.49: Photomicrograph showing of quartz grains within ferruginous cement under PPL and XPL

5.4 STRUCTURE

Primary structures: Bedding planes **(Fig.5.8)** are the most common primary structures. The general attitude of all the litho-units (Kopili Formation & Shella Formation) is sub-horizontal to horizontal in nature with a strike of N10°E-S10°W, dipping 1°-4° towards east and south-east. Laminations of dark grey shale are present in Fossiliferous Limestone, especially near the contact zone with overlying and underlying litho-units.

Secondary structures: Bedding-parallel stylolites **(Fig.5.11)**, consisting of a series of relatively small, alternating, interlocked, toothlike columns of stone, are found abundantly in limestone and are also observed within the core sections. Some vertical fractures are also observed in the cores.

On the basis of drilling data, there may be a presence of fault deciphered in the north western part of the block. According to the graphical lithologs correlation of drilled data a prominent shale layer is present in all the drilled boreholes except PBH-01 and Upper Sylhet Sandstone is encountered in PBH-01 at a depth of 82.76m **(PLATE-IV)**. Whereas in the other boreholes, the Upper Sylhet Limestone is continuing upto 100m depth. So, there may be a presence of low-angle dip fault or upliftment of strata due to some tectonic movements within the block. The fault is shown in detailed geological map as F-F between PBH-1 & 2, trending N27°E, with a throw of 25m towards ESE **(PLATE-II)**. There is no surficial evidence of the presence of the fault.

5.5 METAMORPHISM

No metamorphism has been observed within the study area as the area is comprises of fossiliferous limestone, Sandstone and Shale of Shella and Kopili Formation.

5.6 MINERALOGY OF THE ORE ZONES AND ORE TEXTURES

Fossiliferous Limestones exposed in the study areas are fine-medium grained and mainly composed of calcite mineral. Calcite form the major mineral of the shell of the fossils which is the major allochemical constituent of the limestone of Shella Formation. The microcrystalline calcite grained also occurred as groundmass where allochems are embedded.

5.7 SAMPLING

5.7.1 Petrological samples: 5 nos of petrological samples of different rock types or lithology have been collected from cores and outcrop of different lithology. Thin sections have been prepared in Shiva Analytical (INDIA) Private Limited. Petrographical study of the thin sections are described in section 5.3.

5.7.2 Petrochemical samples: 10 nos of samples from both bed rock and core samples have been chemically analysed at Shiva Analytical (INDIA) Private Limited. (ANNEXURE-VI)

5.7.3 Core sampling: 451 nos. of core samples have been collected from the mineralized zone of the cores and chemical analysis have been done at Shiva Analytical (INDIA) Private Limited (Annexure-IV). The processing of the analysed samples has been described in the later section 8.11 of Chapter 8. Core samples were collected at 1.00 m interval from the mineral zone.

5.8 DETAILS OF INTERPRETED ORE ZONES

In the exploration block, the fossiliferous limestone of Upper Sylhet Limestone covered 60 % of the block. This limestone occurred as thick bedded deposit and it exposed on the surface mainly on the north-western and southern side as an isolated outcrop within the soil covered near the nala sections. This limestone body have horizontal to sub-horizontal bedding with strike trending NNE-SSW to NE-SW with moderate dipping of 2 to 3° south-easterly.

5.9 ENVIRONMENT OF DEPOSITION

The collision of the Indian and Eurasian plates during the Paleocene marked the beginning of the extensive Himalayan foreland basin's formation, which subsequently became a depocenter for Paleocene-Eocene sequences, including the Kopili shale (Alam et al., 2003). Previous studies have documented various diagenetic alterations in the sandstones of the Kopili Formation, such as quartz grain fracturing, sutured grain boundaries, reduced porosity due to quartz replacement, and the precipitation of silica and iron oxide cement (Boruah and Pandey, 2023; Mout and Sarmah, 2024a). The depositional environment of the Kopili shale transitioned from shallow marine to estuarine and deltaic facies (Sarmah and Borgohain, 2012; Trivedi and Ranhotra, 2015; Devi et al., 2021; Mout and Sarmah, 2024a).

Despite these findings, inconsistencies remain in the interpretations of the paleo-weathering, redox conditions, provenance, and tectonic settings associated with the deposition of the Kopili shale. Geochemical proxies, such as CIA, CIW, and ICV, indicate intense chemical weathering under semi-arid to semi-humid conditions during the paleo-weathering of the Kopili shale (Boruah and Pandey, 2023).

The Upper Sylhet Limestone consists of thick nummulitic limestones that were deposited in a shallow marine environment within a gradually shallowing basin. This led to a coarsening-upward sedimentary sequence (Najman et al., 2008; Whiso et al., 2009; Biswal et al., 2021, 2022). The deposition of the Upper Sylhet Limestone began with the formation of a carbonate platform, where carbonate sediments, similar to those found in the sedimentary cycles of the Mediterranean and the Middle East, were deposited (Jauhri and Agarwal, 2001). Fossil assemblages indicate that the Upper Sylhet Limestone was deposited under warm, high-energy conditions in shallow-marine environments (Sarkar, 2019; Singh et al., 2023). The presence of coal patches in Upper Sylhet Sandstone towards the bottom of some core sections indicates an anoxic environment.

5.10 GEOPHYSICAL EXPLORATION

Geophysical exploration was not carried out in Northwest of Boro Lakhindong block.

5.11 GEOCHEMICAL EXPLORATION

Correlation matrix of the major oxide **(Table 5.2)** was prepared from the chemical analysis of 451 nos. of cores samples. It is observed that the CaO have negative correlation with other oxides i.e., Fe_2O_3, K_2O, MgO, TiO_2 & SiO_2. The grade of limestone decreases in ferruginous limestone and intercalation with shale as the value of CaO have inverse correlation with Fe_2O_3, SiO_2 and Al_2O_3.The inverse relationship of CaO with other oxides is also shown in Bivariant plot in **Fig.5.50**.

Table 5.2 Correlation matrix of oxides of limestone core samples

Sr No	Toposheet No	Oxides	Al_2O_3 (%)	CaO (%)	Fe_2O_3 (%)	K_2O (%)	MgO (%)	TiO_2 (%)	SiO_2 (%)
1	83C11	Al_2O_3 (%)	1						
2	83C11	CaO (%)	-0.929	1					
3	83C11	Fe_2O_3 (%)	0.484	-0.601	1				
4	83C11	K_2O (%)	0.983	-0.916	0.438	1			
5	83C11	MgO (%)	0.332	-0.316	0.52	0.30209	1		
6	83C11	TiO_2 (%)	0.913	-0.934	0.404	0.91692	0.167	1	
7	83C11	SiO_2 (%)	0.852	-0.948	0.36	0.85989	0.106	0.929	1

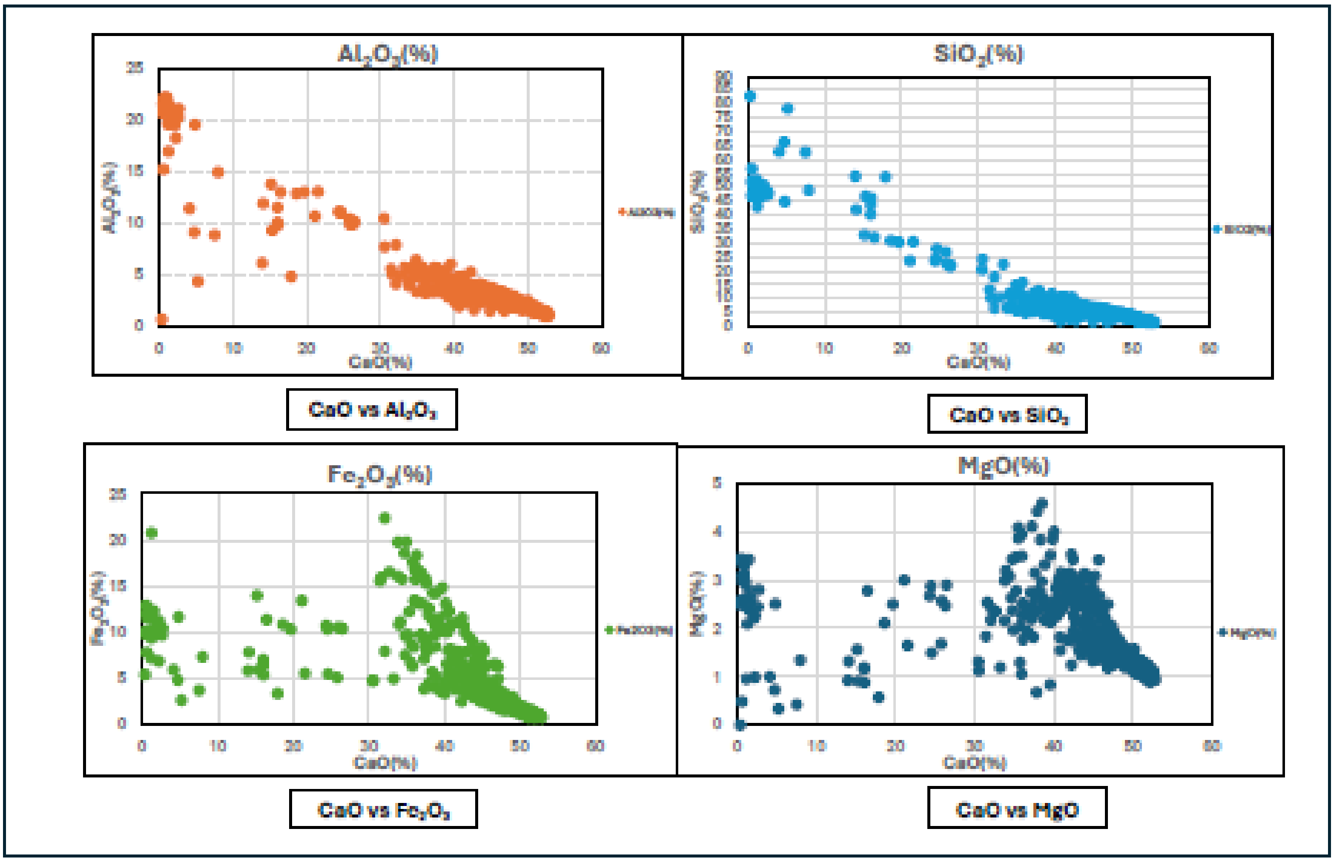

Fig 5.50. Bivariate plots showing relationship between CaO and Al_2O_3, SiO_2, Fe_2O_3 & MgO

CHAPTER 6

INTEGRATION OF GEOLOGY, GEOPHYSICS (WITH AVAILABLE AERO GEOPHYSICAL DATA) AND GEOCHEMICAL EXPLORATION DATA AND THE INTERPRETATION

Not required for bedded type deposit as well as it is also not a part of the NQT.

CHAPTER 7

MINERAL DEPOSIT

7.1 SURFACE INDICATION OF MINERALIZED ZONE

The Upper Sylhet Limestone Member of Shella Formation is the target rock for limestone exploration in Northwest of Boro Lakhindong block and thick beds of limestones are exposed in sections in the block. The maximum thickness exposed is 3.25m (**Fig.5.8)** in central northwest part of the block. Upper Sylhet Limestone disposition is sub horizontal to horizontal, trending N20°E with 1° to 4° dip. The limestone bed is well exposed in approximately 60% of the block area and is mainly exposed along the hill slopes, nala section where it is covered by thick soil cover. The outcrops of limestone are fine to medium grained, hard & compact fossiliferous with fossils of Nummulites sp., Alveolina sp. and Discocyclina sp., highly dissected, rugged with numerous small caves and fractures.

7.2 MODE OF OCCURRENCE

The limestone in the Northwest Boro Lakhindong block is deposited from the accumulation of exoskeletons or tests of marine organisms and cemented by chemically precipitated carbonate. It occurs in the form of a regular, almost sub-horizontal to horizontal, primary bedded deposit with a N20°E, strike and dipping 1° to 4° towards the ESE.

7.3 NATURE OF MINERALIZATION

The limestone is of marine origin, bioclastic, and was deposited as cemented shell fragments and biologically derived precipitates in a euxinic environment on a stable shelf. The Sylhet Limestone, which is exposed in the Mikir, Garo, Khasi and Jaintia Hills, was deposited in a shallow, open marine, warm water environment (Bhandari et al., 1973). The mineralization exhibits a bedded sedimentary nature, formed by the accumulation of loose shells from dead marine organisms. Over time, these shells were transformed into bioclastic limestone through the addition of a chemically precipitated carbonate cement that binds the shell fragments together.

7.4 DETAILS OF MINERALISED ZONES

The Upper Sylhet Limestone is intersected in all drilled boreholes of Northwest of Boro Lakhindong Block. The Upper Sylhet Limestone is overlained by Kopili Formation and underlained by Upper Sylhet Sandstone. The borehole wise thicknesses of Upper Sylhet Limestone are summarized below **(Table 7.1)** and graphical litholog of drilled boreholes in the block have been given in **(Plate- IV)**. Based on the limestone thicknesses recorded in all five boreholes, the average thickness has been calculated to be 85.32 m. The overburden comprises of regolith and Kopili Formation and its thickness ranges between 03.00m and 16.14m.

Table 7.1: Borehole wise total thickness of Upper Sylhet Limestone

Sr No	Toposheet No	Borehole No	Total depth (m)	Intersection of Limestone		Thickness of limestone (m)
				From (m)	To (m)	
1	83C11	PBH-01	100.00	4.00	82.76	78.76
2	83C11	PBH-02	100.00	4.40	100.00	95.60
3	83C11	PBH-03	100.00	15.78	100.00	84.22
4	83C11	PBH-04	100.00	15.80	100.00	84.20
5	83C11	PBH-05	100.00	16.14	100.00	83.86

7.5 GENESIS OF MINERALIZATION/GENETIC MODEL FOR MINERALIZATION

The Upper Sylhet Limestone of the Shella Formation was formed during the Eocene period under shelf conditions (Mathur & Evans, 1964). The limestone was deposited in a marine shelf environment, as evidenced by the presence of foraminifers and its association with shale (Biswal et al., 2021). Most of the fossils are well-preserved, suggesting a relatively low-energy environment. The ferruginous limestone at the top indicates deposition in an oxic environment. The pelitic sediment deposits reflect a period of marine transgression or deepening of the ocean basin. Fossil assemblages such as *Nummulites* sp., *Alveolina* sp., *Discocyclina* sp., *Asterocyclina* sp., *Assilina* sp., and others observed in the limestone point to a shallow marine environment under stable shelf conditions.

The coal-bearing sandstone, encountered in PBH-01 of the Upper Sylhet Sandstone was deposited in estuarine or lagoonal margins. By the Late Eocene, the area transitioned to a deeper marine environment, leading to the deposition of thick shale units of the Kopili Formation.

CHAPTER 8

EXPLORATION BY DRILLING

Exploration by drilling (core) was carried out in Northwest of Boro Lakhindong Block in an area of 4.82 sq. km to assess the potentiality of different grades of limestone. A total of 500m drilling was carried out in 05 vertical boreholes (at a space of 800 m interval) i.e., PBH-1, PBH-2, PBH-3, PBH-4, and PBH-5. The five boreholes are plotted in the detailed geological map which is shown in **Fig.8.1**.

8.1 STAGE OF EXPLORATION

The investigation of the block was initiated under G-3 stage of UNFC, i.e. ‘Prospecting Stage, as the limestone continuity can be established in the area, where grade variation will be known by drill core sample analysis. In addition to drilling programme, detailed mapping of 4.82 sq. km with bed rock, core and petrographic sampling have been carried out.

8.2 DRILLING METHODOLOGY

Two rigs were deployed to carry out the drilling in the block. All the drill machines were hydrostatic rigs with model CSD500L and CSD1300L having the capacity of drilling upto 500m and 1000m respectively. Diamond bits were used for the core drilling process. The azimuth of all the drilling boreholes was vertical as the targeted strata is sub-horizontal to horizontal. Generally wet drilling method has been deployed except in the overburden and loose formations.

8.3 CO-ORDINATE AND RL OF THE COLLARS OF THE BOREHOLES

The co-ordinate and RL of the collars of the boreholes are taken from DGPS survey, given in the Table 8.1 below.

Table 8.1 Co-ordinate and RL of drilled boreholes in Northwest of Boro Lakhindong Block

Borehole No.	Latitude	Longitude	RL of the Collar
PBH-01	25°28'34.72"N	92°36'6.56"E	731.00m
PBH-02	25°28'33.56"N	92°36'35.44"E	736.00m

Borehole No.	Latitude	Longitude	RL of the Collar
PBH-03	25°28'32.41"N	92°37'4.06"E	736.00m
PBH-04	25°28'7.79"N	92°36'19.95"E	741.00m
PBH-05	25°28'5.2"N	92°36'48.3"E	732.00m

8.4 BOREHOLE PLANNING

Total no of 5 boreholes has been planned at a space of 800m along east-west direction since the bedding of the limestone is sub-horizontal to horizontal in nature and the shape of the block boundary is irregular. This grid pattern was planned as per the UNFC norm of G3 stage of exploration and review of TCC meeting. However, slight deviations from the grid pattern have been initiated due to topography of outcrop of the limestone and inaccessibility caused by dense forests and abandoned quarries in certain locations. Details of boreholes and intersection depths of limestone are given in the **Table 8.2**.

Table 8.2 Details of drilled boreholes and intersection depths of limestone in Northwest of Boro Lakhindong Block.

Borehole No.	Date of commencement	Date of closure	Final depth (in m)	Intersection of Limestone		Limestone Thickness (m)
				From (m)	To (m)	
PBH-01	09.12.2024	11.12.2024	100m	4.00	82.76	78.76
PBH-02	04.12.2024	07.12.2024	100m	4.4	100.00	95.60
PBH-03	04.12.2024	06.12.2024	100m	15.78	100.00	84.22
PBH-04	09.12.2024	12.12.2024	100m	15.80	100.00	84.20
PBH-05	14.12.2024	16.12.2024	100m	16.14	100.00	83.86

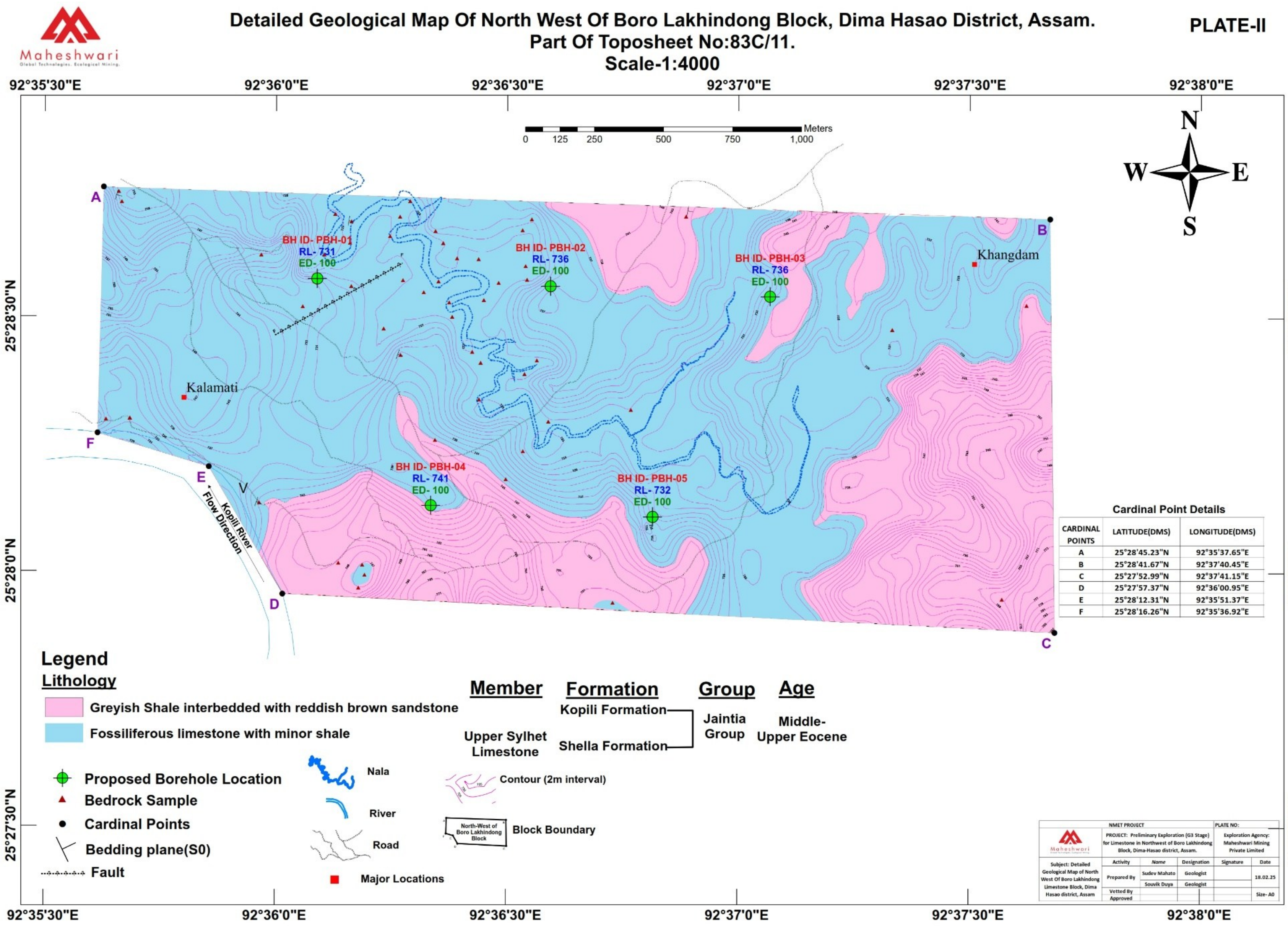

Fig. 8.1: Showing borehole locations in detailed geological map.

8.5 BOREHOLE LOGGING

The drill cores have been logged in details to study the lithology, variation in colour, grain size, nature and details of fossils and structural features. During detailed logging, special care has been taken to distinguish the variation of fossil content, variation in fossil shapes and deformation, variation in grain size, present of mud partings and shale intercalations. The lithologs of boreholes are given in summarized form in Annexure-II and graphical lithologs in Plate-IV. A brief description of all 5 nos. of boreholes is given below.

PBH-01: This borehole is located at latitude 25°28'34.72"N and longitude 92°36'6.56"E. Drilling on this borehole commenced on 09.12.2024 and finished on 11.12.2024. Final depth of this borehole is 100m. Soil was intersected from 0 to 4m depth. Upper Sylhet limestone i.e. mineralized zone was intersected from 4m to 82.76m. Upper Sylher sandstone was intersected from 82.76 to 100m.

PBH-02: This borehole is located at latitude 25°28'33.56"N and longitude 92°36'35.44"E. Drilling on this borehole commenced on 04.12.2024 and finished on 07.12.2024. Final depth of this borehole is 100m. Soil was intersected from 0 to 2m depth. Kopili Shale was intersected from 2.00 to 4.40m. Upper Sylhet limestone i.e. mineralized zone was intersected from 4.40m to 100.00m.

PBH-03: This borehole is located at latitude 25°28'32.41"N and longitude 92°37'4.06"E. Drilling on this borehole commenced on 04.12.2024 and finished on 06.12.2024. Final depth of this borehole is 100m. Soil was intersected from 0 to 5.50m depth. Kopili Shale was intersected from 5.50 to 15.78m. Upper Sylhet limestone i.e. mineralized zone was intersected from 15.78m to 100.00m.

PBH-04: This borehole is located at latitude 25°28'7.79"N and longitude 92°36'19.95"E. Drilling on this borehole commenced on 09.12.2024 and finished on 12.12.2024 Final depth of this borehole is 100m. Soil was intersected from 0 to 3m depth. Kopili Shale was intersected from 3.00 to 15.80m. Upper Sylhet limestone i.e. mineralized zone was intersected from 15.80m to 100.00m.

PBH-05: This borehole is located at latitude 25°28'5.2"N and longitude 92°36'48.3"E. Drilling on this borehole commenced on 14.12.2024 and finished on 16.12.2024. Final depth of this borehole is 100m. Soil was intersected from 0 to 3m depth. Kopili Shale was intersected from 3.00 to 16.14m. Upper Sylhet limestone i.e. mineralized zone was intersected from 16.14m to 100.00m.

8.6 Core recovery percentage

The core recovery of all boreholes is good on an average. The core recovery of the targeted strata, the Upper Sylhet Limestone, is very good (85-90%) where there are no fracture zones. However, in areas where the borehole passes through fracture zones, the core recovery is reduced. Core recovery is low in shale as it is mostly fractured and splintery in nature. Borehole-wise details of core recovery are provided in the **Table 8.3**.

Table 8.3: Core recovery of boreholes of Northwest of Boro Lakhindong Block.

Sr No	Toposheet No	Borehole No	Core recovery (%)
1	83C11	PBH-01	98.51
2	83C11	PBH-02	96.02
3	83C11	PBH-03	96.3
4	83C11	PBH-04	97.07
5	83C11	PBH-05	98.91

8.7 Geophysical logging of boreholes

As per the Nature and Quantum of work approved for this limestone block, there was no geophysical logging.

8.8 Minerology of the ore zone

Mineralogically, the Upper Sylhet Limestone is primarily composed of the mineral calcite, which occurs in the form of microcrystalline grains in the groundmass. Limestone encountered in all the boreholes is Biomicrite. It is mainly dark grey to light grey in colour, medium grain and hard and compact. It is mainly composed of calcite mineral. Calcite occurs as microcrystalline grains in the matrix and shells of the fossils. Vertical variation of fossils content is more prominent in the limestone.

8.9 Borehole deviation test and methodology

As the boreholes were drilled out at vertical angle, no deviation test was carried out.

8.10 Methodology of ore zone sampling

Core samples were obtained from the mineralized zone at 1-meter intervals, with each sample representing 1 meter of core. During sample collection, core recovery and necessary adjustments were made to ensure accurate representation of the zone.

8.11 Sample powder preparation & chemical analysis with laboratory procedures

Core samples were collected at 1.00m interval from the mineralized zone. Then, the samples were split into two longitudinal equal halves by using a core splitter. Thereafter 6mm chip samples were made out of the half core samples. After coning & quartering of 500-600 grams chip samples that 200-300g was powdered to -100 mesh sizes. The remaining chip samples are preserved for future perspective. Rest one half of the core has been preserved in the core box and sent to core repository. The 200-300g powdered samples was repeatedly coned and quartered to obtain primary sample of about 150-200 grams of powder which was divided into two halves. One half was submitted to NABL laboratory (Shiva Analytics) for chemical analysis and the other half was preserved as a duplicate sample. The primary samples were analyzed for CaO, MgO, SiO_2, Al_2O_3, Fe_2O_3, SO_3, P_2O_5, Na_2O, K_2O, and LOI by X-ray fluorescence machine using the standards.

A total of 451 nos. core samples from 5 boreholes were collected, processed and analyzed. In addition to core samples, 50nos of bed rock samples were also collected and chemical composition analyzed.

8.12 Check samples

45 numbers of the core samples and 5 no's of bedrock samples were prepared as check samples and it is analyzed at the SGS Lab (Annexure-V) in order to compare the accuracy of the chemical composition of the original samples. While comparing the chemical result of the check sample with original samples, it is found that the results are almost similar or less deviated.

8.13 Details of the intersected limestone

A total of 500m drilling was carried out in 5 no's of boreholes. The targeted Upper Sylhet Limestone has been intersected in all the boreholes and depth of intersections are described in the Table. However, the grade of limestone in the block is considered by cut-off value of CaO to be 34% (IBM, 2019). The limestone was intersected in all the boreholes at different depth. In boreholes no PBH-01, 02, 03, 04 and 05 the Upper Sylhet Limestone been intersected from 4.00m to 82.76m, 4.40m to 100m, 15.78m to 100m, 15.80m to 100m and 16.14m to 100m respectively.

Table 8.4: Detailed of intersected of limestone of boreholes drilled

Sr No	Toposheet No	Borehole No	Final depth (in m)	Intersection of Limestone		Thickness (m)
				From (m)	To (m)	
1	83C11	PBH-01	100	4.00	82.76	78.76
2	83C11	PBH-02	100	4.40	100.00	95.6
3	83C11	PBH-03	100	15.78	100.00	84.22
4	83C11	PBH-04	100	15.80	100.00	84.2
5	83C11	PBH-05	100	16.14	100.00	83.86

8.14 Depth of Groundwater

As of drilled borehole, the water table varies from 17m to 25m w.r.t the topography in the area. And as the Kopili River and several nalas are present in the northwest and northern part of the block, the water table is present nearly or near about 10m.

CHAPTER-9

GEOTECHNICAL STUDIES

In-situ Bulk density of Limestone and RQD of core samples are measured under geotechnical studies.

9.1 BULK DENSITY

The bulk density of limestone samples was determined by Shiva Analyticals Laboratory using the **Pycnometer Method**, a standard laboratory procedure for accurately measuring the density of solid materials. In this method, finely crushed and oven-dried limestone samples are placed into a pycnometer—a calibrated glass vessel. The volume of the sample is then determined by measuring the displacement of a fluid, usually distilled water, within the pycnometer. By comparing the mass of the dry sample to the volume it displaces, the bulk density (in g/cm³ or t/m³) is calculated with high precision.

This method is particularly suitable for irregular and porous geological samples, as it provides a reliable estimate of true or particle density, excluding pore spaces. The obtained average bulk density value of 2.53 t/m³ **(Table 9.1)** was applied across the deposit for resource estimation purposes. The details of laboratory results are provided in Annexure VII.

Table 9.1: Average bulk density of limestone samples collected

Sr No	Toposheet No	Samples No	Bulk Density (gm/cc)
1	83C11	1	2.48
2	83C11	2	2.61
3	83C11	3	2.49
		Average	**2.526666667**

9.2 RQD (ROCK QUALITY DESIGNATION)

The RQD for all the cores of the drilled boreholes is calculated as per the formula

RQD= (Sum of the length of core pieces >100mm/ total length of the core run) X 100%

The average RQD of the limestone encountered in all the borehole is excellent i.e. above 90%.

Table 9.2 Summarized RQD of Boreholes

Sr No	Toposheet No	Boreholes No	Lithology	RQD (%)
1	83C11	PBH-01	Limestone	89.57
			Intercalation of shale and sandstone	66.46
2	83C11	PBH-02	Limestone (fracture)	83.52
			Shale	17.31
			Limestone	92.32
			Intercalation of shale and limestone	79.5
3	83C11	PBH-03	Shale	23.64
			Limestone (fracture)	88.96
			Shale	20.58
			Limestone	90.19
4	83C11	PBH-04	Intercalation of shale and limestone	36.47
			Limestone (fracture)	80.92
			Shale	37.33
			Limestone	90.33
5	83C11	PBH-05	Intercalation of shale and limestone	21.67
			Limestone (fracture)	83.24
			Shale	41.67
			Limestone	88.21

CHAPTER 10

RESOURCE ESTIMATION

10.1 INTRODUCTION

To assess the grade-wise resource of limestone in the Northwest of Boro Lakhindong block, a G-3 stage (Preliminary Exploration) was conducted over an area of 4.82 sq. km. As per the exploration plan, vertical boreholes were drilled at an 800-meter spacing, conforming to the guidelines for pros-level investigations in limestone deposits. A total of 500 meters of core drilling was completed, with each of the five boreholes reaching a depth of 100 meters. The primary objectives of the investigation were to examine depth continuity of the limestone horizons and to enable grade-wise resource estimation based on subsurface lithological and chemical analysis data. Based on drilling and surface sampling, the entire area is mineralized **(Fig:8.1)**.

10.2 DETAILED DESCRIPTION OF LIMESTONE

The Upper Sylhet Limestone which is encountered in all the boreholes is grey to dark grey in colour, fine to medium grained, hard and compact and mostly fossiliferous limestone. From the sub surface data of the drilled boreholes, it is observed that the Upper Sylhet Limestone is thickly bedded with low dipping of 1° to 4° south-easterly. Different grades of limestone like Portland (Cement), Cement (Blendable), SMS (OH) and unclassified were encountered in all the boreholes.

The detailed of the limestone and different grade of limestone encountered in drilled borehole are given in the **Table 10.1** respectively.

Table 10.1 Details of the limestone encountered in drilled boreholes

Borehole ID	Intersection of Limestone		Limestone thickness(m)
	From (m)	To (m)	
PBH-01	4.00	82.76	78.76
PBH-02	4.40	100.00	95.60
PBH-03	15.78	100.00	84.22
PBH-04	15.80	100.00	84.20
PBH-05	16.14	100.00	83.86

10.3 CORE RECOVERY

The core recovery of the all boreholes is good. The average core recovery percentage is 98.51 within the mineralized zone. Hence, the recovered thickness is considered as actual thickness.

10.4 CUT-OFF GRADE CONSIDERATION

The resource estimation is calculated the limestone was classified into various grades based on the End User Grade Classification, which takes into account its chemical composition. A cut-off grade of 34% CaO has been applied to ensure that only material meeting the minimum industrial requirements is considered. The main categories of limestone grades, based on their chemical content. These classification values are based on the recent publication by the Indian Bureau of Mines (IBM Annual Report, 2019) given in **Table 10.2** below.

Table 10.2: End Use Grade Classification for Limestone

Grade	CaO%	MgO %	SiO_2 %	Al_2O_3 %	Fe_2O_3 %
Cement (Portland)	44 to 52%	3.5 % (max)			
Cement (Blendable/Beneficiable)	38 to 44 %	5% (max)			
Steel Melting Shop (Open Hearth)	48 % (max)	4% (max)	4% (max)		
Steel Melting Shop (Linz-Donawitz)	52 % (min)	Below 2%	1% (max)		
Chemical	50% (min)		2% (max)		0.25% (max)
B.F.	42% (min)	6% (max)	4% (max)		

White Cement	48% (min)			1% (max)	1% (max)
Others (Unclassified)	Estimation for such grade though usable cannot be classified under any grades				

The primary chemical components of limestone include CaO, MgO, SiO_2, Fe_2O_3, and Al_2O_3, which are crucial in determining the grade of limestone based on its suitability for various industries such as cement, iron and steel, chemicals, fertilizers, and glass production. Additionally, other elements like SO_3, P_2O_5, Na_2O, K_2O, and MnO also need to be analyzed, as they significantly influence the grading and overall quality of limestone for these applications. Limestone plays a crucial role in steelmaking, particularly in Steel Melting Shops (SMS) that use processes such as the Open Hearth (OH) furnace or Linz-Donawitz (LD) furnace, the latter being a type of Basic Oxygen Furnace (BOF) technology.

10.5 MINIMUM STOPING WIDTH CONSIDERATION

Stoping width is not applicable for open cast mining.

10.6 GRADE OF LIMESTONE AND CORRELATION

The limestone encountered in each borehole can be classified into different grades based on key chemical constituents such as CaO, MgO, SiO_2, Fe_2O_3, and Al_2O_3. Chemical analysis shows that the majority of the Upper Sylhet Limestone falls into the Cement (Blendable and Portland) grade, SMS (OH) and the Unclassified grade. Limestone with a CaO content ranging from 34% to just under 38% is categorized as unclassified. This is shown in **Table 10.3**.

Table 10.3: Depth wise grade classification of each borehole

Sr No	Toposheet No	Borehole No	From (m)	To (m)	Thickness (m)	Wt Av. CaO%	Grade	Member
1	83C/11	PBH-01	4	13	9	46.213	Cement (P)	UPPER SYLHET LIMESTONE
			13	23	10	41.074	Cement (B)	
			23	32	9	47.44022	Cement (P)	
			32	54	22	50.28641	SMS(OH)	
			54	65	11	45.14209	Cement (P)	
			65	80	15	_	Waste	
			80	82.76	2.76	37.72349	Unclassified	
2	83C/11	PBH-02	5	13	8	38.44	Cement (B)	UPPER SYLHET LIMESTONE
			13	23	10	44.7816	Cement (P)	
			23	31.62	8.62	39.62604	Cement (B)	
			31.62	36	4.38	_	Waste	

			36	47	11	45.42436	Cement (P)	
			47	53	6	41.526	Cement (B)	
			53	64	11	45.12118	Cement (P)	
			64	91	27	50.39893	SMS(OH)	
			91	97	6	45.59367	Cement (P)	
			97	100	3	_	Waste	
3	83C/11	PBH-03	15.7	26	10.3	38.43314	Cement (B)	UPPER SYLHET LIMESTONE
			26	33	7	44.45843	Cement (P)	
			33	42.26	9.26	38.47947	Cement (B)	
			42.26	47	4.74	_	Waste	
			47	58	11	45.27636	Cement (P)	
			58	65	7	40.87357	Cement (B)	
			65	75	10	45.5171	Cement (P)	
			75	100	25	50.29412	SMS(OH)	
4	83C/11	PBH-04	15.8	25	9.2	38.6338	Cement (B)	UPPER SYLHET LIMESTONE
			25	33	8	44.608	Cement (P)	
			33	42	9	38.30089	Cement (B)	
			42	46	4	_	Waste	
			46	57	11	44.73073	Cement (P)	
			57	66	9	41.50744	Cement (B)	
			66	75	9	46.94611	Cement (P)	
			75	100	25	50.50204	SMS(OH)	
5	83C/11	PBH-05	16.14	24	7.86	40.67196	Cement (B)	UPPER SYLHET LIMESTONE
			24	33	9	44.35567	Cement (P)	
			33	42	9	39.77267	Cement (B)	
			42	46	4	_	Waste	
			46	58	12	45.43558	Cement (P)	
			58	68	10	41.8506	Cement (B)	
			68	77	9	47.02544	Cement (P)	
			77	100	23	50.81952	SMS(OH)	

10.7 GRADE WISE CORRELATION OF LIMESTONE

Fence diagram provides a way to visualize the space between multiple overlapping surfaces in 3D space, such as stratigraphic data. Fence diagram has been prepared for correlation of the grade variation of limestone in each borehole.

The analysis of the 3D fence diagram reveals that in the northwestern part of the block, limestone of cement (Portland) and SMS (OH) grades occurs in the upper sections of the boreholes, directly beneath the soil cover. In contrast, in the eastern, southwestern, and southeastern parts of the block, limestone of cement (Portland), cement (Blendable/beneficiable), and SMS (OH) grades is found below the Kopili Formation. This indicates that the limestone bedding is sub-horizontally dipping toward the southeastern side.

10.8 METHODOLOGY OF RESOURCE ESTIMATION

Limestone resource estimation for the Northwest of Boro Lakhindong block has been carried out using the Theissen Polygonal Method.

The following steps were undertaken for the estimation of limestone resources:

a) According to The Minerals (Evidence of Mineral Contents) Rules, 2015 (as amended up to 14th December, 2021), Ministry of Mines, Government of India, issued by the Controller General, IBM, Nagpur (January, 2022) rule five boreholes were approved with space of 800m, considering the horizontal to sub-horizontal attitude of the limestone. Part-III of Schedule-l of the above rule allows 800m grid spacing of boreholes for G3 level of exploration in limestone. NMET-TCC approved these five boreholes. To make the area of influence, best fit strike lines are drawn to match maximum boreholes.

b) The area of influence for each positive borehole is limited to half the distance between two positive borehole points along strike and two consecutive strike lines along dip.

c) When the other borehole is not available as control the area of influence for each borehole is limited either to 350m and 400 m along strike and across strike or to the block boundary.

d) The influence area for resource estimation has been considered in accordance with the drilled borehole locations.

e) The block boundary of the block is irregular in outline. Therefore, the area near to the boundary where the influence of the boreholes is beyond the permissible limit is excluded from the resource calculation.

f) The thickness of limestone measured in each borehole has been considered to be uniform throughout the area of influence of the particular borehole.

g) The limestone is considered to be of uniform characteristics throughout the volume of a particular grade and there is no variation in grade of limestone.

h) Bulk density of 2.53 has been considered/ assumed to the entire deposit as calculated from the borehole cores. It was determined using the pycnometry method, and the analysis was carried out at Shiva Analyticals Laboratory, given in Annexure -VII.

The area of influence is determined using the polygonal method, where area of influence is marked by constructing polygon around each borehole using method demonstrated in **Fig.10.1**.

The area of influence for G3 resource estimation was defined based on drilled borehole locations. Half the distance between two positive boreholes was considered to delineate the influence zone, while a buffer of 400 meters was applied in undrilled areas to limit extrapolation. The remaining portions of the block, where no boreholes were present, were classified under the

G4 category. Although surface indications of limestone exist in these areas, the absence of subsurface data made it unsuitable for higher confidence categorization. Therefore, the overall resource estimation has been reported as a combined total of G3 and G4 categories (**Fig. 10.1**). The thickness of the limestone is determined from the borehole intersection. To calculate the volume, the area of influence is multiplied by the limestone thickness. This volume is then multiplied by the bulk density to estimate the gross tonnage. To calculate the net tonnage for each borehole, 15% of the gross tonnage is subtracted, accounting for the likely presence of underground caverns, solution cavities, or structural discontinuities within the limestone deposit. The bulk density of the limestone is calculated from the core of the limestone, given in Section 9.1. Bulk density is 2.53 gm/ cm3 or tonnes/m3.

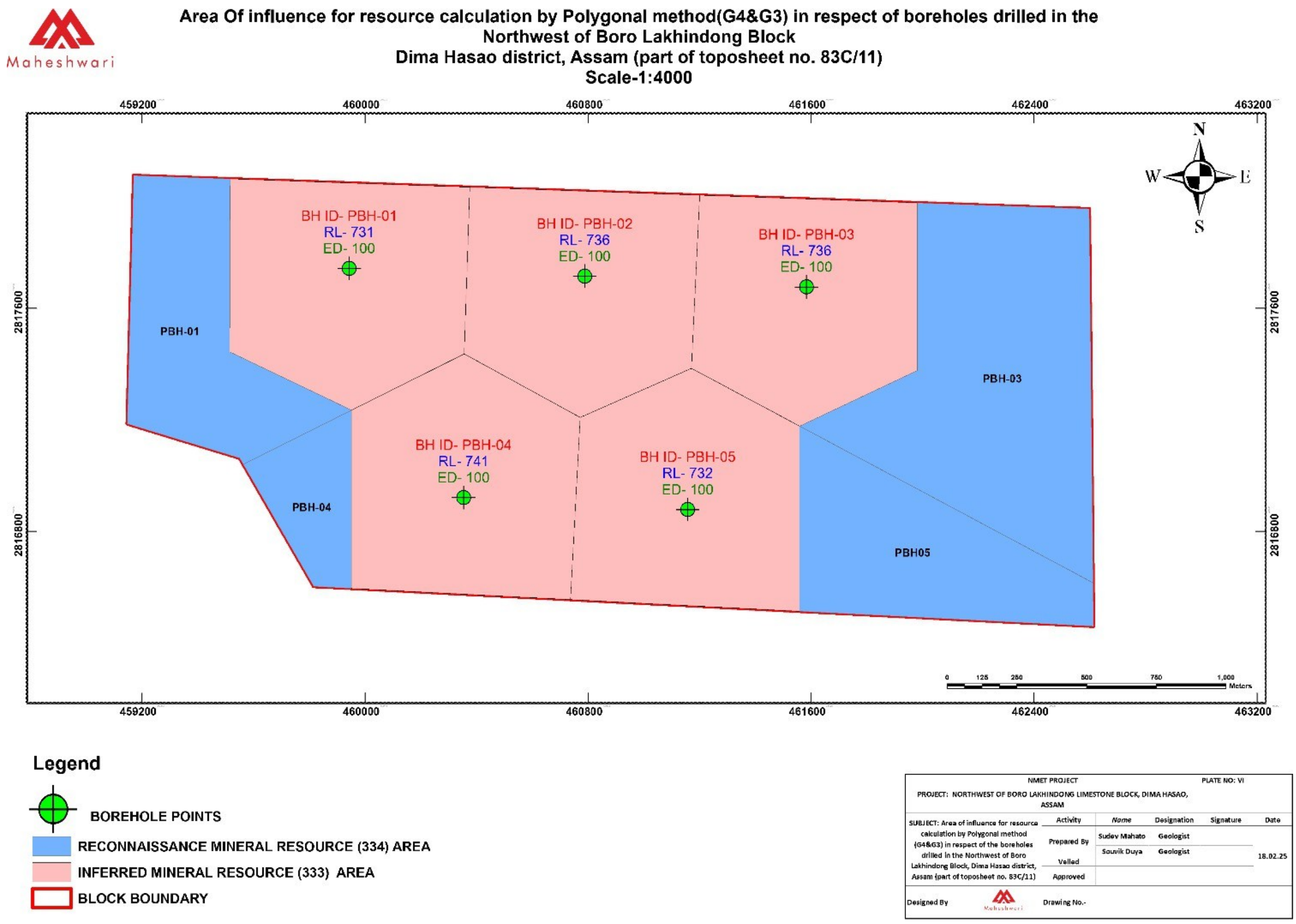

Fig. 10.1: Schematic diagram showing construction of polygons for determining area of influence.

In this method also, the volume of the polygonal area has been calculation by considering the assumption given above.

Volume of polygon= S x T,

Where S = Area of polygon,

T= Thickness of limestone intersected in borehole.

Resources have been estimated by the formula

Resource of one block of rectangle/polygonal area = R = V x Bd = S x T x Bd

Where Bd = Bulk density

R = Resource of one rectangle/polygon

Resource of total deposit = RE = R1 + R2 + R3 .... Rn

Grade of the deposit is calculated as per the chemical grade of the limestone for each borehole.

10.9 RESOURCE

Table 10.4: Showing Category wise Net Resource by using Polygonal Method

Method	Category	Net Resource	Grade (In million tonnes)				UNFC Classification
			Cement (Blendable/ Beneficiable)	Cement (Portland)	SMS (OH)	Unclassified / Others	
Polygonal	G3	498.97	144.4	195.29	155.68	3.59	Class 333
Polygonal	G4	300.79	90.35	113.58	94.32	2.54	Class 334
Polygonal	Total (G3 + G4)	799.76	234.75	308.87	249.99	6.13	Class 334

Table 10.5: Showing the Total Net Resource (G3 as Category 333 of UNFC Classification) by using Polygonal Method

Borehole No	From	To	Thickness (m)	Wt. Average (%)			Grade	Area of influence (sqm)	Volume (m^3)	Bulk density g/cc	Gross Resource (tonnes)	Net Resource (15% deduction) (tonnes)	Total Net Resource (tonnes)	Total grade wise net resource(tonnes) in each borehole	
				CaO	MgO	SiO_2									
PBH-01	0	4	4	–	–	–	Waste	604776.1254	2419104.5	0	0	0	82924410.64	Cement (P)	37716560.67386
	4	13	9	46.213	2.0528889	4.7315556	Cement (P)	604776.1254	5442985.1	2.53	13770752.38	11705139.52		Cement (B)	13005710.57719
	13	23	10	41.074	2.9296	7.7539	Cement (B)	604776.1254	6047761.3	2.53	15300835.97	13005710.58		SMS(OH)	28612563.26983
	23	32	9	47.440222	1.4943333	2.2273158	Cement (P)	604776.1254	5442985.1	2.53	13770752.38	11705139.52		Unclassified	3589576.11931
	32	54	22	50.286409	1.1557727	2.8146818	SMS (OH)	604776.1254	13305075	2.53	33661839.14	28612563.27			
	54	65	11	45.142091	1.4778182	6.57	Cement (P)	604776.1254	6652537.4	2.53	16830919.57	14306281.63			
	65	80	15	–	–	–	Waste	604776.1254	9071641.9	0	0	0			
	80	82.76	2.76	37.723493	0.9548986	13.543507	Unclassified	604776.1254	1669182.1	2.53	4223030.729	3589576.119			
	82.76	100	17.24	–	–	–	Waste	604776.1254	10426340	0	0	0			
PBH-02	0	5	5	–	–	–	Waste	582791.3913	2913957	0	0	0	109813522.8	Cement (P)	47625129.70390
	5	13	8	38.44	2.946625	6.07825	Cement (B)	582791.3913	4662331.1	2.53	11795697.76	10026343.1		Cement (B)	28349485.10269
	13	23	10	44.7816	1.8989	4.5403	Cement (P)	582791.3913	5827913.9	2.53	14744622.2	12532928.87		SMS(OH)	33838907.94751
	23	31.62	8.62	39.626042	2.3534524	7.5847285	Cement (B)	582791.3913	5023661.8	2.53	12709864.34	10803384.69		Unclassified	0
	31.62	36	4.38	–	–	–	Waste	582791.3913	2552626.3	0	0	0			
	36	47	11	45.424364	2.3476364	5.9724545	Cement (P)	582791.3913	6410705.3	2.53	16219084.42	13786221.76			
	47	53	6	41.526	3.3335	7.719	Cement (B)	582791.3913	3496748.3	2.53	8846773.32	7519757.322			
	53	64	11	45.121182	2.1749091	6.2195455	Cement (P)	582791.3913	6410705.3	2.53	16219084.42	13786221.76			
	64	91	27	50.398926	1.3561111	3.1197407	SMS (OH)	582791.3913	15735368	2.53	39810479.94	33838907.95			

	91	97	6	45.593667	1.555	6.2958333	Cement (P)	582791.3913	3496748.3	2.53	8846773.32	7519757.322			
	97	100	3	–	–	–	Waste	582791.3913	1748374.2	0	0	0			
PBH-03	0	15.7	15.7	–	–	–	Waste	568885.6675	8931505	0	0	0	97332799.24	Cement (P)	34254881.58100
	15.7	26	10.3	38.433136	2.3128544	5.9461165	Cement (B)	568885.6675	5859522.4	2.53	14824591.61	12600902.87		Cement (B)	32493201.95683
	26	33	7	44.458429	1.6612857	4.2415714	Cement (P)	568885.6675	3982199.7	2.53	10074965.17	8563720.395		SMS(OH)	30584715.69732
	33	42.26	9.26	38.479467	2.0347343	7.1687279	Cement (B)	568885.6675	5267881.3	2.53	13327739.64	11328578.69		Unclassified	0
	42.26	47	4.74	–	–	–	Waste	568885.6675	2696518.1	0	0	0			
	47	58	11	45.276364	2.1146364	5.5010909	Cement (P)	568885.6675	6257742.3	2.53	15832088.13	13457274.91			
	58	65	7	40.873571	3.0035714	7.9198571	Cement (B)	568885.6675	3982199.7	2.53	10074965.17	8563720.395			
	65	75	10	45.5171	1.8577	5.5466	Cement (P)	568885.6675	5688856.7	2.53	14392807.39	12233886.28			
	75	100	25	50.29412	1.17748	2.85632	SMS (OH)	568885.6675	14222142	2.53	35982018.47	30584715.7			
PBH-04	0	15.8	15.8	–	–	–	Waste	607449.7622	9597706.2	0	0	0	104766921.2	Cement (P)	36576979.98118
	15.8	25	9.2	38.633803	2.3661533	6.2222957	Cement (B)	607449.7622	5588537.8	2.53	14139000.66	12018150.57		Cement (B)	35531923.41029
	25	33	8	44.608	1.63175	4.4755	Cement (P)	607449.7622	4859598.1	2.53	12294783.19	10450565.71		SMS(OH)	32658017.84034
	33	42	9	38.300889	2.065	7.401	Cement (B)	607449.7622	5467047.9	2.53	13831631.09	11756886.42		Unclassified	0
	42	46	4	–	–	–	Waste	607449.7622	2429799	0	0	0			
	46	57	11	44.730727	2.1306364	6.0154545	Cement (P)	607449.7622	6681947.4	2.53	16905326.88	14369527.85			
	57	66	9	41.507444	2.9502222	7.516	Cement (B)	607449.7622	5467047.9	2.53	13831631.09	11756886.42			
	66	75	9	46.946111	1.5818889	5.2183333	Cement (P)	607449.7622	5467047.9	2.53	13831631.09	11756886.42			

	75	100	25	50.50204	1.18768	2.90208	SMS (OH)	607449.7622	15186244	2.53	38421197.46	32658017.84			
PBH-05	0	16.14	16.14	–	–	–	Waste	606339.036	9786312	0	0	0	104132017.3	Cement (P)	39117962.90781
	16.14	24	7.86	40.671963	2.5523397	5.4082481	Cement (B)	606339.036	4765824.8	2.53	12057536.8	10248906.28		Cement (B)	35023616.12346
	24	33	9	44.355667	1.9238889	5.0414444	Cement (P)	606339.036	5457051.3	2.53	13806339.85	11735388.87		SMS(OH)	29990438.22932
	33	42	9	39.772667	2.2982222	7.1897778	Cement (B)	606339.036	5457051.3	2.53	13806339.85	11735388.87		Unclassified	0
	42	46	4	–	–	–	Waste	606339.036	2425356.1	0	0	0			
	46	58	12	45.435583	2.4371917	5.8343083	Cement (P)	606339.036	7276068.4	2.53	18408453.13	15647185.16			
	58	68	10	41.8506	3.23234	7.8074	Cement (B)	606339.036	6063390.4	2.53	15340377.61	13039320.97			
	68	77	9	47.025444	1.7408333	5.3302111	Cement (P)	606339.036	5457051.3	2.53	13806339.85	11735388.87			
	77	100	23	50.819522	1.2850217	2.8948391	SMS (OH)	606339.036	13945798	2.53	35282868.51	29990438.23			
Total											**587023142.496**	**498969671.122**	**498969671.122**	**Total resource**	
														Cement (P)	**195291514.84775**
														Cement (B)	**144403937.17046**
														SMS(OH)	**155684642.98431**
														Unclassified	**3589576.11931**

Table 10.6: Showing the Total Net Resource (G4 as Category 334 of UNFC Classification) by using Polygonal Method

Borehole No	From	To	Thickness (m)	Wt. Average (%)			Grade	Area of influence (sqm)	Volume (m^3)	Bulk density g/cc	Gross Resource (tonnes)	Net Resource (15% deduction) (tonnes)	Total Net Resource (tonnes)	Total grade wise net resource (tonnes) in each borehole	
				CaO	MgO	SiO_2									
PBH-01	0	4	4	–	–	–	Waste	428150	1712599.9	0	0	0	58706161.8	Cement (P)	26701359.66282
	4	13	9	46.213	2.0528889	4.7315556	Cement (P)	428150	3853349.9	2.53	9748975.13	8286628.861		Cement (B)	9207365.40097
	13	23	10	41.074	2.9296	7.7539	Cement (B)	428150	4281499.8	2.53	10832194.59	9207365.401		SMS(OH)	20256203.88214
	23	32	9	47.440222	1.4943333	2.2273158	Cement (P)	428150	3853349.9	2.53	9748975.13	8286628.861		Unclassified	2541232.85067
	32	54	22	50.286409	1.1557727	2.8146818	SMS (OH)	428150	9419299.6	2.53	23830828.1	20256203.88			
	54	65	11	45.142091	1.4778182	6.57	Cement (P)	428150	4709649.8	2.53	11915414.05	10128101.94			
	65	80	15	–	–	–	Waste	428150	6422249.8	0	0	0			
	80	82.76	2.76	37.723493	0.9548986	13.543507	Unclassified	428150	1181694	2.53	2989685.707	2541232.851			
	82.76	100	17.24	–	–	–	Waste	428150	7381305.7	0	0	0			
PBH-03	0	15.7	15.7	–	–	–	Waste	827424	12990557	0	0	0	141567098.2	Cement(P)	49822508.15512
	15.7	26	10.3	38.433136	2.3128544	5.9461165	Cement (B)	827424	8522467.1	2.53	21561841.76	18327565.5		Cement (B)	47260207.73571
	26	33	7	44.458429	1.6612857	4.2415714	Cement (P)	827424	5791967.9	2.53	14653678.87	12455627.04		SMS(OH)	44484382.28135
	33	42.26	9.26	38.479467	2.0347343	7.1687279	Cement (B)	827424	7661946.2	2.53	19384723.76	16477015.2		Unclassified	0
	42.26	47	4.74	–	–	–	Waste	827424	3921989.7	0	0	0			
	47	58	11	45.276364	2.1146364	5.5010909	Cement (P)	827424	9101663.9	2.53	23027209.65	19573128.2			
	58	65	7	40.873571	3.0035714	7.9198571	Cement (B)	827424	5791967.9	2.53	14653678.87	12455627.04			
	65	75	10	45.5171	1.8577	5.5466	Cement (P)	827424	8274239.9	2.53	20933826.96	17793752.91			

	75	100	25	50.29412	1.17748	2.85632	SMS(OH)	827424	20685600	2.53	52334567.39	44484382.28			
PBH-04	0	15.8	15.8	_	_	_	Waste	153069.6	2418499.6	0	0	0	26399928.37	Cement (P)	9216932.59887
	15.8	25	9.2	38.633803	2.3661533	6.2222957	Cement (B)	153069.6	1408240.3	2.53	3562847.895	3028420.711		Cement (B)	8953591.66747
	25	33	8	44.608	1.63175	4.4755	Cement (P)	153069.6	1224556.8	2.53	3098128.605	2633409.314		SMS(OH)	8229404.10613
	33	42	9	38.300889	2.065	7.401	Cement (B)	153069.6	1377626.4	2.53	3485394.68	2962585.478		Unclassified	0
	42	46	4	_	_	_	Waste	153069.6	612278.38	0	0	0			
	46	57	11	44.730727	2.1306364	6.0154545	Cement (P)	153069.6	1683765.5	2.53	4259926.831	3620937.807			
	57	66	9	41.507444	2.9502222	7.516	Cement (B)	153069.6	1377626.4	2.53	3485394.68	2962585.478			
	66	75	9	46.946111	1.5818889	5.2183333	Cement (P)	153069.6	1377626.4	2.53	3485394.68	2962585.478			
	75	100	25	50.50204	1.18768	2.90208	SMS(OH)	153069.6	3826739.9	2.53	9681651.89	8229404.106			
PBH-05	0	16.14	16.14	_	_	_	Waste	431548.4	6965191.8	0	0	0	74113667.29	Cement (P)	27841347.59196
	16.14	24	7.86	40.671963	2.5523397	5.4082481	Cement (B)	431548.4	3391970.7	2.53	8581685.964	7294433.069		Cement (B)	24927286.54400
	24	33	9	44.355667	1.9238889	5.0414444	Cement (P)	431548.4	3883936	2.53	9826357.974	8352404.278		SMS(OH)	21345033.15383
	33	42	9	39.772667	2.2982222	7.1897778	Cement (B)	431548.4	3883936	2.53	9826357.974	8352404.278		Unclassified	0
	42	46	4	_	_	_	Waste	431548.4	1726193.8	0	0	0			
	46	58	12	45.435583	2.4371917	5.8343083	Cement (P)	431548.4	5178581.3	2.53	13101810.63	11136539.04			
	58	68	10	41.8506	3.23234	7.8074	Cement (B)	431548.4	4315484.4	2.53	10918175.53	9280449.197			
	68	77	9	47.025444	1.7408333	5.3302111	Cement (P)	431548.4	3883936	2.53	9826357.974	8352404.278			
	77	100	23	50.819522	1.2850217	2.8948391	SMS (OH)	431548.4	9925614.1	2.53	25111803.71	21345033.15			

Total	**353866888.978**	**300786855.631**	**300786855.631**	**Total resource**	
				Cement (P)	**113582148.00876**
				Cement (B)	**90348451.34815**
				SMS(OH)	**94315023.42346**
				Unclassified	**2541232.85067**

Table 10.7: Showing the Total Net Resource (G3+G4) of UNFC Classification by using Polygonal Method

Borehole No	From	To	Thickness (m)	Wt. Average (%)			Grade	Area of influence (sqm)	Volume (m^3)	Bulk density g/cc	Gross Resource (tonnes)	Net Resource (15% deduction) (tonnes)	Total Net Resource (tonnes)	Total gradewise net resource (tonnes) in each borehole	
				CaO	MgO	SiO_2									
PBH-01	0	4	4	–	–	–	Waste	1032926.109192	4131704.43677	0	0.00000	0.00000	141630572	Cement (P)	64417920.33669
	4	13	9	46.213	2.0528889	4.7315556	Cement (P)	1032926.109192	9296334.98273	2.53	23519727.50630	19991768.38035		Cement (B)	22213075.97817
	13	23	10	41.074	2.9296	7.7539	Cement (B)	1032926.109192	10329261.09192	2.53	26133030.56255	22213075.97817		SMS(OH)	48868767.15197
	23	32	9	47.440222	1.4943333	2.2273158	Cement (P)	1032926.109192	9296334.98273	2.53	23519727.50630	19991768.38035		Unclassified	6130808.96997
	32	54	22	50.286409	1.1557727	2.8146818	SMS (OH)	1032926.109192	22724374.40222	2.53	57492667.23761	48868767.15197			
	54	65	11	45.142091	1.4778182	6.57	Cement (P)	1032926.109192	11362187.20111	2.53	28746333.61881	24434383.57599			
	65	80	15	–	–	–	Waste	1032926.109192	15493891.63788	0	0.00000	0.00000			
	80	82.76	2.76	37.723493	0.9548986	13.543507	Unclassified	1032926.109192	2850876.06137	2.53	7212716.43526	6130808.96997			
	82.76	100	17.24	–	–	–	Waste	1032926.109192	17807646.12247	0	0.00000	0.00000			
PBH-02	0	5	5	–	–	–	Waste	582791.391279	2913956.95639	0	0.00000	0.00000	109813523	Cement (P)	47625129.70390
	5	13	8	38.44	2.946625	6.07825	Cement (B)	582791.391279	4662331.13023	2.53	11795697.75948	10026343.09556		Cement (B)	28349485.10269
	13	23	10	44.7816	1.8989	4.5403	Cement (P)	582791.391279	5827913.91279	2.53	14744622.19935	12532928.86945		SMS(OH)	33838907.94751
	23	31.62	8.62	39.626042	2.3534524	7.5847285	Cement (B)	582791.391279	5023661.79282	2.53	12709864.33584	10803384.68546		Unclassified	0
	31.62	36	4.38	–	–	–	Waste	582791.391279	2552626.29380	0	0.00000	0.00000			
	36	47	11	45.424364	2.3476364	5.9724545	Cement (P)	582791.391279	6410705.30407	2.53	16219084.41929	13786221.75639			
	47	53	6	41.526	3.3335	7.719	Cement (B)	582791.391279	3496748.34767	2.53	8846773.31961	7519757.32167			

	53	64	11	45.121182	2.1749091	6.2195455	Cement (P)	582791.391279	6410705.30407	2.53	16219084.41929	13786221.75639			
	64	91	27	50.398926	1.3561111	3.1197407	SMS (O H)	582791.391279	15735367.56452	2.53	39810479.93825	33838907.94751			
	91	97	6	45.593667	1.555	6.2958333	Cement (P)	582791.391279	3496748.34767	2.53	8846773.31961	7519757.32167			
	97	100	3	_	_	_	Waste	582791.391279	1748374.17384	0	0.00000	0.00000			
PBH-03	0	15.7	15.7	_	_	_	Waste	1396309.657822	21922061.62781	0	0.00000	0.00000	238899897	Cement (P)	84077389.73611
	15.7	26	10.3	38.433136	2.3128544	5.9461165	Cement (B)	1396309.657822	14381989.47557	2.53	36386433.37319	30928468.36721		Cement (B)	79753409.69254
	26	33	7	44.458429	1.6612857	4.2415714	Cement (P)	1396309.657822	9774167.60476	2.53	24728644.04003	21019347.43403		SMS (OH)	75069097.97867
	33	42.26	9.26	38.479467	2.0347343	7.1687279	Cement (B)	1396309.657822	12929827.43143	2.53	32712463.40153	27805593.89130		Unclassified	0
	42.26	47	4.74	_	_	_	Waste	1396309.657822	6618507.77808	0	0.00000	0.00000			
	47	58	11	45.276364	2.1146364	5.5010909	Cement (P)	1396309.657822	15359406.23605	2.53	38859297.77719	33030403.11061			
	58	65	7	40.873571	3.0035714	7.9198571	Cement (B)	1396309.657822	9774167.60476	2.53	24728644.04003	21019347.43403			
	65	75	10	45.5171	1.8577	5.5466	Cement (P)	1396309.657822	13963096.57822	2.53	35326634.34290	30027639.19147			
	75	100	25	50.29412	1.17748	2.85632	SMS (O H)	1396309.657822	34907741.44556	2.53	88316585.85726	75069097.97867			
PBH-04	0	15.8	15.8	_	_	_	Waste	760519.357293	12016205.84523	0	0.00000	0.00000	131166850	Cement (P)	45793912.58005
	15.8	25	9.2	38.633803	2.3661533	6.2222957	Cement (B)	760519.357293	6996778.08710	2.53	17701848.56036	15046571.27630		Cement (B)	44485515.07776
	25	33	8	44.608	1.63175	4.4755	Cement (P)	760519.357293	6084154.85835	2.53	15392911.79161	13083975.02287		SMS (OH)	40887421.94647
	33	42	9	38.300889	2.065	7.401	Cement (B)	760519.357293	6844674.21564	2.53	17317025.76557	14719471.90073		Unclassified	0
	42	46	4	_	_	_	Waste	760519.357293	3042077.42917	0	0.00000	0.00000			
	46	57	11	44.730727	2.1306364	6.0154545	Cement (P)	760519.357293	8365712.93022	2.53	21165253.71347	17990465.65645			
	57	66	9	41.507444	2.9502222	7.516	Cement (B)	760519.357293	6844674.21564	2.53	17317025.76557	14719471.90073			

	66	75	9	46.946111	1.5818889	5.2183333	Cement (P)	760519.357293	6844674.21564	2.53	17317025.76557	14719471.90073			
	75	100	25	50.50204	1.18768	2.90208	SMS (OH)	760519.357293	19012983.93233	2.53	48102849.34879	40887421.94647			
PBH-05	0	16.14	16.14	_	_	_	Waste	1037887.475777	16751503.85904	0	0.00000	0.00000	178245685	Cement (P)	66959310.49976
	16.14	24	7.86	40.671963	2.5523397	5.4082481	Cement (B)	1037887.475777	8157795.55961	2.53	20639222.76581	17543339.35094		Cement (B)	59950902.66745
	24	33	9	44.355667	1.9238889	5.0414444	Cement (P)	1037887.475777	9340987.28199	2.53	23632697.82345	20087793.14993		SMS (OH)	51335471.38315
	33	42	9	39.772667	2.2982222	7.1897778	Cement (B)	1037887.475777	9340987.28199	2.53	23632697.82345	20087793.14993		Unclassified	0
	42	46	4	_	_	_	Waste	1037887.475777	4151549.90311	0	0.00000	0.00000			
	46	58	12	45.435583	2.4371917	5.8343083	Cement (P)	1037887.475777	12454649.70933	2.53	31510263.76459	26783724.19990			
	58	68	10	41.8506	3.23234	7.8074	Cement (B)	1037887.475777	10378874.75777	2.53	26258553.13716	22319770.16659			
	68	77	9	47.025444	1.7408333	5.3302111	Cement (P)	1037887.475777	9340987.28199	2.53	23632697.82345	20087793.14993			
	77	100	23	50.819522	1.2850217	2.8948391	SMS (O H)	1037887.475777	23871411.94287	2.53	60394672.21547	51335471.38315			
Total											**940890031.473971**	**799756526.752875**	**799756527**	**Total resource**	
														Cement (P)	**308873662.85651**
														Cement (B)	**234752388.51862**
														SMS(OH)	**249999666.40777**
														Unclassified	**6130808.96997**

10.10 RESOURCE ESTIMATION BY BLOCK MODEL FOR VALIDATION

In order to validate the resource estimation carried out using the Polygonal Method, an alternative estimation was conducted using a three-dimensional Block Model. The validated resource corresponds to the total block area, encompassing G3+G4 categories, under 334 of UNFC classification. A total net resource of 861.80 million tonnes (G3 + G4) was estimated using the Block Model **(Table 10.8)**, in comparison to 799.76 million tonnes (G3 + G4) estimated through the Polygonal Method (**Table 10.7**). The block model resource estimation yielded a total resource within approximately 5% of the estimate derived from the Polygonal Method.

Due to the minor difference in estimated tonnage between the two methods, the resource figure derived from the Polygonal Method, reflecting a comparatively lower tonnage has been retained for reporting.

A threshold grade of 34% CaO was adopted as the cutoff to distinguish between ore and waste:

- **Borehole intercepts with CaO > 34%** were classified as **ore**.
- **Borehole intercepts with CaO < 34%** were considered as **waste**.

Using the block model, the total resources were calculated on a depth-wise and grade-wise basis. The block model allowed the estimation of:

- **Total volume and tonnage of ore**
- **Average grade (CaO%) per block**
- **Spatial distribution of grade**

The output provided a comprehensive picture of the resource distribution across the block, supporting further mine planning and economic evaluation. The grade-tonnage relationship, as well as sectional and 3D visualizations, were generated and represented in the accompanying below figures **(Fig.10.2-Fig.10.4)**.

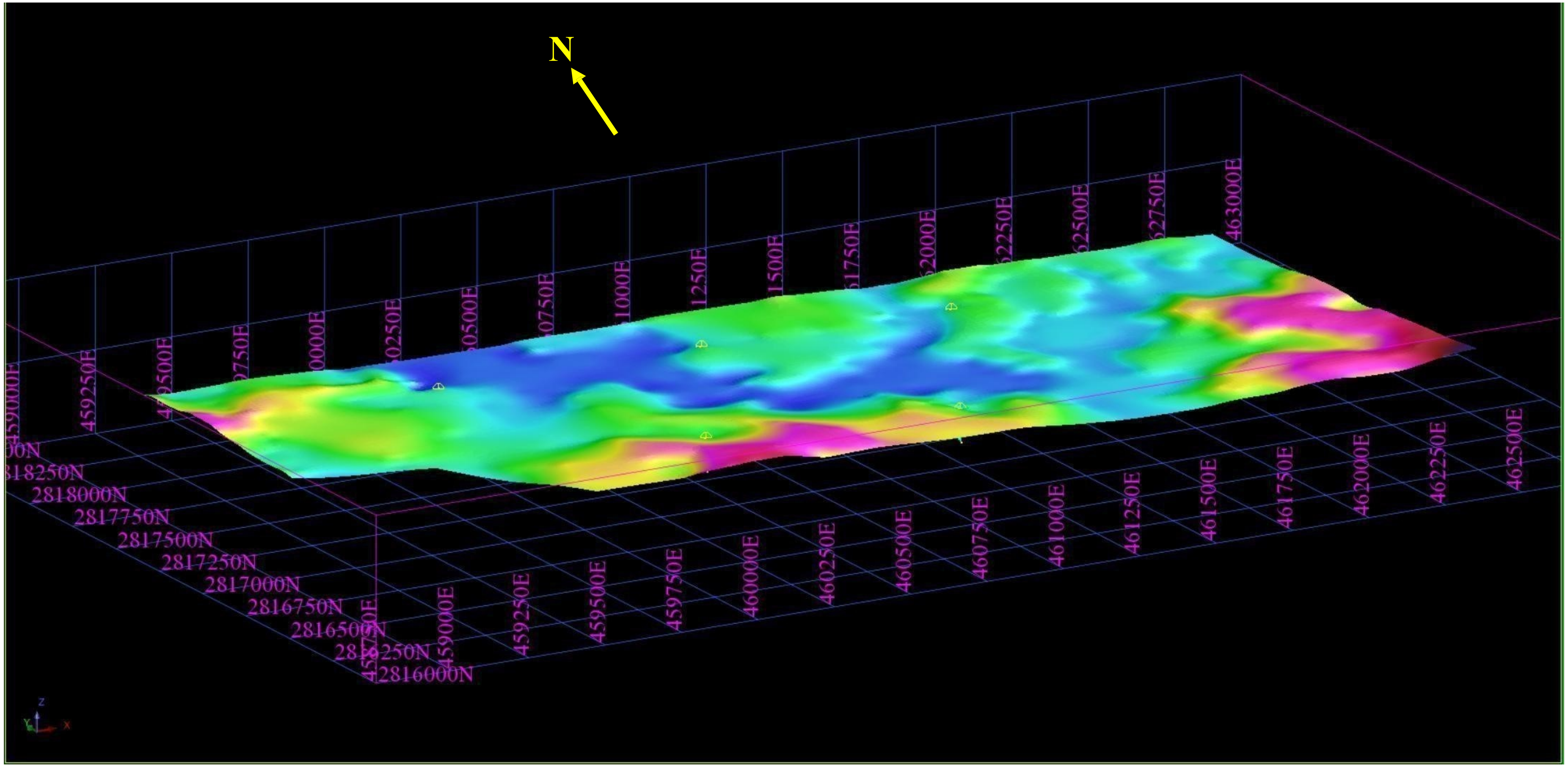

Fig 10.2 Showing 3D Topography of the area

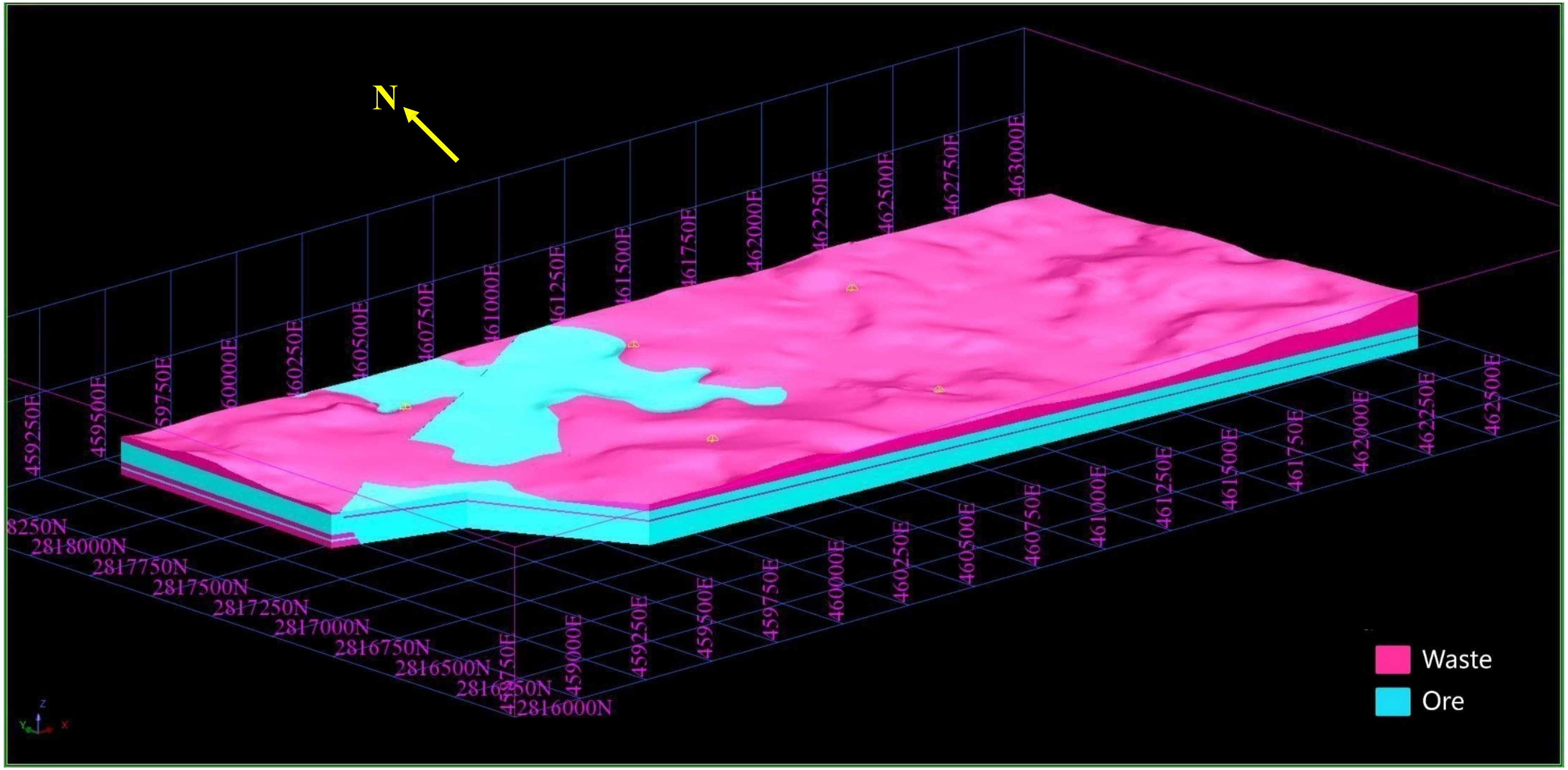

Fig 10.3 3D Solid model showing ore and waste material within the Block

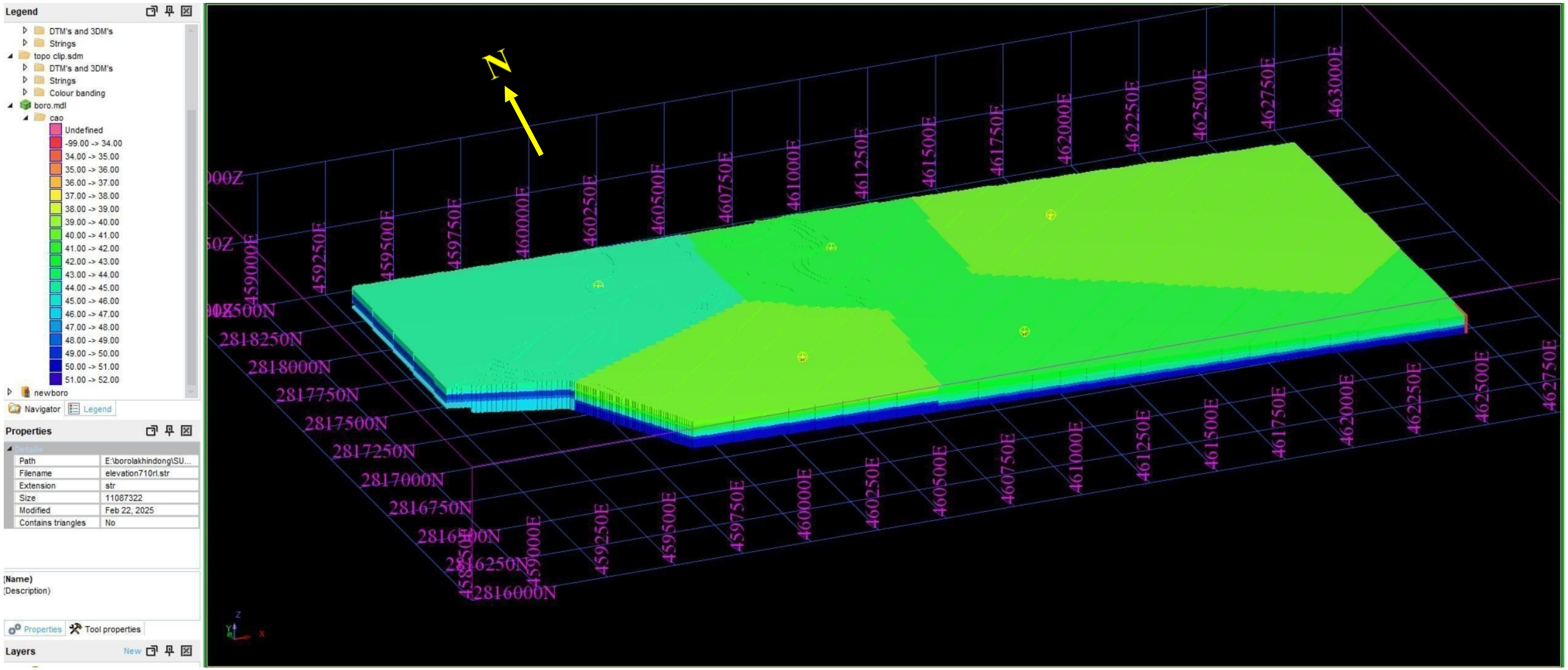

Fig 10.4 3D Solid model Showing distribution of Cao %

Table 10.8: Showing the Gross Total Resource of the block by using Solid Model

CaO (%)	CaO (%)	RL (from)	RL (to)	Volume	Tonnes	CaO (%)	MgO (%)	SiO_2 (%)
40	42	690	700	24000	60720	41.57	2.14	6.32
		700	710	18089562.5	45766593.13	40.93	1.98	5.74
		710	720	19865062.5	50258608.13	41.13	2.06	5.44
		720	730	6245500	15801115	40.88	1.97	5.42
		730	740	583375	1475938.75	40.91	1.97	5.46
42	44	640	650	7375	18658.75	43.06	1.17	8.72
		650	660	1000	2530	43.92	1.23	7.94
		670	680	8000	20240	43.92	2.38	6.08
		680	690	19194562.5	48562243.13	43.05	2.41	6.42
		690	700	31715375	80239898.75	42.41	2.21	6.18
		700	710	12151375	30742978.75	42.53	2.22	5.69
		710	720	3897500	9860675	42.39	2.18	5.41
		720	730	4189625	10599751.25	42.17	2.24	5.24
		730	740	148937.5	376811.875	42.16	2.25	5.23
44	46	640	650	34562.5	87443.125	45.63	1.27	6.48
		650	660	14000	35420	45.45	1.27	6.63
		660	670	24160250	61125432.5	45.34	2.17	5.72
		670	680	29499375	74633418.75	44.5	2.39	5.99
		680	690	13440750	34005097.5	44.26	2.47	6.11
		700	710	8953187.5	22651564.38	45.64	1.95	5.47
		710	720	9662437.5	24445966.88	44.01	2.37	6.08
		720	730	6597750	16692307.5	44.01	2.37	6.08
		730	740	1494937.5	3782191.875	44.01	2.37	6.08
		740	750	22812.5	57715.625	44.01	2.37	6.08
46	48	620	630	793125	2006606.25	46.43	1.28	5.82
		630	640	3210937.5	8123671.875	46.44	1.28	5.81
		640	650	5011312.5	12678620.63	46.44	1.28	5.81
		650	660	5068687.5	12823779.38	46.44	1.28	5.8
		660	670	5117187.5	12946484.38	46.45	1.28	5.8
		670	680	5904750	14939017.5	46.58	2.06	5.27
48	50	620	630	1285437.5	3252156.875	49.09	1.43	3.99
		630	640	5367187.5	13578984.38	49.09	1.43	4
		640	650	5634750	14255917.5	49.09	1.43	4
		650	660	24308750	61501137.5	49.26	1.38	3.57
		660	670	7581500	19181195	49.01	1.39	3.86
		670	680	10295000	26046350	48.12	1.31	4.38
		680	690	10311000	26086830	49.84	1.2	3.16
		690	700	10311000	26086830	49.62	1.22	3.27
50	52	620	630	7951562.5	20117453.13	50.41	1.21	2.95
		630	640	31846250	80571012.5	50.41	1.21	2.95
		640	650	31878250	80651972.5	50.4	1.21	2.93
		650	660	13221687.5	33450869.38	50.53	1.25	2.98
		660	670	5646500	14285645	50.35	1.35	3.1

CaO (%)	CaO (%)	RL (from)	RL (to)	Volume	Tonnes	CaO (%)	MgO (%)	SiO_2 (%)
Grand Total (Gross)				400746187.5	1013887854	46.15	1.79	4.8

10.11 CATEGORY OF RESOURCES AS PER UNFC CLASSIFICATION

Investigation stage of the exploration in Northwest of Boro Lakhindong block was of G-3 stage, so it is categorized under 333 class of UNFC classification. The categorization of resources in UNFC code is given in **Table 10.9** for polygonal method.

Table 10.9 UNFC compliance required for resource estimation

Sr No	Toposheet No	Geological interpretation	The Upper Sylhet Limestone is overlain by intercalation of shale and sandstone of Kopili Formation. It is thickly bedded and horizontal or sub horizontal in nature. Besides the valley region limestone is covered by soil. It can be categorized as type-I of UNFC classification that is Stratiform, Strata bound and tabular deposits of Regular Habit.
1	83C11	Statement of tonnage& grade	Cement (Blendable/Beneficiable): **144.40** million tonnes Cement (Portland): **195.29** million tonnes SMS(OH): **155.68** million tonnes Unclassified/others: **3.58** million tonnes
2	83C11	Geometry of Mineralisation assumed	Horizontal to Sub-horizontal bedded
3	83C11	Method adopted to arrive estimation	Polygonal method
4	83C11	Estimation	498.97 million tonnes (after 15% deduction)

CHAPTER 11

CONCULSION AND RECOMMENDATION

11.1 CONCLUSION:

Preliminary exploration (G3 Stage) for limestone in the northwest part of the Boro Lakhindong block was undertaken during the financial year 2024–25. The primary objective of this exploration was to assess the potential of different grades of limestone within the area. The planned quantum of work for FY 2024–25 was successfully achieved and included detailed geological mapping on a 1:4000 scale, collection of 50 bedrock samples, and five core and bedrock samples for petrological studies. Additionally, a total of 500 meters of vertical drilling was carried out through five boreholes.

The target mineralized horizon for limestone exploration is the Upper Sylhet Limestone of the Shella Formation, which is part of the Jaintia Group. The area also features intercalations of sandstone and shale belonging to the Kopili Formation. The contact between the Kopili Formation and the underlying Upper Sylhet Member of the Shella Formation was established at approximately 727 m RL in the northwestern part and around 721 m RL in the northeastern, central, and remaining parts of the block.

The Upper Sylhet Limestone encountered during drilling is light to medium grey in color, compact, and highly fossiliferous. Notable fossils include Nummulites sp., Discocyclina sp., Alveolina sp., and Assilina sp. Stylolites and thin intercalations of shale and mud are common features. The upper part of the limestone near the contact with the Kopili Formation is ferruginous. Structurally, the limestone unit trends N20°E and dips gently (less than 4°) towards the southeast. Based on borehole data, a subsurface normal fault was interpreted in the northwestern part of the block, located between boreholes PBH-01 and PBH-02. Lithological characteristics and fossil assemblages suggest deposition in a stable, shallow marine environment.

The Upper Sylhet Limestone conformably overlies the Upper Sylhet Sandstone, which is a coal-bearing, grey-colored, medium- to coarse-grained sandstone unit intersected in borehole PBH-

01. All boreholes were drilled vertically at a space of 800 m, covering a total area of 4.82 sq. km.

The Upper Sylhet Limestone was intersected at shallow depths, with thickness ranging from 4.00 m to 100.00 m, and an average thickness of 85.32 m. Overburden thickness ranges from 0.00 m to 16.14 m, with an average of 3.22 m. Core recovery within the mineralized zone was excellent, averaging 97.36%.

Chemical analysis of 451 limestone core samples revealed CaO content ranging from 34.14% to 52.93%, MgO from 0.67% to 4.58%, SiO_2 from 1.49% to 15.83%, Al_2O_3 from 0.93% to 6.44%, and Fe_2O_3 from 0.75% to 19.78%.

Based on the exploration results, a total of 498.96 million tonnes of limestone resource has been estimated and classified under Category 333 (G3 Stage) of the UNFC classification. The grade-wise distribution of this resource is as follows:

Cement (Portland): 195.29 million tonnes

Cement (Blendable/Beneficiable): 144.40 million tonnes

SMS (OH): 155.68 million tonnes

Unclassified/Others: 3.58 million tonnes

11.2 RECOMMENDATION:

In the G3 stage of investigation in the Northwest of Boro Lakhindong Block, total net resource of all grade limestone calculated from all the 05 boreholes of the block as per **UNFC classification** class 333 is estimated to be 498.97 million tonnes with 144.40million tonnes under Cement (Blendable/Beneficiable), 195.29 million tonnes under Cement (Portland), 155.68 million tonnes of SMS (OH) grade and 3.58 million tonnes under unclassified or others category.

The area may be explored for G-2 stage with further closed spacing considering the continuity and considerable resource of limestone in the block.

The overburden ratio is acceptable; hence large-scale open cast mining can be undertaken using modern technology after G-2 stage of investigation.

CHAPTER 12

LOCALITY INDEX

LOCALITY INDEX												
Sr No	**Toposheet No**	**Locality**	**Latitude**	**D**	**M**	**S**	**Lat**	**Longitude**	**D1**	**M1**	**S1**	**Long**
1	83C11	Boro Lakhindong	25°27'37.17"	25	27	37.17	25.46033	92°37'55.5"	92	37	55.5	92.63208
2	83C11	Lanka	25°55'28.56"	25	55	28.56	25.9246	92°56'51.36"	92	56	51.36	92.9476
3	83C11	Lobang	25°26'37.20"	25	26	37.2	25.44367	92°41'38.36"	92	41	38.36	92.69399
4	83C11	Nepali Kunti	25°26'28.12"	25	26	28.12	25.44114	92°37'19.04"	92	37	19.04	92.62196
5	83C11	Tharbe Langso	25°27'20.32"	25	27	20.32	25.45564	92°37'56.73"	92	37	56.73	92.63243
6	83C11	Umrangso	25°30'37.06"	25	30	37.06	25.51029	92°45'42.40"	92	45	42.4	92.76178

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