खान मंत्रालय
MINISTRY OF
MINES

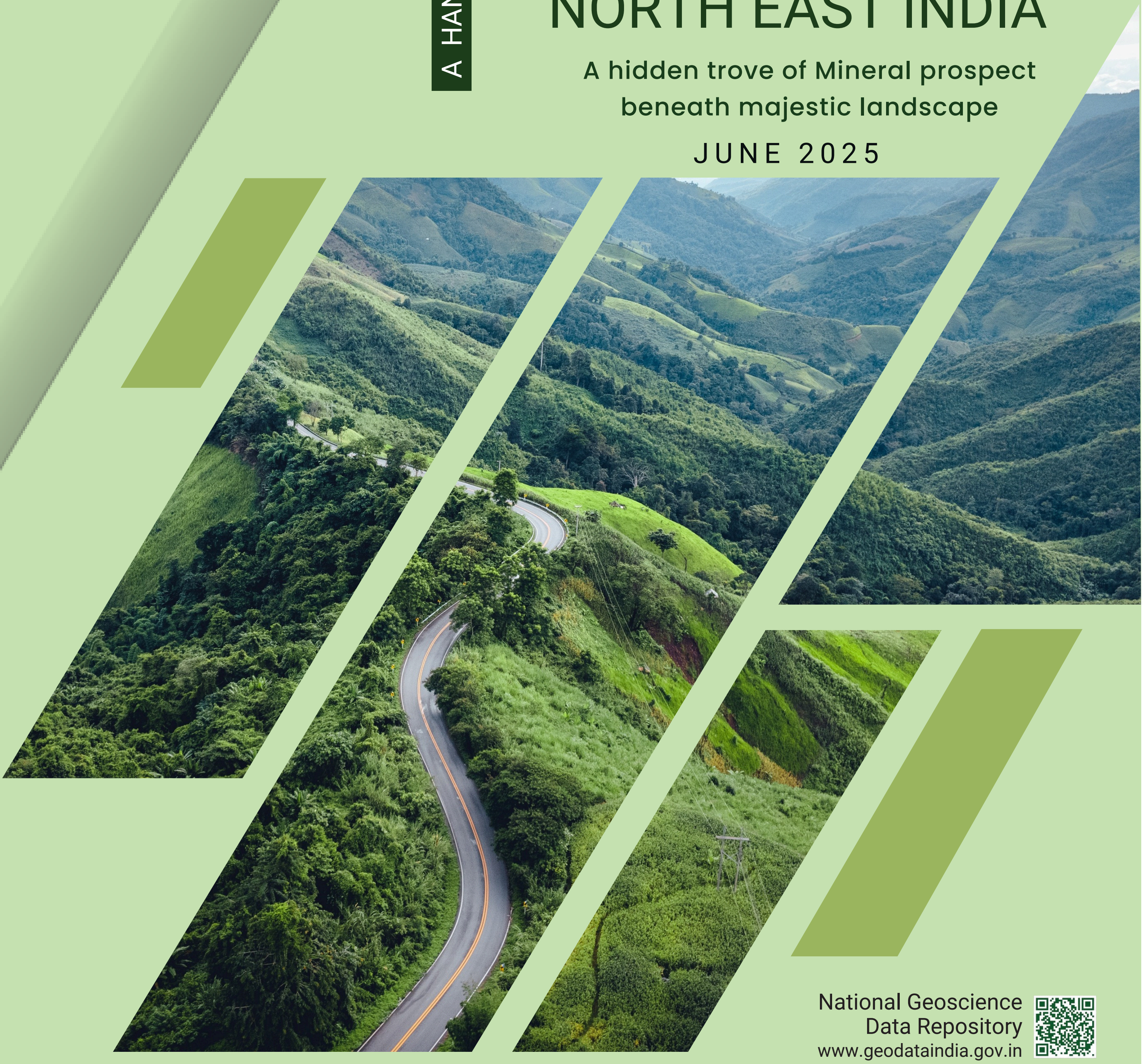
सत्यमेव जयते

A HANDBOOK ON

GEOLOGICAL POTENTIAL OF NORTH EAST INDIA

A hidden trove of Mineral prospect beneath majestic landscape

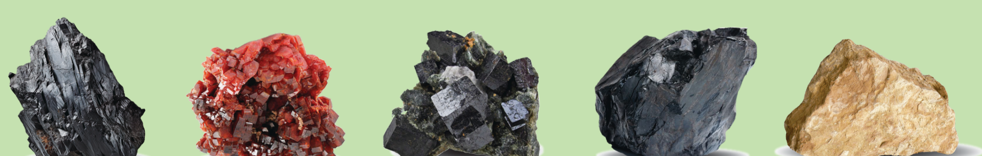
JUNE 2025



National Geoscience Data Repository
www.geodataindia.gov.in

National Mineral Exploration Trust
www.nmet.gov.in

Online Core Business Integrated System
www.gsi.gov.in



Graphite Vanadium Perovskite Coal Limestone

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जी. किशन रेड्डी
జి. కిషన్ రెడ్డి
G. Kishan Reddy

सत्यमेव जयते

कोयला एवं खान मंत्री
भारत सरकार
नई दिल्ली
MINISTER OF COAL AND MINES
GOVERNMENT OF INDIA
NEW DELHI

Foreword

The Government of India envisions the nation's transformation into a developed economy by 2047. This long-term vision of **Viksit Bharat**, guided by the Hon'ble Prime Minister, rests on inclusive growth, regional integration, and strategic resource mobilization. In this journey, the North Eastern Region is emerging not only as a frontier of opportunity but as a key growth area for national progress.

The North East, with its unique geostrategic location and promising mineral endowment, holds immense potential to contribute to India's energy security, industrial development, and future technologies. Its geological richness, comprising critical and strategic minerals such as graphite, vanadium, rare earth elements, limestone, and coal, makes it indispensable to our ambitions in clean energy, digital infrastructure, and advanced manufacturing.

This Handbook on Geological Potential of North East India, meticulously compiled by the Geological Survey of India (GSI), presents a comprehensive synthesis of the region's mineral resources, exploration activities, and future potential. It documents the growing momentum in transforming this region from an underexplored terrain into an investment-ready landscape through policy support, and scientific exploration.

I commend the sustained efforts of GSI in generating high-quality geoscientific data, delineating auctionable blocks, and working hand-in-hand with the states to unlock the region's economic potential. These efforts have already begun to bear fruit, with multiple blocks now auctioned and attracting significant private sector interest.

The Government of India is committed to ensuring the sustainable and inclusive development of the North East. In this context, the mineral sector can play a catalytic role in enhancing regional connectivity, economic growth, and employment. I hope this Handbook will serve as a valuable resource for policymakers, state governments, industry stakeholders, researchers, and students alike.

Let this document serve as both a testimony and a tool in our collective pursuit of mineral-led development that is sustainable, inclusive, and aligned with the vision of Viksit Bharat 2047.

(G. Kishan Reddy)

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सतीश चन्द्र दुबे
Satish Chandra Dubey

सत्यमेव जयते

राज्य मंत्री
कोयला एवं खान
भारत सरकार
MINISTER OF STATE FOR
COAL & MINES
GOVERNMENT OF INDIA

Foreword

India's journey toward becoming a developed economy by 2047, the goal of "**Viksit Bharat"** articulated by the Hon'ble Prime Minister Shri Narendra Modi**,** demands a visionary alignment of natural resource development with national agenda of inclusive, equitable, and sustainable growth. A key enabler in this pursuit is the mineral and mining sector, which provides foundational support to infrastructure, clean energy, advanced technologies and industrial progress.

Over the past decade, the Ministry of Mines, Government of India, has undertaken wide-ranging reforms to enhance transparency, efficiency, and sustainability in mineral governance. These initiatives have not only accelerated resource development but also opened new avenues for exploration and investment across the country.

The North Eastern Region of India is fast emerging as a strategic resource frontier. Rich in geological diversity and ecological uniqueness, the region offers significant potential for the discovery and development of both critical and industrial minerals. The Geological Survey of India (GSI), as the principal agency for geological investigations in the country, has played a crucial role in advancing exploration efforts in the North East with identification of significant occurrences of various mineral commodities. This Handbook on Geological Potential of North East India offers a consolidated overview of the region's mineral potential, exploration achievements, and future prospects. This Handbook is a timely and strategic contribution towards realizing the goals of "Viksit Bharat" through sustainable resource utilization.

I commend GSI for this initiative and hope the Handbook inspires collaborative action among state agencies, industry leaders, academia, and communities to harness the region's resources responsibly. Let this publication serve as a blueprint for transforming the North East into a self-sustaining pillar of mineral-led development.

(Satish Chandra Dubey)

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सचिव
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Foreword

The North Eastern Region of India, with its unique geo-morphological settings, rich biodiversity, and intricate socio-economic challenges, demands focused and innovative geo-scientific approaches to unveil the hidden treasure of mineral resources in this part of the country. Unlocking this potential is essential to achieving the goals of Aatmanirbhar Bharat, which calls for reducing import dependency in key mineral sectors and enhancing domestic supply chains.

Under the stewardship of the Ministry of Mines, significant strides have been made in recent years to prioritize the NER in India's mineral development agenda. Supported by national programs such as the Critical Mineral Assessment Programme (CMAP) and Regional Mineral Targeting (RMT), the Geological Survey of India (GSI) has intensified its exploration work across the region. Exploration in NER is also supported by NMET funding. The recent auctioning of the blocks for graphite, vanadium, and limestone marks a significant turning point in aligning geoscientific data with investment readiness.

This Handbook on Geological Potential of North East India is an important step in that direction. It consolidates the extensive work done by GSI into an accessible format, highlighting not just mineral occurrences but also field achievements, and geological framework.

I am confident that this timely publication will serve as a valuable resource for policymakers, state governments, industry players, and researchers committed to the vision of transformative, inclusive growth in the North East through scientific exploration and responsible resource management.

(V. L. Kantha Rao)

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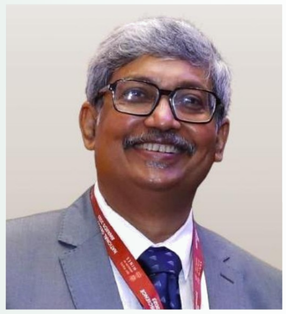
सत्यमेव जयते

असित साहा
महानिदेशक
Asit Saha
Director General



भारत सरकार
भारतीय भूवैज्ञानिक सर्वेक्षण
GOVERNMENT OF INDIA
GEOLOGICAL SURVEY OF INDIA

Preface

Over 174 years, the Geological Survey of India (GSI) has been at the forefront of deciphering the complex geological setup and also unlocking India's mineral prospect through scientific exploration and knowledge dissemination. In recent years, the exploration mandate has assumed greater national urgency with India's aspiration to become Aatmanirbhar; self-reliant in critical and strategic minerals essential for its clean energy transition, digital transformation and economic growth.

Nowhere is this vision more compelling than in the North Eastern Region (NER). Geologically diverse and strategically located, the region presents a complex but promising domain for mineral exploration. Since the MMDR Act amendment in 2015, GSI has significantly intensified its exploration activities in the NER, delineating 38 exploration blocks for auction and augmenting substantial mineral resources, including graphite, vanadium, REEs, coal, limestone, and base metals.

This Handbook is a synthesis of those efforts. It offers readers a state-wise overview of mineral occurrences, exploration milestones, mapping achievements, and future-ready strategies of NER. Through decades of meticulous scientific mapping and exploration, GSI has established itself as a trusted knowledge partner in India's journey towards self-reliance in mineral resources. The integration of new tools, like Regional Mineral Targeting (RMT), Critical Mineral Assessment Programme (CMAP), and the use of AI and geospatial data underscores GSI's commitment to innovation-driven exploration. Besides, GSI contributed significantly in landslide hazard mitigation, engineering projects of Railways, Roads, Hydroelectric power, etc and also on various geoenvironmental aspects across the Northeastern states.

As the custodian of India's geoscientific legacy, GSI is proud to contribute to the building blocks of a self-reliant and future-ready India. This book is not just a repository of data; it is an invitation to states, industry, academia, and other partners to join hands in responsibly harnessing the region's mineral potential.

I express my sincere appreciation to all geoscientists of GSI, North Eastern Region, who contributed to the generation and compilation of data presented here. Their dedication in often difficult and remote field conditions is truly commendable and I hope that this Handbook will serve as a cornerstone document for shaping the next decade of mineral exploration in the NER.

(Asit Saha)
Director General

Content

1. Introduction

1.1 Geographical Context and Strategic Relevance

The North Eastern Region (NER) of India, comprising the states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura, covers approximately 2.62 lakh sq km, representing about 8% of India's total geographical area. The region is bounded by five countries China, Bhutan, Myanmar, Bangladesh, and Nepal, and serves as India's easternmost frontier. This geographical position places NER with strategic significance, both in terms of national security and its potential role in cross-border trade and economic integration under India's Act East Policy.

The region's terrain is largely hilly and mountainous, interspersed with deep valleys, broad river basins, and extensive forest cover. These factors, while contributing to its rich biodiversity, also pose unique logistical and infrastructural challenges. Despite these constraints, the region has begun to attract increasing attention due to its substantial untapped mineral potential.

Table 1: Key Geographic and Geological Statistics of NER States

State	Capital Town	Area (sq km)	Forest Cover (sq km)	Hard Rock Area (sq km)
Arunachal Pradesh	Itanagar	83,578	68,760	74,788
Assam	Dispur	78,523	26,060	27,276
Meghalaya	Shillong	22,489	15,690	21,585
Manipur	Imphal	22,316	17,890	20,308
Nagaland	Kohima	16,527	14,360	15,700
Tripura	Agartala	10,477	5,330	8,000
Mizoram	Aizawl	21,087	18,180	20,087
Sikkim	Gangtok	7,096	3,343	7,096
Total		**2,62,093**	**1,69,613**	**1,94,840**

1.2 Geological Significance and Mineral Resource Endowment

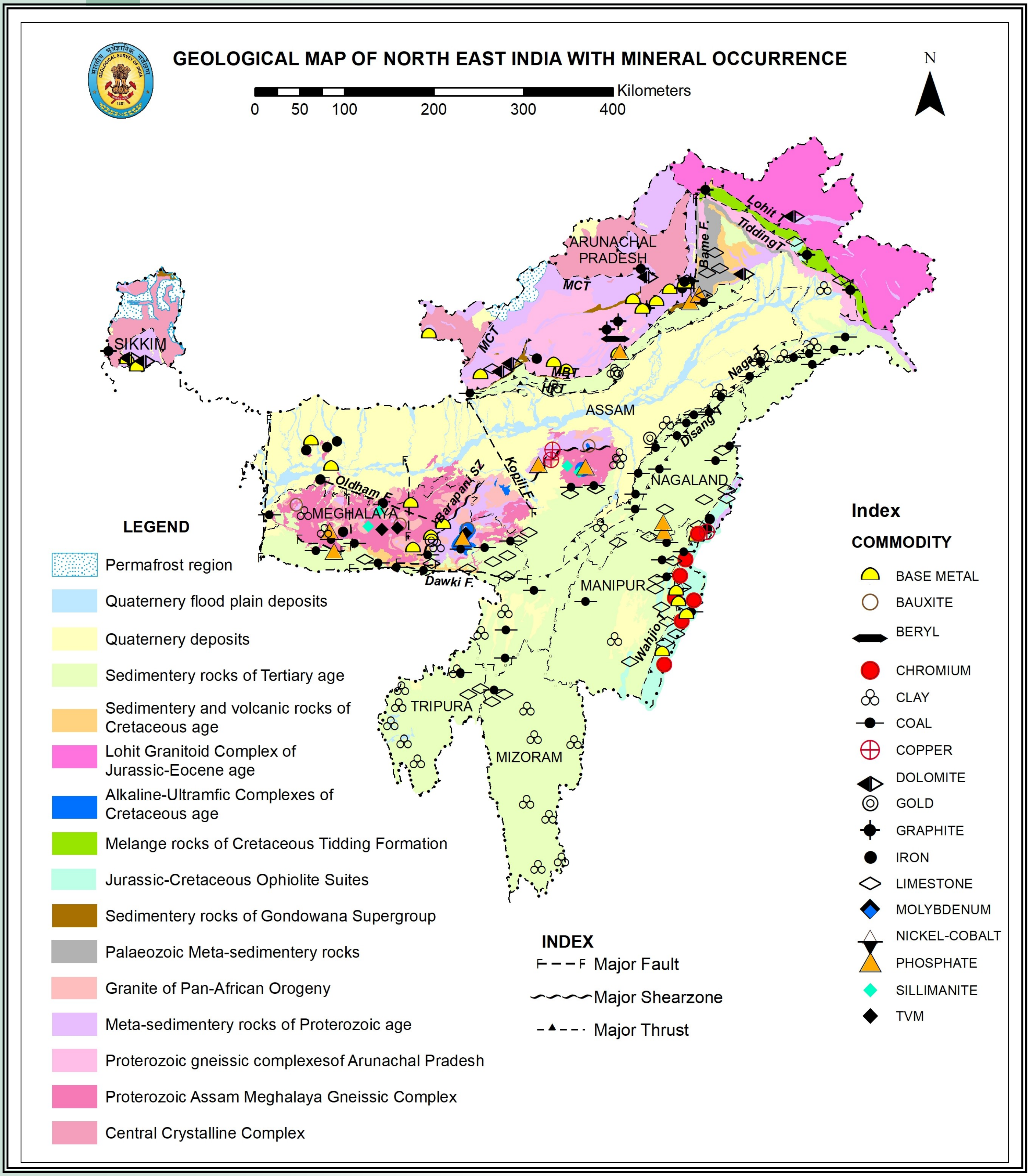
Geologically, the NER lies at the tri-junction of the Indian, Eurasian, and Burmese tectonic plates, resulting in a complex and dynamic geological framework. This includes rock formations ranging in age from the Archaean to the Quaternary and tectonic units such as the Eastern Himalayas, the Shillong Plateau and the Indo-Burma Ranges. The interplay of these geo-tectonic units has given rise to a rich spectrum of mineral occurrences ranging from hydrocarbons and coal to industrial and critical minerals.

Traditionally, the region has been known for its hydrocarbon prospects, with Assam and parts of Arunachal Pradesh having a well-established history of oil and gas exploration since the 19th century. However, in recent decades, detailed geological investigations carried out by the Geological Survey of India (GSI) have confirmed the presence of other economically valuable mineral resources. These include limestone, dolomite, coal, graphite, vanadium, rare earth elements (REEs), rare metals among others.

1.3 Role of Geological Survey of India (GSI)

The Geological Survey of India has played a central role in mapping the geology of the NER and identifying zones of mineral potential. Through its systematic geological, geochemical, and geophysical mapping, GSI has delineated several mineralized belts in the region. These efforts have been further intensified following the MMDR Amendment Act of 2015, which mandated enhanced exploration and the preparation of Geological Reports (GRs) and Geological Memoranda (GMs) for auctionable mineral blocks.

GSI has augmented resource for commodities like REE, graphite, vanadium, Limestone, iron ore etc. and handed over 38 resource bearing blocks since MMDR Amendment Act, 2015 across various states in the NER, contributing to the growing interest of stakeholders in the region's mineral sector. To promote mineral exploration activities in NER, GSI uploads the baseline and exploration data in the National Geo-sciences Data Repository (NGDR) portal as well as Online Core Business Integrated System (OCBIS) portal of GSI which will enable all other stakeholders to take up mineral exploration activities in this region. This handbook aims to present a comprehensive overview of these developments, bringing together geological insights, exploration achievements and a vision for the future.


GEOLOGICAL MAP OF NORTH EAST INDIA WITH MINERAL OCCURRENCE
N
Kilometers
0 50 100 200 300 400
SIKKIM
ARUNACHAL PRADESH
ASSAM
MEGHALAYA
NAGALAND
MANIPUR
TRIPURA
MIZORAM
MCT
MBT
HFT
Bame F.
Lohit T.
TiddingT.
Naga T.
Disang T.
Oldham F.
Barapani SZ
Kopili F.
Dawki F.
Wahjlo T.
LEGEND
Permafrost region
Quaternery flood plain deposits
Quaternery deposits
Sedimentery rocks of Tertiary age
Sedimentery and volcanic rocks of Cretaceous age
Lohit Granitoid Complex of Jurassic-Eocene age
Alkaline-Ultramfic Complexes of Cretaceous age
Melange rocks of Cretaceous Tidding Formation
Jurassic-Cretaceous Ophiolite Suites
Sedimentery rocks of Gondowana Supergroup
Palaeozoic Meta-sedimentery rocks
Granite of Pan-African Orogeny
Meta-sedimentery rocks of Proterozoic age
Proterozoic gneissic complexesof Arunachal Pradesh
Proterozoic Assam Meghalaya Gneissic Complex
Central Crystalline Complex
INDEX
Major Fault
Major Shearzone
Major Thrust
Index
COMMODITY
BASE METAL
BAUXITE
BERYL
CHROMIUM
CLAY
COAL
COPPER
DOLOMITE
GOLD
GRAPHITE
IRON
LIMESTONE
MOLYBDENUM
NICKEL-COBALT
PHOSPHATE
SILLIMANITE
TVM

2. Significance of the North Eastern Region (NER)

2.1 A Gateway to India's Eastern Front

The North Eastern Region (NER) holds immense significance for India, not only due to its geographical and cultural uniqueness but also because of its strategic and economic potential. Enclosed by international borders on nearly all sides and connected to the rest of the country by a narrow land corridor, the region plays a pivotal role in India's geopolitical framework. With the ongoing emphasis on the Act East Policy, the NER is positioned to become a key region for cross-border connectivity and economic cooperation with Southeast Asian nations. The development of mineral resources in the region can catalyze infrastructure growth, enhance logistics, and strengthen India's trade channels with neighbouring countries.

2.2 Ecological and Geological Diversity

The NER is home to some of the most diverse and ecologically sensitive landscapes in the country. From the snow-covered Eastern Himalayas in Arunachal Pradesh to the plateau and hill systems of Meghalaya and Mizoram, and the vast floodplains of the Brahmaputra and Barak rivers in Assam and Tripura, the region offers a variety of terrains. This physiographic diversity is underlain by a rich geological foundation, marked by multiple tectonic domains and a wide range of rock assemblages. This geologically diverse set up contribute significantly to the region's mineral prospects and offer a unique opportunity for exploration of both conventional and unconventional mineral resources.

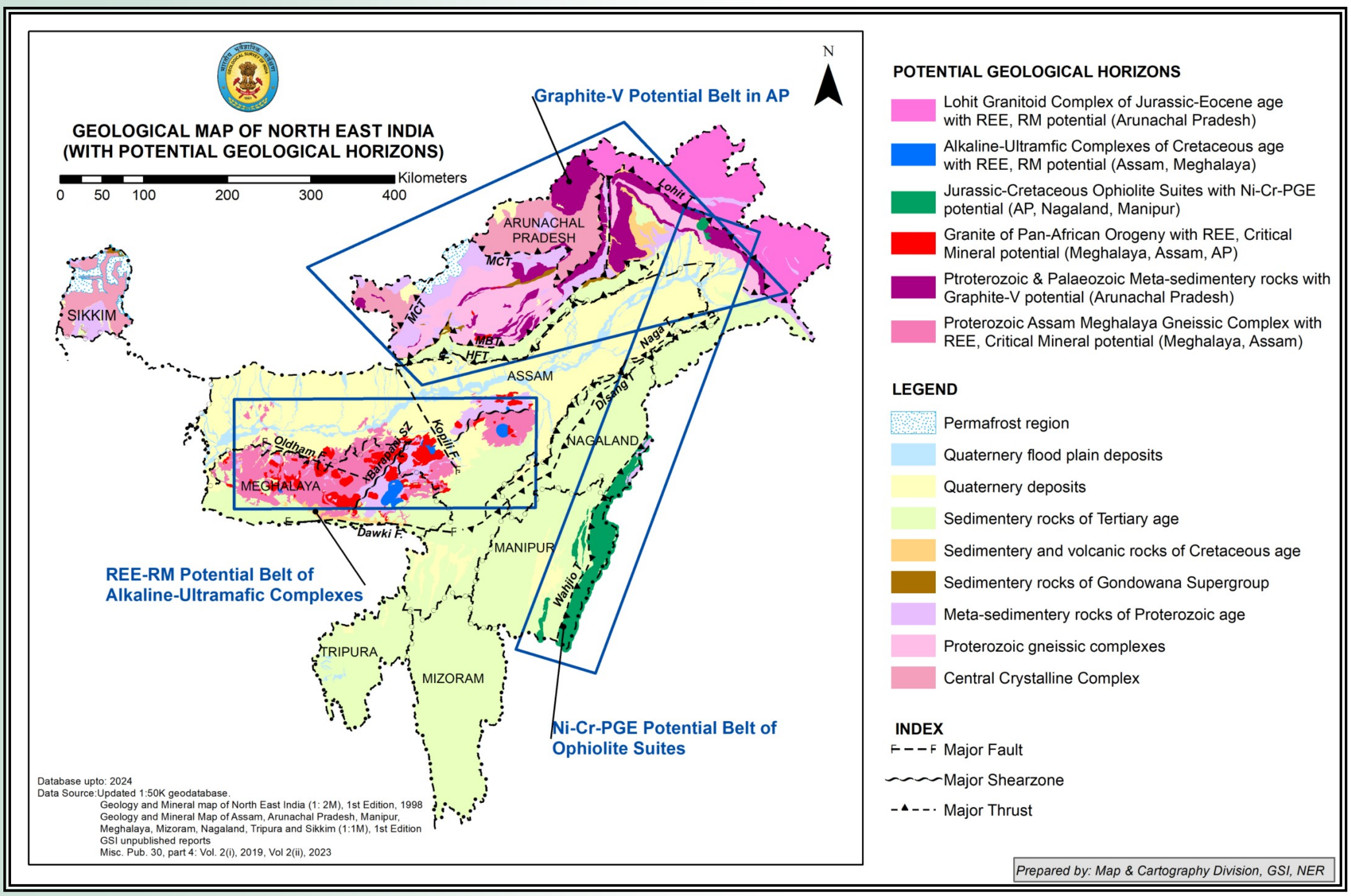
2.3 Untapped Mineral Potential

While the NER has long been associated with hydrocarbons, recent exploration efforts have brought to light substantial deposits of other mineral commodities. The states of Arunachal Pradesh and Assam have emerged as promising zones for graphite, vanadium, REEs, base metals, gold, coal and limestone, while Meghalaya and Nagaland hold extensive resources of limestone, coal, and minor strategic metals. The presence of ophiolite belts, alkaline complexes, and granitic terrains in various parts of the region further indicates its potential for rare metals and industrial minerals.

Despite this potential, mineral development in the NER has historically been limited by challenges such as difficult terrain, ecological sensitivity, limited infrastructure, and socio-political complexities. However, with increased policy support, technological interventions, and coordinated exploration strategies, these challenges are gradually being addressed.

2.4 A Strategic Focus Area for National Growth

Recognizing the potential of the NER to contribute to India's economic and strategic goals, the Ministry of Mines has prioritized the region in its exploration and mineral development agenda. Initiatives such as the Critical Mineral Assessment Programme (CMAP), mineral exploration based on AI-ML technology, Regional Mineral Targeting (RMT) and expansion of baseline geo-science data coverage reflect the Government's commitment to integrate the region into the national mineral supply chain. As India gears up for a mineral-intensive clean energy transition and technological growth, the mineral resources of the NER are poised to play a crucial supporting role.



3. GSI's Strategic Role in Mineral Exploration and Development

3.1 Geological Survey of India: Custodian of India's Subsurface Knowledge

The Geological Survey of India (GSI), established in 1851, has been the country's premier geo-scientific agency entrusted with the mission of creating and disseminating geological knowledge for the nation's development. Over the decades, GSI has evolved from conducting regional geological surveys to undertake integrated multidisciplinary investigations including mineral resource mapping, exploration and data generation. In the context of the North Eastern Region, GSI has been instrumental in unlocking the region's complex geology and identifying zones of significant mineral potential.

3.2 Exploration in the Post-MMDR 2015 Regime: A Paradigm Shift

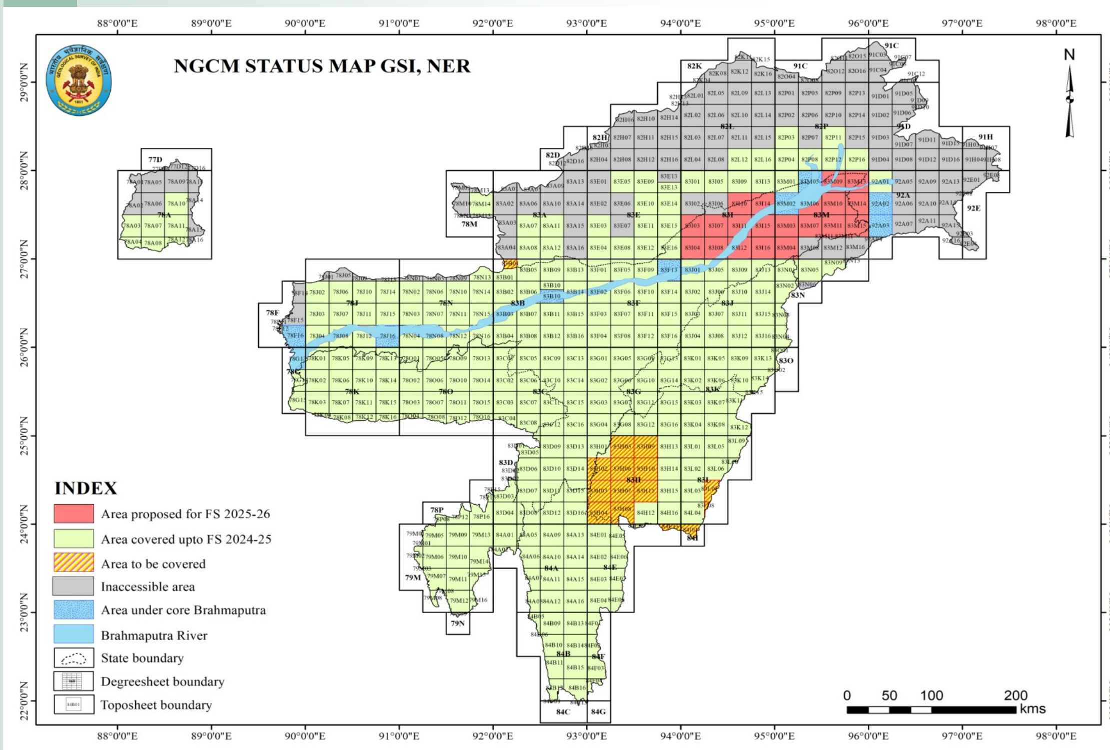
The passage of the Mines and Minerals (Development and Regulation) Amendment Act in 2015 marked a transformative phase in mineral governance in India. The Act mandated exploration agencies like GSI to generate exploration-ready blocks for auction by State/Central Governments. Following this directive, GSI intensified its operations across NER, focusing not only on conventional geological mapping but also on high-priority mineral resource development.

Between 2015 and 2024, GSI has carried out more than 200 nos. various stages (G4/G3/G2) mineral exploration projects and delineated 38 potential blocks in the region across multiple states—Arunachal Prades, Assam, Meghalaya, and Nagaland—through Geological Reports (GR's) and Geological Memorandum (GMs'). These reports encompass both reconnaissance-level and detailed exploration of minerals such as graphite, vanadium, REEs, limestone, copper, nickel, chromium, cobalt, iron and industrial minerals. The outcomes have significantly contributed to the formulation of mineral auctions and private sector engagement in the region.

3.3 Systematic Baseline Data Generation: Building the Geological Foundation

A cornerstone of GSI's work in NER has been the generation of baseline geo-scientific data. Systematic Geological Mapping (SGM) has been covered in the whole region except the permafrost areas. In parallel, Geochemical Mapping (GCM), Geophysical Mapping (GPM), Specialized Thematic mapping (STM) and Photo Geology and Remote Sensing (PGRS) mapping have also been systematically expanded over the large parts of the region.

These baseline data along with existing exploration data has enabled the delineation of mineral potential areas across the region for commodities like REE, Graphite, Ni-Cr-PGE, Gold, basemetal etc. These areas have become the focus of targeted mineral exploration, where further project-level investigations are being planned or executed.


NGCM STATUS MAP GSI, NER
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93°0'0"E
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28°0'0"N
27°0'0"N
26°0'0"N
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24°0'0"N
23°0'0"N
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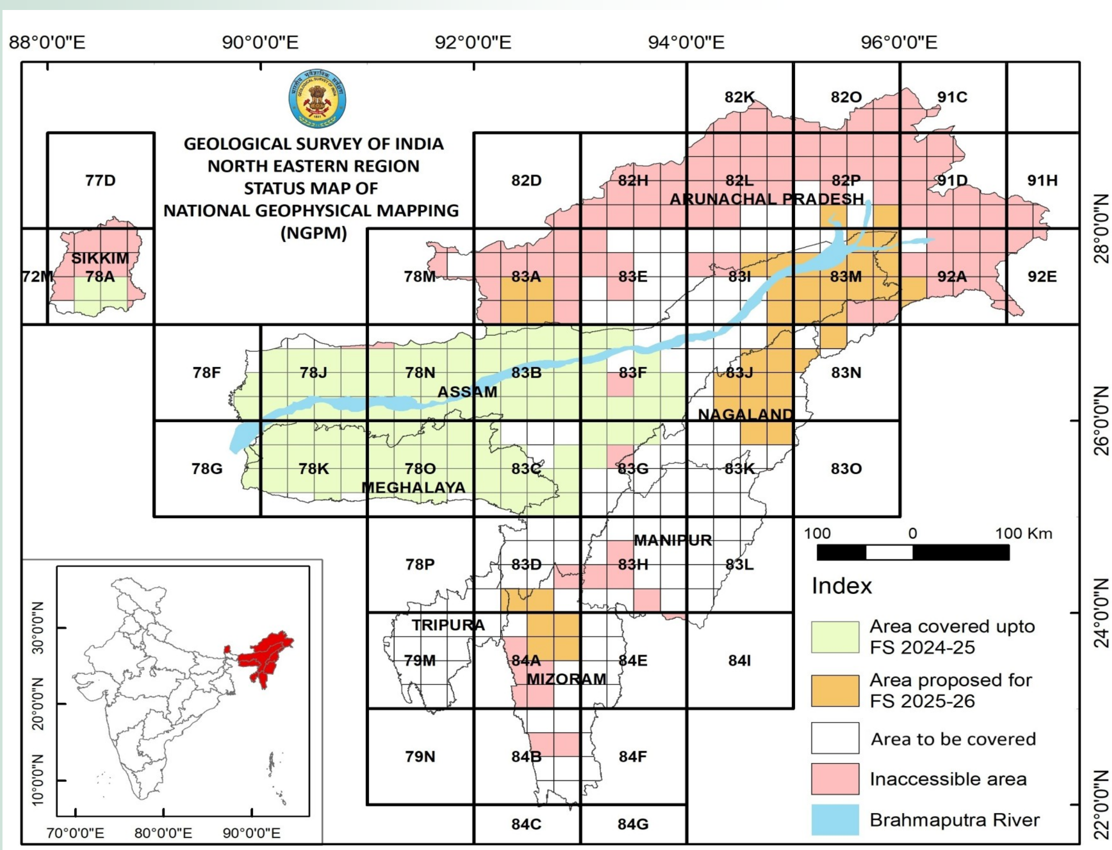
INDEX
Area proposed for FS 2025-26
Area covered upto FS 2024-25
Area to be covered
Inaccessible area
Area under core Brahmaputra
Brahmaputra River
State boundary
Degreesheet boundary
Toposheet boundary
0 50 100 200
kms


GEOLOGICAL SURVEY OF INDIA
NORTH EASTERN REGION
STATUS MAP OF
NATIONAL GEOPHYSICAL MAPPING
(NGPM)
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83L
TRIPURA
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84A
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84I
MIZORAM
79N
84B
84F
84C
84G
100 0 100 Km
Index
Area covered upto FS 2024-25
Area proposed for FS 2025-26
Area to be covered
Inaccessible area
Brahmaputra River
30°0'0"N
20°0'0"N
10°0'0"N
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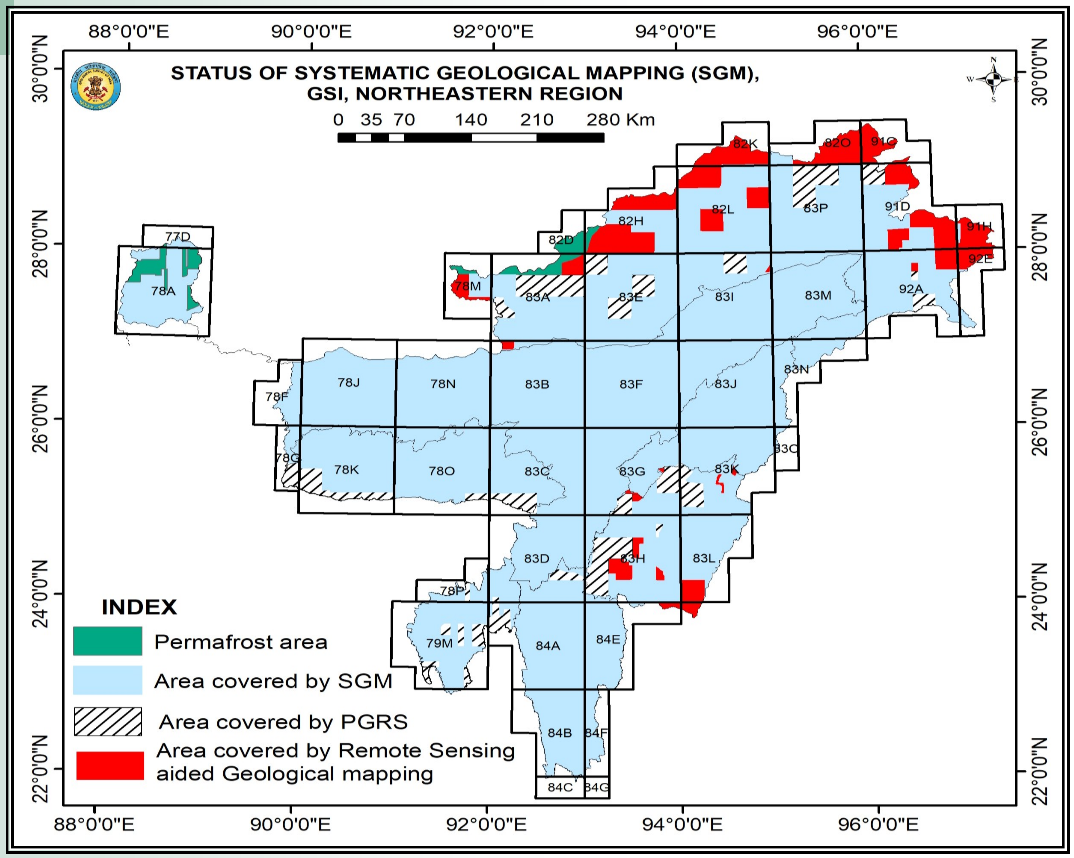
STATUS OF SYSTEMATIC GEOLOGICAL MAPPING (SGM),
GSI, NORTHEASTERN REGION
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83D
83H
83L
78P
79M
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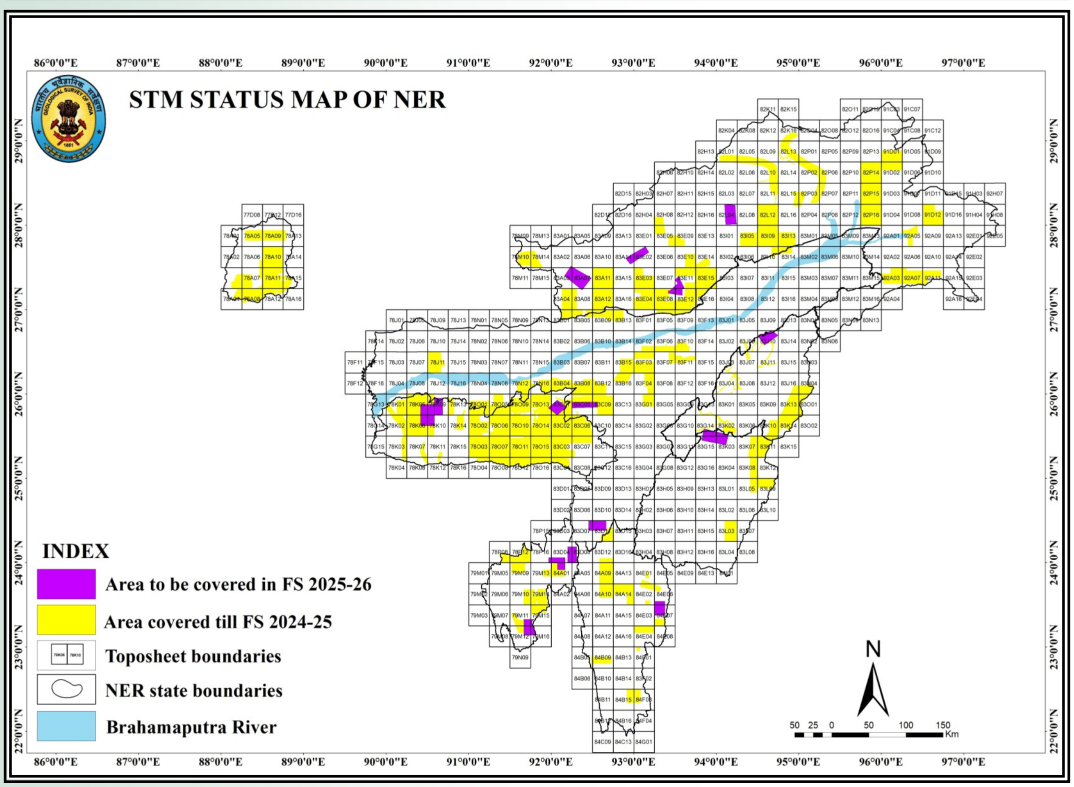
84G
INDEX
Permafrost area
Area covered by SGM
Area covered by PGRS
Area covered by Remote Sensing aided Geological mapping


STM STATUS MAP OF NER
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28°0'0"N
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26°0'0"N
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22°0'0"N
INDEX
Area to be covered in FS 2025-26
Area covered till FS 2024-25
Toposheet boundaries
NER state boundaries
Brahamaputra River
N
50 25 0 50 100 150 Km

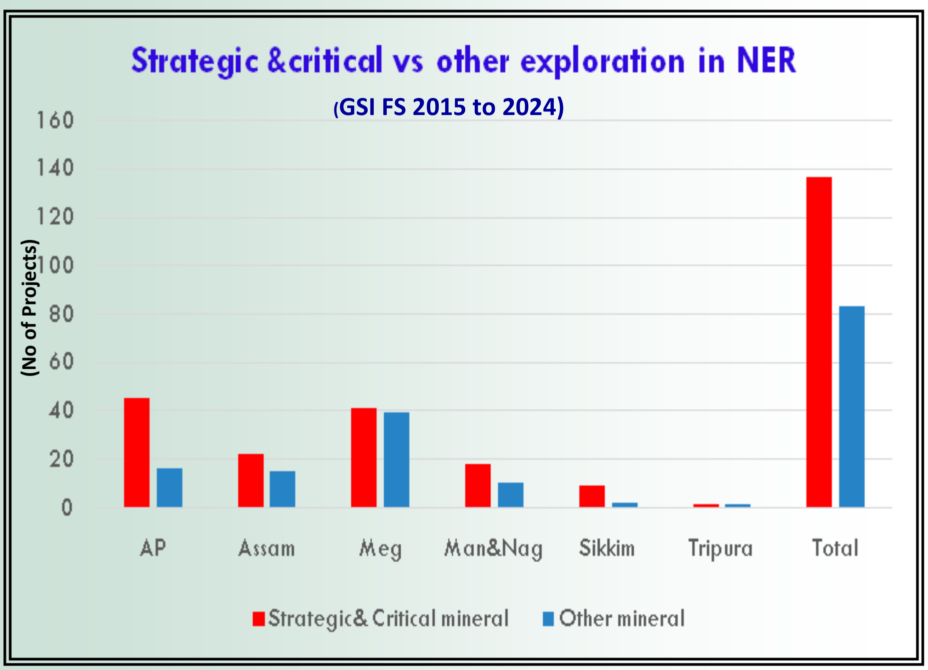
3.4 Resource Augmentation and Auction-Readiness

One of GSI's key mandates is not only to map and explore but also to quantify mineral resources in a manner that meets the standards required for mine auctions. Since 2015, several high-impact resource estimations have been made in the region. These include 24.81 million tonnes of graphite and 17.17 million tonnes of vanadium in Arunachal Pradesh; over 6,600 million tonnes of limestone in Meghalaya; more than 1,400 million tonnes of limestone in Assam and strategic REE resource of 2.15 million tonnes in Arunachal Pradesh and 28.64 million tonnes in Assam.

Of the 38 exploration blocks handed over till date, 7 nos. of blocks on critical and industrial minerals have already been auctioned to preferred bidders, with significant auction premiums recorded reflecting growing industry confidence in the mineral potential of the region.

3.5 A Strategic Pivot Toward Critical and Energy Minerals

GSI's recent exploration strategy in the NER has been aligned with national priorities, particularly in relation to the **critical minerals** that are essential for clean energy technologies, advanced electronics and defence applications. Initiatives such as the **Critical Mineral Assessment Programme (CMAP)** and **Regional Mineral Targeting (RMT)** have been introduced to accelerate the discovery and resource estimation of minerals like REEs, vanadium, lithium, bauxite and gallium.



These programs are designed not only to enhance exploration output but also to de-risk investment by providing high-quality, pre-competitive geological information to states and private stakeholders. With the implementation of these strategies, GSI is paving the way for a structured and sustainable mineral development roadmap for the North Eastern Region.

4. Geological Framework

Understanding the Foundation of Mineral Potential

4.1 A Region of Tectonic Convergence

The North Eastern Region of India occupies a geologically significant position, lying at the triple junction of the Indian, Eurasian, and Burmese tectonic plates. This region represents one of the most geo-dynamically active terrains in the world. The tectonic activity has resulted in an intricate network of thrusts, faults, and fold belts, which over geological time, have shaped the region's topography and mineral endowment.

Six major tectono-geological domains are identified across the region: the Eastern Himalayas, Mishmi Hills, Indo-Burma Ranges, Shillong Plateau, Mikir Hills, and Assam Shelf. These domains not only determine the physiography of the region but also control the distribution of mineral deposits and the types of mineralization encountered.

4.2 Lithological Diversity and Geological Time Span

The rocks of the NER span almost the entire geological time scale—from the Archaean to the Quaternary. The Shillong Plateau and adjoining areas of Assam and Meghalaya are underlain by ancient granitic and gneissic formations of Archaean to Proterozoic age. These are intruded by mafic dykes and overlain by meta-sedimentary and meta-volcanic sequences, which are host for base metals, REEs and Industrial minerals.

The Eastern Himalayas, which spread over Arunachal Pradesh and Sikkim, are primarily composed of metamorphic rocks such as schists, gneisses, and quartzites, interspersed with intrusive granites. In contrast, the Indo-Burma Ranges of Nagaland, Manipur, Mizoram, and Tripura are characterized by folded Tertiary sedimentary sequences, ophiolites, and ultramafic rocks that provide favourable settings for chromite, nickel, cobalt, and minor occurrences of copper and gold.

Quaternary sediments are widespread in the Brahmaputra and Barak River basins and form the fertile plains of Assam and Tripura. Though these areas are generally less prospective for hard-rock minerals, recent studies have indicated potential for placer gold and groundwater-hosted lithium.

4.3 Physiographic Divisions and Their Geological Controls

The NER can be divided into several physiographic units that correspond to its tectonic and lithological divisions:

- **The Himalayan Belt of Arunachal Pradesh** features rugged peaks and steep valleys, underlain by crystalline rocks of Proterozoic to Tertiary age. The region also includes the Sub-Himalayas and the Trans-Himalayan Lohit range, rich in graphite, vanadium, and REEs.
- **The Brahmaputra and Barak Plains**, lying primarily in Assam and Tripura, consist of thick sequences of alluvium. Though seemingly unpromising for hard-rock exploration, these areas are essential for understanding the Quaternary evolution and sediment-hosted resource occurrences such as silica sand and placer minerals.
- **The Shillong Plateau**, occupying much of Meghalaya and parts of Assam, is a Precambrian horst structure known for its exposures of granite, quartzites, and metasediments. It is a key area for limestone, bauxite, REEs, coal and dimension stone.
- **The Indo-Burma Fold Belt**, comprising the eastern hill states—Nagaland, Manipur, Mizoram, and Tripura—is characterized by strongly folded and faulted sedimentary rocks of Tertiary age, including ophiolite suites and ultramafic complexes. This belt hosts chromite, nickel, cobalt, limestone, and coal, albeit with generally lower grade and inconsistence occurrences.
- **Sikkim Himalaya,** features various tectonic domains from Sub-Himalayan to higher Himalayan range comprising granite gneisses, meta-sedimentary rocks of various ages. This belt is potential for basemetal, coal and graphite.

4.4 Geological Mapping and Knowledge Base

Systematic Geological Mapping (SGM) has played a crucial role in unveiling the region's subsurface configuration. As of March 2025, more than 97% of the total area of NER (2.54 lakhs sq. km) has been geologically mapped at a scale of 1:50K. GSI's efforts in thematic mapping such as Geochemical Mapping (GCM) and Geophysical Mapping (GPM) on 1:50K scale and Specialized Thematic Mapping (STM) on 1:25K scale have further refined the understanding of lithological boundaries, geochemical anomalies and subsurface structures. These datasets have formed the backbone for mineral block delineation and future mineral targeting programs. These thematic baseline data has served as the basis for prioritizing target areas for further exploration. A number of mineral exploration projects have been taken up as a spin off of these mapping projects.

Table 4.1: Summary of GRs/GMs Handed Over for Auction

State	GR/GM	Commodity	No. of GRs/GMs
Arunachal Pradesh	GR	Graphite & Vanadium (5), Graphite (2), REE (1), Copper (1)	9
Arunachal Pradesh	GM	Graphite (1), Limestone (1)	2
Assam	GR	Limestone (4), Iron Ore (1), Glass Sand (1)	6
Assam	GM	Limestone	1
Meghalaya	GR	Limestone	19
Nagaland	GM	Nickel, Chromium & Cobalt	1
Total			38

Table 4.2: Status of Auctioned GR/GM Blocks

Sl. No	State	Commodity	Stage	Resources (in MT)	Auctioned Block	Date of Auction	Preferred Bidder (s)
1	Assam	Limestone	G3	474.78	North Boro Hundong A North Boro Hundong B	06.02.2025 25.02.2025	Star Cements Dalmia Bharat Green Vision
2	Assam	Limestone	G3	592.63	South Boro Hundong C	07.02.2025	Ambuja Cements
3	Assam	REE, V, Limestone	G4	-	Boro Hundong (CL)	13.03.2025	Star Cements Meghalaya
4	Arunachal Pradesh	Vanadium & Graphite	G3	V: 0.38 G: 0.43	Depo (CL)	Tranche-IV MoM	Vedanta
5	Arunachal Pradesh	Graphite & Vanadium	G3	V: 5.89 G: 9.67	Radhpu (CL)	Tranche-IV MoM	Orissa Metaliks
6	Arunachal Pradesh	Vanadium & Graphite	G3	V: 6.37 G: 6.549	Phop (CL)	Tranche-IV MoM	Oil India
7	Arunachal Pradesh	Graphite	G4	-	Endolin-Isholin-II (CL)	Tranche-IV MoM	Mamco Mining

Table 4.3: Mineral Resources Augmented by GSI in NER (Post MMDR 2015)

State	Commodity	Exploration Stage	Resource (MT)
Arunachal Pradesh	Graphite	G3	24.81
Arunachal Pradesh	Vanadium	G3	17.17
Arunachal Pradesh	Copper	G3	0.116
Arunachal Pradesh	REE	G3	2.15
Assam	Limestone	G3	1494.30
Assam	REE	G3	28.64
Assam	Iron Ore	G3	18.29
Assam	Glass Sand	G3	4.13
Meghalaya	Limestone	G2	1964.905
Meghalaya	Limestone	G3	4661.786

Lepeidolite, Assam

Magnetite, Assam

Placer Gold, Assam

Basalt with malachite stains, Nagaland

Serpentinite, Manipur

Plastic Clay, Tripura

5. Mineral Exploration

State-wise Overview of Mineral Occurrences and Resource Potential

The North Eastern Region, while historically underexplored, has revealed a vast and varied inventory of mineral resources in recent years. Each state in the region possesses a unique geological identity, translating into a distinctive set of mineral occurrences—from energy minerals like coal and hydrocarbons to critical and strategic minerals such as graphite, vanadium, and rare earth elements. What follows is a state-wise synthesis of the mineral resources based on exploration data generated by the Geological Survey of India (GSI) and allied agencies.

5.1 Arunachal Pradesh: A Frontier of Critical Minerals

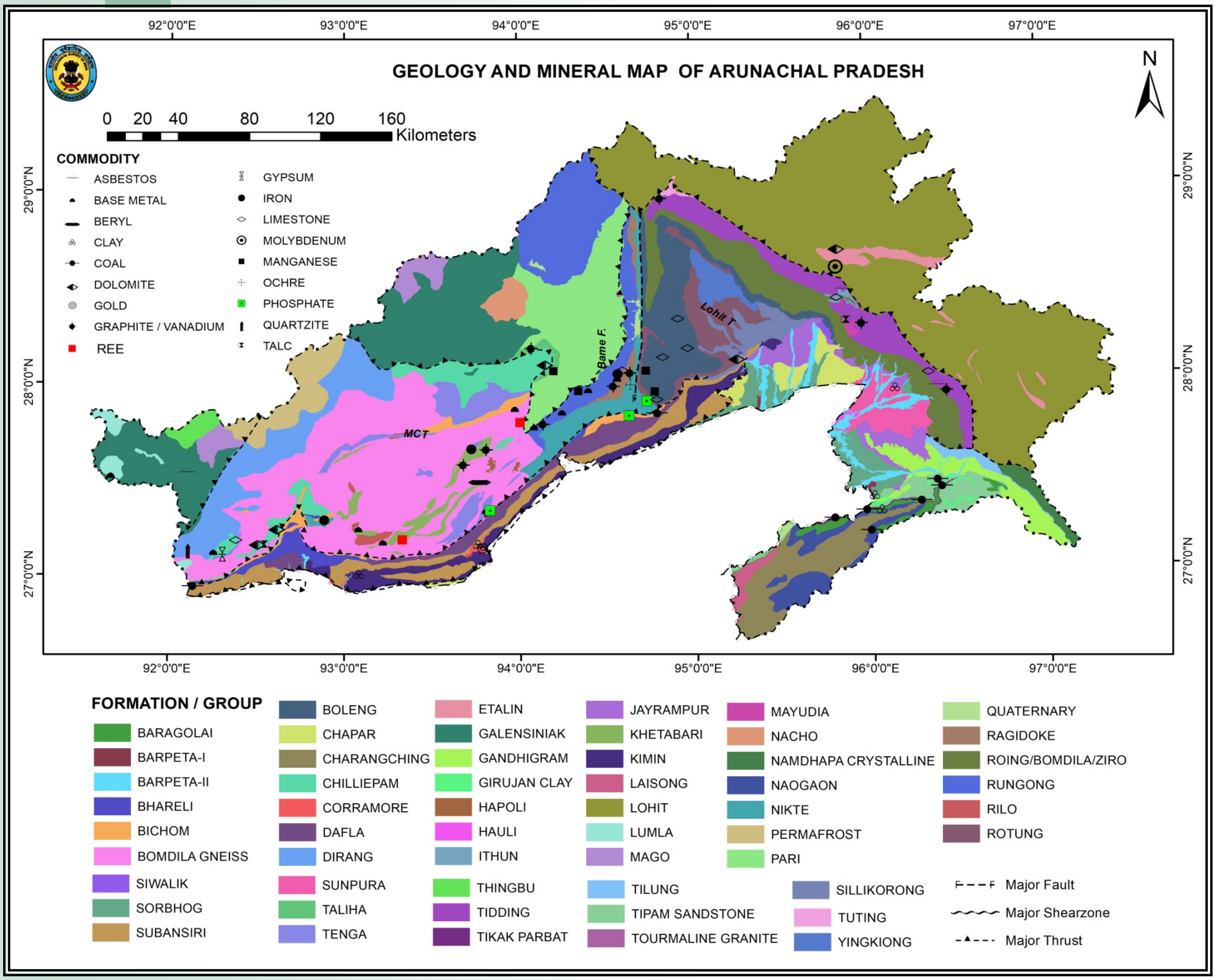
Arunachal Pradesh, often described as the 'land of the rising sun', is geologically characterized by a succession of the Himalayan orogenic belts, including the Tibetan, Higher, Lesser and Sub-Himalayas. The state also hosts the Trans-Himalayan range and parts of the Naga-Patkoi and Mishmi hills. This diverse geological setting is richly endowed with both metallic and non-metallic minerals.

Among the most significant discoveries in recent years is the widespread occurrence of graphite bearing rocks within the Proterozoic meta-sedimentary sequences of the Bomdila Group. These are frequently associated with vanadium, forming a unique mineralization system within carbonaceous phyllite and schist. Since the amendment of the MMDR Act in 2015, GSI has established a graphite resource of over 24.81 million tonnes and a vanadium resource of 17.17 million tonnes across multiple districts, including Lower Subansiri, West Siang and Papum Pare (Table 5.2).

Rare Earth Elements (REEs) have also been identified in the Lodoso area of Papum Pare district, with a delineated resource of 2.15 million tonnes with average grade ∑1.08% REE. Additionally, the crystal-line limestones of the Hunli-Tidding belt and the dolomites of the Menga, Rupa area in Upper Subansiri and West Kameng districts have been mapped as prospective for industrial use.

Copper occurrences, though limited in scale, have been recorded in the Pakke-Kessang district, while minor occurrences of base metals, gold, beryl, molybdenum, and lithium are scattered across the central and eastern parts of the state. The Namchik-Namphuk coalfield in Tirap district represents the only known coal-bearing horizon in the state, although its economic viability is limited.

To date, 11 mineral blocks from Arunachal Pradesh have been handed over for auction, with several already attracting preferred bidders. The state is thus emerging as a key destination for exploration investment, particularly in critical mineral sectors.



Carbonaceous phyllite with a distinct graphite band along NH-13 in Pakro, Pakke-Kessang District, Arunachal Pradesh.

Contact zone between phyllite and carbonaceous phyllite, hosting vanadium and graphite at Sito, Lower Subansiri District, Arunachal Pradesh.

Table 5.1: Geological Reports (GR) and Geological Memoranda (GM) Handed Over for Auction in Arunachal Pradesh (Post-MMDR 2015)

Sl. No.	District	Block Name	Type (GR/GM)	Commodity	Stage	Resource (MT)	Grade Description	FS Period
1	West Siang	Tai-Tachidoni	GR	Graphite	G3	0.36	12.01% Fixed Carbon	2014–16
2	Upper Subansiri	Taliha (Dupit)	GR	Graphite	G3	3.21	26.06% Fixed Carbon	2017–18
3	Papum Pare	Depo Area	GR	Vanadium & Graphite	G3	Vanadium: 0.39 Graphite: 0.43	0.188% V_2O_5 9.43% FC	2018–19
4	Papum Pare	Pakke Kessang	GR	Copper	G3	0.116	0.2386% Copper	2018–19
5	Papum Pare	Lodoso East	GR	REE	G3	2.15	∑REE: 1.08%	2019–21
6	Lower Subansiri	Radhpu	GR	Vanadium & Graphite	G3	Vanadium: 5.8 Graphite: 9.67	0.2482% V_2O_5, 9.998% FC	2020–22
7	Lower Subansiri	Phop	GR	Vanadium & Graphite	G3	Vanadium: 6.37 Graphite: 6.49	0.298% V_2O_5 8.10% FC	2019–21
8	Lower Subansiri	Sito Sikhe Area	GR	Vanadium & Graphite	G3	Vanadium: 3.87 Graphite: 3.97	0.32% V_2O_5 13.30% FC	2021–23
9	PakkeKessang	Pakro	GR	Vanadium & Graphite	G3	Vanadium: 0.74 Graphite: 0.68	0.23% V_2O_5 9.31% FC	2021–23
10	Dibang Valley	Endolin–Isholin	GM	Graphite	G4	Reconnaissance Potential	Block auctioned under Tranche-IV	2019–20
11	Kurung Kumey	Pipa	GM	Limestone	G4	Reconnaissance Potential	GM handed over for future exploration	2023–24

5.2 Assam: A Balance of Energy and Industrial Minerals

Assam's geology is dominated by the sedimentary sequences of the Brahmaputra and Barak plains, the granitic and gneissic cores of the Mikir Hills and the Shillong Group rocks in central Assam. The state is traditionally known for its oil and natural gas reserves, but it also hosts valuable deposits of iron ore, glass sand, limestone, and REEs.

The Jashora alkaline complex and the Samchampi-Samteran belt have emerged as important targets for rare earth exploration with encouraging geochemical anomalies and soil signatures. REE resource of 28.64 million tonnes has been augmented in Jashora Alkaline Complex. The granite gneisses within Assam Meghalaya Gneissic Complex (AMGC) is also potential for REE and Rare Metal (RM).

Assam's largest non-energy mineral resource is limestone, with over 1,490 million tonnes delineated from Dima Hasao district alone. These resources, hosted in the Tertiary formations of the Jaintia Group, are suitable for cement and other industrial applications. 5 nos. GR/GM on limestone have been handed over for blocks such as Sikilangso, Krungming and Boro Hundong areas out of which 3 nos. blocks have been auctioned by the State Government.

Iron ore deposits with an estimated resource of 18.29 million tonnes at an average grade of 37.45% Fe have been reported from the Chandardinga area in Dhubri district.

Glass sand with high silica content (up to 85% SiO_2) has been identified in Nagaon and Karbi Anglong districts, while placer gold has been recorded from the Subansiri River basin in upper Assam. Although modest in grade (0.007 g/t), these gold occurrences are important indicators of potential upstream mineralization.

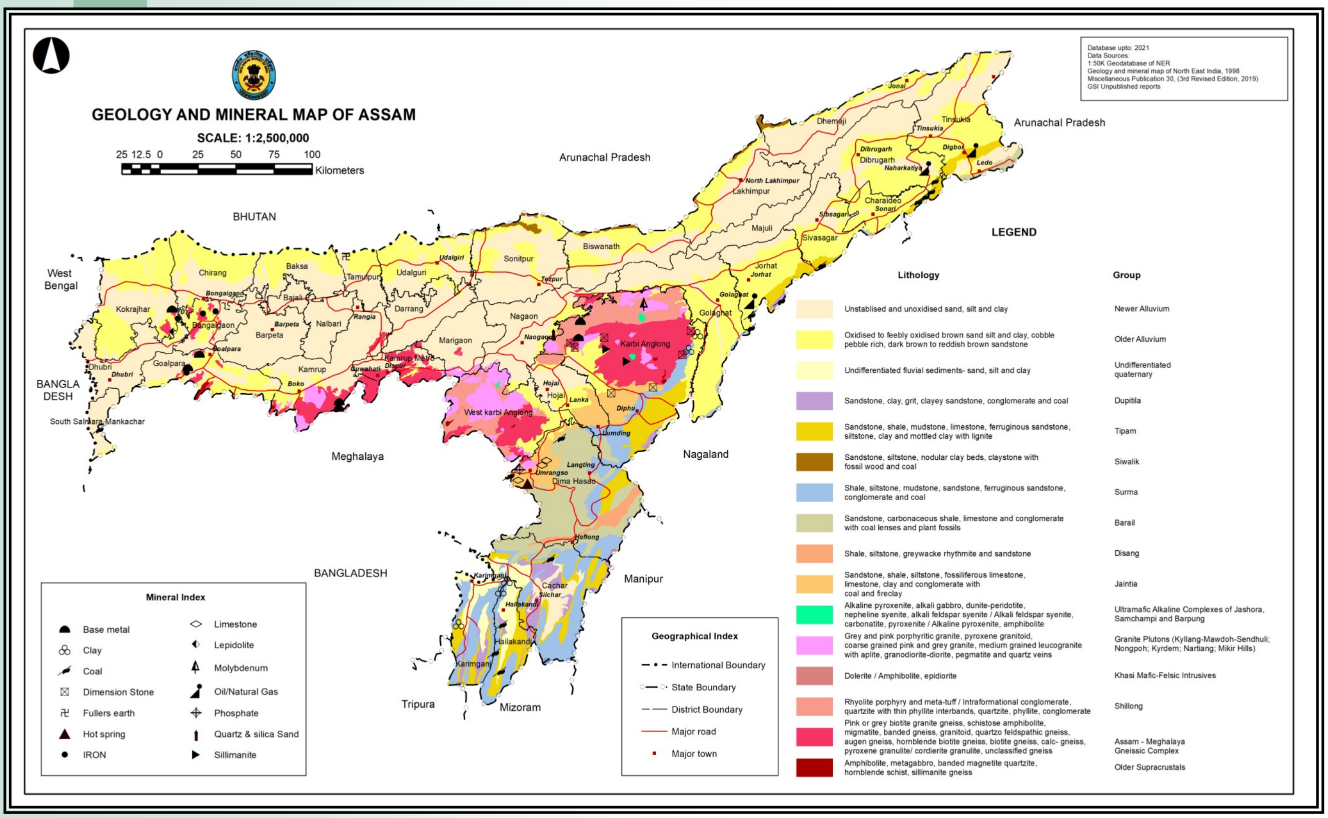
Table 5.2: Mineral Resources Augmented by GSI in Arunachal Pradesh and Assam (Post-MMDR Act, 2015)

Commodity	*Exploration Stage*	*Arunachal Pradesh Resource (Million Tonnes)*
Graphite	G3	24.81 MT
Vanadium	G3	17.17 MT
Copper	G3	0.116 MT
REE	G3	2.15 MT

Commodity	*Exploration Stage*	*Assam Resource (Million Tonnes)*
Limestone	G3	1,494.30 MT
REE	G3	28.64 MT
Iron Ore	G3	18.29 MT
Glass Sand	G3	4.13 MT

Table 5.3: Geological Reports (GR) and Geological Memoranda (GM) Handed Over for Auction in Assam (Post-MMDR Amendment Act, 2015)

Sl. No.	District	Block Name	Type (GR/GM)	Commodity	Exploration Stage	Resource (MT)	Grade / Description	FS Year
1	Nagaon & Karbi Anglong	Silpata–Bamuni–Chapanala–Borhola Block	GR	Glass Sand	G3	4.13	85% SiO_2	2017–18
2	Dhubri (erstwhile Goalpara)	Chandardinga Area	GR	Iron Ore	G3	18.29	37.45% Fe	2016–17
3	Dima Hasao	North Boro Hundong Block	GR	Limestone	G3	474.78	Cement grade (Portland/ Blendable/ Beneficiable)	2019–20
4	Dima Hasao	South Boro Hundong Block	GR	Limestone	G3	588.08	Cement grade (Portland/ Blendable/ Beneficiable)	2019–20
5	Dima Hasao	Sikilnagso Block	GR	Limestone	G3	349.58	Cement grade (Portland/ Blendable/ Beneficiable)	2022–23
6	Dima Hasao	Krungming Block	GR	Limestone	G3	81.86	Cement grade (Portland/ Blendable/ Beneficiable)	2023–24
7	Dima Hasao	Boro Hundong	GM	Limestone	G4	Reconnaissance	GM for future systematic exploration	2019–20



5.3 Meghalaya: Limestone Powerhouse with REE and Bauxite Pockets

Meghalaya's geological landscape is dominated by the Shillong Plateau, composed of Archaean to Proterozoic crystalline rocks intruded by granitic plutons and overlain by sedimentary sequences of Gondwana and Tertiary age. The state is one of India's richest in limestone, particularly in the East Jaintia Hills and Khasi Hills districts.

Since 2015, GSI has delineated more than 6,600 million tonnes of limestone across various grades—cement, SMS, chemical, and blendable—making Meghalaya a key limestone supplier for the northeast and adjoining regions. The Litang Valley , Mawlong–Ishamati and Garo Hills areas are especially prolific.

The Sung Valley Ultramafic-Alkaline Complex has yielded promising values of REEs, particularly from titaniferous bauxite cappings, with ΣREE values ranging from 3,646 to 5,100 ppm. Bauxite itself, primarily of lateritic origin, has been identified in the West Khasi Hills, associated with gneisses and norites.

Meghalaya has had 19 blocks handed over for auction which underscores both the scale and readiness of its mineral resources.

Table 5.4A: Geological Reports Handed Over in Meghalaya (Blocks 1–10)

Sl. No.	District	Block Name	Type	Commodity	Expl. Stage	Resource (MT)	Grade / Description	FS Year
1	Jaintia Hills	Jalaphet Block	GR	Limestone	G2	61.66	Cement grade, Portland blendable, SMS-OH, Unclassified	2015–16
2	Jaintia Hills	Um-Maju Block	GR	Limestone	G2	69.46	Cement, SMS-OH, SMS LD, Chemical grade	2015–16
3	Jaintia Hills	Shyrwang Block	GR	Limestone	G2	247.87	Cement (blendable), Portland, SMS-OH, Unclassified	2015–16
4	East Khasi Hills	West Ishamati Block	GR	Limestone	G2	71.78	51.05% CaO	2016–17
5	Jaintia Hills	North of Larket Block, West of Litang	GR	Limestone	G2	247.45	43.74% CaO	2016–17
6	Jaintia Hills	Shnongrim–Molasngi Block	GR	Limestone	G2	182.11	45.37% CaO	2016–17
7	Jaintia Hills	Tongseng–Shnongrim Block	GR	Limestone	G2	202.61	46.12% CaO	2016–17
8	Jaintia Hills	Mynthning Block	GR	Limestone	G2	97.64	45.16% CaO	2016–17
9	East Jaintia Hills	Samasi–Pala Block	GR	Limestone	G3	363.20	Cement, Portland	2017–18
10	East Jaintia Hills	Umkyrpong Area	GR	Limestone	G3	496.82	Cement, Portland	2017–18

Table 5.4B: Geological Reports Handed Over in Meghalaya (Blocks 11–19)

Sl. No.	District	Block Name	Type	Commodity	Expl. Stage	Resource (MT)	Grade / Description	FS Year
11	East Jaintia Hills	East of Laphet Area	GR	Limestone	G3	607.65	Cement, Portland	2017–18
12	East Jaintia Hills	South of Akshe Area	GR	Limestone	G3	559.36	Cement Portland	2017–18
13	East Jaintia Hills	Akshe Block	GR	Limestone	G3	516.70	Blendable cement, Portland	2018–19
14	East Jaintia Hills	Southeast of Akshe	GR	Limestone	G3	706.80	Portland, Blendable, SMS, Others	2018–19
15	East Jaintia Hills	North Pala Block	GR	Limestone	G3	522.35	Portland, Blendable, SMS, Unclassified	2018–19
16	East Jaintia Hills	Lamarsiang Block	GR	Limestone	G2	228.37	Cement (Blendable/ Beneficiable), Portland, SMS	2019–20
17	East Jaintia Hills	Khaidong–Shnongrim Block	GR	Limestone	G2	385.21	Cement (Blendable), Portland, SMS, Unclassified	2019–20
18	East Jaintia Hills	Southwest of Mynthlu Block	GR	Limestone	G2	170.75	Cement (Blendable), Portland, SMS, Unclassified	2019–20
19	East Jaintia Hills	Khunti Block	GR	Limestone	G3	888.91	Cement (Blendable), Portland, SMS, Unclassified	2023–24

5.4 Nagaland: Mineralization in Ophiolitic Terrains

Nagaland occupies a geologically critical zone along the Indo-Myanmar tectonic boundary. The state is predominantly composed of Tertiary sedimentary formations in the west and ophiolite complexes in the east, which include ultramafic- mafic intrusions, peridotites, and associated volcanic and sedimentary rocks. These ophiolitic belts are of particular interest due to their potential for hosting strategic and critical minerals. Chromite occurrences in Nagaland, while minor, are typically podiform in nature and associated with ultramafic rocks in areas like Reguri, Mollen, and Washello in Phek district. These pods range from massive to disseminated types and are geologically linked to serpentinized dunites and peridotites.

One of the most notable mineral assemblages in the state is the nickel–cobalt–chromium suite found in association with magnetite in ultramafic cumulates. These have been reported from the Mollen-Washello area of Meluri sub-division and have drawn interest for critical mineral assessment. A Geological Memorandum (GM) for this block has been handed over to the State Government. Limestone occurrences are widespread and include both chemical and cement-grade deposits in Tuensang and Phek districts, particularly in areas like Wazeho and Pang. Coal of Tertiary age is also found in the Schuppen Belt, though the seams are thin and discontinuous. Despite the challenging terrain and limited infrastructure, Nagaland remains a high-potential state for future exploration, particularly for critical minerals in ophiolitic rocks.

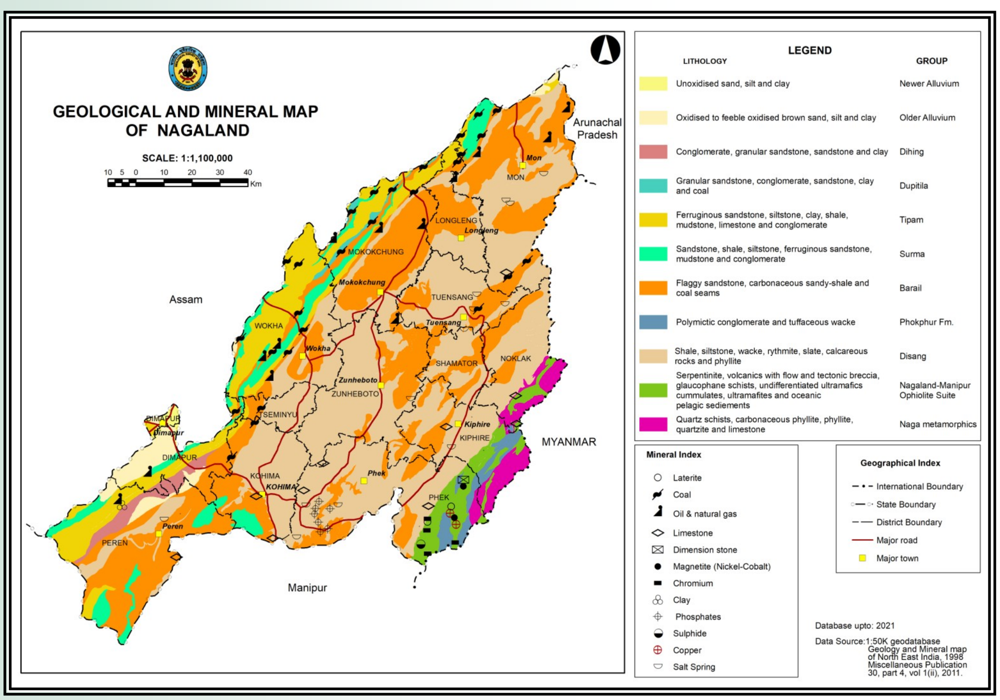
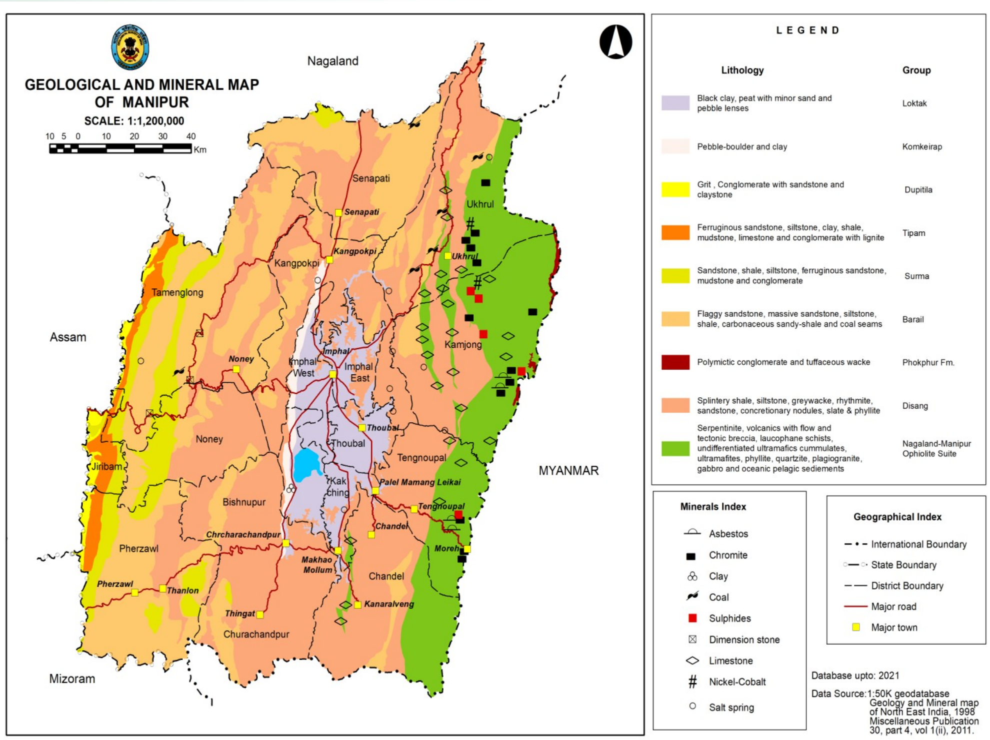


Table 5.5: Geological Memorandum (GM) Handed Over for Auction in Nagaland (Post-MMDR Act, 2015**)**

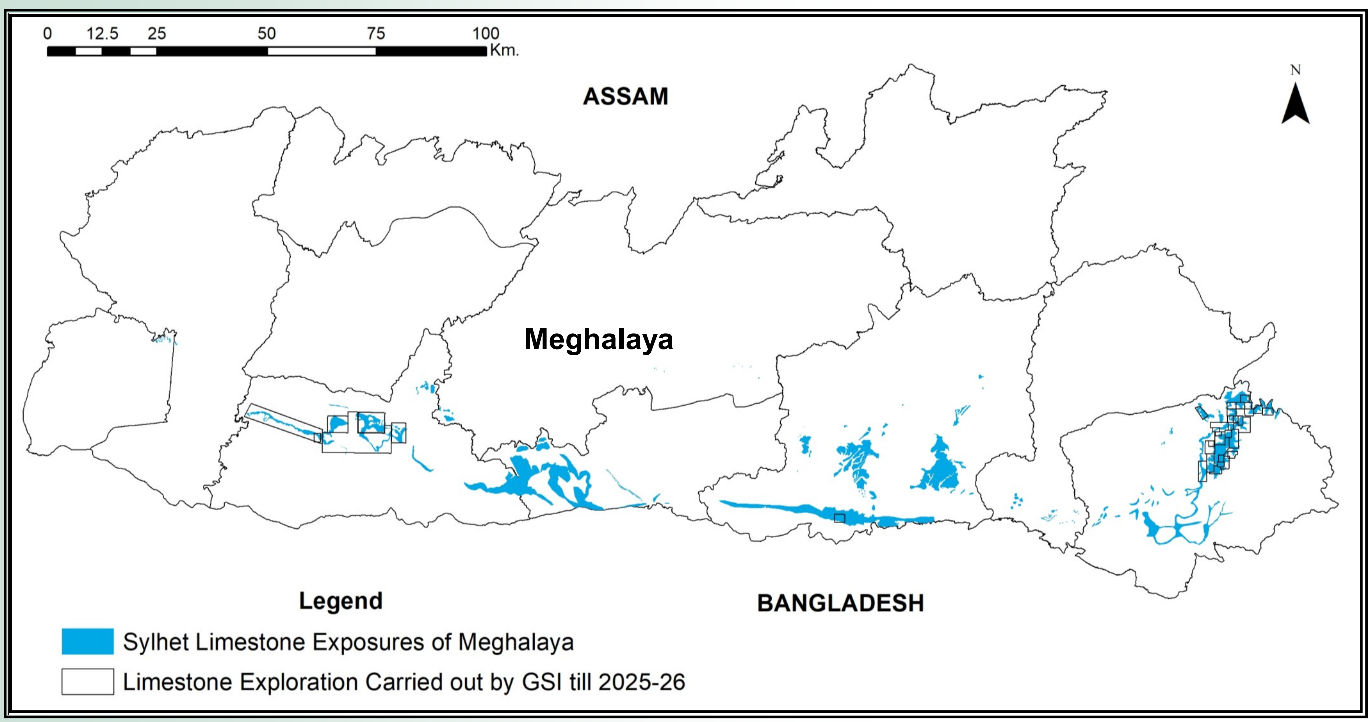
Sl. No.	District	Block Name	Type	Commodity	Expl. Stage	Resource	FS Year
1	Meluri	Mollen–Washelo	GM	Nickel, Chromium & Cobalt	Reconnais-sance	Potential for systematic exploration	2020–21

5.5 Manipur: Geologically Young but Promising

Manipur's geology is a continuation of the Indo-Burma Ranges, consisting largely of Tertiary flysch-type sedimentary rocks and dismembered ophiolite complexes. While the region is younger in geological terms compared to the Shillong Plateau or Himalayan sequences, the presence of ultramafic bodies offers possibilities for chromite, nickel, and associated base metals. Chromite has been identified in podiform settings within the ophiolite belts in Ukhrul district, including areas such as Sirohi, Harbui, and Lunghar. These chromite pockets are typically hosted in serpentinized peridotite and are often small and scattered. Limestone, though not as extensive as in Meghalaya, is found in sporadic lenses and pods within the Disang and Barail Group rocks. The potential for dimension stone and decorative stone also exists, particularly in ophiolite-derived formations. Clay and lignite deposits have been recorded from the Kangvai Valley, but are largely confined to small pockets and are of local significance. Manipur's mineral potential is being reassessed under the Critical Mineral Assessment Programme, especially in relation to lateritic profiles that may host nickel, cobalt and REEs.



Serpentinised peridotite-plagiogranite sequence in Ophiolite Belt, Meluri District, Nagaland



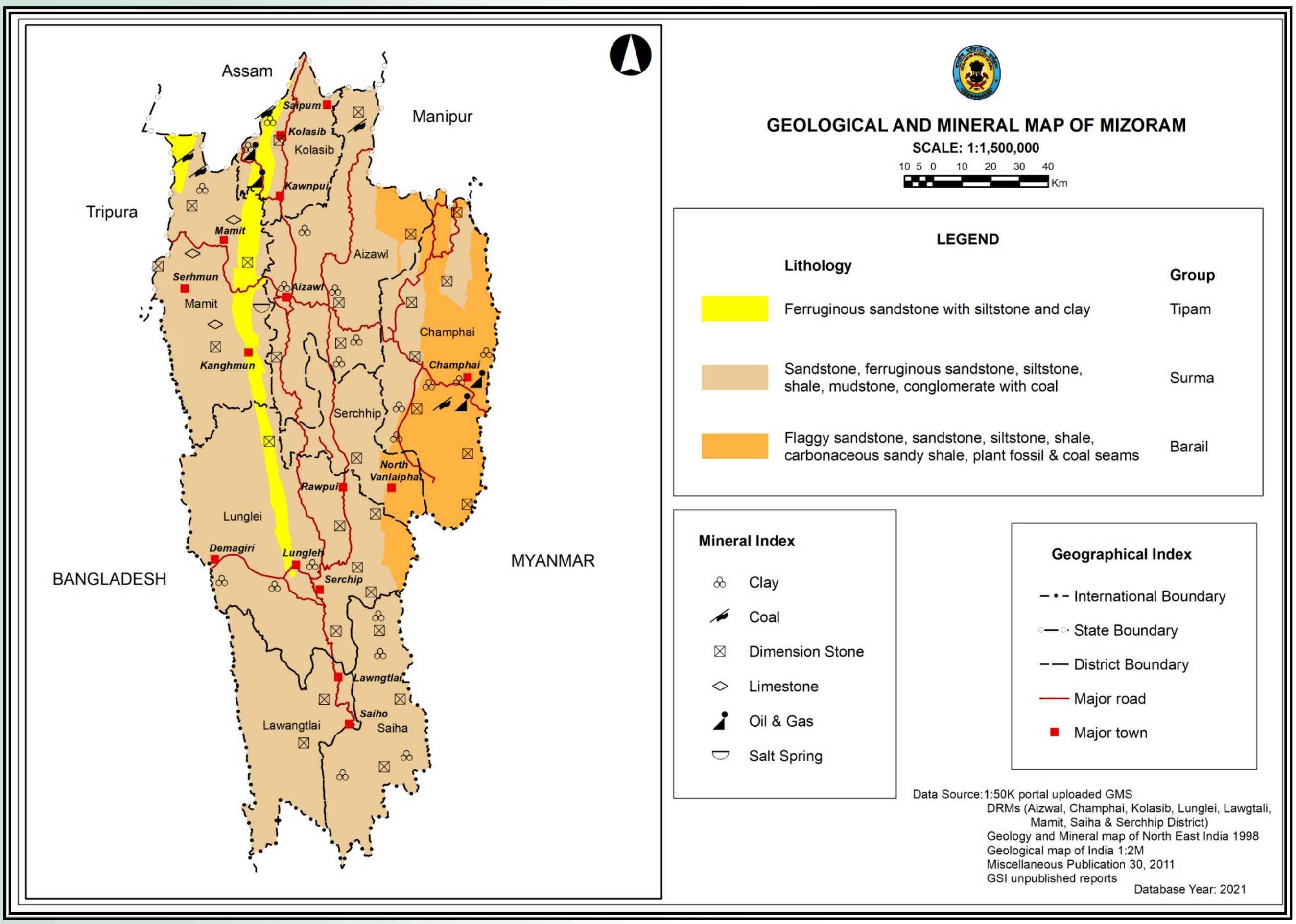
Status Map of Limestone deposit in Meghalaya

5.6 Mizoram: Underexplored but Geologically Intriguing

Mizoram is part of the western arm of the Indo-Burma Ranges and is composed predominantly of folded and faulted Tertiary sediments belonging to the Surma and Barail Groups. These sequences are characterized by alternating bands of sandstone, shale, and siltstone, forming a strongly deformed hill-and-valley landscape.

The mineral resources of Mizoram are limited, primarily due to the region's young geology and limited extent of exposed basement rocks. However, potential exists for hydrocarbons, clay and construction grade materials. Coal seams of limited thickness have been reported, although they are generally discontinuous and poor in quality.

Exploration is currently being proposed in selected areas under the FS 2025–26 plan, particularly to assess the potential for limestone within the sedimentary sequence. Mizoram's mineral potential remains largely untapped and may benefit from targeted reconnaissance surveys in the coming years.

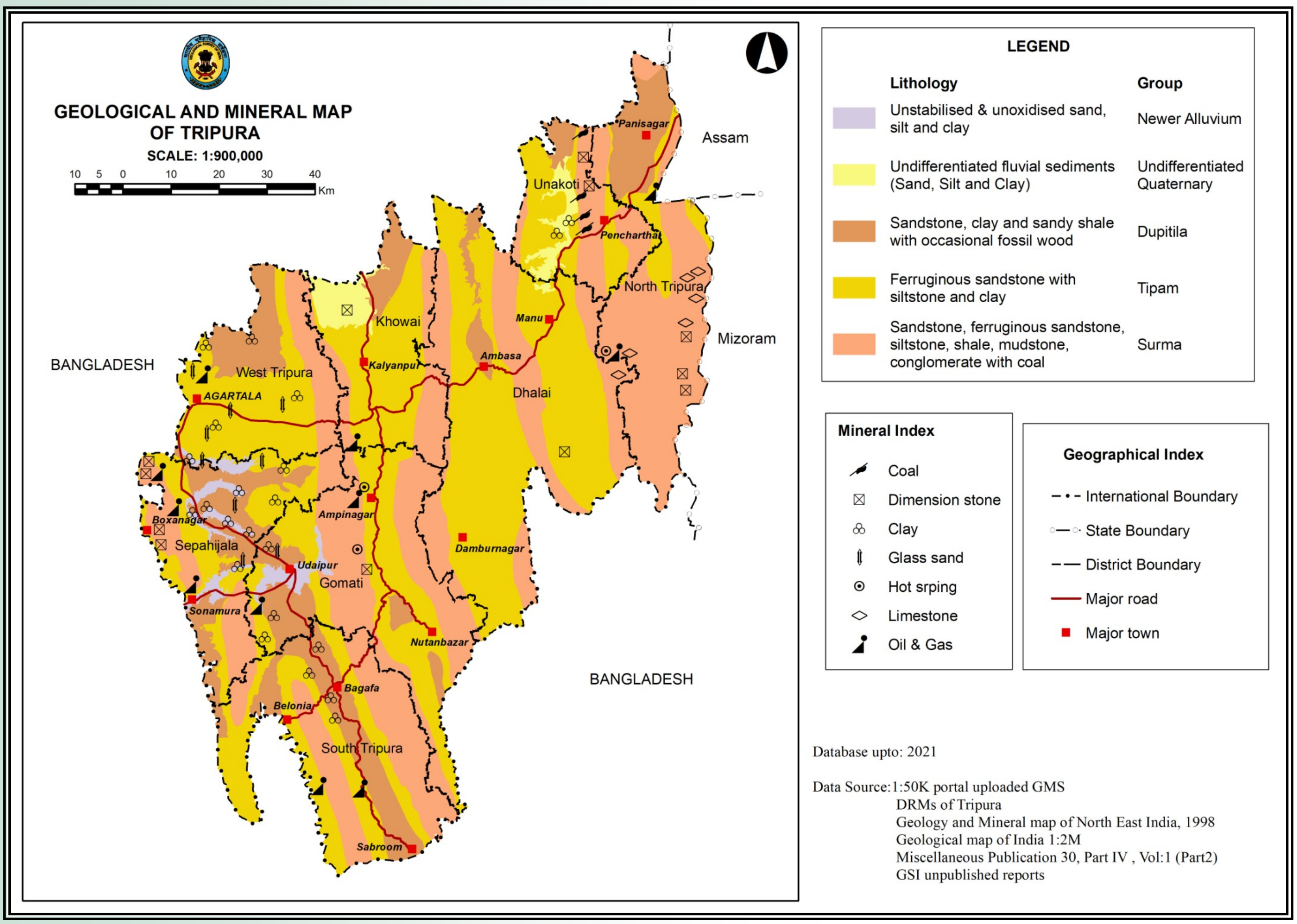


5.7 Tripura: Dominated by Sedimentary Sequences

Tripura's geology is dominated by Tertiary sedimentary rocks, mostly of the Surma and Tipam Groups. These formations consist of alternating sandstone and shale sequences and are part of the same structural belt that extends into the Barak Valley of Assam and western Mizoram.

Known more for its oil and natural gas potential, Tripura has a modest inventory of solid minerals. Resource of plastic clay within Tertiary sedimentary sequence was estimated. Occurrences of low-quality coal along with lateritic soils and minor limestone lenses are also reported. However, no major economic deposits have yet been established.

The scope for mineral development in Tripura lies primarily in its hydrocarbon reserves and in the extraction of construction materials. GSI's recent thematic mapping initiatives aim to better understand the geomorphology and stratigraphy of the state for possible future mineral reconnaissance.

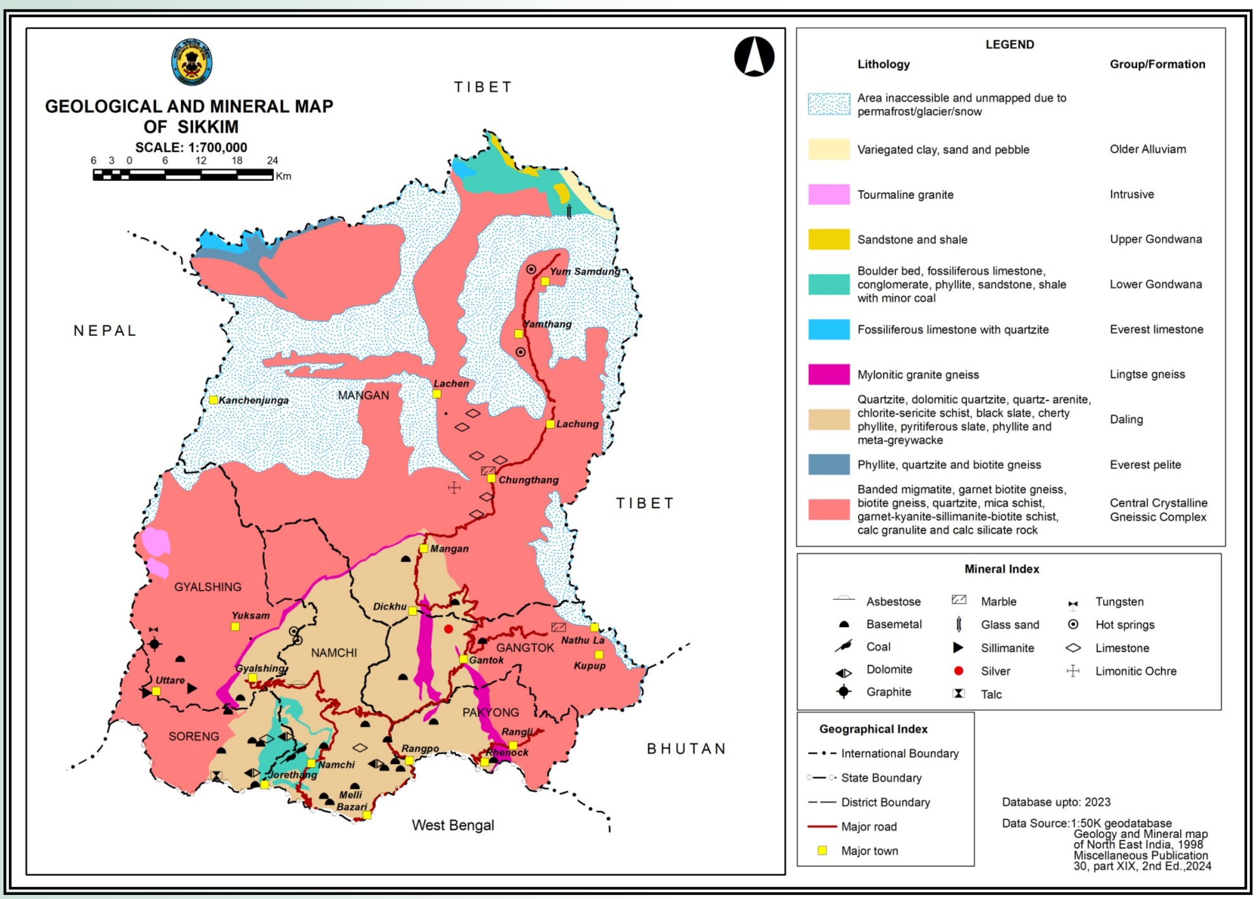


5.8 Sikkim: High Altitude Potential in a Tectonic Convergence Zone

Sikkim, though the smallest state in the NER, is geologically positioned at the core of the Eastern Himalayas. The state is characterized by steep gradients, high seismicity, and a predominance of metamorphic rocks such as gneisses and schists, intruded by granitic bodies. Structurally, the state lies along the Main Central Thrust (MCT), one of the most prominent tectonic boundaries in the Himalayan chain.

Although Sikkim has traditionally not been known for large-scale mineralization, small-scale occurrences of copper, lead-zinc, graphite etc have been reported in the lesser Himalayan terrain. Glacial and fluvio-glacial sediments are present in the high-altitude valleys, but due to ecological sensitivity and rugged topography, exploration remains limited.

Future exploration in Sikkim will likely remain focused on reconnaissance surveys and data integration to evaluate critical mineral potential, particularly in geologically favourable zones along the MCT and adjoining shear zones.



6. Critical and Strategic Minerals

Emerging Frontiers in India's Mineral Security

6.1 Introduction: Strategic Importance of Critical Minerals

In the evolving global context of clean energy transition, digital infrastructure and defence manufacturing, critical and strategic minerals have gained unprecedented importance. These minerals including rare earth elements (REE), graphite, vanadium, lithium, cobalt and others are essential inputs in batteries, permanent magnets, semiconductors, and advanced alloys. India's growing demand for such resources underscores the need to identify and develop domestic sources, particularly in geologically promising regions such as the North East.

The Geological Survey of India (GSI) has taken a proactive role in exploring the critical minerals in the NER. Through dedicated thematic studies, baseline surveys and project-based exploration, GSI has identified several zones enriched with these vital resources. The region's unique geology comprising ophiolite belts, alkaline-ultramafic complexes, and graphite-bearing schists offers favourable settings for a range of critical minerals.

6.2 Graphite: A Leading Resource from Arunachal Pradesh

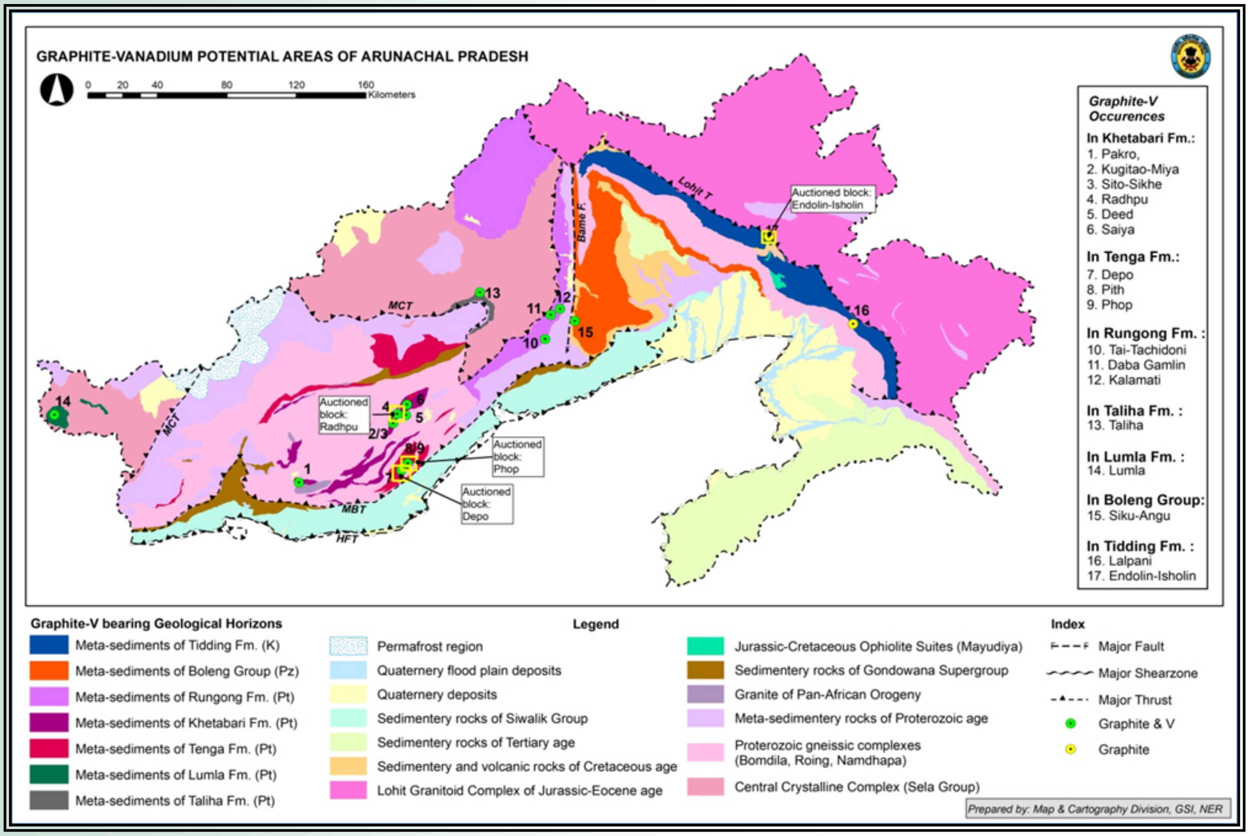
Arunachal Pradesh has emerged as India's most significant domestic source of natural flake graphite. Occurrences of graphite are primarily associated with carbonaceous phyllite, schist, and gneiss of the Proterozoic Bomdila Group and are often found along the contact zones of intrusive granites and meta-sedimentary rocks. Major deposits have been delineated in West Siang, Papum Pare and Lower Subansiri districts.

GSI has established a resource of over 17.89 million tonnes of graphite with significant grades suitable for battery and refractory applications. The graphite in this region is typically fine- to medium-flaked, with fixed carbon content ranging from 5% to 25%. This makes it a viable feedstock for downstream beneficiation and high-value applications such as lithium-ion battery anodes.

6.3 Vanadium: Co-located with Graphite and a Strategic Asset

Often co-occurring with graphite in carbonaceous phyllites, vanadium has been established as a strategic co-product in the same geological belts of Arunachal Pradesh. GSI's exploration has resulted in the establishment of a vanadium resource totalling 13.79 million tonnes, marking India's first major resource of this critical alloying element.

The mineralization typically occurs in association with iron-rich phases and is hosted within metamorphic rocks enriched in silicates, sulfides, and oxides. The concentration of V_2O_5 in these occurrences ranges between 0.5% and 1.5%, making them economically promising for downstream extraction. The importance of vanadium lies in its applications in aerospace alloys and increasingly, in vanadium redox flow batteries a scalable solution for grid-level energy storage.



6.4 Rare Earth Elements (REEs): Key Targets across Assam, Meghalaya, and Arunachal Pradesh

The REEs—grouped into light and heavy categories—are indispensable in modern electronics, wind turbines, electric vehicles and defence systems. GSI's investigations have revealed promising REE anomalies across several states in the NER.

In Arunachal Pradesh, the Lodoso area in Papum Pare district has yielded a delineated resource of 2.15 million tonnes of REE-bearing ferruginous phyllite, with average grade of 1.08 % total REE (including Yttrium). Significant Nd (Neodymium) concentrations (>2000 ppm) have also been recorded from West Siang and East Kameng districts.

Assam's Jashora and Samchampi alkaline complexes have demonstrated encouraging results through pedo-geochemical surveys and trench sampling. These complexes have returned REE concentrations ranging from 1000 to 5000 ppm, alongside associated elements such as Nb and Y.

In Meghalaya, the Sung Valley ultramafic-alkaline-carbonatite complex has shown ΣREE values ranging between 3646 and 5100 ppm in titaniferous bauxite cappings. This highlights the potential for laterite-hosted REE extraction—an approach that has been successful in other tropical countries.

6.5 Other Emerging Critical Minerals: Lithium, Cobalt and Bauxite

Preliminary geochemical indications of lithium have been recorded in brine-rich environments in Arunachal Pradesh and Nagaland as well as Precambrian gneiss in Assam. While still in early stages of investigation, these occurrences merit further exploration, especially given India's dependency on lithium imports.

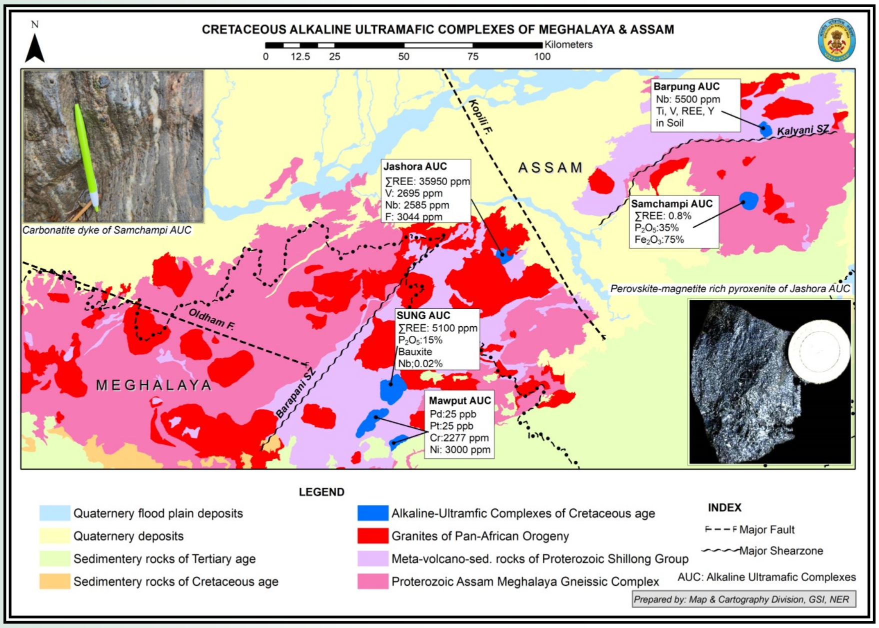
Nickel and cobalt, associated with ophiolite complexes in Nagaland and Manipur, are being targeted through detailed geochemical surveys and petrographic studies. These elements occur as trace constituents in lateritized ultramafic rocks and require advanced beneficiation techniques to recover economically.

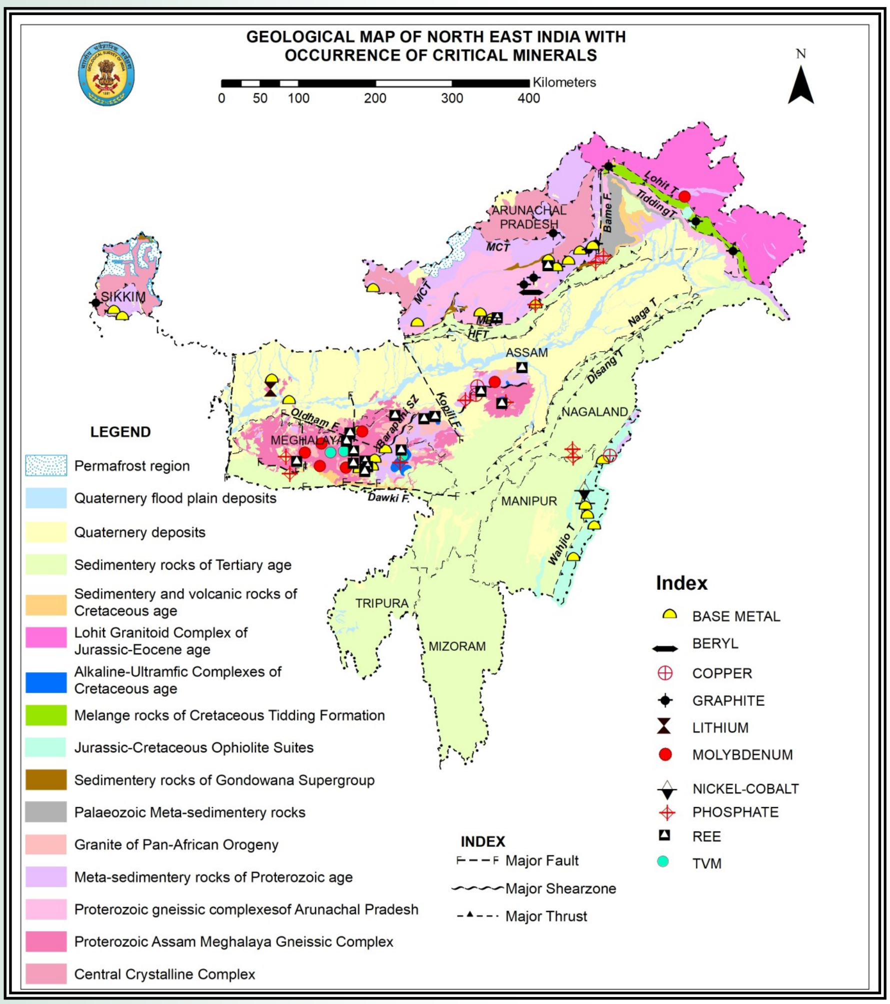
Bauxite, primarily of lateritic origin, is found in Meghalaya (West Khasi Hills) and is often enriched with iron and titanium. Some of these bauxite caps have also returned anomalous REE values, thus presenting the possibility of dual commodity extraction.

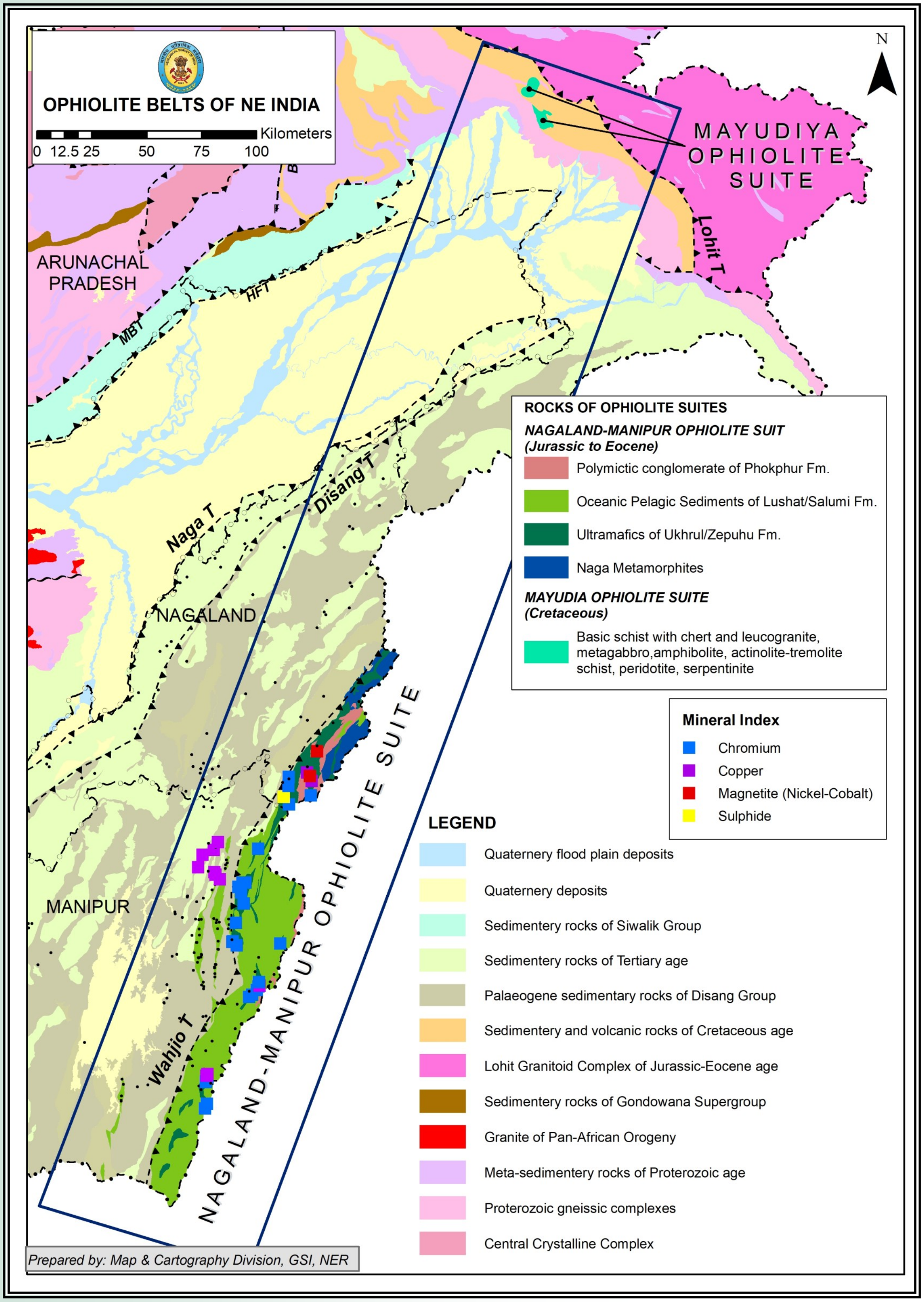
6.6 Strategic Programs for Critical Mineral Development

To formalize and accelerate the search for critical minerals in NER, GSI has launched the **Critical Mineral Assessment Programme (CMAP)** in 2024–25. The program focuses on assessing the potential of laterite/lateritic soils, carbonaceous rocks and alkaline complexes across Manipur-Nagaland, Meghalaya, and Arunachal Pradesh.

In addition, the **Regional Mineral Targeting (RMT)** initiative has been proposed as a multi-disciplinary strategy to integrate geological, geochemical, and geophysical data for large-scale mineral zoning. The first RMT project was implemented in Meghalaya in FS 2019-21 which resulted in formulation of G4 stage mineral exploration projects on tungsten, REE, lithium and molybdenum as spin off item. Together, these programs underscore the NER's growing importance in India's quest for critical mineral self-sufficiency and technological resilience.


CRETACEOUS ALKALINE ULTRAMAFIC COMPLEXES OF MEGHALAYA & ASSAM
N
Kilometers
0 12.5 25 50 75 100
Carbonatite dyke of Samchampi AUC
Kopili F.
ASSAM
MEGHALAYA
Oldham F.
Barapani SZ
Kalyani SZ
Barpung AUC
Nb: 5500 ppm
Ti, V, REE, Y
in Soil
Jashora AUC
ΣREE: 35950 ppm
V: 2695 ppm
Nb: 2585 ppm
F: 3044 ppm
Samchampi AUC
ΣREE: 0.8%
P2O5:35%
Fe2O3:75%
SUNG AUC
ΣREE: 5100 ppm
P2O5:15%
Bauxite
Nb:0.02%
Mawput AUC
Pd:25 ppb
Pt:25 ppb
Cr:2277 ppm
Ni: 3000 ppm
Perovskite-magnetite rich pyroxenite of Jashora AUC
LEGEND
Quaternery flood plain deposits
Quaternery deposits
Sedimentery rocks of Tertiary age
Sedimentery rocks of Cretaceous age
Alkaline-Ultramfic Complexes of Cretaceous age
Granites of Pan-African Orogeny
Meta-volcano-sed. rocks of Proterozoic Shillong Group
Proterozoic Assam Meghalaya Gneissic Complex
INDEX
Major Fault
Major Shearzone
AUC: Alkaline Ultramafic Complexes
Prepared by: Map & Cartography Division, GSI, NER


GEOLOGICAL MAP OF NORTH EAST INDIA WITH
OCCURRENCE OF CRITICAL MINERALS
N
Kilometers
0 50 100 200 300 400
SIKKIM
ARUNACHAL PRADESH
MCT
Bame F.
Lohit T
Tidding T
MBT
HFT
ASSAM
Naga T
Disang T
NAGALAND
MEGHALAYA
Oldham F.
Barapani SZ
Kopili F.
Dawki F.
MANIPUR
Wahjio T
TRIPURA
MIZORAM
LEGEND
Permafrost region
Quaternery flood plain deposits
Quaternery deposits
Sedimentery rocks of Tertiary age
Sedimentery and volcanic rocks of Cretaceous age
Lohit Granitoid Complex of Jurassic-Eocene age
Alkaline-Ultramfic Complexes of Cretaceous age
Melange rocks of Cretaceous Tidding Formation
Jurassic-Cretaceous Ophiolite Suites
Sedimentery rocks of Gondowana Supergroup
Palaeozoic Meta-sedimentery rocks
Granite of Pan-African Orogeny
Meta-sedimentery rocks of Proterozoic age
Proterozoic gneissic complexesof Arunachal Pradesh
Proterozoic Assam Meghalaya Gneissic Complex
Central Crystalline Complex
INDEX
Major Fault
Major Shearzone
Major Thrust
Index
BASE METAL
BERYL
COPPER
GRAPHITE
LITHIUM
MOLYBDENUM
NICKEL-COBALT
PHOSPHATE
REE
TVM


OPHIOLITE BELTS OF NE INDIA
Kilometers
0 12.5 25 50 75 100
N
MAYUDIYA OPHIOLITE SUITE
ARUNACHAL PRADESH
MBT
HFT
Lohit T
Naga T
Disang T
NAGALAND
MANIPUR
Wahjio T
NAGALAND-MANIPUR OPHIOLITE SUITE
ROCKS OF OPHIOLITE SUITES
NAGALAND-MANIPUR OPHIOLITE SUIT (Jurassic to Eocene)
Polymictic conglomerate of Phokphur Fm.
Oceanic Pelagic Sediments of Lushat/Salumi Fm.
Ultramafics of Ukhrul/Zepuhu Fm.
Naga Metamorphites
MAYUDIA OPHIOLITE SUITE (Cretaceous)
Basic schist with chert and leucogranite, metagabbro,amphibolite, actinolite-tremolite schist, peridotite, serpentinite
Mineral Index
Chromium
Copper
Magnetite (Nickel-Cobalt)
Sulphide
LEGEND
Quaternery flood plain deposits
Quaternery deposits
Sedimentery rocks of Siwalik Group
Sedimentery rocks of Tertiary age
Palaeogene sedimentary rocks of Disang Group
Sedimentery and volcanic rocks of Cretaceous age
Lohit Granitoid Complex of Jurassic-Eocene age
Sedimentery rocks of Gondowana Supergroup
Granite of Pan-African Orogeny
Meta-sedimentery rocks of Proterozoic age
Proterozoic gneissic complexes
Central Crystalline Complex
Prepared by: Map & Cartography Division, GSI, NER

7. Mineral Exploration Activities of GSI

Achievements Since the MMDR Act, 2015 and the Path Ahead

7.1 Overview of GSI's Exploration Mandate Post-MMDR Amendment

The amendment of the Mines and Minerals (Development and Regulation) Act in 2015 was a landmark shift in India's mineral governance, emphasizing auction-based allocation of mining rights and placing a greater responsibility on public sector exploration agencies to generate auction-ready blocks. In response, the Geological Survey of India (GSI) realigned its exploration strategy to prioritize the identification, evaluation and documentation of mineral resources under National Mineral Inventory norms, with a clear focus on states like those in the North Eastern Region (NER), where data gaps had long existed.

Since amendments of MMDR act in 2015, GSI has significantly expanded its exploration footprint in the NER. The region, once largely unmapped or understood only at reconnaissance scale, has now seen systematic investigations leading to the generation of high-confidence geological reports (GRs) and geological memorandum (GMs) across multiple commodities.

7.2 Summary of Blocks Handed Over (2015–2024)

Between 2015 and 2024, GSI has completed and handed over **38 exploration blocks** across four key states—**Arunachal Pradesh, Assam, Meghalaya, and Nagaland**. These blocks cover a range of mineral commodities, including graphite, vanadium, REEs, limestone, iron ore, glass sand, copper, nickel, chromium and cobalt.

In **Arunachal Pradesh**, 11 blocks have been handed over for graphite, vanadium, copper and REEs. In Assam 7 blocks have been handed over, notably for limestone, iron ore and silica sand. **Meghalaya**, with its extensive limestone belt, accounts for the largest number of blocks—19 in total. **Nagaland** has contributed 1 block focused on Nickel, Chromium & Cobalt with ultramafic complexes.

Many of these blocks have progressed to the auction stage and 7 nos. blocks have been already auctioned signalling growing industry confidence in the region's resource base.

7.3 Augmented Mineral Resources: A Quantified Outcome

The mineral exploration efforts undertaken by GSI in the North Eastern Region have significantly contributed to the augmentation of mineral resources across several states. In Arunachal Pradesh, exploration has led to the delineation of approximately 24.81 MT of graphite and 17.17 MT of Vanadium resources, along with 2.15 million tonnes of Rare Earth Elements (REE) averaging 1.08% total REE.

In Meghalaya, over 6,600 million tonnes of limestone resources have been added, while Assam accounts for approximately 1,490 million tonnes of limestone and 18.29 million tonnes of iron ore with an average grade of 37.45% Fe. Assam has also yielded REE resource of 28.64 million tonnes , high-quality glass sand occurrences with silica content reaching up to 85% and iron ore with 37.45% Fe. Additionally, lateritic bauxite profiles with REE enrichment have been identified in Meghalaya and the Sung Valley area and placer gold occurrences have been recorded in the Subansiri River basin in Assam, with reconnaissance (G4) resource estimation. These findings, documented as per the UNFC classification system, have been integrated into the National Mineral Inventory and are now available to state governments for onward auctioning under the MMDR framework.

7.4 Field Season-wise Exploration Progress (FS 2015–16 to FS 2024–25)

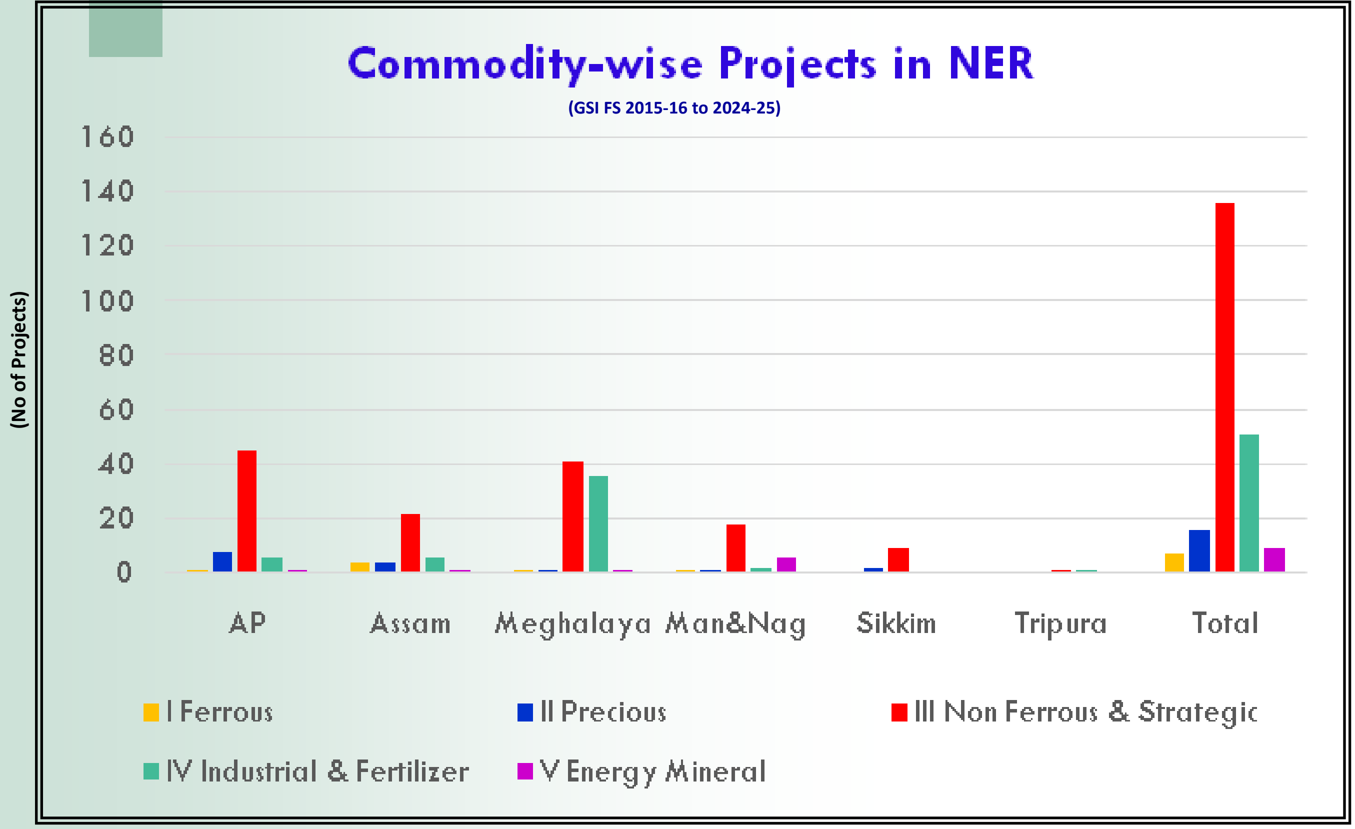
Over the past decade, exploration has been carried out under multiple Field Season (FS) programs, each focused on a mix of thematic mapping, mineral investigations, and resource evaluation. A summary of key achievements includes:

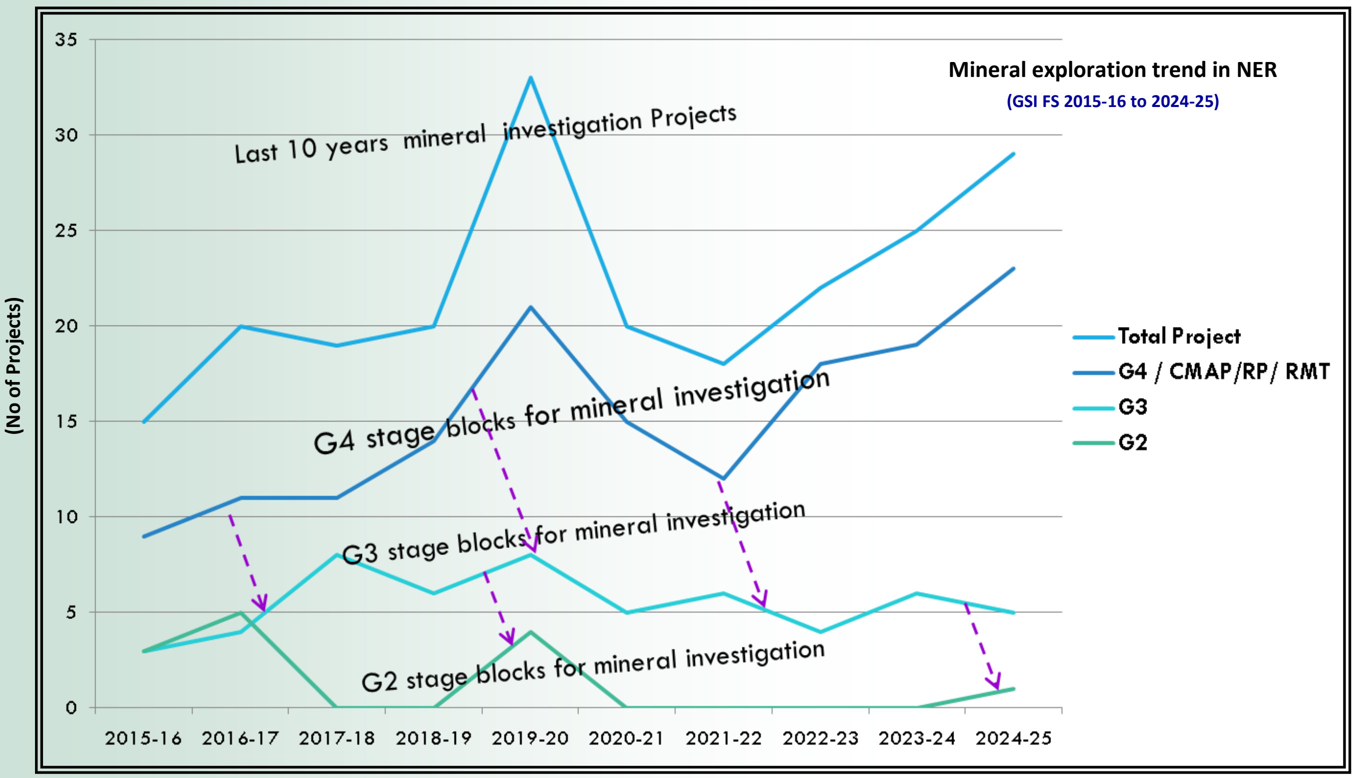
- **FS 2015–16 to FS 2017–18**: Baseline mapping and reconnaissance projects, with initial discoveries of graphite and REE anomalies.
- **FS 2018–19 to FS 2020–21**: Transition to detailed G3-level investigations; resource estimation of graphite, vanadium and REEs in Arunachal Pradesh.
- **FS 2021–22 to FS 2023–24**: Emphasis on preparing auctionable blocks (GR / GM); handover of limestone, graphite, vanadium and REE blocks in Assam, Arunachal Pradesh and Meghalaya; bauxite and iron ore assessments.
- **FS 2024–25**: Launch of critical mineral-focused exploration under CMAP and planning for Regional Mineral Targeting (RMT) campaigns.

Cumulatively, these efforts reflect GSI's role not just as an explorer, but as an enabler of mineral development in the region.

7.5 Mapping the Future: Exploration Projects in the Pipeline

GSI's upcoming exploration agenda for FS 2025–26 and beyond focuses on critical minerals such as REE, vanadium, bauxite and nickel-cobalt-chromite across key formations in Arunachal Pradesh, Assam, Meghalaya, Nagaland and Manipur. Reconnaissance mapping is also planned in unexplored terrains of Mizoram and Tripura. These projects will leverage geospatial technologies, aero-geophysical surveys and mineral system modeling to position the NER as a focused frontier for strategic mineral exploration.


Commodity-wise Projects in NER
(GSI FS 2015-16 to 2024-25)
(No of Projects)
160
140
120
100
80
60
40
20
0
AP
Assam
Meghalaya
Man&Nag
Sikkim
Tripura
Total
I Ferrous
II Precious
III Non Ferrous & Strategic
IV Industrial & Fertilizer
V Energy Mineral

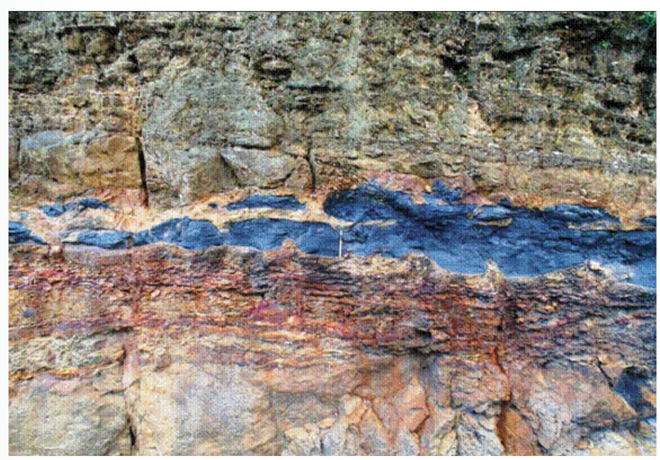

Mineral exploration trend in NER
(GSI FS 2015-16 to 2024-25)
(No of Projects)
35
30
25
20
15
10
5
0
Last 10 years mineral investigation Projects
G4 stage blocks for mineral investigation
G3 stage blocks for mineral investigation
G2 stage blocks for mineral investigation
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
2023-24
2024-25
Total Project
G4 / CMAP/RP/ RMT
G3
G2

8. Coal Exploration

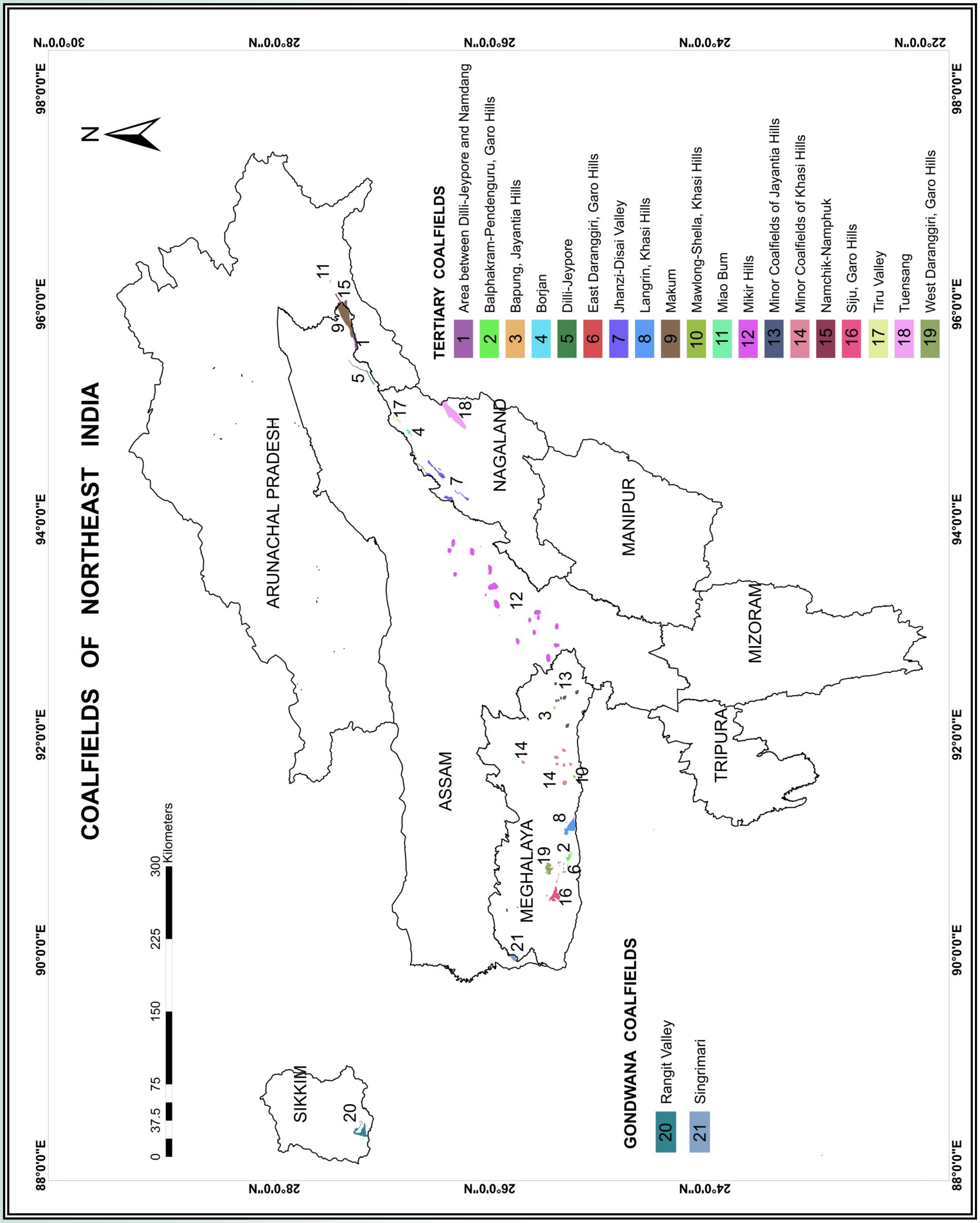
Five north-eastern states of India viz., Assam, Meghalaya, Nagaland, Arunachal Pradesh and Sikkim are endowed with coal bearing formations in a complex geological set up. Coalfields of Makum and Dilli-Jeypore in Assam, Namchik-Nampuk in Arunachal Pradesh, Langrin, West Daranggiri, Siju, Balpakhram-Pengengru and Bapung in Meghalaya and Borjan Coalfield in Nagaland are the important coalfields by virtue of their resource potentiality.

Geological Survey of India through its systematic mapping deciphered the coal belts along with details of coal occurrences, which led the foundation for subsequent exploration activities in different coalfields by GSI, CMPDI, MECL and State Government organisations (like DMR, Meghalaya, DGM, Assam, DGM Nagaland etc.).

State	Type of coal field	Resource as on 01.04.2024
Assam	Gondwana & Tertiary coal field	525.01 MT
Meghalaya	Gondwana & Tertiary coal field	576.48 MT
Arunachal Pradesh	Gondwana & Tertiary coal field	90.23 MT
Nagaland	Tertiary coal field	478.31 MT
Sikkim	Gondwana coal field	101.23 MT



Occurrence of coal seam in Tertiary sedimentary sequence, Shillong-Cherrapunji Road section, Sohra, East Khasi Hills, Meghalaya


COALFIELDS OF NORTHEAST INDIA
N
TERTIARY COALFIELDS
1 Area between Dilli-Jeypore and Namdang
2 Balphakram-Pendenguru, Garo Hills
3 Bapung, Jayantia Hills
4 Borjan
5 Dilli-Jeypore
6 East Daranggiri, Garo Hills
7 Jhanzi-Disai Valley
8 Langrin, Khasi Hills
9 Makum
10 Mawlong-Shella, Khasi Hills
11 Miao Bum
12 Mikir Hills
13 Minor Coalfields of Jayantia Hills
14 Minor Coalfields of Khasi Hills
15 Namchik-Namphuk
16 Siju, Garo Hills
17 Tiru Valley
18 Tuensang
19 West Daranggiri, Garo Hills
GONDWANA COALFIELDS
20 Rangit Valley
21 Singrimari
0 37.5 75 150 225 300 Kilometers
ARUNACHAL PRADESH
NAGALAND
MANIPUR
MIZORAM
TRIPURA
ASSAM
MEGHALAYA
SIKKIM
88°0'0"E
90°0'0"E
92°0'0"E
94°0'0"E
96°0'0"E
98°0'0"E
22°0'0"N
24°0'0"N
26°0'0"N
28°0'0"N
30°0'0"N

9. Maps and Visual Data

Geospatial Insights into the Mineral Landscape of NER

Maps and visual data are essential tools for understanding the spatial distribution of geological formations, mineral occurrences and exploration targets. In the North Eastern Region (NER), where terrain complexity and remoteness pose logistical challenges, high-quality maps generated by GSI form the backbone of all exploration and development planning. These maps not only aid in resource identification but also help streamline policy formulation, investment decisions, and environmental assessment.

9.1 Generalized Geological and Mineral Maps

GSI has developed a range of regional geological and mineral maps up to district level for each of the eight states in NER. These maps highlight major lithological units, structural elements such as thrusts and faults and locations of key mineral occurrences.

The geological map of **Arunachal Pradesh**, for example, illustrates the spatial disposition of the Eastern Himalayan thrust belts, the Bomdila Group and the Tidding Suture Zone each associated with strategic minerals like graphite, vanadium and REEs. Similarly, the **Shillong Plateau map** in Meghalaya emphasizes the extent of the AMGC (Assam-Meghalaya Gneissic Complex) and its potential for bauxite, limestone and REE-bearing laterites.

These maps are prepared at standardized scales (typically 1:50K) and include annotations on lithology, tectonic contacts, mineral exploration, and accessibility—making them a vital resource for state governments and private investors alike.

9.2 Baseline Geoscience Data Coverage

As of March 2025, GSI has achieved substantial coverage in baseline geoscientific data generation across the North Eastern Region through various thematic mapping. Systematic Geological Mapping (SGM) has covered for the entire region while Geochemical Mapping (GCM) has been completed over 1,44,184 sq km. Geophysical Mapping (GPM) is being progressively expanded across accessible areas, with full coverage targeted by 2026–27. These datasets form the foundation for subsurface interpretation and mineral predictive modeling, with GCM proving especially effective in identifying geochemical anomalies linked to REEs, vanadium and base metals in Meghalaya, Assam and Arunachal Pradesh.

9.3 Project Location Maps and Mineral Belts

GSI has also prepared detailed project location maps to visualize the spatial spread of its exploration activities across the region. These maps show the distribution of handed-over blocks, auction-ready GR/GM locations and upcoming exploration projects under the Field Season programs.

In addition, thematic maps of **mineral belts** have been compiled to illustrate key clusters of mineral occurrences. For instance, the **limestone belt of Meghalaya and Assam**, the **REE-graphite corridor in Arunachal Pradesh** and the **ultramafic belt of eastern Nagaland** are represented with geological boundaries, resource estimates and logistical access overlays.

These visual data is of great importance to the readers to contextualize textual information and explore spatial relationships across mineral systems.

9.4 Publication of journals

To disseminate the data generated in the field of mineral exploration to all stakeholders, GSI publishes various thematic journals which are valuable resources for further mineral exploration. A few among them includes :

1.Geology and Mineral Resources of **Sikkim**, Misc. Publication, Number-30, Part-XIX (2nd Revised Edition),2024

2.Geology and Mineral Resources of **Meghalaya**, Misc. Publication, Number-30, Vol 2(ii), 2023

3.Geology and Mineral Resources of **Assam** (3rd Revised Edition) Misc. Publication, Number-30, Vol 2(i), 2019

4.**Limestone** Deposits of Litang Valley, East Jaintia Hills District, Meghalaya (Bulletin Series A), 2022

5.**Limestone** Deposits of Ukhrul district, Manipur (Bulletin Series A), 2017

6.**Sillimanite** Deposits of Sonapahar Area, West Khasi Hills District, Meghalaya (Bulletin Series A), 2016

7.**Coalfields** of North Eastern India (2nd Revised edition, Bulletin Series A) Vol I, 2016

8.Manual of Geology of India Special Publication no. 77, Vol-iii: **Economic Geology of North East India**, 2025

9.6 Future Mapping and Data Initiatives

To further enrich the geospatial database, GSI has planned to take up **Aero-Geophysical Mapping Programme** in inaccessible areas of Arunachal Pradesh, Nagaland, Mizoram and Manipur. These surveys will aid in identifying buried structures, lithological contacts and magnetic anomalies paving the way for a new generation of subsurface mineral discoveries.

Simultaneously, **Geochemical and Geophysical Atlas** are being prepared for areas where GCM and GPM have been completed. This atlas will serve as a reference for mineral zoning and target prioritization in future exploration campaigns.

10. Building a Future-Ready Exploration Strategy

Building the Next Decade of Exploration in the North Eastern Region

As India accelerates its path toward self-reliance in critical and industrial minerals, the North Eastern Region (NER) is emerging as a high-potential frontier. With its intricate geology and largely underexplored terrain, the region is now central to the national strategy for mineral security. The Geological Survey of India (GSI), in coordination with the Ministry of Mines and the National Mineral Exploration Trust (NMET), has developed a forward-looking roadmap aimed at unlocking the region's mineral potential through technology-led, data-driven and regionally balanced exploration.

10.1 NMET as a Catalyst for Regional Mineral Discovery

Established by the Government of India in August 2015, the National Mineral Exploration Trust (NMET) under the Ministry of Mines aims to accelerate mineral exploration and capacity building of all states in NER through strategic funding. Since its inception in 2015, NMET has funded over 35 exploration and capacity-building projects in eight states of NER. Assam, Arunachal Pradesh, Meghalaya, Manipur and Nagaland have benefitted from targeted exploration of rare earth elements (REEs), graphite, vanadium, limestone, nickel, cobalt and iron ore. NMET has also funded procurement of core equipment and analytical tools across all states of NER. These projects have enabled the generation of auctionable blocks and strengthened state exploration capacities.

10.1.1 Project Types

Projects in NER fall into two categories:

- **Exploration Projects** for minerals like REE, graphite, vanadium, limestone, and PGEs
- **Capacity Building** through procurement of field and lab equipment

10.1.2 Measurable Impact

NMET has enabled systematic data generation and early-stage resource definition across the region. It has also equipped state DGMs with modern tools, enhancing their ability to develop auctionable blocks and partner in national-level initiatives. To accelerate mineral exploration in NER, Notified Private Agencies are also awarded exploration projects through NMET with financial assistance. The Trust is now central to the North East's mineral strategy bridging the gap between geology and investment.

Table 10.1: NMET Funding to DGMs, PSUs and NPAs in NER

Category	Total
Total Projects	35
Projects Completed	8
Projects Ongoing	25
Approved	2
Most Funded Minerals	Limestone, REE

(Source: NMET Portal)

Table 10.2: NMET funded Key Projects in NER

State	Project Title	Stage	Minerals	Agency	Cost (₹ Cr)	Status
Assam	Preliminary REE Exploration	G3	REE	MECL	8.82	In Progress
Arunachal Pradesh	Graphite & Vanadium Reconnaissance	G4	Graphite, Vanadium	Pvt. Agency	5.63	In Progress
Meghalaya	Ion-Adsorption Clay & REE Exploration	G3	REE	DMR Meghalaya	3.01	In Progress
Manipur	Ni-Co-Cr Exploration	G3	Nickel, Cobalt, Chromium	Pvt. Agency	6.12	In Progress
Nagaland	Limestone Exploration	G3	Limestone	DGM Nagaland	7.66	In Progress
Mizoram	Exploration Equipment Procurement	—	—	DGM Mizoram	1.96	In Progress

(Source: NMET Portal)

10.2 Exploration Priorities: FS 2025–26 and Beyond

GSI has formulated a multi-year exploration roadmap beginning from Field Season (FS) 2025–26, with a particular focus on converting geo-scientific knowledge into economically viable mineral blocks. The roadmap is based on three principal themes: systematic exploration, critical mineral targeting and regional integration of baseline geo-science datasets.

Planned activities include:

- **Systematic exploration** of graphite-vanadium belts in Arunachal Pradesh
- **Detailed mapping** of REE-enriched alkaline and carbonatite complexes in Assam and Meghalaya
- **Pilot studies** on laterite-hosted and placer-hosted critical minerals in Manipur, Nagaland, and Tripura
- **Expanded mapping** in less-explored terrains of Arunachal Pradesh, Manipur, Nagaland and Mizoram using remote sensing and aero-geophysical data.

These programs will be carried out in collaboration with other national initiatives, such as the India Critical Minerals Mission.

10.3 Critical Mineral Assessment Programme (CMAP)

Launched by GSI in FS 2024–25, CMAP targets REEs, vanadium, lithium, cobalt, and bauxite through systematic investigations across:

- Lateritic caps and ultramafic zones
- Graphite-vanadium bearing schist belts
- Alkaline and ultramafic intrusions
- Riverbed alluvium in the Brahmaputra basin

CMAP aims to generate high-resolution data to support auctionable block preparation and is currently active in Arunachal Pradesh, Assam, Meghalaya and Nagaland.

10.4 Regional Mineral Targeting (RMT): Integrated Approach

The RMT initiative moves beyond commodity-centric surveys by combining geochemical, geophysical, structural, and remote sensing data to delineate mineralized corridors. The pilot campaign in Meghalaya has demonstrated the value of predictive mineral system modelling. Upcoming RMT campaigns in Assam, Manipur, and Arunachal Pradesh will build on this model to accelerate target generation and reduce exploration risk.

Table. 10.4 Target areas for future mineral exploration in NER

Sl	Commodity	Target Areas	State
1	Rare earth elements (REE) & RM	1. Samchampi, Barpung Alkaline pluton 2. Sung Alkaline Complex 3. Assam Meghalaya Gneissic complex 4. Pan African granite plutons 5. Younger granites of Himalayas 6. Clay horizon of Tertiary sed. seq. 7. Tertiary coal-shale sequence	Assam Meghalaya Assam-Meghalaya Assam-Meghalaya Arunachal Pradesh Tripura - Mizoram Meghalaya, Assam, Nagaland, Manipur
2	Graphite & Vanadium	Bomdila graphite vanadium belt of Khetabari Fm	Arunachal Pradesh
3	Limestone	Tertiary limestone sequence. Proterozoic meta-sedimentary sequence	Assam- Meghalaya- Arunachal Pradesh
4	Nickel , Chromite	Ophiolite Belt.	Manipur Nagaland
5	Gold	Placer gold in reworked Siwalik sediments. Precambrian gneisses	Assam, Arunachal Pradesh Sikkim, Meghalaya, Assam, A.P.
6	Critical & Strategic mineral	Laterite/ Lateritic soil cover	Manipur, Nagaland, Meghalaya, AP, Assam
7	Coal	Tertiary sedimentary sequence	Assam, Meghalaya, Nagaland, Manipur

11. Case Studies in Mineral Exploration Success

From Data to Discovery in the North Eastern Region

Once seen as geologically complex and logistically remote, the North Eastern Region (NER) is now yielding significant mineral discoveries through GSI's systematic and multi-disciplinary exploration. The following case studies highlight successful transitions from baseline surveys to resource definition.

11.1 Lodoso REE Discovery, Arunachal Pradesh

In Papum Pare district, reconnaissance in ferruginous phyllite (Bomdila Group) revealed total REE+Y concentrations exceeding 2%. Through detailed sampling during FS 2018–20, GSI established a **2.15 million tonnes** resource averaging **1.08% REE**, with notably high neodymium (>2000 ppm). This strategic REE zone, located along granite–phyllite contacts, underscores the importance of integrating litho-structural mapping with geochemistry in Proterozoic terrains.

11.2 Jashora Alkaline Complex, Assam

Located in Karbi Anglong, the Jashora complex drew interest for its soil geochemistry and alkaline lithology. GSI's FS 2020–22 investigations found **phosphate-rich breccias (up to 35% P_2O_5)** and **REE-enriched soils (up to 5000 ppm)**, along with niobium and iron oxide anomalies. G3 level resource of 28.64 million tonnes of REE has been estimated in this complex. The area is further upgraded to G2-level to delineate auction-ready resource blocks with higher confidence level.

11.3 Bauxite–REE Zone; Sung Valley , Meghalaya

The ultramafic–alkaline complex of Sung Valley hosts lateritic bauxite with embedded REEs. Revealed ΣREE values ranging **3,646–5,100 ppm** within high-alumina bauxite caps. This dual-resource zone offers prospects for integrated critical mineral extraction and is being considered for strategic development.

Perovskite / magnetite, Jashora, Assam

Carbonatite, Sung Valley, Meghalaya

Garnerite veins, Mollen, Nagaland

12. Geo-science Infrastructure and Capacity

Enabling Exploration through Scientific and Operational Readiness

Mineral exploration in the North Eastern Region (NER) relies not only on geological endowment but also on the scientific and operational readiness of institutions on the ground. The Geological Survey of India (GSI) has developed a robust infrastructure network to support high-quality, sustained exploration in this remote and geologically complex region.

12.1 Regional Reach and Field Presence

The GSI operates its NER Regional Mission from Shillong, Meghalaya, serving as the nodal center for geoscientific activity across all eight northeastern states. This central unit is supported by state-specific field offices in Itanagar, Guwahati, Dimapur, Agartala, and Gangtok. These field units facilitate decentralized mapping, sampling, coordination, and stakeholder engagement. A dedicated Geoinformatics Laboratory in Shillong aids in processing and interpretation.

12.2 Tools and Technology for Modern Exploration

GSI has significantly upgraded its technical capabilities in the NER. Remote sensing and GIS-based digital mapping enhance pre-field planning, while ground geophysics including magnetic, resistivity and gravity surveys are deployed for subsurface interpretation. Geochemical laboratories, both mobile and fixed, enable rapid sample analysis for rocks, sediments and soils. Exploratory drilling, initiated in parts of Assam and Meghalaya, is expected to expand to Arunachal Pradesh. Additionally, aero-geophysical surveys have been planned to be take up in challenging terrains of Arunachal, Mizoram and Nagaland.

12.3 Data Accessibility and Digital Integration

All geo-scientific data from the NER are integrated into the National Geoscience Data Repository (NGDR), India's digital platform for geological information. Through NGDR, stakeholders can access maps, mineral occurrences, GR/GM metadata, and thematic reports under open-access protocols. This digital infrastructure facilitates transparency, supports state governments in mineral auctions, and empowers private investors with reliable information.

13. Training and capacity building

13.1 Training & Capacity building

GSI Training Institute (GSITI) with its regional headquarters at Shillong, impart training on various technical and administrative subjects for capacity building and human resource development in NER.

The GSITI imparts various types of training to the geoscientists of GSI as well as state DGMs, PSUs, Universities / Institutions, other govt. organizations of NER keeping pace with the latest development and trends in earth sciences. GSI trainings are meticulously designed to provide a seamless blend of theoretical and field training experiences. The GSITI's core activity remains conducting various thematic training programmes for Geology, Geophysics, Chemistry and Engineering streams including application of industry software, emerging technologies for mineral exploration. In addition, special training programmes are also conducted for DGMs, Institutes , PSUs and other government organizations in NER. Major theme of training programme includes-

- Field based training for **geological mapping** & **mineral exploration.**
- Field based training on **Public Good geosciences**.
- Advanced courses on **Petrology, Geochemistry, Palaeontology** for contemporary research
- Techniques of mineral **exploration** and exploration rules.
- **Information and data dissemination** through use of NGDR and OCBIS portal
- National and International **collaboration**.

Contribution of GSITI , Shillong for capacity building in NER for last 5 years:

Field Season	No. of Trainings	No. of Participants from Various Organizations						Total
		GSI	State Govt.	Central Govt.	PSU	Academia	Students	
2020-21	15	492	99	31	40	403	-	**1065**
2021-22	18	653	42	22	43	116	-	**876**
2022-23	17	361	12	17	5	12	457	**864**
2023-24	11	167	8	46	-	16	884	**1121**
2024-25	14	195	47	7	4	14	146	**413**
Total	**75**	**1868**	**208**	**123**	**92**	**561**	**1487**	**4339**

13.2 Organization of Workshop to promote mineral exploration

GSI, NER periodically hosts workshops in the field of mapping and mineral exploration in different parts of the region with an aim to establish synergy in exploration, maximizing utilization of mutual resources of all the stakeholders. The government, private and public exploration agencies, including NEAs, NPEAs participate in these events to assess the mineral potential of this region as well as to outline the future course of activities without any duplication. Recently conducted workshops in the field of mapping & mineral exploration include-

Sl	Place	Date	Title of the workshop
1	Shillong	17.01.2024	Application of National Geochemical Mapping (NGCM) data and data available at National Geo-science Data Repository (NGDR) portal
2	Guwahati	18.01.2024	Application of NGCM Data and Introduction to National Geo-science Data Repository Portal
3	Guwahati	10.05.2024	Exploring the mineral wealth of Assam (EMWA)- Achievements and Future Prospects
4	Dimapur	22.05.2024	Application of NGCM Data & utility of NGDR portal.
5	Agartala	28.05.2024	Application of NGCM data and utility of NGDR Portal
6	Shillong	14.11.2024	Consultation among stake holders on the Exploration Ecology in North Eastern Region
7	Shillong	07.04.2025	Handholding of North Eastern States on Auctioning of Mineral blocks

Address to the house by Sh. Sanjay Lohia, Addl. Secretary, MoM in the workshop at Guwahati on 10.05.2024

Address to the house by Sh. Asit Saha, DG, GSI in the workshop at Shillong on 07.04.2025

14. Environmental and Social Considerations in Mineral Exploration

Balancing Resource Development with Sustainability in the North Eastern Region

The North Eastern Region (NER) is one of India's most ecologically sensitive and culturally diverse landscapes. Characterized by dense forests, unique biodiversity, high rainfall and fragile hill ecosystems, the region is also home to numerous indigenous communities with traditional livelihoods. In such a context, mineral exploration demands a cautious and responsible approach one that integrates environmental safeguards and social engagement at every stage of activity.

14.1 Ecological Sensitivity and Terrain Challenges

Several parts of the NER, particularly Arunachal Pradesh, Meghalaya, and Nagaland, lie within or near designated **Eco-sensitive Zones (ESZs)**, wildlife sanctuaries, and protected forests. These areas are vulnerable to erosion, landslides and deforestation factors that necessitate careful planning even for low-impact exploration.

GSI ensures that all its operations, from mapping to sampling and drilling, are conducted in strict adherence to environmental regulations. Prior to initiating any field activity, reconnaissance teams assess terrain fragility, water sources, forest cover and land use, in line with guidelines issued by the Ministry of Environment, Forest and Climate Change (MoEFCC).

In recent years, the introduction of **drone-based aerial surveys** and **lightweight portable tools** would allow GSI to reduce its environmental footprint in difficult terrains.

14.2 Community Engagement and Local Participation

Respect for local communities is integral to GSI's operational philosophy in the NER. Given the diverse ethnic and linguistic makeup of the region, GSI field teams work closely with **village councils, tribal elders, and district administrators** to ensure that exploration work is conducted with full transparency and consent. In many instances, such as in West Siang (Arunachal Pradesh) or Karbi Anglong (Assam), local support has been instrumental in facilitating access to remote mineralized belts.

14.3 Integrating Sustainability into the Exploration Strategy

Although exploration activities typically have a lower environmental impact than mining, the potential downstream effects necessitate **early-stage integration of sustainability principles**. Moreover, GSI contributes to national knowledge on **geo-environmental hazards**, **seismic vulnerability** and **natural resource planning**, reinforcing the role of geosciences in sustainable development.

15. Geo-hazard appraisal

Identification of geo -hazards and it's impact on society

Geological hazard and management challenges

The North Eastern Region lies within the seismically active Himalayan belt and has varied physiography ranging from very high hills with steep slopes to undulating landform. Major hazards in NER include **landslides**, which are common in hilly terrains of the states due to weak rock mass, active faults and anthropogenic interferences and trigger mostly due to incessant rainfall, and **earthquake** as the region lies in Seismic Zone V, the highest risk category in the Indian seismic zoning map.

15.1 Landslide Study

GSI has played a pivotal role in identifying and mitigating landslide hazards in Northeast India. Key studies and initiatives include:

- Landslide Susceptibility Mapping (LSM) across the NER under the **National Landslide Susceptibility Mapping (NLSM) Programme(**1:50,000 scale)
- **Meso-scale** LSM programme (1:10,000 scale)
- **Site-specific** landslide studies (1:2000 scale or larger)
- **Post-disaster** landslide investigation
- Development of landslide **early warning system**
- Creation of **public awareness** through contact programmes, and landslide database management, updation and dissemination.

  development.

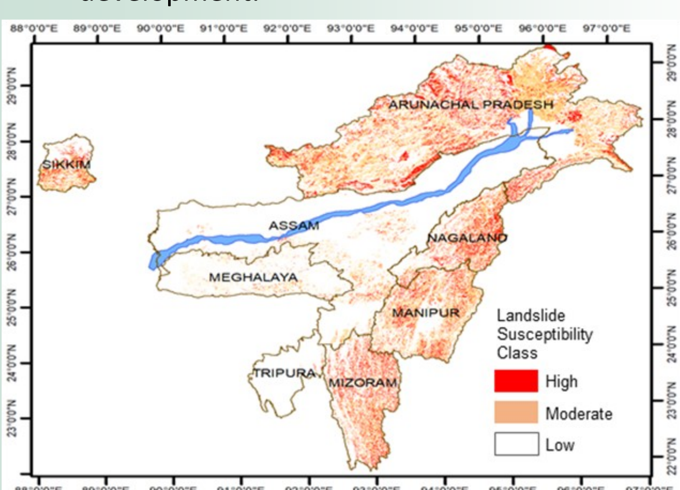


Fig. 15.1: Landslide susceptibility map (1:50000 scale) of NER under NLSM.

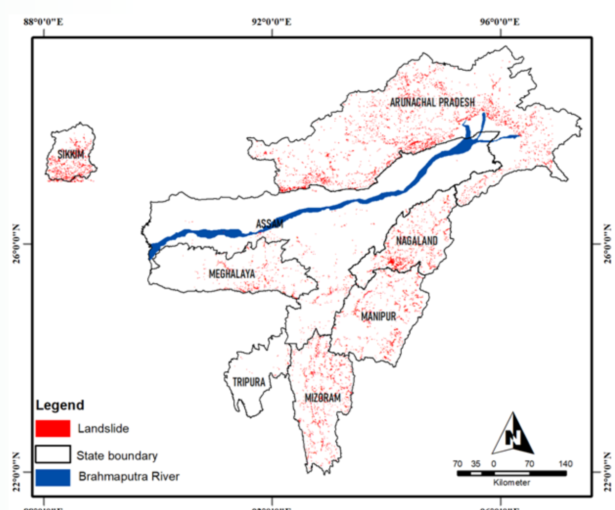


Fig. 15.2: Landslide map of NER

Macro-scale landslide susceptibility map

GSI has completed Landslide susceptibility mapping under NLSM programme covering 1.87 lakh sq. km of hilly terrain of NER, covering all the eight states (Fig. 1) and all the data are available in Bhukosh web-portal and NGDR portal of GSI for public use under 'open' data sharing policy.

The methodology used is both data-driven and heuristic approach of landslide susceptibility modelling by employing multi-class index overlay techniques. The base data used for DEM-derivatives is Aster DEM of 30m resolution and analysis was carried out in a pixel format of 50m grid size. The susceptibility maps categorize areas into High, Moderate and Low susceptible zones. These are essential for guiding landuse and planning and infrastructure. **The susceptibility map indicates that 10% area of the hilly terrain of NER is highly susceptible to slope failures.** The state's susceptibility to landslide varies from 1% hill area in Meghalaya to 17% in Sikkim. Arunachal Pradesh, Mizoram and Nagaland have their respective 14% to 16% hill area highly susceptible to slope failure.

Meso-scale landslide susceptibility mapping

GSI has taken a national programme to upgrade its macro-scale LSM to meso-scale LSM at defined sectors as indicated in the MoM Approved Strategy Paper on Landslide Hazard Management. It includes 89 sectors, containing both major and vulnerable (rail) road corridor and towns in NER (Fig. 3).

The methodology used is heuristic approach of landslide type specific susceptibility modelling. The base data used for DEM-derivatives is Alos Palsar 12.5 m / CartoDEM10m resolution and analysis was carried out in a pixel format of 10m grid size.

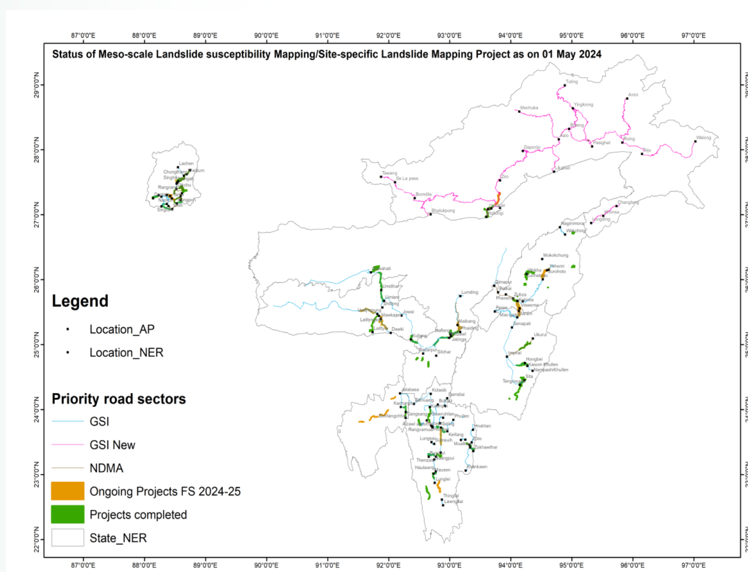


Fig.15.3: Status of meso-scale LSM in NER.

Meso-scale LSM provides information on geotechnical characteristics of slope forming media, kinematic failure map of rock slide and rock fall, landslide hazard and risk indicator and the cut slope domain provides prior information on slopes that can lead to planar or wedge rock failure if the slope is modified during excavation/road widening process. This 1:10,000 scale LSM map is apt for landslide disaster management and land use planning.

Landslide distribution

GSI carries out landslide inventory mapping during the susceptibility mapping work as well as after any major landslide event. Bhukosh web-portal and NGDR portal of GSI also contain landslide inventory primary GIS database containing 87,430 landslide polygons covering 19 States/UTs of the country. Out of these, for 31,545 landslides a detailed inventory data containing 42 parameters is available for public use. In NER there are about 40,800 landslide incidences, out of which 8534 landslides are mapped and studied in detail using 42-parameter inventory sheet. Landslide occur in all sizes and of all types in NER.

Landslide hazard and risk indicators of Arunachal Pradesh

NLSM data has been used to prepare various landslide risk indicator maps in the hilly terrain of Arunachal Pradesh. Out of 83,578 sq. km of land area of Arunachal Pradesh, 70,304 sq. km area is hilly terrain and 1587 sq. km area has permafrost, snow cover and glacial lakes.

- About 15% (10,455 sq. km) of the hill area of Arunachal Pradesh is susceptible to landslides (**Fig. 15.4A**).
- The high susceptible slopes occur both as a continuous zone as well as in segregation throughout the state. Number of landslides per district varies from <50 to 3019 incidences (**Fig. 15.4B**).
- In terms of density of susceptible slopes in different districts, Itanagar has highest density while Kra Daadi, Lower Dibang Valley and Lohit having 6% each and East Kameng (5%) (**Fig. 15.4C**).
- In terms of density of landslides, Lower Subansiri and Tawang districts have one landslide per 32 and 12 sq. km area, respectively (**Fig. 15.4D**).
- Papumpare has the maximum settlement area (53 sq. km) followed by Upper Subansiri (43 sq. km), Kamle (34 sq. km) etc. Dibang Valley (2.8 sq. km) and Siang (4.8 sq. km) are having small area having settlement clusters.
- In Longding District, 36% of its settlement falls within high susceptible zone (**Fig. 15.4E**) with 41 landslides being located within 200m from the settlement. Similarly, each of Shi Yomi, Papum Pare and Changlang has 30-32% of their settlement within high susceptible zone with 43, 94 and 60 landslides being located within 200m from boundary, respectively. Lower Dibang Valley (0.09%), Lower Subansiri (2.3%) and Leparada (4.5%) are among the safest as having less than 5% of their settlement within high susceptible zone and also with 11, 2 and 7 landslides being located within 200m from their boundary, respectively.
- Papum Pare, Shi Yomi, Lower Siang, West Kameng, Upper Subansiri are the most vulnerable to landslide risk to population (**Fig. 15.4F**). Nambai has no landslide risk.
- The above district-wise data have been analyzed using Multi-Criteria Decision Analysis (MCDA) method to rank the districts of Arunachal Pradesh in terms of population exposure to landslide risk.

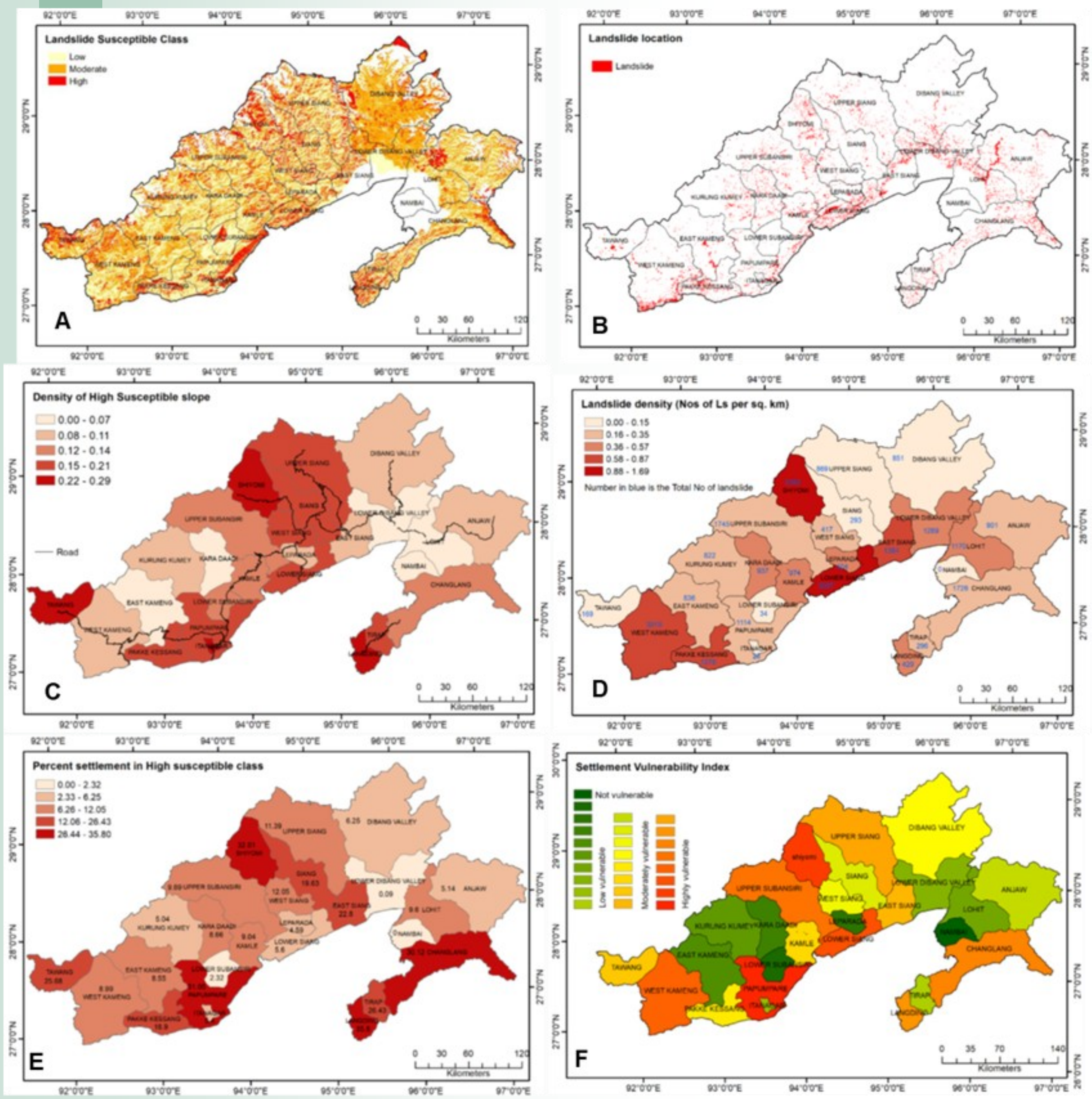


Fig.15.4: Landslide risk indicators of Arunachal Pradesh

NER's vulnerability to landslides is a complex interplay of natural and human-induced factors. While GSI has made significant contributions through zonation, investigations, and awareness programs, there is a pressing need for a coordinated, multi-agency approach involving real-time monitoring, integrated planning, and community engagement. Strengthening institutional frameworks, incorporating scientific recommendations into planning, and fostering public awareness are essential to make Northeast India resilient to landslide hazards.

15.2 Seismic Study

The North Eastern Region, a geo-dynamically active zone, is located at the intersection of three major tectonic plates: Indian Plate, Eurasian Plate and Burmese Plate**.** As per the seismic zoning map of the country, North Eastern Region lies in Seismic Zone V, the highest risk category in the Indian seismic zoning map.

Seismo-tectonic setup and significant earthquake history of the area

Based on the spatial distribution of earthquake epicenters, fault plane solutions and geotectonic features, northeastern part of India is influenced by major tectonic units e.g. 1) Eastern Himalayan thrust zone (EHTZ), 2) Eastern Himalayan Syntaxis (EHS), 3) Indo-Myanmar Ranges (IMR), 4) Bengal Basin (BeB), 5) Shillong –Mikir Massif (SMZ), and 6) Assam valley (AV) **.**

These tectonic zones are delineated by the active/ neotectonic faults which are producing earthquakes in response with plate movements. Each of these tectonic domains has its own evolutionary history, characteristic pattern, and geometry of inter and intra-domain dynamics of movements producing characteristic seismicity. Because of their diverse kinematics and tectonic complexity, these distinct tectonic domains are the sites of frequent earthquakes along the Himalayan arc (Curray et al., 1979).

Table 15.1: Significant Earthquakes in NER (≥7Mw)

Earthquake	Magni-tude (M)	Year of occurrence
Arkan Earthquake	~8.8	1762
Cachar Earthquake	7.8	1869
Assam / Shillong	8.1	1897
Srimangal Earthquake	7.6	1918
SW Assam Earthquake	7.1	1923
Dhubri	7.1	1931
Assam Earthquake	7.6	1931
NE Assam	7.2	1943
Great Assam Earthquake	8.6	1950

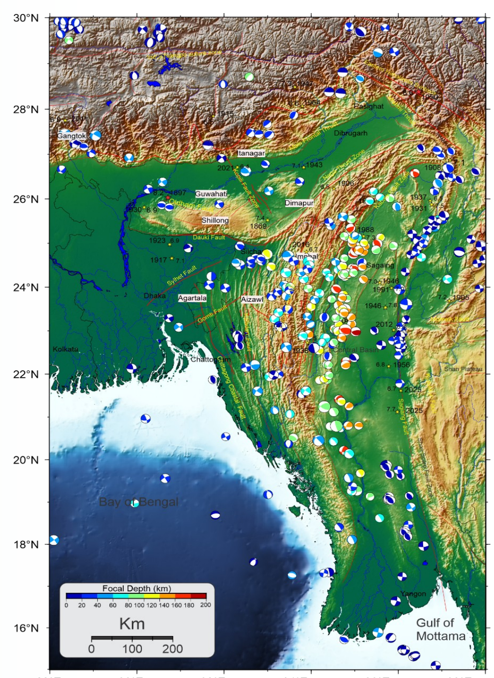


Fig.15.5: Seismotectonic map with >6M earthquake since 1869

Earthquake studies carried out by the GSI can be broadly be classified into four categories:

(i) Seismic Microzonation
(ii) Active Fault Studies
(iii) Monitoring of Ground Motion
(iv) Macroseismic Survey.

Seismic Microzonation (SMZ) study : Based on the request received from CGPB/SGPB/ SDMA/ State Govt. Seismic Microzonation studies are carried out in various cities / townships of NER to identify potential seismic or earthquake prone area into zones with respect to ground motion characteristics taking into account of source and site conditions.

Table 15.2: Details of Seismic microzonation studies in NER

State Name	City / township where SMZ study carried out
Assam	Guwahati, Dibrugarh, Tinsukia, Silchar, Jorhat
Meghalaya	Shillong
Manipur	Imphal
Mizoram	Kolasib, Aizawl, Champhai,
Nagaland	Kohima
Tripura	Dharmanagar, Agartala, Udaipur,
Arunachal Pradesh	Itanagar, Pasighat
Sikkim	Gangtok

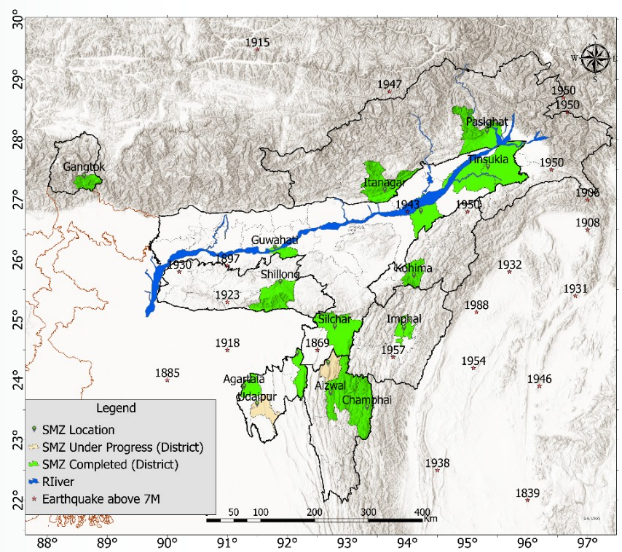


Fig.15.6: Status map of Seismic Microzonation in NER

Active Fault Studies: Active fault studies carried out along the foot hills of eastern Himalayas and northern slope of Shillong plateau to understand the seismic activity of Himalayan frontal thrust and Oldham fault

Monitoring of Ground Motion: The GNSS (Global Navigation Satellite System) stations play a crucial role in geodynamic studies by providing measurements of ground movement and deformation over time. GSI has been maintaining a pan-India network comprising 34 Permanent GNSS stations across the country including NER. From the stations installed on the Indian peninsula, the average Indian plate velocity with respect to ITRF14 reference frame has been calculated to be 51.04 mm/yr. in the N40.76°E direction. The GNSS station installed at Shillong shows northward and eastward velocity as 32.97 mm/yr and 42.78 mm/yr respectively .

Macro-seismic Survey: The word "macro-seismic" is used to denote those effects of an earthquake that can be determined without the use of instruments. Macro-seismic studies of modern earthquakes are vital for (i) calibrating studies of historical earthquakes; (ii) studying local attenuation, and (iii) investigations of vulnerability, seismic hazard and seismic risk.

Table.15.3: Last five years details of Macroseismic survey in NER

Sl	Year	Month	Day	Magnitude	Epicenter
1	2021	4	5	5.1	Sikkim
2	2021	4	28	6.4	Sonitpur
3	2023	8	14	5.4	Karimganj
4	2023	10	2	5.2	N.Garo Hills
5	2023	12	2	5.6	Ramganj
6	2025	1	7	7.1	XIZANG, CHINA
7	2025	2	27	5	Morigaon, Assam
8	2025	3	28	7.7	Myanmar
9	2025	5	28	5.2	Moirang, Manipur

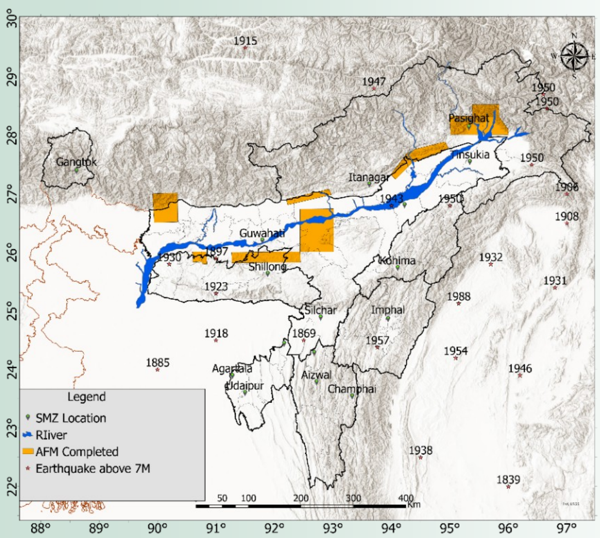


Fig. 15.7:Status map of Active Fault Studies in NER

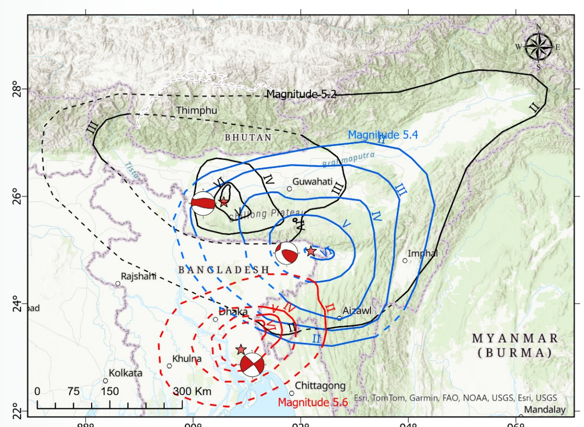


Fig.15.8: Combined Macroseismic isoseismal of 14.08.2023, 02.10.2023 and 02.12.2023 Earthquake in blue, black, and red solid and dotted lines respectively.

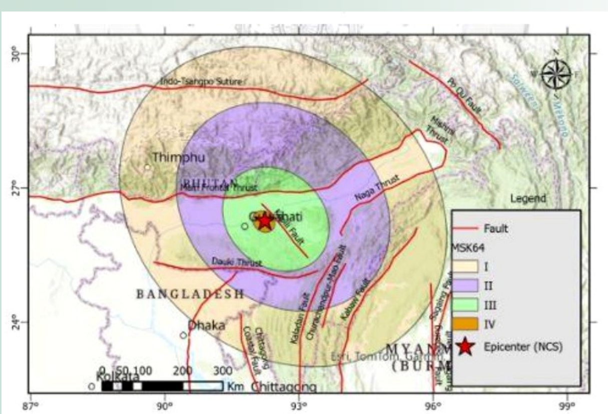


Fig.15.9: Isoseismal map of 27.02.2025, Morigaon earthquake, Assam

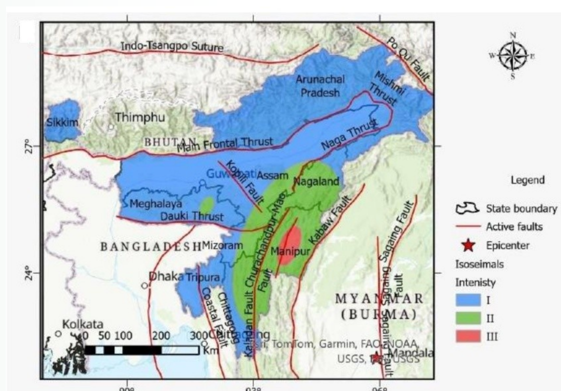


Fig.15.10: Isoseismal map of M 7.5, 28th March 2025 Mandalay earthquake, Myanmar

16. Glossary of Geological and Mineral Terms

A Quick Reference for Understanding Key Concepts

This glossary provides concise explanations of selected geological and mineral-related terms commonly used throughout this Handbook. It is intended to aid readers—especially non-specialists—in navigating technical terminology related to mineral exploration in the North Eastern Region.

Alkaline Complex : A type of intrusive igneous rock formation rich in alkali metals (sodium and potassium) often associated with rare earth elements (REE), niobium, and phosphate mineralization.

Basement Rocks: The oldest crystalline rocks in a region, typically of Archaean or Proterozoic age, forming the foundation over which younger sedimentary rocks are deposited.

Bauxite: An aluminium-rich lateritic ore that serves as the primary raw material for aluminium production. Often forms in tropical regions through intense weathering.

Carbonatite: An igneous rock composed predominantly of carbonate minerals, often associated with REEs, niobium, and phosphate.

Critical Minerals: Minerals essential for high-tech, renewable energy, defense, or strategic applications, for which secure supply is economically or geopolitically important. Examples: REEs, graphite, vanadium, lithium.

Ferruginous Phyllite: A fine-grained metamorphic rock enriched with iron oxides; often a host rock for REEs and vanadium in Arunachal Pradesh.

Geological Report (GR): A detailed scientific report prepared by GSI documenting geological observations, exploration methodology, analytical results, and resource estimates for a given area/block.

Geological Memorandum (GM): A simplified geological document usually prepared for preliminary exploration or when a resource estimate is not yet viable.

Graphite: A naturally occurring form of crystalline carbon used in electrodes, refractories, and battery anodes, particularly in electric vehicles.

Laterite: A weathering product rich in iron and aluminium, typically found in tropical regions; can host bauxite and REE mineralization.

Main Central Thrust (MCT): A major Himalayan tectonic boundary where high-grade metamorphic rocks of the Higher Himalaya have been thrust over the Lesser Himalayan sequences.

Ophiolite: A section of oceanic crust and upper mantle rocks obducted onto continental crust, often associated with chromite, nickel, and cobalt mineralization.

Rare Earth Elements (REEs): A group of 17 chemically similar elements (including lanthanum, neodymium, yttrium) critical in magnets, electronics, and green technologies.

Systematic Geological Mapping (SGM): A standardized process of surveying and documenting the geology of a region, typically at a 1:50,000 scale, forming the basis for further mineral exploration.

UNFC Classification: The United Nations Framework Classification for Resources—a globally accepted system used to categorize mineral resource estimates based on geological confidence and feasibility.

Vanadium: A critical alloying element used in steel production and redox-flow batteries for renewable energy storage.

Acknowledgement

This Handbook on Geological Potential of North East India is the outcome of collaborative efforts by the Geological Survey of India (GSI) under the Ministry of Mines, Government of India.

We gratefully acknowledge the Ministry of Mines for its policy direction and sustained support in advancing mineral exploration in the NER. The leadership of the Hon'ble Minister of Mines has been pivotal in bringing strategic focus to the region.

Special thanks are due to the Director General, GSI, for guiding the organization's efforts toward critical mineral targeting and regional resource development, and to the dedicated officers of GSI's NER Regional Mission, State Units, and Thematic Divisions for their fieldwork and data contributions in demanding terrains.

We also thank the State Directorates of Geology and Mining for their partnership in block validation and auction facilitation.

Finally, we appreciate the contributions of the editorial, cartography, GIS, and design teams for shaping this publication into a comprehensive and user-friendly reference for stakeholders engaged in unlocking the NER's mineral potential.

“North East India: Where Mountains, Plateaus, and Valleys Tell a Billion-Year-Old Geological Story.”

The North Eastern Region (NER) of India, comprising eight states Assam, Arunachal Pradesh, Meghalaya, Manipur, Nagaland, Tripura, Mizoram and Sikkim, features diverse geography—from the high Himalayas in Arunachal Pradesh to the Brahmaputra floodplains and Meghalaya Plateau. The region has a complex geological makeup with rocks from the Archaean to Quaternary age. It is rich in natural resources, especially hydrocarbons, and also holds significant deposits of coal, graphite, REE, limestone, bauxite, and more.

Majestic rock structure in Kolodyne River, Siaha district, Mizoram

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