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700-2009 (DSK-II)

असम का भूविज्ञान एवं खनिज संसाधन

भारतीय भूवैज्ञानिक सर्वेक्षण
विविध प्रकाशन
संख्या 30 खण्ड-IV, भाग 2(i) असम

GEOLOGICAL SURVEY OF INDIA

Miscellaneous Publication No.30 Part IV VOL:2(i):ASSAM

GEOLOGY AND MINERAL RESOURCES OF ASSAM

GEOLOGICAL SURVEY OF INDIA
Miscellaneous Publication
No.30 Part IV VOL:2(i):ASSAM

150
YEARS
in the service of the nation



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FOREWORD

The Miscellaneous Publication 30 Series of the Geological Survey of India brings out concise information on the geology and mineral resources of the states of India. The present volume Part IV, Vol. 2(i) of the series, pertaining to the state of Assam, is a revised and updated version of the first edition published in 1974. During the span of three decades since the first edition was published, enormous knowledge has been added in the sphere of geology of the area, hence warranting publication of a revised edition. The Geological and Mineral Map presented in this volume is based on the 1:2 million scale geological map of North-East India published in 1998.

Geological Survey of India continues its untiring work in different realms of earth sciences – a committed goal of 'digging the past to light the future'. DOVEMAP studies in Assam were taken up for development of village economy through mineral appraisal Programme and to bring both the scientific knowledge regarding land, mineral and water resources as well as environment at the basic level of social set up. There was a need for revision in the lithostratigraphy of the state in the light of the data available through the recent works both in the field and in the laboratory.

Some new mineral occurrences have been located in the state through geological and exploration programme. The occurrences of coal from two geological horizons viz. Gondwana and Tertiary of which Tertiary coal deposits of Makum, Mikir Hills and Dilli-Jeypore are the most noteworthy amongst them.

This publication will update the knowledge-base on the geology and mineral resources of the state of Assam and will be of great use to the professionals, students of geology and entrepreneurs alike. Thus it will help in boosting the economy of the region.



(N. K. DUTTA)

Director General

Geological Survey of India

PLACE : Kolkata
November, 2009

"With their four-dimensional minds, and in their inter disciplinary ultraverbal way, geologists can wiggle out of almost anything."

– John McPhee

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Geology and Mineral Resources of Assam

Introduction

The Geological Survey of India published the first Misc. Pub. No. 30, Pt. IV in 1974 elucidating the geology and mineral resources of all the seven states of North Eastern Region in one volume. Since its publication quantum progress in the field of geological mapping, mineral investigations, structure and tectonics of the region has been achieved out by officers of GSI and to some extent by earth scientists of other institutions. This has resulted in better understanding of the geology of North Eastern India, its natural resources and arrive at a modified stratigraphic set up of the North Eastern India. Large volume of geological data has been generated in the North Eastern Region over the past three decades, in view of this, the Misc. Pub. No. 30, Pt. 4, Vol. 2 (Part-1) is exclusively dedicated to the geology and mineral resources of Assam. The State of Assam, covering an area of 78,523 sq. km, is the gateway to other six sister states of the North Eastern Region.

The state can be broadly divided into the following physiographic domains :-

a) Brahmaputra valley - The vast alluvial plains of Brahmaputra valley occupy most of the North Assam covering Goalpara, Kokrajhar, Dhubri, Kamrup, Nalbari, Barpeta, Nagaon, Darrang, Sonitpur, Sibsagar, Jorhat, Golaghat, Lakhimpur and Dibrugarh districts. The Brahmaputra valley is bounded by Arunachal Himalaya in the north and northeast, Patkai – Naga - Lushai range of Nagaland and the Shillong Plateau in the south and southeast.

b) Central Assam Hills -The Central Assam which essentially is a hilly terrain comprised of Mikir Hill in Karbi Anglong and North Cachar Hill districts.

c) Barak valley - The hilly and alluvial terrain in the south covering the Cachar and Karimganj districts in the Barak (Surma) valley.

Table 1: Basic Statistics of Assam

Capital City	Dispur		
Population	26,655,528	Forest cover	26,060 sq. km
Area	78,523 sq. km	Road length	68,913 km
Population Density	286 persons/sq. km	Total Hard rock area	21,585 sq. km
Villages	22,000 nos.	Quaternary area	51247 sq. km
Literacy	63.3%	Hard rock mapping coverage *	23,625 sq. km
Total no. of districts	23	Quaternary mapping coverage *	49,867 sq. km
Major Minerals	Coal, Limestone, clay and Oil & Natural Gas		
Minor Minerals	Base metals, Bauxite, Phosphate, Glass sand, Iron ore, Beryl, Feldspar, Mica, Platinoids, Rare earths, Gold, Construction materials and Refractory minerals.		

* Revised upto 2007-2008.

The Brahmaputra valley with an average elevation from 50 to 120 m above m.s.l. represents an unique landscape comprising of a 800 km long and 130 km wide valley delimited by the low-lying valley to its south and the Mikir hills and Barail range comprising the North Cachar hills in the central part.

(i) CLIMATE :

Assam experiences the predominant influence of the southwest tropical monsoon which is normally active from April to October with occasional winter showers. The approach of the monsoon is usually marked by strong winds, overcast skies accompanied by occasional thunder showers, hailstorms and at times by cyclones between April and May. Heavy downpour starts from June. The annual average rainfall of the state varies between 160 cm and 430 cm from place to place. The average rainfall for the state as a whole is about 290 cm with maximum precipitation during June and July. The average temperature in the state varies from 4°C to 19°C during the winter and 26°C to 37°C during the summer accompanied by high humidity.

(ii) FLORA, FAUNA AND CULTIVATION:

The diverse landscape of the state has a variety of mixed dense forests which include numerous varieties of trees, bamboos, cane groves, tall grasses, herbaceous and shrubby vegetations. In the state different varieties of deciduous and evergreen timber producing trees flourish like *Sal* (*Shorea robusta*), *Makai* (*Shorea assamica*), *Nageshwara* (*Mesua ferrea*), *Tiachapa* (*Micheelia champaka*), *Sonaru* (*Classia fistula*), *Gunsarai* (*Chinamonum glanduliferum*), *Ajhar* (*Lagerstraeia flos regina*), *Agar* (*Aquilaria agallocha*), *Hollock* (*Terminalia bicolorata*), *Hollong* (*Dipterocarpus bondii*), *Simul* (*Bombak malabaricum*), *Khair* (*Accacia cateshu*), etc. The forests also shelter various types of parasites, epiphytes and orchids.

The most important amongst the fauna in Assam is the single horned Indian Rhino (*Rhinoceros unicornis*). Besides this, the forests in the state provides habitat for a variety of other animals such as wild elephant, wild buffalo, wild pig, gaur, bison, chital, sambar, swamp deer, hog deer, barking deer, tiger, bear, wild cat, wild dog, hare,

panther, and monkey. Amongst birds, wild geese, teal, black and marsh partridge, wild fowl, pea fowl, wood cock, snipe and varieties of peasant are found. The pelican and adjutant storks are also seen in the Kaziranga wild life sanctuary, which has been recently declared as a National Park. The other wild life sanctuary at Manas is at the foothills of Bhutan. It is famous for wild elephants, gaur, bison, and chital. Varieties of snakes including python, king cobra and vipers are abundant at places. In the rivers of the state variety of fishes and minor aquatic animals are found.

The chief agricultural products of the state are varieties of rice, tea, jute, mustard, pulses, sugarcane, potatoes, oranges, pineapples, coconut, betels, black pepper, citrus fruits, bananas besides many types of *vegetables*. In tea, Assam excels as a number one tea producing state in the country contributing to over half (215, 157, 000 Kg) of the total annual production of the country. From tea alone the state earns about 11 % of its revenue. The total annual production of rice in the state is about 2.02 million tons.

(iii) NATURAL RESOURCES:

The State of Assam was the only oil producing state in India till the oil fields of Gujarat and Bombay Highs were discovered. Along with oil there are also a modest reserves of natural gas in Assam. The state also has good reserves of coal in the Upper Assam coalfields (Makum & Dilli-Jeypore) and in Karbi-Anglong district. Apart from coal, limestone deposits occur in the Karbi-Anglong and North Cachar Hills districts. Other mineral found are clay, feldspar, mica, beryl, gypsum, iron ore, placer gold, pyrite, salt and sillimanite, which do not have known economic importance.

(iv) PHYSIOGRAPHY AND DRAINAGE:

The evolution of the modern day topographic and physiographic architecture of Assam, leading to development of the mighty Brahmaputra Valley, the Central Assam range comprising of the Mikir and North Cachar (Barail) hills and the Surma Valley extending south-westward into alluvial plains of Bangladesh are due to the effect of several complicated cycles of geological events of

the North East India which are discussed separately in the forthcoming chapters on structure, tectonics and geological history.

The Brahmaputra Valley of Assam is the eastern continuity of the Indo-Gangetic trough of North India. While, the peninsular rock masses are represented in the Mikir Hills of Karbi Anglong district of Assam is an extension from the Meghalaya Plateau.

The Karbi (Mikir) Hills with an average elevation of 1,000 m (m.s.l) represent a peneplained surface of metamorphosed rocks with sedimentary cover rock of sandstone, clay-shales and limestone along its southern and eastern margins. The Barail Range of North Cachar Hills comprising of post Oligocene sedimentary rocks merges with Mikir Hills to the north and further extends into the Naga Hills towards southeast. The Barail Range with an average elevation ranging between 1300 and 1650 m defines the main watershed between Brahmaputra and Surma basin. The regional trend of central Assam range is ENE-WSW which towards the east is NE-SW.

The Brahmaputra and the Surma (or Barak) are the two major river systems of the State. The Brahmaputra River originates at an elevation of about 5,000 m above (m.s.l.) in Tibet. The Bhramaputra River, known as Tsang Po in Tibet, after a long eastward course of 1,600 km abruptly veers towards south around Namcha Barwa peak (7,710 m) in Eastern Himalaya. This southward course of the river flowing through Arunachal Pradesh is known as Siang River. It passes through tortuous course across the mountains of Arunachal Pradesh and then emerges on to the plains of Assam, where downstream it is met by the Dihang, which is known as the largest tributary of the Brahmaputra, further fed by tributaries like Dibong, Sessiri, Lohit and Noa-Dihing around Saikhowaghat. The river known as Brahmaputra in Assam initially flows south-westward and thereafter towards west in the Brahmaputra Valley. Further down streams, the river swings towards south and passes on to the plains of Bangladesh. The Brahmaputra River between Namcha Barwa and the confluence with Dihang descend by about 2,200 m and its water power resources have been estimated to be the third biggest in the world coming after Congo and

Amazon basins. Along the northern bank, the Brahmaputra River is joined by the tributaries like Subansiri, Ranga *Nadi*, Dikrong, Gabharu, North Dhansiri, Pagladiya, Manas, Aie, Beki, Champamati, Gangadhar, and Raidak. All these tributaries more or less flow in straight courses up to the junction of the main river. On the south bank tributaries like Benhi-Dihing, Disang, Dikhau, and South Dhansiri originate from Naga-Patkai Hills. The Kopili River originates from North Cachar Hills, while the Digaru, Bharalu, Kulsi, Singra, Dudnai and Krisnai originate from Meghalaya Plateau. Some of the rivers and tributaries originating from the south flow for quite a distance almost parallel to the Brahmaputra River before joining the main river.

In the Surma Valley, the Surma River originates in the North Cachar Hills. The Barak River is an important tributary of Surma which rises in the North Manipur. This river after flowing west through Cachar district meets the Kushiara River and then unites with the Surma, further downstream in Bangladesh known as Meghna River. The Surma River is fed by numerous small tributaries originating from the Meghalaya plateau and North Cachar Hills.

The Brahmaputra Valley is mainly a Quaternary fill valley with a few isolated sedimentary residual hills in Upper Assam and inselbergs and hills of gneissic rocks in the Darrang, Kamrup, and Goalpara districts. The drainage pattern in the valley apparently seems to be of antecedent type. The often changing meandering course of the Brahmaputra and its tributaries are not only due to lateral erosion because of the low gradient of the rivers but also due to periodic, local and sudden changes in the basement levels due to the neotectonic activity.

The Surma River Valley is situated in a triangular area between the Meghalaya in the northwest, the North Cachar and Manipur Hills in the east and Mizoram and Tripura Hills to the south. The valley is low-lying with swamps and perfectly levelled alluvial flats (barring the low hillocks in the Cachar and Karimganj districts) stretching upto the base of steep rocky escarpment of Shillong Plateau. The Surma River and its tributaries over short distances only have steep gradients soon losing all

the perceptible falls and thereafter become tortuous, anastomosing water channels.

Trellis to sub-trellis drainage pattern is present in the Mikir Hills. Here the straight stream courses mainly follow the joint pattern of the country rock.

(iv) PREVIOUS WORK:

(a) Systematic Hard Rock Geological Mapping:

The pioneering work in the field of geology was done by H.B. Medlicott (1865) and Mallet (1876) whose valuable reports on geological mapping of Upper Assam coal belts were published in G.S.I. Memoirs. Subsequent significant geological contribution was made by the premier Assam Oil Company established in 1912 at Digboi in Upper Assam. Extensive prospecting for oil was carried out by this company during that period. Evans (1932) of Assam Oil Company recorded a detailed account of stratigraphy and structure of the Tertiary sediments of Assam.

The Geological Survey of India during the pre and post Independence era has been subsequently carrying out geological investigations and appraisals of mineral occurrence in different parts of Assam.

The earliest geological mapping in the hard rock terrain of Mikir Hills (Karbi Anglong district) was carried out by F.H. Smith (1896) and later followed up by V.R.R. Khedkar (1938-39) and D.R. Chandra (1947-48). Geological mapping of part of North Cachar Hills was carried out by P.N. Mukherji (1939-40) and S.N. Sen (1953-54).

After Mallet (1876), geological mapping and traverses in parts of Upper Assam were followed up by T.H.D. La Touche (1886), J.M. Maclaren (1904), J.C. Brown (1912), E.H. Pascoe (1912), Murray Stuart (1923), T. Benerji (1951) and A.C. Goswami (1959-60 and 1960-61). Laskar (1953-54), S.D. Banerji (1955-56), A.C. Goswami and V.K. Raina (1956-57), M.B. Pande and S. Banerji (1959-60) and G.N. Dutta (1960-61) carried out study of the Archaean rocks in parts Kamrup and Nagaon districts.

Detailed programmes of systematic mapping in different parts of the state have subsequently followed up by GSI during the post independence. Systematic mapping

in parts of Mikir Hills was carried out by M.B. Pawde, S.K. Banerjee, M.M. Munshi, B.K. Duara, B.D. Adhikari, A.C. Bhattacharya, G. Barman, K.K. Sen, R.N. Mukhopadhyaya, Ashim Dutta, A.R. Nambiar, P.K. Muralidharan, G.K. Pancholi, Des Raj and K. Chadrashekhara during field seasons from 1959-60 to 1978-79 and A.K. Buragohain, J.C. Dutta, V.N. Bajpai, Y. Kumar, D.P. Das and H.S. Shrivastava during 1982-83 and 1983-84 field season. Parts of North Cachar Hills was mapped by B. Dayal, P.C. Raj, B.D. Adhikari, S.K. Shrivastava, R.N. Patnaik, R. Bandopadhyay, Y. Kumar and J.C. Dutta during 1964-65, 1968-69, 1972-73, 1974-75, 1975-76 and 1981-82 field seasons. Systematic mapping in parts of Cachar district was carried out by B. Dayal, P.C. Raj, S.K. Shrivastava, Ashim Datta, S.D. Mohanty, S.C. Sharma, G.K. Pancholi, S.N. Mitra, A.K. Roychoudhuri, J.K. Sinha, A.K. Buragohain and D.P. Das during 1963-64, 1971-72, 1973-74, 1974-75, 1975-76, 1976-77, 1980-81 and 1981-82 field seasons. The Kopili reservoir area was mapped partly by M.G. Rao, J.P. Dias, C. Chakrabarti, S.K. Shrivastava, and S. Chopra during 1963-64, 1965-66 1972-73 and 1974-75 field seasons. D.N. Bandopadhyay (1976-77) mapped the area around Jagi Road in Kamrup and Nagaon districts.

(b) Quaternary Geological Studies:

The Quaternary terrain of Goalpara and part of Kamrup districts were mapped initially by M.G. Rao during field seasons 1961-62 to 1966-67 and that in parts of Kamrup and Darrang districts by S.N. Sar, S. Basu Chowdhury, and B.K. Duara during 1965-66. An integrated study of Manas, Pagladiya, Jia Bhareli, and Subansiri Basins for the purpose of Brahmaputra Flood Control Commission during 1970-72 was conducted by B.C. Poddar, T.V. Viswanathan, S.K. Mazumdar, C. Chakrabarty, A.C. Paul, B.K. Duara and others. Work on similar lines was extended to cover more Quaternary areas of Assam including Lower and Upper Brahmaputra Valley between the period 1975-80 by a number of workers including B.C. Poddar, A.B. Goswami, C. Chakrabarti, P. Chakrabarti, B.K. Duara, K.K. Sinha, S.N. Banerjee, R.K. Sinha, A.U. Khan, S.K. Kar, S.K. Bandopadhyaya, N.R. Ramesh and R.N. Verma.

(c) Mineral Investigation:

I. Coal: The existence of coal in the Upper Assam was known to the Britishers as early as in 1825, however nothing was done for its exploration till H.B. Medlicott visited the most inaccessible hilly terrain across Dihing river in Upper Assam in 1865. His investigation not only brought to light the superior quality and large reserves of coal deposits, but also indicated possibility of petroleum reserves in the region. On his recommendation the collieries in the Margherita area, Upper Assam came up during 1889. Subsequent investigations in the area were followed up by F.R. Mallet (1876), R.R. Simpson (1906), H.H. Hayden (1910), E.H. Pascoe (1911), B. Laskar (1950), A.M.N. Ghosh (1950) and T. Banerji (1951). Systematic mapping of the adjacent Makum coalfield area in Upper Assam was carried out by A.C. Goswami in 1959-60 and 1960-61 field seasons. Large scale mapping of Makum coalfields in Upper Assam was carried out by A.C. Goswami and A.N. Trivedi during 1961-62 and 1962-63 field seasons. Seam-wise estimation of reserves of coal in part of Makum coal field was done by A.C. Goswami, P.C. Raj and P. Majumdar during 1964-65 and 1965-66 field seasons. The investigation was further followed up by N. Venkatappaiyya, A.K. Majumdar, A.K. Chowdhury and V.D. Puri of the Coal Division, G.S.I. during 1966-67 field seasons. Large scale mapping of Dilli- Jeypore colliery was completed by J.P. Dias, R.N. Sinha Roy and B.D. Adhikari during 1963-64 and further investigation was carried out by A.K. Chowdhury, V.D. Puri and others during 1967-68.

Coal occurrence of Mikir Hills was examined by A.M.N. Ghosh in 1950s and V.K. Raina and M.M. Munshi in 1958-59. Further investigations of the coal fields in Mikir Hills were carried out by M.M. Munshi (1962) and M.D. Limaye (1966-67). Coal and limestone occurrences along the eastern flank of Mikir Hills were examined first by La Touche (1886) followed by M.D. Limaye (1966-67). Limaye (1966-67) examined a reported occurrence of coal in Jiribum in Assam-Manipur border. Occurrence of coal in Bhutan foothills along Kamrup border was investigated by G.E. Pilgrim in 1906. A.C. Goswami further visited the area in 1965 for an alleged occurrence of coal and alum shale.

II. Petroleum : The earliest reference of oil find in Assam was by Medlicott (1865). Since then many attempts were made by different oil companies in different parts of the belt between Makum Pathar and Jeypore, till accidental discovery of the Digboi oil field during Dibrugarh-Ledo Railway Link construction in 1889. The details of petroleum occurrences in Assam were recorded by Pascoe (1914). Since the establishment of the Assam Oil Company at Digboi during 1912, prospecting for oil in the area was carried out by the geologists of the company. Some reported occurrences of oil seepages in Kamrup district in Hathikhali in North Cachar district were examined by T. Banerjee (1950) and B. Laskar (1953). Since 1956 onwards, oil prospecting in the region has been carried out by the Oil and Natural Gas Corporation (ONGC) and Oil India Limited (OIL).

III. Limestone : Reference on the limestone in the Mikir Hills was first made by Medlicott in 1869 and subsequently by La Touche (1886). A detailed investigation on Mikir Hills limestone deposits was carried out by D.K. Chandra in 1949. Munshi and Raina (1958-59), A.C. Bhattacharya, G. Barman and M. D. Limaye (1966-67) further examined the deposits in different parts of the area. The limestone deposit in parts of Garampani (Kopili) area of the North Cachar Hills was investigated in detail by K. Gopalakrishnan (1962-63).

R.N. Patnaik and R. Bandopadhyay carried out large scale mapping of limestone exposed on the Garampani-Lanka road during 1974-75 and 1975-76 field seasons. The Directorate of Geology and Mining, Govt. of Assam prospected for cement grade limestone in Timbung Basti (Garampani) in 1978-79.

IV. Iron ore: Occurrences of weathered deposit of magnetite-hematite-quartzite bands in gneissic hills in Goalpara district were investigated by M.G. Rao (1961-62, 1962-63 and 1966-67). A.C. Goswami examined alleged occurrences of iron ore in Kamrup district in 1969-70. The D.G.M. Assam investigated the iron ore occurrences at Lengupara and Kumri areas, Goalpara district, in 1972-73.

V. Phosphate: B.D. Adhikari examined the Kopili shales in the Garampani (Kopili) area for possible occur-

rences of phosphatic nodules at the base of the formation during 1968-69.

VI. **Lepidolite:** Investigation of lepidolite bearing mica near Dhir bil in Goalpara district was investigated by K. Gogoi in 1969-70.

VII. **Gypsum:** In the Badarpur area alleged occurrences of gypsum in Cachar district and Mahur area in North Cachar Hills were examined by A.C. Goswami in 1959-60.

VIII. **Pyrite:** B.Laskar (1954) examined reported occurrence of disseminated pyrite near Chatachura in the Cachar district. The D.G.M. Assam, conducted investigations for pyrite at Purna Mengaon area, Karbi Anglong District in 1977-78.

IX. **Beryl:** Reported occurrences of beryl at places in the north eastern part of Mikir Hills were investigated by A.C. Goswami in 1958.

X. **Precious Metals:** Mallet (1882) examined a minor flake of iridosmine placer in the Noa-Dihing river. Occurrence of gold placers in some rivers of the Upper Assam rivers were examined in detail by J.M. Maclaren in 1904. The D.G.M. Assam carried out investigation for placer gold in the Subansiri river valley during 1971-74.

(v): ACKNOWLEDGEMENTS

The Director General, Geological Survey of India, conceived of the project on the write up on geology of the different states of India and this work in North Eastern Region comprises a part of the larger, all India project of Geological Survey of India.

The present compilation on Geology and Mineral resources of North Eastern Region under the Misc. Pub-

lication 30 is an endeavour as per the broader framework of comprehensive write up of the Geology and Mineral resources of the States of India as formulated by the Central Headquarters of GSI.

The co-ordinated efforts of the Deputy Directors General, Geological Survey of India, NER, Shillong and supervisory officers at Shillong facilitated availability of manuscripts of the state for this present compilation.

The material has been updated after critical reviews by the Publication Division CHQ, GSI, Kolkata. An overall co-ordination from Central Headquarters was needed to orient the objective of this publication as per the guidelines set by CHQ.

Various Divisions of Geological Survey of India, Northeastern Region have provided the draft material which has been compiled, recast as per the prescribed format of this publication. Since the work for this volume started some years before the actual publication, some of the manuscripts were irretrievable and portions had to be rewritten. This would not have been possible without the background information on the data sources provided by the various Divisions/Projects. Coal Wing, Geological Survey of India provided the material pertaining to coal which has been incorporated.

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General Geology and Stratigraphy

The State of Assam is occupied by rocks belonging to, (a) Proterozoic Gneissic Complex, (b) Shillong Group of Meso-Palaeo Proterozoic age, (c) Granite Plutons of Neo-Proterozoic-Lower Palaeozoic age, (d) Lower Gondwana sedimentary rocks of Permo-carboniferous age (e) Alkali Complexes of Samchampi, Borpung and volcanic rocks represented by Sylhet Trap of Cretaceous age, (f) Lower Tertiary (Paleocene-Eocene) shelf sediments of the Jaintia Group extending along the southern and eastern flanks of Mikir Hills and geosynclinal sediments of Disang Group in parts of the North Cachar Hills, (g) Upper Tertiary (Oligocene to Pliocene) shelf and

geosynclinal sediments covering the southern flanks of Mikir Hills, the North Cachar Hills and the hills of the Cachar district in the Surma valley area. These rocks are also exposed along the northern foothills of Naga-Patkai range bordering the southern margin of Sibsagar, Jorhat and Dibrugarh districts. Along the southern foothills of Eastern Himalaya facing the northern border of Assam a narrow strip of Siwalik rocks are exposed (h) the Quaternary deposits comprising of Older and Newer Alluvium occur in flood plains and terraces of the Brahmaputra valley, Surma valley and other river basins of Assam.

STRATIGRAPHIC SET UP (Table 2)

Age	Group Name	Formation (Thickness)	Lithology
Holocene	Unclassified	Newer or Low Level Alluvium	Sand, silt and clay
Middle to Upper Pleistocene	Unclassified	Older Alluvium	Sand, clay, pebble, gravel and boulder deposit
----- Unconformity/ Tectonic -----			
Pliocene- Pleistocene	Siwalik Group	Kimin Formation	Sandstone with clay stone
		Subansiri	Micaceous sandstone
Pliocene	Dihing Group	Dihing Formation (900m)	Pebble beds, soft sandy clay, clay, conglomerates, grit and sandstone
----- Unconformity -----			
Mio-Pliocene	Dupitila Group	Dupitila Formation (Surma Valley: 3300 m)	Sandstone, mottled clay, grit and conglomerate; locally with beds of coal, conglomerate and poorly consolidated sandstone with layers and pockets of pebbles

		Namsang Formation (Upper Assam: 800 m)	Coarse, gritty, poorly consolidated sandstone and conglomerate of coal pebbles
----- Unconformity -----			
Mio-Pliocene	Tipam Group	Girujan Clay Formation (1800 m)	Mottled clays, sandy shale and subordinate mottled, coarse to gritty sandstone
		Tipam Sandstone Formation (2300 m)	Bluish grey to greenish, coarse to gritty, false bedded, ferruginous sandstone, clays, shales and conglomerates
----- Unconformity -----			
Miocene	Surma Group	Bokabil Formation (900 to 1800 m)	shale, sandy Shale, siltstone, mudstone and lenticular, coarse ferruginous sandstone
		Bhuban Formation (1400 to 2400 m)	Alternations of sandstone and sandy shale and thin conglomerate, argillaceous in middle part
----- Unconformity -----			
Eocene-Oligocene	Barail Group	Renji Formation (600 to 1000 m)	Massive bedded sandstone; its equivalent - the Tikak Parbat Formation in the Upper Assam is marked by thick coal seam in basal part
		Jenam Formation (1000 to 3300 m)	Shale, sandy shale, and carbonaceous shales with interbedded hard sandstone; its equivalent the Bargolai Formation in Upper Assam is marked by thin coal seams
		Laisong Formation (2000 to 2500 m)	Well bedded compact flaggy sandstone and subordinate shale; its equivalent- the Nagaon Formation in Upper Assam is marked by thin bedded, hard sandstone and interbedded shale.

	Disang Group		Splintery dark grey shale and thin sandstone
Palaeocene-Eocene	Jaintia Group	Kopili Formation	Shale, sandstone and marl.
		Shella Formation	Sylhet Limestone (Fossiliferous Limestone) Sylhet sandstone Sandstone, clay and thin coal seam
		Langpar Formation (exposed in Meghalaya)	Calcareous shale, sandstone-limestone
----- Unconformity -----			
Cretaceous	Alkali Complex of Samchampi		Pyroxenite – Serpentinite with abundant development of melilite pyroxene rock, ijolite, syenite and carbonatite
----- Unconformity -----			
Cretaceous		Sylhet Trap (exposed in Meghalaya) (600m)	Basalt, alkali basalt, rhyolite, acid tuff
----- Unconformity -----			
Permo-carboniferous	Lower Gondwana	Kaharbari Formation	Very coarse to coarse grained sandstone with conglomerate lense, shale, carbonaceous shale and coal
		Talchir Formation	Basal tillite, conglomerate with sandstone bands, siltstone and shale
----- Unconformity -----			
Neo-Proterozoic - Early Palaeozoic	Granite Plutons	Porphyritic coarse granite, pegmatite, aplite, quartz vein traversed by epidiorite, dolerite
----- Intrusive contact -----			
Palaeo-Meso Proterozoic	Shillong Group	Quartzite, phyllite, quartz – sericite schist, conglomerate
----- Unconformity -----			
Archaean (?) Proterozoic	Gneissic Complex	Complex metamorphic group comprising ortho and para gneisses and schists, migmatites granulites etc. Later intruded by acidic and basic intrusives-

(A) GNEISSIC COMPLEX:

The rocks of Gneissic Complex are exposed in Assam in the north western extension of the Proterozoic rocks of Meghalaya Plateau. It occupies a large part of the central Assam and few isolated inselbergs jutting out of the Quaternary plains of western Brahmaputra basins. The Gneissic Complex comprises of gneiss, schist, migmatitic granitoid intruded by younger acidic (granite, aplite, pegmatite) and basic (metadolerite, epidiorite, amphibolite) rocks. The granite plutons are often of batholithic dimensions. The predominant rock type of this complex is gneiss, particularly biotite-bearing quartzofeldspathic gneiss. Dating by K-Ar method has indicated that the last metamorphic event is around ~500 my, however, original rocks could be much older.

The rocks of the Gneissic Complex exposed in parts of Goalpara, Kamrup districts and in northern part of North Cachar Hills and Nagaon districts including the isolated inselbergs in the Brahmaputra Basin, mainly consist of biotite, and biotite-hornblende gneisses with bands of granulites and bosses of intrusive granites, pegmatites, quartz veins and minor basic bands. Minor meta-sedimentary bands comprising magnetite-hematite quartzite are associated with the gneiss in some of the isolated outcrops in the vicinity of Chandardinga, Bilasipara and Abhayapuri in the Goalpara district. In Sonaikuchi reserve forest area of Nagaon district, two pyroxene gneisses containing scapolite, saphirine and sillimanite-cordierite have been reported.

In the Karbi (Mikir) Hills the rock types vary from coarse grained, porphyritic granite to foliated biotite-granites and seem to be associated with fine grained, banded foliated gneisses, schists and granulites with intrusive pegmatite, quartz veins and basic sills and dykes. From the neighbourhood of Koilajan in central Mikir Hills, pyroxene granulite assemblages resembling charnockite were identified. Recently, large extensions of sillimanite bearing quartzites have been reported from the gneissic belts of central Karbi Hills. Here the geological setting resembles to sillimanite occurrences found in Sonapahar area in Meghalaya.

The structural framework of the gneissic complex and its history of evolution combined with associated intrusives are complex issues. Effects of polyphase deformation and intrusion are indicated from several places. At least two distinct phases of folding are indicated. An earlier one along E-W axis and a later one along NE-SW axis. A third phase of folding is also indicated at places by broad N-S upwarps and tight synforms. Syntectonic granitisation related to the first phase of folding is postulated to have given rise to gneissic granites and associated migmatitic rocks, while the emplacement of porphyritic granites are related to a later phase of folding. The granites were subsequently deformed to augen-gneisses. As proposed by Mazumdar (1986), on a regional scale, this basement terrain may be considered as a mosaic of different tectonic blocks, each with its own characteristic tectonic style.

These rocks have undergone regional metamorphism of amphibolite-granulite facies from place to place and has given rise to gneisses and schists on the one hand and the granulites on the other. Quartz veins which have intruded the schists are found to be co-folded along with these schists. These quartz veins are, therefore, older than those which traverse the overlying Shillong Group of rocks, as they were not affected by fold movements.

(B) SHILLONG GROUP :

Gneissic Complex is unconformably overlain by Shillong Group of rocks of Meso-Palaeo Proterozoic age. These rocks mainly comprise of conglomerate and meta-sedimentaries like quartzite-phyllite-schist association. The type section of Shillong Group is found in Meghalaya. In Assam the rocks of Shillong Group outcrop along the northern part of North Cachar Hills district and the western and northern part of the Mikir Hills across the Kopili valley. The structural trend of these rocks are NE-SW with dip varying from low to high angles.

Relict primary sedimentary structures like current bedding, ripple marks and graded bedding are often found within the quartzites. These rocks are metamorphosed to a low green-schist facies. Intrusion by granite plutons in Shillong Group exhibits contact metamorphism which

is represented by development of andalusite, garnet and staurolite in the contact zones. The strike continuity of the Gneissic Complex and the Shillong Group across the Kopili valley in a roughly collinear trend suggests the continuity of the rocks from the Meghalaya massif are possibly separated by the Kopili graben.

(C) GRANITE PLUTON:

A number of granite bodies, often of batholithic size transect both Gneissic Complex and Shillong Group. In Mikir Hills area, two types of granite occur, a) non-porphyrific foliated medium to coarse grained pink granite, occurring in the central part of the batholithic mass, and b) porphyritic granite encircling the non-porphyrific granite. Conclusive evidence to establish that these two granites mark separate phases of intrusions is not established. Chandra Chowdhury et. al., 1977 have opined that it mainly represents different phases of crystallisation of the same magma. However, Maswood (1977) feels that weakly foliated pink granite around Guwahati is a product of migmatization of biotite schist which was the original country rock.

In Mikir Hills, around Siliguri area small bodies of amphibolites and metadolerites are seen within schists and quartzites of Shillong Group. These intrusives also occur within granite around Samchampi and along Luhajuri-Bajajuri-Tarapung-Barapung *nala* sections.

(D) LOWER GONDWANA GROUP:

The occurrence of Lower Gondwana rocks was first reported from Assam area by Fox (1934) and later by Fermor (1935). These rocks are exposed in Singrimari area along the Meghalaya border in the extreme western corner of Assam. Though Singrimari (° Hallydayganj) village is located within the territorial limits of Meghalaya State, these rocks extend over to the State of Assam. Fox (1934) reported plant fossils and pieces of vitrified coal from these beds, based on which he concluded Gondwana affinity. Acharyya and Ghosh (1968b) grouped the entire sequence into Karharbari Formation (Permian). Banerjee et.al, (1977) based on mega and microflora finds in the fossiliferous carbonaceous shale assigned an age equivalent to lower Barakar. De and Boral (1978) further differentiated these sediments lithostratigraphically into the Talchir and Karharbari Formations.

entiated these sediments lithostratigraphically into the Talchir and Karharbari Formations.

(a) Talchir Formation:

The Gondwana succession in the area starts with the boulder conglomerate in the basal part which is well exposed south of Singrimari township at the road junction leading to Mancachar and Tura. The road cutting exposes shale overlain by a layer of conglomerate. This sequence can be further traced towards north in the Boldamiri *nala* where about 10 m alternating sequence of conglomerate and shale is exposed. The shale is *khaki* green to dirty greenish, silty and micaceous in nature. The boulder conglomerate is greyish brown to dirty grey with subangular to rounded clasts within the silty matrix. The clasts are composed of quartz, quartzite, gneisses and pegmatites which vary in size from pebble to large cobbles of 12 to 15 cm diameter. They are unsorted and do not exhibit stratification nor provide any directional palaeocurrent properties.

(b) Karharbari Formation:

The overlying younger sequence is poorly exposed. Best exposures can be studied in the area around of Singrimari Inspection Bungalow (IB). Here thin layers of sandstone and carbonaceous shales with a thick layer of conglomerate capping are exposed.

The shale is brownish red to dark grey, highly micaceous and contains well preserved plant impressions. The conglomerate is brownish grey to greenish grey with clasts of vein quartz embedded within a sandy matrix. These clasts show a greater degree of sphericity and roundness and vary in size from small pebble to cobble.

Well preserved leaf impressions of *Vertebraria sp.* and *Glossopteris sp.* are within the reddish brown to black micaceous shale which is underlying the coal band.

(E) ALKALI COMPLEX OF SAMCHAMPI :

Alkaline mafic-ultramafic-carbonatite complex at Samchampi is emplaced within granitic host rock. The rock types include mainly a variety of syenites which cover large part of the area, mafic rocks which include alkaline pyroxenite, shonkinite, biotite pyroxenite,

ultramafics (ijolite, melteigite), apatite-hematite-magnetite rock, carbonatite and cherty rocks. A zone of fenitisation encircles the complex. Carbonatite occurs mainly in the northern and eastern peripheral parts of the complex as dykes. At places, they laterally grade into mafics and ultramafic rocks and occasionally contain partly digested xenoliths of syenites and mafic-ultramafic rocks. The central part of the complex is occupied by apatite bearing magnetite-hematite rock. The carbonatites are mainly associated with minor kasenite.

Carbonatite bodies with associated rhyolite flows have been located along Brik *nala*, south of Matikhola Parbat in Mikir Hills. An ultrabasic radioactive diatreme containing magnetite and occasional sulphides are reported from Luhajuri-Bajajuri-Tarapung-Borpung area from the Central Mikir Hills. This occurrence resembles the carbonatite complex of Sung valley in Meghalaya. The volcanic nature of these rocks, lack of metamorphism and presence of volcanic glass suggest that all these occurrences belong to a common volcanic episode, which might be coeval with Sylhet Traps occurring along the southern fringe of Meghalaya Plateau.

(F) SYLHET TRAP :

Patchy occurrences of highly weathered trap rocks presumably belonging to Sylhet suite of Meghalaya have been reported from vicinity of Koilajan, Selvetta and a few other places in Karbi-Anglong district of Assam. The outcrop shows highly weathered and altered chert/olive green trap rocks overlying the gneisses.

Similar trap outcrops have been encountered in the Barapathar oil well drilled by Oil and Natural Gas Corporation (ONGC). Palynofossils obtained from the section suggests an early Cretaceous age.

Sylhet trap are exposed in a narrow 4 km wide and 8 km long strip along the southern margin of Shillong Plateau. In Assam these outcrops are highly weathered. These sporadic outcrops present in the area have small aerial extent and are not possible to plot on the map of attached scale.

TERTIARIES

The Tertiary rocks, rest over the weathered platforms

of Precambrian rocks, these comprise of both shelf and geosynclinal facies sediments of Palaeocene-Eocene age represented by the Jaintia and Disang Groups respectively. The overlying Barail (Eocene-Oligocene), Surma (Lower Miocene), Tipam (Mio-Pliocene), Dupi tila (Focene-Mio-Pliocene) and Dihing (Pliocene) Groups also represent both shelf and geosynclinal facies. The Tertiary sedimentary history of Assam is an integral part of the tectono-sedimentary setting of the Tertiary sediments of the North East India and is influenced by the prominent 'Brahmaputra Arch' running parallel to Brahmaputra River. The thickness of Tertiary rocks is seen to increase towards southeast. Whereas the thickness of Quaternary sediments of Bhramaputra Basin increases towards north and northwest.

In the Early Tertiary sediments there is a sharp distinction between a geosynclinal facies and a shelf facies. In the Late-Tertiary sediments there are minor differences in lithology, except that the shelf sediments are much thinner. The geosynclinal sediments are very thick where deposition took place in a sinking basin.

(G) JAINTIA GROUP :

The shelf facies sediments (Jaintia Group) of Eocene age are calcareous and abundantly fossiliferous. They differ markedly from the Eocene shales of the geosyncline (Disang Group) facies.

Jaintia Group is classified into three formation as given below :

Palaeocene-Eocene	Jaintia Group	Kopili Formation	Shale, sandstone and marl
		Shella Formation	Sylhet Limestone Member (Fossiliferous Limestone) Sylhet sandstone Member (Sandstone, clay and thin coal seam)
		Langpar Formation (exposed in Meghalaya)	Calcareous shale, Sandstone-limestone.

Jaintia Group comprising Shella and overlying Kopili Formations is seen around Garampani area of the North Cachar Hills. It also extends north-easterly along the southern and eastern slopes of the Karbi (Mikir) Hills. These rocks are exposed from the vicinity of Selvetta in west through Dilai Parbat in the east and then through Doigrung further north-east. Workable seams of coal are present in the Sylhet Sandstone Member at Selvetta, Koilajan and Sylhet Limestone Member in Selvetta, Jarapgaon, Koilajan and Nambar areas.

(a) Shella Formation:

The Shella Formation is well developed with three limestone bands alternating with three interbedded clastic sandstone units. In the basal part of this formation Theria-Cherra Sandstone member has been redesignated as Lower Sylhet Sandstone Member. In Garampani area a single limestone horizon underlain by sandstone represents the base. The limestone designated as Sylhet Limestone Member in Meghalaya is found to be equivalent to Upper Sylhet Limestone Member of the southern scarp of Meghalaya. The underlying unit, Lower Sylhet Sandstone Member in Assam represents the facies variant of the underlying limestone/ sandstone units exposed along the southern scarp of Khasi and Jaintia Hills, Meghalaya.

The Sylhet Sandstone (lower member) in Garampani area rests unconformably over the Precambrian basement. It is about 60 m thick and includes thick beds of sandstone with interstratified shale, carbonaceous shale and thin (0.3 m) coal seam, which overlies 2 to 3 meters thick basal conglomerate bed. An impure white clay bed is developed locally in the bottom part of the member. At places the sandstone is quartzitic in nature.

The overlying Sylhet Limestone (upper member) in Garampani area is upto 120 m thick consisting of thick beds of foraminiferal limestone with minor shale and marl bands. The limestone is hard and compact, traversed by several sets of vertical joints in different directions, giving rise to karst morphology and solution channels. Presence of *Nummulites bagelensis*, *Assilina spira*, *Coperculina sp.*, *Alveolina elliptica* in the Upper Sylhet Limestone are indicative of Middle to Upper Eocene age.

East of Garampani, the limestone is under alluvium cover, at around Lauka. It again reappears striking the south-southeastern Karbi-Anglong Hills with variable thickness. The underlying grit/sandstone bed is at places friable. In few locations the sandstone beds bear thin seams of coal. Northeast of Hazihaja, the limestone is overlapped by beds of Surma Group, and it reappears in Nambar area in the extreme northeast.

(b) Kopili Formation:

The Shella Formation is conformably overlain by Kopili Formation, consisting mainly of greyish, usually ferruginous, splintery shales with interbedded sandstone and calcareous marl of variable thickness. The thickness of this formation is about 500 m in the area around Kharungma and exhibits conformable trend similar to that of the underlying Shella Formation.

Northeast of Kharungma, Kopili sequence includes bands of white sandstone, calcareous or grey shales, sandy shales, and ferruginous shales, often with coaly material. At Samkhijan, near Lumding the upper part of the formation includes light grey clays with ferruginous nodules. Northeast of Lumding, Kopili Formation is overlapped by beds of Surma Group.

The rocks of Kopili Formation contains fossils like *Nummulites pengaroensis*, *Globigerina semi involuta* etc. indicative of Upper Eocene age.

(H) DISANG GROUP :

Disang Group in Assam are represented by monotonous sequence of dark grey, splintery, shale with thin sandstone interbands. The shale is usually limonite coated. The Disang are predominantly arenaceous in the upper part and exhibit vertical as well as lateral facies change to its overlying Barail Group of rocks.

In Assam, Disang Group is exposed along a narrow strip southwest of Haflong-Disang thrust in the central part of North Cachar Hills. This sequence is exposed from Jatinga valley eastward upto the headwaters of Dhansiri. In the upper part, beds of this sequence are cut-off by a thrust along which these rocks are seen to override the younger Tertiaries. Good exposures of these rocks are

seen along the railway cutting and stream sections near Mahur where shales contain streaks of soapstone. In North Cachar Hills, they are highly disturbed by overfolding. West of Jatinga valley, Disang rocks extend as narrow strip along the northern boundary of Cachar district.

In Upper Assam, Disang Group comprises of a thick sequence of alternating splintery shale with thin partings of hard greyish flaggy sandstone and sandy shales. They are generally iron stained, light to dark grey and carry fine streaks of carbonaceous matter. Thin veins of quartz and encrustations of soapstone characterise these shales in south-western part of Patkai Hills.

Foraminifera reported from the outcrops south-east of Haflong-Disang thrust suggests the age equivalence to Jaintia (Evans, 1935) Group.

(I) BARAIL GROUP :

Barail Group represents a lithological package belonging to the geosynclinal facies. Rocks of this group are exposed along two different strips, in the south-eastern part of North Cachar Hills, i.e. to the South of Haflong-Disang Thrust and secondly in parts North of the Cachar and Karbi (Mikir) Hills i.e. to the north of Haflong-Disang Thrust in Upper Assam.

The unclassified shelf facies rocks of Barail Group which overlie the Kopili Formation cover a large area with a gross thickness of about 1000 m. Lithologically they consist of fairly coarse sandstone, shale and carbonaceous shale with streaks of minor seams of coal. Outcrops of Barail Group in this part of the area are seen near Mupa, Langling, Latikhali, Chota Langher along the Lumding-Badarpur railway cuttings of North-East Frontier Railway as well as along road section between Haflong and Garampani-Kopili. The geosynclinal facies of Barail Group in Surma valley and North Cachar Hills are subdivided into Laisong, Jenam and Renji Formations.

Barail Group	Renji Formation	Hard massive sandstone with rare beds of shale and sandy shale.
	Jenam Formation	Shale, sandy shale, carbonaceous shale with streaks of coal and interbedded hard sandstone.
	Laisong Formation	Greyish sandstone with interbedded thin sandy shale, rare massive sandstone, carbonaceous shales and streaks of coal.

(a) Laisong Formation:

It consists of thin bedded greyish sandstone with interbedded thin sandy shale, rare massive sandstone, carbonaceous shales and streaks of coal. The assemblage of Laisong Formation comprises *Cicatricosisporites macrocostatus*, *Polypodiaceasporites tertiarus*, *Polypodiisporites speciosus*, *P. oligocenicus*, *Palmaepollenites communis*, and *Favitricolporites* complex. The pollen *Tetracolporites paucus*, *Graminidites assaminus*, *Polyadopollenites sp.* appear for the first time and *eyeripollis naharkotensis* is most abundant in Laisong Formation (Sah. 1974). On the basis of microfauna and palyno-fossil the Laisong Formation has been dated as Auversian-Bartonian.

(b) Jenam Formation:

Laisong Formation gradationally passes into argillaceous Jenam Formation comprising mainly of shale, sandy shale, carbonaceous shale with streaks of coal and interbedded hard sandstone. The carbonaceous shales of the Jenam Formation are characterised by the relative increase in the abundance of pteridophytic flora and a decrease in the frequency of angiospermous elements, in particular, *Meyeripollis naharkotensis*. On the basis of

microfauna and palyno-fossil the Jenam Formation has been dated as Lattorfian.

(c) Renji Formation:

Renji Formation comprises of hard massive sandstone with rare beds of shale and sandy shale. The Renji Formation is distinguished from the former two by the increased frequency of *Cicatricosisporites macrocostatus* and presence of *Polypodiisporites speciosus* and *P. oligocenicus*. On the basis of microfauna and palyno-fossil the Renji Formation has been dated as Chattian.

In upper Assam, the Barail Group has been classified as below :

Barail Group	Tikak Parbat Formation	Light coloured quartzose sandstone with interbedded shale, sandy shale, clay, carbonaceous shale with coal seams
	Bargolai Formation	Sandstone, clay, clayey sandstone, sandy clay, carbonaceous shale and coal seams
	Nagaon Sandstone Formation	Light to darker grey flaggy sandstone with thin partings of greyish splintery shales and sandy shales

(i) Nagaon Sandstone Formation:

The lowermost Nagaon Sandstone Formation (= Laisong Formation) consists of fine grained, hard, thin bedded, light to darker grey flaggy sandstone with thin partings of greyish splintery shales and thinly bedded sandy shales.

(ii) Bargolai Formation:

The overlying Bargolai Formation is a 900–2500 meter thick sequence comprising of sandstone, clay, clayey sandstone, sandy clay, carbonaceous shale and coal seams. The lower part of the formation is represented by hard sandstone, bluish grey micaceous sandstone with alternating bluish grey clay beds and carbonaceous shales. The

top part comprises massive sandstone, overlain by thick alternating assemblage of clay, sandy clay, clayey sandstone, thin ferruginous sandstone and carbonaceous shale with laminae of coaly material and leaf impressions. This formation includes several oil-sand horizons in Upper Assam. It is equivalent to the upper part of Laisong Formation and lower part of Jenam Formation.

(iii) Tikak Parbat Formation:

Tikak Parbat Formation which overlies Bargolai Formation comprises of medium to coarse grained light coloured quartzose sandstone with interbedded shale, sandy shales, clays, carbonaceous shale with at least five workable coal seams in the basal part. The carbonaceous shales exhibit leaf impressions. This formation is well exposed in Dilli-Jaipur and Makum coalfield areas in Upper Assam. The base of this formation in Makum coalfield area is defined at the base of the 18 meter thick coal seam in the bottom part of the sequence. This is also the thickest recorded coal seam in Assam. A total of five workable coal seams in the basal 160 m of Tikak Parbat Formation in Namdang area have been recorded. The rocks of this formation strike ENE-WSW with 45° southerly dip near Namdang colliery and 15° near Tirap colliery. It is equivalent to the upper part of Jenam Formation and the lower part of Renji Formations in the North Cachar Hills.

The thickness of Barail Group in southeastern part of Upper Assam Valley decreases in a north-westerly direction and this group may pinch out to the north of Brahmaputra – Baruah & Ratnam, C, (1982).

The Barail Group contains meagre fossil fauna. However, it contains a fairly rich palynofossil assemblage.

(J) SURMA GROUP:

Barail Group is unconformably overlain by Lower Miocene Surma Group, which covers a large area in Surma valley and North Cachar Hills. This group is divided into a lower arenaceous facies (Bhuban Formation) and an upper argillaceous facies (Bokabil Formation). Surma Group as a whole is well exposed as inliers in the southern part of the Surma valley and also occupies a strip in the northern part of the valley. In the North Cachar Hills, the rocks of Surma Group occupy a large tract in the vicinity

of Maibong and further northeastward upto Lumding. These rocks further continue northwards and are exposed in the south-eastern part of the Karbi (Mikir) Hills, as a narrow strip over the eastern base of the Karbi Hills. These rocks overlap the older horizons like Kopili, Sylhet limestone and metamorphite. The Bokabil Formation includes soft micaceous sandstone, siltstone, shale and clay with occasional intercalation of limestone and fossil wood. Shale samples collected from south of Khumbaman Parbat yielded a moderate assemblage of pteridophytic spore and some angiospermic pollen, which indicate an age range from Oligocene to Miocene.

Surma Group in Upper Assam is represented by about 30 to 60 m thick estuarine sandstone, shale and conglomerate unconformably overlying the Barails. Elsewhere the group is missing either due to overlap or by lateral passage of Bokabils into overlying Tipam Group which directly rests over the Barails in the Dilli-Jaipore and Makum coalfield areas.

(a) Bhuban Formation:

Bhuban Formation consists of sandstones, sandy shales and conglomerate intervened by shale, sandy shale and lenticular sandstone.

The fossil fauna in Bhuban Formation is extremely rare. Sale (1932) and Sale and Evans (1940) reported occurrence of molluscan fauna namely *Bassilia*, *Cancellaria*, *Hipponyx*, *Isocardia*, *Scutus*, etc, in Early Miocene in Kanchanpur. Biswas (1961) assigned Middle Miocene age on the basis of a few foraminifera exposed in Halflong-Dulu-Damchar area. Pascoe (1962), however, assigned Chattian age to the Kanchanpur fauna.

The palyno-fossil assemblage of the Bhuban Formation includes the following taxa:

Dicolpollis emineus, *Marginipollis grandis*, *Tricolpites oratus*, *Favitracolporites usitatus*, *Oudhkusumites immodicus*, *Couperipollis duratus*, *Hexapollentes artificiosus*, *Fusiformisporites adrogans*, etc (Salujha et al, 1973)

(b) Bokabil Formation:

Bokabil Formation consists of shale, sandy shale, siltstone, mudstone and fairly thick lenticular, coarse

grained, ferruginous sandstone. The sand-shale ratio frequently varies laterally and the Bokabil facies represents a gradational passage from the Bhuban Formation to the overlying Tipam Sandstone Formation (Upper Miocene). At Kanchanpur near Silchar in Cachar district, a thin fossiliferous horizon occurs at the base of Bokabil Formation. The marine fauna assemblage mainly comprises of *lamellibranch*, *gastropod*, *cirripidia*, *actinozoa* & *echinoids* which assigns Lower Miocene (Aquitania) age to this formation.

(K) TIPAM GROUP :

Tipam Group comprises a lower arenaceous facies Tipam Sandstone Formation and an upper argillaceous facies Girujan Clay Formation. Tipam Group has a general strike of ENE–WSW with a northerly dip varying from 50°–70°.

The rocks of Tipam Group are exposed in many areas in the Surma valley. Upper part of the Tipam sequence at many places is found to be eroded away, prior to the deposition of overlying Dupitila Group. However, Girujan Clay is exposed in the hills between Chargaola and Longai valleys and the low hills to the east of Jatinga and Cachar district. Rocks of this group are present also in the Labak-Diksha and Darby-Dwarband areas.

In Assam valley, Tipam Group occupies a 300 km long strip from Langting to Digboi interrupted by small patches of alluvium cover.

Both Tipam and underlying Surma Groups include fragments of silicified and semi carbonised fossil wood. Tipam Group also includes several oil-sand horizons in Upper Assam. Along the northern border of the state, facing the southern foothills of eastern Himalayas, light greyish, fine to coarse, micaceous sandstone having a typical “pepper and salt” texture with thin beds of shale are exposed below the terrace deposits. The group designated as Subamgiri Formation of Siwalik Group is equivalent to Tipam Group. These sandstones are invariably associated with fragments of semi silicified, semi carbonised fossil wood, with minor seams of lignite and rarely with thin impersistent layers of pebble. The shale is rarely carbonaceous. The Siwalik beds are well exposed in

Subansiri river section in Lakhimpur district and Bharali River in Darrang district.

(a) Tipam Sandstone Formation:

Tipam Sandstone consists of fairly coarse to gritty false-bedded, ferruginous sandstone interbedded with shale, sandy shale, clay and conglomerate. The sandstone is usually bluish grey to greenish giving a brownish tint on weathering.

Shrivastava et.al, (1974) have recorded from sub-surface samples of the Tipam Sandstone of Upper Assam following palynological assemblage of Mid-Miocene-Pliocene age: *Dicksoniaceasporites* sp., *Podocarpidites* sp., *Pinuspollenites* sp., *Quercoidites* sp., *Castaneapollenites* sp., *Tetracolpites* sp., *LLexpollenites* sp., *Alnipollenites* sp., *Alnipollenites* sp., *Ericipites* sp., *Sporitescirculus* sp., *Scabratriletes* sp., *Pteridacidites* sp., *Cyathidites* sp., *Graminidites* sp., *Compositoipollenites* sp., *Juglanspollenites* sp., and *Impatiensidites* sp.,

Based on the palynological studies two palyzones one of Miocene age and another of Pliocene- Plietocene age have been recognised.

Lalitha and Prakash (1979) have recorded a fossil wood *Gymnosporia* of the family *celatraceae* from the Tipam Sandstones exposed at Sultanicherra, which is about 55 km south of Hailakandi, district Cachar. The wood is important as its modern comparable species. *Gymnosporia emerginate* Roth, grows in the Eastern Ghats in dry deciduous forests and on the slopes of Nilgiris and Annamalais.

Singh and Saxena (1979) have studied a palynofloral assemblage from the Neogene sediments of Jorajan well-3, Upper Assam. The assemblage includes a new genus *Verrualets* 16 general and 23 species, besides *Assamiapollenites*.

(b) Girujan Clay Formation:

The Girujan Clay Formation consists of lacustrine mottled clay, sandy mottled clay, sandy shale and subordinate mottled, coarse to gritty, ferruginous sandstone.

Isopach maps of Baruah and Ratnam (1982) for Tipam Sandstone Formation and Girujan Clay Formation in the south eastern part of Upper Assam Valley reveal that thicknesses of these formations gradually decrease towards the north-west direction.

(L) DUPITILA GROUP :

Tipam Group is unconformably overlain by the Mio-Pliocene Dupitila Group consisting of coarse, loose and ferruginous sand, clay, mottled clay, mottled sandstone and poorly consolidated sand with layers and pockets of pebbles. These beds are well exposed at intervals, as patches over Tipam Group in Cachar and Karimganj districts, forming low mounds in valley areas.

A characteristic lithostratigraphic section is exposed in Surma valley where it attains a thickness of 3300 m and is named as Dupitila Formation. It comprises of sandstone, mottled clay, grit and conglomerate, locally with beds of coal, conglomerate and poorly consolidated sand with layers and pockets of pebbles.

In Upper Assam, Dupitila Group is represented by fluviatile Namsang Formation, which consists of coarse, gritty, poorly consolidated sandstone, mottled clay and conglomerate, which at places, is almost entirely composed of pebbles of coal derived from Barail Group. Lignitised fossil wood fragments are abundantly found in this group. Namsang Formation overlies Girujan Clay Formation with an unconformable contact at places and is well exposed in Dihing river section near Jaipur.

These rocks are devoid of diagnostic fossil fauna and flora, however, fossil wood remains are common but

are non-diagnostic. A few indeterminate leaf impressions and reworked Permian Eocene palynofossils are reported. Mathur and Evans (1964) assigned a Mio-Pliocene age to Dupitila on the basis of correlation with lithologically similar sequence in the fossiliferous Irrawady Series of Burma.

(M) DIHING GROUP:

Dupitila and Namsang Formations are succeeded by fluvial Pliocene deposit named as Dihing Group consisting of thick pebble beds alternating with coarse, soft sandstone, clay, grit and conglomerate containing half decomposed plant remains. The unconformable relationship between Dihing and underlying Namsang Formation is well exposed along Dihing river section near Jaipur in Upper Assam. Locally, at the base of the group, there are unconsolidated sands with relatively few pebbles (Dhekiajuli bed in Digboi oil field area).

In Makum coalfields, this group comprises alternating pebble beds, sandstone and clays. The sandstones are gritty to coarse grained, loose ferruginous and generally greyish in colour. Along Margherita thrust, Tipam Sandstone is seen in juxtaposition with the Dihing beds.

In Surma valley, Dupitila Formation is conformably overlain by a sequence of conglomerate, grit, sandstone and clay corresponding possibly to Dihing Group of Upper Assam. These beds, with steep dip are seen near Bishramkandi and Nagar Tea Garden.

Dihing Group is correlated with the Kimi Formation of Siwalik Group exposed in the foothill of Arunachal Himalayas. Recently, characteristic palynofossils like *Corrugatisporites terminalis*, *Polygonacidites frequens* and *Polyporina globosa* have been reported.

In the oil field area, the alluvium passes downward without any abrupt change into a sequence of soft sands with bands of clay and silt which has been named Dhekiajulis in this area. Dhekiajulis can be considered as equivalents of a thick mass of boulder conglomerates with subordinate soft sands and clays, called the Dihings, which intervene between the Namsang beds and the alluvial terraces in the Naga-Patkoi hill zone of schuppen. In this Schuppen belt, the Dihings have been strongly folded

in many places and eroded before the alluvial terraces were formed. There are small sporadic outcrop present in the area but are not mappable on 1:1000000 scale.

(N) SIWALIK GROUP :

Middle and Upper Siwalik rocks designated as Subansiri and Kimin formations are exposed in Sonitpur district of Assam, along the foot hills of Arunachal Himalaya. The Subansiri Formation is represented in the area by micaceous massive fine to medium grained pale brown sandstone while the Kimin Formation in the area comprises soft, grey sandstone with bands of claystone.

(O) QUATERNARY SEDIMENTS:

Dihing Group is unconformably overlain by Quaternary sequence which in the Upper Assam has been described variously by different workers as "Terrace Deposits", "Unstratified Drifts", "Older or High Level Alluvium" or "Red bank Soil". It consists of indurated, yellow, brown or red clay with sand, gravel and boulder deposits. These deposits do not belong to the typical fluvial Quaternary deposits of the Brahmaputra Basin and are possibly weathered derivatives of the underlying older rocks. These deposits, sometimes without much difference from underlying Dihing, cover large tracts along (i) the northern border of the state, (ii) around Digboi and Margherita, (iii) along the southern border of the state facing the Tirap district of Arunachal Pradesh and Nagaland, (iv) in parts of eastern Cachar in the Surma valley, (v) in isolated inliers around Tezpur and Behali areas in Darrang district, and (vi) along the courses of Dhansiri and Kopili Rivers respectively in Sibsagar and Nagaon districts in Assam.

A major part of the area flanking the Brahmaputra River in Lower and Upper Assam is covered by thick Quaternary fluvial sequence. These Quaternary deposits of the Brahmaputra Basin have been classified under four geomorphic units viz., Kaklung (=Chapar), Sarbhog, Hauli and Barpeta (=Recent) surfaces, each underlain by alluvial formation of the same name, ranging in age from Pleistocene to Recent. Palynological and pedological studies reveal that the Kaklung (Chapar) formation has undergone deep lateritic type of pedogenesis, under a warm

humid i.e. tropical to subtropical type climate. The Sarbhog soil is of podzolic type formed under relatively temperate conditions indicating that the time when Sarbhog sediments were deposited, both temperature and humidity had decreased effectively. Thus, these Quaternary deposits record the fluctuations in the climatic regime during the post-glacial times.

The Older Alluvium (Kaklung/Chapar formation) is exposed near the hills of the granite (Precambrian) in the southern side and as river terrace close to the Himalayan foothills in the northern side. The Younger Alluvium {Hauli & Recent (Barpeta) Formations} is exposed along the present course of Brahmaputra River.

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Structure and Tectonics

Gneissic Complex of Assam, which is in continuity with geological set up of Meghalaya, comprising the peninsular crystalline rocks, shows evidences of deformation causing intricate folding and development of deep-seated fracture lineaments trending E-W and NE-SW. These fractures may be related to first order fundamental lineaments connected with sub-crustal movements which divide this segment into a number of blocks.

The present configuration of Brahmaputra valley is the result of uplift and subsidence of different blocks of Precambrian crystalline autochthon—the remnant of which is now represented by Karbi Hills and Shillong Plateau. This mass forms a “foreland spur” (Mathur and Evans, 1964) which has been overthrust from northwest by Eastern Himalayas, from northeast by Mishmi Hills, and from southeast by Naga-Patkai range during Tertiary geotectonic cycle.

The following geotectonic provinces are identified in Northeast India:

- I. Comparatively stable shield area of the Shillong Plateau and Mikir Hills
- II. Platform area peripheral to the shield, now covering the Brahmaputra valley, North Cachar Hills and Bangladesh plains
- III. Naga-Patkai and Eastern Himalayan mobile geosyncline belt
- IV. Transitional zones between the platform and geosyncline, probably with narrow pericratonic downwraps marginal to the shield

The above geologic domains are bounded by the following major tectonic lineaments which remained active

during different stages of the tectonic cycles and have effected the area throughout geological history commencing from, cratonisation of Gneissic Complex, followed by the deposition of Shillong Group of rocks in intracratonic basins, succeeded by further sedimentation upto the Pleistocene times:

- a) The basement faults consisting of (1) E-W Dauki Fault along southern margin of the Shillong plateau extending upto Haflong in the North Cachar Hills, (2) a suspected E-W fault along the Brahmaputra valley, (3) NW-SE fault to the west of Shillong plateau, the Mikir Hills and to the east of the latter.
- b) The belt of Schuppen, a NE-SW belt of imbricate thrusts over the northern part of Naga-Patkai range.
- c) The E-W and NE-SW frontal Himalayan thrust belt.
- d) The NW-SE Mishmi Thrust along Lohit foothills over the N-E Himalayan syntaxis
- e) Probable north-easterly extension of NE-SW Calcutta-Mymensing gravity high to the south of the North Cachar Hills through Cachar district.

Subsurface geology of Upper Assam oil fields indicates that Tertiary sediments overlying the basement are gently folded into domes and anticlines with low to moderate dipping limbs affected by numerous faults with a throw ranging upto 200 m. The faults mainly trend ENE-WSW, NNE-SSW, NE-SW, NW-SE, and E-W. The Naharkatiya field is broken up by large and small criss-

cross faults giving rise to a mosaic in which individual blocks lie at different levels, at places being warped and tilted (Mathur and Evans, 1964). The Moran field is dissected by a major NW-SE reverse fault. Rudrasagar field, a gentle dome and Lakwa field, a large ENE-WSW anticline are affected by several criss-cross faults. Except Moran fault, the others affecting the oil fields are normal tensional faults.

The faulting continued intermittently throughout the sedimentation from Eocene to Pleistocene; some of the faults affected only Oligocene rocks and others extend upto the younger group of rocks. Some of the major faults marginal to the shield area are of the nature of down to basin faults along which subsidence of the basin floor occurred during the evolution of the mobile belts. The intricate pattern of faults has developed along ancient fracture lines which deformed the basement, presumably during the Precambrian times, during intrusive movements. The later movements affect the sediments laid down over the crystalline platform due to tectonic reactivation along some of these weak planes at different intervals. The fault pattern is of similar nature as visible over the shelf sediments covering the southern margin of the Garo Hills of Meghalaya. The attainment of the present configuration of the Brahmaputra basin is resultant of uplifts of the Mikir Hills and Shillong Plateau relative to the *Pari Passu* subsidence of basin floor.

Along thrust belts, the sediments are thrown up into tight folds cut-off later by faults. The data about East Himalayan thrust belts are scanty. The "belt of Schuppen" over the northern front of Naga-Patkai range consists of a series of complex overthrusts with an imbricate pattern, one thrust overlapping another. The outermost boundary thrust of the belt called Naga thrust closely follows the boundary of Quaternary valley fill of Assam for about 350 kms and with a swing continues southwestwards for another 50 km upto Haflong. The Naga thrust is, however, not a single thrust; it comprises a succession of six different thrusts (Mathur and Evans, 1964). The innermost boundary of the belt is represented by Disang thrust, which is persistent and an important thrust in the belt. The thrust system in the belt cuts off the the folded Tertiary sediments into several interlocking slices some of which

enclose the coalfields of Upper Assam and Nagaland.

The allochthonous pits of Cenozoic rocks of Schuppen belt exhibit certain distinctive features in contrast to the homotaxial rocks of Assam shelf.

- (a) There is a remarkable increase in thickness of the sediments in the Schuppen belt compared to that of Assam shelf.
- (b) The contrasting depositional style between the two tectonic domains is also reflected in the Surma Group. The Surma Group is developed as thin discontinuous unit in Upper Assam subsurface, but in the Schuppen belt, it is well exposed.
- (c) In Assam shelf, the Barail coal seams, though locally thick, are disposed as lenses. But in the Schuppen belt, the Barail coal seams are not only thick but also persistent and they are exposed in Makum, Dilli-Jeypore and Borjan coalfields.

Thus Cenozoic rocks of Schuppen belt were formed in an environment in which sedimentation went *pari passu* with continued sinking. On the contrary, on Assam platform, basement geometry, vertical movement along basement faults and a slower rate of subsidence shaped the depositional model.

The NW-SE Mishmi thrust, against which Mishmi block along the East Himalayan syntaxis is upheaved, is the youngest in the region. Against this thrust, the metamorphics of the Mishmi Hills override the younger Tertiaries and Quaternary bed (Dihing Group) of the frontal Himalayan thrust belt, Naga Patkai belt and those in the head of the Brahmaputra valley. This thrust overrides the earlier thrusts in the belt of Schuppen as well as those in the East Himalayan front.

Surma valley, the eastern part of which falls in the Cachar district of Assam, represents a region of N-S to NE-SW folding. Here, asymmetrical anticlines having their steeper flanks invariably faulted are intervened by broad symmetrical synclines. The folding of the sediments in this region was, presumably, caused by down-to-basin normal faults, during the Tertiary time but there is no overthrusting in the belt of Schuppen (Mathur and Evans, 1964).

Geological History

The Assam Shelf area flanks the Shillong-Mikir massif, with the slope of the basement both towards the north-east and southeast (Dasgupta, et.al., 1995-97). The Lower Gondwana sediments of the Talchir and the Barakar Formations (Permian) occur only in the northwestern tip of the Shillong massif. The predominance of Lower Gondwana miospores in the younger Tertiary sediments documents larger spread of the Gondwana basin on the cratonic area than those exposed now. South of Shillong, basic volcanic flows of the Sylhet Trap overlies the basement, which continues in depth in the Garo Hills to the northeast. Fission track dating of apatite of alkaline ultramafic carbonatite complex (105 Ma) from central Mikir Hills suggests possible contemporaneous mantle activity. The Sylhet volcanics floor the Upper Cretaceous or younger sediments, which occur as embayments over the southern flank of the Shillong-Mikir shelf. Upper Cretaceous sediments are usually absent in the Upper Assam shelf but embayments of these sediments occur in a local fault bounded basin around Jorhat (Murthy, 1983).

The Cenozoic sedimentation on the Assam-Shillong shelf begins with the deposition of the Jaintia Group of

Paleocene-Eocene age which has a large spread in the Upper Assam sub-surface and in the Mikir Hills. From bottom to upwards it is mainly made up of basal arkose, blanket limestone and black shale association of stable to slightly unstable shelf and littoral to sub-littoral environment (Murthy, 1983). The deposition of the Eocene sequence on the platform, under shallow marine to lagoonal environments, was primarily controlled by vertical movements along basement faults (Dasgupta, et.al., 1995-97). The Oligocene in Assam Shelf is represented by 600-1000m thick sediments. The Barail Group displays a lower sandstone-dominated unit and an upper argillaceous facies. The basinal areas during the deposition of the Barail intermittently witnessed shallow marine, lagoonal and deltaic and estuarine environment (Murthy, 1983).

Succeeding the deposition of the Barail sequence, the shelf area experienced uplift and erosion and the Surma Group shows rapid thinning towards the northern part of the shelf and elsewhere merges imperceptively with the overlying Tipam sediments (Miocene). The Tipam and the Namsang Beds (Mio-Pliocene) were deposited after a prominent break in fluvial milieu (Murthy, 1983).



Development of Village Economy Through Mineral Appraisal Programme (DOVEMAP)

(V) DEVELOPMENT OF VILLAGE ECONOMY THROUGH MINERAL APPRAISAL PROGRAMME (DOVEMAP):

Keeping in view the rapid urbanization and industrial growth in the north eastern region particularly in the Brahmaputra and Barak basins in Assam, it was envisaged that there would be an increasing demand for building and construction material which would be met by small scale rural entrepreneurs. The exploitation and utilizations of these resources being highly labour intensive would generate employment opportunities for the weaker sections of the rural society. With this objective, the DOVEMAP studies in Assam for development of village economy through mineral appraisal Programme was initiated during F.S.1996-97 by the GSI, NER in order to empower the rural folk and to impart basic scientific knowledge regarding land, mineral and water resources and environment. In this era of Panchayat Raj system, where the basic development work in rural sector needs a great impetus at the village panchayat and block level, the programme envisaged at generating rural employment and arrest migration towards the urban areas.

In F.S.1996-97, initiation of the Project DOVEMAP, for covering ten villages in Kamrup, Nagaon, Darrang and Jorhat districts was launched on cadastral map base scale on (16²= 1 mile scale). All the villages covered under this programme lie in Quaternary terrain. In Kamrup district, the basement rocks are encountered at variable depth below the Quaternary sediments. In the course of the survey, natural resources of clay bands suitable for pottery and brick-making, sand and hard rock boulders suitable as building material were located. Water table conditions, landuse pattern and geoenvironmental hazards

were mapped and identified. Suitable measures to overcome the hazards were suggested.

Subsequently during F.S.1997-98, (DOVEMAP) was extended to seven more districts of Assam on the cadastral map base, where in 140 villages were covered in Tinsukia, Jorhat, Golaghat, Morigaron, Goalpara, Sonitpur and Kamrup districts.

Thereafter in F.S.1998-99, a total of 90 villages in four districts of Assam namely Jorhat, Nagaon, Marigaon and Sibsagar were studied in detail. Three sets of thematic maps viz. geological and geomorphological, soil and landuse maps apart from natural resources and hazard maps were prepared. Shallow drilling for collecting various samples were carried out to gather subsurface data.

During the field season 1999-2000, a total of 160 villages in seven districts of Assam namely Goalpara, Jorhat, Nagaon, Kamrup, Tinsukia, Cachar and Marigaon were covered.

During the F.S. 2000-2001, a total of 171 villages in seven districts of Assam namely Cachar, Dibrugarh, Goalpara, Golaghat, Kamrup, Nagaon and Tinsukia were studied. Some of the water and soil samples were tested in the field with portable water testing kit. Shallow drilling was carried out in three districts to study and collect subsurface data, where a total of 447.45 m drilling has been carried out.

Lastly, during the F.S. 2001-2002, a total of 70 villages in four districts, viz., Dibrugarh, Golaghat, Sonitpur and Karimganj were covered to study geology, geomorphology, landuse soil, natural resources underground water and geoenvironmental appraisal.

Mineral Resources

The Precambrian Gneissic Complex of Assam like its counter parts in other States of India should have been a potential site for major economic minerals, particularly metallic ores. Unfortunately, no major deposit has been located in this terrain so far, although minor occurrences of base metal sulphides are reported from different localities. The Precambrian terrains of Assam merit detailed systematic research for economic mineral deposits.

The other major rock group in Assam includes the Tertiary sediments. These are rich storehouse of quite a few economic mineral deposits like oil, coal, limestone and clay. Besides, several minerals of little or yet unknown economic importance are reported to occur in different parts of Assam and are dealt below.

(i) OIL AND NATURAL GAS :

Hydrocarbon indications have been encountered in the Eocene rocks (i.e. Disang) in Chantongia (Naga-Patkoi Hills), where a large seepage of oil has been known for many years. In the shelf zone, oil was discovered just above the basement at Borholla and gas in Eocene sand near Tengakhat.

The upper part of Barails contains the largest amount of oil discovered in this region so far. The oil occurs primarily in sandstone bands in the upper shale-coal sequence, and in the upper most part of the thick sandy group that lies immediately below the shale-coal sequence. Most of the sandstone bands in the upper shale-coal sequence are channel sands. The occurrences of petroleum in these are controlled by the configuration of channels and bars as well as by the regional structural setting and numerous faults. Barail oil is closely associated with coal, which is low in ash & high in sulphur. This coal can be

easily liquefied with the application of temperature and pressure. While the associated coal is rich in sulphur, the oil is almost free from it and so both need not be genetically associated. Possibly the oil could have migrated from other area and accumulated in Barail sandstones with coal seams.

Next to the Barails, the Tipams have so far proved to be another important oil productive horizons and sizeable accumulations exist in a number of structures close to the Naga-Patkoi hills. The Tipam Sandstones are good reservoir rocks for petroleum accumulation and the Girujan Clays could be good cap rocks.

In all these petroleum occurrences there is an overall pattern of having hydrocarbons in younger horizons close to the main Naga-Patkoi mountains. The older formations have progressively more hydrocarbons towards north-west.

(ii) COAL :

The coal occurrences in Assam are reported from two geological horizons viz., Gondwana and Tertiary of which Tertiary coal deposits of Makum, Mikir Hills and Dilli-Jeypore are the most important coalfields.

The Gondwana coal deposits in the westernmost part of Garo Hills of Meghalaya is extending into the Hallidayganj area, Dhubri district of Assam and is known as the Singrimari Coal deposits with a total resources of 2.79 million tonnes of non-coking coal including the Meghalaya part of the coal deposits

The Tertiary coal deposits of Assam are the major coal resource of the state. The coal deposits of Tertiary are reported from rocks of Eocene as well as of Oligocene

age. Coal deposits of Eocene are known from Mikir Hills area where as Makum and Dilli-Jeypore coalfields belong to Oligocene age. The Makum Coalfield of Assam is the most important in the entire North-Eastern India so far as the resource of coal and the infrastructural facilities are concerned.

The coal deposits in Mikir Hills occur within Sylhet Formation of Jaintia Group and are located in the southern part of Mikir Hills and to the north of the railway line between Lumding and Dimapur. Coal exposures are located from Koilajan, Selvetta area, Khunbaman Range, Khota Arda, Garampani, Dithor Dishai *nala* and minor occurrences at a few places along Diphu *nala*, Nambar River and Daigurung River, Tisomgaon, Longlai, Lungi, Lataang Umrangshu, Dehangi, Khorangora and Hamagisim areas. All the soil occurrences in hilly terrain and some of the occurrences are reachable only through foot tracks. Of the above occurrences the Koilajan deposits are worth mentioning with seam thickness varying from 1.3 to 2.2 m. Three coal seams are reported from

Sylvetta with thickness varying from 0.35 m (top) to 1.28 m (bottom). The Mikir Hills coal are characterised by high moisture (6.7 to 9.3%), medium ash (18.8 to 26.3%) and high sulphur (3.08 to 6.35%). Out of a total of 3.71 million tonnes of coal 1.19 m.t (proved + inferred) and 2.52 m.t. under Inferred category has been assessed through drilling and mapping respectively..

The Makum coalfield lies along the outermost flank of the Patkoi range between the latitudes 27°15' and 27°25' North and longitudes 95°40' and 95°55' East and is well connected by roads and railway with the rest of the country. The coal seams are confined mainly within the basal part of Tikak Parbat Formation and also a few thin coal seams within the Baragolai Formation of Barail Group. Coal seams of Tikak Parbat Formation are fairly thick where as those of Baragolai Formation are varying in thickness from 0.5 to 0.8 m only. Five regionally persistent coal seams were reported from the Makum Coalfield confined within the basal 200 m section of the Tikak Formation. The generalised sequence of the coal bearing deposits as follows:

Seam Name	Thickness (in m)
'8ft Seam' Parting	2.4 30 to 40
'5ft Seam' Parting	1.2 to 1.8 3 to 18
'20 ft Seam' Parting	6 to 7 38 to 68
'New Seam' Parting	1.5 to 2.6 5 to 20
'60 ft Seam'	15 to 33

All the coal seams are interbanded with dirt bands. The coal seams are exposed at several places between the Namdang colliery in the west and the Tipang colliery in the east and are being mined at several collieries in between. The coal from the Makum Coalfield is of good quality with generally low to very low ash (1.9 to 5.9%), low moisture (1.9 to 3.9%) and high C.I. (17-24 B.S.S). Sulphur content is fairly high and lies between 1.53 and 5.43%. A total resource of 1327.00 million tonnes has been assessed for the Makum Coalfield up to 600m depth.

Dilli-Jeypore Coalfield is the second most important coalfield of the northeastern region. The coal bearing Titak Parbat Formation of this coalfield extends continuously over a length of 33 km from Bimalpur Tea Garden in the southwest to Dhekiajuli in the northeast with an average width of 300 to 600 m. The coalfield is bounded by latitudes 27°04' N and 27°12' N and longitudes 95°15'

E and 95°29'E. Two coal bearing horizons separated by barren arenaceous zone, 60 to 125 m thick have been established in this coalfield. The lower coal horizon is exposed along the Disang River whereas the upper one was intersected in the boreholes drilled in this coal field. The lower coal horizon, which is 70 to 90 m thick, contains three coal seams whereas the upper one with 100 to 113 m thickness contain eight coal seams. All the coal seams in the Dilli-Jeypore coalfield are generally thin, impersistent and show number of splits with thickness varying from < 1 to 7.5 m. The basal seam is the thickest one with > 20 m thickness. The coals have moisture content of 2 to 8.3 % and ash content of 3 to 19.8%, which occasionally goes up to 37.6%. The total sulphur content varies from 1.3 to 13.5 % and the coal is non coking. A total resource of 54.02 million tonnes has been assessed for the Dilli-Jeypore coalfield up to 300 m depth.

GEOLOGICAL RESOURCE OF COAL OF ASSAM COAL FIELDS (as on 01.04.2009)

(Resource is million tonne)

Type of coal	Depth	Proved	Indicated	Inferred Exploration)	Inferred (Mapping)	Total
1	2	3	4	5	6	7
ASSAM						
1. SINGRAIMARI COAL FIELD						
Non Coking	0-300	0.00	2.79	0.00		2.79
Total Non Coking		0.00	2.79	0.00		2.79
TOTAL FOR SINGRIMARI		0.00	2.79	0.00		2.79
2. MAKUM COALFIELD						
High Sulphur	0-300	172.37	0.00	0.00		172.37
	300-600	143.59	11.04			154.63
Total High Sulphur		315.96	11.04	0.00		327.00
TOTAL FOR MAKUM		315.96	11.04	0.00		327.00
3. DILLI-JEYPORE COALFIELD						
High Sulphur	0-300	32.00	22.02			54.02
Total High Sulphur		32.00	22.02			54.02
TOTAL FOR DILLI-JEYPORE		32.00	22.02			54.02
4. MIKIR HILLS COALFIELD						
High Sulphur	0-300	0.69	0.00	0.50	2.52	3.71
Total High Sulphur		0.69	0.00	0.50	2.52	3.71
TOTAL FOR MIKIR HILLS		0.69	0.00	0.50	2.52	3.71
TOTAL FOR ASSAM		348.65	35.85	0.50	2.52	387.52

(iii) LIMESTONE:

Thick deposits of limestone, belonging to Shella Formation of Jaintia Group extend more or less as continuous belt along the southern base of Meghalaya Plateau. The richest development of the belt is between Jadukata River in the west and Lubha River in the east where the belt comprises three prominent bands viz, Lower, Middle and Upper Sylhet Limestone Members with intervening Middle and Upper Sylhet Sandstone Members. At Khaddum on the Lubha, the belt abruptly swings towards north and extends north-wards with the immediate dying out of Lower and Middle limestone bands. Between Umte and Nonghlieh on the eastern Jaintia Hills, only a single band of limestone conforming to Upper Sylhet limestone is developed.

The Upper Sylhet Limestone seen in Nonghlieh area continues north-eastwards as a single, 80 to 90 m thick band across Kopili River into the Garampani area in North Cachar Hills. Promising deposits are located near Lobang, Longkingdong, Larphing and Baralarphing; these deposits are confined within a zone covering 6.5 km in length and about 2.5 km in average width. The limestone here is generally siliceous with CaO between 40 and 50%, MgO less than 2.5% and insolubles between 5 and 15%. Workable deposits in this area are in between 3.5 and 6.5 km posts along Garampani road exposing a 60 m thick horizon of limestone extending along a ridge on the western side of the Umrang valley. Inferred reserves of limestone are about 900 million tonnes. GSI examined a part of this deposits covering 1.8 sq km block which contains a 20 m thick bottom horizon with 43 million tonnes of cement grade limestone, a 20 m thick middle zone with 30 million tonnes of blending quality and a 20-30 m thick top zone having high R_2O_3 . Detailed exploration for cement grade limestone by DGM, Assam, at Timbung established a total reserve of 4.6 million tone, of which only 1.5 million tones were found fit for economic exploitation. The composition of limestone is analysed CaO 46.64 to 48.37%, MgO 2.08 to 2.92%, Fe_2O_3 1.09 to 3.53%, Al_2O_3 1.01 to 2.51% and acid insolubles 3.49 to 10.01%. However, the quality of limestone varies both laterally as well as vertically.

Directorate of Geology and Mining (DGM) Assam has investigated a few more deposit around Churanganshu and Garampani Cement Factory area in North Cachar Hills district. At Tassimur, a deposit with a total reserve of 3.2 million tonnes of high R_2O_3 has been located. Near 4 km post on the Garampani-Lauka road, a deposit with 26 million tonnes of cement grade limestone has been located. This deposit being near reservoir of Kopili Hydel project may not be available for exploitation for safety of the reservoir. Another deposit located near Churanganshu at 11 km post on Garampani-Lauka road accounts for 6.4 million tonnes of cement grade limestone.

Recently, the Directorate of Geology and Mining, Assam has located another deposit at Churanganshu near the 16 km post on Garampani-Lauka road. The limestone is about 80 m thick. The bottom part of the deposit accounts for a reserve of 26.7 million tonnes and is found to be cement grade. The upper horizon accounting for 9.3 million tonnes is high in R_2O_3 .

An indicated reserve of 105.6 million tonnes of limestone has also been reported from an exposure in North Cachar Hills around Langkri *nala* beyond 21 Km post on Garampani-Lauka road. The grade and workability of this limestone are to be ascertained. Preliminary investigation for cement grade limestone at Boralokhinder and ($92^{\circ}37'4''$: $92^{\circ}38'17''$) in North Cachar Hills district was carried by DGM, Assam Govt and inferred a reserve of 12.35 million tons with the following analytical values: CaO: 37.82 to 51.03%, MgO: 0.40 to 2.70%, Fe_2O_3 : 1.99 to 5.98%, Al_2O_3 : 0.21 to 8.62%, SiO_2 : 2.56 to 8.14%

A few scattered occurrences are also found in the Karbi Hills. The Selvetta-Meyongdisa area (between $25^{\circ}54'$: $26^{\circ}06'$ and $93^{\circ}10'$: $93^{\circ}41'$) exposes 15 to 60 m thick band within an area of 5 sq. km along the Jamuna valley. This limestone is ferruginous and may be suitable only for manufacture of "Ferroportland Cement". Analysis shows Fe_2O_3 8.38%, CaO 42.38 to 51.9% and MgO 1.42%. The total reserve of cement grade limestone in this area is estimated around 2 million tones. Similar occurrences have been found in Chopping and Lengloi hill areas about 19 kms north of Lumding.

The largest deposit of limestone in Mikir Hills is found in Koilajon area near Dilai. This deposit extends over an area of 12 sq km, and has 5 different limestone bands (with 47.2% CaO and 1.3% MgO) and is suitable for cement manufacture. Inferred reserve for this limestone band is about 31 million tonnes. Directorate of Geology and Mining, Assam and Indian Bureau of Mines, investigated Koilajon deposit in 1962 and estimated a reserve of 30 million tonnes of cement grade limestone.

Several occurrences of nodular earthy limestone have been reported from the Saini Lango, Harihajang and Dilai *na'as* near Bor Harihajan and these analyse 38-44% CaO, 0.7 to 1.7 % MgO, 0.9 to 5% Al_2O_3 , 3 to 6% Fe_2O_3 and 4 to 8% SiO_2 . Saini Lango deposit has reserve of 0.626 million tonnes and is being used by Bokajan Cement factory of Cement Corporation of India.

The total inferred reserve of limestone from Mikir Hills is about 154 million tons.

(iv) BASE METAL :

Occurrences of base metal sulphide minerals are reported from Gneissic Complex of Mahamaya Pancharatna and Agia areas and Deolina and Khardong Hills in Goalpara district. The occurrences are yet to be investigated in detail. Geochemical analysis of rock and soil samples collected from Pancharatna have not yielded encouraging result. Elsewhere, rock chips and soil samples show presence of Cu up to 700 ppm and Zn up to 1500 ppm at isolated places.

In Karbi Hills, occurrences of sulphide minerals (pyrite and calcopyrite) have been noticed in basic rocks (epidiorite and amphibolite) and also in quartz veins traversing basic rocks around Borjuri. Occasional sulphide minerals have been reported from suspected ultrabasic diatreme in Luhajuri–Bajajuri–Tarapung areas. Minor disseminations of chalcopyrite are noticed in basic rocks around Silijuri.

(v) BERYL:

Occurrences of beryl have been reported from some of the pegmatite veins in gneissic rocks in Naga-Largo-Mukjap area of the northeastern parts of Karbi Hills.

However, no economically important deposit so far has been located. Minor occurrences of beryl have also been reported from a few places of Goalpara district.

(vi) BUILDING STONE:

Granite and granite gneisses occurring along the northern hills of the Shillong Plateau in Goalpara, Kamrup and Nagaon districts are being quarried for use as building stone and road metals. The quarry near Jagi road is well known. A number of similar quarries are seen at several places near Guwahati by the side of National Highway 31 and 37.

The pink and grey granite found in parts of Karbi Hills and Goalpara and Dhubri districts are suitable for production of decorative stones.

Directorate of Geology and Mining, Assam carried out preliminary investigation in Agiyathuri, Digheswari hill ranges (near Guwahati) and identified three blocks for extracting pink granite and grey granite as decorative stones. DGM, Assam also carried out detailed investigation for pink granite in Center bazaar and Mahamaya hills near Dokinoka in Karbi Anglong district and identified promising blocks for extraction of stones for polishing purpose.

Buragohain (1994-95) carried out detailed survey for dimension stones in Bura Parbat area of Nagaon and Karbi Anglong districts. Granite outcrops suitable for polishing industry were identified at Seconee (9, 11,250 tonnes) and in Hatigaon area (81, 00,000 tonnes).

The rock boulders carried down by rivers from Himalaya on the north bank are being used as road metals as well as for flood control measures, such as preventing bank erosion.

Basaltic rocks found in Mikir Hills, especially near Koliajan area, the Jamuna, Hariajan and the Deopani River beds and near the Namber falls are suitable for use as road metal and as aggregate in concrete.

In Upper Assam, hard and massive sandstone underlying the coal measures are found abundantly in headwaters of the Namdang, Ledo and the Likha streams, the Tipang and Tirap Rivers. Laterite, ferruginous conglomerate

erate, compact hard calcareous and ferruginous sandstone of the Surma Group in Cachar district are also used locally for building purpose and road metals.

(vii) CLAY

- (a) **Pottery clay** : Plastic clays derived from the weathered and decomposed gneisses rich in feldspar are locally used for making earthenware and bricks in different parts of Kamrup districts. Alluvial plastic clay, often highly plastic is ubiquitous in alluvial tracts of Assam. Locally this clay is used for manufacture of bricks and tiles. The well known brick industry of Margherita belonging to A.R.T. Company and another at Jalukbari are using this alluvial clay. Grey, plastic clay, occurring as pockets within Bokabil Formation in Cachar districts are locally used for color washing the houses.
- (b) **Fire clay** : Fire clay commonly occurs in association with coal seams of Upper Assam. Several thin fire clay bands containing small amounts of impurities are found with seams in Makum and Jaipur coalfields. These might be suitable for manufacture of firebricks after proper beneficiation and blending. A 3 m to 5 m band of fire clay occurs below coal outcrops at Koilajan in Mikir Hills. Inferred reserve of this deposit is about 2 million tons.

Another 1.5 m thick band of white clay is found associated with coal seams at Selvetta area containing an inferred reserve of about 55,000 tones. In Namdang-Ledo area, fireclay bands are found below the coal seams that belong to the Barail Group. The inferred reserve of fireclay around Namdang is estimated to be 47,115 tons.

(c) Kaolin (China clay):

Kaolin is reported from Dora River in Lakhimpur district. Recently, kaolin has been found as an altered product of feldspar in granites of Selvetta area. The washed product gives about 35% of raw material. Directorate of Geology and Mining, Assam has calculated a reserve of 58,390 tons of crude clay based on recent borehole data.

Kaolin of grade II (I.S.) has been located by Directorate of Geology and Mining, Assam in Upper Deopani area. The Kaolin deposit covers an area of 0.043075 sq. km and the reserve of crude kaolin is estimated at 260252 tons. Considering the recovery of clay at 28%, the actual clay content of the deposit is 74170 tons. The overburden of Kaolin deposit ranges from 0.00 to 18.40m, the average thickness is 6.62 m. This Kaolin is found to be suitable for ceramic industries, where firing color is not important.

DGM, Assam also carried out investigation for Kaolin in Tengralangso and Kukibasti areas, Karbi Anglong district. But this deposit is in the form of two small pockets and the inferred reserve is only 331 tonnes.

Several other minor occurrences of clay are reported from Khunbamon, Takhi and along the Dimapur-Dabaka road between 37th and 38th milestones. Fine white clay has been reported from Namber River and from Barpathar in Sibsagar district.

- (d) **Fullers' Earth**: An occurrence of inferior quality fuller's earth has been reported from north of Bhutan Khuti, north of Suban Khata on left bank of Pagladiya River in northern part of Kamrup district. The inferred reserve is 13 million tons. The deposit is of inferior grade.
- (e) **Oil well drilling clay**: Large deposits of black alluvial clay are located near Mathurapur along Sibsagar-Nahorkatiya road in Sibsagar district. Black clay is also found within Dihing Group and Older Alluvium in several parts of Dibrugarh district. These clays are being used by O.N.G.C. and Oil India Limited as oil well drilling clays.

(viii) FELDSPAR:

Feldspar occurs in pegmatites in Precambrian massif in Karbi and North Cachar Hills, Goalpara and Kamrup districts. Pegmatite veins containing feldspar occur in biotite gneiss near Pancharatna in Goalpara district, where veins upto 40 meters thick have been reported.

Occurrences of feldspar are recorded from Gowardhan

Hill, west of Suarmari (25°49':90°30") and also from many places in pegmatite veins traversing Archaean rocks in Goalpara district. The DGM, Assam estimated an inferred reserve of 2200 million tons of feldspar in pegmatite which is located at Hahime in Kamrup district.

(ix) GOLD:

Although occurrences of native placer gold have been recorded from a few places in rivers of Upper Assam, of which the Subansiri river bed was the best gold producing area in Assam in older days. Small grains of native gold were won by panning alluvial sand. In view of insignificant quantity of gold commercial exploitation of gold, is not possible. The placers presumably have been derived from auriferous quartz veins in the metamorphic rocks of north-eastern Himalayas.

(x) GYPSUM:

Minor occurrences of gypsum within shales have been reported from Badarpur and Mahur in North Cachar Hills district.

Selenite crystals in clays are seen in Mayoung Disa area in Karbi Hills. The occurrence has no economic significance.

(xi) IRON:

Iron ore associated with ferruginous quartzite are found near Chandradinga Hill, Chakrasila range and Malai Hills in Goalpara district. The ore minerals include mainly magnetite, hematite and goethite. The iron content varies from 23 to 50%. The estimated reserves are 12 million tonnes in Chandradinga Hill, 2.2 million tonnes in Malai Hill, and 0.64 million tonnes in Chakrasila range. Occurrences of iron ore are also reported from adjoining Lengupara and Kumri Hills in Goalpara district. The Directorate of Geology and Mining, Assam has inferred a total reserve of 7 million tonnes and 1 million tonnes in Lengupara and Kumri Hills respectively.

A few bands of banded hematite-quartzite are located near Ranighat for an extent of about 1500 m. The occurrences are, however, in nature of scattered fragmentary masses supporting no promising deposit. The existence of old excavations for iron ore is mentioned near

Jaipur in North Lakhimpur district.

Ferruginous sandstone passing laterally into hematite and hematitic conglomerate was observed by Smith (1898) in Karbi Hills in large quantity but the hematite is seldom sufficiently concentrated to provide workable ore.

Iron ore occurrences have been reported from Malegarh and adjacent Lengupara and Kummi hills in the Goalpara district.

(xii) MICA

- a) **Muscovite** : Several thin veins of pegmatite containing small books (10 cms x 7 cms) of muscovite along with feldspar, tourmaline and smoky quartz occur in Naga Langso and Mukjam Hills areas along Kaliani River, Mikir Hills. No undeformed size mica book has so far been located.

The reported occurrence of mica in pegmatites, west of Abhayapuri, Goalpara district, is not of any economic value.

- b) **Lithium Mica**: An unusual lepidolite rock comprising almost entirely flakes of lepidolite mica is found in association with pegmatite veins in biotite-gneiss and pyroxenites occurring on the northern tip of Dhir Bil in Goalpara district; one specimen analysed 3.8% Li₂O. Large blocks and boulders of lepidolite rock lie scattered on a 120 m long and 30 m wide zone following more or less the foliation trend of the gneiss. About 260 tons of such rock will be available from the surface boulders. The reserve will be more, provided veins of lepidolite rock could be traced at depth by deep trenching or by drilling.

(xiii) HOT SPRINGS

- a) **Garampani**: On the right bank of Kopili River there are three sulphurous hot springs. The springs lie on faulted contact between Lower Sandstone Member and overlying Sylhet Limestone Member of Shella Formation belonging to Jaintia Group. The water of the springs belongs to Na-HCO₃-SO₄ type and the temperature, pH and discharge values are 47.4°C to 55°C, 7.4 to 8.2 and 65 liters per minute respectively.

- b) Nambar: A hot spring is located near the bridge on Golaghat-Dimapur road, 18 kms south of Golaghat town. The water has sulphurous smell, a temperature of about 35°C and a discharge of about 35 liters per minute.
- c) Lumding: A warm spring with salt and sulphur is reported from Kopili shales and sandstone (Upper Eocene) exposed along the Samkhujan stream. No detailed information is available about this spring.
- d) Luhajuri-Bajajuri-Tarapung *nala* sections, Central Mihar Hills: A few warm springs having a N-S alignment has been reported from these *nala* sections. These probably denote a fault zone through Precambrian granitic terrain.

(xiv) PYRITE

Along southern border of Goalpara district, sparse disseminations of pyrite in quartzo-feldspathic gneiss, hardly exceeding 35 percent even in the richest portion is traced for about 1.6 kms along crest of Gowardhan Hill, west of Suramari.

Pyrite shales are associated with coal seams of Malaum and Jaipur Coalfields in Upper Assam, but it is doubtful whether they contain a sufficiently high proportion of the sulphide to be profitably worked as a source of sulphur.

Small pyritiferous lenses have recently been reported by D.G.M., Assam, from the gneisses of Purana Mengoan area of Karbi Anglong district. A tentative reserve of 1413 tons has been estimated. Massive and nodular pyrite of little economic importance was seen in localities south-east of Dereng Parbat.

(xv) RADIOACTIVE MINERALS

The radioactive ultrabasic diatreme located in Luhajuri-Bajajuri-Tarapung area of central Mihar Hills is expected to yield besides uranium, some quantities of niobium, cerium and other related minerals. In Bargaon, Donkamokam and Teragaon (Karbi-Anglong district) radioactivity due to thorium and uranium has been noticed in pink porphyritic biotite granite.

Carbonatite samples from Khumbaman Parbat yielded 1000 ppm – 1500 ppm Nb and high concentration of Zr and Sr. In Sylvetta-Keolari area (Karbi-Anglong district), whitish clay bands within granites and also overlying Tertiary sediments show low order radioactivity.

Indications of radioactivity to the extent of 3 to 4 times background value on G.M. counter have been noted on a quartz vein body located SW of Pancharatna. In Dillai area (Karbi Anglong district) laterites exposed in bed of Kailajan River show radioactivity due to thorium.

(xvi) SALT

Brine springs occur in Cachar district at several places and salt was formerly being prepared in north-western corner of Hailakandi valley. Salt was also being made near Sadiya and Jorhat in early days. Other local sources of salt of Assam require further detailed investigation.

(xvii) SILLIMANITE

Significant concentration (10% to 15% of the bulk) of sillimanite has recently been reported from sillimanite bearing schist of Bamuni area of Nagaon district. Biotite being the major associated mineral, economic values of sillimanite is doubtful. Occurrences of sillimanite bearing rocks and massive sillimanite have been reported from gneissic rocks at Ingti Goan, Chippilangso and Samelangso areas of Karbi Anglong district. Directorate of Geology and Mining, Assam carried out investigation at Chippilangso and delineated three deposits of sillimanite. The Al_2O_3 content of the sillimanite ranges from 58.90 to 59.80% and was considered to be useful for refractory bricks manufacturing. Other occurrences of sillimanite in the form of sillimanite schist, quartz-sillimanite-schist are recorded from Upper Chibabu, Chailangso and Antreng areas of Karbi Anglong district. The concentration of sillimanite in rock varies from 10 to 100%. A total reserve of 50 million tonnes has been tentatively estimated. The sillimanite is reported to be of good quality, suitable for refractory industry.

LOCALITY INDEX

Locality	Latitude (N)	Longitude (E)
Abhayapuri	26°20'00"	90°00'40"
Antreng	25°26' 00"	92°35' 00"
Badarpur	25°30'30"	92°38'30"
Bamuni	26°13'10"	92°49'30"
Baralarphing	25°30' 00"	92°46' 00"
Barpathar	26°18'00"	95°52'30"
Bishramkandi	24°44' 00"	92°59' 00"
Bilasipara	26°15'20"	90°38'00"
Boralokhinder	25°26'54"	25°28'30"
Bor Harihajan	26°04' 00"	93°49' 00"
Borjuri	26°24'40"	92°51'00"
Chandardinga	26°23'50"	90°16'30"
Chibabu	26°10' 00"	93°10' 00"
Chailangso	26°19' 00"	93°46' 00"
Chippilangso	26°11' 00"	93°12' 00"
Churanganshu	25°31'15"	92°43'20"
Deopani	26°13'45"	93°47'35"
Dereng Parbat	26°10'30"	93°17'30"
Dhir Bil	26°16' 00"	90°23' 00"
Digboi	27°22' 00"	95°37' 00"
Dilai	26°00' 00"	93°35' 00"
Dilli-Jaipur	27°16' 00"	95°25' 00"
Garampani	25°32' 00"	92°38' 00"
Hailakandi	24°40'00"	92°33'00"
Haflong	25°10' 00"	93°01' 00"

Hahime	25°58'30"	91°31'30"
Hazihaja	26°05' 00"	93°38' 00"
Ingti Goan	26°10' 00"	93°16' 00"
Jaipur	27°16' 00"	95°25' 00"
Jalukbari	26°10'00"	91°45'30"
Jorhat	26°38'00"	94°11'30"
Kanchanpur	24°47' 00"	92°44' 00"
Karimganj	24°52' 00"	92°23' 00"
Khaddum	25°09' 00"	92°27' 00"
Kharungma	25°26' 00"	92°45' 00"
Khumbaman Parbat	26°07' 00"	93°29' 00"
Koilajan	26°00'00"	90°34'00"
Kumri Hills	26°16' 00"	90°32' 00"
Langting	25°26' 00"	90°23' 00"
Larphing	25°30' 00"	92°41' 00"
Lauka	25°56'00"	92°57'00"
Ledo	27°18' 00"	95°52' 00"
Lengupara	26°34' 00"	90°28' 00"
Lobang	25°26' 00"	92°40' 00"
Longkingdong	25°29' 00"	92°37' 00"
Lumding	25°46'00"	90°08' 00"
Mahamaya Pancharatna	26°12' 00"	90°35' 00"
Mahur	25°11' 00"	93°07' 00"
Makum	27°27' 00"	95°27' 00"
Malai Hills	26°17' 00"	90°39' 00"
Malegarh	26°15'20"	90°38'00"
Matikhola Parbat	26°12'35"	93°24'10"

Mathurapur	26°57' 00"	94°52' 00"
Mukjam Hills	26°25' 00"	93°43' 00"
Nagar Tea Garden	24°57' 00"	92°53' 00"
Naga Langso	26°25' 45"	93°44' 31"
Nambar	26°20' 00"	93°50' 00"
Namdang	26°59' 00"	94°38' 00"
Nonghlieh	26°20' 00"	92°32' 00"
Pancharatna	26°12' 00"	90°35' 00"
Ranighat	25°50' 00"	91°10' 30"
Sadiya	27°51' 00"	93°38' 00"
Samelangso	26°17' 00"	93°12' 00"
Samchampi	26°12' 00"	93°23' 00"
Samkhijan	25°48' 00"	93°09' 00"
Selvetta	26°00' 00"	93°18' 00"
Siliguri	26°37' 00"	93°30' 00"
Singrimari	25°44' 00"	39°54' 00"
Suban Khata	26°50' 48"	91°25' 00"
Suramari	25°49' 00"	90°30' 00"
Timbung	25°28' 45"	92°35' 35"
Tassimur	25°44' 15"	92°49' 45"
Umrang valley	25°26' 00"	92°40' 00"
Umte	25°17' 33"	92°30' 47"

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REFERENCES

- Acharya, S.K. and Ghosh, S.K. (1968b):** Geology and Coal resources of Siju Coalfield (eastern part) Garo Hills District, Assam. *Rep. F.S. 1967 - 68.*
- Acharya, S.K. and Sastry, M.V.A. (1976):** Stratigraphy of Eastern Himalaya. *Him. Geol. Sem. 1976, New Delhi. Geol. Surv. of India, Misc. Pub. 41, pt. 1, pp 49-66.*
- Acharyya, S. K and Ghosh, S. c. (1966-67) :** Geology and coal resources of the eastern part of the Siju Coalfield, Garo Hills, Assam. *Geol. Surv. Rep. (Unpub).*
- Allen, B.C., (1905-1906):** *Assam District Gazetteers.*
- Anon, 1986 :** *G.S.I. News (CHQ) 17 (2): 17*
- Anon. (1957 to 1970: Reports of the Regional Coal Survey Station 1957 to 1970, C.F.R.I., Jorhat.**
- Anon. (1964):** *Mineral development in Assam Directorate of Geology and Mining, Govt. Of Assam (Symposium volume).*
- Anon. (1966):** *Industrial Programme for the Fourth plan for Assam. National Council for Applied Economic Research, New Delhi.*
- Anon. (1966):** *Project report "CEMENT". N.I.D.C., New Delhi.*
- Anon. (1968-1969):** Material for NEFA circle, *GSI, Annual General Report.*
- Anon. (1969-70):** Mineral resources of NEFA, *Indian Minerals, Vol. 25, No. 2.*
- Anon. (1971):** Mineral Resource of North East Frontier Agency. *Ind., Min. 25, 1971, 101-118.*
- Anon. (1974) :** Director General, GSI, Address on Geology and Mineral resources of the states of India, *Part IV, GSI Misc. Pub. No. 30, p30.*
- Anon. (1974):** Geology and Mineral resources of the states of India. *GSI Misc. Pub. 30 part IV. 124p.*
- Anon. (1978):** Exploration for Uranium and other atomic minerals in North East Region - *Progress Rep. 1978. Atomic Minerals Division, Northeastern Region, Shillong.*
- Anon. (1980):** *Indian Minerals Year Book, 1976 and 1977. Indian Bureau of Mines, Nagpur*
- Arogyaswami, R.N.P. and Desikachar, S.V. (1954):** Economics-Kaolin, glass making sands iron-ore, petroleum etc. *Rep. F.S. 1953 - 54.*
- Awasthi, (1966):** In a catalogue of Indian Fossil plants by Lakhanpal, F.N., Maheshwari, H.K., and Awasthi, M.; *B.S.I.P. 112.*
- Balasundaram, M.S, 1972a:** Annual General Report *Rec. G.S.I., 103(1): 186-197.*
- Banerjee, T. (1951):** Geological observations in portion of the outer Himalayan the Sela sub agency, NEFA. *Geol. Surv. of India. Progress Report. F.S.*
- Banerjee, T. (1951):** Report on the coal and clay investigations in parts of Upper Assam. *Geol. Surv. of India report. F.S.*
- Banerjee, M., Mitra, P. and Chakravorty, D.K. (1977):** Occurrence of lower Gondwana rocks in western Garo Hill, India. *IV Int. Gond. Symp. India., 1, 71-75.*
- Barkeley, A.K. (In Heron AM) (1920):** Baljong, Dogring and Waimong Coalfields Garo Hills, Assam. Director's General report. *Rec. Geol. Surv. Ind. Vol. 72, Pt. 1 pp. 37.*
- Barooah, B.C. (1973 - 74):** Geological investigations in the Lower Gondwana Formation around Singrimari, Directorate of Geology and Mining, *Govt. of Assam. rep.*
- Baruah J. M. B. and Ratnam, C., 1982:** Variation of thickness of sedimentary succession in the Upper Assam valley. *Rec. G.S.I. 112 (IV): 26-90.*
- Baruah, J. M. B, Handique, G. K., Rath, S. and Mallick, R. K., 1992:** Exploration for Palaeocene-Lower Eocene Hydrocarbon prospects in the eastern parts of upper Assam Basin. *Ind: J. pet. Geol. 1(1): 117-129.*
- Bhalla, J.K. and Bishui, P.K., 1989:** Geochronology and geochemistry of granite emplacement and metamorphism in northeastern Himalaya. *Rec. G.S.I. 122(2): 18-20.*

- Bhattacharya, A.C. and Barman, G. (1966):** Geology of the area along the Jamuna valley, United Mikir Hill and North Cachar Hills district, Assam. *rep. F.S. 1965 - 66.*
- Bhuyan, R. T & Rao, S. Someswara (2001):** Appraisal of mineral/natural resource potential for rural development on Cadastral Map Base in parts of Jorhat district, Assam (*Proj: DOVEMAP*) *F.S. 1999-2000.*
- Biswas, B (1961) :** Geology of Bengal Basin with special reference to stratigraphy and micropalaeontology, *STANVAC (Calcutta), I & II (Unpub).*
- Biswas, B.(1961):** Geology of Bengal Basin with special reference to stratigraphy and micropalaeontology. *STANVAC (Calcutta), I & II (unpublished).*
- Bose, P.N. (1904):** Um Rileng coal bed. *Rec. Geol. Surv. Ind. Vol. 22 Pt. 1.*
- Bose, U. and Chowdhury, A. (1966-67):** Geology and coal resources of a part of Namchik- Namphuk coalfield, Tirap district, NEFA (with plates I to III). *Geol. Surv. of India. Progress Report (unpublished).*
- Bose, U. and Chowdhury, A., and Puri, V.D. (1970):** Geological investigation of the northern sector of Namchik-Namphuk coalfield. (including Maio Bum area). Tirap dist. NEFA. *Rep. Geol. Surv. of India. Progress Report.*
- Boume, A.H. (1962):** *Sedimentology of some flysch deposits.*
- Brown, J. Coggin (1912):** A geological Reconnaissance through Dihang valley, *Rec. GSI Vol. 42 (4), pp 231-253.*
- Bulletins No.45: Coalfields of India-edited by C.S.Raja Rao, Vol.1(1981).**
- Buragohain, A.K.(1994-95):** Final report on resource survey for Dimension stones in Bura Parbat area, Nagaon & Karbi Anglong dist., Assam.
- Chakraborti, S.N. and Ghosh, S.K. (1968-69):** Geology and coal resources of central and western parts of the Langrin Coal fields, United Khasi and Jaintia Hills dist. Assam. *rep.*
- Chakraborti, S.N. and Mukherjee, A.K. (1966-67):** Geology and coal resources of eastern part of the Langrin Coalfield, United Khasi and Jaintia Hills dist. *Assam. rep.*
- Chakraborti, S.N. and Mukherjee, A.K. (1967-68):** Geology and coal resources of the central part of the Langrin Coalfield United Khasi and Jaintia Hills dist. *Assam. rep.*
- Chatterjee, N.N. (1944):** Heavy mineral study of the Barakar sandstone, Singrimari-Garo Hills, Assam. *Proc. 31st. Ind. Sci. Cong. 1944, Pt. III. Sec. IV. Geol. Cong. Sec. P - 68.*
- Chattopadhyay, B., 1984:** North-east corner of the Indian Plate -An appraisal. *Rec. G.S.I. 113(4): 22-66.*
- Chaudhury, M.K., Dasgupta, H.S. and Khating, D.T. (1979):** North-east Coal: an assesment of its potential as a Germanium source. *Chemistry and Industry, July, 1964.*
- Choudhury J.M. and Rao, M. N., (1975):** A review of the Precambrian stratigraphy of Assam Meghalaya Plateau. *GSI Misc. Pub. No. 23, pt. I pp. 27-35.*
- Das D. P. & Rao, K. S. Bhaskara (2001):** Appraisal of mineral/natural resource potential for rural development on Cadastral Map Base in parts of Kamrup district, Assam (*Proj: DOVEMAP*) *F.S. 1999-2000*
- Das, D. P. & Rao, K. S. Bhaskara (2001):** Appraisal of mineral/natural resource potential for rural development on Cadastral Map Base in parts of Kamrup district, Assam (*Proj: DOVEMAP*) *F.S. 1999-2000.*
- Dasgupta, Sujit., Bhattacharya, A. & Jana, Tapan Kr., (1995-97):** Report on : (i) Seismic Hazard Assessment in Eastern-Northeastern India through Poisson Probability Density function Analysis. (ii). Seismicity Pattern, Geometry of the Benioff zone and Stress distribution along the Indo- Burmese Convergent Margin.. *Geol. Surv. of India. Progress Report.*
- De, A. K and Boral, M. C. (1978):** A note on the

Singsimani (Hallidagganj) area, Garo Hills, Meghalaya, *Geol. Surv. Rep.*

Dey A.K. and Shah, A.K. (1954): A petrological Study of rock types between Dening and Minutang, Mishmi hills, Assam. *Rec. Geol. Surv. of India, Vol. 83, Pt. 2, pp 493 - 500.*

Dias, J.P., Sunhat Roy, R.N. and Debadhikari, B. (1965): The detailed Geological Mapping of the Dilli-Jeypore Coalfield and contiguous area, Lakhimpur and Sibsagar district, Assam and parts of Khonsa Sub. Div., NEFA. *rep. F.S. 1963 - 64.*

Duraisamy, K. Bruah, Binod & Kumar, Alok (2001): Appraisal of mineral/natural resource potential for rural development on Cadastral Map Base in parts of Marigaon district, Assam (*Proj: DOVEMAP F.S. 1999-2000.*

Dutt, N.R. (1980): Coal Resource Potentialities of the Northeastern States. (*Manuscript*).

Evans, P. (1932): Explanatory notes to accompany a table showing the Tertiary succession in Assam. *Trans. Min. Geol. Met. Inst. Ind. Vol. 27. pp. 168 - 248.*

Evans, P. (1932): Tertiary succession in Assam. *Trans. Min. Geol. Inst. India. Vol. 27(3).*

Evans, P. (1964): The tectonic framework of Assam. *Journ. Geol. Soc. Ind. Vol. 5, pp. 80 - 96.*

Evans, P. (1965): Structure of NEFA area of Assam. *Min. Geol. Me HI. Inst. Ind. Dr. Wadia Commemorative Volume, p 693.*

Evans, P. and Mathur, L.P. (1964): 'Oil in India'. *International Geological Cong. 22 Session, India, 1964.*

Evans, P., (1932): Table showing the Tertiary succession of Assam - *T.M.G. I.I Vol. 27.*

Evans, P., (1935): General Report of Geological Survey of India. *Rec. Geol. Surv. Ind., 69, 83.*

Fermor, L.L. (1935): General Report, 1934, *Rec. Geol. Surv. Ind. Vol. 69, Pt. 1, pp. 82.*

Fox, C.S. (1934 - 35): Garo Hills Coalfields, Assam.

Director's General report. In Heron, A.M. *Rec. Geol. Surv. Ind. Vol. 71, Pt. 1, pp. 35.*

Fox, C.S. (1934): The Lower Gondwana Coalfields of India. *Mem. Geol. Surv. Ind. Vol. 59, pp. 1 - 386.*

Fox, C.S. (1937): Hidden Coalfields of the Garo Hills, Assam. Director's General report. In Heron, A.M. *Rec. Geol. Surv. Ind., Vol. 72, Pt. 1, pp. 40 - 41.*

Fox, C.S. (1947): The economic mineral resources of Assam. *Govt. of Assam Publication.*

Ghevariya, Z. G & Baruah, B (1999) : Appraisal of mineral/natural resource potential for rural development on Cadastral Map Base in Golaghat district, Assam (*Proj: DOVEMAP F.S. 1997-98.*

Ghevariya, Z. G & Baruah, B (1999): Appraisal of mineral/ natural resource potential for rural development on Cadastral Map Base survey in Assam (*Proj: DOVEMAP F.S. 1996-97.*

Ghevariya, Z. G & Baruah, B (1999): Appraisal of mineral/natural resource potential for rural development on Cadastral Map Base in Jorhat district, Assam (*Proj: DOVEMAP F.S. 1997-98.*

Ghosh. A.M.N. (1956): Recent advances in geology and structure of Eastern Himalaya. *Proc. Ind. Sc. Cong. 43rd Session, Presidential Address.*

Goswami, A.C. (1960): Geological Mapping of the Makum and Jeypore areas bordering the Lakhimpur district, Assam. *rep. F.S. 1959 - 60. Geol. Surv. of India. Progress Report (unpublished).*

Goswami, A.C. and Raj, P.C. (1965): Large scale mapping of a part of the Namdang colliery area in the Makum coalfield, Lakhimpur dist. *Assam. rep. F.S. 1964 - 65.*

Goswami, A.C. and Trivedi, A. N. (1962): Geological mapping and investigation of coal resources of the Makum coalfield area between Namdang and Tipangpani river, Lakhimpur dist. *Assam. rep. F.S. 1961 - 62.*

- Hayden, H.E. (1910):** Some coalfields in northeastern Assam. *Rec. GSI, Vol. 40 pt. 4.*
- Hayden, H.H. (1910):** Northeast Assam Coal Fields. *Rec. G.S.I. Vol. 30, pp 283-319.*
- Hayden, H.H. (1910):** Some coalfields in the Northeastern Assam. *Rec. Geol. Surv. Ind. Vol. 40, Pt. 4, pp. 283 - 319.*
- Hines, G.E. (1931):** Descriptions of the collieries of Makum coalfield, Assam. *Trans. Instt. Min. Engg. (Lond.), Vol. 81, Pt. 5.*
- Jacob, K. and Benerjea, T. (1954):** The occurrence of Glossopteris in N.E. Frontier tracts with a brief review of Gondwana of N.E. India. *Proc. Nat. Sc. India Vol. 20 (1), pp 53-61.*
- Kar, S.K., Prasad, S. and Kumar, G., 1997:** Quaternary sediments in parts of Indo-Gangetic, Brahmaputra and adjoining inland basins and the problem of Pleistocene-Holocene boundary, *Palaeobotanist, 46 (1-2) : 196-210.*
- Kar, S.K., Prasad, S. and Kumar, G., 1997:** Quaternary sediments in parts of Indo-Gangetic, Brahmaputra and adjoining inland basins and the problem of Pleistocene-Holocene boundary, *Palaeobotanist, 46 (1-2): 196-210.*
- Karunakaran, C and Ranga Rao, A.(1979):** Status of exploration for hydrocarbons in the Himalayan region. Contribution to stratigraphy and structure. Him.Geol.Sem.1976, New Delhi *Misc.Pub. 41,Pt.V,pp 1-66.*
- Karunakaran, C and Ranga Rao, A., 1979:** Status of exploration for hydrocarbons in the Himalayan region-contribution to stratigraphy and structure. *G.S.I., Misc. Pub. 41(V):1-66.*
- Krishnan, M. S (1953):** The structural and tectonic history of India *Mem. GSI, Vol. 81, p. 109.*
- Kumar, M.N. and Mazumder, A.K. (1967 - 68):** Geology of the area in between Namdang and Lakhimpur in Makum coalfield, Lakhimpur dist. Assam with special reference to its coal resources. *rep. F.S. 1967 - 68.*
- Kumar, M.N. and Mazumder, A.K. (1968 - 69):** Detailed Geological mapping and prospecting for coal in the area east of Lakhimpur coalfield, Lakhimpur dist. Assam. *rep. F.S. 1968 - 69.*
- La Touche, T.D. (1883):** Note on traverse through Khasi, Jaintia and North Cachar Hills, *Rec. GSI, Vol. 16, pp. 198-203.*
- La Touche, T.D. (1885):** Note on the Geology of Aka Hills, Assam. *Rec. GSI, Vol. 18,pt. 2, 1885.*
- La,Touche, T.H.D. (1886):** Coal and limestone in Doigrung river near Goalaghat, Assam - *Rec. G.S.I. 17 pp 31-32.*
- La,Touche, T.H.D. (1886):** Geology of the Upper Dihing Basin in the Singhpoh hills. *Rec. G.S.I. Vol. 19 pt. 2. pp. 111-115.*
- Lalitha, C and Prakash, U. (1979) :** Gymnospond – A new addition to fossil records, *Symp Evol. Botany and Biostratigraphy Calcutta University 3 (Abs)*
- Laskar, B. (1953):** Reconnaissance for Economic Mineral Deposits in NEFA. *Geol. Surv. of India. Progress Report (unpublished).*
- Laskar, B. (1953):** Reconnaissance for economic mineral deposits in NEFA. *rep.*
- Laskar, B. (1954):** *Geol. Surv. of India. Progress Report (unpublished).*
- Laskar, B. (1956):** On certain intercalation of marine source rocks for oil with Sub Himalayan Gondwana. *(Abs). Proc. Ind. Sc. Cong. 43rd Ser. pp 3. p. 194.*
- Laskar, B. (1959):** On Permo-Carboniferous of the foothills of the Assam Himalaya. Un-Ecafe, Mineral resources development series *No. 10, Pt.II, sec. C, 171-172.*
- Laskar, B. and Sen, S.N. (1952-55):** Geol. Surv. of India. Progress Report (unpublished). La Touche, T.D. (1884): Report on the Langrin coal feild, south-west Khasi Hills, *GSI Rec. Vol. 17, Pt. 4, pp143-145.*
- Laskar, B., (1958):** General report of the G.S.I. for the

year 1953. *Rec. G.S.I.* 87 (1) :46 - 47.

LaTouche, T.H.D. (1883): Notes on traverse through Khasi Jaintia and North Cachar Hills - *Rec. G.S.I. Vol. 10*, pp. 198-203.

LaTouche, T.H.D. (1885): Coal and limestone in Doigrung river near Golaghar, Assam- *Rec. GSI, Vol. 17*, pp. 31-32.

LaTouche, T.H.D. (1886): Geology of upper Dihing basin in the Singpho Hills, *Rec. GSI, Vol. 19*, pp. 111-115.

Limaye, M. (1967): Geological mapping and preliminary investigation of coal resources in Khumbamer Parbat area, Lengloi Parbat area, Namer river etc. in Mikir, United Mikir and North Cachar Hills, Assam. *rep. F.S. 1966 - 67*.

Maclaren, J.M. (1904): a) Geology of Upper Assam (b) The Auriferous occurrences of Assam; *Rec. G.S. Vol. 31 pt. 4* pp. 170-232.

Majumder, A.K. and Ghosh, S.K. (1969-70): Detailed Geological mapping with special reference to coal in the eastern part of the Makum coalfield and adjoining part of Namchik-Namphuk coalfields, Tirap dist., *NEFA. rep. F.S. 1969 - 70*.

Mallet, F.R. (1875): Note on coals recently found near Moflong, Khasia Hills, *Rec. Geol. Surv. Ind. Vol. 8 Pt. 3*.

Mallet, F.R. (1876): On the coal field of Naga hills, bordering the Sibsagar and Lakhimpur districts, *Mem. GSI. Vol. 12 Pt. 2*, pp 1-95

Mallet, F.R. (1882): On Iridesmine from Noa-Dihing river, Assam, *Rec. GSI. Pt. 1*, pp 53-55.

Maswood M.D. and Goswami D.N.D. 1974 : Basic rocks from precambrian terrain around Gauhati Assam, *The Indian Mineralogist, Vol. 15*, pp 55-62.

Maswood, M.D. (1977): Petrology of the pink Granite around Gauhati, Assam -*Jour. Assam Sci. Soc. Vol. 20*-pp 72-75.

Mathur, L. P. and Evan, P (1964) : Oil in India, *Int. Geol.*

Cong, 22nd Session India, 1964.

Mazumdar, S. K. (1986): The Precambrian framework of part of the Khasi Hills, Meghalaya, *Geol. Surv. of India, Records, Vol. 117*, part-2.

McLaren, J.M., ((1904): Geology of Upper Assam. *Rec. GSI, Vol. 31. (4)*, 179 -204.

Medlicott, H.B. (1865): The coal of Assam, results of a brief visit to the coalfields that province in 1865; with Geological note on Assam and the Hills to the south of it, *Mem. Geol. Surv. Ind. Vol. 4, Pt. 3* pp. 388 - 442.

Misra, A. P. & Bhuyan, R. T. (2000): Appraisal of mineral/natural resource potential for rural development on Cadastral Map Base in Jorhat district, Assam (*Proj: DOVEMAP*) *F.S. 1998-99*.

Mukherjee, B.C. (1976): Petrographic characters of coal from Makum coalfield, Assam. *Journ. Geol. Soc. Ind. Vol. 17. March, 1976. No. 1.* pp. 89 - 93.

Mukherjee, K.N., Pal, J.C., Dutt, N.R. and Raja Rao, C.S. (1980): *Trace element studies in the Tertiary Coalfields of northeastern India. (Manuscript).*

Munshi, M.M. (1962): Report on the Geological mapping and investigation for coal along Jaintia Valley, United Mikir and North Cachar Hills, Assam. *rep. F.S. 1961 - 62*.

Munshi, M.M. and Goswami, A.C. (1959 - 61): On the Geology of parts of North Tirap and Namsung-Bordhuria areas, Tirap distt., *NEFA. rep. F.S. 1959 - 61*.

Munshi, M.M. and Rao, M.G. (1962 - 63) : Report on Geological mapping of Namchik coalfield and expedition along the Nao-Dihing river, Tirap Frontier Div., *NEFA. rep. F.S. 1962 - 63*.

Murthy, K..N. (1983) : Geology and hydrocarbon prospects of Assam Shelf-recent advances and present status. *Petrol. Asia Jour., v.6,no.4*, pp.1-14.

Murthy, M.V.N. (1968) : Basement controlled structure and tectonics in upper Assam oil fields. *Paper read in the*

First India Petroleum conference, Duliajan, 1968.

Murthy, M.V.N. (1968) : Geomorphological Evolution of Assam Plateau. Proc. 21st International Geographical Congress 1968 - *A Gauhati University Publication.*

Murthy, M.V.N. (1972) : Stratigraphic Nomenclature and Stratigraphic Lexicon for Assam and other Areas (*Material submitted for stratigraphic Lexicon of India*).

Murthy, M.V.N. (1970) : Tectonics and Mafic Igneous activity in Northeast India, Proc. II *Ind. Symposium on Upper Mouth Project, Dec. 1970 Hyderabad.*

Nandy D.R. and Basak, A. (1966-67) : Detailed investigation graphite deposit at Lalpani district, NEFA. *Geol. Surv. of India. Progress Report (unpublished).*

Nandy, D.R. (1975) : Geology of NEFA Himalaya. *GSI Misc. Pub. No. 29, Part I, p. 91-114.*

Nandy, D.R. (1983) : The Eastern Himalaya and the Indo-Buraman orogen in relation to the Indian plate movement. Symposium Geol. and Min. Resources of North Eastern Himalayas, Shillong, 1976. *GSI Misc. Pub. 43, pp 153-159.*

Nandy, D.R., Mullick, B.B., Basu Chowdhury, S. and Murthy, M.V.N. 1975 : Geology of the NEFA Himalaya, *G.S.I., Misc. Pub. 24(1) : 91-144.*

Nayak, P.N. and Yahkar D.D. (1976) : Geological Evolution of Geophysical traverse taken over Older alluvium near Himalayan foothills in Assam. (*Abs.*) *Symposium Geol. and Min. Resources of North Eastern Himalayas, Shillong.*

Neogi, S., Dasgupta, S and Fukuoka, F., 1998 : High P-T Polymetamorphism, Dehydration Melting and Generation of Migmatites and Granites in Higher Himalayan Crystalline Complex, Sikkim, India, *J. Pet. 39 : 61-99.*

Pascoe E.H. (1911) : Coal in Namchik valley Upper Assam. *Rec. G.S.I. Vol. 1 pt 3 pp 214-216.*

Pascoe E.H. (1914) : The Petroleum occurrences of

Assam and Bengal. *Mem. G.S.I. Vol.40. pt. 2 pp 270-329.*

Pascoe, E (1962) : *A manual of geology of India and Burma. III, 1345 - 2130*

Pascoe, E.H. (1912) : Coal in the Namchik Valley, Upper Assam. *Rec. Geol. Surv. Ind. Vol. 41 Pt. 3 pp. 214 - 216.*

Puri, V.D. (1968) : A report on investigation by drilling in Ledo area. Makum coalfield, Lakhimpur dt., *Assam.rep. F.S. 1966-68.*

Raju, A.T.R. (1968) : Geological evolution of Tertiary basins of Assam and Cambay, *India. Bull. Am. Assoc. Petrol. Geologists. Dec.68, Vol. 52, No. 12, pp. 2422 - 2436.*

Raju, t.r., 1968 (1968) : Geological Evolution of Assam and Cambay Tertiary Basins of India, *A.A.P. Bulletin vol. 52-12, December, 1968, pp. 2422-2437*

Ranga Rao, A. (1983) : Geology and hydrocarbon potentials of a part of Assam-Arakan basin and its adjoining region. *Symp. Petroliferous basins of India. Pp 127-158.*

Ranga Rao, A. and Babu, P.V.I.P. (1976) : On the floor of the Tertiary in Eastern Himalaya. *Him. Geol. Sem. 1976, New Delhi.*

Rao, E. Hanumantha & Ramesh, V (2001) : Appraisal of mineral/natural resource potential for rural development on Cadastral Map Base in Goalpara district, Assam (*Proj: DOVEMAP*) *F.S. 1999-2000*

Rao, M.G. and Limaye, M.D. (1966) : Reconnaissance geological mapping and mineral investigation at Delil's camp in the Tirap Frontier Division, NEFA. *rep. F.S. 1964 - 65.*

Ray, S. (1947) : Zonal metamorphism in the Eastern Himalaya and some aspects of local geology, *Quart. Jour. Geol. Min. Soc. India. Vol. 14, No. 4 pp 117-140.*

Roy Chowdhury, J. (1978e) : Coal memoir for the North Eastern Indian coalfields. *Geol. Surv. of India. Progress Report (unpublished).*

Roy Chowdhury, M.K. (1974) : *Geological and mineral map*

of Assam, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram and Tripura.

Sah, S. C. D (1974) : *Palaeogene biostratigraphy of the Shillong plateau. In aspects and appraisal of Indian Palaeobotany* (Ed. K. R. Surangs, R. N. Lakhanpal and Dr. Bharadwaj) Bidwal Sahni Institute of Palaeobotany, 525-533.

Sale, H.M.(1932): The Kanachanpur fossil bed(Abs.). *Proc. 19th Indian Sci. Congr.*, 381.

Sale, H.M., and Evans, P.(1940): The geology of British oilfields: 1, The Geology of Assam-Arakan oil Region(India and Burma). *Geol. Mag.*, 77, 337-363.

Sarkar, A. K. & Gosami, A. N. (1999): Appraisal of mineral/natural resource potential for rural development on Cadastral Map Base in Marigaon district, Assam (Proj: DOVEMAP) F.S. 1997-98

Sarkar, A. K. & Gosami, A. N. (2000): Appraisal of mineral/natural resource potential for rural development on Cadastral Map Base in Nagaon district, Assam (Proj: DOVEMAP) F.S. 1998-99.

Satujha, S. K , Rehman, K and Kindra, G.S (1973) : Distinction between the Bhujan and Bokabil sediments on the southern edge of Shillong plateau based on palynofossil assemblages *Bull G. C. India*, 10, 109-117.

Sen, N. and Srivastava, B.B.P. (1974): *A preliminary geological map of Dilli-Jeypore coalfields, Assam. Department of Exploration, C.M.P.D.I., Ranchi.*

Sen, S.N. (1976): Present status of Geology of North Eastern Himalaya. Him. Geol. Sem. 1976, New Delhi.

GSI Misc. Pub.41. Pt. 2, pp 23-35.

Shrivastava, P. K. , Ganesan, s and Roy, d. (2974) : Tipam Group in the sub surface of Assam Valley, south of Brahmaputra Jour. *Geol Soc India* 15 (2), 165 – 181.

Simpson, R.R. (1906): Jaipur and Nazira Coalfields, Upper Assam. *Rec. Geol. Surv. Ind. Vol. 34, Pt. 4 pp. 199 - 238.*

Simpson, R.R. 1896: The Geology of Mikir Hills, Mem. GSI, Vol. 28, pt. 1, pp. 71-95

Simpson, R.R. 1906 : Notes on Upper Assam coalfields. *Rec. G.S.I. Vol.34, pt 4, pp 199-241.*

Sinha, N. K. and Mishra, U. K., 1984: *G.S.I., NER News*, 6 (1).

Smith, F.H. (1898): The Geology of the Mikir Hills in Assam. *Mem. Geol. Surv. Ind. Vol. 28, Pt. 1.*

Stuart Murray, 1923: Geological Traverse from Assam to Myitkyina. *Rec. G.S.I. Vol. 54, pt. 4, pp 402-405.*

Thakur, V.C. (1973): Tectonic Eastern Himalaya syntaxis. *Current Science Vol, 43, Part II, p 783 - 785.*

Thakur, V.C. and Jain, A.K. (1974): Tectonic Eastern Himalaya syntaxis. *Current Science Vol, No. 24. II, pp 783 - 785.*

Vacheli, E.T. (1942): *Q.J.G.M.S.I. vol. Xiv, No.1, pp9-12.*

Venkatappayya, N., Kumar, M.N. and Majumder, A.K. (1966-67): Geology of the area around Ledo-Makum coalfield, Lakhimpur Dt., Assam, with special reference to its coal resources. *rep. 1966 67.*

NOTES

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