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Front & Back cover : Aerial view of Loktak Lake, Manipur

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GEOLOGY AND MINERAL RESOURCES OF MANIPUR, MIZORAM, NAGALAND AND TRIPURA

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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. 1(ii) of the series, pertaining to the states of Manipur, Mizoram, Nagaland and Tripura, is a revised and updated version of the first edition published in 1974. During the span of three and a half decades since the first edition was published, enormous knowledge has been added in the sphere of geology of the area warranting a revised edition of this volume. Geological and Mineral Map of each state presented in this volume is a modified and updated one.

Geological Survey of India continues its dedicated work in different realms of Earth sciences. Revisions in the lithostratigraphic succession of the rocks based on the recent advances in geological mapping and laboratory works have been necessary.

The coal horizons of Nazira Coalfield and that of Changkikong-Japukong region appear to be the most important among the economic minerals found in Nagaland so far. Various other important minerals like chromite, magnetite, nickel-ore and limestone, have been located in Nagaland.

Chromite is reported mainly from Ukhrul, Gamnom and Moreh areas of Manipur. The lignite, associated with clay, occurs in Kangvai area of Southern Manipur.

Good quality clay deposits are scattered all over the state of Tripura and can be used for manufacture of sanitary wares, sewerage pipes, electric insulator, fillers in paper, rubber, paint and ceramic industries. Silica sands are also known to occur near Baidyathakurpara, Dukli, Maheshkhola, Anandanagar, Mohonpur and around Dasaram Bari areas of Tripura.

Occurrence of shell limestone, coal, hard sandstone bands (suitable as building material), saline springs and a few gas seepage have been located in Mizoram.

I wish, the publication with updated knowledge-base on the geology and mineral resources of the state of Manipur, Mizoram, Nagaland and Tripura will be of immense use to the students of geology as well as to the professionals and entrepreneurs interested to make investment for developing mineral industry in the region which will augment the economic growth of the area.

(JASWANT SINGH)
Director General (Acting)
Geological Survey of India

Place : Kolkata
Date :

"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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Introduction

The northeastern part of India is a land of extremes and undoubtedly one of the most picturesque parts of our country. Within its area of 2,55,997 sq. km.. We have, on the one hand, steep, rugged and inaccessible peaks of Arunachal Pradesh, rising beyond 6000m above m.s.l. with temperate to cold climate and on the other, the enormous flood plain of Brahmaputra River, covering 0.9 lakh sq. km. with sub-tropical climate and supporting large population with agricultural yields. The southern scarp of the Meghalaya upland (600-1800 m. above sea level) sandwiched between Bangladesh plains in south and the Brahmaputra valley in north, is marked by magnificent deep gorges with wide valleys at their head, which often look like huge amphitheatres adorned by tall monolithic columns. The world's rainiest spot Mawsynram is located here. Rocks of diverse geological ages from the Archaean to the Quaternary comprise the geology of the region.

Table 1.1.1 : Basic Statistics of North Eastern Region

Capital City	Agartala, Aizawl, Dispur, Imphal, Itangar, Kohima, Shillong		
Population	31,547,314	**Forest cover**	166,270 sq. km
Area	255,997 sq. km	**Road length**	116,551 km
Population Density	123.7 persons/sq. km	**Total Hard rock area**	187,621 sq. km
Villages	39,720	**Quaternary area**	67,376sq. km
Literacy	44.44%	**Hard rock mapping coverage ***	1,38,707 sq. km
Total no. of districts	62	**Quaternary mapping coverage ***	61,297 sq. km
Major Minerals	Coal, dolomite, limestone, magnetite, natural gas, oil, sillimanite and uranium		
Minor Minerals	Apatite, asbestos, building stones, clay, chromite, cobalt, copper, fireclay, Fuller's earth, glass sand, gold, graphite, iron ore, kaolin, lead-zinc, lignite, marble, nickel, phosphate, platinoids, rare earths, sillimanite, talc, tin and tungsten		

** Upto July, 2009*

MANIPUR

Manipur, a small state of Northeastern India, is bordered by the states of Assam, Nagaland and Mizoram and by Myanmar on the eastern side.

Table 1.1.2 : Basic Statistics of Manipur

Capital	Imphal	**Forest cover**	17,890 sq. kms.
Population	1,837,149	**Road length**	6,765 kms
Area	22,316 sq. kms.	**Total Hard rock area**	20,308 sq. kms
Population Density	82.32 persons / sq. km	**Quaternary area**	2,008 sq. kms
Villages	2,035	**Hard rock mapping coverage ***	11,146 sq. kms
Literacy	49.00 %	**Quaternary mapping coverage ***	1,850 sq. kms
Districts	Senapati, Tamenglong, Churachandpur, Chandel, Thoubal, Bishnupur, Imphal West, Imphal East, Ukhrul.		
Major minerals	Limestone.		
Minor Minerals	Asbestos, chromite, clay, coal, cobalt, lignite, nickel, platinoids, talc, tin, and tungsten.		

** Upto July, 2009*

MIZORAM

The State of Mizoram is bordered by Bangladesh to the west and southwest, Myanmar to the east and south-east, Assam to the north, Tripura to the west and Manipur to the northeast. It occupies a total area of 21,087 sq. kms, out of which 5% (1000 sq. kms) is covered by Quaternary sediments occurring mainly along river valleys. Silchar in Assam is the nearest railway station on Silchar-Lumding metre-gauge track of NE Frontier Railway. National Highway 50 connects Mizoram with rest of the country through the adjoining Cachar district of Assam. Recently, the state capital, Aizawl, has been connected to Silchar and Calcutta by Air India.

Table 1.1.3 : Basic Statistics of Mizoram

Capital	Aizawl	**Forest cover**	18,180 sq. kms.
Population	689,756	**Road length**	3,708 kms
Area	21,087 sq. kms.	**Total Hard rock area**	21,087 sq. kms
Population Density	32.71 persons / sq. km	**Quaternary area**	1000 sq. kms
Villages	722	**Hard rock mapping coverage ***	20,087 sq. kms
Literacy	67.36%	**Quaternary mapping coverage ***	0 sq. kms
Districts	Aizawl, Lunglei, Chimtuipui, Champai, Kolasib, Lawngtlai, Lunglei, Mamit, Saiha, Serchhip		
Major minerals	NIL		
Minor Minerals	Construction material, limestone		

** Upto July, 2009*

NAGALAND

Framed between the Assam plains to the west, Myanmar to the east, Nagaland is located on the northern part of Indo-Myanmar mountain range. The state is bound between the parallels of 25°15' and 27°00' N latitudes and 93°20' and 95°15' E longitudes. Dimapur is an important city of the state and an important railhead of North East Frontier Railway (NEFR). About 48 % of the area could not be covered by systematic geological mapping on 1: 50,000 scale owing to inaccessibility.

Table 1.1.3 : Basic Statistics of Nagaland

Capital	Kohima	**Road length**	8,805 kms
Population	12,09,546	**Forest cover**	14,360 sq. ,kms
Area	16,527 sq. kms.	**Total Hard rock area**	15,700 sq. kms
Population Density	73.19 persons / sq. km	**Quaternary area**	827 sq. kms
Villages	963	**Hard rock mapping coverage ***	13,294 sq. kms
Literacy	51.09%	**Quaternary mapping coverage ***	800 sq. kms
Districts	Kohima, Mokokchung, Mon, Phek, Tuensang, Wokha, Zunheboto, Dimapur, Peren		
Major minerals	Coal, limestone, magnetite		
Minor Minerals	Basemetal sulphides, chromite, cobalt, nickel, platinoids		

** Upto July, 2009*

TRIPURA

Tripura is another small state located at the south-west extremity of the northeastern region. It covers an area of 10,477 sq. kms bound by latitudes 22°56' to 24°32' N and longitudes 91°10' to 91°21' E. A total of 935 kms, about 80 percent of its frontier marks the international boundary with Bangladesh in the north, west and south. Towards east lie the states of Assam and Mizoram. About 60 percent of the state is covered by N-S trending hill ranges and the rest constitutes plain land. The state capital Agartala is linked by air to Kolkata, Guwahati and Silchar. The northernmost town, Dharmanagar is connected by railway from Badarpur in Assam. The railway line is being extended till Kumarghat, about 60 km south of Dharmanagar. National Highway 44 links the state with the rest of the country.

Table 1.1.4 : Basic Statistics of Tripura

Capital	Agartala	**Forest cover**	5,330 sq. kms.
Population	27,57,205	**Road length**	13,008 kms
Area	10,477 sq. kms.	**Total Hard rock area**	8,000 sq. kms
Population Density	263.17 persons / sq. km	**Quaternary area**	2,477 sq. kms
Villages	4,727	**Hard rock mapping coverage ***	7,082 sq. kms
Literacy	49.86%	**Quaternary mapping coverage ***	2,000 sq. kms
Districts	West Tripura, North Tripura, South Tripura, Dhalai		
Major minerals	Clays, Glass sand, construction material, gas		
Minor Minerals	NIL		

** Upto July, 2009*

II. Physiography and Drainage

Manipur:

From the geographical point of view, Manipur has limited accessibility because of poor communication facility, highly rugged topography and thick vegetation cover. The average annual rainfall of the state is 2016 mm. The inaccessibility factor combined with frequent insurgency problems have lately affected the working conditions in the state.

Mizoram:

The topography of Mizoram is largely immature except for the eastern part. There are N-S trending mostly anticlinal strike ridges with steep slopes and narrow intervening synclinal valleys and series of parallel hummocks or topographic highs. The highest point is Blue Mountain (2165 metres) where an expedition was recently undertaken. The average height of hill ranges is about 900 metres above m.s.l. The elevation difference between the hilltops and the valley floors greatly varies from west to east and range from 200 to 600 metres. Locally the ridges display en-echelon pattern.

The other landforms of the state are dissected ridges with deep gorges, spurs, keels, etc. Faulting in many areas has produced steep fault scarps. Fluvial processes coupled with mass wasting are the main agents for development of the diverse landform of the region.

The major rivers of Mizoram flow either northerly or southerly creating deep gorges between the N-S trending hill ranges. In the northern part of the state, Dhaleswari, Sonai and Tuivawl Rivers are northerly flowing and they join Barak River in Cachar district of Assam. In the southern part of the state, the Karnafuli River flows northerly and enters Bangladesh, whereas, the Kolodyne River enters Mizoram from Myanmar and flows southwards to re-enter Myanmar. The major drainage pattern of the tributaries and streamlets are angular, sub parallel to parallel and dendritic. The main drainage system of the state has a straight flow regime.

Nagaland:

Nagaland is located in the northern extension of the Arakan-Yoma ranges. Almost the entire state is hilly, except along the foothills flanking the Assam plains. The general elevation increases towards the east, the highest peak Saramati (3826.15 metres) belongs to the easternmost hill ranges of the state.

Geomorphologically, the terrain can be broadly grouped into four topographic units:

Alluvial plains: 150 to 200 meters above m.s.l.

Low to moderate linear hills: 200 to 500 meters above m.s.l..

Moderate hills: 500 to 800 meters above m.s.l.

High hills: 800 meters and above.

The Barail hill range, in the southwest corner of the state runs approximately due northeast almost upto Kohima, which has a height of 1465 metres. Near Kohima, it merges with the hill ranges extending up to Manipur border which swings northerly. Between Mao and Kohima, there are several high peaks including Japvo. Barail and Japvo ranges and their extensions in Mokokchung and Tuensang mark a prominent water divide separating Brahmaputra and the Chindwin River systems. Tapu, Dima and Dikhu are important Rivers in the north block while Tizu is important in the southeastern block. The drainage pattern is mainly dendritic and controlled by trend lines and lineaments at places. In plain country meandering pattern is observed. The drainage is structurally controlled and locally trellis in nature in the eastern mountain belt.

Tripura:

Geomorphologically, the terrain of Tripura is immature and represents first order topography. The N-S oriented hills are anticlinal and intervening valleys are synclinal. There are five distinct hill ranges and valleys in Tripura. They are Baramura, Atharamura, Longtarai, Sakhan, Jampui and the valleys are Agartala-Udaipur, Khowai-Teliamura, Kamalpur-Ambasa, Kailasahar-Manu and Dharmanagar-Kanchanpur. The highest peak is 937 metres high on the Jampui hills and the general altitude of the state varies between 10 metres and 600 m.s.l.

In Tripura generally the summits of all hill ranges form the water divides. The north flowing major rivers are Khowai, Dholai, Manu, Turi and Langui. Gomti River flows towards the West. Fenny and Muhari are the important rivers in the South. All the rivers are tributaries to the major rivers of Bangladesh. The drainage patterns are dendritic, parallel to sub parallel and rectangular types.

III. Climate, Forests and Cultivation

Except for the higher altitudes of the Himalaya and Meghalaya hills, the entire region has a sub-tropical climate. Each state enjoys heavy rainfall, the rainy season generally persisting from April to September/October. The high altitude areas (1500 m and above) located in the Himalaya and the Meghalaya plateau are characterised by temperate to cold climate.

Mizoram:

Climate of Mizoram is pleasant. It is generally cool in summer, the temperature ranging from 8°C to 29°C whereas during the winter the temperature varies from 11°C to 24°C. The average annual rainfall is about 254 cms.

There are dense forests in the valleys and hill slopes. Bamboo is the most important forest produce. Wild animals include elephant, tiger, leopard, bear, mithun, deer, etc.

Nagaland:

Climate of Nagaland is humid tropical type and minor variations are caused by change in physiography such as: Plain area experience warm and subtropical climate. The foothill areas with rolling to undulatory topography experience subtropical climate. Low to moderate ranges with varying degree of slopes have submontane climate.

Out of 16,527 sq. kms of total land area, about 14,360 sq. kms is under forests. The forests under government control are reported to be about 28.5% of the total forest area. The different forests types are temperate evergreen type, tropical evergreen forest, tropical semi-evergreen forest, tropical moist deciduous type, bamboo forests, and degraded forests. The last type is partially the anthropogenically affected forests as a result of Jhum cultivation and partially due to geomorphological effects.

Cultivation exists within degraded forests. It is mainly confined to areas of moderate to high hills. The western borders and valleys of Ghaspani, Jharnepani and Bara Monghi Rivers are the areas of active permanent cultivation.

Soil and landuse maps of Nagaland show that substantial areas can be brought under permanent cultivation with irrigation and under rainfed conditions. Rainfall pattern is in excess of soil storage capacity causing nutrient losses through leaching, run-off and erosion. Soil potential, however, can be utilised for different crops by careful handling.

Tripura:

Climate of Tripura is subtropical, humid and hot. The average maximum temperature is 35°C in summer and average minimum is 10°C (December, January). Winter temperature drops down to 5°C. Annual average rainfall is high, of the order of 200 to 250 cms. Monsoon commences in late May and continues upto September. Flooding in rivers is common during monsoon.

The major part of the state was thickly covered with primeval forest even upto the early 1950s. Deforestation in the recent times has claimed a lot of forest lands. The forest is classified into three main types. These are (1) climatic type (evergreen and moist deciduous type), (2) seral type (swampy and riverine forest) and (3) subsidiary edaphic type (bamboo, gurjan and grassland). The forest generally covers the tilla lands, hillocks and flanks of hill ranges. It is virtually absent in the lower lands which is mainly used for cultivation.

IV. Accessibility

Except for valley areas, major part of the region is lacking in communication. The railway lines and most of the motorable roads are located in the Brahmaputra and Barak/Surma valleys. There are no railway lines in the hilly terrains and very few motorable roads connect these areas with the valley plains. Such lack of communication and deficiency in infrastructure are the major constraints in the mineral development of the region. Recently, North Eastern Council has drawn up scheme to link the mineral deposit areas spread out in Nagaland, Manipur, Assam, Meghalaya and Arunachal Pradesh.

V. Previous Work

Northeast India is rich in non-metallic mineral resources, specially in respect of high grade limestone and coal containing high sulphur and low ash. Substantial reserves of these deposits have already been explored and quantified, and the resource figures are likely to be multiplied with additional exploration. Significant deposits of dolomite, clay, refractories, low grade glass sands and low grade graphite occur here. An enormous amount of construction raw material e.g. gravel, sand, silt-clay and soft rock aggregates also exist. The present outlook is, however, not encouraging in respect of the metallic minerals. Exploration conducted so far has revealed only minor subeconomic concentrations. Search for metallic mineral resources in the region has, therefore, to be given a new thrust and orientation. Geological analysis shows that from metallic mineralisation point of view Precambrian and Lower Proterozoic territories in Meghalaya, Assam, Arunachal Pradesh and the Ophiolite Belt of Nagaland and Manipur are of primary significance. Certain built-in terrain conditions, e.g., inaccessibility, rugged topography, deep weathering profile and thick vegetation here pose problems in locating metallic deposits by traditional methods of ore search. In view of these facts, new geochemical and geophysical methods have to be applied to explore the geologically promising areas and appropriate exploration strategies have to be evolved to overcome the terrain constraints. Steps in this direction have recently been taken.

Metallogenic Domains:

Conceivably the rock milieu of diverse stratigraphic age in different tectonic set up would have different orders of mineralisation potential. Based on the available data, they can be grouped as follows:

The geosynclinal clastics constituting the Tertiary mountain belt (of Naga-Lushai-Patkai) appear to be devoid of mineral resources, but for oil, natural gas and coal along the shelf fringe.

Except for sporadic occurrences of sulphides, podiform chromites, nickeliferous magnetite etc. no major metallic ore deposit has yet been located in Naga Ophiolite belt so far. But inter-disciplinary programmes of studies have recently been taken up with the objective of delineation of the mineralised zones.

Sufficient observations in Manipur have not been made, due to which the geological picture is still incomplete. After the pioneering traverse taken by Oldham (1883) a big hiatus existed in geological investigations in Manipur till 1930s, when geologists of Burmah Oil Company/ Assam Oil Company took up studies of the Tertiary sedimentaries in quest of petroleum. GSI put some stress on the study of this area during the World War II in connection with search for strategic minerals; however the investigations were of cursory nature. A little more attention was paid to this area during the late fifties and sixties in quest of nickeliferous rocks and limestones. Thorough geological investigations were launched during the early seventies of previous century. The geological data collected so far relate to the rocks around 'Ophiolite Belt' of this terrain and a large part of the state is yet to be mapped. However, the rock formations in and around 'Ophiolite Belt' serve the purpose of understanding the stratigraphy in general.

La Touche (1891) was a pioneer worker who took a few selected traverses in Mizoram and considered the rocks of Mizoram as flysch sedimentary sequence folded into North-South trending hills. He also stated that the rocks are the southern continuation of Cachar Hills and were probably deposited in the receding delta or estuary of a large river basin during the late Tertiary period.

Hayden (1937) took short traverses in Mizoram. Franklin (1948) was the first to map part of the Mizo hills on aerial photographs. Dasgupta (1948) considered that the rocks of Mizoram belong to Bhuban Stage and folded into meridional structures. Munshi (1964) mapped the central part of northern Mizoram and correlated the rocks with Surma Series and divided them into Bhuban Stage and Bokabil Stage. According to him the rocks were tightly folded representing a considerable compression effect. He located four saline and one oil seepage.

Subsequently, Nandy, Mukherjee, Mazumdar (1972), Nandy and Sarkar (1972), Saxena and Mukherjee (1973) proposed a lithostratigraphic classification and divided Surma into Bhuban and Bokabil sub-groups. Further, they recognised Lower, Middle and Upper Bhuban Formations.

Banerjee et.al, (1977) Banerjee and Trichal (1978), also recognised folded sequence of Lower, Middle and Upper Bhuban and Bokabil Formations with the folds as trending NNW-SSE. Venkatesh et.al, (1981) located fossil horizon in the Bhairabi area in western Aizawl district.

A lithostratigraphic classification using local names was suggested by some workers in preference to chronostratigraphic nomenclatures (Nagaraja Rao et.al, 1981). The major lithounits were divided into three formations viz. Kolasib Formation, Bhairabi Formation and Buchang Formation in western Aizawl district which range in age from Lower to Middle Miocene of Evans (1934). Sundara Murthy et.al, 1985 reported Barail Group of rocks from eastern part of Mizoram.

During an expedition to Blue Mountain, an angular unconformity was recognised (Chakraborty and Rajendran 1987) between two formations. It has been postulated that the unconformity between the lower predominantly argillaceous formation and upper predominantly arenaceous sequence represents a break between Barail Group and Surma Group respectively.

Jaggi et.al, (1985-86) adopted the lithostratigraphic classification as proposed by Evans and Mathur. The arenaceous rocks were grouped under Upper Bhuban Formation and the argillaceous formation was grouped under the Middle Bhuban Formations.

Madhusudan et.al, (1986-87) worked out lithostratigraphy of the area in accordance with ‘Code of Stratigraphic Nomenclature of India’ and proposed a local stratigraphic terminology. Three formations viz. Rengdil, Chuhvel and Lockicherra were recognised and correlated with the Upper Bhuban, Bokabil Formations (Surma Group) and Tipam Group respectively.

Beeriah and Patel (1987-88) proposed stratigraphic division of Surma Group into Upper Bhuban Formation and Middle Bhuban Formation based on the predominance of arenaceous or argillaceous rocks.

Purushothaman and Vidyasagar (1988-89) made stratigraphic classification of Surma Group into Middle and Upper Bhuban Formations by taking into consideration the lithological attributes, argillaceous-arenaceous ratio, structure and topography.

Prior to independence, geological information on the Naga Hills was based mainly on the reconnoitary traverses. Mallet (1876) in his memoir gave a comprehensive account of the Nazira coalfield area in Nagaland and pointed out that the coal seams gradually thin out towards the SW of Dikhu valley and further westwards they are represented merely by carbonaceous shales. Hayden (1910), however, gave a comprehensive account of Nazira coalfield, the major coal mining centre in Nagaland. The existence of a major mafic and ultramafic belt, now known as Ophiolite Suite was brought out by Oldham (1883) and Pascoe (1912). The latter in his traverse from Dimapur to the neighbourhood of Saramati in a expedition gave an account of a wide spectrum of rocks in the ophiolite belts which included hornblende-enstatite-olivine gabbro, diabase gabbro, lherzolite, wehrlite, peridotite, harzburgite and andesites. Even after a lapse of several decades, Pascoe’s identification of the mafic and ultramafic suite is treated as a faithful account of the rock types exposed in the most inaccessible part of the Indo-Myanmar range. Later, Evans (1932) on behalf of Assam Oil Company, carried out systematic survey in parts of Naga Hills. In spite of rapid strides that have been made in geological mapping in the Naga Hills the stratigraphic classification proposed by Evans has withstood the test of time.

After a lapse of several decades, geological mapping was initiated in the sixties when Dayal and Raj (1964-65) and Debadhikari (1967) mapped parts of Schuppen Belt. Mitra and Chowdhury (1968-72) laid emphasis on the mapping of coal belts of Borjan and Changki areas. Bhaumik, Majumdar and Ahmed (1973) reported the magnetite in and around Phokphur which were later surveyed in details by Majumdar and Pandey (1974), Majumdar and Prabhakar (1976), Ravi Kumar (1977), and Ravi Kumar and Prabhakar (1978). Minor incidences of sulphide mineralisation in the ophiolite belt were examined by Venkatraman et.al, (1982), Singh et.al, (1983) and Sengupta et.al, (1983).

Due priority was accorded to systematic mapping in hitherto unsurveyed areas of Nagaland because of its geodynamic significance and mineral potential of ophiolite belt in Indo-Myanmar range. Majumdar et.al, (1974-75), Singh and Adiga, (1975-76), Kumar and Prabhakar (1975-76), Singh and Adiga (1976-77), Chattopadhya and Roy (1976-77), Singh (1977-78), Singh et.al, (1980-81), Vidhyadharan et.al, (1981-82), Srivastava, Bhattacharya and Jena (1981-82), Acharya et.al, (1981-82), Vidhyadharan and Joshi (1982-83) Srivastava et.al, (1983-84), Bhattacharya and Sanwal (1983-85) contributed to greater understanding of the stratigraphy, structure and tectonics of the Ophiolite Suite of rocks of Nagaland. In the sedimentary belt in the West, Sen (1971-72), Sen and Jha (1971-74), Sen and Tej Kishan (1974-75), Sen and Singh (1975-76), Chakraborty and Sarma (1977-78), Bhartiya and Sarma (1977-78), Chakraborty and Sarma (1979-80),Saxena and Verma (1979-80), Verma and Yedekar (1980-81), Prasad and Sarma (1980-82), Singh et.al, (1980-81), Verma and Gaur (1981-82), Joshi and Yedekar (1981-82), Chakraborty and Naskar (1981-

82), Yedekar and Jena (1982-83), Naskar and Sarma (1982-83), Yedekar and Roy (1983-84), Jena and Devdas (1983-84), Sarma and Naik (1983-84), Chakradhar and Gaur (1984-85), Devdas and Gandhi (1984-85), Sarma (1984-85) carried out systematic surveys and brought out a comprehensive picture of the structural and stratigraphic framework of the sedimentary domain.

Tertiary foldbelt of Tripura has been studied as early as 1908 when H.C. Dasgupta classified the folded sediments of Tripura into 'Coal measures' and 'Tipam Group'. Subsequently, Das (1939) recorded that the North-South trending hill ranges are asymmetrical to symmetrical anticlines affected by thrusts. He classified the rock formations into three major groups, namely: Lower or Unokoti-Jampui, Middle or Baramura-Dotamura and Upper or Fossilwood Group. Vachell (1942) further subdivided the rock formations into stages and sub-stages and attempted a correlation with the Upper Bhuban and parts of Bokabil stages of Surma Series of Tertiaries of Assam-Arakan ranges.

Geological mapping in the state dates back to 1950s when Sen (1952-57) carried out systematic geological mapping of extensive areas and attempted to bring out a stratigraphic order in the fold belt of Cachar-Tripura region. He subdivided the Surma into Middle Bhuban, Upper Bhuban and Bokabil stages overlain by Tipam Sandstone stage and finally with an unconformity by Dupi-Tila Stage. He reported the shell limestone for the first time at the ridge crest of Sakhan range. Subsequently, Trivedi (1962-64), Sar (1964-65), Sen (1967-68) and Roy (1968-69), covered extensive areas and suggested various refinements. Goswami and Dasgupta (1969-70), Nandy and Dasgupta (1970-71), Nandy and Saxena (1971-72), Dasgupta, Ghosh and Kumar (1972-73), Dasgupta and Bhattacharji (1976-77) documented various lithostratigraphic units and recorded comprehensive lithostratigraphic description of the different groups and subgroups. In the recent years Chakrabarti and Chatterjee (1981-82) and Sundaramurti and Mishra (1983-84) classified the rock units on the basis of lithological assemblages and attempted correlation with the type areas of Tipam, Bokabil and Bhuban rocks. The systematic mapping by these workers helped to build up the stratigraphic framework of the rock units exposed in the state and preparation of the mineral inventory.

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Geology and Mineral Resources of Manipur State

Prior to Independence, the activities of Geological Survey of India in the hilly inaccessible terrains of the north-eastern part of the country were by and large limited to traverses on expedition basis. Subsequently, in order to make a preliminary assessment of mineral resources and to unravel the stratigraphic and tectonic set-up of the 'terra incognita', the Survey undertook a systematic geological study in accessible parts of this region. The contributions of the survey during the last decade in Manipur in understanding the mineral potential of the state are significant.

Manipur is endowed with occurrences of limestone, nickel, copper, lignite, dimension stones and minor asbestos. The investigation for limestone around Ukhrul and Hung dung for ascertaining the feasibility of erecting a small scale cement plant was completed. Lignite occurrence around Kangvai village was investigated by drilling. Detailed integrated surveys were taken up to search for nickel, copper and cobalt, with emphasis on the serpentinised belt.

Since a large part of Manipur State still remains to be mapped, the Geological Survey of India did set up a circle office for Manipur and Nagaland at Dimapur to step up the progress of work. This facilitated a better co-ordination of the activities of the Geological Survey vis-à-vis the development programmes in the state.

Previous Work:

Oldham (1883) was the first worker who gave a geological picture of Manipur. Later Pascoe (1912) and Evans (1964) in their reports described the rocks west of Imphal valley as mainly belonging to Barails and those to the east as Disangs. Dayal and Duara (1962-63) carried out systematic geological mapping to the south and northeast of Imphal valley and they adopted a geological succession much similar to that suggested by Oldham.

Sriram and Mukhopadhaya (1971) and Sriram, Mukhopadhaya and Rapa (1972) carried out systematic geological mapping in Ukhrul district and they subdivided Disang Group into Litan Formation, Ukhrul Formation and Siohi Formation.

Geological Investigations : Geological activities in Manipur and adjacent regions were of the nature of scanty traverses during the pre-independent period of India. The earliest broad geological information of Manipur was given by Theobald (1873) and Oldham (1883) who correlated the rock sequence there with the "Axials" of Arakan Yoma in Burma.

Pascoe (1912) studied the rocks exposed in the east and west of Imphal Valley of Manipur and considered that the "Axials" of Oldham were in fact much similar to Mallet's description of the 'Disang Series' of upper Assam. He also pointed out that bulk of the Disangs had more in common with the Negrais beds in Burma.

Hayden (1910) suggested that the parallel hill ranges between Burma and Assam may be made up of flysch sediments of Mesozoics and opined that the shales of Lushai Hills (in Mizoram) may extend up to Tertiary in age.

Evans (1932), Mathur and Evans (1964) referred the sequence of dark grey shales with thin bands of sandstones to the 'Disang Series' and noted that near Ukhrul the Disang shales are closely associated with Cretaceous limestone but the field relationship was not fully established.

Pascoe (1950) has mentioned that the contact of Disangs and Makware beds of Burma (more like Disangs but showing greater degree of metamorphism, foliated habit) is characterized by serpentinite intrusions which are probably of Upper Cretaceous age.

Clegg (1941) suggested that the limestone of the Nungshang- Khang valley is of a peculiar character and is absolutely identical in appearance and structure with the greyish limestone in Pegu area has been attributed by Theobald to Cretaceous age.

Geological Survey of India has carried out mineral investigation and systematic geological mapping from time to time in different parts of Manipur state. Preliminary studies for copper and nickel mineralization around Nungoui, Ningthi, Kogan – Thana were carried out by Chakraborty and Raina (1958).

Dutt (1959) carried out preliminary investigation for Nickel at Kwatha, Nampesha, Huimine areas and indicated nickel concentration in the soil resting over ultramafic rocks.

Aiwar, Banerjee and Dayal (1960-61) carried out investigation for Nickel and Copper mineralization in Moreh areas.

Dayal and Duara (1962-63) carried out geological mapping and mineral investigation in Ukhrul subdivision, Manipur and classified the sedimentaries, with limestone pockets, as Axials. They opined that the Chimi conglomerate of Pascoe (op. cit) is similar to Ukhrul conglomerate.

Basu and Ranga Raju (1964) mapped several horizons of limestone near Ukhrul, Lambuil Hungdung and on Pallel-Tamu road in Chandal district of Manipur.

Nandy and Sriram (1969-70) carried out some detailed work and located several limestone deposits. They found some Upper Cretaceous fossils in one of the limestone bands and correlated them with the 'Axial' of Oldham.

Sriram and Mukhopadhyay (1971) carried out mapping near Ukhrul and proposed the following stratigraphical succession:

Sirohi Formation	Intrusive serpentinite bodies.
Ukhrul Formation	Shale, siltstone, sandstone, grit, conglomerate, limestone etc.
Litan Formation	Dark grey shale, siltstone.

Ghosal (1972) carried out detailed investigation for limestone in Ukhrul, Hungdung, Mova, Khangkhui areas and observed that the contact of the Cretaceous beds overlying the Disang shale is tectonic and allochthonous in nature.

Mazumdar and Rapa (1972-73), 1973-74) carried out geochemical sampling for estimation of nickel and cobalt in the soil of the serpentinite belt in parts of Manipur East district.

Chattopadhyay and Roy (1975-76) carried out mapping in parts of Manipur East district and classified the rock into lower argillaceous Chingal Group and upper arenaceous Kongal Group based on lithology and fossil assemblages.

Ghosh, Dutta and Chandrashekhar (1980) carried out integrated survey in parts of ultramafic belet of Manipur and located several small pockets of chromite in Gamnom areas. They opined that the sedimentary rocks occurring on either side of the ultramafic body are sedimentaries without differentiation.

Palaeontological investigations : In a basinal marl facies near Tupokpi in Manipur, Biswas (1962) identified pelagic and benthonic smaller foraminifers in which Globigerina, Globotruncans and Psedotextularia were the dominant forms. Biswas (op. cit) gave an informal designation to the mark facies as 'Axial limestone' and considered it to be equivalent to the upper part of Mahadek Formation or the lower part of the Langpar Formation of Meghalaya.

From Chingai group Chattopadhyay and Roy (1975-76) collected mollusks which included Pinna sp, Pecten sp, Chlamys sp, Spondylus sp, Lucina sp, Tellina sp, Ostrea sp, Trigonite sp, Cardium sp, Turritella sp and coralline algae. The assemblage indicates a Lower Tertiary age for the group of rocks.

Near Challao the calcareous shale and limestone within the Chingai group contain Globotruncane sp, Globigerins sp and Nodosaria sp indicating an Upper Cretaceous age.

A number of plant fossils have been recorded in arkosic sandstone and clays of Kongai group; these are Magnifera sp, Annona sp, Fucus sp, Psidium sp, and Shores sp, indicating post-Palaeogene age. He correlated these beds with Surmas and the Tipams.

An ONGC laboratory report (1976) says that the limestone bands have yielded upper Cretaceous foraminifers at several localities in Manipur as given below:

Planktonic Foraminifers : *Globoturuncana arca, G. fanseri, G. stuarti, G. cf. G. ventricose, Heterohelix globulose, H. sp, indet and Rugoglobigerina sp., indet*.

Benthonic Foraminifers : *Anomalina sp., Bolovina sp., Bulimina sp., Cibicides sp., Entalina sp., Lagena sp., Nonion sp., Bonionella sp.,*

The above assemblage is indicating of Maestrichtian age.

Detailed work was carried out by Bhattacharyya and Bhattacharyya (1976) on stratigraphy and paleontology of the limestones around Ukhrul and Moreh and they proposed the following stratigraphic succession.

Basic emplacement	Serpentinite, peridotite and diorite
Ukhrul Formation	Argillaceous limestone, greywacke, arkose, conglomerate and diorite embedded in stratified argillites.
Lamlang Formation	Predominantly a sandstone flysch

Foraminifers were found in argillaceous limestone and moluscs in calcareous sandstone as under:

Foraminifers :*Anomaline sp., Cytheerelle sp.,* *Cytherelloides sp., Globigerina sp., Globotruncana arca, G. pinneiana, G. stuarti, Nodosaria sp., Pseudotextularia sp.,*

These forms are of Upper Cretaceous age.

Molluscs: *Cerithium sp., Corbula harpa, C. vredenburgi, Corimya sp., Modiolus asperilus, Nemocardia sp., Nerita sp., Pleurotamaria babylonia, Septifer sp., Solen sp., Turritella affines, Venericardia sp.,*

These forms are of Paleocene – Eocene age.

Venkataramana (1977-78) located few limestone bands in Narum area of Chandel district. Agarwal and Bharatiya (1977-78) carried out systematic mapping of Jessami – Kharasom area.

Roy (1980) has reported the following

Radioloria : *Cenellipasis, Cenodiscus, Cenosphaera, Ellipsidium, Lilthapium, Sethocyrtis and Tricolocapsa.*

The assemblage indicates Maestrichtian age.

Duarah, Saikhia and Bhattacharjee (1983) have identified radiolarians from chert beds of Sirohi, Manipur East district. They found Archaeodictyomitra which is indicative of Valanginian – Aptian age.

Satsangi and Chatterjee (1978) collected invertebrates from the calcareous shales near Sumdal. The mollusks identified as Barbatia sp., Cardium sp., Cerithium sp., Lumatia sp., Ostrea sp., Pinna sp., Terrina sp., Turritella sp., and some unidentifiable arcide. The plant fossils consist fo Bambuse sp., and Poacites sp.,. These forms are indicative of Eocene age.

Mishra and Satsangi (1982) identified the following invertebrates near Lamlang Gate. The forms are Arctica sp., Barbatia sp., Certithium sp., Cirsotreema sp., Ficus sp., Nucula sp., and Tellina sp., and some unidentifiable bivalve impressions.

Mishra (1983) identified a number of foraminifera from the Disangs in the area south of lower Phaibung. These are Bathysiphon sp., Globigerina sp., Globigeerinella sp., Globigerinoides sp., Globorotalia sp., Globotruncana sp., and Pleurostomella. The fauna is indicative of Upper Cretaceous age.

Vidhyadharan and Joshi (1984) differentiated the sedimentaries occurring on either side of the ophiolite belt in Manipur. They designated them as Upper Disang containing olistostromal limestone bodies as “wild flysch”. They also opined that the sedimentaries towards east of the ophiolite belt belong to “wild flysch” and those towards west of the ophiolite belt constitute oceano-pelagic sediments.

Shukla et al, (1985) worked in eastern part of Ukhrul district and around Kudenthabi in Chandel district, Manipur reported sporadic occurrences of rodingites in the ophiolite belt.

Mishra (1985) reported radiolorians and foraminifers of Maestrichtian age from cherts and limestones associated with the ophiolite suite of rocks. The olistostromal limestones west of ophiolite belt contain mainly foraminefers varying in age from Maestrichtian to Palaeocene and Lower to Middle Eocene. The typical Disang and Barail sediments are exposed to the west of the eolistostromal zone. The biota from these are mainly dominated by mega invertebrates of Upper Eocene age. Further, Mishra (1987) reported palaeobiota from Chandal district, Manipur.

The other workers who reported a large number of mega and microfossils from Manipur East and Chandel districts are Das and Shukla (1987), Shukla and Natu (1987) and Mishra (1987-92)

Prithiviraj, Mishra and Sahni (1992) recorded foraminiferal assemblages from exotic blocks in the mélange zone of Ukhrul, Manipur and assigned them to late and terminal Cretaceous age.

II. GEOLOGY:

The geological framework of Manipur including Indo-Burma range along its eastern frontier is closely linked up with the evolution of Neogene Surma basin, Inner Palaeogene fold belt and Ophiolite suture zone. The ophiolite belt occurring along Indo-Myanmar border in Manipur, forms a part of Naga-Arakan Yoma flysch trough of Upper Cretaceous-Middle Miocene age. Geological data collected so far mainly relates to Ophiolite zone and adjoining terrain. A large part of the state is yet to be covered by systematic geological mapping. About 64% of the total area of the state has been covered by systematic geological mapping on 1: 50,000 scale. These are the main mineral-bearing areas which have already been covered. The study of the rock formations in and around ophiolite belt elucidates and helps in understanding the broad stratigraphy and structure of the whole terrain. Available information brings forth a geological picture depicting the spread of Tertiary rocks over the entire state with small patches of Quaternary sediments in the central part (e.g. Imphal valley) and a long narrow N-S trending ophiolite belt towards the eastern margin of the state. It, thus, emerges that geotectonically three distinct domains exist which are: (1) Neogene Surma basin, (2) Inner Palaeogene fold belt and (3) Ophiolite zone associated with Late Mesozoic-Tertiary sediments.

OPHIOLITE ZONE

Ophiolite zone is linearly aligned in north-south direction from Nagaland in the north and nearly parallel to the eastern margin in the southern part of the Manipur. This belt extends to southwest of Moreh. It occurs as a series of lensoid bodies of ophiolite rocks of variable dimensions. The bodies are steeply dipping and striking in NNE-SSW directions. They occur as fault-contacted slices within pelagic shale- sandstone association. The ophiolites and enclosing sedimentary rocks have been thrusted over by metamorphics in the east of Jessami in the northeastern part, which comprise quartzite, phyllite and marble. The thrusted contact is characterised by intense fracturing, brecciation, mylonitisation and silicification (Venkataramana, 1985). Sedimentary rocks enclosing the ophiolites are referred to as Disang Group and comprise a thick pile of argillaceous rocks interbedded with greywacke and minor limestone.

Limestone containing Late Cretaceous (Maestrichtian) fossils earlier led to erroneous stratigraphic interpretation of age in Eastern Manipur. Species of *Globotruncana* and *Gumlelina* have been recorded in the limestone pockets within sedimentary rocks around Ukhrul by Duara and Adhikari (1964), Dayal and Duara (1965) and Nandy and Sriram (1970). These findings led them to assume a Cretaceous age for the entire sedimentary formation. Since the formation enveloping the limestones had many similarities with Disang Group, many geologists including Evans (1964) postulated that Disang Group in Eastern Manipur may range down to Cretaceous. Ghosal (1972) carried out detailed geological investigations around Ukhrul and interpreted a reverse sequence there and ascribed it to thrust faulting resulting in Cretaceous beds to overlie Disang Group. Recent studies by Mitra *et. al,* (1986) have revealed that these limestone pockets are olistostromal bodies embedded within the wild flysch sediments of Upper Disang Formation.

Sriram and Mukhopadhyay (1971) worked in the eastern part of Manipur around Ukhrul and included all sedimentary formations of the area under Disang Group and suggested a classification as given in Table 1.2.1.

They also observed that subdivisions of Ukhrul Formation may be made on the basis of (1) presence of limestone, (2) occurrence of coarse grained sediments and (3) absence of intrusive serpentinites. Chattopadhyay and Roy (1975 & 1976), working in the northeastern part of Ukhrul district, attempted a classification of the sedimentaries on the basis of detailed petro-mineralogical studies of the rock units. In their classification, a lower argillaceous unit (Chingai Formation) equivalent to Upper Disang Formation and an upper arenaceous unit (Kongai Formation) equivalent to the Tipam Group were suggested. The correlation of the arenaceous unit with the Tipam Group was made on the basis of plant remains. These plant fossils indicate a larger chronostratigraphic range and are not convincing evidences to favour equivalence with Tipam Group. They seem to be the strike extension of Barail rocks from the western side of that area.

Ophiolite zone contains a group of oceanic pelagic rocks which occur mainly in the east and include chert, thin limestone, quartzite and phyllite. The rocks exhibit feeble metamorphic characters but occurrences of radiolaria and diatoms in the cherts bear a positive indication of their origin in deep oceanic sector. Vidhyadharan and Joshi (1984) have correlated this epimetamorphic rock group, especially occurring in northeastern part of Manipur, to the Nimi Formation of Nagaland. The rocks of the oceanic pelagic group are well exposed in the vicinity of Lushat (Ukhrul district) and have been designated as Lushat Formation (Shukla *et. al,* 1985). Venkataramana (1978) carried out mapping in parts of Southern Manipur (Tengnoupal district) and located a few limestone bands in the Narum area. Later, Gupta and Mohanty (1985) mapped the area in more detail to decipher the economic potentiality of the limestone bodies and recognised Disang Group, oceanic pelagic sediments and associated ultramafic slices in that area. They also recorded some limestone pockets around Narum within the oceanic pelagic sediments. Microforaminifers and radiolarians collected from limestones of the oceanic pelagic sediments in the Narum area were studied by Mishra (1985) and a Lower Eocene age was assigned for them.

Vidhyadharan and Joshi (1984) and Venkataramana (1985) noted rocks of volcano-sedimentary associations especially in the northeastern part of Manipur. These comprise volcanic tuff and breccia. Tuff consists of highly foliated greyish brown ash bed with fragments of basalt, spherulites and shards. The whole rock is permeated by carbonate matrix. Chert beds, varying in colour from red, green, grey to white are found in close association with volcanic rocks. Red chert at places contains *radiolaria*. Diatom (*Melosia sulcata*) bearing cherty bed in one such place indicated Lower Eocene age. A limestone band within the volcanics lying east of Lungahar yielded fossils indicating Palaeocene to Lower Eocene age.

The contact between ophiolites and the enclosing sedimentaries is usually sharp but at many places the con-

Table 1.2.1: Lithostratigraphic classification near Ukhrul, Eastern Manipur (after Sriram and Mukhopadhyay, 1971)

Group	Formation	Lithology
Sirohi Group	Ukhrul Formation	Serpentinite (intrusive), shale, siltstone, sandstone, conglomerate, limestone, etc
Disang Group	Litan Formation	Dark grey shale and siltstone

tact is concealed. Venkataramana (1985) noted the development of chlorite and tremolite at some places while profuse fracturing of the enclosing sedimentaries was observed at the immediate contact. In the later case, the fracture planes were filled by secondary calcite and quartz veins. Vidhyadharan and Joshi (1984) reported silicified zones at the contact of many tectonic slices of the ophiolite zone and limestone east of Nunybi Khullen along Khamasom track. Gossan- like structure comprising criss-cross veinlets of quartz was produced at these places by weathering.

Ophiolite Suture Zone includes: (1) meta-peridotite, (2) ultramafic to mafic cumulates, (3) mafic volcanic sequence and (4) volcano-clastic sediments associated with cherts. The meta-peridotite is identified by tectonic fabrics, while the cumulates are characterised by assimilate texture. The constituent rocks of the ophiolite zone were subjected to metamorphism under conditions of greenschist facies. Some chromite, magnetite and sulphide minerals have been recorded within the ultramafics. Mukhopadhyay and Rapa (1974) noted a structural concordance of the ultramafic bodies with the enclosing sedimentaries and no significant changes at the contact except minor baking, induration and iron metasomatism of the sedimentary rocks were recorded.

Parts of the ophiolite belt have been explored for chromite and other metals like Ni, Co, Cu, etc. The cumulate chromite which is of minor economic importance is found to be associated with dunites, cumulate peridotites, pyroxenites and gabbros. On the other hand, podiform chromite was found (Venkataramana, 1985) in association with metamorphic peridotites. Chromite pods are similar to those of Alpine type in the mode of occurrence and physical and chemical characters. Dutta (1959) carried out preliminary investigation for nickel at Kwatha, Nampesha, Humine areas and suggested that the nickel concentration in the soil resting over serpentinites was due to dunite body. Alwar *et. al,* (1960) carried out investigation for nickel and copper mineralisation in Moreh area. Mukhopadhyay and Rapa (1974) made a geochemical exploration in the southern part of the ophiolite belt to decipher the nature and occurrence of secondary dispersions of nickel and cobalt in the weathered mantle over the ultramafics. Chattopadhyay and Aggarwal (1981) carried out geological mapping and recconaisance survey of reported occurrences of lead, zinc, copper and silver around Sugnu area of Tengnoupal district. Ghosh, Dutta and Chandrashekharan (1980) carried out integrated survey in parts of the ultramafic belt of Manipur around Sirohi and Gamnom. They located several pockets of chromite of smaller dimensions. They have ascribed the origin of these chromite bodies to primary differentiation from parent magma. Jagannathan and Mahapatra (1985-86) worked in the southern part of ophiolite belt near Moreh and studied the petrological variation of the igneous suite as well as the associated sedimentaries.

INNER PALAEOGENE FOLD BELT:

The Inner Palaeogene fold belt comprises a vast expanse of sedimentaries belonging to Disang Group and Barail Group, occupying parts of northern, central and southern Manipur to the West of the ophiolite zone. Though the entire area had not been covered by systematic geological mapping, isolated areas had been covered by Duara and Adhikari (1964), Verma, Gaur and Nagarajan (1983), Gaur and Khan (1984), Khan Jayaraman and Mishra (1984-85) and Khan, Sable and Mishra (1985-86). A major part of the Disang rocks consists of argillaceous sediments. Grey to buff coloured, splintery shales constitute the major volume of the Disang Group, which has been locally metamorphosed to a very low degree and usually encountered in the anticlinal cores. In northern Manipur, a major syncline exists to the east of the Mao anticlinal structure. This Synclinal structure passes through Phuba-Phaibung- Khullen village areas. A well- preserved section of Barail rocks has been recorded by Verma, Gaur and Nagarajan (1983) from this locality. They classified the Barail rocks into a lower Phaibung Formation (alternation of shale and sandstone) and an upper Phuba Formation (dominantly shale). However, in many places of the Palaeogene fold belt, Barail Group has not yet been classified or subdivided, where it is recognised as an undifferentiated sedimentary group.

Since the Barail Group forms a conformable sequence with the underlying Disangs at many places, the chronostratigraphic demarcation between the two units poses a general problem in the area of Manipur-Nagaland. As a thumb rule, the first appearance of multistoried sandstone over Upper Disang rocks is taken as a marker for beginning of the Barail sediments. The basal zone of Barail sediments at many places is characterised by a thin, coarse, pebbly, conglomeratic horizon. This polymictic conglomerate representing a disconformity at the top of Disang Group has been reported from many locations around Ukhrul in eastern Manipur (Vidhyadharan and Joshi, 1984). Local variations of this conglomerate have also been observed by Gaur and Khan (1984) near Paoi and by Jayaraman, Khan and Mishra (1985) in the Saikul-Tuinem area.

Regional mapping in the Inner Palaeogene fold belt of Manipur-Nagaland in recent years recorded the existence of a rich fossiliferous zone near the contact of Disang Group with Barail Group. The assemblage comprises gastropods, pelecypods, corals and sometimes foraminifers indicating an Upper Eocene age. This observation has also been taken into consideration for delineating the Disang/Barail boundary. Further studies on the fossil assemblage are likely to throw more light on the stratigraphy of the Inner Palaeogene fold belt.

Reference has already been made earlier about the occurrence of olistostromal rocks within the wild flysch of Upper Disangs in the ophiolitic belt. Gradual progress of mapping revealed the occurrence of olistostromes within the Inner Palaeogene fold belt to the West and southwest of Ukhrul [Verma, Gaur and Nagrajan (1983), Gaur and Khan (1984), Khan, Jayaraman and Mishra (1985), and Khan and Sable (1986)].

NEOGENE - SURMA BASIN:

Sedimentary rocks younger than the Disang and Barail Groups are restricted to the western and southwestern parts of Manipur. The Tertiary rocks in Mizoram and southern Assam have merged with the younger Tertiary sediments in this part of Manipur. According to Ranga Rao (1983), in Nagaland adjacent to Cachar area, Lower Bhuban Member is quite thick and Upper Bhuban Member has not been developed, but in Western Manipur, adjacent to the southernmost Assam, the Upper Bhuban Member is well developed and quite thick (about 3000 metres). At a few places in Western Manipur, Barail Group has been observed to pass conformably upward into Surma rocks. In Jiribam area, Laisong Formation, the lowermost formation of Barail Group, comprising mainly sandstone overlies Disang Group and is in turn overlain by Jenam Formation consisting mainly of argillaceous rocks. Renji Formation, the uppermost formation of Barail Group, is represented by interlayered sequence of shale and sandstone. Bhuban Formation of Surma Group comprises alternations of sandstone and shale which grade into less consolidated rocks with sand and clay. Chakraborty and Bhartiya (1979) have recorded Surma rocks from the Tipaimukh area where the general strike of the formation is NNE-SSW to NE-SW, dipping moderately towards east. Minor changes of dip noted in the area are presumably due to folding which affected the sedimentaries.

QUATERNARY DEPOSITS

The majority of the Quaternary deposits in the state are located in Imphal valley, covering an area of about 2250 sq km. Loktak lake, Imphal River and its tributaries viz., Iril, Thoubal and Nambul exist in this valley and as such the deposits are of both laccustrine and fluvial types. Morphostratigraphy, soil stratigraphy, degree of dissection and oxidation of the different geomorphological units have been studied. Based on the work of Poddar, Guha Roy, Kar, Shukla & Mahapatra(1985-86), the general stratigraphic sequence along with the geomorphic background of the Quaternary deposits can be represented as in the Table 1.2.2.

The older units viz., Motbung and Kangla-Tongbi surface are best developed in northern and western periphery of the valley. They abut against Tertiary hills having distinct fan characters. Sekmai surface is a flat to gently sloping alluvial terrain bearing both escarpments and overlapping relation with Kangla-Tongbi and Lamsang surfaces. Lamsang surface shows relict flood plain features like levees and back-swamps. Lilong surface is laccustro-fluvial in nature and comprises the present day natural levees of Imphal, Iril, Thoubal and other tributaries. The wetlands, south of the valley, comprising Loktak lake, Khodium Pat, Pumlen Pat and other small water bodies and marshy lands belong to the Loktak surface.

Evidences of neotectonism have been recorded in the northern part of the valley along a lineament trending N 35º W-S35ºE and can be traced along the Limakong River, a tributary of the Imphal River. The river sections expose a sequence of folded and tilted peat beds of probable Pleistocene age overlain by a blanket of undisturbed Upper Pleistocene and Holocene fluviatile sediments.

Table 1.2.2: General morphostratigraphic sequence and landforms of Quaternary deposits of Imphal valley, Manipur

Morphostratigraphic ie Surface	Relative age	Type Locality	Geomorphic expression	Enviromental process
1. Loktak Surface	Late Holocene (H_2)	Loktak Lake	lakes and marshes	Lacustrine
2. Lilong Surface	Late Holocene (H_2)	Lilong Bazar	levees and back swamps	Lacustro-fluvial
3. Lamsang Surface	Early Holocene (H_1)	Lamsang	Palaeo-levee, backswamp	Fluvial
4. Sekmai Surface	Late Pleistocene (P_3)	Sekmai	Flat to gently sloping alluvial plain	Fluvial
5. Kangla-Tongbi Surface	Middle Pleistocene (P_2)	Kangla-Tongbi village	Fan cut, moderately, dissected terrace	Fluvial and slope processes
6. Motbung Surface	Early Pleistocene (P_1)	Motbung Village	High level-colluvial fan and fan cut terrace, highly dissected	Dominant slope spocesses, modified by stream action

The geological environment is summarized as follows:

1. Disang Group is probably represented by synorogenic trench-fill sediments, the trenches being located in the peripheral zone of a geosyncline. The sedimentary basin became shallower during the Upper Disang although an oscillatory movement was present within the basin. The upper part of Disang Group embodies olistostrome of limestone and sandstone which slide off within the submarine trenches from the continental margin. The dominantly shaley Disang Group grades into Barail Group with frequent occurrences of a pebbly horizon at the base of the Barail Group. Data regarding the Upper Tertiary rocks are meager. The dominantly arenaceous formation exhibits a rather shallow water environment.

2. Quaternary sediments occupy mainly Imphal/Manipur valley area where lacustrine and fluviatile beds form the major constituents.

The generalised stratigraphic succession is given in Table 1.2.3. Laisong, Jenam and Renji Formations of Barail Group have not been separated in the stratigraphic column as they are not identifiable in different places of the state.

Table 1.2.3: Generalised Stratigraphic succession of rocks in Manipur

Group	Formation	Lithology	Age
Quaternary		Sand, silt, gravel, boulder, clay etc.	**Recent**
Tipam Group		Sandstone, clay	**Miocene**
Surma Group	**Bokabil Formation** **Bhuban Formation**	Shale, siltstone alternation with minor sandstone	
~~**Disconformable Boundary**~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~			
Barail Group	**Renji Formation** **Jenam Formation** **Laisong Formation**	Coarse, gritty, massive and well bedded sandstone with current bedding and ripple marks, with plant remains and coal streaks and conglomerates	**Oligocene**

Contact gradational : boundary containing patchy conglomerate at places			
Disang Group	**Upper Disang Formation**	Shale, siltstone, graywacke with rhythmite, olitrostome with fossils and slices of ophiolitic rocks	**Middle to Upper Eocene**
	Lower Disang Formation	Shale, graywacke with rhythmites and minor sandstone bands	**Upper Cretaceous to Lower Eocene**
~~**Tectonic Contact**~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~			
Oceanic Pelagic Sediments	**Lushat Formation**	Cherts (light grey and pink) radiolarian and diatom bearing cherts, limestone (fossiliferous at places), red shales, greywacke with minor volcanics	**Cretaceous to Lower Eocene**
	Ophiolitic Suite (Igneous rocks)	Volcanic rocks with flow breccia, gabbro / plagiogranite/pyroxenite/lherzolite/harzburgite/ dunite/peridotite with disseminated nodular and massive podiform chromite (The ultramafics in various stages of serpentinisation)	

PETROLOGICAL CHARACTERS

OPHIOLITES:

Expanded version of Penrose Conference definition of ophiolites (Moore, 1981) includes in its ambit igneous, basic and ultrabasic rocks associated with some oceanic pelagic sediments. The ophiolite of Manipur comprises a wide spectrum of rock types such as ultramafics and and mafic plutonic rocks of varying composition, basalts with interbanded cherts and limestones. Vast exposures of ophiolite rocks are seen in Harbui-Khayey-Gamnom-Singcha section, Ukhrul-Jessami section, Gamnom-Pushing section, Lunghar -Sihai section and east of Chingai in Ukhrul district and Tengnoupal-Moreh section in Chandel district.

In addition to the major ultramafics zones, minor opholite slices occur within the Disang Group around Lambui, Shanshak and Nungbi villages.

Petrological characters of important members of the opholite suite are described below:

Tectonised peridotite / Meta peridotite

These rocks are irregularly distributed as tectonic slices of variable shapes and sizes. Modally, these rocks correspond to dunite, harzburgite, lherzolite, garnet lherzolite (mafic) and have been recorded as thin discontinuous lenses and layers within the peridotites.

Harzburgite forms the most predominant member. Petrographically, these rock comprise olivine which is invariably altered to serpentine and bastitised orthopyroxene. The rocks with cumulate texture contain brown spinel and magnetite. Near Chingai, talcose serpentinised veins occur within harzburgite. Serpentinite showing mesh and ribbon texture with unaltered olivine cores are quite common.

Lherzolite forms a minor but notable constituent of the ophiolite suite of rocks. These rocks are recorded along Gamnom road, east of Poi, north of Harbui Khayui and northwest of Siruhi Funa, and comprise predominantly of altered olivine, clinopyroxene, orthopyroxene, and rounded spinel.

Garnet-bearing lherzolite was recorded from the east of Tusom Cici (Shukla *et. al,* 1985). They are disposed as three bands within serpentinised ultramafic rocks and comprising of orthopyroxene, clinopyroxene, brown amphibole, basic plagioclase and garnet. Garnet constitutes about 20-25% of the total rock. It is surrounded by kelyphilic rims of amphibole, pyroxene and saussuritized plagioclase.

Dunite occurs as minor lenticular bodies which are usually altered. Serpentinised dunite with disseminations and pods of chromite are noted around Thangrai, Phangrai, Sirohi, Gamnom and Pushing. The dominant mineral is olivine altered in varying degrees to serpentine chromite, magnetite and brown spinel occur as accessory minerals.

Ultramafic Cumulates

Coarse pyroxenites are often recorded in cumulate sequence as observed in Sirohi peak. Often the individual pyroxene crystals are of 10cm x 8cm in size. These comprise mainly bastitised orthopyroxene with minor amount of clinopyroxene. Associated with the ophiolite suite are amphibolites which are well exposed in Numsang Khunour and east of Tusom Cici. In the latter area, they are closely associated with garnet lherzolite. The rock shows either schistose or granoblastic texture. Essential minerals are hornblende, plagioclase, pyroxene, epidote, tremolite, zoisite, sphene and opaque (iron ores). Hornblende, the most predominant mineral occurs as stout prismatic crystals and is pleochroic from light brown to light green. Often it is associated with diallage. Granular aggregates of epidote occupy the interspaces between hornblende grains. In altered rocks, calcium metasomatism is quite common.

Mafic Cumulates

The mafic cumulates are represented chiefly by gabbro and its anorthositic variants. They occur often in close association with ultramafic cumulate sequence of dunite, harzburgite and pyroxenite. The gabbros crop out near Gamnom, south of Nungshang, Khunou, west of Shihai Khullen along Khangkhui-Pushing track, Hungdung, south of Huishu, near Chammu Turrel, east of Challao and east of Tusom Cici. Coarse melanocratic gabbroic variants are exposed in the Mapung Lok River in close association with coarse pyroxenite. The gabbroic mafic cumulates often interdigitate with the volcanic suites. In thin section, rock shows coarse altered plagioclase with minor amount of altered pyroxene and amphibole. The essential minerals are basic plagioclase which are usually altered and sericitised with inclusions of amphibole and opaque. Both orthopyroxene and clinopyroxene are present. The brown hornblende is usually secondary after pyroxene. Brownish green chlorite and epidote are important accessories. The rocks show usually ophitic texture.

Mafic Volcanics

Light green, violet and grey coloured, amygdoidal volcanics and trap breccia are dominant components of the mafic suite. Major volcanic zones are noted southwest of Pushing, west of Mapung, northwest of Shihaifurar, south and southwest of Thangrai, west and north of Khamasom, east of Chammu Turrel, between Hyang Kuki and Border Pillar 130 in Ukhrul district. In Chandel district, volcanics crop out southeast of Khudeng Thabi near Kwatha and in Lainikong *nala* section. The volcanics show pillow-like structures in Lainikong *nala* and Lokchao River sections and also south of Thangrai. As the rocks have been highly deformed, pillow structure is not often clearly defined. Huge blocks of volcanic agglomerate containing angular fragments of gabbro, serpentinite in a volcanic matrix are noted in Sirohi and Mapung tracks and around New Pushing, which testify to the explosive phase of the volcanism. Volcanic bombs have been reported from the vicinity of Khamasom village which occur in association with tuff. The bombs are spherical to ovoid and are set in a greenish chloritic matrix. Brecciated volcanic rocks are also recorded from southwest of Shihai Kullen associated with tuffaceous horizon. They consist of angular fragments of basic volcanics similar to hyaloclastites. The presence of volcanic bombs and hyaloclastites indicate vicinity of eruptive centre and explosive nature of volcanism.

The volcanic rocks are often interbedded with chert and limestone. One limestone band within the volcanics has been noted on the foot-track from Lunghar to Shihai Khullen. This yeilded rich biotas some of which are time sensitive and as such have indicated the precise age of that particular volcanic suite(Chattopadhyay et.al,1983).

The rock is fine to medium grained with laths of plagioclase and subhedral grains of pyroxene in a very fine grained groundmass which constitute more than 30 percent of the rock by volume. The plagioclase laths are andesine-labradorite in composition and display-corroded margin.

The mafic minerals comprise mainly augite which occur as prismatic and euhedral grains. Quartz occurs as a minor accessory mineral. The groundmass is colourless to yellowish green with considerable brown coloured glass. The vesicular amygdules are filled with calcite, epidote, chert, chlorite and zeolite. Mafic and felsic minerary minerals include palagonite, chlorite, quartz, calcite and tremolite. The porphyritic texture with plagioclase phenocryst is quite common. The glomeroporphyritic texture is also commonly formed by plagioclase laths. Occassionally intersertal texture is noted in the volcanics. Volcanics from west of Shihai Khullen show parallel alignments of plagioclase laths in a glass matrix showing flow alignment. (Vidhyadharan and Joshi, 1984). Based on the mineral composition these volcanics correspond to trachy-basalts or basalts.

The chemical data of volcanic suites of the ophiolite are meagre. A few samples of basalts which have been chemically analysed correspond to tholeiitic basalt and basaltic andesite. Their highly alkaline nature is indicated in the $Na_2O + K_2O$ vs. SiO_2 plot. In the normative Or-Ab-An diagram, most of the plots fall in alkali basalt and Hawaiite fields. Greater degree of fractional crystallisation shows them to be geochemically different from mid-oceanic ridge basalt.

The coexistence of tholeiitic and alkaline basalts suggests their generation in the oceanic islands. The major element chemistry also suggests their tectonic setting to be a non-spreading aseismic ridge. However, the trace element data is indicative of within-plate basalt

(Venkataramana 1885). Probably, the parental tholeiitic lava was contaminated by sea water, ocean floor weathering (Chattopadhyay, op.cit) and metasomatism which enriched its alkali content, particularly Na_2O. The alkaline nature of these volcanics may suggest their generation in ocean island within plate, rift zone environment (Fisher and Schimcke, 1984).

Plagiogranite

Leucocratic rocks consisting predominantly of plagioclase and quartz with a gabbroic texture occur as isolated slices and dykes at Sanshak, Nungbi, east Umching Lok, near Poi and east of Hyang Kuki and Tusom Cici. The plagioclase feldspar is of albite-oligoclase in composition with some of the grains showing albite twins. They are usually saussiritised. Quartz occurs as inequidimensional grains often occupying the interstices of feldspar. The mafics are usually less than 10%. Chlorite grains are noted as secondary to hornblende and opaque. A plagio-granite body occuring discontinuously on the hill southeast of Kudangthabi shows intrusive relationship with harzburgite and contains xenoliths of basic volcanics. Compositionally, they range from plagioclase rich tonalite-trondhjemite to hornblende-biotite rich diorite.

Oceanic Pelagic Sediments

This sequence comprises a thick unit of shale with thin interbands of pelagic limestone and chert. It is a characteristic cover rock over the volcanic suite of ophiolites. The limestone bands are usually fine grained and sometimes cherty. They occur in various shades of grey, white, pink and cream comprising micritic and sparitic calcites. Cherts are of grey and green colour and reveal abundant remains of rounded to elliptical radiolarian structures. Similar pelagic litho-facies were found over the volcanics in Salumi area of Nagaland. The presence of radiolarian chert in the shale sequence suggests pelagic environment in the oceanic domain. Such rocks are well exposed around Huishu, east of Poi, at Singcha, Pushing, Lushat, Kamjong and Mapung in Ukhrul district and east of Tengnoupal in Chandel district. The oceanic pelagic rocks are well exposed around Narum, Khaosat, Yangoupokpi, Dotaibungi and Lamayang villages (Gupta and Mohanty, 1985). Oceanic pelagic sediments have large spread in the vicinity of Moreh.

Limestone lenses within oceanic pelagic sediments are well exposed near Chamu Turrel along the track to Huishu. A grey limestone and a chert bed in association with shale are exposed between Lushat and Loni. A limestone band associated with shale crops out at Mapung and has yielded rich biota suggestive of Palaeocene to Lower Eocene age. Red coloured chert within the shale sequence is seen east of Tusom Cici and in the river bed of Chamu Turrel. Grey to greenish, well bedded cherts, 15 to 20 metres in thickness are exposed within the shale sequence near Lushat. East of Walleli, on way to Khaiyang, 20 metres thick chert bed is noted. Similar cherts are also reported between Phungre and border pillar 125. A chert bed is also observed near Yangkul village on the foot track near Taret River.

Disang Group

Disang Group covers a major part of eastern and central segment of the state. The base of this group is nowhere exposed and as such the total thickness has not been estimated. The lower units of this group are characterised by grey, khaki grey, black splintery shales with thin silty interbands. The thickness and frequency of sandstone and siltstone increase towards the upper part. Locally the sandstone is as thick as 6 to 8 metres occurs as lensiod body within the shales.

In Northern Manipur, rocks belonging to Disang Group are well exposed (Verma, Gaur and Nagrajan, 1983) along the cores of anticlinal structures following the Barak, Chamu, Chahelru Turel and Laini Lok Rivers. It shows a monotonous sequence of grey to dark grey and Khaki shales. Shales are splintery in nature and nodular at places. The nodules are made up of clayey matter with pyrite, quartz or clay in nucleus. Similar shaley facies are also exposed in Imphal valley, 25 km north of Imphal, near Kangpokpi, where Disang Shales have yielded foraminifera. Presence of *Modiscus, Trachommine, and Bulnina,* etc., are indicative of a shallow marine environment (Ranga Rao, 1983). Well developed sections of Disang Group are exposed around Poi, Paorei, Tolloi, and Huimi area. In Paorei village, 1850 metres thick section of Disang rocks have been critically studied (Gaur and Khan, 1984). The 600 metres thick basal section shows rhythmic alternation of graded bedded sandstone/ siltstone/ shale which is typical of turbidite facies. The middle 500 metres comprise mainly grey to dark grey Khaki, splintery nodular shales with rare sandstone bands. This is succeeded by 600 m thick olistostromal sequence containing exotic blocks of limestone, chert, and silicified sandstone. The biggest block of limestone of 100 m x 150 m has been noted near New Paoyi village (Singh, 1984). Similar facies of olistostrome are noted further northwest, about 2 km south of lower Phaibung (Verma, Gaur and Nagrajan, 1983). Exotic blocks of limestone and sandstone are seen within a shaley sequence close to the hill slopes near Lairi

Lok. The biggest exotic limestone measures 5 m x 3 m on the surface of observation.

A predominantly argillaceous sequence of Disang Group occurs about 3 km south of Huining village. In this section about 75 metres thick upper olistostromal sequence and 400 metres thick rhythmites and shale sequence are exposed. Chattopadhyay and Roy (1975) discussed the lithological attributes of Disang Group, which was named as Chingai Formation. It was reported that towards the top of the formation minor evaporites occur as encrustations or as thin lamellae within the shally sequence. In Ukhrul area, the lower section of the formation shows rhythmic alternations of sandstone and shale with recurrent graded bedding. The lower unit is conspicuously exposed in the anticlinal valley of Marak Lok, Chilui, Khong *nala* east of Ukhrul. These units are succeeded by a thick sequence of shales in which exotic blocks of various dimensions are embedded.

The distribution pattern of the olistostromal horizon at the top of Disang Formation shows that the development of the horizon is along the axial trace of a syncline running from Paybi in north, through Ukhrul and Hungdung to Lambui in south. The horizon within Disang Group is folded and repeated in east and west. The westerly exposure of the olistostromal horizon with maximum thickness of 2 metres is found in a stretch between Shongphel and Siraru Khong in the western part of Ukhrul district. Large blocks of exotic limestone are noted in Hungdung. Other large blocks of limestone are reported from Lambui (50 metres x 35 metres). The details of their petrology and biotic record have been summarised by Mitra *et. al,* (1986). It has emerged from the study that the different exotic blocks are of different affinity viz. Mastrichtian, Palaeocene, Lower and Middle Eocene (Mishra,1986). Invertebrate fossil records of the host turbidites of the exotics are dated as Eocene.

The petrographic studies of the sandstones have been made by Chattopadhyay and Roy (1976), Gaur and Khan (1984) Vidhyadharan and Joshi, (1984). Thin sections of sandstone show that the framework grain is composed of quartz, plagioclase (both fresh and altered), chert and volcanic rock fragments. The matrix is dominantly chloritic and sericitic. Modal analysis of a few representative samples (Chattopadhyay and Roy, 1975) shows 43-65% quartz, 4.4 -14.7 % feldspar, 0.5 to 7.1 % rock fragments. Matrix constitutes 15.5- 34.5% of the whole rock. The sandstone corresponds to graywacke and lithic graywacke. The C-M pattern (Passega, 1957) of Disang Group is rectilinear and sub-parallel with the C-M line curve which indicates the process of deposition through turbidity current. The occurrence of evaporites and shallow water marine invertebrates and plant fossils in some rocks of Disang Group of this area are suggestive of their deposition in shelf environment. Evidently, the Disang basin in Manipur witnessed tectonic instability with episodic deep water condition followed by uplift and shallowing of the basin condition under oscillating tectonic impulses.

Barail Group

Barail Group occurs in two distinct geotectonic settings. Extensive Barail rocks are known to occur in the western part of Manipur, where the rocks continue from the main Barail scarp of Kohima Syncline and rest conformably over Disang Shales. A three fold division of the Barail Group into Laisong, Jenam and Renji Formations is not manifested in all places of the state.

Barail Group occurs as outliers in the cores of the synclines in eastern and northern Manipur. In Mao-Tadubi-Maram area of northern Manipur, the lower unit of Barail Group is characterised by alternation of sandstone and shale. The sandstone is grey to dark green, fine to medium grained, compact and often flaggy in nature. Carbonised fragmentary plant remains are numerous within the sandstone. Apart from this, well preserved leaf impressions and remains of bivalves and gastropods are observed in the lower section of Barail Group which is well exposed around Phuba. This unit is made up of well bedded thick sandstones forming thick scarps. The sandstone is medium grained, grey in colour, well bedded to massive. Carbonised plant remains are abundant. Some minor coal streaks and lenses rarely exceeding 5 cm in thickness are observed within this unit.

In eastern Manipur, a conglomerate bed at the top of Disang Group heralds the deposition of Barail Group. The polymictic conglomerate representing a local unconformity at the top Disang Group is reported from Paoyi in the north to Ukhrul in the south. Exposures of this conglomerate are noted near Paoyi, Paorei, Ukhrul, north of Sangjing on the bank of River Nungshang Khong, South of Lower Hungdung, east of Singdeng, south Yarshoka, north of Charga along Gamnom road and south of Furing (Vidhyadharan and Joshi, 1984). The composition of the pebbles of the conglomerate varies from place to place. Near Phungchang, volcanic rock constitutes a significant proportion of the pebbles but near Paoyi the conglomerate pebbles are mostly composed of chert and vein quartz (Gaur and Khan, 1984). In general, conglomerates and gritty pebbly sandstones are made up of clasts of quartz, red and green chert, volcanics, serpentinites and fragments of shales which are set in an arenaceous matrix. In western Manipur along the southern continuation of Kohima Synclinorium such conglomerate beds are not observed at the base of the Barail Group. The conglomeratic zones are succeeded by reddish, grey or buff coloured well- bedded micaceous and feldspathic sandstone with interbedded shale and siltstone. Thin lenses of coal varying from a few mm to 5 cm in thickness can be observed.

In the area northeast of Ukhrul, Chattopadhyay and Roy (1975) identified similar facies and designated them as Kongai Group. As a matter of fact, these are the strike extension of Barail Group. Here, again the base of the Barail Group is defined by a polymictic conglomerate comprising pebbles of quartz, chert, jasper and basic rocks in a quartzo-feldspathic matrix. The sandstone is predominantly coarse grained consisting of quartz, feldspar, muscovite, chert and opaques. The modal analyses show that quartz constitutes 60-88% of the rock and the proportion of the feldspar varies from 5.7 to 19.2%. Rock fragments occur in minor but notable amount. The matrix proportion varies from 6 to 14% which is mostly sericitic. Siliceous and ferruginous cement binding the grains have been recorded.

The clast composition of the conglomerates suggests their derivation from ophiolitic provinces. The limited palaeocurrent data also corroborates the derivation of sediments from east. The clast - matrix pattern of the rocks suggests their deposition in shallow intermontane basins. The presence of bivalves, gastropods and foraminiferal remains indicates marine signature.

The fossiliferrous horizons from Barail Group are located at Tolloi-Humi road and half way down from Huimi towards Kachai Hokhrim. The fossils include *Solariclla, Pecten, Nautica* and *Assilin*a (Gaur and Khan, 1984). Mishra (1985) reported pelecypods, gastropods and foraminifers from Barail rocks of Siraru Khong which include *Nummulites sp., Echinochilus*, which are showing Upper Eocene affinity.

Surma Group

Meager data exists regarding the rocks of Surma Group rocks of Manipur. Based on regional setting and broad lithological associations, Chakraborty and Bhartiya (1979) have correlated the arenaceous rocks around Tipaimukh in southwestern Manipur with Surma Group.

The stratigraphy of Surma Group, as corroborated by overall regional set up in different parts of Northeast India, comprises two fold subdivision of the rocks. Surma Group of rocks between Lakhimpur and Jirighat, comprises of alternations of shale and sandstone. The lower unit, Bhuban Formation, has been found to pass conformably into the Bokabils. East of Jiri River, the Bokabils pass into the Tipam rocks. The rock types present in the area, although arenaceous, contain shales and siltstones. The rocks are poorly consolidated, soft and friable. Shale-siltstone units are usually grey, yellow or brown in colour. Occasionally thick bands of grey, hard, compact sandstones are found which contain carbonised woody streaks.

Tipam Group

Limaye (1967) has recognised Tipam Group of rocks 10 km east of Jiribam on the Jiribam-Imphal road. These are coarse, ferruginous, micaceous, soft sandstone and clays occasionally with carbonised wood.

Quaternary Rocks

Motbung and Kangla-Tongbi surfaces (Table 1.2.2) depict their origin by both slope process and stream action and are composed of unsorted, angular to subrounded fragments ranging from pebbles to boulders in a sandy matrix. Sekmai surface comprises sediments predominantly composed of silt with minor pebble beds and clay pockets. Lamsang surface consists of sand and silt with minor pebble beds and clay pockets occurring at a depth of 5 - 10 metres. Lilong surface comprises the present day natural levees of Imphal, Iril, Thoubal and the major tributaries. In the back swamps, a thin veneer of alluvial sediments overlies lacustrine clay and silt.

III STRUCTURE AND GEOLOGICAL HISTORY

The structural picture of Manipur State is not yet fully complete due to incomplete geological coverage. Based on available geological data, Ranga Rao (1983) identified three broad structural zones as follows:

(i). Central Manipur anticlinorium,

(ii) the tightly folded zone of Western Manipur,

(iii) a zone of folding and thrusting in Eastern Manipur.

It has been visualised that the Central Manipur anticlinorium is mostly occupied by the Manipur valley. Broadly, the anticlinorium comprises a N-S trending doubly plunging anticline in Disang Group. Several anticlines and synclines characterise this anticlinorium. The Koubru range in western Manipur hills is the continuation of the main Barail scarp of Kohima syncline. Evidently in Koubru syncline, the Laisong Formation is occupying its core.

The structural setting of the area east of Manipur anticlinorium is complex. The structural elements on both mesoscopic and megascopic scales provide some guides to regional tectonics. Chattopadhyay and Roy (1976) attempted an analysis of structural history of the eastern part of Manipur. It is envisaged that the area has experienced three generations of fold movements which have left their imprints on mesoscopic and regional scale. Sengupta *et. al*, have critically examined the structural style of Disang sediments and the ophiolite- associated rocks of Manipur.

According to Chattopadhyay and Roy (1976), the earliest folds (F1) are of flexural slip type and vary from tight isoclinal to open fold. The fold axis plunges at a low angle towards north or south. This fold movement has affected Disang Group but not Barail Group. It has been visualised that emplacement of the ophiolites coincided with the dying phase of the first generation folds. Subsequently, deposition of Barail rocks took place. Vidhyadharan and Joshi (1984), however, correlated the first phase of deformation with the formation of regional anticlinal and synclinal structures. F_1 folds are isoclinal and asymmetrical folds. The examples of such structures are reported from Disang rocks, north of Sirohi and oceanic pelagic sediments near Khamasom. Axial planar structures are associated with these folds.

F_2 folds, plunge 0-15° towards NE or SE. These regional NW-SE and E-W folds with broad rounded hinge and subvertical axial plane. In the southeastern part, the axial trace swerves to a N-S orientation. The axes of the folds are subhorizontal with occasional gentle plunge towards NNE or SSW. The doubly plunging nature of the folds has produced elliptical outcrop pattern of the Barail rocks of Eastern Manipur. No axial planar structure is associated with these folds, though occasionally the chert bands of oceanic pelagic sediments show fan like structures as seen in the hinge area. This character of F_2 fold is identical in both Disang sediments and in the sediments associated with ophiolite. The F_2 fold axes are parallel to, or form acute angle with F_1 folds axes.

F_3 folds have affected both Disang and Barail rocks and have long wave length and low amplitude. The fold axes plunge at low to moderate angle towards E-W to ESE-WSW. This generation of folding took place nearly perpendicular to the first generation fold and had steep E-W trending axial plane. It has been visualised that some F1 folds could be accretionary folds formed during the emplacement of ophiolite slices. The F_3 folds of chevron type represent the latest phase of folding and tectonic adjustment.

Sengupta *et. al*, (op. cit.) have opined that in Late Oligocene when the ophiolite zone was brought as an allochthonous mass, imbrication of ophiolite and Disang sediments took place along a narrow zone. Accretionary folds developed over a long period of time, earlier in the oceanic pelagic sediments, and subsequently the Disang sediments allochthonous stack were emplaced. The large scale regional upright F_2 folding of Pliocene deformational history may have also affected both Surma and Tipam sediments. The F_3 chevron folds may also mark some Quaternary movements.

Geological history:

The geological framework of Manipur including the Indo-Burman range along its eastern frontier has to be analysed keeping in view the evolutionary history of Neogene Surma basin, inner Palaeogene Belt of Manipur-Nagaland and the Ophiolite Suture Zone. The geological history of Manipur is a summation of the tectono-sedimentological events which were operating in these domains during the Late Mesozoic and Tertiary era.

Neogene-Surma basin is characterised by NNW-SSE trending series of linear narrow anticlines and synclines forming a unique foreland fold belt. This belt continues in Western Manipur and has an integrated history of evolution with that of Cachar-Mizoram fold belt. It has generally been observed that these folds have a convexity towards west. Structural complexity and intensity of deformation have gradually increased from west to east. As a result, the folds in Western Manipur in Palaeogene and Neogene sediments are open and upright with large wavelength. Nandy (1983) has opined that the deformation of the sedimentary rocks was initiated by E-W compressive stress resulting in shortening, principally by folding and strike faulting. Inner Palaeogene fold belt in Central Manipur exposes mainly Disang Group which has been deformed into open upright folds with vertical to subvertical axial planes. The younger Barail sediments occur only in the synclinal cores. Despite the folding and deformation of Disang sediments in Manipur, the recent surveys give an insight into the pattern of regional facies variation in conformity with tectono-geomorphic setting. The Disang rocks are widely believed to be flysch sediments. But the lithological attributes of Disang rocks of Northern, Western and Central Manipur are diagnostic of their shallow water depositional environment. The abundance of the fragmentary plant remains and a few reported occurrence of arenaceous foraminifers in Disang sediments also coroborate this postulate. In short, they show proximal to distal shelf character of the sediments over a platform. But towards east, close to Ophiolite Suture Zone, Disang Group exhibits the characters of typical turbidites and wild flysch. In other words, Disang basin deepens towards the southeastern part of Manipur. Olistostromal facies, which is remarkably restricted to this belt, is considered to have formed in marginal trenches when tectonic disruption took place along the continental margin. These are generally developed along the steep slopes of the continental margin at the foot of trench wall or a deeply incised canyon by a major phase of gravity gliding (Mitra *et. al,* 1986). It is the dividing threshold facies between the distal shelf sediment to the west and the deep sea sediment to the east. Similar wild flysch to the west of the Indo- Myanmar range is also reported from the adjacent Chin hills (Brunnschieller, 1966) and from Arakan-Yoma and Ramvri Island. Evidently, the olistostromal zone along the western flank of the Naga-Chin-Arakan-Yoma denotes the outline of the continental margin during Eocene period.

The Cretaceous scenario of Indo-Myanmar range is drawn from the study of ophiolite belt of Manipur. This zone comprises the ophiolitic rocks which document certain distinctive characters, viz., alkaline nature of volcanics, absence of sheeted dyke complex and dominance of cumulate complex and slivers of blueschist facies rock. This lithological association and chemistry of the major element of Naga hills ophiolite suggest a possible tectonic setting of their formation as linear ocean island chains, or as non-spreading asiesmic ridge (Venkatramana, 1985).

In Nagaland sector of Naga hills the ophiolite was considered to have been emplaced after Maestrichtian and before Eocene. In adjoining Chin hills the ophiolite sequence is overlain by Upper Albian limestone (Mitchel and Mckerrow, 1975) which documents an earlier age of emplacement. Recent studies in Manipur have indicated that the limestone interbedded with volcanics contain distinct Palaeocene to Lower Eocene biota. It is envisaged that the oceanic crust in this area continued to form up to Lower Eocene period. The oceanic pelagic sedimentary cover over the basaltic rocks also contains rich microforaminiferal biota of Palaeocene to Lower Eocene age. There are also paralic ophiolite-derived sediments of Middle Eocene age. These biotic records indirectly help in reconstructing the temporal sequence of geological events. The minimum age of emplacement of ophiolite indicated by such cover rocks shows that by Middle Eocene a stack of several ophiolite slices was created and oceanic domain between Indian and Burmese plates shrunk in geometry. The continental shelf towards west was receiving Disang and subsequently Barail sediments in Eocene and Early Oligocene. The Late Oligocene regional angular unconformity probably marks the actual Indo-Myanmar continental collision when the ophiolite stack was brought as an allochthonous mass against the Disang-Barail sediments. The ophiolite is, therefore, a rootless sheet-like body emplaced by Middle Eocene. Subsequently, it was carried with the leading edge of Myanmar continent and brought against the distal shelf sediment in Late Oligocene period . The tectonic signature of this event is marked by overturned, reclined to recumbent folds in Palaeogene shelf sediments.

With the suturing of Indian plate with Burmese plate and uplift of Indo-Myanmar range, Miocene molasse basin of Surma valley and Western Manipur evolved to the west of uplifted Indo-Myanmar range. Post-Tipam folding of the Palaeogene rocks of the inner belt of Manipur and molasse sediment to the west led to the development of large scale, open upright folds which marked the linearity of this mobile belt. Continued crustal shortening during the Pliocene period resulted in the development of thrusts in the western margin of this fold belt against the rigid crustal blocks towards west. Minor tectonic events also continued in the Quaternary period which was manifested in tectonic feature of the Quaternary deposits of Imphal valley.

IV. MINERAL RESOURCES

The principal minerals of some economic significance in Manipur are limestone, chromite, dimension stone, lignite and clay. The limestones occur in Upper Disang and Ophiolite zone. The important deposits are located at Ukhrul(25° 06' 45" : 94° 27' 30"), Hungdung (25° 03' 00" : 94° 20' 30"), Khangoi (25° 03' 07" : 94° 21' 50''), Lambui (25° 00' : 94° 16'), New Paoyi and Narum(24° 28' 45" : 94° 19' 25"). Chromite is reported mainly from Ukhrul(25° 06' 45'' : 94° 27' 30''), Gamnom(25° 00' 30" : 94° 27' 30") and Moreh (24° 14' : 94° 19") areas. The lignite, associated with clay, occurs in Kangvai area of Southern Manipur. The other minerals having little or no economic significance include copper, nickel and cobalt bearing minerals, magnetite, asbestos and salt. Dimension stones occur in the ophiolite zones and Barail rocks.

(i) LIMESTONE

Limestone is the chief mineral of Manipur State. Though no large deposit has been located, smaller deposits exist at a number of localities of Ukhrul(25° 06' 45" : 94° 27' 30") and Chandel districts. Eighteen locations have already been identified. Geologically, the limestone deposits could be classified into two broad categories: (i) those associated with Disang Group and (ii) those associated with oceanic pelagic sediments. In the first category, occur olistostromal limestones, which are exotic in nature. These limestones are usually lensoid in shape and randomly oriented within shales- phyllites of Disang Group. They normally occur along or near the western margin of the main ophiolite belt. The largest occurrence is at Ukhrul town. The smaller bodies are located at Hungdung, Khangoi, Lambui and Phungyar-Meiring. On the other hand, Oceanic pelagic sediments associated limestone bodies investigated so far occur in Narum, Lamayang and Kulyang areas of Chandel district. Oceanic pelagic sediments comprise radiolarian chert, shale and sandstone (graywacke). These pelagic limestones are grey to chocolate in colour, fine grained and homogenous. Sometimes, they are cherty and occur as small lensoid bodies are of bedded nature, with a few metres in thickness and tens of metres in length. The oceanic pelagic sediments bearing areas are suitable sites for searching limestone bodies.

Considering small nature of the deposits, the limestone could be better utilised for mini cement plants and lime kilns which would be suitable for such hilly and remote terrain. Such plants would reduce the cost of transportation as they would cater to the local needs only. The cost of infrastructural development for such plants is also limited and their investment would be within the reach of small to medium entrepreneurs. The mini cement plant at Ukhrul is an example.

Salient features of some important limestone deposits / occurrences of the state are described below.

Ukhrul limestone deposit

The deposit occurs on northern and eastern slope of the helipad hill, about 400 metres east of Ukhrul town, near Ukhrul- Sirohi road.

Limestone occurs within shales and sandstones of Disang Group. The limestone bands are overlain conformably by gritty sandstone with minor interbedded shales. The lower contact of the limestone band with shale is not very clear. The regional trend of the beds is NNW-SSE with a westerly dip between 20° and 25°. The deposit has two limestone bands separated by 15 metres thick shale parting. The limestone is massive, fine grained, jointed, fossiliferous (*Globutruncana* sp. and *Gumbelina* sp.) and occasionally occur with clayey materials and lenticles of chert. Chemical analysis of samples indicates the CaO content exceeds 43% and may conform to specification for cement but SiO_2 (14%-20%) and Al_2O_3 (up to 7%) in many samples exceed the specifications. Thus, it is to be upgraded by ore dressing or proper blending.

The extent of the two limestone bands are as follows: the lower band is 120 m x 90 m while the upper band is 260 m x 165 m Exploration by drilling (Ghosal, 1972) revealed a lensoid nature of the limestone bodies with a maximum thickness of 80 m in the central part. A part of the upper band is exposed at the surface and overlain by gritty sandstone and conglomerate. The lower band is not exposed. A reserve of 4.6 million tonnes was proved by drilling. The limestone / overburden ratio is 3:2 for the upper band. This deposit although located at high altitude is accessible.

Hungdung limestone deposit

Limestone occurs here as two separate lensoid bodies. They are spread over a strike length of approximately 3 km, near the village of lower Hungdung. Hungdung (North) deposit is located 8 km south of Ukhrul town on the eastern side of Old Ukhrul-Imphal road. Hungdung (South) deposit is about 3 km further south of Hungdung (North) deposit.

The Hungdung (North) deposit consists of two lensoid bodies, separated by a 9 m thick shale parting. Both the bands dip easterly around 18°. The lower band is 130 m in strike length and is 31 m to 54 m (average 32.77 m thick, while the upper band is 190 m in strike length and having a vertical thickness 32.50 m to 78.25 m (average thickness 51.80 m). The limestone is massive and white, grey and brownish red in colour. The chemical composition of the limestone is given in Table 1.2.4.

Table1.2.4: Chemical composition of Hungdung (North and South blocks) limestone Manipur

	CaO %	MgO %	R_2O_3 %	Insoluble %
Hungdung (North)	43.47	1	4.17	2.24
Hungdung (South)	51.13	1	1.30	6.41

The chemical quality of Hungdung (South) deposit is well within the specifications of cement grade. It may also be used for blending purposes. The proved reserves as estimated by the GSI for the Hungdung (North) is 0.627 million tonnes on the basis of drilling, and the probable reserve for the Hungdung (South) is 0.17 million tonnes. The Hungdung (South) deposit is exposed in a pyramidal shape with a base area of 4500 sq metres.

Khangoi and Mova limestone deposits

These are small limestone deposits located in nearby areas of Ukhrul and Hungdung, occurring within upper part of Disang Group. Limestone at Khangoi occurs as hillock about 18 km southeast of Ukhrul town. The limestone is a cone shaped body occupying a base area of 2500 sq m, massive, jointed and having many cavities. It occurs in white, pink and grey shades, with a strike N65°E-S65°W and dip 10°-15° southeasterly. Probable reserve estimated is 0.26 million tonnes. The average chemical composition of Khangoi limestone is given in Table 1.2.5.

At Mova, limestone occurs about 15 km south of Ukhrul-Imphal road. The deposit is exposed along the Langeshong Khong River and is 75m x 75m in extent with a strike NNW-SSE and a dip of 28° towards NE.

Average chemical composition of Mova limestone, as determined from chip samples, is given in Table 1.2.5.

Phungyar-Meiring limestone area

The area comprises sedimentary formations of Upper Cretaceous to Upper Eocene age. The deposit comprises exotic blocks associated with melange unit. The contact zones are highly tectonised and are indicated by presence of slickensides and silicification near the contacts with Disang Group.

3.2 million tonnes of cement grade limestone as probable reserve has been estimated for Phungyar deposit. Exploration undertaken at Meiring may prove over 3 million tonnes. The deposit can support a 200 TPD cement plant and also augment 50 TPD plant being planned near Hungdung.

Lambui limestone deposit

The deposit is located 28 km southwest of Ukhrul on the old Ukhrul-Imphal road via Lambui. It occurs as small lensoid body within a sequence of shale and sandstone and is exposed in a quarry face. It is milky white, jointed and traversed by thin veins of calcite. The limestone is not exposed along the strike (N15°E-S15°W) but the probable extension of the deposit may be upto 50 m. Due to paucity of exposures the reserve could not be estimated. Chemical analysis of a chip sample gave the composition as given in Table 1.2.5.

Table 1.2.5: Chemical Composition of Khanggoi , Mova and Lambui limestone deposits of Manipur

Components	Khanggoi	Mova	Lambui
CaO	47.74%	51.16%	50%,
MgO	1.00%	0.56%	<1%,
R_2O_3	2.37%	-	3 %,
Insoluble	10.71%	6.39%	<5%.
Fe_2O_3	-	0.45%	-
Al_2O_3	-	0.54%	-

New Paoyi limestone deposit

Three isolated small limestone deposits are located near Paoyi village of Ukhrul district. The area is approachable from Ukhrul by a 30 Km unmetalled road. The olistoliths containing the limestone bodies occur along the axial region of NNE-SSW trending, doubly plunging synclinal fold. The limestones do not show any bedding traces but the associated shale is well bedded. They occur in small mounds in a shaly terrain.

One limestone body occurs just north of New Paoyi village. It is 170 m in length, with an average width of 35 m. The second one occurs at about 770 m S29°E of the first occurrence, and extends for a strike length of 78 m, the average width being 12 m. Both limestones are white in colour, though pink, buff and grey shades have also been observed. They are fine grained, compact and usually massive. The third limestone body occurs at about 950 m N73°E of the first occurrence. This limestone is generally grey and white in colour, compact and crystalline in nature. It is sickle shaped and extends for a length of 164 m The width varies from 15 to 30 m, the average being 20 metres.

The chemical composition of the limestones is given in Table1.2.6.

Table 1.2.6: Chemical characters of the three bands of New Paoyi Limestone

	CaO %	MgO %	Insolubles
1st Occurrence	42.18-45.60	0.82-1.43	14.47-18.73
2nd Occurrence	40.47-45.60	13.51-19.04	13.51-19.04
3rd Occurrence	45.60-55.29	0.82-1.21	0.32-1.46

The limestones are, in general, suitable for cement manufacturing after blending. The deposits have no overburden. The inferred reserves for the first, second and third limestone deposits are 0.222, 0.013 and 0.084 million tonnes, respectively, the total being 0.319 million tonnes. Deducting a 20% allowance due to cavities, mining loss etc. the figure for useable reserve is computed at 0.256 million tonnes.

Kasom limestone deposit

There are three small deposits of limestone along the nala flowing roughly NW-SE on the eastern side of the old Ukhrul road between Kasom and Sokpao villages.

1. A small quarry is exposed along the nala about 1 km east of Kasom (24°58': 94°15'). The strike of the limestone is N5°E-S5°W and dip is 45° towards west. The limestone appears to be similar to that of Lambui deposit, milky white, fine grained.

2. A small cliff section along the nala about 1 km away from the first occurrence. The strike of the limestone bed is N10°E-S10°W and dips 45° towards west. The limestone is fine grained, light grey and traversed by thin veins of calcite and contains argillaceous impurities. The bed is exposed for a strike length of 75 m and the thickness is about 12 m to 14 m. Assuming a minimum width of 12 m and probable reserve upto 15 m may be estimated at 27000 tonnes.

3. The third occurrence of limestone is about 0.8 km further downstream, where the strike is N80°W-S80°E and the dip is 40° towards south. The limestone is massive, cream coloured. The bed is exposed for a strike length of 50 m and the thickness is about 12 m. The probable reserve upto 15 m depth may be estimated as 18,000 tonnes.

Chemical analysis of 5 chip samples from the Kasom area show CaO: 38.41-47.49%, MgO: 0.21-0.81% and insoluble 9.93- 23.08% indicating that the limestones may be used for cement industry after necessary treatment/ blending.

Paorie limestone deposit

Limestone occurs north of Paorie village (24°14’30": 94°24’15") in a N-S trending zone measuring 50 m x 15 m. Limestone blocks ranging in size from 2 m x 2 m to 0.5 m x 0.3 m are spread over this zone. Limestone is associated with stylolites and often traversed by calcite veins. East of Paorie village limestone occurs in a similar way in a zone of 40 m x 15 m. The boulders range in size upto 5.0 m x 3.0 m.

Shangphel limestone deposit

Outcrops of limestone are found about 2 km SSE of Shongphel (25°01’15": 94°01’15") on the Sirarukhong-Imphal road at the 13.5 km stone. The limestone occurs as boulders of 1 m x 1 m dimension which are scattered over a 50 m x 20 m area with E-W trend. On chemical analysis it indicates CaO nearly 50%, MgO < 1% and insolubles < 6%.

Sirarukhong limestone deposit

The deposit occurs 2 km NW of the Sirarukhong (25°04’40":94°14’00") village. The limestone occurs in dense jungle and is approachable from Sirarukhong Tuinam tract, which is jeepable in dry season. Boulders of limestone having approximate diametres from 1 m x 2 m are spread over an area of about 50 sq m. The limestone is of ash colour with thin stringers of calcite veins. Estimation of the reserve of the deposit is hindered due to thick vegetation cover. The analysis of limestone gives CaO = 50%, MgO <1 %, acid insolubles >0 %, R_2O_3 >3%.

Narum limestone deposit

A small limestone deposit occurs 2 km north of Narum (24°28’45":94°19’25") village in Chandel district. The area is approachable from Tengnoupal (24°23’08":94°09’00") by an unmetalled road. Large scale (1: 2000) geological mapping was carried out (Gupta and Mohanty, 1985) to assess the nature and potentiality of the deposit. The limestone occurs as a bedded deposit in the form of a crescent-shaped antiformal structure within pelagic shale. The shape of the body is lensoid. It is thickest (70 m) at the crest. The strike length along NE-SW direction is about 250 m. The average width has been computed at 20 m. The limestone is grey in colour, hard, massive, very fine grained and homogenous in composition. The composition of the limestone is given in Table 1.2.7.

Table 1.2.7: Chemical composition of Narum Limestone

Component	Range	Modal value
CaO	37.08 - 51.96%	44.00%
MgO	0.40 - 2.20%	0.50%
Fe_2O_3	1.50 - 3.50%	-
Al_2O_3	Traces to 0.96%	-
Insolubles	5.98 - 16.32%	10.00%

Based on the surface data the inferred reserve has been estimated at 0.158 million tonnes. Difficulty in approach to the deposit is the main constraint for its utilisation.

Seven other small lenses of limestone occur around Narum, Lamayang (24°28’15": 94°18’05") and Kulyang (24°33’20”:94°17’50") villages, the general nature of which is similar to that mentioned above.

(ii) CHROMITE

Chromite occurs in Manipur as small pockets, lenses and pods in Ukhrul and Chandel districts and are similar to those of Alpine type in their mode of occurrence, physical and chemical characters. They are associated with the meta-ultramafic units of the ophiolite suite. The host rocks are harzburgite, dunite, and serpentinite or combination of these. Physically the chromites are of massive, granular, nodular, banded and podiform types. Besides, chromite is disseminated in dunite and peridotite in which it occurs as highly fractured, granulated and very rarely as idiomorphs within serpentine and bastitied pyroxene.

Important occurrences have been observed in Sirohi-Gamnom areas of Ukhrul district and Moreh area of Chandel district. Though no large deposit has been found so far, small occurrences of upto a few metres in extent have been prospected and worked by surface pitting. The chromites are of high grade with Cr_2O_3 content varying from 44 to 59%. Chemically they are comparable with alpine type chromite in high Cr_2O_3 content (44-59%), low TiO_2 (trace), Cr/Cr+Al (0.59 to 0.88%) and Mg/Mg+Fe_2+(0.46 to 0.74%) content (Venkataraman *et al.* 1984).

Sirohi area

This area is located at about 19 km to the east of Ukhrul. The chromite is of different types namely massive chromite, disseminated chromite and nodular chromite which occur in small pockets. Amongst these, a small but sizeable chromite lens occurs north of the Sirohi peak at an altitude of 1120 m and is known as Northern Lens (Anon, 1973). It has a strike length of 11 m and a width of 8 m and continues up to a depth of 2.5 m. The chromite has a Cr_2O_3 content 47.68 to 56.59% and Fe_2O_3 13.91 to 15.21 %.

The chromite variety is massive, lumpy, and compact and is composed of fine grains of lustrous chromite with very little gangue mineral (serpentine). At places they show slickensided surface. A transition zone between massive chromitite and host serpentinised peridotite is observed at places, which is a weathered friable zone with brownish chromite grains and serpentine materials.

The disseminated chromite is fine grained compact variety composed of chromite grains and minor serpentinite matrix occurring as small clots, patches and stingers. However, the serpentine content is highly variable. The nodular variety of chromite consists of rounded to ellipsoidal chromite grains enclosed in a greenish matrix of serpentinised peridotite. The sizes of the chromite grains varies from 3 cm to 1 cm. The grains are at contact with each other without the presence of serpentine matrix at some places. Sometimes, the nodules show a crude alignment on particular plane.

The chromite bodies of Sirohi area were being mined by M/s Orissa Industries Ltd., Rourkela, a private enterprise by selective quarrying. Most of the pits are of small dimensions ranging from 5 m x 5 m to 12 m x 12 m. Only three pits located north of Ranshokhong area are of larger dimensions of about 20 m x 15 m x 6 m.

Gamnom area

The area is about 10 km southeast of Ukhrul and connected by an unmetalled road, which is jeepable only in dry season. Nine small chromite pockets are located around Gamnom, over an area of 0.4 sq. km, near 40 km post on the Gamnom-Chassad road. These pockets are generally lensoid in nature and arranged in an en-echelon fashion. The intervening areas are covered with boulders of ultramafics and soil. The lengths of the lenses vary from 5 to 20 m and width from 1 to 5 m. Due to soil covered nature of the area, it is difficult to ascertain the continuity of the lenses. The host rocks are serpentinised dunite-harzburgite. Most of the occurrences are composed of massive chromitite, although disseminated and nodular types are also present. Sometimes, the latter two show transitional relationship with the former. The chromitite shows slickensided surface, and the disseminated and nodular types have minor effects of recrystrallisation.

In Harbui Khajui area, one small pocket measuring 20 m x 10 m is located on the 2230 m peak. Its shape is lensoid, the host rock is serpentinite. The chromite is coarse grained and disseminated type.

The chemical composition of the three types of chromite from few samples in Gamnom block are given in Table 1.2.8

Component	Chromitite	Nodular Chromite	Disseminated chromite
Cr_2O_3 %	44.07 to 49.05	45.63 to 46.39	35.75
Al_2O_3 %	18.40 to 20.50	16.30 to 20.00	16.20
Fe_2O_3 %	15.60 to 17.60	16.00 to 16.40	-
MgO %	15.16 to 16.76	15.96	-
SiO_2 %	2.60 to 33.90	3.80 to 4.30	9.02
TiO_2 %	Traces	Traces	Traces

Moreh area

Float boulders of chromite of different types occur near Minou village, over an area of 0.5 sq. km and some small pockets of chromite occur 5 km North of Moreh near Kudeng Thabi which were being worked by M/s Orissa Industries Ltd, Rourkela.

Different types of chromite from Moreh area have the compositions given in Table 1.2.9.

Table 1.2.9: Chemical composition of chromites from Moreh area

Component	Chromitite	Nodular chromite	Disseminated chromite	Host serpentinised peridotite
Cr_2O_3 %	42.32 to 51.24	40.49 to 47.93	47.93	Traces
Al_2O_3 %	1.36 to 1.47	1.34 to 1.47	1.32	0.33
Fe_2O_3 %	13.12 to 14.04	13.06 to 14.37	13.26	6.35
SiO_2 %	3.64 to 10.24	5.72 to 8.54	5.90	40.14
MgO %	13.12 to 15.54	14.05 to 16.92	15.20	33.16
TiO_2 %	Traces	Traces	Traces	Traces

Quality and utilisation prospects

The analyses of chromite from three blocks described in the preceeding paragraphs indicate that they are comparable with the podiform chromites (Cr_2O_3 = 45%) of Alpine belt (Thayer, 1969). Low SiO_2 and Fe_2O_3 in majority of the samples suggest that the chromites would be suitable for refractory industries. From the metallurgical point of view, they are of grade-I and grade-II refractory types. Integrated geochemical and geophysical surveys may complement the geological data to locate more chromite bodies in this belt.

(iii) NICKEL-COBALT MINERALISATION

The Ni-Co concentrations have been reported from the ophiolite belt at several locations. Ni-Co is generally concentrated in peridotite/pyroxenite, weathered ultramafic rocks and ultramafics derived soils. Some higher Ni zones (Ni 0.6%) in two blocks, viz. Gamnom and Sirohi Blocks have been studied systematically (Ghosh *et. al*, 1980). Seven zones were investigated in Gamnom block and ten zones in Sirohi block to assess the nature of nickel concentration. In Gamnom block, nickel values range from 0.62 to 0.66 %. and cobalt values from 30 to 155 ppm. In Sirohi block, the corresponding ranges are 0.25 to 1.68% and 15 to 1000 ppm respectively.

In Moreh block two small patches of massive coarse grained peridotite contained 0.6% Ni on the road section. A few soil samples from Moreh area showed 0.4% Ni, while weathered serpentinites yielded 0.24-0.90% Ni. In Kwatha-Nampesh and Humine areas, the Ni concentration in soil is reported as high as 0.9% (Alwar and Banerjee, 1963).

Dispersion and utilisation prospects of nickel:

No lateritic nickel deposits have developed in this terrain. However, geochemical surveys indicate that Ni is distributed mainly in the massive, ferruginised and brecciated zones of the ultramafic rocks (peridotite / pyroxenite / serpentinite).

Though no regular dispersion patterns are found amongst the massive, ferruginised and brecciated ultramafic zones, it is observed that very often the ferruginised zones are richer in Ni concentration than non-ferruginised zones. Similarly, the massive rock zones show higher Ni concentration than the brecciated rock zones. It is also observed that there is a higher Ni enrichment where the brecciated zones are ferruginised. These features suggest that Ni- enrichment might be largely controlled by the original Ni-content of the parent rocks and the degree of ferruginisation. Serpentinisation does not appear to have played any role in Ni-enrichment.

(iv) DIMENSION STONES

Serpentinite and ultramafic rocks occur extensively in Chandel and Ukhrul districts in the ophiolite belt. They hold prospect of being utilised as dimensional stones for manufacture of tiles, slabs and other building blocks. They take good polish and offer good designs. Idocrase has been found to occur in host serpentinites as pockets, lenses and floats. It can be used for semiprecious jewellery industry, statuettes and other decorative/ornamental stone products. Besides these, Barail sandstones can also be utilized for making dimensional stones. Rock types which are more suitable for dimension stones in the ophiolite belt include varieties of gabbro, dunite, pyroxenite, peridorite, serpentinite and limestone.

(v) SULPHIDES AND IRON BEARING MINERALS

Though no massive sulphide deposit of Cyprus type has been located in this ophiolite belt, occurrences of disseminated and vein-type sulphides are reported from some locations which are associated with the mafic-ultramafic rocks. Nickeliferous copper sulphides, chalcopyrite, chalcocite, cuprite and malachite occur in Nungau and Kongal Thana areas of Chandel district. The mineralisation occurs as small veins and lenses in mafic-ultramafic rocks of the Ophiolite Zone. Few samples from Nungau analysed 1.23-3.3% Cu with trace amounts of Ni and Co.

Few old pits in Sadangching Hill, 5.6 km North of Kwatha village, Chandel district showed presence of oxidised copper materials e.g. malachite, azurite, and associated iron oxide along foliation and joint planes in the serpentinites. Some grab samples analysed 10.56% Cu and 0.33% Ni.

A sulphide occurrence is also located 3 km SSW of Yendem village in Gamnom Block. It occurs as minor, parallel bands of thickness varying from 5 to 20 cm within serpentinite and serpentinised peridotite. The sulphide bands show conformable relationship with the host serpentinite, which strikes N20°E and dips steeply towards south. Serpentinites are exposed over a width of 200 m in the Sonalak river section. At some other spots, sulphides occur as specks and disseminations and rarely as thin bands. Ore microscopic studies indicate marcasite as the predominant mineral phase with minor pyrite and chalcopyrite. The chemical analysis of five grab samples (Ghosh *et. al, al,*1980) is given in Table 1.2.10.

Table 1.2.10: Chemical analysis of samples from sulphide occurrence of Gamnom block, (Values in ppm)

Cu	Ni	Co	Cr	Pb	Au
450-9400	1060-1920	480-900	1000-2000	20-30	1.1-14.5

A 50 m thick band of massive, fine grained, highly compact, brown coloured cherty quartzite in ferruginised and serpentinised peridotite in Sirohi block occurs near 26 Km post on Ukhrul-Jessami road. The quartzite is traversed by veins and encrustations of secondary quartz which contains specks, clots and disseminations of sulphides (mainly pyrite). The pyrite is also replaced by goethite. The chemical analysis of nine quartzite samples did not yield any significant copper (20-90 ppm) or other basemetals. On the other hand, they show nickel concentration ranging from 0.26 to 1.5%.

Besides the above, volcanic rocks, gabbros and plagiogranite at number of places in Sirohi Block show minor and sporadic disseminations of pyrite and chalcopyrite. At Sirohi, sulphide minerals occur within volcanic rocks at the contact of a 30 cm thick magnetite band. They are permeated by malachite stains. The metallic minerals are magnetite (80%), pyrite, chalcopyrite and galena. Pyrite occurs as fractured and isolated grains within chalcopyrite.

(vi) KANGVAI LIGNITE - CLAY DEPOSIT

This deposit occurs near Kangvai village in Manipur South district. Lignite occurs as widely spaced thin lenses, being closely associated with clay of various shades. It shows bedding dip of 45° towards west. It is disposed in a narrow faulted trough underlain by the Disang shales. The deposit covers a strike length of 300 m in north-south and width of 200 m in east-west. An E-W trending cross-fault offsets the continuation of the composite lignite seam. It has a black to brownish black colour and is soft and friable.

Drilling data reveals that the lignite lenses range in thickness from 0.10 m to 0.5 m upto a workable depth of 25 m (Bhattacharya, 1973). It has an overburden of clay of variable thicknesses. The clay is highly plastic when mixed with water. The proved reserve of lignite is of the order of 12,262 metric tonnes, and that of clay is 2.52 million tonnes.

(vii) SALT SPRINGS

Brine solution in natural state is available in several salt springs in Manipur occurring mainly as brine wells. A fairly organised cottage industry for manufacturing of common salt has been developed by local people from this natural brine. Salt is produced by crude methods either by solar dessication in small earthen pots, or by heating small iron pans over fire place utilising local firewoods. The salt cakes thus produced are sold in local markets.

The occurrences of salt springs and minor evaporite in Disang Group were reported by some workers. A large number of salt springs were reported by Dayal (1963) from Disang shales at Waikhong (24°25':93°56') and Shikhong in addition to a few more at Chandrakhong (24°25': 94°08'), Phonjoukhong, Nongnaukunon, Ningel and Keithelmanbi (24°44':94°08'). Chattopadhyay and Roy (1975), reported a few salt springs around Chingai, Mariamphung, Namrei, Lachaikhulen, and Kharasom all of which occur within Chingai Group. Gaur and Khan (1984) reported a salt spring situated 399 m NNE of Thiwa village. Khan and Jayaraman (1985) reported two salt springs located 1.5 Km SE and 0.75 Km ESE of Sanakeithel village respectively.

Most of these salt springs are reportedly seasonal and their discharge varies. Chemical analyses of two brine samples from Sanakeithel village collected by Khan and Jayaraman (1985) and two from Challao and Chingai springs by Chattopadhyay and Roy (1975) are given in ppm in Table 1.2.11.

Table 1.2.11: Chemical analysis of Sanakiethal, Challao, Chingai Brine springs

Parametres	Sanakeithal 1	Sanakeithal 2	Challao	Chingai
TDS	4092	1806	-	-
Na	1236	551	840	20
Ca	76	64	-	-
Mg	50	29	-	-
K	417	545	870	18
$CaCO_3$	400	280	-	-
Cl	2201	790	-	-

X-ray analyses of two samples of evaporite encrustations from north of Kongai village of Manipur East district revealed following mineral constituents (Roy,1986):

Sample No.	Constituents
BR/94a/74-75 & BR/273/74-75	Epsomite (Mg SO_4,7H_2O……..Major. Halotrichite…………..Good amount Anhydrous $MgSO_4$….Small amount

DISCUSSION ABOUT THE ECONOMIC MINERAL DEPOSITS

Mineral occurrences of Manipur State are mainly confined to the Ophiolite belt in the east and its marginal areas. Limestone is found as the main mineral commodity. The nature, quality and reserves of its various occurrences and deposits have already been described in the preceeding paragraphs. These limestone deposits can be utilised for manufacture of cement through small to medium sized plants. They can also find use in lime kilns. Chromite is another important mineral in the ophiolite belt but it occurs only in some small, sporadic and discontinuous pockets, lenses, and pods. Nickel-cobalt concentrations in the ultramafics, weathered ultramafic rocks and soil profiles are highly variable and no significant deposits are located. However, the ophiolite rocks e.g., ultramafics, mafics, volcanics, serpentinite, limestone, chert, quartzite, rodingite etc. hold potential for manufacture of decrorative and dimensional stones.

Inner Palaeogene Disang belt of Central Manipur does not show mineral occurrences except a small lignite-clay deposit of Kangvai valley and a number of saline springs which are used in making salt cakes for local consumption. However, the hard Barail sandstones at the cores of synclines over the Disang Group can be utilised for manufacture of dimensional stones. The western margin sedimentary belt of Manipur which are in continuation of the Surma basin rocks may also hold prospect for oil and gas.

★ ★ ★

LOCALITY INDEX

1	B.P. 130 (25° 26' 32" : 94° 40' 40")	29	Mao (25° 31' 00" : 94° 09' 00")
2	B.P. 125 (25° 13' 00" : 94° 34' 55")	30	Maram (25° 25' 00" : 94° 07' 00")
3	Chingai (25° 18' 48" : 94° 30' 02")	31	Nungbi (25° 12' 10" : 94° 28' 07")
4	Chammu (25° 03' 47" : 94° 36' 45")	32	Narum (24° 28' 45" : 94° 19' 25")
5	Challao (25° 20' 40" : 94° 33' 50")	33	Pushing (25° 03' 00" : 94° 26' 00")
6	Furing (25° 15' 00" : 94° 28' 00")	34	Poi (25° 17' 00" : 94° 34' 00")
7	Gamnom (25° 00' 30" : 94° 27' 30")	35	Phangrai (25° 10' 00" : 94° 28' 30")
8	Harbui Khui (25° 02' 30" : 94° 26' 00")	36	Phungre (25° 11' 22" : 94° 31' 15")
9	Hungdung (25° 03' 00" : 94° 20' 30")	37	Paoroi (25° 14' 00" : 94° 24' 00")
10	Huishi (25° 14' 45" : 94° 33' 30")	38	Paoyi (25° 17' 00" : 94° 24' 00")
11	Hyang Kuki (25° 27' 45" : 94° 36' 52")	39	Phaibung (25° 26' 00" : 94° 22' 00")
12	Huimi (25° 14' 30" : 94° 19' 00")	40	Phuba (25° 26' 00" : 94° 15' 00")
13	Huining (25° 10' 30" : 94° 22' 30")	41	Singcha (25° 00' 30" : 94° 30' 00")
14	Imphal (25° 47' 30" : 93° 57' 00")	42	Sihai Khullen (25° 10' 15" : 94° 24' 30")
15	Jessami (25° 37' 18" : 94° 32' 40")	43	Sihai Khunou (25° 10' 02" : 94° 30' 37")
16	Khamasom (25° 11' 30" : 94° 30' 15')	44	Shangshak (25° 00' 30" : 94° 20' 30")
17	Kudengthabi (24° 18' 15" : 94° 15' 30")	45	Siruhi Furar (25° 00' 60" : 94° 27' 30")
18	Kwatha (24° 20' 30" : 94° 17' 00")	46	Siruhi (25° 08' 00" : 94° 25' 30")
19	Kamjong (25° 52' 00" : 94° 31' 00")	47	Sindong (25° 05' 15" : 94° 19' 30")
20	Khaooat (25° 31' 07" : 94° 20' 50")	48	Tongnoupal (24° 23' 08" : 94° 09' 00')
21	Khaiyang (25° 05' 52" : 94° 38' 45")	49	Tasom Cioi (25° 24' 30" : 94° 35' 38")
22	Kongai (25° 03' 07" : 94° 21' 50")	50	Thangrai (25° 10' 15" : 94° 27' 30")
23	Kunghar (25° 10' 00" : 94° 26' 00")	51	Tolloi (25° 00' 15" : 94° 19' 35")
24	Lambui (25° 00' : 94° 16')	52	Tadubi (25° 29' 00" : 94° 08' 00")
25	Lushat (25° 00' 30" : 94° 31' 30")	53	Ukhrul (25° 06' 45" : 94° 27' 30")
26	Lamayang (24° 28' 15" : 94° 18' 07")	54	Walloli (25° 10' 45" : 94° 30' 37")
27	Moreh (24° 14' : 94° 19')	55	Yangoupokpi (24° 26' 22" : 94° 23' 52")
28	Mapum (25° 04' 45" : 94° 30' 45")	56	Yongkul (24° 30' 00" : 94° 20' 52")

Geology and Mineral Resources of Mizoram State

I. INTRODUCTION:

Geographically, the Mizoram State forms one of the easternmost parts of India, bordered by Bangladesh to the west and south-west, Tripura to the west, Assam to the north, Manipur to the northeast and Burma to the east and southeast. It occupies an area of 23,980 sq.km and the terrain is very rugged and geologically young. It is connected with Assam and rest of the country through the adjoining Cachar district of Assam lying to the north.

The general first order topography of the state is expressed by the dissection of several almost N-S trending longitudinal valleys containing series of small and flat hummocks located between the N-S trending long parallel to sub-parallel hill ranges.

(a) Geomorphology:

The terrain characteristic exhibit a very immature topography. The major geomorphic elements are structurally. In Mizoram the topography and physiographic expression of the state is imparted by approximately N-S trending steep, mostly anticlinal, parallel to sub-parallel hill ranges and narrow adjoining synclinal valleys with series of parallel hummocks or topographic highs. In general, the western limbs of the anticlines are steeper than the eastern limbs. Faulting in many cases have produced steep fault scarps, especially along the steep-dipping fault planes. The other geomorphic elements are the highly dissected ridges with the formation of deep gorges, spurs, keels and cols, which has developed due to intensive erosion. The difference of elevation between valley floors and hill tops varies greatly from west to east and ranges from 200 m to 600 m. The steep hill ranges occur are more towards the east part of the state.

(b) Drainage:

The major drainage pattern having different bifurcation ratios follow the N-S trending depressions and gorges in the low level topography, separated by highland topography in between them. The depressions and gorges, in most cases, are the physiographic manifestations of the faults and other structural trends. The tributaries and streamlets forming ‘angular’, ‘sub-parallel’ to ‘parallel’ and ‘dendritic’ drainage pattern. The drainage gradient in general is moderate. The hills are steep and separated by rivers which flow either to the north or south, creating deep gorges between the hill ranges. There are innumerable rivers, streams and brooks in the state. In the north, the Tlawng (Dhaleswari), the Tuirail (Sonai) and the Tuivawl start from the middle of Mizoram and flowing north fall in the Barak River in Cachar district. In the south, the Karnafuli flows north from the southern tip of the state and from near Demagiri in West Central Mizoram, it flows to Bangladesh where it is being tapped for a huge hydel project. The Koladyne River enters Mizoram from Burma and near Lunglei it takes a U turn and re-enters Burma again.

(c) Climate and rainfall:

Mizoram has a pleasant climate. It is generally cool in the summer and not very cold in winter. In the winter the temperature varies from 11°C to 24°C and in summer between 18°C to 29°C. The area receives good with heavy rainfall from May to September, with an average rainfall of 254 cm. per year.

(d) Vegetation and wild life:

Vegetation growth in the state is abundant with plenty of trees, plants, bushes, grass. bamboos grow here abundantly. The forests are also crowded with wild animal like the elephant, tiger, leopard, bear, wild dog, mithun, deer, wild pig, etc.

(e) Previous work:

La-Touche (1891) was the earliest worker in Mizoram, who took short traverses in the area (the then Assam-Arakan geological province) and found the area to consists of a great flysch facies of rocks comprising monotonous sequences of shale and sandstone which are folded into N-S orientation. He believed that the rocks are, southerly continuation of the Cachar Hills and were probably laid down in a delta or estuary of a large river during the Late Tertiary period. No mineral deposit of economic importance was located by him in the area.

Later, Munshi (1962) mapped the rocks of the central part of Northern Mizoram and divided the rocks of the Surma Series into Bhuban and Bokabil, stages. According to him, the rocks were thrown into folds representing a series of longitudinal anticlinal hills and narrow synclinal valleys under considerable compressional forces. Four saline seepages and one oil seepage here were located by him. Recently, Nandy, Mukherjee and Majumdar (1972) recasted the stratigraphy and gave the sedimentation behaviour and tectonic history of the central part of Mizoram by conducting systematic geological traverses. They sub-divided the Surmas on lithostratigraphic basis into Bhuban Sub-group into Lower, Middle and Upper formations. The Barails have been mapped in the eastern most part of Mizoram. They also described different structural patterns of Barails and Surmas. According to them, the rocks belonging to Surma Group were laid down in relatively shallow water conditions in a near shore environment or deltaic conditions.

Subsequently, Nandy and Sarkar (1973), and Mukherjee and Saxena (1973) worked separately in the western part of Central Mizoram and Southern Mizoram respectively. Following the previous lithostratigraphic scheme they traced the same stratigraphy and elucidated the sedimentation history. Further, Nandy and Sarkar (op.cit) divided the rock formations into several facies on the basis of lithology and sedimentary structures. Nandy and Sarkar (op.cit) are of the opinion that the sedimentation in these parts took place in deep sea flysch environment by the action of turbidity current. Mukherjee and Saxena (op.cit), however, also expressed the same view from their observations.

II. Geology

Until recently, only the northern and western parts of Mizoram were covered by systematic geological mapping. In the central and southern part of the state only small portions were covered. The general geology of the area mapped exhibits repetitive succession of Neogene sedimentary rocks of Surma Group and Tipam Formation. These sequence are folded into a series of approximately N-S trending longitudinal plunging anticlines and synclines. The lithounits include mostly sandstone, siltstone and shale. The topographic expression of the area often imparts fairly good indication of their lithology. The arenaceous and argillaceous group of rocks occupy relatively higher and lower grounds respectively. Based on the work carried out far in the state, a generalised lithostratigraphic succession is given in Table 1.3.1.

Forming the small proportion of area mapped in the eastern most part of the state, knowledge of geology of this area is far from complete. Reconnaissance traverse from Aizawl to Champhai indicated the presence of Barail Group of rocks in and around Champhai subdivision, Aizawl district and Bhuban Formation exposed in the west. Barail Group comprises a monotonous sequence of shale interbedded with siltstone and hard compact, thinly bedded, grey to khaki, fine grained sandstone. Locally they include minor bands of weathered, micaceous felspathic sandstone. The geology of this part is modified as per compiled 1:50K geological map of the area.

Table 1.3.1: Lithostratigraphy of rocks in Mizoram

Group	Formation	Lithology
	Recent	Loose, friable and unconsolidated pebbles of sandstone and fragments of shale in sandy matrix
	~~ unconformity ~~~~~~~~~~~~~~~~~~~~	
Tipam Group	Tipam Formation	Mainly arenaceous rocks consisting of medium to coarse, buff coloured loose, friable micaceous sandstone with subordinate shale and siltstone. Fossilwood (drifted) has been reported from this unit
	------------ Contact conformable to transitional ------------	
S U R M A	Bokabil Formation	Mainly argillaceous rocks represented by shale / siltstone and thinly bedded sandstone alternations with subordinate buff coloured, fine to medium grained soft, friable sandstone
	———— Contact conformable to transitional ————	
	Upper Bhuban Formation	Mainly arenaceous rocks which includes mainly thickly bedded, grey, khaki, buff coloured fine to medium grained, at places friable, kaolinised sandstone with very fine grained sandstone, siltstone, shale (grey, olive green) interbands, with shell limestone as lensoidal bodies, conglomeratic at places, grey, very fine grained to fine grained, hard compact, calcareous sandstones
	———— Contact conformable to transitional ————	

G R O U P	Middle Bhuban Formation	Mainly argillaceous rocks which include grey, khaki shale, silty shale and siltstone/ shale interlaminations with grey, buff coloured hard, compact, micaceous, fine to medium grained, thinly to moderately bedded sandstone with a few thick, grey, hard, very fine grained, micaceous sandstone bands
	Contact conformable to transitional	
	Lower Bhuban Formation	Mainly arenaceous rocks which includes fine to very fine grained, compact, blue, ash, green coloured, massive to well bedded sandstone exhibiting turbidite features and well laminated siltstone, olive green silty shale/shale interlaminations
	~~ unconformity ~~~~~~~~~~~~~~~~~~~~~~~~~~~~	
BARAIL GROUP		Shale and siltstone with bands of weathered and micaceous, medium grained yellowish greywackes. Locally, a few hard, dark grey compact, medium to fine grained quartzwacke bands are present

Barail Group:

Barail Group occupies the entire eastern part of the state. Barail Group is lithologically dissimilar from those of the Bhuban Formation lying to the west. Further they exhibit different structural alignments. The Barails comprise monotonous sequence of weathered shale, interbedded and interlaminated with siltstone exhibiting different colourations on weathering like pink, violet, greenish grey, white etc. Locally, they enclose bands of weathered micaceous, feldspathic, soft, medium grained sandstone (greywacke) with a few dark grey, hard, compact, medium to fine grained sandstone bands. Rarely, the sandstone contains thin stringers and streaks of carbonaceous matter. Unlike the Bhubans, the Barails contain few sedimentary structures like flute casts and oscillatory ripples, etc. The rocks have low (3°-15°) rolling dips and have been folded into a broad anticline with the axis trending approximately E-W.

Surma Group:

The major litho unit exposed in the Mizoram State is the rocks of Surma Group and is represented by Bhuban and Bokabil Formations. Based on the lithological characters, physical characteristics and order of superposition, Bhuban Formation are further subdivided into Lower, Middle and Upper.

Bhuban Formation:

1. Lower Bhuban Formation:

It is predominantly arenaceous and composed of fine to very fine grained, compact, grey or blue, thickly bedded lithic greywacke, and buff coloured massive, medium to fine grained less compact sandstone. The grey sandstone is poorly sorted and locally calcareous, thinly bedded, hard, compact, fine to very fine grained with interlaminations of well-laminated siltstone and shale showing certain turbidite features. The shales are dark grey, micaceous, compact, locally splintery and iron stained. No fossils have been recorded so far from this formation.

2. Middle Bhuban Formation:

This unit conformably overlies Lower Bhuban Formation with gradational contact. It is predominantly argillaceous and characterised by thinly bedded shale, siltstone, mudstone with subordinate sandstone. The shales are of dark grey to greenish grey colour, moderately hard, usually splintery and frequently iron stained. Siltstones are dull, pale-greenish grey in colour and well laminated. The sandstones are normally thinly bedded, but however, at places there are thick beds. They are grey or khaki-coloured, fine to very fine grained, micaceous, hard, locally calcareous in nature and occur in alternation with shale and siltstone. The moderately thick to thick bedded sandstones are comparatively soft, friable, medium to fine grained at places and enclose fragments and patches of shale. Sedimentary structures like linguoid ripple marks, micro-cross stratification, lenticular and wavy bedding, convolute laminations, slump structures and load casts are found to be associated with this unit. Worm burrows of different shapes and sizes are observed both along and across the bedding plane.

3. Upper Bhuban Formation:

This unit conformably overlies the Middle Bhuban Formation with gradational contact. It is predominantly arenaceous, represented mainly by thick sandstone beds. They are hard, compact, grey to khaki coloured and medium to very fine grained. Locally thinly bedded, micaceous sandstone with subordinate siltstone and shale also occur within this unit. Weathered sandstones are buff coloured and comparatively less compact. At many places, fragments and patches of shale / clay and irregular streaks, stringers and patches of lignite-bituminous coal with or without pyrite are enclosed within khaki coloured sandstone. The shale is grey to ash grey in colour and breaks into splintery fragments due to multiple joint sets. Petrographically, sandstone is poorly sorted, immature to sub-mature, angular to subangular greywacke. The primary structures of fine-grained sandstone which are thinly bedded with alternate siltstone / shale bands are indicative of turbidity current and tidal flat features.

Apart from this, shelly limestone lenses, thin calcareous sandstone bands and pebble beds are also present within this formation. The limestone is hard, compact and dark grey in colour and contains broken or complete shells along with pebble, sandstone and shale.

Various shapes and sizes of calcareous concretions and spheroidal nodules also characterise the Upper Bhuban Formation. This unit exhibits linguoid ripple marks, ripple drift laminations, lenticular and wavy bedding, cross stratification, ball and pillow structures, convolute laminations, flute casts and load casts at places, along the bedding plane of the sandstone a white film of precipitated fine salt is observed. Chemical analysis of this salt indicates that it comprises of 20.70% insolubles, 13.40% MgO, 32.28% SO3 and 1.65% R2O3.

Pelecypods and gastropods have been recorded from sandstone and grey shale at a number of localities. Ichnofossils of various shapes and sizes are also noticed along as well as across the bedding planes. These are detailed in Table1.3.2.

Table 1.3.2: Fossils assemblage of Upper Bhuban Formation.

Fossils	**Genera**
Pelecypods	*Chlamya sp., Pecten sp., Corbula sp., Spondylus sp., Nuculuna sp., Pitar sp., Solen sp., Venericardium sp., Grassetella sp., Tellina sp., Barbatia sp., Nucula sp., Mactra sp., Donax sp.*
Gastropods	*Ramella sp., Volutospina sp., Conus sp., Solariella sp., Lunatias sp., Oliver sp., Murex sp., Harpa sp., Architectornica sp.*
Foraminifera	*Ammonia sp., cf. beccari, Ammonia papplilosa, Globigerina sp.*
Ostracoda	*Laguminocytheris sp.*
Bryozoa	*Acanthodesia sp.,* Cheilostome bryozoans
Echinoid	*Omissaster sp., Oppissaster sp.,*
Coral	Individual Polyps (very rare)
Cirripedia	Burnacles
Crustaceans	*Portunus sp.,* and other indet forms
Vertebrates	*Hemipristis sp., Carcharodon sp., Odontaspis cuspidata*
Ichnofossils	Worms burrows both parallel and perpendicular to bedding, mostly branching type
Plant	Fragmentary impressions of Bark tree

Bokabil Formation:

This unit conformably overlies Upper Bhuban Formation and their contact is also gradational. It mainly occurs on either flanks on the anticlinal ridges or in the core of the synclines. It is predominantly argillaceous comprising shale, siltstone and thinly bedded sandstone alternation with sub-ordinate friable, buff-coloured, medium to fine grained, micaceous sandstone. The shale is khaki, brown, purple-coloured, micaceous and breaks into splintery fragments.

Tipam Formation:

Tipam Formation conformably overlies Bokabil Formation with a gradational contact. It is a dominantly arenaceous unit and occurs in northern and western parts of Mizoram. It comprises buff coloured, medium to coarse grained, massive, loose, micaceous sandstone with subordinate laminated grey siltstone / shale intercalations. In the lower horizon, the sandstone becomes bluish grey in colour and comparatively hard. Fossil wood (drifted) has been recorded from this formation.

III. STRUCTURE AND GEOLOGICAL HISTORY

The major structural trends in the state coincide with regional tectonic trends. The average strike of the bedding is NNE-SSW with dips varying from 40° to 50° towards both east and west. The sediments are folded into close to open asymmetrical anticlines and synclines along

N-S axis. Locally the folds are doubly plunging and show shallow (15° to 20°) plunge towards north / south. The limbs of the major folds are often folded into meso-megascopic chevron type of later folds. The megascopic folds are commonly developed in siltstone-shale units and less commonly in sandstone units. Mesoscopic folds are observed mainly on the incompetent units of Middle Bhuban Formation. The overall folding geometry remains similar throughout the area, though the intensity of the folding are more in the east compared to the west.

Faults present in the area are longitudinal, transverse and oblique types affecting the folded sequence. The major faults are longitudinal strike faults along the crest of the folded beds. It is difficult to measure the throw of the faults due to the absence of any marker horizon.

There are four sets of joints, viz, N-S, ENE-WSW, WNW-ESE, NW-SE. The bedding joints are most prominent.

Sedimentary structures include simple and interfering ripple marks (linguoid and rhombohedral type); ripple drift cross- laminations; lenticular/wavy bedding, flaser bedding, cross- stratification, flute-casts, load casts, groove marks and convolute laminations.

The palaeocurrent directions inferred from sedimentary features reveal a mean southerly transport direction which is indicative of a southerly slope of the basin floor.

Geological History:

The paucity of data on Barail Group has led the compilations on geological history to be confined to post Barail formations. From the study of provenance, palaeoslope, dispersal pattern of primary sedimentary structures and regional tectonic pattern of the sediments, it is concluded that deposition in the tectonic trough after the Barail upheaval was likely.

The lower part of this entire sedimentary sequence is dominantly argillaceous, while the upper part is dominantly arenaceous. The lithic greywacke of the lower part shows a distinct rhythmicity. Generally current bedding is absent, while slump structures and convolute bedding are common. Occurrences of cut and fill structures, total absence of pelagic clay, graded bedding, volcanics or tuffs are noted in the sequence. The upper part shows discernible current bedding, flaser bedding, shallow-water biota and ichnofossils. The biota and the sedimentary structures show the deposition of the lower part of the sequence in a deep water flysch type of sedimentary environment, while the upper part of the sequence exhibits molassic characteristics.The entire pile of sediments was uplifted and folded during the Mio-Pliocene time.

IV. MINERAL RESOURCES

No major mineral deposits of economic importance have been reported so far in the state. However, in course of systematic geological mapping, occurrence of shell limestone, coal, hard sandstone bands (suitable as building material), saline springs and a few gas seepage have been located.

(i) COAL

Chubel village (24°03'30":92°25'55"): Occurrence of a 3-metres-long and 10-cms-thick, grey, pyrite-bearing, lignite patch in soft, brownish, yellow, ferruginous, Bokabil Sandstone has been reported south of Chubel village. About 6.5 kms southeast of Ngopa, a few lenticular pockets of coal within very fine grained, greyish white quartzwacke of Barail Group(?) are located. These isolated pockets do not exceed 25 sq. cms in section and have a maximum thickness of 5 cms. Also streaks, stringers and patches of coal are found in the Upper Bhuban Sandstone.

(ii) LIMESTONE

Sporadic occurrences of Shell limestone bands and boulders within Upper Bhuban Formation have been located at the following localities:

1. 7 kms NE of Muthi village.
2. About 4 kms east of Kwarte Thanwveng along Kwartethanwveng - Derlak foot track.
3. 5 kms east of Sesawang village, Dam Lui .
4. Nghrum Lui near the Turial bridge.
5. Laipui Tlang (Chanmari Lui) at Aizawl and near P.H.E. rest house on Reick-Aizawl road.

The shell limestone bands usually occur as detatched lensoidal bodies associated with sandstone and siltstone of Upper Bhuban Formation and have thicknesses ranging from 10 cms to nearly 1 metre with strike continuity of about 5 metres. However, bands of shell limestone occurring at Muthi extend over a strike length of over 150 metres. Shell limestone boulders ranging in size from 1 to 1.5 cubic metres occurring over limited strike length and embedded in sandstone-siltstone of Upper Bhuban Formation have been noticed on Aizawl-Reick road. Shell limestone boulders occurring at Chanmari-Lui (Aizawl) and Nghrum Lui near Turial bridge vary in size from 0.1 to 1.0 cubic metres. As per ISI specifications, this limestone can be used in making lime puzzolana.

(iii) BUILDING MATERIAL

In view of the great dearth of hard rocks in Mizoram, the massive, hard compact, grey, calcareous sandstone of Lower and Upper Bhuban Formation is suitable for use as road metal and building material. Hard rock potential localities in Mizoram include Dhaleswari river bed north of Kamzawal(22° 56' 04" : 92° 46' 15"), 1 km east of Hnathial(23° 34' 45" : 92° 28' 06") on Hnaithial- Tarpho road west of Buarpui and two discontinuous ridges almost parallel to Hnathial-Bungtlang road on both sides, Tui Chang river bed southeast of Kaithum 2 kms SW of Pilar along Kartunm-North Vanlaiphai road, North of Demagiri on the eastern bank of Karnaphuli river, 1.5 kms southwest of New Vervek, 1 km north of Lungsum, 1.2 kms west of Lungsum, south and north of Theiriat, south of Zobawk(22°51'45":92°49'00"), around Darzo, western side of South Vahlaiphai, southern side of Lunglai(22°53'30":92°50'00"), Khawava- Lui-Zatland sector, along Tuity Lui, northern side of Dawan, bank of Mat river and Hnamgchal Kawn-Kamzawl road, south of Rulkual(22°23'30":92°52'50"), southwest of Bingt Lang, east of Thingfal(22°37'00": 92°52'40"), west of Vanhni(22°24'20":92°54'10"), north of Mante(22°37'00":92°55'10"), southwest of Saikah and along the Lawngtlai-Saiha road. The quantities of these types of sandstone though not estimated are large. Border Road Task Force is already quarrying this sandstone for use as road metal.

(iv) GAS AND OIL

Indication of oil, saline springs and a few gas seepage in the central part of Mizoram were reported by Munshi (1964). Salt spring has been located north of Sabual village in western part of Mizoram (Moorthy,A.S.,1984-85). Recently, Oil and Natural Gas Corporation (ONGC) has taken up exploration in a big way, particularly in Western Mizoram.

(v) CLAY

A thin horizon of clay is noticed northwest of Borai, near Momchera and in the valley near Phura village. At Borai and Momchera, clay is dark grey in colour and is found associated with buff coloured medium to fine grained, less compact, friable sandstone. At Plura village(22° 14' 00" : 92° 54' 40"), the clay is silty and at places mixed with sand. The clay has a potential for brick making.

LOCALITY INDEX

1	Chubal village (24° 03' 30" : 94° 25' 55")
2	Hnathial (23° 34' 45" : 92° 28' 06")
3	Kamzawal (22° 56' 04" : 92° 46' 15")
4	Langpu (23° 49' 45" : 92° 38' 10")
5	Lawngtlai (22° 31' 50" : 92° 54' 10")
6	Lungsen (22° 52' 45" : 92° 35' 30")
7	Lunglei (22° 53' 30" : 92° 50' 00")
8	Mante (22° 37' 00" : 92° 55' 10")
9	Plura (22° 14' 00" : 92° 54' 40")
10	Rulkual (22° 23' 30" : 92° 52' 50")
11	Saithual village (23° 41' 15" : 92° 39' 00")
12	Thingfal (22° 37' 00" : 92° 52' 40")
13	Vanhni (22° 24' 20" : 92° 54' 10")
14	Zobawk (22° 51' 45" : 92° 49' 00")
15	Sesawang (23°44'30" : 92°51'30")

★ ★ ★

Geology and Mineral Resources of Nagland

INTRODUCTION:

Nagaland is located in the northern extension of the Arakan Yoma ranges representing orogenic upheavals in this part of the country during Cretaceous and Tertiary periods. It has three neighbouring states, Arunachal Pradesh on north, Assam on west and Manipur on south. With an area of 16,527 sq km, it has a population of 1,99,0036 people according to the 2001 census.

The state is largely a hilly region and people prefer to build their houses on the hills and mountain tops rather than in the valleys or the terraces of the hills. The highest mountain in the state is 3000 m high and most of its 1112 villages are located in the lower hills with some of them being placed even in the upper reaches.

Prior to Independence, the activity of the Geological Survey of India in Nagaland was of the nature of traverses, and the search for mineral resources was largely restricted to the more accessible parts.

After the Burma Oil Company had assumed technical control of the Assam Oil Company in 1921, a unified programme of geological mapping and test-well drilling could be applied to the whole of Assam and neighbouring regions. After Independence, besides systematic geological mapping for preliminary mineral assessment and for unravelling the stratigraphic and tectonic features of the state, mineral investigations were undertaken from time to time by the Geological Survey of India. It is in this background of geological studies, the Survey had drawn up plans for comprehensive and integrated geological surveys and as a first step towards achieving this a Directorate of the Survey for Nagaland-Manipur had been set up for fulfilling the tasks. This Directorate is steadily enhancing its activities and broadening its spectrum of scientific investigations aided by sophisticated instruments. With the active co-operation of the Government of Nagaland and full-fledged collaborative programmes of work between the State Directorate of Geology and the Geological Survey of India, Nagaland will move forward with long strides in developing its mineral potential fully.

An inventory of the existing information pertaining to the mineral resources of the state reveals that the coal horizons of Nazira Coalfield and that of Changkikong-Japukong region appear to be most important among the economic minerals found in Nagaland so far. Various other important minerals like chromite, magnetite, nickel-ore and limestone, have been located and detailed investigations are envisaged in the coming field seasons.

Previous work:

Mallet (1876), in his memoir, gave a comprehensive account of the Nazira Coalfield in Nagaland. Later on Hayden (1910) working in some of the coalfields in Nagaland pointed out that the coal seams gradually thin out to the southwest of the Dikhu Valley and further westward they are represented merely by carbonaceous shales. Evans and Mathur (1964) gave a regional geological picture of the entire belt of Schuppen. Limaye and Debadhikari (1967) and Debadhikari (1968) mapped the Changikong -Japukong area and investigated coal and limestone occurrences. In 1969 and 1970 Mitra and Chowdhury have carried out detailed mapping of Borjan-Changikong Coalfields in Nagaland. Bhaumik, Majumder and Ahmed(1973), in a reconnaissance survey, studied the reported occurrence of magnetite, nickel and coal belt in and around Pukphar village, Tuensang district.

Agarwal and Iqbal (1970-71) carried out geological expedition to Saramalai peak on Indo-Burma border, Tuensang district and discovered a limestone deposit. Das (1986-87) carried out detailed study of Manipur-Nagaland ophiolite. Roy and Acharya (1987-88,1988-89,1989-90) carried out detailed comparative study of ophiolite belts in Andaman and Nagaland. Photogeological study of different parts of Nagaland was carried out by Verma (1988-89). Mapping of Quaternary deposit which is of limited extent was carried out by Madhav Chandra (FS 1988-89). Geoenvironmental appraisal of Kohima and Dimapur was carried out by Shukla (1986-87, 1987-88).

During the past two decades, the geologists of GSI (Agarwal and Chandramadhav (1988-89), Ananda Murthy and Madhav Chandra (1989-90), Sengupta (1982-83,1984-85), Srivastava (1982-83),Sahu and Venkatasamy (1989-90), Chakradhar and Gaur (1984-85), Chakradhar and Jayraman (1985-86), Chakradhar (1985-86), Sahu and

Venkatasamy (1988-89), Devdas and Gandhi (1984-85, 1985-86), Sahu and Naik (1987-88), Sarma (1983-84,1984-85), Jana and Devdas (1983-84), Shitiri (1993-94) carried out geological mapping in Phek, Tuensang, Zunheboto, Kohima, Mon, Mokokchung and Wokha districts of Nagaland.

II. GEOLOGY

Geotectonically four distinct domains have been identified in the Naga Hills, which are framed between the foreland spur of Shillong and Mikir Massifs to the west and central Myanmar basin to the east. These are: (1) Assam Shelf, (2) Schuppen Belt, outer belt of imbricate, anastomising thrusts (Evans and Mathur 1964), (3) Inner Palaeogene Fold Belt, comprising thick folded sequence of Disang and Barail rocks, and (4) Ophiolitic Complex occurring further east, close to Indo-Myanmar border, associated with Late Mesozoic-Tertiary sediments.The general stratigraphic succession of the belts is given in Table 1.4.1.

Table1.4.1: Generalised stratigraphic succession in Nagaland

Age	Group	Assam Shelf	Belt of Schuppen	Palaeogene Inner Belt	Ophiolite Belt
Recent and Pleistocene		Alluvium and Terrace deposit	Alluvium and Terrace deposit	Alluvium and Terrace deposit	Alluvium and Terrace deposit
			~~unconformity~~~	~~~unconformity~~~	~~~unconformity~~~
Plio-Pleistocene			**Dihing Formation:** Conglomerates, grits, sandstone and clay beds		
			~~unconformity~~~		
Pliocene			**Namsang Formation:** Thick beds of grits and conglomerates with occasional sandstone and claystone		
			~~unconformity~~~		
Miocene	**Tipam Group**		**Girujan Clay Formation:** Clay, mottled sandy clay, mudstone with subordinate ferruginous sandstone		
		Tipam Sandstone Formation: Grey, thickly bedded sandstone Green claystone towards top	**Tipam Sandstone Formation:** Thickly bedded, medium to coarse ferruginous sandstones with interbands of siltstones and clay		
			Bokabil Formation: Alternating sandstone and shale		
			Upper Bhuban: Sandstones with subordinate siltstone and thin shale bands with a basal conglomerate		

Miocene	**Surma Group**		**Middle Bhuban:** Siltstones and shales with subordinate sandstone often have characteristic basal conglomerates		
			~~unconformity~~~		
			Lower Bhuban : Sandstones with shale, siltstone and clay with a few pebble beds and conglomerates		
Oligocene	**Barail Group**		**Renji Formation:** Very thick sequence of hard, ferruginous, thickly bedded sandstone with minor shale and siltstone	**Renji Formation:** Hard, ferruginous, very thickly bedded multistoreyed massive sandstones	
			~~unconformity~~~		
			Jenam Formation: Shales carbonaceous shales siltstone and sandstone with a number of coal seams	**Jenam Formation:** Alternating sandstone, siltstone and grey to dark grey shale with few coal seams	
			Laisong Formation: Well bedded, laminated sandstone occasionally with alternating siltstones. Thick units of shales occur sometimes in the upper part	**Laisong Formation:** Medium to fine grained, well bedded, hard, light grey to grey laminated sandstone alternating with grey shale, sandy shale and siltstone	
Upper Cretaceous to Eocene				**Disang Formation:** Grey, khaki grey, black splintery shales with silty interbands, lensoidal sandstones (6 to 8m thick) and rhythmites	
Middle Eocene					**Phokphur Formation**: Polymictic conglomerate, tuffaceous greywacke, lithic feldspathic arenite. These sediments are mainly derived from the underlying ophiolites
					~~unconformity~~~
Palaeocene to Lower Eocene					**Salumi Formation:** Shale and siltstone with interbands of radiolarian chert

Cretaceous to Lower Eocene					**Ophiolite Suite:** Dismembered tectonic slices of serpentinites, cumulates and volcanics associated with cherts and limestones
					~~Tectonic contact~~
Lr. Eocene to Up. Cretaceous					**Nimi Formation:** Quartz-sericite-chlorite schist, phyllite, feldspathic quartzite, limestone
					~~Tectonic contact~~
Pre-Mesozoic					**Saramati Formation:** (Naga Metamorphites) Quartz-muscovite-biotite schist, quartz schist, carbonaceous phyllite, quartzite, sheared granites

Assam Shelf comprises a relatively thin sequence of sediments of Barail Group, Surma Group and Tipam Group resting unconformably on a pre-Tertiary granitic basement exposed mainly in Dhansiri valley. Part of Assam Shelf sediments has been thrust over by tectonic slices of Schuppen Belt.

Schuppen Belt is a composite of six tectonic blocks formed by several thrust slices occurring along Naga-Patkai hill ranges of Nagaland. The belt comprises Barail Group, Surma Group, Tipam Group, Namsang Formation and Dihing Formation.

Inner Palaeogene Fold Belt comprises folded and thrusted post-Upper Cretaceous sequence commencing from Disang Group onwards to Surma Group of sedimentary rocks, over which Recent and Pleistocene sediments have been deposited.

Ophiolite belt has a tectonic contact with Inner Palaeogene fold belt in the west and Saramati Formation in the east of pre – Mesozoic age as the oldest formation in the belt. Nimi Formation overlies Saramati Formation which is succeeded by Ophiolite Suite, followed by Salumi Formation. Phokphur Formation is the youngest group of rocks in the belt.

Saramati Formation:

Tectonic slices of meta-sediments occur east of ophiolite belt for which different terms have been used by different authors. These were correlated with the Naga Metamorphites (mesograde) by Brunschieller (1966), who described them in the Myanmar sector. Agarwal and Iqbal (1970-71) grouped the meta-sediments east of the Ophiolite Belt as the 'Metamorphics'. Acharya et. al, (1982) later termed them as Saramati Formation. These are extensive lithostratigraphic units of schistose quartzite, quartz-mica schist, and carbonaceous phyllite exhibiting banded structures. This formation is well developed in and around Saramati peak (25°44'24":95°02'25").The sedimentary nature of this formation is indicated by the clastic nature of the rocks, bedded sequence marked by arenaceous and argillaceous alternations, current & graded beddings and cut-and-fill structures. Banded nature is observed throughout but in the upper member the banding is less conspicuous.The lithostratigraphy of westerly dipping Saramati Formation is given in Table 1.4.2.

Table1.4. 2: Lithostratigraphy of Saramati Formation

Member	Lithology
Upper (dominantly argillaceous)	Quartz-muscovite schist, quartz biotite schist with fine intercalations and interbands of foliated quartzites
Lower (dominantly arenaceous)	Alternating sequence of grey foliated quartz-muscovite schist, quartz schist and carbonaceous phyllites.

Dominant members of this unit are schist, quartzite, gneiss, their admixtures and mylonitised/phyllonitic equivalents. Mineral assemblages indicate that metamorphism probably took place between 250º and 450º C and at 2-4 Kb.

Lower Member:

The older member of Saramati Formation is restricted to east of Thanameir village near Saramati peak. The member is offset by a major NW-SE trending fault. The rock types are foliated feldspathic quartzites alternating with muscovite-biotite schist. Arenaceous units dominate over the argillaceous. Dark brownish grey schistose rocks are interbanded with grey quartzites. Persistence of biotite in the mineral assemblage indicates slight increase in grade of metamorphism. Petrographically the predominant mineral in feldspathic quartzite is quartz,feldspar with muscovite and biotite in minor proportions. Rock shows granulation in the form of breakdown of larger grains and deformation lamellae. Quartz grains are strained and show wavy extinction. Muscovite and biotite have developed as scaly aggregates along straight to curved interface of quartz grains. Epidote occurs as an accessory. Rounded epidote grains point to their sedimentary nature (Bhattacharya and Sanyal, 1983).

Muscovite-biotite schist is composed of muscovite, biotite, and quartz. Fine flakes of muscovite and biotite alternate with thin bands of fine grained quartz. Biotite alters marginally to chlorite at places. Very minor flakes of graphite are noted.

Upper Member:

The lower unit of this formation is gradationally overlain by an assemblage of meta-sedimentary rocks, wherein argillaceous units are dominant. Banded nature is present throughout the area of Fakimile and Thanameir. The member has a thrusted contact against the younger Nimi Formation. The prominent units of this member are dark grey to brown sericite schist and sericite-muscovite schist with thin intercalations of quartzites.

Recent studies of the less deformed units of this formation have failed to yield any fossil. The rocks have a well developed schistosity and are affected by folds of complex geometry. In the absence of any radiometric age data or fossil occurrence, the stratigraphic position of the Saramati Formation is not known. Saramati Formation (Naga Metamorphites) was regarded to be pre-Mesozoic in age by Brunschieller(1966).

The stratigraphic status of Saramati Formation is rather enigmatic. The suite of metamorphic rocks, in the descriptions of Naga Metamorphites (Brunschieller 1966), correspond to a meso-thermal assemblage, whereas the metamorphics of the Saramati Formation define an epi-thermal grade. Further, Naga Metamorphites bear imprints of pre-Alpine deformation, whereas the structural style of Nimi Formation and Saramati Formation, which have overridden it, do not show any remarkable difference. It is, therefore, to be ascertained by further studies whether the Saramati Formation forms the basement for Nimi Formation and their present tectonostratigraphic position is due to translation along the overthrusts. Therefore, the Saramati rocks may tentatively be assigned a pre-Cretaceous age. An attempt to correlate it with the Naga Metamorphites sensu stricto or Kanpetlet Schists of Myanmar may be premature at this stage.

Nimi Formation:

Very little was known about the stratigraphy of the thick meta-sedimentaries named Nimi Formation near Nimi village (25°42'45":94°46'30"). It comprises calc-psammo-pelitic association in the eastern segment of Naga Hills, close to the Indo-Myanmar border. Earlier workers referred to them as Nimi Formation and the nomenclature has found acceptance. These rest on the metamorphics which are supposedly the equivalents of Naga Metamorphites.

The multiplicity of formational names for these meta-sedimentaries occurring east of Ophiolite Belt of Nagaland compounded the confusion, which was prevailing in the stratigraphic nomenclature of rocks in the Indo-Myanmar range. Further, the meta-sedimentaries showing epi-thermal grade metamorphism were variously included under Naga Metamorphites, Nimi Formation, or feebly metamorphosed cover rock over the ophiolites. Bhattacharya and Sanyal, (1984–85) made an attempt to solve this complex problem. The survey in the Nimi-Khongka area has indicated that the entire stretch between Tezu River and Indo-Myanmar border is covered by rocks of Nimi Formation. The Phukungri Formation of Singh et al. (1983), was found to be facies equivalent of Nimi Formation. In Fakimile-Thanamier area,the exposed meta-sedimentaries also tally with the Nimi Formation.

Detailed work by Bhattacharya and Sanyal (1984) generated a stratigraphic sequence of Nimi Formation in Nimi-Khongka area which is given in Table 1.4.3. This calcareous psammo-pelitic sequence is disposed as a tectonic slice and is exposed east of the Ophiolite Belt. It is thrust over by a metamorphosed sequence of quartz-sericite schist, quartz-biotite schist, quartzites and carbonaceous phyllites of Saramati Formation (Bhattacharyya and Sanyal, 1985). The recent find of Orbitolina and Dictyoconus fixes its age as Upper Cretaceous to Lower Eocene. It is reasonable to believe that the Nimi Formation is older to Ophiolite Suite and in all probability has Late Cretaceous to Lower Eocene affinity. Nimi Formation resembles the Pansat beds in Myanmar sector.

Table 1.4.3 : Stratigraphic sequence of Nimi Formation

Member	Lithology
Younger phyllites	Green to buff coloured phyllites with intercalations of quartz sericite schist and limestone horizons with slices of ultramafics
Schistose quartzite	Schistose quartzite with grey, red to white coloured, medium to fine grained interbedded quartz sericite, schistose quartzite with minor slices of serpentinised ultramafics, schist
Feldspathic quartzite and limestone	Felspathic quartzite and medium to fine grained white to pale yellow felspathic limestone with gritty quartzite. Interbands of green to brown phyllites with quartzite interbands of noncrystalline greyish limestone.Intercalations of phyllites and quartzite
Older phyllites	Brownish grey to greenish grey to grey phyllites, calcareous phyllites and sericite quartz schist with veins of quartz
~~Thrust~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	
Ultramafic suites	

Thick limestone bands associated with felspathic quartzites are prominent in this area. They occur as a belt of continuous to discontinuous bands from south of Turati nala to south of Khongka village. The general trend of this belt varies from NE-SW in the northern part of the area and NNE-SSW in the area south of Khongka village. The limestone is grey in colour. Fine grained limestone with oxidised pyrite cubes is usually intercalated with minor bands of calcareous phyllite and quartzite. Limestone bands around Nimi-Khongka area occur in the vicinity of Nimi antiform, and are referred to as the northwest and southeast bands (Bhattacharya and Sanyal, 1985). Table1.4.4 summarises details of the limestone bands.

There is a significant difference between the Saramati and Nimi Formations, in terms of lithology and mineral paragenesis. Saramati rocks are made up of schistose quartzite and quartz-mica schist with remarkable persistence of biotite, undoubtedly showing a comparatively higher grade of metamorphism than the calc-psammopelitic association of Nimi Formation. Structurally, both have undergone a common deformation history, characterised by 3 phases of folding. The extensive cataclastic deformation and profound mylonitisation in the Nimi Formation is probably the effect of enormous stresses created when it was overridden by a thick pile of homoclinal rocks of Saramati Formation.

Table1.4.4: Summarised details of limestone bands of Nimi Formation

Location	Details
Northwest band	
West of Nimi Village	Approximate strike length and average thickness of the limestone bands are 1.5 kms and 120 metres respectively
Pyaktsu Hill	There are 7 bands of limestone, varying in thickness from 5-40 metres and average strike length is about 120 metres
South of Khongka Village	3 minor exposures, strike lengths vary from 200 to 800 metres and average thickness is 40 metres
Southeast band	
Southeast of Nimi village	Approximate strike length is 1.3 kms with average thickness of about 50 metres
East of Pyakatsu Hill	Approximate strike length is about 1.6 kms with average thickness of about 50 metres
South of Chizati Nala	Approximate strike length is about 2 kms and average thickness is about 45 metres, which increases to 100 metres towards south
Southeast of Khongka village	Strike length is about 0.5 kms and average thickness is about 45 metres

The two formations are not in stratigraphic superposition, but are two distinct lithotectonic domains, brought in juxtaposition by tectonic transportation resulting in attenuation of the eastern limb of Nimi Anticline by a thrust which delineates the boundary of the two formations.

Ophiolite Suite and the associated metamorphics:

Ophiolite Suite in Nagaland comprises a wide spectrum of mafic and ultramafic suites. It is subdivided into six lithological units.

1. Ultramafic complex, comprising (a) tectonised peridotite and (b) cumulate ultramafics
2. Gabbroic complex comprising (a) layered gabbros and (b) massive gabbros
3. Dolerite dykes
4. Ultramafic and Volcanic complex
5. Plagiogranites
6. Salumi Formation comprising sedimentary deposits interbedded with volcanics

Ophiolites usually show features of ocean floor metamorphism, tectonic transport and emplacment in the crust, and those of post-emplacement deformation and associated dynamo-thermal metamorphism. It is difficult to isolate all types of metamorphic changes in Naga Hill ophiolites. Metamorphism is marked by complete serpentinisation of the suite. The rocks contain penetrative schistosity, marked by parallel alignment of fibrous minerals, elongation and fracturing of chromite/picotite grains and development of kink bands in clinopyroxene. From the work carried out, it is probable that the temperature of metamorphism of the tectonised peridotite is between 200°C to 400°C, which corresponds to low grade metamorphism of Winkler (1976). Effect of metamorphism in this unit may be classified under the process of serpentinisation.

Relict parent mineralogical assemblage of the garnet-lherzolite containing almandine garnet with about 20% pyrope, jadeite, diopside, orthopyroxene, olivine, plagioclase, also suggest high temperature-high pressure mantle condition. P-T condition for similar mineralogical assemblages from other occurrences of garnet lherzolite segregations in ophiolite mantle sequences has been estimated around 700-950°C and 7-20 Kb (Spray, 1982).

1. Ultramafic complex :

(a) Tectonised peridotite:

It is irregularly distributed as tectonic blocks of variable dimensions and shapes, occurring as highly sheared bodies and as polygons to ovoid masses within a matrix of crushed serpentinites formed by the intersection of steep dipping (80°-85°), conjugate shear planes. Peridotite is pale green, olive green to black displaying mesh texture. The highly deformed type exhibit ribbon and bladed-mat texture. Sometimes, olivine is totally replaced by serpentine. Minute grains of anhedral magnetite occur along grain boundaries of olivine psuedomorphs. Fractured and irregular grains of picotite and chromite form elongate trails. Modally, these rocks correspond to dunite, harzburgite and lherzolite.

In Wui, Chiphur and Chokla section in Tuensang district the tectonised foliated serpentinite is most common (Vidhyadharan and Joshi, 1983). Similar tectonised and serpentinised peridotite has been reported east of Luthur by Srivastava (1983). It is schistose in nature, crumpled and sheared. Tectonised peridotite is also reported near the contact with the Disang sedimentaries from Satuza-Moki-Laruri areas by Srivastava, et al. (1983). These serpentinites act as host for talc, chlorite and magnesian carbonate minerals.

The ultramafic tectonites exposed in Lacham area (Phek district) and Wui area (Tuensang district) consist mainly of dunite with minor harzburgite and lherzolite (Roy,1989).These tectonites show ubiquitous presence of chrome-spinel (picotite), evidences of plastic deformation (e.g kinks and bending of cleavages in pyroxene grains) and recrystallisation (granoblastic texture). The dunites-harzburgites are richer in nickel (>1000 ppm), cobalt (45-90ppm) and chromium (800->1000 ppm) but deficient in CaO (1.80%) compared to their cumulate counterparts (clinopyroxenite-websterite) with nickel (100-500 ppm), cobalt (25-35 ppm), chromium (3-450 ppm) and CaO (2.31-7.25%).

An important but rare member of tectonised peridotite is garnet lherzolite, associated with sheared serpentinite, occurring 2 km east of Luthur (Acharya and Jena, 1982). The rock is made of garnet, aegerine-augite, glaucophane, zoisite, chlorite and sphene with hypidiomorphic, equigranular texture. Garnet, with cell dimensions 11.608 ± 0.005 A^o and R.I. 1.785 ± 0.001 A^o, appears to be mainly almandine, with 20% pyrope and minor grossularite. Garnetiferous lherzolite has been reported as a linear, north-south trending body, south of Ankhen near the Disang-ophiolite tectonic contact (Sengupta and Bhattacharya, 1983). The rocks comprise approximately 40% hornblende, 15-25% garnet, and the rest is epidote, saussuritized feldspar and clinopyroxene. The tectonised peridotites are marked by low SiO_2 (<45%), SiO_2/MgO ratio is nearly 1. The high Cr (mean 0.14%) and Ni (mean 0.24%), Mg/(Mg+Fe) ratio of 0.78-0.83 together with strong depletion of Ti, Ba, and Zr indicate their refractory nature.

(b) Cumulate ultramafics:

These are extensively developed and exposed over a wide stretch from Phokphur to Ankhen and New Thewati, Pang-New Basti foot track and east of Luthur. They are composed of different tectonic slices. Igneous layering of restricted lateral extent is observed at places. These are dark green to black, coarse to very coarse grained. These range in composition from peridotite to pyroxenite. Occasionally pods, lenses and streaks of chromitite rarely with nodular structure, occurs within dunite-harzburgite units. Chromite disseminations are also recorded. Well developed rhythmic layering in cumulate ultramafics is seen along the Pang-New Basti track and east of Luthur. Cumulates of ultramafic rocks are coarse to very coarse grained, dark green to black in colour with various proportions of olivine, clinopyroxene, orthopyroxene and opaques are present. Modally they fall in the fields of peridotites and pyroxenites.

The largest outcrop (approx. 16 km X 7 km) of the cumulate ultramafics and serpentinites (Roy, 1989) occur on the western flank of Mollen-Jopi ridge (Phek district). It is lithologically composed of clinopyroxenite, websterite, wehrlite, dunite, harzburgite, gabbro and minor plagiogranite. The rocks show small to large scale igneous layerings, rhythmic as well as cryptic. The TiO_2 content (0.12%) of these cumulate mafic-ultramafic rocks is significantly lower than that of the world's non-ophiolitic layered igneous complexes like Bushveld or Skaergaard.

Metamorphic effects in cumulate ultramafics and layered gabbros are characterised by their mineralogy. Secondary alterations in these rocks are marked by partial serpentinisation of olivine, chloritisation and amphibolisation of pyroxene and saussuritisation of plagioclase. These are possibly effects produced over a long time and indicate a very low grade of metamorphism (Winkler, 1976).

(i) Peridotites:

These are dominantly the cumulate ultramafics and these are varied in composition, represented by dunite to harzburgite, lherzolite and wehrlite, having hypidiomorphic granular texture. In these rocks subhedral and anhedral olivine, and subhedral clinopyroxene grains form an interlocking mosaic with olivine, orthopyroxene, clinopyroxene and opaques forming intercumulus phase. Rocks are characterised by presence of corroded olivine within large clinopyroxene grains. Clinopyroxenes are marked by paired twins on (100) and exsolved orthopyroxene are also present.

The ultramafic cumulate sequence in Wui-Chokla area is constituted by dunite, harzburgite, wehrlite and orthopyroxenite (Vidhyadharan and Joshi, 1983). The dunite body comprising mainly olivine and chromite is reported around the ?1817 metres hill. Cumulate ultramafics of this area contain mainly harzburgite with its characteristic hob-nailed texture. The pyroxenites are noted northeast of Chokla and south of Pang and comprise mainly orthopyroxene . Pyroxenites at Pang are composed mainly of augite. The ultramafic cumulates were also reported from south of Satuza and along Purr-Laruri tract (Srivastava et al., 1983). It includes peridotite, pyroxenites and dunite. Southeast of Luthur village, layered cumulates show repetition of dunite, peridotite, pyroxenite and gabbro, which are overlain by basic rocks to the west and Phokphur sediments to the east (Srivastava, 1983).

(ii) Pyroxenites:

The peridotites grade into olivine websterite, olivine-clinopyroxenite and clinopyroxenite. The rocks exhibit well developed layering, with moderately strong preferred orientation defined by alignment of clinopyroxene laths. The dominant phase in all three types is clinopyroxene. In the cumulate ultramafics, orthopyroxene dominant pyroxenites are rare and have been recorded from Phokphur (Chattopadhya and Bhattacharya, 1979).

These cumulate ultramafics have wider SiO_2/ MgO ratio range (1.11-5.71) high amounts of Al_2O_3 and CaO and lower Cr (0.01 - 0.04%) and Ni (0.01-0.02%) and Mg/(Mg+Fe) ratio is 0.53 to 0.79.

2. Gabbroic complex:

(a) Layered Gabbros:

In the Pang-New Basti, Luthur-Penkim and east of Moki, the cumulate ultramafics grade into layered gabbros. The fine to medium grained gabbroic rocks display well developed layering with preferred orientation defined by plagioclase laths. Rocks are made up of various proportions of plagioclase, clinopyroxene, olivine, orthopyroxene, hornblende and opaques having hypidiomorphic texture with large, subhedral, partially to completely saussuritised plagioclase which encloses resorbed oikocrysts of clinopyroxene, orthopyroxene, hornblende and opaque. In most thin sections the minerals are optically strain free. Hornblende is rimmed by secondary chlorite and magnetite.

Layered gabbros exhibit a wide compositional variation which is indicated by the wide variation of Mg/(Mg+Fe) ratio from 0.76 to 0.26. The near linear variation of various oxides with the solidification index (SI)=100 x MgO/(MgO+Fe_2O_3t +Na_2O+K_2O) indicates that they are a comagmatic sequence.

Gabbro occurs as masses layered with ultramafics around Moki village where it exhibits alternate dark and light coloured layers. Clinopyroxene, orthopyroxene, olivine and hornblende form mafic minerals, whereas andesine-bytownite felspar defines the leucocratic layers.

Cumulate ultramafics and layered gabbros are cogenetic and an overall differentiation trend from Mg-rich peridotites to Al and Ca-rich gabbros is observed. Datta et. al. (1985) commented on the layered sequence that these features indicate an origin of fractional crystallisation by slow cooling in relatively large magma chamber. Repetition of rocks of same composition, however, suggests fresh influx of magma into this chamber. The cumulate ultramafics and layered gabbros were derived from an alkali-deficient calcic and highly magnesian magma. The parent composition of Nagaland cumulates appears to be comparable to that of picrite and olivine tholeiite (Wilson, 1959).

(b) Massive gabbros:

The layered gabbros grade into medium grained, massive gabbros. They have a hypidiomorphic texture with an interlocking mosaic of subhedral plagioclase, clinopyroxene, olivine, and rare orthopyroxene. These gabbros are comparable to high level gabbros of Troodos complex (Wilson, 1959).

The ultramafic cumulates are associated with gabbros in northeast and southeast of Chiphur. The main constituents of these rocks are plagioclase and blue-green pleochroic hornblende. Actinolite and epidote are accessories (Vidhyadharan and Joshi, 1983). Compositionally, this mafic cumulate varies in composition from gabbro to gabbroic anorthosite (Srivastava, et. al, 1983).

Southeast of Luthur village layered cumulates show repetition of ultramafic rocks and gabbro. It has well developed cumulus texture and comprises saussuritised plagioclase, diopside, enstatite and rare opaques (Srivastava, 1983). Bhattacharyya and Sanyal (1985) reported 37.5 metres thick mafic-ultramafic cumulate sequence southeast of Waziho, where pyroxenites are sandwiched between gabbros comprising altered plagioclase of andesine-labradorite composition, hypersthene and augite.

3. Dolerite dykes: They occur as intrusives in cumulate ultramafics. The width of the dykes varies from 1-5 metres with limited strike length. Rocks are fine grained, olive green to greenish black in colour and comprise various proportions of plagioclase, clinopyroxene and opaques.

Subophitic to intergranular texture is observed, where augite grains enclose partially corroded and saussuritised plagioclase laths. Iron is relatively high and they fall in the calc-alkali field. Dolerite dykes have been reported from Ziphu area with width varying from 0.8 to 2.5 metres. They occur within the greenish volcanics (Bhattacharyya and Sanyal, 1985).

4. Ultramafic and Volcanic complex :

This is one of the major units of the Ophiolite Suite comprising utramafic and volcanics. Volcanics are mostly confined to the northern, central and eastern parts of the belt. Their contacts with other members of the suite are usually tectonic. In Nagaland, two types of volcanics are found, viz. (a) sheet flow and (b) pillow lava, metamorphosed at places. However, sheet flow lavas of massive type are more common than pillow lavas (Roy, 1989).

(a) Sheet flow:

These are well exposed in road section from Waziho to Ziphu. The individual flows vary in thickness from 3 to 6 metres. At places they are interbedded with dominantly radiolarian cherts and grey to white limestone. The rocks are fine to very fine grained, olive green to greenish grey in colour. They exhibit round/elliptical vesicles (2 mm to 1 cm in size). At places, these vesicles are filled with chalcedony, zeolites, calcite and epidote. The rocks display intergranular, locally subophitic texture. Some rocks show K-felspar as a separate mineral phase making them compositionally similar to trachybasalt/ basalt/ trachy-andesite/ mugearite. The mafic and felsic minerals show different stages of low grade alteration. The common secondary minerals are palagonite, chlorite, quartz, calcite, and tremolite.

Northwest of Chiphur, the volcanics are quite widespread. The main constituents are plagioclase, chlorite, epidote, actinolite and quartz. Accessories include glaucophane and pumpellyite (Vidhyadharan and Joshi, 1983).The predominance of sheet flow volcanics of massive type in this ophiolite belt suggests the possibility of a less viscous parental magma, or a quicker eruption rate, or flat surfaces of the erupting centres, or any combination of them in the tectonic setting (Roy,1989).

(c) Pillow Lavas:

In Nagaland Ophiolites, pillow lavas are recorded from 1 km NNW of Salumi, Aipunger, East of New Basti and SE of Zaongar (Ghosh and Singh, 1980; Chattopadhya et al., 1983, Srivastava, 1983). The pillows occur with round/elliptical outline, and the flow tops are bulbous with fractured surface. In cross section at least 3 zones can be recognised. An outer chilled glassy margin (1-3 cms), followed inward by a zone rich in vesicles, and at the centre a massive portion with very few vesicles. Textural and structural variations from centre to margin have been recorded. The margin portion is almost aphanitic and its texture varies from intersertal to variolitic in the central portion.

The rock comprises mainly cloudy plagioclase and chlorite psuedomorphs after clinopyroxene within an aphanitic groundmass.Well developed pillow structures in volcanics have been reported in Waziho-Ziphu road section by Bhattacharya and Sanyal (1985). Ellipsoidal pillow structures have long diameter from 10 cm to 1.5 m, the chilled margin being 1.5 cm in thickness. Radial cracks are imperfectly developed. The pillow structures are stretched and aligned in a preferred orientation. Basic rocks also occur to the east of Aipunger and Luthur villages. Southwards it extends across the Thannaremto nala and joins with the volcanics forming Kamku ridge. These rocks are commonly foliated and comprise altered augite, orthopyroxene, and plagioclase set in a glassy groundmass. Often the augite forms phenocrysts in the aphanitic groundmass. Actinolite, chlorite, and epidote occur as accessories (Srivastava, 1983). Jena and Acharya (1982) studied the volcanic rocks east of Luthur, where plagioclase is albitic and the rocks show spilitic character. Meta-volcanics have been reported by them 700 m north of Mukhate nala crossing, comprising an assemblage of glaucophane, actinolite, chlorite, zoisite, epidote. The best section of volcanics is exposed in the newly cut road section in Waziho-Ziphu-Washello area (Bhattacharya and Sanyal, 1985). The tectonostratigraphic succession of the volcanics and the slivers of the ultramafites as observed in this area (from SE to NW) is given in Table 1.4.5.

The volcanics are green, purple, violet and yellowish green. The different types are (1) massive volcanics, (2) schistose volcanics, (3) amygdaloidal volcanic breccia and (4) volcanics with pillow structure. These are invariably interbedded with chert of 200 to 300 metres thickness. Massive volcanics occur southeast of Ziphu and comprise plagioclase and augite with subordinate chlorite. Schistose volcanics contain plagioclase, augite, actinolite, epidote, and lawsonite(?). Volcanic breccia is quite frequent in Ziphu section. Angular to subrounded fragments of purple volcanics, 10 cm to 2 m in size, are set in a volcanic matrix. At places such rocks alternate with thin bands of reddish brown tuffaceous material.

Table 1.4.5: Tectonostratigraphic succession of volcanics and ultramafite slivers observed in Waziho-Ziphu-Washello area, Nagaland.

Sl.No	Description	Thickness
10	Tectonic melange: meta-ultramafites, cumulates, and volcanics with limestone	187.5 metres
9	Purple and green volcanics, interbedded with tectonic slices of ultramafites	325.0 metres
8	Reddish brown bedded chert with intervening brown tuffaceous shale and agglomerates	235.0 metres
7	Green and purple volcanics, interbedded with chert and limestones	1325.0 metres
6	Green and violet volcanics, interbedded with cherts and minor tectonic slices of meta-ultramafites	586.0 metres
5	Reddish brown bedded cherts with reddish to greenish tuffaceous shale	220.0 metres
4	Meta-ultramafites with minor purple and green volcanics	730.0 metres
3	Schistose volcanics (actinolite-glaucophane-lawsonite) with minor purple and greenish volcanics	45.0 metres
2	Meta-ultramafite slices within green volcanics	130.0 metres
1	Green and purple volcanics with minor cherts	370.0 metres
	Disang Group - Shale, phyllite, siltstone with minor sandstones	

Kamku ridge volcanics band, extending from Lacham lake to the scarp west of Laruri, are separated by ultramafic complex (Srivastava, *et. al.* 1983). The basic rocks show a well developed schistosity around Moki village, south of Purr, in Laruri foot track on the Nimi track. The basic schists comprise glaucophane, hornblende, lawsonite, epidote, quartz and carbonates. From Kamku hill to Salumi the basic rocks are covered by metasedimentaries. Schistose basic rocks of Kamku ridge contain albite, hornblende, glaucophane, actinolite, quartz, carbonates, epidote and chlorite. Schistosity is well pronounced and is often folded. Glaucophane bearing schists occur as highly sheared lensoid outcrops within the volcanics and are reported from Moya, Kamku, Salumi, Chiphur, Phokphur, New Basti, and Ziphu areas (Chattopadhya *et. al*, 1983, Bhattacharya and Sanyal, 1984). These blue schist rocks are indicative of high pressure-low temperature metamorphism due to a subduction regime.

In Laruri Lacham lake area, the volcanics are fine grained and feebly foliated in appearance. Disseminations of pyrite are common. In their western contact with ultramafites, they show a layered or banded nature. Volcanics near Laruri are capped by tuffaceous sediments and contain plagioclase, clinopyroxene, olivine, chlorite and carbonates exhibiting hypidiomorphic and porphyritic texture. The porphyries contain phenocrysts of olivine, pyroxene and plagioclase in a glassy groundmass. East of Lacham lake, pink coloured volcanic rocks with fragments of volcanics and red cherts are observed. Similar volcanic breccia is also observed to the West of Laruri. Volcanic rocks also crop out east of New Thewati and north of Old Thewati. Minor sulphide mineralisations occur at Old Thewati associated with volcanics (Singh, *et. al*, 1983). Pillow structures in basaltic and spilitic rocks have been observed (Roy *et. al,* 1982; Roy, 1989) north of Thongshonyu and east of Salumi (Tuensang district) and between Wazaho and Ziphu (Phek district).

The individual layers vary in thickness from 0.75 m to 10 m. Spilitization is very common and intense in the basaltic volcanics between Wazeho and Ziphu. It could indicate a state of extensive hydration of the parental magma through rock sea water interaction. However, the degree of spilitization is found variable from place to place. The mineral assemblage in the spilitic rocks is quartz + epidote + sphene + rutile +smectite + pumpellyite + relict pyroxene (augite). These volcanic rocks have undergone a strong alkali enrichment (Na_2O+K_2O being about 5.37%) through the processes of ocean floor alteration and metamorphism. (Roy et. al, 1982). The ocean floor sea water interaction seems to have played a predominant role in the alkali migration.

Near Reguri, volcanics occurring as tectonic slices within Disang Formation have dioritic composition, hornblende, plagioclase and quartz (Srivastava and Naskar, 1983). Volcanics are also reported from South of Akhen resting over ultramafic sequence and the topmost part is interbedded with cherts. The rock comprises plagioclase, augite, hornblende, chlorite and glass or sericite-prehnite and chlorite association (Sengupta and Bhattacharya, 1983)

Chemical compositions of 34 volcanic rocks were analysed and on that basis certain conclusions had been drawn.

I. On the basis of SiO_2 content these rocks can be classified into basalts (45 to 52%) and basaltic andesite (52-57%).

II. Their high alkalic nature is indicated. The lavas are marked by low MgO (mean = 5.85%), low Cr (mean = 116 ppm), low Co (mean = 53 ppm), and high total alkalis (4.81 %).

III. These characters indicate that they are not primary mantle material but have undergone fractional crystallisation to a greater degree than those from typical spreading ridges (MORB).

IV. From their high total alkalies and TiO_2 (mean = 2.02%), moderate FeO, low MgO (mean = 5.85%), these rocks are comparable to those of aseismic ridges, intraplate hotspots, seamounts and ocean island basalts especially those from Indian Ocean.

Limestones interbedded with basalts of Ophiolite Suite have, in general, yielded a rich assemblage of microforaminifera and nanoplanktons, which indicate a Maestrichtian age for the volcanic rocks. The microforaminifera from limestone interbands, within the volcanics in Manipur, have shown a Lower Eocene age for the volcanic suites. Phokphur Formation may be dated as Middle Eocene.

Volcanics are metamorphosed and characterised by schistose and decussate textures. It is suggested that the approximate P-T conditions of metamorphism of the volcanics is between 350°-500°C at pressures of 3-5 Kb. The assemblage indicates an overall low metamorphic grade similar to those of ocean floor metamorphism. Small occurrences of garnetiferous amphibolite (oxyhornblende + garnet + diopside + plagioclase) have been found associated with the volcanic rocks (Chattopadhya and Roy, 1977). These are dismembered slices and high temperature-high pressure assemblages. These may possibly represent either metamorphosed lower continental crust or metamorphic aureoles located at the base of cumulate peridotites. Tectonic emplacement distorted their original geometry and an accurate geological evaluation of the formation is very difficult. It may be surmised that the superposed effects of different metamorphic types in the ophiolites finally produced a low grade metamorphic assemblage.

5. Plagiogranites:

These leucocratic, fine grained rocks occur as intrusives in the form of veins, dykes and small stocks within cumulate ultramafics and layered gabbros at a few places. In Luthur and Reguri, plagiogranite veins intrude all the members of ophiolites. They are also found to intrude Phokphur Formation. These rocks show granophyric to hypidiomorphic texture and comprise plagioclase, quartz, minor augite, hornblende, magnetite and sphene. Compositionally they are similar to trondhjemite-tonalite and quartz rich granitoids. Plagioclase is albite (An_{8-10}) in composition. Both twinned and untwinned varieties are present. Occasionally they display zoning, which is accentuated by differential alteration. Quartz grains are anhedral and of two generations.

A small plagiogranite body was reported by Vidhyadharan and Joshi (1983) which occurs northwest of Chokla. This contains mainly plagioclase and quartz with minor amount of hornblende and biotite and is close to tonalite in composition.

Leucocratic, coarse to fine grained plagiogranite occurring as small dykes and stocks are reported from Phokphur-Zaonger section. At Luthur, the plagiogranite occurs as an oval shaped body with a maximum length of 200 metres and a width of 120 metres. Plagioclase laths, partially/completely altered together with mafic minerals form intergranular texture. Quartz is more common near the periphery. Mafics include pyroxene with subordinate hornblende. These show minor disseminations of pyrite and chalcopyrite (Sengupta and Bhattacharya, 1983).

Plagiogranites are characterised by low K_2O (0.11 to 0.4%), moderate to high SiO_2 (60.05 to 72.4 %), high Na_2O (1.45 to 8.25%) and moderate Al_2O_3 (11.14 to 17.12 %). They are comparable to oceanic plagiogranites and their origin can be traced as differentiated products of a potassium depleted tholeiitic melt.

Petrochemistry:

The petrography and petrochemistry of ophiolite rocks have been worked out by several workers and the results of their findings have been summarised in GSI Mem. V.119 by Venkataramana et.al,1986.

In addition to the normal chemical analysis, trace element and rare earth element analysis were carried out. Trace element studies conform to the geochemical pattern of 'within plate alkaline volcanics' and are distinctly different from arc and Mid-Oceanic ridge volcanics. In all plots, Naga Hills Ophiolites fall in 'within plate basalt' field. Total absence of an island arc component in the assemblage is definitely brought out in the Ti/Cr versus Ni diagram. All the plots in this diagram are in the field of ocean tholeiite. Detailed petrochemical studies of Naga Hills ophiolites were carried out and the following interpretations have emerged:

(i) Sheeted dyke complex are characteristically absent or rare showing that they were not formed in spreading ridge. Pillow lavas are minor in Naga Hills ophiolites in contrast to the other ophiolite belts.

(ii) Tectonised nature, restricted modal compositions and highly magnesian chemistry, with very low incompatible trace element concentration indicate the tectonised peridotite to be the residue mantle material.

(iii) Cumulate ultramafics and associated layers are cogenetic. The chemistry and mineralogy of this suite indicate that they were derived from an alkali deficient calcic magma. These are usually generated in the ocean islands. The lithological assemblage and major element chemistry of Naga Hills ophiolites suggest that possible tectonic setting as linear ocean island chain or a nonspreading aseismic ridge comparable to those of Indian Ocean.

(iv) Trace element data rules out possibility of volcanics being erupted in an island arc situation. On the contrary, they suggest 'within plate suture' character. Some trace element data independently point to the ocean island character of the volcanics. This is also supported by rare earth element data. Now the crux of the problem is whether two types of lavas (tholeiitic and alkaline) are of common lineage, as is found in oceanic islands and seamounts. This is indeed a theoretical possibility but there is a major disagreement when the major element chemistry is considered.

According to Venkatramana (GSI Mem. 119), a more suitable explanation would be that in a regime of thickened lithosphere, the alkaline magma erupted from a deeper undepleted mantle source. Such a situation is commonly observed in the form of seamount volcanics in 'within plate' location and is explained to be the result of 'hot spot' activity. Samples with tholeiitic affinity possibly represent dismembered pieces of the pre-seamount ocean floor. Abundance of alkali basalts suggests these to be relatively smaller topographic features away from the mid-oceanic ridges.

Based on geological evidences and chemical compositions of the volcanic rocks,Roy et al, 1982 suggested a united spreading ridge plus ocean-island environment for genesis of this ophiolite. A mixed type of origin seems more plausible. The high Ti02 content (1.27 to 2.32%) of the volcanics may suggest a relatively high spreading rate of the concerned ocean floor. It could be around 3.2 cm/year (half rate) as estimated from the logarithmic relationship of oceanic spreading rate with mean $Ti0_2$ (Roy *et. al*, 1982). The trace elements abundance and their inter-relationships compared this ophiolite geochemically with the modern oceanic crust and the Bay of Islands ophiolite. The tectonic melanges and a complex metamorphic spectrum of greenchist, blueschist and amphibolite facies suggested an ancient convergent plate boundary along the ophiolite belt of Indo-Burman ranges and its tectonic emplacement. But the presence of pronounced seismic activity of shallow, intermediate and deep focus earthquakes all along the Indo-Burman ranges and Central Low lands of Burma in the east suggest an active nature of the Indian plate margin along its eastern periphery.

6. Salumi Formation:

These rocks are exposed in Luthur (25°49':94°44') - Salumi area (25°47':94°53') in Tuensang district. Oceanic pelagic sediments of Salumi Formation form the nonconformable, immediate cover of the basaltic crust, and are also included in the ophiolites. These consist of shales, thin interbedded cherts and limestones. These rocks show patchy distribution. Chert, limestone and phyllites are often interbedded and intercalated with the volcanics on various scales.

(a) **Cherts:** These are interlayered with volcanics (e.g. Ziphu,Washello) and variegated colours, dominantly reddish brown but also red, green, grey, buff and black. These have wide distribution, occurring as beds of varying thickness from a few centimetres to about 30 metres (Ziphu, Mollen and Waziho), and comprised mainly cryptocrystalline silica (Bhattacharya and Sanyal, 1985). At times they are seen as lensoid bands and slivers arranged *en èchelon* within tectonised peridotites. Some are fossiliferous while others are cut across by quartz veins. South of Waziho, small exposures of agglomerate are associated with chert bands. Thin bedded cherts are highly fractured and stretched with development of boudins. Secondary quartz veins are seen at places. Fossil forms which have been identified in chert beds are given below:

Radiolaria: *Omnatospyris sp., Kassina s,.* and *Spongprunum.*

Foraminifera: *Textularia sp.,* badly preserved.

Presence of *Kassina* is the basis for assignment of Cretaceous age for the formation.

(b) **Limestone:** These are bedded, varying in colour from white to grey and are often intercalated with minor chert bands and sandy partings (e.g. Waziho and New Mollen). Bhattacharya and Sanyal (1985) found a few lensoid bodies of crystalline limestone within the volcanics along Waziho-Ziphu and Washello road section. Rocks are composed of calcite, with fine grained aggregates of quartz. The percentage of SiO_2 goes upto 20% in a few thin sections.

The red cherts and some recrystallised limestones are fossiliferous. The cherts contain only radiolaria and calcareous nanofossils. The radiolarian assemblage with long ranging forms is not age specific but the presence of genera like *Kassina, Spongocanthus, Acanthocircus,* etc. points to a Cretaceous affinity (Acharya, et.al, 1986,mem.vol.119). However, the calcareous nanofossils favour in general, a Maestrichtian age. In a few cases *Coccolithus hoeuvikensis (?) and Polycyclolithus sp. (?)* of Upper Albian to Cenomanian affinity are found to be associated with other calcareous nanofossils of undoubted Maestrichtian age. Among the limestones associated with volcanics and cherts, fossils near Chiphur area are mainly calcareous nanofossils represented by *Arkhangelskiella cymbiformis, A. obliqua, Coccolithus turbatus, Zygodiscus spiralus(?), Biscutum sp., Deflandrius cretaceous,* etc. which indicate a Maestrichtian age(Acharya, et.al, 1986, mem.vol.119).

The pelagic limestones have yielded a rich microforaminiferal biota, consisting of *Globorotalia cf. lehneri, Globigerina cf. fringa, Globigerina cf. lineaparta* of Palaeocene to Lower Eocene age, which indicates that the oceanic realm continued to prevail upto Lower Eocene period.

Phokphur Formation:

Ophiolites are nonconformably overlain by subhorizontal sedimentary sequences near Phokphur (25°53'40":94°51'00"), varying in thickness from 10 to 700 metres (Acharya and Jena, 1982, Bhattacharya and Sanyal, 1984, Srivastava and Naskar, 1980-81, Srivastava, 1983).

These are ophiolite derived marine to paralic sediments comprising polymictic conglomerates, shales, tuffaceous greywacke, carbonaceous shales and lithic felspathic arenite with thin coal streaks. This formation has been designated as Phokphur Formation after the locality of the type section. A basal conglomerate comprising pebbles and cobbles of quartz and chert of several colours with clast to matrix ratio of 70:30 is present.

Phokphur Formation has yielded a rich gastropod assemblage comprising *Solariella, Nerita, Pitar, Turritella, Assilina* and plant fossils like *Anthocephalus, Litchi, Citrus, Mangifera, Psychotin, Wendlandia, Bridelia, Psidum, Syzginum,* etc. The forms are long ranging and suggest a shallow marine environment. Presence of *Assilina* assigns an Eocene age (Ranga Rao, 1983). These fossils are indicative of a hot, tropical climate. This formation compares broadly with lithology and setting of Eocene sediments overlying the ophiolites of Chin Hills of Myanmar.

A conglomerate bed of Phokphur Formation with pebbles of chert, volcanics and phyllites occurring between Luthur and Salumi has yielded *Nonion, Globigerina sp.* with fragmentary bryozoa. The fossil assemblage is typically marine but not age specific.

Near Reguri, a limestone bed within basal conglomerate of Phokphur Formation has yielded a radiolarian and foraminiferal fossil which suggests shallow marine to fluvial conditions and broadly corresponds to Eocene age. The assemblage comprises:

Radiolaria: *Ommatodiscus sp. and cf., Perichlamydium sp., Coccolarcous sp., Canosphaera sp.,Lithocampe sp.*

Foraminifera: *Textularia sp.,*

Bryozoa: *Hincksina sp.,* and *cf., Aplaucina sp.*

Disang Group :

Disang Group was first described by Mallet in 1876 from the type section of Disang river, wherein the lower part of the sequence comprising dark grey, finely laminated shales were predominant, whereas flaggy sandstone of variable thickness occur higher up in the sequence. Subsequently, Oldham (1883) described the shale-sandstone sequence with serpentinites in East Manipur and correlated them with 'Axials' of Arakan Yoma. Correlation was done by Evans (1932) with 'Kopili' and 'Sylhet Limestone' stages and 'Lungsha Shales' of Myanmar. Pascoe(1912), corroborated equivalence with 'Lungsha Shales'. Clegg (1941) while describing the limestone occurrences of Manipur pointed out their similarity with Cretaceous 'Pegu Limestones' of Myanmar.

Disang Group has a large spread in the Inner Palaeogene Fold Belt. Barail Group of rocks occur as caps in synformal cores of the folded sequence. Due to the intricate folding of Disang Group, the stratigraphic sequence of the Disang Group is yet to be completely understood. Haflong-Disang Thrust limits the western extremity of Disang Group.

The lower units comprise grey, khaki grey, black, splintery shales with sandy and silty interbands at places. Thin, interbedded, hard, flaggy greywacke sandstones varying in thickness from a few cms to more than a metre occur higher up in the sequence. The formation is shaly towards the basal part and sandstone layers are more abundant towards the upper part. In the lower part the usual colour of the shale is dark grey to grey. Lighter coloured shales, ferruginous shales and siltstones are local variations. Some Disang shales are prone to spheroidal weathering. Occasional development of concretions is common within these shales. Shale pellets are seen parallel to the bedding (Sarma, 1985; Devdas and Gandhi, 1985).

Rhythmic alternations of siltstones, shales and fine grained sandstones, 100-200 metres thick, are recorded in the upper part of Disang Group, displaying more or less turbidite like facies. They are invariably ill- sorted (Sarma, 1985). In Mokokchung district, hard, compact greywacke, fine grained sandstones and grey shales with rhythmic components of upper part of Disang Group (Devdas and Gandhi, 1985) are seen.

The contacts of sandstone with shale is very sharp. The former stands out as prominent bands within the weathered shales. The thinner sandstone bands display parallel laminations while the thicker ones exhibit planar cross stratification. The lower units display cross bedding, indicating their deposition in relatively shallower depths. Sole marks or graded bedding are conspicuously absent. Chattopadhyay and Roy (1977), however, noticed sedimentary structures like rhythmic bedding, graded bedding, ripple marks, load casts, flute casts and groove casts in upper Disang sediments, north of Meluri in Phek district.

Petrographic studies of some sandstone and siltstones of Disang Group was carried out by Sarma (1985), and Sarma and Naik (1984). They found the main constituents to be quartz, sodic felspar, calcite, and rock fragments with minor epidote, sericite, muscovite, chlorite, opaques and zircon. Rocks belong to lithic and sublithic wacke. Quartz (30-60%) forms the bulk of the constituents in the sandstones. The grains are subrounded, subangular to angular. Monocrystalline quartz is common but polycrystalline quartz in graded bedding is also found. Sutured grain contact and secondary overgrowths of silica are observed. Felspar, represented by sodic plagioclase, constitutes 10-15% of the bulk composition. Most of them are twinned and more than 50% altered to sericite. Rock fragments (10-20%) consist of chert, phyllite, shale and some schistose rocks. Cement is siliceous and calcareous. Grains are embedded in clay and silt size argillaceous matrix. Sorting is poor and the rocks are termed as sublithic greywacke. Texturally, Disang sandstones are not mature as it contains more matrix (25-30%), angular and polycrystalline quartz. Heavy minerals are dominated by opaques and nonopaques are mainly tourmaline with little biotite and rutile (Devdas and Gandhi, 1985).

Disang shales contain illite, montmorrillonite, chlorite, quartz, and other fine detrital grains, whereas the sandstone and limestone members, except for minor compaction and recrystallisation retain their original sedimentary structures and clastic texture.

The Lower part of Disang Group has yielded fossils from two localities. In one section exposed in Tehai Reu stream near New Ngwalwa megaforminifers (*Nummulites*), lamellibranchs (*Cardiocardita, Nucula*), and sinistral molluscs indicate a Lower Eocene-Middle Eocene affinity (Gaur and Chakradhar, 1985). Around Meluri, the lower sections of Disang Formation have also yielded *Dictyoconoides sp.* of Middle Eocene affinity (Sinha and Chatterejee, 1982). In the upper part of Disang Formation the frequency and thickness of sandstone-siltstone beds seems to increase and the rocks assume a rhythmite facies - a classical section of such Upper Disang rhythmites is exposed in Longkhim village, near Mokokchung.

Some of the units of Disang Group in Nagaland yield abundant remains of plant fragments (Sarma and Naik, 1984, Sarma, 1985, Devdas and Gandhi, 1985, Sarma, 1985; Singh and Adiga, 1978) which are suggestive of their shallow water deposition. The carbonaceous material found in small lenses is possibly the alteration product of marine algae or seaweed which flourished locally in shallow Disang sea. The occasional find of arenaceous foraminifera also suggest a brackish, shallow water environment. The palynofossils from this horizon consist of coastal elements (Ranga Rao, 1983).

The thick argillaceous sequence of Disang Group broadly resembles the Palaeocene-Eocene shaly facies deposited on the inner side of Bengal basin. Ranga Rao (1983) suggested brackish water, tidal flat environment of deposition for some of the members of Disang Group. Its sedimentary record shows a continuity of shelf environment, where rapid subsidence favoured accumulation of a thick pile of Palaeogene rocks. It is clear that Disang Group does not represent flyschoid sediments of Assam-Arakan geosyncline. The evidence on lithological, floral or faunal records also do not designate the Disang sediments of Palaeogene belt as a flysch sequence.

Towards eastern part of Naga hills, Disang Group shows initiation of metamorphism with development of rudimentary slaty cleavage. Disang Group is represented by hard, dark blue slates. The slaty nature is not confined to any particular zone and these slates are often cut across by quartz veins. Within the Disang Group, deformation and phyllitisation increases eastward. The formation always shows a thrust contact with the ophiolites. Saline springs are commonly associated with these rocks.

Regional mapping of Inner Palaeogene Fold Belt in Nagaland and Manipur, has delineated a rich fossiliferous zone near Disang-Barail contact. The assemblage consists of pelecypods, gastropods, corals and some foraminifers. This zone has been traced for a considerable distance and work in the future will possibly delineate a definite marker horizon separating the Disang and Barail Formations and establish for the first time a precise Disang-Barail contact. Palaeontological studies may provide the answers for the chronostratigraphy of Disang-Barail contact on which a number of investigations have been carried out.

Separation of Disang Group from Barail Group is presently based on the first appearance of multistoried sandstones which defines the base of Barail Group. This approach is convenient for lithostratigraphic subdivision, but it has certain practical limitations. Recent mapping (Sarma, 1985; Devdas and Gandhi, 1986; Srivastava and Ray, 1986) shows that multistoried units in the basal part of Barail Group is not regionally persistent. They often interdigitate with siltstones and sandy shales which causes uncertainty for precise delineation of the base of Barail Group. Further, the lowermost multistoried sandstone unit is often overlain by another sequence of shales as observed in Mokokchung area, which has similar lithological attributes as those of Disang rocks. Evans (1932) has also recorded this aspect of similarity between the lower units of Laisong shales and the underlying Disang shales. The rapid alternation of 3-4 metres of sandstones and shales in basal sequence of lowermost Laisong unit further prevents precise delineation of the contact. Similarly, in the uppermost units of Disang Formation, a rhythmic alternation of sandstones and shales is observed. In such situation, often the formational contact has been drawn arbitrarily keeping the thicker sandstone beds within Laisong Formation.

Regional mapping in Manipur and Nagaland has shown that the basal unit of Barail Group, typified by pebbly conglomerate unit, rests with an angular discordance over the Disang Group in Ukhrul area. Due to lack of marker horizon, the formational contact between Disang Group and Barail Group is time transgressive, though at the basin periphery an erosional gap separates the two lithostratigraphic units. Towards the interior of the basin, with the decrease in grain size, the Barail rocks tend to be conformable with the underlying Disang rocks.

Recently, the different biozones identified near the formational contact were critically studied to explore whether the biotic record provides any clue for subdividing the two lithostratigraphic units. It has been observed that the biozones containing mostly pelecypods, gastropods, plants, ostracods, etc. occur both in uppermost Disang Group and lowermost Barail Group and the faunal assemblages in both the cases give a broad Upper Eocene age. Unless time sensitive foraminiferal remains are recorded, the palaeontological assemblage with long ranging forms may not help to solve the boundary problem satisfactorily.

Barail Group:

Barail Group is represented by the oldest Laisong Formation, Jenam Formation, and the youngest Renji Formation in Assam Shelf, Schuppen Belt and Inner Palaeogene Belt.The basement of Assam Shelf is covered by a granite wash with a thin conglomerate. Upward, the section consists of medium grained sandstones with intercalations of shale and thin coal bands. This formation in all probability does not exceed few tens of metres. The seismic survey conducted in Dhansiri valley shows that Barail Group of rocks (Upper Eocene and Oligocene) continues with a reduced thickness in the subthrust block of the Naga Hills.

Laisong Formation:

In Schuppen Belt the Laisong Formation is the oldest lithounit recorded. It consists of hard, compact and well bedded sandstones. The sandstones show different shades of colour from white to grey and become reddish brown and pink on weathering. White kaolinitic bands are seen in association with sandstones.

Two km northwest of Peren, the sandstones exhibit herringbone cross bedding which indicates periodic variation of flow direction of the transporting medium (Gaur and Chakradhar, 1985). The thickness of the formation measured along Dimapur-Kohima road section is 1730 metres (Ranga Rao, 1983). Along Mokokchung-Mariani road section a 200 metre sequence of current bedded sandstones on the upthrust block of the Chongliyimsen Thrust is referred to as Laisong Formation on the basis of lithological characters. In Borjan coal belt the sequence of thin bedded sandstone with alternation of shale and streaks of coal has been designated by Mitra and Chowdhury, (1970) as Nagaon Formation which is usually considered to be homotaxial to Laisong Formation. The Laisongs have yielded *Nummulites* and *Dictyoconoides* of Middle and Upper Eocene affinity in NE of Ngalwa (Acharrya, 1982) and *Operculina sp., Biplanispira sp., Nummulites chavanessa* of Upper Eocene affinity from Henning Kungwla area (Ranga Rao, 1983). Laisong Formation, in Inner Paleogene Fold Belt, gradationally overlies Disang rocks in different synclinal troughs of Konya Syncline, Mokokchung Syncline, Zunheboto Syncline and Kohima Syncline. It is exposed in the Mon district and has been studied in details by Sarma (1985). It consists of medium to fine grained, well bedded, very hard, light grey to grey laminated sandstone alternating with minor grey shale, sandy shale and siltstone. The sandstones on weathered surface appear as light brown, light pink, light greenish brown in colour. Dark grey to ash grey, and at places, dark brown to greenish brown shale constitutes 30-50% of the Laisong Formation. Concretions are noticed within the shales.

Laisong sandstones comprise sublithic arenite to lithic wacke composed of quartz, felspar, rock fragments with minor epidote, detrital and secondary Sericite, chlorite, muscovite and some opaques. Quartz dominates with a content varying from 30-60%. Polycrystalline grains are less in comparison than in Disang Formation. Secondary overgrowths on quartz have been observed. Sodic plagioclase is abundant (10-15% of bulk composition of rock). Plagioclase grains are altered to sericite. Rock fragments belong to chert, shale, phyllite and schistose rocks. Heavy minerals include epidote, chlorite, muscovite and zircon. Opaques are invariably present. Calcite present may be a product of diagenesis. Silica is the main cementing material although ferruginous cement is also present. The grains are embedded in clay matrix (5-25%) formed by sericite and clusters of epidote. These sandstones as a whole may be classed as transitional type from lithic to sublithicarenite to lithic or felspathic greywacke, (Sarma, 1985*).* Sedimentary structures include cross bedding, ripple marks, load and flute casts. In the lower part of Laisong Formation, some profusely, bioturbated beds were found and one such location lies to the South of Tang. These burrows possess prominent ophiomorpha type of rings. Laisong Formation near Chizami has yielded *Nummulites chavanessa, Nummulites sp., and Operculina sp.* of Upper Eocene age (Ranga Rao, 1983).

Jenam Formation:

In a majority of tectonic blocks of Schuppen Belt, Jenam Formation is the oldest unit exposed. In the southern part of the belt, it is represented by a predominantly argillaceous sequence of dark grey siltstones, shales, thin sandstone bands, carbonaceous bands, and a number of coal seams. Small scale cross laminations and parallel bedding are characteristic sedimentary structures of siltstones. The shales contain molluscs and carbonised plant matter at places. Around Jaluke, thin bands and streaks of coal are recorded (Gaur and Chakradhar, 1985). The thickness of this formation along Dimapur-Kohima road section is about 800 metres. (Ranga Rao, 1983). Zubza area in north shows that Jenam Formation is characterised by a thick argillaceous unit represented by gypsiferous shale, bluish grey shale, carbonaceous shale and a few cm thick coal seams. In the lower part a number of carbonaceous shale horizons are noted along the right bank of Dayang river, north of Liphania (Yedekar and Jena, 1983).

Northeast of Zubza in Changpang-Mirinokpo area, Wokha district, Jenam Formation retains its predominant argillaceous character consisting carbonaceous shale, bluish grey shale, purple shale and sandstone. These are associated with lenticular sandstones, flaggy at places and well bedded unlateritised conglomerates. 3 to 7.5 m thick coal seams characterise this segment at Shang Tsu (Yedekar and Ray, 1984).

Coal seams are also noted West of Lio-Longidang at the junction of Chelitsu and Khangstang, west of Changpang, Tsupangla *nala* and northwest of Changpang. Along Mariani-Mokokchung road section, Jenam rocks attain a thickness of 750 metres with a lower shaly unit containing coal seams, a middle unit of alternating shale and wavy laminated sandstone and an upper arenaceous unit with interbands of coal (Mitra and Chowdhury, 1971). In the northern part of Naga Hills around Borjan Colliery, Jenam Formation attains considerable thickness with development of coal seams, upto 6 metres thick.

Jenam facies of Schuppen Belt are equated with Baragolai Formation of Upper Assam and lower part of Tikak Parbat Formation is correlated with upper units of Jenam Formation and the lower units of Renji Formation. It is evident that the coal forming environment during the deposition of Jenam sediments prevailed in the northeastern part of the Schuppen Belt while towards the southwest with the deepening of the basin no coal seams of economic thickness were formed. No significant coal seams are noted in the south of Dai Ru stream.

Evans (1932) synthesised that Jenam beds, within Schuppen Belt, are argillaceous in lower part and arenaceous in upper part, thus forming a transition into the overlying Renji Stage. Throughout the Jenams, especially in lower part, carbonaceous shale is abundant. North of Pherima village, Kohima district, the sandy clays have yielded invertebrate fossils of lamellibranch, gastropod, foraminifera and ostracod. Foraminifera identified are *Quinquiloculina seminulum, Triloculina cuneta, and Textularia agglutinuis*. Ostracoda is represented by Bairdia *sp.* These forms are long ranging extending from Jurassic to Recent. Marine fossils were located from sandy clays of New Ngwalwa area. These include *Nummulites* and other invertebrates. The other species found in this locality are *Glossus sp., Macoma sp.* and few fragmentary shells of *Turritella sp. Nummulites* do not indicate a typical Eocene age but may be younger in age as indicated from the flaring nature of whorls. Other fossils are long ranging (Prasad and Sarma, 1983).

In a section of Konya Syncline of Inner Palaeogene Fold Belt, Jenam Formation overlies Laisong Formation. It comprises alternating thinly bedded sandstone and grey to dark grey shales. This unit, mainly argillaceous, shows development of a few coal seams, two important seams having thicknesses of 1.8 and 1.3 metres (Chakravarty and Sarma, 1978-79).

Renji Formation:

A great thickness of ferruginous sandstone, defines the top of Barail Group in Schuppen Belt. The thickness of Renji rocks in the different tectonic slices of Schuppen Belt vary widely due to changes in depositional environment and unconformable overlap of Surma rocks. In Zubza river section, Renji Formation has a thickness of 500 metres, but in Lakhuni and Changpang tectonic blocks, in west, it is considerably reduced, and locally Surma rocks rest on the denuded surface of Jenam Formation (Yedekar and Ray, 1984).

The best exposure of Renji Formation is seen in the Changki unit where it can be traced continuously from Moilang to north of Tuli, with a thickness of 400-500 metres. At Borjan in north, it is represented by 140 metres of coarse gritty sandstones, which defines the basin marginal facies. Renji Formation thus tends to pinch out both towards north and west of Schuppen Belt. This tendency may account for the absence of thick arenaceous horizons in the upper part of Barail Group in Upper Assam subsurface. Sandstones of Renji Formation are quartz arenites, quite hard and compact and characterised by occasional presence of grit beds containing only quartz and chert granules. Based on available palaeontological records, it is interpreted that Barail sedimentation commenced in Upper Eocene period, but in absence of diagnostic fossil beds, the period of Oligocene sedimentation is yet to be precisely confirmed.

Renji Formation, the uppermost unit of Barail Group, is conspicuously developed in the cliffs and peaks of Japvo rising almost to 10,000 ft. above sea level, forming a part of Inner Paleaeaogene Belt. Evans (1932) described this unit as “a great thickness of hard, ferruginous, usually massive sandstones occurring above the soft Jenam beds”. It is made up of very thick multistoried sandstone units with a number of grit beds (2000 metres).

Surma Group:

Surma Group, in Schuppen Belt, rests unconformably on Barail rocks often with the characteristic basal conglomerate. The basal conglomerate of Surma Group traceable in most of the lithotectonic belts of the Schuppen Belt shows maximum development in southern part around Zubza and Dayang rivers, where it is more than 1250 metres thick. Evans (1932) mentions that north of Dayang thickness of Surma Group of Schuppen Belt is reduced from 900 metres to 300 metres within a stretch of 7 km and further north it is totally absent, where Tipam Group is structurally overlain by Barail Group. The representative sections recorded by Evans show that the shaly sequence of Middle Bhuban Formation, occurring unconformably over Renji Formation, attains a thickness of 480 metres in Zubza river section, but, in Dayang valley to the north this lithounit pinches out and the sandy sequence of Upper Bhuban Formation, about 720 metres thick, rests directly on the Renji Formation. Further 7 km North, Bokabil Formation, which is 180 to 200 metres thick in Dayang valley, is reduced to 50 metres. Likewise the underlying Upper Bhuban Formation is attenuated to 270 metres.

The basal conglomerate shows a wide variation in thickness from a few cms to 13 metres. The clasts comprise fine grained sandstone, calcareous sandstone, siltstone, coal, quartzite, vein quartz and chert with clast size varying from a few cms to over 15 cms. Clasts are mostly subrounded in nature and matrix is composed of medium to coarse grained, buff coloured sand. The conglomerate is either partially or completely lateritised. Though the pebbles are mostly of intrabasinal origin, some of the extrabasinal clasts of sericite quartzite have been reported by Yedekar and Ray (1984).

Bhuban beds of Naga Hills do not differ appreciably from the beds of this formation in the Surma valley, except for greater abundance of conglomerate (Evans, 1932). At places Surma sedimentation commenced with the deposition of Middle Bhuban Formation and is followed by Upper Bhuban and Bokabil Formations. The study of Surma Group shows a distinctive pattern of progressive transgression of Surma Sea in the Naga Hills Schuppen Belt.

The age of Surma Group in Schuppen Belt has not yet been resolved. Fossil bones have been collected from the basal unit of Surma Group in Cheki Tsu in Wokha district of Nagaland. Surma rocks of Naga Hills have yielded *Pholodomyo sp., Ostrea sp., Carophyllum sp.,* which do not provide any precise chronology. In Zubza river section presence of *Ammonici* was recorded which indicates Miocene or younger age (Ranga Rao, 1983). Based on the available data, a Lower Miocene age is suggested for Surma Group in Nagaland. In Changpang area (Cheki Tsu), the basal conglomerate has yielded some vertebrate remains of Miocene affinity (Yedekar and Ray, 1984). This conglomerate gradually decreases in thickness northwards.

Siltstones and shales of Middle Bhuban unit (450 metres) are noted along Mariani-Mokokchung road and in streams SW of Zubza. The basal part is defined by a sandstone unit which overlies the unconformity above lower Bhuban Member. The sandy shale and laminated siltstone of Middle Bhuban Member shows lenticular bedding, flaser bedding, wavy bedding and occasional slump structures (Ranga Rao, 1983). Middle Bhuban units are overlain by sandstone-dominated units of Upper Bhuban Member (600 m). This unit on Dimapur-Kohima road secton comprises thick sandstones which exhibit ripple-drift, cross lamination, wavy laminations and parallel laminations. These sedimentary structures impart a striped appearance to the sandstone of the Upper Bhuban unit. North of Dimapur-Kohima road secton, Upper Bhuban Formation rests on the basal conglomerate and comprises hard, fine grained sandstone with abundant clay pellets. Conglomerate bands are often associated with sandstone. Stringers of coal are ubiquitous and the occurrences of coal streaks along bedding and cross bedding are quite common. Thinly bedded shales are usually associated with the sandstones. Carbonised and silicified woods are noted at places (Yedekar and Joshi, 1983).

Bokabil Formaton, the topmost unit of Surma Group, displays characteristic lithological attributes, with alternation of ripple drift, cross laminated sandstone and shales (200 metres). However, in northern part of Schuppen Belt there is a progressive overlap on Barail Group by the younger units of Surma Group and at the same time the Surma facies shows lateral passage into Tipam sediments, having lost its lithological identity.

In Changpang-Mirinokpo area, locally Bokabil Formation is seen directly to rest on Barail rocks. The unit has a predominantly argillaceous lithology dominated by khaki coloured, finely cross laminated siltstones, sandstones with thin sandstone lenses. A fine alternation of laminated sandstones and shales is the distinguishing feature of the Bokabil Formation (Yedekar and Ray, 1984). North of Changpang-Mirinokpo area and Phiro area, Bokabil Formation is dominantly argillaceous consisting of finely cross laminated, wavy laminated and occasionally flaggy siltstone with alternating parallel laminated fine to medium grained sandstone. These grade upward into overlying Tipams. Sedimentary structures like cut-and-fill, flame, cross lamination, convolute lamination and interference ripples are recorded in the lithounits of Bokabil Formation (Jena and Devdas, 1984). In the vicinity of Borjan Colliery, Surma Group loses its total identity and has probably merged laterally into Tipam Formation.

In Changpang-Mirinokpo area, the total thickness of the Surma Group in Schuppen Belt is reduced to 250 metres and Bhuban Formation shows a preponderance of sandstones with conglomeratic lenses (Yedekar and Ray,1984). North of Changpang-Mirinokpo area, in Changkikong and Japukong range, Bhuban Formation shows an attenuated thickness of 150 to 250 metres. Here it consists of parallel laminated and wavy laminated, fine to medium grained sandstone alternating with khaki to bluish grey siltstone (Jena and Devdas, 1984).

Petrographic studies of the Surma Group in Schuppen Belt has been carried out by Jena and Devdas (1984) and Devdas and Gandhi (1985). Jena and Devdas, (*op. cit*.) found that sandstones of Surma Group exposed in Wokha district are poorly sorted and comprise quartz, felspar, mica, chert, shale fragments, etc. and they can be classified as felspathic greywackes. Devdas and Gandhi (1985), working in Mokokchung district, found Surma sandstones to be well sorted. The grains are mostly subangular, matrix being usually more than 15%. Quartz constitutes nearly 80% of the framework grains. The other minerals in order of abundance are chert, plagioclase, K-felspar, mica, chlorite, tourmaline, garnet, rutile etc.

Heavy mineral studies carried out on Surma Group exposed in the Changpang-Mirinokpo area by Yedekar and Ray (1984), revealed appearance of epidote in the basal part. Upper part shows drastic decrease in opaques and iron coated grains. Characteristic predominance of garnet and epidote with respect to other non-opaques such as chlorites, staurolite etc has been seen. Yedekar and Ray (*op cit.*) feel that presence of epidote heralds the beginning of Bhuban and Bokabil Formations, which are characterised by predominance of garnet, followed by epidote over opaques and nonopaques in the heavy mineral suite comprising zircon, rutile, staurolite, chlorite, chloritoid, sphene and tourmaline. From the basal unit of Surma Group in Chali Tsu in Wokha district, *Pholadomya sp., Ostrea sp., and Carophyllum sp.* have been reported. (Yedekar and Ray, 1984). These are long ranging fossils not useful for assigning precise age but point to a shallow marine environment of deposition. In Zubza river section, the Surmas have recorded the presence of *Ammonia beccarii* which points to a Miocene or younger age (Ranga Rao, 1983).

Exposures of Surma Group in Inner Palaeogene Belt occur along the axial part of the Kohima Syncline. Surma Group was identified for the first time in the Inner belt by Prasad and Sarma (1981). The rock types comprise arenaceous units of Lower Bhuban, argillaceous facies of Middle Bhuban and coarse grained sandstone of Upper Bhuban.

It essentially consists of an alternation of shale, siltstone and sandstone with intervening pebble beds and conglomerates. The shales are grey/dark grey and sometimes olive green in colour but are not generally splintery. Intervening pebble beds contain quartz, chert, jasper and some darker rock fragments. Conglomerates with coal clast are common. Sedimentary structures observed are cross bedding, small scale channelling, interference ripples, ridge and furrow structure, convolution, flame structure, load cast and other penecontemporaneous deformation structures. Chief minerals in these rocks are quartz, feldspar and rock fragments. Other minerals present are mica and hornblende. The quartz is angular to subrounded. Many rock fragments of cherts and other metamorphic rocks are present. These generally correspond to lithic greywacke with minor percentage of arkosic grey wacke (Prasad and Sarma, 1983).

In Assam Shelf, Surma Group is represented by Bokabil Formation which rests over the denuded surface of the Barail rocks.

Tipam Group:

Tipam Group is conspicuously developed in Schuppen Belt and Assam Shelf. In Schuppen Belt it is having a thickness of 1800-2200 metres in Zubza area. It is subdivided into the lower Tipam Sandstone Formation and the upper Girujan Clay Formation. The palynological studies show that microplanktonic and coastal varieties are absent in Tipam miospore assemblages suggesting fluviatile condition of deposition. High altitude plant varieties are abundant in Tipam Group.

Tipam Sandstone Formation overlies Surma Group with gradational contact indicating that Tipam-Surma contact may be a facies boundary and time transgressive. Tipam Sandstone Formation, exhibits very little variation in lithological characters, and comprises thickly bedded bluish grey to light grey ferruginous sandstones with thin interbands of siltstones and shales, which become light brown on weathering. Fairly coarse current bedded sandstones and megacross beddings make up the bulk of this rock. The formation is at its thickest in the Dayang river section near its confluence with the Baghty, where it comprises essentially coarse ferruginous sandstone with thin sandy shale near its upper part. Evans (1932a) recorded that in outcrops of Tipam Group southwest of Naga Hills the clay beds within Tipam Sandstone are generally rare and appear to be lenticular. Tipam Sandstone in Naga Hills has yielded some bivalve fossils only, which are not age specific. The microflora suggests a Middle-Upper Miocene age. Multistoreyed sandstone are common with streaks of lignitised material, petrified logs of wood and clay pellets. Prominent spherical concretionary structures are seen in Changpang-Mirinokpo area (Yedekar and Ray, 1984).

It attains a thickness of 750 metres north of the section. Near Yimpang, a similar lithological setup of Tipam Sandstone was recorded with a thickness of about 1800 metres. It is observed that the formation tends to thin out towards the West from 1900 to 2200 metres in Zubza area and Merapani-Wokha road section to 900 to 1000 metres in Lakhuni tectonic block. This generalisation has followed the work of Chakradhar and Gaur (1984-85), Prasad and Sarma (1981-82), Sarma and Bharatiya (1977-78), Naskar and Chakraborty (1981-82), Yedekar and Ray (1983-84), Devdas and Gandhi (1984-85), Joshi and Yedekar (1981-82), Jena and Devdas (1983-84), Saxena *et. Al.* (1979-80) and Sarma and Naik (1983-84)

Tipam Sandstone is composed of quartz, felspar (both plagioclase and microcline), micas, rock fragments, chert and opaques. Ferruginous materials act as cement. It is a poorly sorted sediment of low maturity. The heavy minerals studies by Sarma and Naik (1984), Yedekar and Ray (1984), Jena and Devdas (1984) and Devdas and Gandhi (1985) showed that heavies are dominated by opaques and the nonopaque heavy minerals are garnet, hornblende, zircon, epidote, staurolite, chlorite, zoisite, rutile, tourmaline, chloritoid and sphene. Garnet and epidote appear to be in equal proportion. The appearance of hornblende marks the beginning of Tipam sedimentation (Jena and Devdas, 1984).

Girujan Clays Formation rests over Tipam Sandstone Formation and comprises argillaceous sequence of reddish, buff, grey mottled clays, sandy clays and channel sandstones. Sedimentary structures like large scale current bedding and flaser bedding are common. Escape traces of worm burrows are noted at places (Chakradhar and Gaur, 1985). The best exposure of Girujan Clays in Schuppen Belt is seen in Merapani-Wokha road section around Baghty where mottled clay-channel sandstone association bears the distinct environmental signature of flood plain deposits with network of meandering stream channels (Joshi and Yedekar, 1983).

Petrographic studies reveal that quartz is the dominant mineral with a few plagioclase and rock fragments. Quartz grains are subrounded to subangular, moderately sorted and with less matrix (Prasad and Sarma, 1983). The heavies show a high proportion of opaques and less epidote than found in Tipam Sandstone (Jena and Devdas, 1984).

Tipam Group has not yielded any biota which is diagnostic of well defined age. Palynological studies show that microplanktonic and coastal elements are totally absent and a high altitude microflora characterises the Tipam miospore assemblage. The microflora suggests Middle to Upper Miocene age.

Tipam Sandstone Formation sequence succeeds Bokabil Formation in Assam Shelf and is represented by the thick, grey, bedded sandstone with occasional greenish claystones towards the top. Tipam Group (Miocene) has attained a thickness of more than 1000 metres in Dhansiri valley near Dimapur.

Namsang Formation:

Namsang Formation is the youngest Neogene sequence of Schuppen Belt. It is well exposed in Lakhuni and Changki Tectonic blocks, where locally it attains a thickness of 600 metres (Yedekar and Ray, 1984). It overlies Girujan Clays with an erosional unconformity, marked by thick beds of conglomerate with subrounded clasts of sandstone and channel grits. Pebbles are mainly of Barail and Surma Sandstone, siltstone, and clay (Prasad and Sarma, 1983, Devdas and Gandhi, 1985). Pebble length varies from a few cm to 20 cms. The pebble imbrication indicates the current direction from East to West (Devdas and Gandhi, 1985). Variegated shales and siltstones are interbedded with the conglomerates. The sandstones are poorly sorted, immature and quartz dominant. Heavies show a dominance of opaques, the non-opaques are mostly garnet followed by zircon, chlorite and staurolite (Devdas and Gandhi, 1985).

Based on its superposition over a denuded surface of Girujan Clays, a Pliocene age is tentatively assigned to Namsang Formation.

Dihing Formation:

Pebble beds of Dihing Formation unconformably overlie the Namsang Formation and Girujan Clays (Chakradhar and Gaur, 1985). These are exposed around Jaluke area, Kohima district. It comprises thick beds of gravel with subordinate clay and has a thickness of 150 to 250 metres. The gravel beds exhibit poor sorting. Nature and attitude of beds are in conformity with the regional trend and help in differentiating this formation from the overlying Quaternary gravels in which vectoral conformity to the regional elements is lacking.

Sarma and Bhartiya (1978) described Dihing Formation from Tuli area. It occurs as a pebble bed occupying a strip northwest of Tuli. Pebbles are reworked and vary in size from 1 to 10 cms. Boulders are uncommon. Pebbles are derived from older formations and cementing material is a mixture of silica and clay.

Alluvium and Terrace deposits:

Alluvium and terrace deposits are Quaternary sediments which have been deposited in fluvial regimes. They have been tilted to varying degrees showing their involvement in diastrophic movements in some areas and has a subhorizontal disposition in areas devoid of diastrophism.

III. STRUCTURE AND GEOLOGICAL HISTORY

The four major geotectonic belts of Nagaland viz. Assam Shelf, Schuppen Belt, Inner Palaeogene Fold belt and Ophiolite Suite exhibit diverse structural parameters distinct from each other.

(1) Assam Shelf: A segment of Assam Shelf extends into parts of Dhansiri valley in Nagaland. Geology of the alluvial area is deciphered only from the geophysical surveys conducted in search of hydrocarbons. These surveys show that from a broad basement arch in the region of the present day Brahmaputra River, the basement slopes towards Naga hills in the South (Ranga Rao, 1983). The structural pattern of the sedimentary cover is controlled primarily by irregularities of the basement topography and differential movement along basement faults. In other words, the structures are typical of platform cover dissected by numerous faults.

The seismic work conducted in the frontal part of Schuppen Belt clearly indicates extension of Assam Shelf under the Schuppen Belt in Nagaland. The NW-SE structural elements in the platform appear to continue underneath the NE-SW striking Schuppen Belt (Ranga Rao, op. cit). As to the northern movement of Schuppen Belt, the seismic data now available indicate only a thin wedge of the strata got sliced off and pushed upon the shelf.

(2) Schuppen Belt: This belt defines the western flank of Naga Hills. Mathur and Evans (1964) described this as a narrow linear belt of imbricate thrust slices which follows the boundary of Assam valley alluvium for a distance of about 350 km along the flank of Naga-Patkai ranges. The belt is 20-25 km wide and extends for 200 km along the strike from Mishmi Thrust in the northeast to Maibong in the southwest, at the junction of Naga and Haflong-Disang thrusts.

Structurally, Schuppen Belt is a mosaic of several well defined litho-tectonic blocks seperated by thrust planes which often intersect each other. Evans (1964) postulated that the total horizontal movement of all the thrusts together is estimated to be over 200 km. Desikachar (1974 & 1977) however, expressed reservations on such large scale lateral movement of the thrust slices of Schuppen Belt. It is postulated that this belt comprises eight or possibly more overthrusts along which Naga hills have moved northwards relative to the foreland spur. The southeast margin of Schuppen Belt is delineated by Disang Thrust, and western limit is defined by Naga Thrust along the margins of Assam valley alluvium. These thrusts are aligned in a NNE-SSW direction.

Studies reveal that the belt comprises six well defined lithotectonic units sandwiched between thrusts on either side. From west to east the tectonic blocks are:

1. Tsori block bounded by Naga Thrust and Champang Thrust.

2. Champang block between Champang Thrust and Lakhuni Thrust.

3. Lakhuni block between Lakhuni Thrust and Sanis-Chongliyimsen Thrust.

4. Baghty block between Baghty Thrust and Sanis-Chongliyimsen Thrust.

5. Changki block between Sanis-Chongliyimsen Thrust and New Camp Thrust.

6. New Camp block between New Camp Thrust and Haflong-Disang Thrust.

In addition to the major thrusts, there are also some minor ones which often truncate the lithological sequence. The thrusts usually dip at 45°-50° near the surface and become flatter at depth. Tertiary sediments in Schuppen Belt are folded and the individual thrust blocks depict distinctively different fold styles. Some of the folds are steeply plunging due to rotation caused by movement along thrust planes.

In the southern part of Schuppen Belt, in Naga Hills, close to Dimapur-Kohima road section, Ranga Rao (1983) identified only two sub-parallel thrusts-Chathe Thrust and Piphema Thrust between Naga Thrust and Haflong-Disang Thrust.

In southwestern part of Wokha district, Naga Thrust has been traced along Dadi Ru stream. The rocks are deformed into steeply plunging folds close to the thrust (Yedekar and Jena, 1983). Baghty Thrust, Sanis Thrust and Yankeli Thrust lie east of Dadi Ru stream.

Yedekar and Jena (op. cit.) have opined that each thrust plane is a single tectonic plane having regional continuity and is not constituted by a number of small thrust planes overlapping on each other as visualised earlier. In Bhandari-Lakhuti-Lotsu area, to the northeast, similar structural setting has been reported by Joshi and Yedekar (1983). Close to the thrust contacts, they reported folds within Tertiary rocks which vary in style from close reclined to recumbent and open. In Kulajan area, exposures of coal are noted along a tight and sheared anticline. At places, layer to layer disharmonic type of folds with minor shearing has been recorded. In Changpang area, from east of Naga Thrust, Changpang, Lakhuni, and Sanis-Chongliyimsen Thrusts have been delineated by Yedekar and Ray (1984). They reported that where Barail rocks are juxtaposed against the thrust, a coal seam or carbonaceous shale with coal defines the thrust plane. In Changpang lithotectonic block, a coal seam exposed in Tsupangpa *nala* section marks the thrusted contact. The same is seen in Lakhuni Thrust where a coal seam forms a tectonic plane in Tyeba-Alosi section.

In northern part of Schuppen Belt, Devdas and Gandhi, (1985-86) have delineated Naga Thrust in the west and Lakhuni, Chongliyimsen-Khari and Haflong-Disang Thrusts in the east. Along the Chongliyimsen Thrust, a narrow strip of Barail Formation is found to be juxtaposed against Namsang Formation of Pliocene age. Evidently, the imbricate thrusting is a young geological episode. In the northern part of Schuppen Belt around Borjan two major thrusts viz. West Kongan and East Kongan Thrusts have been identified between Naga and Halflong-Disang Thrusts. In between Kongan Thrusts, the coal bearing Tikak Parbat (of Upper Assam area) and

Bargolai Formations occur as a truncated, doubly plunging anticline structure (Mitra and Chowdhury, 1970).

The regional structural trend in the Schuppen Belt is NE-SW and a subordinate trend is NW-SE to WNW-ESE. The F_2 regional movement, which was a long-lived progressive deformational event, produced large size NE-SW trending folds (eg. Bandersulia Anticline, Tiru Hill Anticline) and high angle thrust faults (e.g Lakhuni thrust, Choglyimsen thrust) in the Schuppen belt (Roy and Kacher, 1986). The regional F_3 deformation produced some NW-SE and WNW-ESE cross folds and strike-slip faults.

The cross folds are of relatively small dimensions than the very large NE-folds. Compared to Disang rocks in the Inner Palaeogene Belt, the Schuppen Belt has responded more to fracturing than buckling during deformations because of more competent nature of lithology and subcontinental obstacle in its western margin. The seismic survey also revealed an extension of Assam shelf sediments beneath the Schuppen Belt (Ranga Rao, 1983).

(3) Inner Palaeogene Fold Belt: A fold belt of Palaeogene rocks covers major part of central segment of Naga Hills. It occurs Haflong-Disang Thrust on the west, and ophiolite-sedimentary thrust contact in the east. This belt consists essentially of folded and thrusted pile of monotonous shaly sequence of Disang Formation (Upper Cretaceous to Middle Eocene). The synclinal cores contain molassic Barail Group. In Kohima Syncline undifferentiated Surma Group rests over Barail Group and the sequence continues into Manipur and Cachar Hills. There is perfect lithological gradation between the shaly sequence of Disang Formation and sand-dominated units of Barail Group.

The broad structural set up of this belt shows NNE-SSW trending folds which are usually open type towards west but become tightly compressed towards the eastern boundary with the ophiolites. Palaeogene rocks are deformed into open, upright folds with vertical to subvertical axial planes. The folds have gentle northeasterly plunge. In anticlinal zones, Disang Group is exposed with several symmetrical folds, whereas the younger rocks of Barail Group are seen in the cores of the major synclines. (Devdas and Gandhi, 1985, Sarma, 1984-85, Verma and Yedekar, 1983, Singh and Adiga, 1977).

The most prominent structural feature is defined by Mao anticlinal structure which runs along Dikhu river course, east of Mokokchung. The anticline is flanked to the west by Kohima Syncline, Wokha Syncline, Mokokchung Syncline, Wakching Syncline. In east, it is flanked by Zunheboto-Longkim Syncline. Further east, along the Tizu river a major anticlinal axis passes which is flanked to the East by Meluri-Konya Syncline. Part of the fold belt is delineated by Zunki Lineament, the tectonic significance of which is yet to be understood. East of this lineament, rocks of Disang Formation are metamorphosed to slates or even phyllites and are characterised by tight, compressed folds, often isoclinal in nature.

On mesoscopic scale, folding in Disang shales is very complex and slippage along axial plane is commonly noticed. The folds are generally tight, asymmetrical, overturned and locally rootless folds. They show layer to layer disharmonic style. Folds in the arenaceous rocks of Barail Group tend to be symmetrical and often form broad, open warps (Yedekar and Verma, 1983).

Singh and Yedekar, (1982) have stated that near Kiphire, the older units of Disang Formation are reported to be thrust over the younger units of the same formation. They reported major thrust along the contact of Disang and Barail rocks, 4 km along Kiphire-Zunheboto road which has resulted in Disang Formation to override the Barail Group.

The regional fold style of the belt around Meluri, Phokungri and Pfutzero in Phek district has been summarised by Chattopadhyay and Roy (1976-77). The first generation folds trend approximately in a N-S direction, represented by tight to isoclinal folds with moderate to steep dipping axial planes. The second generation folds trend nearly NE-SW comprising moderately tight and open type folds with low plunges (10°-15°). The third generation folds are broad, open type with large wavelength and low amplitude. They trend WNW- ESE to WSW-ENE with steep axial planes. Chevron folds and puckers are related to this phase of folding. The second generation folds define the regional structures and can be traced in the form of alternate antiforms and synforms and define the trend of this mobile belt.

(4) Ophiolite suite and the adjoining Naga Metamorphites: N-S to NNE-SSW trending arcuate Ophiolite Belt of Nagaland and Manipur extends approximately for 200 kilometres from northeast of Chokla in Nagaland to South of Moreh in Manipur and continues further south in Indo-Myanmar range, Chin and Arakan-Yoma to Andaman and Nicobar Group of islands.

Tectonised and dismembered ophiolitic rocks are thrust over Disang Formation in west. Ophiolite Suite or their sedimentary cover, are, in places, overthrust by Saramati Formation (Pre-Mesozoic) and Nimi Formation (Cretaceous-Lower Eocene). This linear zone comprises most of the members of the typical Ophiolite Belt and is overlain by a thick sequence Salumi Formation which is differentiated as a distinct lithostratigraphic unit. Ophiolite Belt and Salumi Formation are unconformably overlain by the immature, mainly ophiolite derived, shallow marine to paralic, volcano-clastic Phokphur Formation of Eocene Age.

As a result of the increased interest in the geology of ophiolites, a wealth of useful data has accumulated on the Naga hills ophiolite in recent times. The generally accepted view is that ophiolitic rocks occur as dismembered, steeply dipping tectonic slices and are brought in juxtaposition against the sediments of the Disang Group. The contact between Ophiolite suite and Disang Formation is marked by shearing, brecciation and silicification with occasional development of tight to isoclinal folds. Stretching and rupture of limb and nose of the folds have given rise to a band, as seen in a locality near the contact. Drags and minor slips are noted. The contact is inferred to be a high angle reverse fault.

Within the Ophiolite suite, various members occur as faulted slices. The metaultramafites show tectonic fabrics defined by parallelism of serpentine grains. Planar structure in the metavolcanics is defined by parallel alignment of amphibole, chlorite and epidote. Variable trends are seen in these secondary planar structures and the layering in the associated cumulates.

Bhattacharya and Sanyal (1985) observed that within the metamorphics, the most pervasive planar structure is cleavage/schistosity. With increase in deformation, the schistosity (S_1) is folded with development of slip schistosity/crenulation cleavage and fracture cleavage. These are noticed in sericite schist and quartz-muscovite schists.

Three folding episodes have resulted in corresponding fold types in Naga metamorphics. These are:

1. F_1 - Tight flexure folds with N-S to NNE-SSW trending axial planes dipping moderately towards NE.

2. F_2 - Tight folds with E-W trending axial plane, a steep dip towards N and S. Fold axis plunges towards E or W.

3. F_3 - Large scale drag folds along N-S trending horizontal axis and N-S striking vertical axial plane.

Acharya and Jena, (1982) record that in Jaonger-Phokphur section the ophiolitic basement and Phokphur Formation have been faulted, imbricated and folded. Open, overturned to isoclinal folds with N-S to NE-SW trends are developed within Phokphur Formation. These are accompanied by development of axial plane type slaty cleavage. A characteristic structural style in Ophiolite Belt is defined by isolated klippes of highly deformed and sheared quartz phyllonites and quartz-sericite-schist, possibly of Saramati Formation, which overlies the serpentinite and volcanics further towards the west. The isolated klippes show open northerly trending folds corresponding to F_1 folds of Phokphur Formation. Such klippes are reported around Phokphur, Salumi and Kamku Hills (Acharya and Jena, 1982).

Naga Hills are characterised by multiple deformation and fracturing. Structural studies reveal that there are three generations of folding within the mafic-ultramafic and the sedimentary rocks. The first generation folds trending, generally in a N-S direction, have low plunging, isoclinal folds with steeply dipping axial planes. Ophiolite suite was probably emplaced during the waning stages of the first generation of folding.The second generation folds trend NE-SW and are moderately tight to open type with axial plane dipping at moderate angles towards east and west. The third generation folds are transverse to the trend of orogenic belt. They are broad, open type, having WNW-ESE trend with steeply dipping axial planes towards the SW and NE.

The studies of the structural elements of the Ophiolite Belt in Manipur show that the different tectonic slices of the ophiolites are further modified by folding (Sengupta, *et al.*, 1986). These are mainly rootless bodies, which are repeated on the surface due to regional, open upright folds. The dips of the tectonic contacts of the ophiolite are clearly visible in most of the exposures and are conformable with the dips in adjacent sediments. They have usually changing attitudes, compatible with the geometry of the major folds and appear like a multilayered stack of ophiolite slices on Disang Group, co-folded with the Disang Formation during a later deformation history.

The macrofracture system includes mainly faults viz. longitudinal and transverse. The longitudinal faults trend NNE-SSW to NE-SW dipping towards east or west. They are mostly high angle reverse faults. The major transverse faults trend NW-SE, and are of wrench fault type. They account for the major off-set of the lithological makeup of the ophiolite belt.

Structural Evolution : The thrust system in the Schuppen Belt cuts off the folded Tertiary sediments into interlocking tectonic slices. The respective thrust blocks depict distinctive fold style related to sequential deformation.

1. The genetic history of Schuppen Belt is closely linked with the Upper Eocene emplacement of ophiolites along the eastern margin of the Indian Plate. The tectonic signature of this event is marked by overturned reclined to recumbent folds in Disang-lower Barail sediments.

2. With the suturing of Indian Plate with the Eurasian Plate and Myanmar microcontinent and uplift of Indo-Myanmar range, Oligocene- Miocene molasse basins evolved west of the uplifted Indo-Myanmar range. The platform areas witnessed block adjustments mainly due to vertical movements.

3. Late Miocene or part of Surma folding of the continental margin sequence and mollasse sediments led to development of large scale is upright folds which marks the linearity of this mobile belt. Syntectonic adjustment of the basement to crustal shortening resulted in development of basement faults and reactivation of pre-existing basement faults.

4. Continued crustal shortening in Pliocene resulted in the growth of the faults into thrusts along western margins of the fold belt due to asymmetric nature of the westerly directed push against rigid crustal blocks in the west. The coal seams often facilitated the gliding. Implicit in this model is the idea that the tectonic blocks in the Schuppen Belt, although allochthonous in nature probably did not have large scale horizontal translation from the east as visualized earlier. The Schuppen Belt could have formed in a narrow, linear, graben type, tectonic basin at the periphery of Shillong - Mikir massif. This situaton might be nearly similar to the development of Siwalik basin on the northern margin of the Indian continent.

5. Movements along thrusts often caused rotation of post-Surma folds into steeply plunging folds in the thrust block of the Schuppen Belt. The varying degree of rotation caused local variations in the fold style of the Schuppen belt.

6. Pleistocene tectonic movements (chevron type folds) variably affected the thrust slices. Even Quaternary beds have been tilted to varying amounts.

GEOLOGICAL HISTORY

The basement rocks are nowhere exposed over the major part of the state but a few boreholes drilled for oil exploration show a pronounced erosional history during the Palaeozoic and major part of Mesozoic era.

Late Cretaceous period heralded the onset of sedimentation in parts of this peneplained country. Deposition of lower shale units of Disang Formation ushered a new spell of sedimentation. It is widely held, that in the shallower part of master basin in Upper Assam and Mikir Hills, Sylhet Limestone and Kopili Formation were deposited, while the upper units of the Disang Formation accumulated at the same time in relatively deeper parts of the present Naga Hills, south of Disang Thrust (Ranga Rao, 1983).

Recent finds of Lower Eocene foraminifera from the shales and cherty sequence of lower unit of Disang Formation in Taheru *nala* near Jaluke (Chakradhar and Gaur, 1985) probably testify to the deposition of the lower units of Disang Formation in relatively deeper water conditions. But with passage of time there was a general shallowing of Assam-Arakan basin. As a result of this, upper units of Disang Formation over large stretch of this basin display characteristics of a shallow water distal shelf facies. Occasional presence of arenaceous foraminifera, palynofossils of coastal elements and gypsiferous bands in shales of Disang Formation are all suggestive of their deposition in shallow water environment. But near the continental margin, Disang facies assume a ‘wild flysch’ character with which olistoliths of limestones are associated. Such records of olistostromal horizons is excellently preserved in Ukhrul area in Manipur and its extension in Kiphire area in Nagaland is proved by the occurrence of exotic limestone blocks in the upper unit of Disang Formation. This olistostromal horizon probably defines the palaeoplate boundary and was emplaced in the trenches and canyons on the continental margin due to the phenomenon of gravity gliding (Robertson, 1977).

A narrow ocean basin separated this segment of Indian Plate from that of Myanmar. In the oceanic domain flanking Disang basin the oceanic crust continued to form till the end of Meastrichtian and possibly in Lower Eocene as testified by convincing palaeontological records from limestone interbands within basalts cropping out in Manipur. Palaeoecological conditions of oceanic domain can be visualised from the nature of biota of cherts and limestones associated with oceanic basalts and from geochemistry of the volcanic rocks of Ophiolite Suite. The volcanics are characterised by high total alkalies and TiO_2, moderate FeO and MgO and are comparable to those of aseismic ridges, seamounts and ocean island basalts (Venkatramana *et al.*, 1983).

Evidently, a number of seamounts characterised the physiography of the oceanic domain of Naga Hills. Radiolaria and cocoliths from chert and limestone interbands within the volcanics also suggest their deposition below carbon compensation depth (CCD).

By the end of Lower Eocene a chain of islands were created along the Naga-Chin-Arakan-Yoma belt with arc trench basins to its back and a flysch trough to the front. The dynamic regime of this period was a destructive one when subduction and lithospheric consumption began. Seamounts came into subduction zone thereby obstructing the process. Eastward subduction continued with scraping off of lithospheric slices and their accretion to the leading edge of the eastern continental mass. The trench, developed on the Indian continental side during this process, started receiving the olistoliths. By Middle Eocene a stack of ophiolite slices was created and oceanic domain was transformed into shallow isolated marine basins. Upliftment of ophiolites during Middle Eocene resulted in these interspersed shallow water seas to become locales for deposition of ophiolite derived volcanoclastic open marine to paralic sediments of Phokphur Formation. The associated flora and fauna of the Phokphur also bear signatures of very shallow marine environment of deposition.

The continental shelf in west was receiving upper units of Disang Formation and subsequently Barail Group sediments in Upper Eocene and Lower Oligocene. The newly uplifted ophiolitic stack also shed its detritus in Upper Disang-Barail basins. At this period outer molasse basin evolved close to shelf. Shallow marine conditions gave place to delta on which mangrove, coastal and terrestrial plants flourished to form the coaly facies of Barail Group (Ranga Rao, 1983). Barail rocks were deposited in tide dominated deltas.

Late Oligocene marked a sea level change in palaeogeographic panorama, when regional unconformity actually marked the collision between Indian and Eurasian continental plates at Myanmar. The uplifted ophiolite stack was brought as an allocthonous land mass against Disang sediments. The rootless ophiolite sheets were carried by the leading edge of Myanmar continental margin and brought against distal shelf of Disang sediments.

In Miocene, deposition of sediments of Surma and Tipam Groups continued in outer molasse basins of Naga Hills and in adjoining part of Surma valley along with post Tipam folding of molasse sediments in Late Tertiary period. This led to the development of large scale tight, upright folds which mark the linearity of this mobile belt.

Syntectonic adjustment of basement to crustal shortening resulted in development of basement faults and reactivation of pre-existing ones. Continued crustal shortening in Pliocene transformed these faults into thrusts along western margin of the fold belt due to asymmetric nature of push from the east against rigid crustal basement in the west.

Coal seams helped in this gliding process. Tectonic blocks of the Schuppen Belt evolved in this manner along the western flank of Naga Hills. Movements along thrusts often caused rotation of post-Surma folds into steeply plunging folds in thrust blocks of Schuppen Belt. Westward translation of tectonic blocks often resulted in large scale folding of the Tertiary sediments. A spectacular example of such fault-induced recumbent fold is seen near Pherima village, on Dimapur-Kohima road and folding of thrust slices is the effect of Pleistocene tectonic movements.

Quaternary sediments of Naga Hills bear imprints of neotectonic events.

IV. MINERAL RESOURCES

In Nagaland, the major minerals are limestone, coal and nickel-cobalt bearing magnetite. Limestone deposits occur in Nimi, Khonga, Kamku, Salumi, New Basti, Pang, and Wui Chokla areas of Tuensang district and Wazeho, Satus and Mollen arreas of Phek district. They are associated with the ophiolite suite and metamorphic rock belt. Coal deposits which occur in Tikak Parbat / Jenam Formations of Barail Group are located in Borjan-Tiru areas of Mon district, Changki-Chongliyimsen and Lakhuni areas of Mokokchung district, Leo Longidang area of Wokha district and Konya area of Tuensang district. The nickel-cobalt bearing magnetite occurs in Phokphur area of Tuensang district and Ziphu, Washello, Reguri, Molhe and Phor areas of Phek district. They are associated with cumulate ultramafic parts of the ophiolite complex. There are good quality dimension stones associated with the ophiolite belt.

Minor chromite occurrences are located in the ophiolite belt in Reguri and Washello areas of Phek district and Pang, Phokphur and Wui areas of Tuensang district. Sulphide (Cu-Fe) occurrences are noted in chert-volcanics and mafic-ultramafic association of ophiolite belt at some places of Phek and Tuensang districts. Minor non-metallic mineral occurrences include slate, clay, glass sands, serpentine and sporadic talc, magnesite and asbestos. Oil and natural gas occur in western foothill areas and Schuppen Belt, being trapped in fractured and weathered basement rocks, and in the overlying Tertiary cover sediments of Kopili / Barail / Surma / Tipam rocks. Trial production of hydrocarbon was done by Oil and Natural Gas Corporation in the Changpang area of Wokha district.

Some of the mineral deposits are described below, in brief, for general understanding of their nature, size, utility prospects, approachability and implications for industrial development in this under developed state.

(i). LIMESTONE

Nimi limestone deposit : Limestone is exposed around Nimi village of Tuensang district over a strike length of about 10 km within Nimi Formation. Southern part of this deposit is divided into two blocks, namely Pyakatsu block and Nimi block, bound between Turati and Chizati *nalas*. In all, six limestone bands occur in this area, being associated with phyllite and quartzite. Thickness of limestone bands varies from 9 metres to 120 metres. Partings of phyllite-quartzite vary in thickness from 20 to 70 metres. Second, third and fourth limestone bands together constitute the most important limestone deposit, having a total thickness of 120 meters over a strike length of 3 km. The limestone is fine grained, whitish to ash grey and crystalline. The analyses of Nimi limestone deposit is given in Table 1.4.6.

Table 1.4.6: Chemical composition of Nimi limestone deposit and Wazeho limestone deposit, Tuensang district and Wazeho limestone deposit and Satuza limestone deposit, Phek district, Nagaland.

Constituent	Nimi limestone deposit	Wazeho limestone deposit	Satuza limestone deposit
CaO	42.6-54.6%	48.56%	49.5-55.01%
MgO	0.3-6.3%	0.84%.	0.38-3.0%
R_2O_3	0.1-3.7%	0.89%	0.1-0.56%
FeO		0.18%	
Insolubles	0.3-5.6%		0.2-3.8%

The Directorate of Geology and Mining, Nagaland reported an inferred reserve of 111.07 million tonnes of limestone upto a workable depth of 100 metres (based on large scale mapping). This deposit is now being connected with Pungro (65 km) and Kiphire (100 km) by a motorable road which was constructed by the Border Roads Organisation. This deposit could be utilised for cement, chemical and paper/ pulp industries when supported by necessary infra–structure facilities. A state-owned 300 t.p.d. cement plant is planned for utilising limestone mined from this deposit.

Wazeho limestone deposit: This deposit is located at a distance of about 3 km southeast of Wazeho village in Phek district. Limestone occurs as several detached pockets and lenses of various dimensions. Other rock types are phyllite, chert, basic volcanics and minor serpentinite. The area is a part of western margin of Naga Hills Ophiolite Belt and is spread over approximately 0.5 sq. km. The largest limestone band occurs in the southeastern corner of the area, extending for a strike length of approximately 500 metres with a thickness of 5 to 20 metres. The limestone is fine grained, whitish to ash grey and crystalline. The average composition of the limestone is given in Table 1.4. 6.

The Directorate of Geology and Mining, Nagaland proved limestone reserve of about 0.9 million tonnes based on detailed drilling. Limestone from this deposit is being used in a 50 t.p.d. cement plant by the State Government.

Satuza limestone deposit: This limestone deposit occurs in strike continuation towards northeast of Wazeho deposit. About ten small limestone pockets occur in this deposit located south and southeast of Satuza village in Phek district. Other associated rocks in the area are chert, quartzite, basic volcanics, serpentinite and glaucophane schist of ophiolite complex. The chemical analysis of the deposit is given in Table 1.4.6.

The State Directorate of Geology of Mining worked out this deposit. The deposit is near the motorable road constructed by the Border Road Organisaton. Because of their nearness to the infrastructural facility, Wazeho-Satuza-Moke deposits could be utilized for cement manufacturing and dimension stones.

(ii) DIMENSION STONES

Ophiolite belt of Nagaland with its varied lithology offers a good potential for dimension stones. Peridotite, pyroxenite, gabbro, serpentinite, basalt, spilite, red chert, limestone, and marble can be cut into required size, polished and used for decorative purpose. Hard sandstones of Barail Group and slates of Disang Formation also hold potential for dimension stones. Although no specific deposits have been prospected so far for dimensional stones, large deposits of good quality stones exist in the ophiolite and metamorphic belts in Phek and Tuensang districts of Nagaland.

(iii) MAGNETITE

Phokphur magnetite deposit:

This deposit occurs about 2.5 km east of Phokphur village in Tuensang district. Magnetite occurs as a tabular body trending NNE-SSW and dipping 30°- 40° towards WNW. It has a strike extension of about 1 km and dip extension of about 300 metres. The thickness of the ore body varies from 1.2 to 12 metres. This deposit is significant because of its appreciable content of strategic metals like nickel and cobalt. The general composition of the ore is given in the table below.

Table 1.4.7: Chemical composition of Phokphur magnetite deposit, Tuensang district, Nagaland.

Constituent	Amount
Fe_2O_3	65.25%
Cr_2O_3	4.45%
NiO	0.63%
CoO	0.09%

Towards south, the ore body is covered by an overburden of conglomerate-sandstone-shale horizon which increases in thickness to a few hundred metres in the adjacent Penkim ridge to its south. Recently, two more magnetite bands are reported by the Directorate of Geology and Mining, Nagaland in southern continuity of this deposit. Several similar nickel-bearing magnetite deposits occur in Phek district in the ophiolite complex.

Phokphur deposit was divided into north and south blocks for exploration purpose. GSI took up exploration drilling in north block and estimated an indicated reserve of 1.83 million tonnes over an area of 0.17 sq. km. The Directorate of Geology and Mining, Nagaland estimated an indicated reserve of 1.62 million tonnes from the south block based on semi detailed drilling, over an area of 0.14 sq. km. This ore could be utilised either for extraction of strategic metals like nickel and cobalt or for ferroalloy industry. The main constraint for nickel extraction is the occurrence of nickel in both oxide and silicate phases. Research for utilisation of nickel was in progress under sponsorship of the State Government in collaboration with research institutes of the country.

(iv). COAL

Tertiary coal occurs in Schuppen Belt associated with Barail Group of rocks. Important coal seams occur in the lower argillaceous member of Tikak Parbat Formation of Barail Group in Mon district. Besides these, coal occurrences have also been reported from Tuensang, Wokha and Mokokchung districts. These are high sulphur (4.3%), low ash (3.0%) and low moisture (5.4%) coal. They are poorly caking. Coal occurrences in Nagaland can be grouped areawise into the following four sectors:

Borjan area:

In this area of Mon distirict, some important coal seams occur. Coal mining started in this area as far back as in1914. Working continued intermittently upto 1966. Major coal seams are located in the Tikak Parbat Formation. The coal bearing formation is bound between two subparallel, NNE trending thrusts. Based on large scale mapping, the GSI estimated a reserve of 55 million tonnes of coal upto a depth of 150 metres (Mitra and Chowdhury, 1970). The Directorate of Geology and Mining, Nagaland, in an effort to revive coal mining in this area started extensive exploratory drilling in this deposit since 1973. Rock types in the area are sandstone, shale, carbonaceous shale and clay. The State DGM proved a reserve of 4 million tonnes of coal from the Wakting seam in its first phase of exploratory drilling. The area needs further exploration to assess the still untapped potential of this coal belt.

The generalized sequence of coal seams of the lower argillaceous member of Tikak Parbat Formation (GSI, 1974) is as follows :

Table 1.4.8: Generalized sequence of coal seams.

Seam No.	Shale and grey shale	Roof
IV	Shale and grey shale Coal and interbedded shale Parting	3 metres 50-60 metres
III	Coal Parting (grey shale and carb shale)	1 metre 35-40 metres
II	Coal Parting (shale)	0.90 to 1.20 metres 20-25 metres
I	Coal (Wakting seam)	3- 4.5 metres

Tiru area:

This area also belongs to Mon district. Three coal seams associated with Tikak Parbat Formation were reported by the State DGM, (Ahmed and Roy, 1978). These are: (i) Coal seam (thickness: 1.25m) at the confluence of Saffrai-Tihok Rivers, (ii) Coal seam (thickness: 2.5 m) upstream of the first occurrence and (iii) the two seams (thickness: 2.25 m to 3 m) 3 km SE of Tiru village (DGM, 1978). Barail, Surma and Disang rocks are exposed in this area. The regional strike of beds is NE-SW with moderate to steep dip towards SE. The coal seams have been affected by tectonic disturbances associated with Schuppen Belt.

Jhanji-Desai Valley:

Coal occurrences are reported from several places of Mokokchung district. They occur mostly in the Changkikong - Japukong region being associated with Barail Group. Areally, the coal bearing areas can be grouped into three sectors as follows:

(i) Changki-Chonglymsen area:

A number of workable coal seams are recorded between Changki village in the south and Chonglymsen village in the north. Some thick coal seams also occur northwest of Changki. The top seam of the area is 1.5 to 2.2 metres thick and exposed in a number of nala courses and hill scarps. It is exposed in a nala about 1 km SE of Merakyong, 1 km NNW of Chonglymsen and on a scarp 1.5 km south of Athuphumi village. This seam is tectonically less disturbed. Its occurrence has been recorded discountinuously over a strike length of about 8 km. The State DGM took up exploratory drilling in Merakyong area of Changki-Chonglymsen section in 1971. Analyses of coal samples from this area are as follows:

Table 1.4.8: Analysis of coal samples

Constituents	Changi Area	Chonglymsen
Moisture	4.3-9.5	4.3-4.9
Ash	1.9-2.6	6.6-7.7
Volatile matter	34.7-35.2	40.2-40.6
Fixed carbon	52.7-59	47.3-47.9
Sulphur	1.72-1.74	2.32-5.59

(ii) Waromung-Mongchen area:

A coal seam of 3.5 m thickness occurs about 20 metres below Khari fault. It increases in thickness towards SW to 5 metres including shale partings. Besides this, two compound seams occur near Khari village, northwest of Waromung, six coal seams of varying thickness ranging from 1 to 6 m occur within 1000 m rock strata. Coal seams of workable thickness also occur in the Ait *nala* NW of Mongchen village.

Analyses of coal samples from Waromung area are as follows:

Table 1.4.9: Analysis of coal samples

Constituents	Percentage
Moisture	2. 9-4. 8
Ash	2. 2-9. 7
Volatile matter	43. 7-45 .8
Fixed carbon	43 .9-49 .5
Sulphur	1.93 -6 .8

(iii) Lakhuni – Mirinpoh area:

A 3.4 m thick coal seam occurs about 20 m below the top of Barail rocks, north of Mirinpoh. It extends strike-wise for about 1.5 km with diminishing thickness. Two coal seams of 4.4 m and 1 m thickness are also recorded west of Lakhuni.

Analyses of coal samples from Lakhuni area are as follows:

Table 1.4.10 : Analysis of coal samples

Constituents	Percentage
Moisture	4.8 – 9.3
Ash	2.8 – 20.7
Volatile matter	33 – 43
Fixed carbon	37.8 – 49.4
Sulphur	0.86 – 2.53

(iv) Konya area:

Coal occurs around Konya village of Tuensang district in Tikak Parbat Formation of Barail Group. The Barail rocks occur in the core of a syncline flanked by Disang rocks of Inner Palaeogene Belt. Konya coal deposit is a distinct identity being located in the midst of Inner Palaeogene Disang belt of Central Nagaland far away from Schuppen Belt of the west. It seems that during the Upper Eocene-Lower Oligocene, there was more than one coal forming Barail basins isolated from one another but with similar deltaic environment favourable to coaly facies. The Konya basin may be one such example of a small, isolated, coal-forming basin.

Five coal seams were located around Konya village by the State Directorate of Geology and Mining (1972). They range in thickness from 1.4m to 6.0 m and are separated by partings of shale, carbonaceous shale and clay. The seams are tectonically very disturbed by folding and faulting. A reserve of 0.75 million tonnes of coal was inferred from three coal seams of the area by Directorate of Geology and Mining, Nagaland. Analyses of coal samples by the Central Fuel Research Institute, Jorhat, showed the following characteristics.

Table 1.4.11: Analysis of coal samples

Constituents	Percentage
Moisture	3.2-16.9
Ash	12.4-25.8
Volatile matter	27-29.6
Fixed carbon	42.1-50.7

It is observed that Tertiary coal seams and layers associated with Barail Group whether inside or outside Schuppen belt are inconsistent in nature with regard to their thicknesses, strike lengths, depth persistence, compositions, structural set-up, etc. Moreover, they are tectonically very disturbed. They pinch and swell erratically. Thick coal seems are sometimes lost by pinching even within a very short distance. Their persistence along strike and dip is unpredictable. Core recovery is very poor during drilling because of tectonic disturbances and fragmentary nature of the coal seams. However, a detailed inventory of the coal occurrences of Nagaland is necessary to plan any resource utilization scheme for development purpose.

(v) PODIFORM CHROMITE

Podiform chromite occurrences are minor in the Nagaland part of the ophiolite belt, in contrast to that of the Manipur (Ghosh et, al 1980; Agarwal & Rao, 1978; Chattopadhyaya, et al, 1983; Venkataramana, et al, 1984). Though minor occurrences have been recorded in a few places, laboratory studies were carried out from samples mainly from Reguri, Washello and Mollen post in the Phek district and Kenjoing in the Tuensang district. The salient features of these occurrences are described below:

PHEK DISTRICT

The chromite occurrences could be described as three types:

Massive Chromite: This occurs as pods (1m x 3m), lenses (0.5 m x 2m) and streaks (width 3 mm) in serpentinised dunite and harzburgite. Their distribution is irregular. The steep dipping pods are parallel to the trend of foliation of the enclosing rock.

Nodular Chromite: The ellipsoidal to sub-rounded nodules, usually 10 mm to 20 mm across, often show effects of deformation. They are either separated or juxtaposed locally showing crude alignment.

Coarse Crystalline Chromite: These occur mostly as tabular sheets, varying in dimension from 1m x 0.5m to 2 m x 0.5 m within metaultramafites and are often brittle in nature. Besides, chromite also occurs as disseminations in dunite.

In chromitite, the only one mineral is highly fractured chromite which occurs as granulated and rarely as idiomorphic grains within serpentine and pyroxene. The ratio of ore and silicate varies from 0.5 to 0.33, while locally the chromtite grains show annealing texture indicating syntectonic rebinding (Augustithesis, 1976)

A fraction of pure chromite separated by standard methods (Hutchinson, 1974) shows the following characteristics (Venkataramana, *et al,* 1984):

i) The Cr_2O_3 – content (44 to 50 %) is comparable to that observed in podiform chromtie (Thayer, 1969, 1970).

ii) TiO_2 – content is in traces which is typical of Alpine chromite (Dickey, 1975)

The scatter of Cr/Cr+Al and Mg/Mg+ Fe_{2+} indicates their affinity to Alpine chromite (Irvine, 1967, Thayer 1969; 1970).

Al and Cr show negative correlation suggesting possible exhange of Al and Cr in the crystal structure. This is common in Alpine chromite (Thayer, 1970) suggesting that these chromites crystallized under high pressure-probably mantle condition.

The restricted occurrence of chromitite within the metaultramafics of the ophiolite suite could suggest that they represent residual products of fractional crystallization of the parental magma.

Selected grab samples from this area analysed as follows:

Table 1.4.12: Selected grab samples.

	SiO_2	Al_2O_3	Fe_2O_3	Cr_2O_3 (in wt. percent)	MgO	Ni	Co
Chromitite	15.40	7.20	17.16	50.80	3.97	0.19	0.04
	9.90	10.06	15.96	50.29	6.45	0.25	0.07
	12.14	7.20	15.16	49.10	9.6	0.17	0.03
	11.56	13.54	14.17	45.57	0.67	0.17	0.03
Nodular Chromite	11.56	7.20	13.57	49.30	11.61	0.26	0.02
Coarse Crystalline Chromite	7.12	14.54	16.46	51.54	6.45	0.12	0.03

It may be seen from the above, that the chromites of this area correspond to the Grade-II of the refractory type (Prusti, 1977).

TUENSANG DISTRICT:

In this area, chromite occurs as crude parallel layers (less than 1 cm in thickness) in dunite and more rarely harzburgite. Locally the chromite grains show minor stretching and/ or even pulling apart of chromite crystals. The hairline cracks in chromite are filled up by olivine suggestive of the history of chromite.

In course of recent mapping dissemination of chromite in dunite bodies have been located near Kenjong. The host rock shows profuse limonitisation. Traverse in the adjacent area suggest that the chromite bearing zone may extend up to east of Wui.

No stytematic sampling has been carried out in this zone. However, two grab samples from the chromite-bearing rocks analysed as follows:

Table 1.4.13: Analysis of samples.

Sample No.	Cr_2O_3	Fe_2O_3	
1	9.72	8.82	X-ray studies show cell dim-
2	10.71	0.83	ension of the chromite as 8.299 A° suggesting magnesio-chrmote composition

X-ray study by Shri Ram Pratap, GSI, NER, Shillong

LATERITE:

Occurrence of laterite is very rare in the Nagaland Ophiolite belt. Recently, small isolated pockets of laterite over serpentinised ultramafic cumulate have been recorded in a few localities viz, south-east of Mollen, north of Washello and north of Reguri, (Venkataraman et al, 1982).

The thickness of the laterite profile varies from 5 cm to 1 m and the individual bodies occupy areas between 0.1 sq.m to 10 sq.m. They are confined to flat to gently sloping (average 10°) saddle between 1500 m and 1800 m contours in an otherwise highly dissected topography. Texturally, they vary from coarse grained loose aggregates of partially altered ultramafic held together by fine grained quartz-ferruginous material (mostly goethite) to fine grained fawn to pink coloured hard, compact, porous rock.

The analytical data of selected samples are summarized in the following table:

Table 1.4.14: Analysis of samples.

Sample No.	Al_2O_3	Fe_2O_3	Ni	MgO	Mineralogical Data		
	(In present)				Major	Minor	Trace
231A	20.57	37.12	0.65	Tr	Quartz	Goethite	-
231B	17.00	33.53	0.45	Tr	Quartz	Garnierite	-
231C	11.29	11.37	0.62	Tr	Quartz	Goethite	-
345	13.34	39.92	0.67	Tr	Goethite	-	-
120	20.02	43.51	1.78	Tr	-	-	-

It may be seen from the above, that locally, the laterite contains high values of Ni in which either goethite or garnierite is present. This is comparable to that observed in Gamnom/ Sirohi areas of Manipur (Ghosh, et al, 1980).

Recently, detailed studies have been undertaken in areas south-east of New Mollen and some of the salient features of the observations are given below.

The following tentative vertical sequence has been built up, though it is not uniformly preserved in all the outcrops.

(a) The top brown soil zone is composed of granules of laterite and is loose, loamy in nature. The thickness of the zone varies from 5 to 10 cm. It supports sparse grass and pines.

(b) The underlying pisolitic zone is composed of goethite + limonite + secondary silica boxwork having pisolitic, colloidal / colloform texture. The colour varies from fawn to yellowish brown. Crypto-crystalline silica often forms upto 40 percent of the rocks, wherever this pisolitic zone overlies the bedrock. Partially altered parent rock minerals also occur as inclusions.

(c) The granular goethite zone overlying the bedrock could be sub-divided into two sub-zones viz, (i) hard ferruginous granular aggregates. The round to elliptical goethite granules vary from 1 mm to 10 mm in size and held by ferruginous material (limonite). Presence of partially altered rock minerals (viz, clinopyroxene, spinel) has been noted (ii) Granular aggregates of goethite + limonite + minor quartz granules range in size from 1 mm to 10 mm.

The major phase in both the zones is goethite with quartz occurring in the upper part of the granular goethite zone and pisolite zone. Minor talc and montmorillonite are also present in the granular zone. The bedrock is medium to coarse grained, massive, well jointed serpentinised peridotite (dunite, harzburgite and lherzolite) with minor pyroxenite (Wehrlite).

Compared to the bedrock, the laterite shows higher Al_2O_3 (1.54 to 20.57 percent); Fe_2O_3 (11.37 to 53.39 percent); Ni (0.11 to 1.8 percent) and Co (Tr to 0.43 percent) and lower MgO (trace), CaO (trace), Na_2O (0.02 to 0.3 percent) and K_2O (0.08 to 0.5 percent).

The high loss on ignition (L.O.I.) content (4.81 to 20.40 percent) is possibly due to H_2O, as no CO_2 bearing mineral is identified in the laterite. This suggests that most of the Fe and Al are present in the hydroxides. The absence of crystalline aluminous phase (gibbsite, bohlmite, bayerite) indicates that most of the alumina, might be accommodated within goethite, montmorillonite and talc while the rest might be occurring as non-crystalline aluminous gel.

Most of the analyses fall in the laterite field in the SiO_2 – Al_2O_3 -Fe_2O_3 diagram of Lukens (1964) and indicate a basic–ultramafic parent rock. The average chemical composition of the concretionary type of laterite of this area shows that the low MgO, CaO, high Fe_2O_3, Al_2O_3 and moderate Ni-content is comparable to those recorded from Simlipal and Sukinda area, Orissa.

(v) OIL AND GAS

Oil and gas bearing Tertiary sediments occur in the Schuppen Belt and western foot hill areas of Nagaland. Many oil and gas seepages are recorded along nalas, streams and hill slopes near thrust planes. Oil is trapped in weathered and fractured basement rocks and overlying sediments of Kopili, Barail, Surma, Tipam and Namsang in the foothills. Several anticlinal structures and thrust planes are recorded in the Tertiary sediments. There are structural as well as stratigraphic traps. Some known anticlinal structures are Nichuguard, Bandersulia, Tiru etc. These areas were reconnoitred by some British oil companies even in the nineteenth century. In 1970s, Oil and Natural Gas Coroporation identified several oil prospective structures and commenced exploratory drilling. Results were encouraging in some of the structures. For example, Champang area of Wokha district was found to be oil-bearing.

Some of the oil/gas seepages recorded during geological traverses and mapping are as follows:

(i) West of Dibuia (Mokokchung district)
(ii) 4 km NW of Lakhuni (Mokokchung district)
(iii) 4 km NW of Longsamtang (Mokokchung district)
(iv) 2.4 km NNE of Namsang-Chingchung (Mokokchung district)
(v) 4 km NE of Sukhavi (Kohima district)
(vi) West of Champang-Tsori (Wokha district)
(vii) Near Alongkima village (Mokokchung district)
(viii) NNE of Khari village (Mokokchung district)
(ix) 6 km SW of Lakhuni village (Mokokchung district)
(x) 6 km north of Satsukba village (Mokokchung district)

Besides these, there are a number of oil seepages which are reported from time to time by the local villagers from Schuppen Belt. Presence of large number of oil seepages in Schuppen Belt and its western foothills suggests that these areas can be selected for systematic exploration of hydrocarbons. Such exploratory efforts can only confirm or rule out the presence of economic oil deposits in different parts of Schuppen Belt and its adjoining areas. The proto-hydrocarbon organic materials are usually abundant in continental margins and shelf areas. Barails are considered to be source rocks for high wax oil in Assam (Saikia and Dutta,1980). But the formation of oil pool depends on whether a substantial amount of the organic materials were converted into hydrocarbons and accumulated in some favourable traps . Besides bacterial activity, geothermal and pressure gradients also seem to play a part in oil transformation and accumulation. For example, high temperature and high pressure areas are not favourable for oil bearing. After formation of hydrocarbons, deformational tectonics, both horizontal and vertical, play a vital role in migraton, accumulation and entrapment of oil and gas in structural and stratigraphic traps.

From Assam shelf, in the west, to the Ophiolite Belt of Nagaland, in the east, the area can be divided into four broad P-T zones in relation to plate tectonics and bydrocarbon accumulation. These are:

(i) Very high pressure(P)-Low temperature(T) zone of ophiolites (i.e area of plate convergence)
(ii) High P-Low T zone of Inner Palaeogene Disang Belt.
(iii) Moderate P-Low T zone of Schuppen Belt.
(iv) Low P- Low T zone of Assam shelf.

Ideally, LowP-LowT zones are most oil bearing. For example, Assam shelf areas have been found to be most oil productive. A number of oil fields are located in these shelf sediments. Next in importance, are the moderate P-LowT zone of Schuppen Belt of Nagaland and the western margin of Schuppen Belt.Consequently, the subthrust blocks of foot hill areas of Schuppen Belt become priority areas for hydrocarbon exploration. The oil bearing Champang field of Wokha district is located in one such environment of foot hills in Nagaland.

Schuppen Belt remains to be an enigmatic area for oil exploration. Favourable stratigraphic units and trap rocks like Barail, Surma, Tipam and Namsang in appreciable thickness are present in the Schuppen Belt. A large number of oil seepages are reported from this belt. A number of folds and faults occur in its rock formations which can favour oil accummulations. In spite of being endowed with favourable geological characteristics, systematic exploration for oil has not yet been attempted in this belt. Though surface geology is favourable, it needs to be further probed by geophysical surveys and exploratory drilling. There can be possibility of encountering some stratigraphic traps or structural-cum-stratigraphic traps in the Schuppen Belt. The stratigraphic units being constant, surface geological studies suggest that three factors can be considered for formulation of any plan of subsurface probing in this belt.

These are:

(i) Presence of oil and gas seepages
(ii) Nearness to the NE trending thrust planes for stratigraphic traps.
(iii) Presence of NW-SE, NE-SW and WNW-ESE trending anticlinal structures for structural-cum-stratigraphic traps.

A study in a part of Changkikong-Japukong range of Schuppen Belt in Khari, Changki, Chonglymsen, Merakyong and Alongkima areas showed presence of many oil shows in Barail and Surma rocks associated with F_2 and F_3 anticlinal folds (Roy and Kacker, 1986). There were associations of NW-SE trending, moderately large F_3 folds with oil shows. So, the presence of large F_3 folds, NE thrust planes and oil seepages can be taken as a favourable combination to select intial prospecting areas in the Schuppen Belt. F_2 and F_3 are broad, open, upright, asymmetrical folds. Some F_3(cross) folds have moderately large dimensions and deformed the NE thrust planes. A few of the folds and thrust planes in Chaingki-Chonglymsen-Alongkima sector are as follows:

(i) On Lakhuni thrust zone

(a) Chamra anticline (F_3) with oil shows in Surmas.
Axial plane strikes WNW-ESE and dips 75-78º towards SSW.Axis plunges 50º towards S30º E.
Enveloping rocks: Namsang (core), Surma and Tipam (thrusted contact)

(b) Teyaba anticline (F_3) with oil shows in Barails. Axial plane strikes WNW-ESE and dips 65-68º towards SSW. Axis plunges 40º towards E25º S. Enveloping rocks: Barail (Core), Surma, Tipam.

(c) Semsa anticline (F_3) with oil shows in Barails .Axial plane strikes NNW –SSE. Axis plunges 31º towards S12º E

(ii) On Chonglymsen thrust zone :

(a) Alongkima anticline (F_3) with oil shows in Barails. Axis plunges 35º towards ESE. Enveloping rocks : Girujan(Core),Namsang and Barail (thrusted contact)

(b) Remnant (F_2) anticline in Merakyong area Axial plane strikes NE-SW and dips 50-55º towards NW.
Axis plunges 40º towards S30º W.

(iii) On Khari Thrust Zone:

(b) Khari anticline (F_3) with oil shows in Barails. Axial plane strikes NW-SE and dips 60º towards NE.Axis plunges 60º towards N25º W. Envelope rocks: Disang (core), Barail (thrusted contact), Tipam (thrusted contact).

In Schupen Belt, field observations suggest that oil seepages are associated with F_3 anticlinal structures and NE thrust planes which have been affected by F_3 folds. So, it is possible that one major phase of oil migration and accumulation took place during F_3 deformation. Incidentally, NE trending larger F_2 folds (e.g Nichuguard) in the Schupen Belt and its foot hills are not oil bearing. It could mean that either major oil migraton and accumulation did not take place during F_2 deformation or oil might have escaped from F_2 structures because of extensive NE thrusting. So, it is plausible that reaccummulation and reorganization of oil pools might take place during F_3 deformation in Schuppen Belt. Large F_3 folds and NE trending thrust planes in Schuppen Belt together could form some oil traps .Stratigraphic traps could be formed by NE thrust planes. The structural -cum-stratigraphic traps are possible to be formed by combintion of F_3 folds and NE thrust planes which could seal the escape routes for oil. Application of such strategy might be useful for oil search in the Schuppen Belt. In foot hill areas, however, the subthrust blocks may remain as potential target areas for oil and gas exploration.

GROUNDWATER POTENTIALITIES

Nagaland has been divided into two distinct physiographic units for study of ground-water conditions, viz.(i) alluvial terrain and (ii) hilly terrain.

(i) Alluvial areas around Dimapur, Rangapahar and Dhansiripar:

Inventory of thirty two wells was taken up. Study revealed that groundwater occurs both under the unconfined and confined conditions. Water table aquifer occurs between 1.5 metres to 10 metres below ground level. Most of the dug wells tap this zone. Sufficient data is not available to delineate the deeper aquifers and to arrive at a definite conclusion. Three confined aquifers occur at depths of 20-30 metres, 41-66 metres and 86.62-91.40 metres below land surface. Water table around Dimapur varies from 3 to 7 metres below ground level as measured in the shallow wells varying in depth from 5 to 15 metres below land surface. The first aquifer has a discharge of 12 litres/minute and the second and third aquifers yield 45 litres and 469 litres/hr respectively. The recharge to shallow aquifer takes place mainly from precipitation and due to the permeable nature of the surface sediments. Inflow from Dhansiri River and its tributaries, through coarse sand, cobbles, pebbles and boulder terrace also adds to recharge of groundwater body during the rainy season.

(ii) **Hilly terrain around Kohima, Wokha and Mokokchung:** It is very difficult to assess the ground water conditions on account of the absence of the shallow or deep wells. Discharge is about 5 litres/minute. They generally go dry during summers as reported by local people. Analysis of samples from vicinity of Dimapur, Rangapahar and Dhansiripar areas reveals that the water from shallow wells is slightly acidic in nature; pH varies between 6 and 7. Water from deeper zone (100 m) in this area is slightly alkaline (pH 7.70 - 7.95) and chloride content varies from 7-14 ppm. The water is suitable for domestic and industrial purpose. Results of chemical analysis of ground water from hilly regions around Wokha, Mokokchung and Kohima reveals that water is acidic in nature, pH varies between 5.5 and 6.9. Chloride content varies from 7-20 ppm. The water is soft and suitable for all practical purposes including domestic, irrigation and some industrial uses.

DISCUSSION ABOUT THE ECONOMIC DEPOSITS OF THE STATE

The mineral occurrences of this state are mainly restricted to (a) the ophiolite belt in the east and (b) outer Schuppen Belt of Tertiaries in the west. Metallic minerals are normally to be expected in Ophiolite Belt, while coal, oil and gas occur in Schuppen Belt. Inner fold belt is very poor in its mineral potential.

The mineral occurrences, so far, located in Nagaland part of the ophiolite belt are broadly grouped as follows:

1. Very minor chromite pods in ultramafic cumulates.
2. Sporadic disseminations of sulphides within volcanics.
3. Disseminations / streaks of sulphides in hydrothermally altered rocks/ bosses of plagiogranite.
4. Ni- Co bearing magnetite in cumulates.

5. Laterites in weathered profile.

6. Limestones with Pelagic sediments.

There are several limitations and constraints in exploratory efforts undertaken in this belt. These can be listed as follows:

1. Inhospitability of terrain encouraged the traverses to be taken along existing foot tracks and negotiable streams. Wide intervening gaps have to be studied.

2. Systematic bed rock sampling has not been possible due to paucity of exposures; steep slopes with transported soil and dense vegetation pose dificulties in systematic soil sampling.

3. Highly dissected and inaccessible terrain conditions create difficulties for carrying out regional or detailed stream sediment surveys.

4. No systematic geophysical surveys have been carried out due to rugged terrain conditions.

Besides the inherent difficulties, possibilities of occurrence of mineral concentrations as economically viable deposits, in the areas studied; do not appear to be as encouraging as in the ophiolite belts in other parts of the globe. To explain this, the nature of the magma is to be studied for its metallogenic characteristics. Controversies exist whether the parental melt of the ocean floor and ophiolite basalt is tholeiitic (MgO= 9-11%) or picritic (MgO >16%) in nature. Petrochemical data of Naga Hills ophiolites suggests that the cumulates are products of fractional crystallisation of picritic/olivine tholeiitic melt at shallow depth. Besides, slow cooling in a relatively large magma chamber and fresh influx of magma are also suggested. The volcanics show ocean island tholeiitic and alkaline (within plate situation) nature and a total absence of island arc component. It is postulated that they are comparable to the asiesmic ridges (seamounts generated by interplate hot spot activity). The plagiogranite are considered to be differentiated products of K-depleted tholeiitic melt. Such petrochemical characters and postulated tectonic setting are rarely linked to major ore deposits.

1. Petrochemical data suggests that parental magma is chromium depleted, hence the rarity of chromite occurrence.

2. Metals of platinum group usually show pronounced, preferred association with chromitite. In the absence of significant concentration of massive chromite/chromitite in Naga Hills ophiolites, the prospect of metals of platinum group can be expected to be of low order.

3. Stratabound sulphides in ophiolites represent hydrothermal deposits formed at a basalt- sea water interface. The volcanics of Naga Hills ophiolites are comparable to 'within plate' ocean island tholeiites and alkaline volcanics. The seamounts in 'within plate' setting are unstable features and as such are unfavourable locales for concentration of products formed at water- rock interface. It is usually observed that stratabound sulphides form in fault bounded ocean trough where low Eh and restricted circulation favour deposition of sulphide ores, but the postulated setting of the ocean crust of Naga Hills ophiolites does not provide such favourable locales of ore formation. Low concentration of Cu in the volcanics may explain the rarity of Cu-bearing phases in sulphide assemblage.

4. Distribution of plagio granites in Naga Hills Ophiolites is very restricted. They are late differentiates of a K-depleted tholeiitic melt following Thingumuli trend intersecting all the members of the ophiolite suite, which are themselves poor in the content of chalcophile elements. Thus, there is limited scope for major concentration of chalcophile elements, within the hydrothermally altered zones of these plagio-granites.

5. In Nagaland, magnetite occurrences have been located in a number of localities though normally it is unusual to find magnetite in cumulates. The formation of the magnetite bands can be explained due to the removal of available Fe from the melt as Fe-oxide (magnetite) by oxidation caused by high activity of water and oxygen.

6. Dimenstion stones in the ophiolite and metamorphic belts have greater potential to be utilized in the stone cutting and polishing industry.

Highly dismembered nature of Naga Hills ophiolites together with the primary character of the melt as discussed above, and also the tectonic environment of its generation suggest an overall low order of mineralisation potential of the belt.

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LOCALITY INDEX

1	Athupumi village (26° 28' 00" : 94° 25' 20")	16	Pang (25° 55' 00" : 94° 45' 30")
2	Chakhabama (25° 37' 00" : 94° 12' 00")	17	Pang village (25° 56' 00" : 94° 58' 00")
3	Changki (26° 25' 15" : 94° 23' 30")	18	Pesu (25° 02' 45" : 94° 58' 15^2)
4	Chongliyimsen (26° 25' 43" : 94° 25' 43")	19	Phokpur (25° 52' 30" : 94° 57' 00")
5	Chingchung village (26° 43' 30" : 94° 49' 00")	20	Reguri (25° 32' 50" : 94° 35' 50")
6	Khari village (26° 28' 00" : 94° 28' 30")	21	Salumi (25° 47' 30" : 94° 53' 30")
7	Kohima & Dibui (26° 31' 30" : 94° 31' 00")	22	Thonokyu (25° 58' 00" : 94° 54' 30")
8	Konya (26° 15' 45" : 94° 53' 00")	23	Tuensang village (26° 16' 00" : 94° 49' 30")
9	Lakuni (26° 31' 30" : 94° 20" 00")	24	Tuzu valley (25° 40' 00" : 94° 40' 00")
10	Leo-Longidang (26° 22' 00" : 94° 12' 24")	25	Washello (25° 34' 30" : 94° 46' 00")
11	Merapani (26° 18' 00" : 96° 06' 30)	26	Waziho (25° 40' 00" : 94° 43' 00")
12	Merakyong village (26° 25' 20" : 94° 24' 23")	27	Waromung (26° 33' 30" : 94° 32' 00")
13	Mongchan (26° 30' 03" : 94° 28' 43")	28	Wui (25° 02' 00" : 95° 61' 00")
14	Mirinpoh (26° 25' 30" : 94° 36' 30")	29	Yachang (26° 41' 00" : 94° 32' 15")
15	Nimi (25° 43' 00" : 94° 54' 45")	30	Zunki nala (26° 03' 00" : 94° 55' 15")

Geology and Mineral Resources of Tripura State

I. INTRODUCTION

Tripura State lies in the eastern part of India, bordered by Bangladesh to the west, south and north, by Assam to the north-east, and by Mizoram to the east. It is bounded by latitudes 22°56'N and 24°32'N, and longitudes 91°10'E and 92°21'E. It has an area of 10,477 sq. km., and is a rugged and geologically a younger terrain. It has a link with Assam and rest of the country through the adjoining Cachar district, lying to the north-east.

Previous work

H.C.Dasgupta of the Geological Survey of India, in 1908, first classified the folded sediments of Tripura into 'Coal measures' and 'Tipam' Groups. Later, K.L.Das (1939) classified them into three major groups—the Lower or Unokoti Jampui, the Middle or Baramura-Deotamura and the Upper or Fossilwood Group which were correlated respectively with Barails, Surmas and Tipams of Evans (1964). These groups were separated by unconformities with a basal conglomerate in between them.

Vacheli (1942), however, correlated the oldest arenaceous group of rocks, forming the core of the high Jampui, Shakan, Langtarai and the Atharamura ranges in the Eastern Tripura, with Upper Bhuban stage of Surma series of Assam, He stated that the folds in the Western Tripura, viz., the Baramura and other anticlines to the west, do not expose rocks older than the Bokabils. According to him, the lower group of rocks as suggested by K.L.Das (1939) includes parts of Bokabil and parts of Tipam stages, whereas the upper group includes parts of Tipam and Dupitila series of Assam, The unconformities, according to him, are local breaks within the Surma series. He, however, recorded the hiatus between the Tipams and Dupitilas and thus accounted for the apparent absence of the Girujan clay of Tipam Group in Tripura.

S.N.Sen (1950-57) classified the sediments into five formations, each separated from the other by an unconformity. Later, he modified his earlier classification and advocated Middle Bhuban, Upper Bhuban, and Bokabil stages of Surmas, and the Tipam Sandstone stage and the Dupitila stage, showing only unconformity below Dupitilas. He further suggested a three fold sub-division of the Tipam sandstone into a predominantly arenaceous upper and lower groups separated by a middle argillaceous alternation.

Trivedy (1962-64), Trivedy and Sar (1964-65) and Sar (1967-68) broadly grouped the sediments into four different stages, the Bhuban and Bokabil stages of Surma series and the Tipam Sandstone and Girujan Clay stages of Tipam series.

Roy (1968-69) gave a lithostratigraphic classification and grouped the rocks into the Bokabil Sub-group of the Surma Group, the Tipam Sandstone Sub-group of the Tipam Group and Dupitila Formation of the Dupitila Group for the western part of Belonia Sub-Division and in the southern part of the Udaipur Sub-Division of Tripura State. The three fold sub-divisions of the Tipam of Sen (op.cit.) was not recognized in the Western Tripura, and Roy (op.cit.) suggested a two fold sub-division — the Lower Tipam Formation and Upper Tipam Formation.

Following Roy's (op.cit.) main lithostratigraphic scheme, Goswami and Das Gupta, (1969-70), Nandy and Das Gupta (1970-71), Nandy and Saxena (71-72), Dasgupta, Ghosh and Kumar (1972-73) mapped the area including Belonia, Sabrum, Amarpur, Kailashar, Dharmanagar Sub-Divisions on the basis of the same lithostratigraphic unit and gave the full lithologic description of the different groups and Sub-groups. Nandy and Dasgupta (op.cit.) during their systematic geological mapping in parts of Amarpur and Sabrum area, sub-divided first the Tipams into two formations—the Upper, 'Champanagar Formation' and the Lower, 'Manu Bazar Formation'.

Physiography

Geomorphology

The topography is immature. The major geomorphic elements observed in the area are both structural and topographic 'highs' and 'depressions', 'flats' and 'slopes', sculptured on the topographic surface in a linear and areal fashion. In Tripura the topographic highs and lows are in accordance with the normal first order structural elements.

The state is dissected by a number of broad and long valleys, viz.,Agartala-Udaipur-Sabrum, Khowai-Telimura-Amarpur-Silachari, Kamalpur-Ambasa-Candachara, Kailashar-Kumarghat, Dharmanagar-Panisagar, etc. located between the N-S trending parallel to sub-parallel antiformal hill ranges (topographic highs), such as the Baramura-Deotamura Ranges, the Atharamura Ranges, the Langtarai Ranges, the Shakan Ranges, and the anticlinal ranges. There are a few disconnected open and shallow anticlinal ridges, viz. Gazalia-Mamunbhagna anticline, Sonamura anticline, Agartala dome, etc. Besides, small-scale elements like the spurs, keels, and the moderate gorges are the other geomorphic elements formed.

Drainage

Generally, the valleys are broad and flat with low to moderate Bed Relief Index (BRI), which are separated from the adjacent highs with domes and conical peaks. Some of the peaks of the hills are also flat. The R. L. differences between the elevations of the peaks and valleys increases eastwards constantly. The general altitude of the state varies between 16 m to 600 m above m.s.l. The drainage patterns are of 'dendritic', 'parallel' to 'sub-parallel' and 'rectangular' types. The stream channel patterns lie mainly within the 'piedmont', 'straight' and 'meandering' reaches. The 'braided reach' is, however, not noticed along the course of the stream channels. The drainage flows down along north by the Khowai, Dolai, Manu, Juri and Langai Rivers ; west by the Gumti River and southwest by the Fenny and Muhari Rivers.

Climate and Rainfall

The climate is generally hot and humid, the average maximum temperature being 35°C and the average minimum 10.5°C. The state has a fairly good annual rainfall (around 230 cm. per annum). The monsoon generally starts in the middle of April and continues up to September. Heavy rainfall causes severe floods almost every year, disconnecting the state to the rest of the country.

II. GEOLOGY

The rock formations in Tripura are none or less like those of Assam comprising Tertiary succession. The succession has been studied extensively by several workers. The continuity of sedimentary succession from Assam, has allowed adoption of Assam Tertiary classification and nomenclature for Tripura, as proposed by Evans, (1932), with minor modifications. The major units are Surma Group, Tipam Group and Dupitila Formation (Table1.6.1).

Lithostratigraphy:

Table 1.6.1: Generalised stratigraphic succession in Tripura

Age	Group	Formation	Litho-assemblage
Holocene		Khowai Formation Ghilatoli Formation Teliamura Formation	Alluvium deposits of recent or subrecent rivers comprising silica sand, silt and clay and vegetation debris Unconsolidated, pale yellow to dirty sand, silt, clay with organic and decomposed vegetable matter; massive, coarse grained, gritty poorly cemented sandstone with current bedding
Quaternary		Kalyanpur Formation	Unconsolidated, pale yellow to dirty grey sand, silt, clay with organic and decomposed vegetation matter; massive, coarse grained, gritty poorly cemented sandstone with current bedding
Pliocene to Early Quaternary		Dupitila Formation	Pockets of clay and silica sand common. Fossil wood occurs frequently; thin sand pebble conglomerate
~~Unconformity~~~~~~~~~~~~~~~~~~~~~~~			
Pliocene	Tipam Group	Upper Tipam Formation	Thick unit of massive grey to buff coloured medium to coarse grained sandstone showing ribbed structure in the lower portion; contains boulders and calcareous concretion and coal streaks
		Lower Tipam Formation	Thick unit of fine to medium grained sandstone, subarkosic sandstone, siltstone and sandy mudstone of brackish to fresh water shallow marine facies.
--- Conformable --			

Lower Miocene to Pliocene	Surma Group	Bokabil Formation	Mainly argillaceous facies represented by huge thickness of laminated siltstone, silty shale with narrow bands of sandstone; occasionally lenticular zone of medium to coarse micaceous ferruginous sandstone with mudstone
		---------- Conformable ----------	
Upper Oligocene to Lower Miocene (?)		Bhuban Formation	Calcareous sandstone, calcareous siltstone, yellow to buff coloured fine grained, thinly laminated sandstone and interbanded shell limestone
			Base Not Exposed

Geological framework:

Tripura forms part of the Tertiary Naga-Arakan-Yoma basin and is located to the southwest of Palaeogene fold belt of Naga hills. Neogene belt is broadly confined by Haflong-Dawki Fault to north and Barisal Chandpur High to west and northwest. Post Barail upheaval of Palaeogene sediments shallowed distal southwestern part of the basin wherein Neogene sediments of Tripura (Cachar-Mizoram) were deposited. Relationship between Palaeogene and Neogene sediments in Tripura have not been established as Barail Group is not exposed in Tripura. It is likely that Neogene sediments were deposited on the folded, but not uplifted, Palaeogene sediments and were subsequently co-folded with the latter. Unconformity between Tipam Group and Dupitila Formation in Cachar area clearly indicates Tipam upheaval, during which the Upper Tertiary sediments were folded into a series of linear anticlines and synclines. The tectonic cycle ended with a weak deformation of Dupitila sediments.

In the absence of any marker horizons and due to paucity of fossils, local terminologies had proliferated in respect of the units which display a departure of facies from standard sections proposed by Evans (1932). The predominant group of rocks belong to Bokabil Formation. Precise age of Surma Group is uncertain. Fossil horizons at the top of Bhuban Formation at Kanchanpur (Cachar) shows Miocene affinity. Upper Bhuban Formation exposed near Manpui in Eastern Tripura containing Miogypsina,Operculina, Rotalia, etc. indicate an Upper Oligocene-Lower Miocene age (Dasgupta, 1982). Mammalian remains of Gomphotherium from Bokabil of Chidang-Cherra (East-Central Tripura) shows a Middle to Upper Miocene age (op cit.) and Trivedi (1966) reported Trilophodon of Miocene affinity from Bokabil Formation of Baramura, the westernmost hill ranges of Tripura. The reported occurrence of Hipparion theobaldi also from Bokabil Formation of Baramura lends a distinct Pliocene aspect to this formation. Apparent imprecision in age of the thick sequences of Bhuban and Bokabil Formations would largely be avoided with more emphasis on identification of stratigraphic position of each of the fossil locations. The age of the lower and upper formations of Surma Group apparently ranges from Upper Oligocene to Lower (?) Miocene and Upper (?) Miocene to Lower Pliocene, respectively, which dates Tipam as Pliocene, and also, therefore dates Dupitila Formation as Pliocene to Early Quaternary.

Recent mapping in the state together with integrated study of the surface and subsurface data alongwith interpretation of aerial photography and satellite imagery has provided certain clues to stratigraphic sub-divisions and correlation of Neogene sediments. A brief description of the stratigraphic subdivisions is given below.

Surma Group:

This group is further subdivided into the lower, Bhuban Formation (arenaceous assemblag) and the upper, Bokabil Formation (argillaceous assemblage). Surma Group fossil assemblage has been studied in some details and is given in Table 1.6.2.

Bhuban Formation:

The standard three fold classification of Bhuban Formation, (Evans, 1932) is not completely exposed in Tripura. While Lower Bhuban Formation is totally unexposed, Middle Bhuban Formation is exposed as isolated small patches in the two eastern ridges of Tripura and Upper Bhuban Formation forms the bulk of Lower Surma Group.

The formation is exposed in the central part of Jampui, Sakhan and Langtaral ranges. It forms the core of N-S trending anticlines. Association of calcareous units are characteristic of this formation and comprises calcareous sandstone, calcareous shale, fine grained sandstone and limestone. Calcareous sandstone is dark grey and contains fossils of bivalves, gastropods, coelenterates and echinoid spines. Calcareous shale is dark grey, fine grained and highly micaceous and alternates with calcareous sandstone.

Limestone unit occurs as small lensoid bands within the calcareous shale. Fine grained sandstone contains sand lenses which show current bedding. Limestone bands form prominent geomorphic units on the slopes of Jampui and Sakhan hills due to differential weathering. The dark grey, discontinuous limestone bands vary in thickness from 0.2 metres to 2.3 metres and contain broken bivalve shells. The bands grade into calcareous sandstone.

Bokabil Formation:

Bhuban Formation is overlain by Bokabil Formation with a gradational contact. This formation consists of siltstone with small interbanded sandstone and has a typical geomorphic expression manifested by linear, low lying sharp hills with a topographic break at its contact with Bhuban Formation.

The lower member of the formation is calcareous siltstone which grades upwards into siltstone with dominant thin interbanded sandstone; siltstone is dark grey, thinly laminated and shows splintery weathering surface. The sandstone members are pale brown in colour, medium grained and massive. They contain numerous, hard, calcareous concretions and impression of small broken fossils.

The intraformational conglomerate occurring as a thin band at the top of Bokabil Formation contains unsorted pebbles of sandstone, siltstone and limestone embedded in ferruginous and calcareous sand matrix with fossils of bivalves and gastropods derived from older formation. The pebbles vary from well rounded to elongated highly flattened type and range in size from 1 cm to 4 cms. There are a number of thinly bedded micaceous sandstone beds which mark the end of Bokabil formation.

Table 1.6.2: Details of fossil assemblage of Surma Group in Mizoram.

Locality	Reporting by	Assemblage	Indicated
Bokabil Formation			
Limestone of West Manipur	Dasgupta and Bhattacharya (1977)	**Forams:** *Miogypsina sp., Globorotalia sp., Globigerina sp., Operculina sp., Nonionsp., Eponides sp., Signoclopsis sp.* **Ostracods:** *Acuticytheis sp., Bairdia sp., Lequminocythereis sp.* Besides unidentifiable corals, fish remains, gastropods and shark teeth.	Upper Oligocene to Lower Miocene
Limestone of Jampui	Chatterjee and Mathur (1978)	**Forams:** *(Miolepidocyclina) Miogysina sp.* **Pelecypods:** *Pecten (Ammussipecten)* **Gastropods:** *Natica sp.*	Upper Oligocene-Lower Miocene
Bhuban Formation			
Southwest of Tiprubaru in Baramura	Biswas (1961)	**Forams:** *Globigerina sp., Eutocoleria sp., Rotalia sp., Quiquiloculina cf. lamarckana, Strobulus sp., Elphidium sp., Astrorotalia sp., Bolivina cf. hughesi, Cassidula sp., Nonion sp.*	Pliocene
Batchia area	Khamseva *et al.* (1965)	**Forams:** *Rotalia sp., Bulimina sp., Cibicides sp., Nonion sp., Ammonia papillosus.* **Pelecypods:** *Corbula sp.,Cyrena sp., Venerids.*	
Baramura	Sahay *et al.* (1965)	**Palynomorph :** monolete (*polypediacea* and other types) trilete (*gleicheniacea, schizieacea, pycopediacea*) *disdecites* (*piones* and other types) monocolpate, tricolpate, tetraporate, and polyporate	Miocene
Conglomerate horizon from Teliamura and Baramura	Trivedy (1966)	**Pisces:** *Oxyrhina spallazhani, Oxybina cf. pagoda, Prinodon gangeticus.* **Reptilia:** *Crocodilus palustris, Gharialis gangeticus* **Mammalia:** *Trilophodon angustidens, Dorcartherium sp.*	Tortonian

Conglomerate band 8.5 Kms northwestern of Hawabari in Baramura area	Pandey (1966), Sinha (1975)	**Mammalia:** *Potarochoerus hysudricus, Stegolophodon, cantlezi, S. latidens, Hipparion theoboldi.* **Reptilia:** *Chelonian and Crocodilia* teeth. **Pisces:** Shark teeth.	
Upper Bhuban and Lower Bokabil exposed in Batchia section	Soodan (1960), Pandey and Soodan (1973)	**Forams:** *Globorotalia menardii, archaemenarbi, G foshi barisanensis, G. (Turborotalia), Opima contimusa, G (T) mazesi, Globigerina preabulloides, G. falcomensis.*	Lower Miocene to lower part of Upper Miocene
Interformational Conglomerate 4.5 Kms ENE of Kumarghat	Dasgupta (1974), Basu and Dasgupta (1976).	**Pisces:** *Carchariae gangeticus, Isurus spellazani.* **Reptilia:** *Gavialis sp.* **Mammalia:** *Gomphotherium cf. pondionis, Pachyportex nagrii.*	Not older than Upper Miocene
Chandipar *nala* Gainarma Chara Bhouri Chara Chandrai Chara	Sinha (1980)	**Bivalve:** *Clinocardium sp., Lymnnocardium sp., Mactra sp., Periglupta sp., Venus sp.* **Gastropod:** *Turritella sp.* **Annelida:** *Iquitoia* and worms of family *Sabellidae*	Suggested age : Sarmatian

Tipam Group:

Tipam Group conformably overlies Surma Group and the gradational contact is marked by a ribbed sandstone unit with minor thin siltstone bands.

The transitional Bokabil-Tipam boundary often poses problem for its demarcation. It is observed that sandstone unit towards the top of Bokabil Formation commonly shows a ribbing pattern. The occurrence of 'ribbed sandstone unit' could define changes in depositional parameters and thereby the base of Tipam Group.

Mapping by Nandy (1973) and Chatterjee, (1983) in parts of the state showed that Tipam Group can be broadly divided into two formations.

(a) Lower Tipam Formation: (studied at Manzu Bazar) consisting of fairly thick unit of fine to medium grained sandstone, subarkosic sandstone, including laminated layers of thick lenticular bands of sandy shale, siltstone and sandy mudstone of brackish to fresh water shallow marine facies.

The sandstone unit is medium grained, current bedded having a distinct ribbed pattern, contains boulders of calcareous concretions and coal streaks. The concretions are rounded, spheroidal and oval shaped varying from 10 cms to 30 cms in diameter. The outer surface of boulders has ferruginous coating but the inner portion is hard and calcareous. Reworked siltstones are closely associated with the lower part of Tipam Group.

Ribbed sandstone unit varies in thickness from 2 to 10 metres and occurs above the conglomerate of Bokabil Formation. It has been studied at Atharamura, Longtarai, Sakhan and Jampui hill ranges and also recognised in the western part of Mizoram and adjoining Tripura. The sandstone contains calcareous concretions in the form of pebbles and boulders, besides carbonised streaks / pockets of coal and abundant fossilwood. The ribbed sandstone appears to indicate the first recognisable change in lithology of Bokabil Formation from underlying argillaceous beds.

Fossil wood collected from Khowai bridge at Teliamura has been assigned Miocene(?) age (Awasthi 1966). Fossilised tree trunks measuring 1 to 1.6 metres in length and 0.39 to 0.85 metres in diameter are reported from a number of localities viz. Hawabari, Phulkamari, etc. Palynofossils are reported from sediments of Gojalia Anticline which are mainly Foveosporite sp. and Stephanoporopollerites sp. suggestive of Tertiary age.

(b) Upper Tipam Formation: (Studied at Champaknagar) Consists of coarse, poorly sorted, massive arkosic sandstone with occasional laminated layers of sandy shale and silicified fossil wood.

Dupitila Formation: Dupitila Formation overlies Tipam Group with an angular unconformity. The contact is marked by a thin band of pebble- conglomerate. It comprises white to yellowish, loose, unconsolidated ferruginous sandstone with pink and yellow clay bands.

The coarse grained sandstone contains fragments of quartz, quartzite, muscovite, biotite and feldspar with profuse lithic fragments. Bedding is indistinct due to massive and unconsolidated nature of sand rock. There are pockets of well-sorted, medium to coarse grained quartz and white clay. Sandstone from which ferruginous material has been leached away, has formed sand pockets. Few discontinuous horizons of iron-coated clay pebbles and angular clasts of sandstone occur in ferruginous sand matrix within sandstone.

Thin lateritic soil cappings have been recorded on the top of several mounds composed of the sandstone . Plant and insect fossils from Jampui Bazar (Chakravarti et al. 1982) contain Bridella tomemtosa, Glochidion laceolarium, Mallotus nepalemsis, which are characteristic of tropical to subtropical climate and suggest Cretaceous to Recent age.

Quaternary fluvial deposits

Quaternary and geomorphological mapping in the recent years (Ramesh, 1985) in parts of Khowai and Haora basins revealed the presence of a sequence of four tier Quaternary terraces.

The four terraces have been named as Kalyanpur Formation, Teliamura Formation, Ghilatoli Formation and Khowai Formation, after the geographical localities. Based on geomorphic expression, geological setting and degree of pedogenesis, and C14 dating, Kalyanpur Formation has been assigned Pleistocene age and the rest three Holocene age.

Kalyanpur Formation: Several rich Neolithic and pre-Neolithic sites have been reported from this unit. C14 dating by Birbal Sahni Institute of Palaeobotany established an age of 34,680 ± 2980 yrs B.P. corresponding to Upper Pleistocene. It has a dominant lateritic profile intruded by numerous sand plugs containing caliche nodules.

Teliamura Formation: This formation comprises of multiple sequences of sand-silt- clay with gradual increase in fineness of units. The members are feebly oxidised to an inceptisol profile. C14 dating indicated Holocene age of this formation (1100 ± 90 to 3450 ± 110 years B.P.).

Ghilatoli and Khowai Formations: Ghilatoli and Khowai Formations comprise soils belonging to entisol order. C14 dating of the sediments drawn from these formations indicated their age as 165 ± 80 yrs B.P, thereby placing them in Holocene.

Contrasted opinions have been expressed on stratigraphic position assignment of Quaternary formations. Some workers have favoured Pleistocene sediments to form part of Duptitila Formation. Sufficient evidence and data in its favour is presently not available.

Alluvium: Alluvial deposits occupy the flood plains and palaeochannels of the recent to sub-recent rivers, and also in the smaller point bars on river terraces. Mineralogically they comprise silica sand, mica, illite and opaques along with minor heavy mineral. The process of soil formation has imparted a mottled nature in the silt and clay part. Vegetable debris are common constituent.

III. DEVELOPMENT OF VILLAGE ECONOMY THROUGH MINERAL APPRAISAL PROGRAMME (DOVEMAP)

With the changing scenario of planning and development in course of time, an innovative programme, viz. Development of Village Economy through Mineral Appraisal Programme (DOVEMAP) was taken up in districts on the cadastral map base. The main objective of the project was to transfer the scientific knowledge about terrain evaluation to grass root level and to educate the rural folk about the natural / mineral potential of the area. It is expected that it would accelerate the process of sustainable development at panchayat level as the terrain conditions vary from place to place.

The basic objective of the work was to assess socio-economic scenario of the villages, geology, geomorphology, soil, land use pattern, search of low-value high-volume minerals and to identify natural hazards if any, in the villages. The studies have brought to light geological and geomorhological set up, type of land cover soil and landuse pattern, natural resource and hazards present in the villages. The problems identified and their remedial measures suggested for each revenue village have been reflected in the village specific reports.

During the F.S. 1997-98, 25 revenue villages were covered under DOVEMAP project in Tripura. The villages studied in West Tripura and South Tripura districts are either located in the geomorphic set up of degraded mounds/ linear valleys or in the terraces/ flood plains of the organized drainage networks, hosting ferruginous sandstone, shale and clay.

During the F.S. 1998-99, eight revenue villages in West Tripura and South Tripura districts were covered under DOVEMAP project for assessing natural resources, terrain evaluation and socio-economic status for sustainable development of the village economy. The findings on geology, geomorphology, landuse pattern, environmental hazard and resources besides the socio-economic status are discussed in detail. Based on the studies, some recommendations are made for the development of the studied villages.

During the F.S. 1999-2000 one item on "Appraisal of Mineral/ Natural Resource potential on cadastral map base in Tripura" (Project DOVEMAP) was carried out. A total of 8 revenue villages distributed in 34 cadastral sheets (1:4000) covering an area of 62.04 sq km in districts of West and North Tripura were completed.

During the F.S. 2000-2001 one item on "Appraisal of Mineral/ Natural resources potential on cadastral map base in Tripura" (Project : DOVEMAP) was carried out by seven geologists. A total of 7 revenue villages spread over 30 cadastral sheets (1:4000) covering 58.47 sq. km. in West and North districts of Tripura state was completed.

As limited villages have been covered under this project it is too early to asses the benefit by this survey. However, the villagers have appreciated this work wherever the surveys have been conducted. Introduction to DOVEMAP in state level workshop on 'GRAMODAY' conducted by Planning Development and Panchayats has indicated that the work would prove fruitful in village development planning.

IV. STRUCTURE AND GEOLOGICAL HISTORY

The folds are characterised by compressed anticlines alternating with broad, very flat symmetrical synclines. The anticlines are usually sharp and asymmetrical. Fifteen (Nandy et.al, 1983) major, long, arcuate anticlines and synclines trending NNW-SSE to NNE-SSW, with variable plunges have been recorded. The folds often have convexity towards west. Many anticlines bifurcate to form two anticlinal ridges with sub-parallel axial traces. In some cases such split axes merge again to enclose an elliptical synclinal valley. Atharamura, Langtarai, and Machmara Anticlines are box-shaped and flat-crested whereas other anticlines in the neighbourhood are sharp-crested. In general fold movements are accompanied by syn- to post-tectonic sub-vertical faults which are often parallel to the axial plane of the fold. The throw of the faults increases towards the flank of the hills as have been recorded in Atharamura, Sakhan and Jampui hills.

GEOLOGICAL HISTORY

Surma Group has the largest spread in this state. Primary sedimentary structure such as bedding plane, ripple marks and flaser bedding recorded from Surma Group indicate a shallow marine to paralic environment, while Tipam rocks show distinct fluviatile influences. The dominant sandstone of Tipam Formation is coarser grained and shows large scale current beddings. Bedding and other sedimentary structures are developed in occasional siltstone bands of Tipam Group. Emergence of Surma-Tipam pile of sediments constitutes the major tectonic episode of this region. Interestingly, Girujan Clay Formation, representing the phase of argillaceous sedimentation in the upper part of Tipam Group, elsewhere, has not reported from Tripura. After deposition of Tipam sediments partial submergence of the basin took place again when Dupitila Formation was deposited unconformably as a valley-fill over the Surma-Tipam sediments. Elevation of Dupitila saw the end of tectonism of the basin. Quaternary records in parts of Tripura, therefore, indicate an angular unconformity between the Quaternary units and the Neogene substrata.

V. MINERAL RESOURCES

The most important mineral resources are oil and natural gas which are being explored by Oil and Natural Gas Corporation. Glass sands, lignite, limestone, and plastic clay deposits are other exploitable mineral resources. Hard rocks available have been used as construction material.

Clay

Sedimentary clay deposits, useful for a number of applications are present in several localities in the state. The clay deposits are lensoid in nature and intimately associated either with glass sand along river valleys or occur below a lateritic / ferruginous sand cappings of low isolated hillocks of Dupitila Formation. The clays are of fluvial origin having been deposited as river bank deposits. Brief description of the deposits is given below:

a) Mohanpur-Damutia-Kamalghat area: Clay deposits occur along the right bank of Lahor *nala* near Otlaba village (southeast of Mohanpur). Two lenses, 0.20 metres to 1.25 metres thick, grey to greyish white plastic clay occur under an overburden of 0.50 to 1.25 metres. About 9000 tonnes of plastic clay, including some sandy clay, in the two bands has been estimated.

Chemical analysis of the clay shows that the amount of iron and titanium oxides are higher than the specification for fine ceramics. These oxides are colouring agents and affect the quality of such ceramics. The clay can be used for manufacture of sanitary wares, stone wares, sewerage pipes and electrical insulator and other products where colour is not an important factor, or as fillers in paper, rubber and paint industries. The laboratory tests show that Mohanpur clay changes colour after burning and that it can be grouped under the ball clay.

b) Bishramganj-Bagma area: The clay deposits occur along alluvial valley and at the base of the isolated hillocks at south of Bishramganj. The hillocks are made up of ferruginous silty sand in the upper part and greyish white to pink, highly plastic clay in the lower part. Other small deposits have also been reported from south of Bhagma, Noachaara and Rangahara River.

Grey to white plastic clay has been reported from two localities near Bishramganj. The larger of the two occurs in a paddy field west of 34 km stone on the Agartala-Udaipur road. Other one is located in the stream bed of Latia Chara. The deposits lie below the overburden of 0.60 to 1.25 metres, are 0.4 to 1.25 metres thick, with reserves of about 5200 tonnes of grey plastic clay. Detailed exploratory estimates show 1.6 million tonnes of low grade clay of possible category at the northwest of Bishramganj, along the left bank of Rangapani *nadi*.

Several small deposits are also reported from Malchara, Karaimura, Patalin, Kalkhola, south of Baghma and Bagabasa (Roy,1969). All these deposits occur in the paddy fields at a depth of 2.5 metres overlain by a sandy clay.

The clay deposits lying between 45 and 46 km stones on the Agartala-Udaipur road had been studied by Benerjee and Trichal (1978). The only band occurring in the area is below a 3.40 metres thick lateritic and clay-sand horizon. The clay band is 0.80 to 3.40 metres thick, white to cream in colour, with brown, purple and yellow patches. Several clay pockets are exposed along the road cuttings near Bagma. Reserves of 0.265 million tonnes have been estimated for the area of 0.30 sq km Analysis of clay samples shows that 10% of Bagma and Bishramganj clays are suitable for manufacture of whitewares and 20-25% are of stoneware quality. The clays have been found unsuitable for refractory purposes.

Champamura-Baldakhal-Jogendranagar area: The clays are alluvial and confined between Bageswar River in the west and Haora River in the north. A few pockets of white clay were also located at the base of isolated hillocks. The clay pockets overly a thin band of sand 1 to 1.5 metres thickness. Mottled clay, a weathered product of shale, have been found in shallow pits near Agartala(23° 49'30":91°17'00"). White and plastic clay is reported from Jogendranagar area, near Agartala(23° 49'30":91°17'00"), at the base of low hillocks after College Tilla, south of Haora River.

Kaolinite is the dominant mineral constituent of these clays and its specific gravity slightly higher to that of pure kaolinite. Mica and pyrite are absent. Champamura- Baldakhal clays do not fuse at 1250°C, conforming to refractory grade. Its colour after firing at 1250°C is whitish cream without any appreciable change in volume on shrinkage. Its plasticity by Atterberg's method resembles to that of ball clay from Devonshire, England. Since these clays are refractory and moderately plastic, they can be utilised for manufacture of slightly coloured chinawares.

Mottled clay of medium plasticity, becomes grey after firing, and does not fuse at 1380°C. It has a linear shrinkage of about 10%. High proportion of iron in the mottled clay, gets oxidised producing a rose tint on chinaware.

Reserves of about 1 million tonnes of plastic clay from Baldakhal area, 35,000 tonnes from Jogendranagar area and 50,000 tonnes from Champamura have been estimated.

d) Shantir Bazar-Udaipur area: The area between Udaipur and Shantir Bazar, comprises hilly terrains composed of loose, brownish yellow, silty sand mixed with clay, with pockets of relatively pure plastic clay. The physico-chemical tests indicate that these clays are suitable for the manufacture of facing tiles, roofing tiles, stoneware pipes etc.

e) Khowai(24°04'30'':91°37'30'')**-Teliamura** (23°50'20":91°38'30") **- Amphi area :** Pockets of white clay are seen along the North-South road cuttings of Khowai-Amphi. Geological set-up of the deposit is similar to Udaipur-Shantir Bazar deposit. The clay is white to dull, cream in colour, highly plastic, and can be utilised for ceramic industry.

f) Kumarghat area: Holocene alluvial deposits of Manu and Deo Rivers near Kumarghat contain clays. The clays are associated / intermixed with sand and silt and three varieties are identified viz. (a) sand-silt-clay, (b) brown sandy / silty clay and (c) grey plastic clay.

I. Sand-Silt-Clay: Sand-silt-clay deposits occupy flood plains and palaeochannels of recent to subrecent rivers. Fine grained sand, brown to yellow in colour occurs between *Lungas,* or mounds of alluvial deposits, in the northern part of the area. Along the river banks the sand is white to grey, and silt is yellowish brown due to presence of iron oxide. It is often intermixed with clay, grey to black in colour due to presence of decayed organic matter.

II. Brown sandy clay / silty clay: This is reddish brown to yellowish brown in colour. The high percentage of iron imparts the reddish colour. This clay contains admixtures of sand / silt between 30 to 90%.

III. Grey plastic clay: This is steel grey in colour and becomes white on drying. Sometimes woody material is present which makes the clay black. A total reserve of about 9.31 million tonnes of clay was estimated over an area of 5 sq. kms.

Analysis of 92 clay samples from Kumarghat area shows that $SiO_2 + Al_2O_3 + Fe_2O_3$ <70%, SiO_2 <40%, CaO >10%, and MgO >3%. $Na_2O + K_2O$ varies from 3.21 to 3.63%. Most of the samples analyse >10% loss O_2 ignition.

The result of lime reactivity tests carried out on clay samples by Central Road Research Institute, New Delhi shows that except for one sample all the samples are highly reactive.

The reserves of plastic clay are in excess of the requirements for use in the proposed Pazzoluna manufacture unit in the state.

g) Baidyathakurpara-Anandnagar-Maheshkhola-Dukli and Soanimuri areas : Plastic clays occur at Baidyathakurpara-Anandnagar-Maheshkhola-Dukli area, West Tripura district and Soanimuri area, North Tripura district, in point bars, meanders and flood plains of Manu and Haora Rivers and their tributaries. The deposits occur as pockets and lenses within Quaternary formations. A total of 2.61 million tonnes of plastic clay has been estimated (Sarangi et al. 1981-89) from these areas. The plastic clay from Sonaimuri area (reserve of 2.36 million tonnes) satisfied the chemical specification of burnt clay lime Pazzoluna mix. Insoluble ($SiO_2 + Al_2O_3$ etc.) content ranges from 72.78% to 88%, CaO varies from 0.86 to 1.05% and MgO varies from 0.36 to 2.56%. Tests for use of plastic clay from other areas (125 million tonnes) are to be conducted for use in ceramic industry.

The clay reserves from zones A, B and C of soil profile were estimated to be 1.73 million tonnes out of which nearly 1.34 million tonnes are at Teliamura and Bagma areas. Deposits of Mohanpur are within paddy fields and those of Champamura and Bagma are exposed along road cuttings within the undulatory terrain. The exploitation of clay deposits from the latter may be easier.

The quality of clay at Mohanpur, Champamura (23°50'00":91°20'00") and Bagma areas are better suited for pottery industry, as compared to those occurring in river valleys below paddy fields. The reserves from Champamura(23°50'00":91°20'00") and Bagma can meet the requirements of medium-sized pottery industry, producing tinted pottery / ceramics. All clay deposits in Tripura can be used for manufacture of low temperature insulator and medium quality potteries, stoneware pipes and similar products on the basis of analytical tests conducted by Central Glass and Ceramic Research Institute (CGCRI), Calcutta.

Glass Sand

Dupitila Formation contains sand deposits which may have been reworked by the then prevailing river systems and redeposited in the Holocene flood plains. The resultant white sands are composed of quartz with subordinate mica, vegetable matter and variable quantities of clay and ferruginous material.

The sand deposits occur along the banks of Bijni-Nandi stream in Bisramganj (23°36'30":91°21'00") and have been traced for nearly 1.3 kms along NW-SE with an estimated reserve of 1,60,000 tonnes. The reserves of glass sand have been estimated at 50,000 tonnes near Old Agartala.

The sand deposits occur beneath an overburden of soil or clay varying in thickness from 0.90 to 2.60 metres. The clays occurring above the glass sand are usually highly iron stained and yellow to yellowish brown.

Samples from Bishramganj(23°36'30":91°21'00") area after beneficiation and washing analysed 99.15% SiO_2, 0.63% Al_2O_3 and 0.07% Fe_2O_3.

The sand deposits are suitable for manufacture of ordinary glasswares and glass containers to meet the local demands. A glass factory was proposed to be set up at Arundhatinagar near Agartala.

Reserves of glass sand from Baidyathakurpara, Dukli, Maheshkhola, and Anandnagar area of North and West Tripura districts are estimated to be 85,563 tonnes upto 15 metre depth. The glass sands contains 79-90% SiO_2 and require to be beneficiated. 97,875 tonnes of glass sand was estimated from Mohanpur area(23°58'38":91°22'00"), West Tripura district. On the bank of Haora River, sands occur within Holocene sediments consisting of coarse grained silica, micaceous sand and sandy silt.

Around Dasaram Bari area, West Tripura district, 53,316 tonnes of glass sand has been estimated.

Hard rock Resources

Six bands of hard rocks are located on the slopes of Jampui hill. The bands comprise dark grey calcareous sandstone and shell limestone occurring within Bhuban Formation. The bands vary in thickness from 10 to 30 metres extending over a strike length of 30 kms. They are being quarried for road metals at Manpui and Kanchanpur by Public Works Department of the state government.

In Longtarai hill ranges, hard sandstone bands with subordinate siltstone unit occur within Bokabil Formation. The streams and rivulets, locally called *charas,* traversing the above units bring down the boulders of hard rock of various sizes. Preliminary estimates indicate an availability of approximately 952,347.29 cu.mts. of hard rock bands and about 6500 boulders of calcareous concretions in Chandrai, Gola, Gagra, Chalta and Ranga streams. Physical tests have been carried out on a few samples collected from Bahuri Chara area (Ramachandran, 1963) and two samples from Gagrachara (23°35'30":91°13'30"), at Alipore Test House, and PWD soil testing laboratories, Agartala. The result shows the crushing strength of the sample ranges from 6 to 11 tonnes /sq. inch under dry condition. After a few weeks of soaking in water, the strength gets reduced to 2.5 to 7 tonnes/ sq. inch. Aggregate impact value ranges between 39.23 and 16.57% and water absorption value ranges between 1.82 to 0.76%. The above hard rocks are suitable for 2 cm thick bitumen and tar carpet roads, water-bound macadam road and also for asphaltizing concrete road. About six hundred hard calcareous boulders are available around Atharamura hill range North Tripura district.

A reserve of about 10,000 cu.mts. hard rock upto a depth of 5 metres has been estimated from Doapta Chhara, Phuldengsei, Khantlang area of Jampui hill range, North Tripura district. Hard rock bands belonging to Bhuban Formation occur as thin lensoidal calcareous sandstone / siltstone bands. Thickness of these bands range from a few cms to 4 cms over an extent of 500 to 1000 metres. Aggregate impact valve (AIV) for some representative sample ranges from 24.92 to 28.61% for fresh rock and 30.50 to 34.39% for partly weathered rocks. 106 metres^3 of hard rocks boulders ranging upto 5 metres in diameter are present around Jampui hill area. About 0.1 metric tonnes of hard and compact shell limestone occurs as thin lensoidal bands of upto 2 metres thickness in Bhuban Formation, along the flanks of Jampui hill in Kanchanpui, Manpui, and Khedachara areas.

A reserve of 47,537 cu.mts. is estimated from hard rock bands of North Sakhan range-Sermantilla-Kobangshi Tilla which contain calcareous sandstone and siltstone of Upper Bhuban Formation. They occur as lenses, thin discontinuous bands and boulders. Crushing strength of these rocks vary from 8.50 to 11.50 tonne / sq.inch..

Lignite

Occurrences of lignite have been reported from Ujan-Tangang (24°21':92°15"), near Hirachara Tea Estate (24°22':92°03'), Dertirchara (24°14':92°03'), North of Kumarghat(24°10'00":92°03'00"), near Nattingchara Tea Estate (24°12':92°03') and other areas. The bands vary in thickness from 15 cms to 60 cms. At places it is pyritiferous and is of non-caking character. The occurrences are mostly very small and are overlain by thick cover of rocks and as such they do not appear to have any economic significance.

Limestone

Bands of shell limestone occur at Sakhan and Jampui hill ranges. In Jampui hill range, 12 discontinuous bands occur along hill slopes. The limestone bodies are small and lensoid in nature and occur as interbanded sequence within the calcareous sandstone and shale. The limestones are dark grey, very hard, siliceous and contain shells of bivalves and gastropods. The concentration of shells are patchy, locally rich in calcium contents. Where the concentration of shells are less, the rock grades into calcareous sandstone. The analytical results of a few samples show an average CaO content of 30%. Preliminary reserve estimates indicates 90,000 metric tonnes of limestone near Manpui and surrounding areas. Although available limestone is not of cement grade, it can be used along with clay for preparing lime Pazzoluna mix. The raw material for the proposed mini lime Pazzoluna mix plant at Kumarghat(24°10'00":92°03'00"), is sourced from shell limestone of Jampui hill range.

VI. RIVER VALLEY DEVELOPMENT PROJECTS

The state has a rugged topography with moderately high N-S trending hill ranges and intermediate flat valleys opening out in north or west. There are north, northwest and westerly flowing rivers which form part of the Barak Basin. The extreme southern portions of the state are drained by small rivers flowing towards southwest draining into Bay of Bengal. Major tributaries of Barak River are Juri, Manu, Gumti, Khowai, Dholai, and Haora Rivers. Southwest flowing rivers are Muhuri and Feny. Khowai River has a catchment of 1310 sq. kms and Manu River has a catchment of 1960 sq kms. The average annual rainfall in the state is 1600 to 2500 mm out of which maximum rainfall occurs during monsoon period from May to September.

Most of the rivers are flowing through broad, open valleys and are having low gradient. High natural head is not available in the rivers. These river valleys are being developed for medium irrigation and flood control projects with minor Hydel power generation component.

Gumti Hydel Project: The project over River Gumti has been commissioned and is producing 10 MW of power by utilising 100 cu sec. of water by the construction of high masonry dam. Micaceous sandstones of Surma Group are exposed in the project area.

Khowai Hydel Project: The project envisages utilisation of water of Khowai River by making a 43 m high dam across River Khowai for generating 15 MW of power. Soft sandstone, shale and siltstone of Tipam Group are exposed in the area. The project is likely to face the problem of slope stabilisation in penstock and in spillway area where the rocks are highly friable and permeable. A positive cut-off with a deep grout curtain shall be provided to avoid the seepage below the dam.

Apart from above, a number of micro-hydel schemes are under various stages of investigation. These are Manu, Deo multipurpose Projects, Paticherra, Saikar-bari, Juri, Dhalai, Haora and Muhuri Projects. Out of these, Pathicherra, Juri and Dhalai are in the initial stages of construction.

LOCALITY INDEX

1	Agartala (23°49'30":91°17'00")	12	Khowai (24°04'30":91°37'30")
2	Ampi Bazar (23°41'00":91°28'00')	13	Kumarghat (24°10'00" :92°03'00")
3	Amtali (23° 43¢' 00":91° 43' 00")	14	Latiachara (23°39'00" :91°20'40")
4	Andhrachara(24°13'00":92°10' 00")	15	Manu (23°04'00:91°39'00")
5	Bokasa (24°22'00" :92°13'30")	16	Mohanpur (23°58'38":91°22'00")
6	Bijanandi (23°34'00":91°22'00")	17	Pabichara (24°09'00":92°13'00")
7	Bisramganj (23°36'30":91°21'00")	18	Rajnagar (23°14'56":91°17'34")
8	Champamura(23°50'00":91°20'00")	19	Sinchukumarpara(24°57'00":92°58'00")
9	Dertuichara (24°14'00":92°03' 00")	20	Silbari (24°11'30":92°09'00")
10	Gagrachara (23°35'30":91°13' 30")	21	Ujan-Tangang (24°21'00":92°15'00")
11	Kamalghat (23°55'30":91°20' 00")	22	Teliamura (23°50'20":91°38'30")

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