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# अरुणाचल प्रदेश
# का
# भूविज्ञान
# एवं
# खनिज संसाधन

# GEOLOGY
# AND
# MINERAL RESOURCES
# OF
# ARUNACHAL PRADESH

**भारतीय भूवैज्ञानिक सर्वेक्षण**
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# GEOLOGY AND MINERAL RESOURCES OF ARUNACHAL PRADESH

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# FOREWARD

The Miscellaneous Publication 30 Series of the Geological Survey of India brings out concise information on the geology and mineral resources of the states of India. The present volume Part IV, Vol. 2(i) of the series, pertaining to the state of Arunachal Pradesh, 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 of a revised edition of this volume. Thus Geological and Mineral Map presented in this volume is a modified version incorporating 1:2 million scale Geological Map of North-East India (1998).

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

Occurrences of limestone and graphite in Lower and Upper Subansiri, West Siang and Lohit districts and clay, beryl and base metal mineralization near Potin village in Ranga valley of Lower Subansiri district of Arunachal Pradesh have evolved interest because of the indicated cobalt values in pyrite and nickel in pyrrhotite. Investigation for locating limestone-marble occurrences has resulted in the discovery of Tidding Limestone and Dora Marble deposits in Lohit district. The coal deposits of Namphuk in Tirap district was investigated by GSI and a reserve of 17 million tones with the help of drilling and about 100 million tonnes in the indicated category has been established.

This publication with update knowledge-base on the geology and mineral resources of the state of Arunachal Pradesh 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.

**(N. K. DUTTA)**
*Director General*
Geological Survey of India

PLACE : Kolkata

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GSI Misc. Pub. 30 Pt. 4 Vol. 1(i)

# *Introduction*

The studies of the individuals and institutions have been analyzed and synthesized periodically and the document published by GSI in 1974 as Miscellaneous Publication No. 30, part IV incorporated all the available data pertaining to the geology and mineral resources of the seven states and territories of the NER. Since then, a number of major mineral investigations have been completed, new ones have commenced and interesting geological findings have been recorded. The additional data thus collected by GSI and other organizations in their intensified efforts are mostly scattered in numerous departmental published and unpublished records. Nevertheless, a reappraisal of the available data inspite of gaps in knowledge existing due to the diverse concepts, approach and accessibility by individual scientists, for an acceptable interpretation everywhere, it has become necessary in the present revised edition of the volume to attempt a glimpse of the present status of knowledge about the geological setting and mineral resources in each of the seven states of the region.

The north-eastern part of India is a land of extremes and undoubtedly one of the most picturesque parts of our country. Within its area of 0.255 million sq km, we have, on the one hand, steep, rugged and inaccessible peaks of Arunachal Pradesh, rising above 6000 m.s.l. with temperate to cold climate and, on the other the enormous flood plain of Brahmaputra River, covering 0.009 million 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 huge monolithic columns. The world's wettest spot Mawsynram is located here. Rocks of diverse geological ages from the Archaean Gneissic Complex to the Quaternary deposits form the geological sub-strata of the region.

Northeast India is rich in non-metallic mineral resources, especially in respect of high grade limestone and coal containing high sulfur 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 Palaeozoic (?) territories in Meghalaya, Assam, Arunachal Pradesh and the Ophiolite Belt of Nagaland and Manipur are primarily significant. 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

**Table 1.0.1: Basic Statistics of North Eastern Region**

| | | | |
|---|---|---|---|
| **Capital Cities** | **Agartala, Aizawl, Dispur, Imphal, Itanagar, Kohima, Shillong** | | |
| **Population** | 31,547,314 | **Forest cover** | 166,270 sq. kms |
| **Area** | 254,997 sq. kms | **Road length** | 116,551 kms |
| **Population Density** | 123.7 persons / sq. km | **Total Hard rock area** | 187,621 sq. kms |
| **Villages** | 39,720 | **Quaternary area** | 67,376 sq. kms |
| **Literacy** | 44.44% | **Hard rock mapping coverage *** | 138,707 sq. kms |
| **Total no. of districts** | 62 | **Quaternary mapping coverage *** | 61,297 sq. kms |
| **Major Mineral deposits** | Coal, dolomite, limestone, magnetite, natural gas, oil, sillimanite and uranium. | | |
| **Minor Mineral deposits** | 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. | | |

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to explore the geologically promising areas and appropriate exploration strategies have to be evolved to overcome the geological and terrain constraints. Steps in this direction have recently been taken.

## II PHYSIOGRAPHY:

Arunachal Pradesh, the 'Land of the rising sun' is located towards the northeastern tip of India. It presents a breathtaking beautiful landscape with towering snow-clad peaks, steep precipitous gorges, lush green valleys and innumerable streams. The state is bound by neighboring countries like China (Tibet), Bhutan and Myanmar towards North, West and East respectively. Arunachal Pradesh lies between 26°28' and 29°30' N and 91°30' and 97°25' E. It occupies an area of 83,578 sq. kms and has been divided into fifteen administrative districts, namely, Tawang, West and East Kameng, Lower and Upper Subansiri, Papumparae, West, East, and Upper Siang, Upper Dibang valley, Lower Dibang valley, Lohit , Changlang, Tirap and Kurung Kumey Laying.

Arunachal Pradesh is largely inaccessible rugged terrain with dense impenetrable forests, unpredictable climatic conditions and poor road communications. Thus, it is geologically, a rather lesser known region.

Arunachal Pradesh consists of four physiographic domains viz. a) Himalayan range, b) Trans-Himalayan range c) Naga-Patkoi range and d) Brahmaputra plain. Each domain has a distinctive geological and tectonic history.

## A HIMALAYAN RANGE :

The Himalayan range rising abruptly from the Brahmaputra plain covers about 350 km length of the easternmost part of the Himalaya extending from the border of Bhutan to the Dibang and Lohit valleys and terminating against the Tidding-Tuting suture. It has a general elevation of 100 m in the south to above 1000 m. in the north above the m.s.l. with a few peaks attaining heights more than 7000 m. On the basis of geographic characters and type and density of vegetation, the Himalayan range of Arunachal Pradesh is sub-divided into four sub parallel linear zones. These, from north to south, are as follows:

### A (i) Tibetan Himalaya:

This covers the north-western part of Arunachal Pradesh bordering Bhutan and Tibet and is represented by a NE-SW trending 30-40 km wide zone of high altitude, low relief, gentle slopes and sparse alpine type vegetation. The altitude, in general, ranges between 3000 m and 6000 m above m.s.l. The highest point is an unnamed peak of 7089 m altitude. It comprises a part of the high grade schists and gneisses of the Sela Group, Proterozoic metasediments of Lumla Formation and a part of probable Tethyan sequence.

### A (ii) Higher Himalaya:

This is bounded by the Tibetan Himalaya in the north and the Lesser Himalaya in the south and the southern limit is generally defined by the Main Central Thrust as in adjacent Bhutan and Western Himalayas. It has an ENE-WSW trend adjacent to Bhutan that changes gradually to NE-SW eastward. In general, the zone has a high relief around 6000 m, rugged topography with high ridges, precipitous slopes and narrow deep gorges. High ridges mostly remain snow clad; the precipitous slopes are occupied mainly by grasses and the valley and gorges by alpine type vegetation. Palaeoproterozoic high grade gneisses and schists of the Se La Group and Tertiary intrusive granites are major rock types exposed in this belt.

### A (iii) Lesser Himalaya:

The Lesser Himalayan zone bounded by the Higher Himalaya in the north and the Sub-Himalaya in the south is comparatively of lower elevation ranging between 2500 m and 4000 m. This zone is E-W trending in the western part and gradually swings to NNE-SSW till the syntaxial bend after which it swings to NW-SE and abuts against the Tidding-Tutting suture in the Dibang valley and Lohit districts. The southern boundary of this zone is defined by the Main Boundary Fault which terminates against the Roing Fault. A major part of this zone is made up of the Palaeoproterozoic metasediments of the

**Table 1.0.2: Basic Statistics of Arunachal Pradesh**

| | | | |
|---|---|---|---|
| **Capital** | Itanagar | **Forest cover** | 68,760 sq. kms |
| **Population** | 1,09,1117 | **Road length** | 7,520 kms |
| **Area** | 83,578 sq. kms | **Total Hard rock area** | 74,788 sq. kms |
| **Population Density** | 13 persons / sq. km | **Quaternary area** | 8,790 sq. kms |
| **Villages** | 3,644 | **Hard rock mapping coverage *** | 40,888 sq. kms |
| **Literacy** | 52.74 % | **Quaternary mapping coverage *** | 5,615 sq. kms |
| **Districts** | West Kameng, East Kameng, Lower Subansiri, Upper Subansiri, Upper Siang, East Siang, Lower Dibang valley, Upper Dibang valley, Changlang, Tirap, East Kameng, Kurung Kumey Laying, Lohit, Papumpare, Tawang | | |
| **Major mineral deposits** | Coal, dolomite, limestone. | | |
| **Minor Mineral deposits** | Cobalt, copper, gold, platinoids, graphite, lead-zinc, marble, nickel, tin and tungsten. | | |

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Bomdila Group, Ziro Gneisses and narrow discontinuous outcrops of Upper Palaeozoic sediments. However, in the eastern part Upper Cretaceous to Lower Eocene sediments and Abor volcanics are also exposed.

**A (iv) Sub Himalaya:**

The Sub-Himalaya or the foothill foredeep is represented by the Siwalik hill range varying in width from 10 to 20 km. The sedimentaries in Siwalik range is followed to the south by the thick alluvial cover of the mighty Brahmaputra and Digaru. The altitude ranges from 1700 m to 2000 m. This zone trends E-W near Bhutan border, gradually swings to ENE-WSW towards east where it gradually turns and terminates against the Roing Fault at Dibang valley. This belt is characterised by longitudinal ridges and well defined "Dun" type valleys and supports luxuriant vegetation.

The Himalayan landform, in general, represents a mega folded, faulted and thrusted terrain. Due to presence of tectonic lineament and heterogeneity in lithology with approaching immaturity of dissection, this landform has attained a high degree of relief. Simultaneous rejuvenation, along with operating erosional cycle, has rendered rivers of aggrading nature mainly. In this process, a macro relief of parallel ridges and valleys has been imprinted over the whole region.

## B TRANS-HIMALAYAN RANGE:

In the easternmost part of Arunachal Pradesh the Himalayn range abuts against the Trans Himalayan range commonly known as the Mishmi hills along the Tidding suture. The NW-SE trending mountain range appears to be equivalent of the Ladakh range lying to the north of the Indus-Tsangpo suture with a syntaxial bend near Tutting. The Trans-Himalayan range can be subdivided into two parallel belts – (a) one bounded by the Tidding suture to the west and the Lohit Thrust to the east and (b) the other to the east of the Lohit Thrust. The former comprising metasedimentaries and ultramafics, abuts against the Naga-Patkoi Range along the Mishmi Thrust and the latter, comprising the Lohit Granitoid Complex, continues to the SE as the northern Myanmar Range. The general elevation of the Trans-Himalayan Range is between 2500 m and 6000 m.

## C NAGA-PATKOI RANGE:

The Naga-Patkoi range attains an altitude upto 2780 m and defines the southern limit of the Upper Brahmaputra plain. These form a part of the ENE-WSW trending Arakan Youma Mountain chain which assumes an arcuate pattern in the vicinity of the Mishmi Thrust. The Naga-Patkoi range is made up of Tertiary sequences of Assam and south-eastern Arunachal Pradesh.

## D BRAHMAPUTRA PLAIN:

Part of the eastern extremity of the vast Brahmaputra plain falls in Arunachal Pradesh where it is bounded to the north and east by the Himalayan range and to the south by the Naga-Patkoi range. The terrain is underlain by post-Siwalik Quaternary sediments.

## III. DRAINAGE:

All the major rivers draining Arunachal Pradesh are tributaries to the mighty Brahmaputra. The Brahmaputra in the upper reaches of Arunachal Pradesh is known as Dihang or Siang River and is joined by several tributary streams viz., the Siyom, Yamme and Yang Sang Chu. The Bhareli or Kameng and the Subansiri are principal north bank tributaries draining the Himalayan range and joining the River Brahmaputra. The Dihang River originating from the 5355 m peak at the Chinese border and the Lohit River originating from the Yunnan Province of China join the Brahmaputra River from the north east and east, respectively whereas the Disang, Noa Dihing and Buri Dihing draining the Naga-Patkoi range join the Brahmaputra River from the south east. Besides the above, two other north bank tributaries viz. the Ranga and the Dikrong originate in the lesser Himalaya and debouches into the River Brahmaputra. The above tributaries are fed by several perennial streams some of which are Tenga, Bichom and Papu flowing into the Bhareli (Kameng); Kamla and Kamlang joining the Subansiri, Emra, Ahui, Dri and Ange debouching into the Dibang and Deleri, Hayluliang and Tidding joining the Lohit river.

## IV. CLIMATE, FORESTS AND CULTIVATION:

In Arunachal Pradesh, the frontal area, bordering Assam, experiences all the three seasons viz. summer, rainy and winter. During summer, the temperature rises to 36°C, whereas during winter the mercury drops down to 8°C. The Lesser Himalaya has relatively long rainy and winter season but a short and pleasant summer. During winter the mercury drops below 0°C and during summer, the maximum temperature is about 25°C. Upper reaches of Higher Himalaya generally remain snow-clad round the year, experience severe winter and rainy season. Annual average rainfall of Arunachal Pradesh is about 500 cms.

## V. ACCESSIBILITY:

Except for valley areas, major part of the region is characterised by lack of 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.

## VI. PREVIOUS WORK:

The earliest geological information on Arunachal Pradesh dates back to 1825 when Wilcox (1832) made some preliminary observations on the geology of Lohit district. Subsequent information came from Rowlette (1845) who recorded presence of 'gneiss and mica slate' between Dihing and Daphpam. Medlicott (1865) reported for the first time the presence of coal in Tertiary rocks of Namchik area. In 1975, Godwin Austen mapped part of the Dafla hills in the Bhareli valley. La Touche (1885) also took traverse in the Bhareli valley. He also recorded the presence of Tertiary coal in Patkoi ranges. Maclaren (1904b) prepared a geological map on 1 inch to 16 miles covering parts of Sub-Himalaya, Lesser Himalaya, Mishmi Hills and the Patkoi range and worked out a stratigraphy. Coggin Brown (1912) worked on the Abor Volcanics and brought it in the stratigraphic map of India. A.M.N. Ghosh, (1935) made geological observation along the left bank of Dibang River. Ludlow (1940) and Laskar (in Krishnan, 1956) studied the geology of Subansiri and Siang districts. Laskar (op.cit) first postulated the presence of marine sequence associated with the Gondwana and also named the quartzite of the Kamala valley in Upper Subansiri district as the Miri Formation. Banerjee (1954) established the presence of continental Gondwana in Arunachal Pradesh on the basis of presence of Glossopteris indica. During geotechnical investigation in connection with road alignments, Banerjee (1954 (a) in Anon 1974), Balasundaram (1956, in Anon 1974) and Laskar, 1976, reported occurrence of sulphide mineralisation in Ranga valley and limestone and peat in Ziro valley.

Extensive traverses by Dhoundial (in Balasundaram, 1972), Kakoti, et.al, (in Balalsundaram, 1972) and Banerjee (1973) provided the basis for compilation of geology and mineral resources of Arunachal Pradesh (Anon 1974). The geology of the Himalayan part and that of the Lohit valley were described separately in their compilation. In the former, the successions were grouped into seven thrust bound lithotectonic units viz. the Sela Group, Bomdila Group, Tenga Formation, Dedza Formation, Bichom Group, Gondwana and the Tertiary sequence (Siwalik equivalent). However, Nandy, et.al, (1975) classified the succession into five lithotectonic units; - the Siwalik, the Gondwana, the Buxa (including the Abor volcanics) the Dalings and the Crystallines, they (op.cit) considered the Miri as a part of the Buxa which Laskar as well as Dhoundial (in Nandy, et.al, 1975) did not agree. In the Lohit Himalaya absence of Gondwana and Siwalik rocks and existence of a zone of ultrabasic and granodiorite associated with metasediments were noted. During the last quarter of the twentieth century extensive geological studies have been carried out by the Geological Survey of India, the Wadia Institute of Himalayan Geology and Oil and Natural Gas Commission in different parts of Arunachal Pradesh. However, rugged terrain with dense impenetrable forests, unfavorable climatic conditions involving heavy rains and snowfall, poor road communications and logistic difficulties have largely been a big challenge to the geologists for systematic mapping in Arunachal Pradesh. As a result, out of a total area of about 83,578 sq km, only 39,988 sq km in hard rock and 5615 sq km in Quaternary has been covered by systematic geological mapping. The unfossilifereous nature of rocks, in large part, intense tectonisation by virtue of its being close to the eastern syntaxis and use of a plethora of informal stratigraphic nomenclature by various workers remained major problems for establishing a secular stratigraphy of Arunachal Pradesh. The present compilation and the accompanying geological map is mainly based on the voluminous data collected mainly by a large number of geologists of the Geological Survey of India which are available in unpublished reports and various published accounts. Significant and important works carried out by several workers outside Geological Survey of India have also been cited at places. For convenience, geology of the Himalayan Belt, Trans-Himalayan Belt and southeastern Arunachal Pradesh are dealt with separately.

**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 Pre-Cambrian crystallines exposed in the Arunachal Himalaya and the Mishmi hills show incidences of basemetals, tin-tungsten mineralization; no ore grade deposits have been located as yet, but intensified searches are in progress.

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

Occurrences of limestone, dolomite, base metals etc. have been recorded in Palaeozoic of Arunachal Pradesh. This zone requires more intensive search.

After independence, geological work in this territory was geared up with a view to locate areas with hydroelectric, mineral and fossil fuel potential. Academic interest like marine fauna associated with Gondwanas and correlation of different stratigraphic and tectonic units with those of Darjeeling, Sikkim-Bhutan Himalaya were given due importance. In 1960s, Assam Circle of Geological Survey of India located a few occurrences of limestone and graphite in Lower and Upper Subansiri, West Siang and Lohit districts. Occurrences of clay, beryl and base metals near Potin village in Ranga valley of Lower Subansiri district also received attention because of the indicated cobalt values in pyrite and nickel in pyrrhotite. Investigation for locating limestone-marble was undertaken by officers of GSI which resulted in the discovery of Tidding Limestone and Dora Marble deposits in Lohit district. The coal deposits of Namphuk in Tirap district was investigated by GSI. Proved reserve of 17 million tones with the help of drilling and about 100 million tones in the indicated category were established. Duara (1965-66) brought out the geology of parts of foothills of East and West Kameng districts, whereas Limaye and Mullick (1965-66) mapped the area around Miao in Changlang district and adjoining parts of Lohit district of Arunachal Pradesh.

After the establishment of Arunachal Pradesh Circle in 1969, a broad geological picture could be quickly drawn by GSI through geological traverses, mapping and mineral investigations. These included base metal investigations of Middle Proterozoics in Shergaon, West Kameng district; investigation of pozzolonic clay in East Kameng and Lower Subansiri districts ; plastic clay in Lohit and West Kameng districts; dolomite investigation in West Kameng district; graphite investigation within Khetabari Formation in Upper Subansiri district; investigation of limestone in Dibang valley (Hunli Deposit) in Lohit and West Siang districts; and sulphide investigation in Khetabari-Potin Formation in Lower Subansiri and East Kameng districts.

Investigations for coal in Gondwanas were carried out in West Kameng district (Bhalukpong-Bomdila section). Preliminary investigation for placer gold in Siwalik rocks was carried out in Lower Subansiri district. Occurrence of molybdenite was reported in Apruni village in Dibang valley district and search for platinoids in Tidding area, Lohit district was carried out.

Since then, the geologists of GSI have been studying different parts of the region - a task indeed difficult in many areas due to inaccessibility, remoteness, ruggedness, dense forest and other related factors. Whatever basic data on stratigraphy, structure and the tectonic frame of the region is known today could be ascribed to these efforts of the GSI. Fortunately, because of the presence of petroleum in the plains of Assam, the efforts of GSI were supplemented and embellished by studies undertaken by various organisations like Burmah Oil Co., Assam Oil Co. etc. The exploratory activities of Oil and Natural Gas Corporation, Atomic Minerals Division and other central agencies over the last few decades have also enriched the existing documentation. The State Departments of Mines and Geology in several states are distinguished new comers in this domain of study.

## VII. LANDSLIDES AND SIESMOTECTONICS:

The region is prone to earthquake. Since the middle of the nineteenth century, there had been at least two major earthquakes (1897 and 1950), which are among the most destructive earthquakes in human history. The mountainous tracts of the region are inhabited by people of diverse ethnic groups and cultural affinities lured by the pioneering spirit of man in quest of the unknown, be it geographical or geological. The earliest reference of the region is found in the Mahabharata and documentation of the geological information was made mostly by the British military expeditions during the early part of the nineteenth century prior to establishment of the GSI in 1851. This excludes the meticulous records of the earthquakes which are available since the middle of the last century.

## VIII. ACKNOWLEDGEMENTS:

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

The coordinated efforts of the Deputy Director General, Geological Survey of India, North Eastern Region, Shillong with supervisory officers at Agartala, Dimapur, Guwahati, Itanagar and Shillong were responsible for availability of manuscripts of the different states.

The manuscript has benefited from thoughtful reviews by officers of Publication & Information division, CHQ, Kolkata. An overall co-ordination from Central Headquarters was necessary for uniformity in the publication, parts of which have been compiled at different regions of GSI.

Various divisions of Geological Survey of India, Northeastern Region have provided the basic material which has been compiled and modified to conform to the format of this volume. Since the work for this volume started some years before the actual publication, some of the manuscripts were irretrievable and portions had to be rewritten. This would not have been possible without the background information on the data sources provided by the divisions. Coal Wing, Geological Survey of India provided the material which has been incorporated in the coal chapters of this volume.

The support provided by Smt. Lamonsie Laitflang Kesari, Smt. Aradhana Saikia and Smt. Dorothy L.Fanai, Library Information Assistants of the Publication Division, GSI, NER, was very important in composing, editing and for retrieval of material, as available, for authentication of details, as necessary.

★★★

# 1.1: Geology of the Himalayan Belt

Traverse and systematic geological mapping have been carried out over the years and an area of about 45,603 sq km has been covered on scale 1:63360 / 1:50,000, out of a total area of about 83,743 sq km. However, geological and traverse mapping could be carried out only in accessible areas of the states, leaving the intervening areas, which are very rugged, remote or snow capped and devoid of communication facilities. The stratigraphic succession of the Himalayan belt of Arunachal Pradesh is shown in the Table 1. The general lithostratigraphic succession as shown in Table 1 has been worked out on the basis of order of superposition, lithological characteristics, grade of metamorhism and palaeontological evidences (wherever available). Description of the litho-units is dealt with in the subsequent pages.

## A. PALAEO-PROTEROZOIC

The oldest sequence presumably of Late Archaean (?) to Palaeo-Proterozoic age identified in Arunachal Pradesh includes a high grade pelitic and psammitic psammopelitic metasediments and intervening mafic bodies, represented by sillimanite-kyanite-bearing schists, gneisses and amphibolites respectively. There is no record of an earlier crust on which the sedimentation started in a basin developed in an extensional regime followed by mafic volcanism. An epeirogenic movement of short duration was responsible for the deposition of oligomictic conglomerate, persistent bands of quartzite and pelitic schists and limestone. Deposition of limestone with development of stromatolite in a photic zone is indicative of a stable basin condition during the later period with shallow marine / lacustrine environments.

**Table 1.1.1: Stratigraphic succession of the Himalayan belt**

| | | | |
|---|---|---|---|
| | Hapoli Formation (Newer Alluvium) | Sand, Clay and peat | Holocene to Recent |
| **QUATERNARY SEDIMENTS** | Older Alluvium | Unconsolidated sediments represented by boulders, cobble, pebble, sand and sandy clay beds | Middle to Upper Pleistocene |
| ------------ Main Frontal Fault ------------ | | | |
| **SIWALIK GROUP** | Kimin Formation (Upper Siwalik) | Boulder conglomerate, pebble sandstone | Mio-Pliocene |
| | Subansiri Formation (Middle Siwalik) | Salt and pebble lithic arenite | Mio-Pliocene |
| | Dafla Formation (Lower Siwalik) | Micaceous sandstone with calcareous concretions | Miocene |
| **TOURMALINE BEARNG LEUCOGRANITE** | | Unfoliated two mica medium to coarse grained tourmaline bearing leucogranite | 29 ± 7 Ma |
| **YINKIONG GROUP** | Dalbuing Formation | Limestone with shale intercalation | Early to Mid Eocene |
| | Geku Formation | Purple and pale green shales sandstones black shale, nodular grey shale, quartzite (occasionally calcareous) | Late Paleocene to Early Eocene |
| **GONDWANA GROUP** | Yamne Formation | Pale brown ferruginous shale | Upper Permian |
| | Abor Volcanics | Porphyritic aphyric basalt, andesite, acidic tuffs, agglomerates aquagine tuff, volcanic sediments | |
| | Bhareli Formation/ Khelong Formation | **Upper Member:** Feldspathic sandstone, black and carbonaceous shale with thin impersistant lenticular coal **Lower Member:** Arkosic red sandstone-siltstone and black carbonaceous shale with thin impersistant lenticular coal | |
| | Lichi Volcanics | Light to dark green basic volcanics | Permo-Carboniferous |

| | | | |
|---|---|---|---|
| | Bichom Formation | **Sesa Member:** Grey to black tuffaceous (?) shale with impersistant bands of quartzite<br>**Bomte Member:** Grey to black shale with calcareous and phosphatic chert nodules<br>**Rilu member:** Diamictite with subordinate sandstone, shale and grits | |
| | Miri Formation | Purple to pinkish, white to grayish white feldspathic quartzite, purple micaceous shale, diamictite conglomerate | Lower Palaeozoic |
| **BIOTITE GRANITE** | | Biotite granite. (Deed Granite / Hawa Pass Granite / Tamen Gneiss) | 500 + 19 Ma & 480 Ma |
| **THINGBU FORMATION** | | Low-grade carbonaceous mica schist and micaceous quartzite | Neo- Proterozoic |
| ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ Unconformity(?) ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ | | | |
| **DIRANG / LUMLA FORMATION** | | Garnetiferous mica schist, Phyllite, sericite quartzite, calc silicate and tremolite – actinolite marble | Meso- Proterozoic |
| ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~Unconformity ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ | | | |
| **BOMDILA GROUP** | Bomdila/ Ziro/ Daporijo Gneiss | Biotite Granite Gneiss | 1536±23 to 1914±23 Ma |
| | Chilliepam/ Dedza/ Menga/ Mukatang Formation | **Niumi Member:**<br>Carbonates (limestone and dolomite) with alternation of greenish grey, purple and dark grey, carbonaceous phyllite<br>**Kabak Member:**<br>Basal oligomictic conglomerate, quartzite with impersistant bands of dolomite and black to dark grey phyllite | **Palaeo-Proterozoic** |
| | Tenga/ Potin/ Dublo Kho/ Ragidodoke Formation | **Reyang Member:**<br>Basic meta-volcanics and Chlorite-biotite-garnet schist interbedded with flaggy quartzite and thin beds of marble<br>**Garubuthan Member:**<br>White to greyish white schist, quartzite, purple quartzite with purple silky shale, Sericite quartzite and phyllite | |
| | Khetabari Formation | Sericite–quartz phyllite, garnetiferous phyllite and schist, graphite / carbonaceous phyllite, quartzite, minor carbonates chert and para- amphibolite | |
| ------------------------------ Tectonic Contact ------------------------------ | | | |
| **Se La GROUP** | Galensiniak Formation | High grade schist, gneiss and migmatites (intruded by younger tourmaline granite and pegmatite of Tertiary age) | **Palaeo- Proterozoic** |
| | Taliha / Taksing Formation | Graphite schist, calc-silicate, marble, amphibolite and schistose quartzite | |

**(i) Se La GROUP :**

Se La Group is structurally the highest unit which is separated from the Dirang Formation to the south by Main Central Thrust (MCT). This suite of medium grade to high grade rocks derived its name from the Se La pass in West Kameng district (Bakliwal and Das, 1971). The predominance of migmatites, lit-par-lit injections, higher grade of metamorphism and profuse intrusions of tourmaline granite characteristically differentiate this sequence from the structurally underlying Dirang Formation.

In the area around Se La pass the rocks exposed include garnetiferous gneiss, sillimanite-kyanite-garnet-bearing gneiss, migmatite, lit-par-lit biotite gneiss, calc-gneiss/marble, staurolite-bearing schist, tourmaline granite, quartzite and veins of pegmatite. In the Diggin valley, the rocks exposed include coarse, schistose, garnetiferous gneiss, small tongues and veins of tourmaline granite and quartz veins.

Though the Se La Group was first described from the Se La section, its best exposed section is in Subansiri valley, upstream of Taliha. On the basis of lithology and their metamorphic grade the rocks of Se La Group are divisible into two formations; - namely the Taliha Formation and the Galensiniak Formation (Dhoundial, et.al, 1989).

| | | |
|---|---|---|
| **Se La Group** | Galensiniak Formation | Medium to high grade gneisses, migmatites, schists and quartzite |
| | Taliha Formation | High grade gneisses, schists and calc-silicate and marble |

**Taliha Formation:**

This unit comprises graphite schist, calc-silicates, marble, amphibolite and schistose quartzite (Dutta, et.al, 1983). The marble and calc-silicates are coarsely crystalline and contain diopside, actinolite, calcite, plagioclase (andesine-labradorite) and scapolite. Amphibolites are schistose and comprise blue amphibole, plagioclase, biotite, epidote and sphene. Stringers of sulphides are found at places in amphibolites and schistose quartzite. Ubiquitous presence of biotite and quartz recorded in gneisses. The mineralogical composition of the gneisses is: quartz+biotite+garnet+ kyanite+staurolite.

Calc-silicate rocks are exposed around Taliha, Majam, Chetu and Takshing. A few hot springs are located around Chetu, where scapolite marble is exposed.

**Galensiniak Formation:**

This unit consists predominantly of high grade schists and gneisses intruded by younger tourmaline granite and pegmatite of Tertiary age.

The Se La Group has a general E-W trend in the area west of Taliha, but in the eastern extension it swings to NE-SW in Siyom valley where it has been designated as Siyom Group by Singh & De (1989). Beyond this it takes further northward swing and is terminated against the Tidding suture in the Dihang (Upper Siang) valley west of Tuting (Kumar, 1997)

Different local stratigraphic names have been used by various workers to describe sequences similar to that of the Se La Group. Some of these which may be considered as equivalent of the Se La Group are: Pari Mountain and Pidi Formations (Singh and Malhotra, 1983), Siang Group (Singh, 1989) and Subansiri Group. These are considered equivalent of the Central Crystalline of Western Himalaya, Kanchanjungha Gneiss of Sikkim-Darjeeling and Thimpu Group of Bhutan Himalaya (Jangpangi, 1978, Anon 1984b).

There is no direct evidence to ascertain the antiquity of the rocks of the Se La Group. However, on the basis of earliest acid magmatism dating 2300-2100 Ma in rocks occurring in similar tectonic and stratigraphic position in northwestern Himalaya, the Se La Group may be considered to represent an early Palaeoproterozoic sequence (Wang, 1986)

**(ii) BOMDILA GROUP :**

A sequence of low to medium grade metasediments with associated gneisses and younger granitoids occupying expansive areas throughout the lesser Himalaya of Arunachal Pradesh from Siang valley in the east to Kameng valley and Bhutan in the west is designated as the Bomdila Group. Similar sequence of granite gneiss, schist, quartzite, minor marble and amphibolite is known as Ithun Formation (Ray & Dutta, 1982; Srivastava, et.al, 1984) and the quartzite-metavolcanic-carbonate sequence described as Rikor Group in Dibang valley and Lohit valley areas. Tilung Formation and Namdhapa Crystalline Complex of Dasgupta, et.al, 1995-96 and Kesari and Patel (1996-97) are also included in this group. From west to east the Bomdila Group is overlain by the Dirang Formation till east of Subansiri River. In Siyom and Siang River sections, they are tectonically overlain (MCT) by the rocks of the Se La Group. The southern contact of the Bomdila Group is also known to be thrusted bringing it over either the Gondwanas or the Neogene-Quaternary sequences in western and central Arunachal Pradesh. In the eastern limb of the Siang dome, it rests over the Palaeogene sequences (vide Geological Map). Lithostratigraphically, the sequence has been classified differently by different workers (cf. Anon, 1974; Das, et.al, 1975; Jain, et.al, 1974; Singh, 1993). Bhusan (1999) on the basis of section measurement between the MBF and MCT in western Arunachal Pradesh has subdivided the rocks of the Bomdila Group into Tenga Formation, Dedza Formation, Dirang Formation and intrusives in ascending order. Kumar (1997) subdivided the Bomdila Group into three formations viz., Khetabari, Tenga and the Chilliepam (Dedza) Formations and the biotite gneisses variously referred as Ziro, Chako, Sepla or Daporijo Gneisses were considered by him as intrusives into the Bomdila Group. In the present compilation, the classification of rock units has been adopted from Dhoundial, et.al, (1989) and Kumar (1997), with some modifications (vide Table-1). For example, the 'Ziro Gneisses' have been assigned an infra-Chilliepam but supra-Tenga position because of two considerations. Firstly, the Khetabari and the Tenga Formations are intimately associated with the Ziro Gneisses showing intrusive relation and feldspathisation at places

**LITHOSTRATIGRAPHIC SUBDIVISION OF BOMDILA GROUP**

Dirang / Lumla Formation

~~~~~~~~~~~~~~~~~~~~ Unconformity ~~~~~~~~~~~~~~~~~~~~ (tectonism responsible for birth of Prototethys)

| | |
|---|---|
| **BOMDILA GROUP** | Bomdila/ Ziro/Daporijo Gneiss(Older Intrusive) |
| | Chilliepam/Dedza/Menga/Mukatang Formation |
| | Tenga/Potin/Dublo Kho/Ragidoko Formation |
| | Khetabari Formation |

------------------------------------------------------- Thrusted over by **Se La Group** -------------------------------------------------------

(Bhusan et.al, 1991). Whereas, the rocks of the Chilliepam Formation appear to be unaffected by the emplacement of the Ziro Gneisses. Secondly, the Khetabari and Tenga Formations show higher grade of metamorphism than the Chilliepam Formation.

The description of the various stratigraphic units of the Bomdila Group is given below:

**Khetabari Formation:**

The metasediments comprising sericite-quartz phyllite, garnetiferous phyllite and schists, graphitic/carbonaceous phyllite, quartzite, minor carbonates, chert and para-amphibolite exposed around Khetabari in the Lower Subansiri districts constitute the Khetabari Formation. The Yazali Formation (Das, 1979) and the Potin Formation (Kakoti, et.al, 1969-70) of Ranga valley area are also included in this Group because of similar lithological assemblage. In Pakro and Yazali areas, large enclaves of Khetabari Formation are seen in the granitic gneisses. Staurolite in schists has developed in the vicinity of granitoid intrusives, particularly near Rilo in East Kameng district. The quartzites in Pakro and Yazali areas contain magnetite rich zones with sulphide mineralisation. A sequence comprising biotite gneiss, quartzite, garnetiferous schist and para-amphibolite exposed along Roing- Hunli road between 26 and 65 km stones described as Ithun Formation and correlated with the Daling rocks (Nandy and Banerjee, 1967-68) may be considered equivalent to the undifferentiated Ziro Gneiss and Khetabari Formation.

**Tenga Formation:**

The low grade metasediments consisting of green phyllite, metavolcanics sericite-quartz phyllite and quartzite originally described from Tenga valley by Das, et.al, (1975) are referred to as Tenga Formation. The exposed section lying between Bame and Pangin, consisting of metavolcanics, quartzite, and carbonate rocks are also described as equivalent of Tenga Formation. Dhoundial et.al, (1989) have divided the Tenga Formation into two members on the basis of comparison with similar rocks in the Darjeeling-Sikkim Himalaya. The lower Garubuthan Member comprises white to greyish white schistose quartzite, purplish quartzite with purplish silty shale and sericite-quartzite and phyllite. The upper member named as Reyang Member comprises basic metavolcanics, at places altered to green chlorite phyllite and chlorite-biotite-garnet schist interbedded with flaggy quartzite and thin beds of marble. Bhusan, et.al, (1989) also divided the Tenga Formation into a lower and an upper member on the basis of lithostratigraphic section measurements in West Kameng district. In the Bame-Panging section, the lower and the upper members of the Tenga Formation have been referred as Along Member and Jameri Member respectively with an intervening granitoid.

The Along Member is characterised dominantly by basic metavolcanics with thin bands of flaggy quartzite, marble/dolomite and sericitic quartzose phyllite. The basic metavolcanics are generally of dull green colour showing variable alteration from chlorite-actinolite to chlorite-biotite phyllite as seen in Nechiphu-Jameri and Foothill-Tenga sections. In Basar-Bame section, the metavolcanics are least altered and vesciular and amygdaloidal characters of the mafic volcanics are retained. In the area east of Siang valley the rocks have undergone higher grade of metamorphism and have been referred as Frontal Metamorphics by Dhoundial, et.al, (1976).

The Jameri Member is predominantly a quartzite with thin bands of phyllite and black shale. The quartzites are grey to milky white, thinly bedded, occasionally schistose and mylonitised.

**Chillipam Formation:**

A thick succession of dominantly carbonate rock, unconformably overlying the Tenga Formation occurs in Tenga Valley in West Kameng district. This sequence variously referred as Chilliepam Formation (Anon 1974, Jain et.al, 1979, Dedza Formation (Das et.al, 1975) or Menga Formation (Subansiri valley, Tripathi and Roy Chowdhury, 1983) is well exposed around Dedza\Chilliepam Menga, Pangin and Palin. The Chilliepam Formation can be broadly divided into two members (cf. Kumar, 1997, 1999). The lower member broadly corresponds to the Kabak Formation (Roy Chowdhury and Lakshminarayana in Krishnaswamy, 1986) and referred here as Kabak Member. It consists of a basal oligomictic conglomerate with pebbles and cobbles of quartzite in a phyllitic matrix, quartzite with impersistant bands of dolomite, massive grey to white dolomite/limestone and black to dark grey phyllite (Bhusan et.al, 1991).The upper member referred to as Niumi Member (Kumar and Bora, 1984-85) comprises mainly carbonates (limestone and dolomite) with alternations of greenish grey, purple and dark grey carbonaceous phyllites.
~~~~~~~~~~~~~~~~~~~~

In Menga area stromatolites viz. Collenia pseudocolomnariis Maslov Conophytn Raben, Stratifera Korolyuk and Cryptozoan Hall have been recorded (Das et.al, 1986). The Chilliepam Formation may be correlated with a part of the Buxa Group on the basis of lithology and stromatolites (cf.Acharyya, 1980).

**Bomdila / Ziro / Daporijo Gneiss:**

Extensive area of the Lesser Himalaya of Arunachal Pradesh is occupied by a gneissic complex. This has been variously referred as Bomdila Gneiss, Chakko Gneiss, Sepla Gneiss, Darporizo Gneiss (Anon, 1974), Bakliwal et.al, (1979), Bhusan et.al, (1991), Singh and Ahmed (1989), Reddy and Kumar, (1990), Singh and Sharma, (1990) referred these as Ziro Gneisses. In earlier works it was considered as the basement for the metasediments of the Bomdila Group (Kumar and Singh, 1980). Subsequently, the Ziro Gneiss was considered to be intrusive bodies of batholithic dimensions (Bhusan, et.al, 1989, Singh and Ahmed, 1989, Saha et.al, 1989).

The vast granitoid terrain in the Lesser Himalaya of Arunachal Pradesh is a complex body comprising several phases ranging in age from Proterozoic to Cambrian. However, in the present compilation only the gneisses representing the older phases are treated as the Ziro Gneiss Formation. The older biotite granite gneiss consists of several variants such as foliated gneiss with occasional megacrysts of feldspar and quartz-migmatitic orthogneiss, streaky feldspathic gneiss and augen gneiss. Good exposures of these gneisses are seen in the Nechiphu-Bomdila section, Ziro-Daporizo section and Seppa-Veo section. The augen gneisses are particularly found close to shear zones and are probably the products of ductile deformation. Mineralogically these gneisses comprise orthoclase-perthite, oligoclase, quartz, biotite, sericite, minor muscovite with epidote, apatite and zircon as accessories.

Whole rock Rb-Sr isotopic studies of some of the older granitoid gneisses of the Bomdila Group have yielded the following ages:

i) Migmatitic orthogneiss of Tenga (Bhalla et. al, 1994) - 1644 Ma/Isr 0.7198

ii) Gneisses of Bomdila area (Bhalla et. al, 1994) - 1676 Ma/Isr 0.7625

iii) Augen gneiss from Bomdila (Dikshitalu et. al, 1995) - 1914+23 Ma

iv) Salari granite (Dikshitalu et. al, 1995) - 1536 + 60 Ma

Some of the geochemical characters of the Himalayan granitoids of Arunachal Pradesh mentioned above are as follows (Bhalla et.al, op. cit.).

i) All the granitoids have $SiO_2$ range within 71.2% - 75.35%.

ii) Bomdila, Tenga , Deed and Se La granitoids have higher total alkalies (7.42% - 8.00%) and lower $Na_2O/K_2O$ ratio (<1)

iii) In the $Na_2O$-$K_2O$ plot, Bomdila gneiss in adamellite-granite field and the samples of Tenga Gneiss show spread from granite to granodiorite field.

iv) All the granitoids are characterised by moderate to high Rb content and moderate to low Sr content with Rb/Sr ratio more than 1.

**B. MESO-PROTEROZOIC**

**(i) Dirang/Lumla Formation:**

A thick sequence of low grade metasedimentaries comprising garnetiferous mica schist, phyllite, sericite quartzite, calc-silicate and tremolite-actinolite marble unconformably overlying the Bomdila Group and truncated in the north by the MCT has been designated as Dirang Formation. It was first mapped as Dirang Schist in Diggin Valley (Anon 1974, Das et.al, 1975). It is intruded by biotite-augen gneiss (Bhusan et.al, 1991). Similar sequence has been mapped in the Pachuk river section (Singh and Sharma, 1990) and Subansiri river section overlying the Menga Formation (=Chilliepam Formation), around Rupa and Shergaon (Bhusan, 1999). Bhusan et.al, (1989) in Shergaon-Morshing area, has subdivided the Dirang Formation into five units (A-E). The 'A' member is characterised by a basal oligomictic conglomerate and a golden yellow dolomite is characteristic of the 'B' member. The member 'C' is an interbedded sequence of tremolite marble, schist and quartzite whereas the member 'D' comprises garnetiferous schist, flaggy quartzite and intrusive augen gneiss.

A sequence of medium grade metasediments comprising quartzite, garnetiferous mica schist with occasionally developed staurolite, marble, calc-silicate and amphibolite exposed in the Tawang-Woming La section in Tawang district has been described as Lumla Formation (Tripathi et.al, 1979, Singh, 1988). Similar sequence is also mapped in the Upper reaches of Subansiri valley and in Menchuka in Siyom valley (Singh and De, 1989).

Although the Lumla Formation is considered to represent a separate unit overlying the Se La Group (Kumar 1997), Mathur and Mukhopadhyay (1999) consider this sequence as a part of the Se La Group only. However, the systematic mapping around Tawang and Lumla by Kaura and Basu Roy (1982) clearly indicates that this sequence occurs in a tectonic window bounded by the rocks of the Se La Group. In the core of the window biotite gneiss similar to the Ziro gneiss (=Bomdila Gneiss) is exposed. It is most likely that the MCT is gently folded or, curviplanar in nature and the Lumla Formation/Dirang Formation is exposed in the core of the antiform due to the erosion of the tectonically overlying Se La Group. Similar set up is also found in the areas around Menchuka and north of Taliha. On the basis of lithological assemblage and tectonic position, Dirang/Lumla Formation appears to be the continuation of the Jaishidanda Formation of the Bhutan Himalaya where isolated outcrops of the latter are also found within the

Thimpu Group as tectonic windows (Dasgupta, 1995).

## C. NEO-PROTEROZOIC

### (i) Thingbu Formation:

A sequence of low grade carbonaceous mica schists and micaceous quartzite containing biotite porphyroblasts transverse to schistosity, mapped by Rana and Duttagupta (1996) in Thingbu, Panga Sera and Thungung areas of Tawang district has been described as a part of the Tethyan sequence. On the basis of textural characteristic, this has been tentatively correlated with the Chekha Formation (Early Cambrian) of the adjacent Bhutan Himalaya. The metasedimentary sequence has a WNW-ESE disposition in the northwestern part and ENE-WSW in the northeastern part. Although the contact between the Thingbu Formation and the underlying rock formation is not directly exposed, it has been interpreted that the low grade rocks of the Thingbu Formation has an unconformable relation with the underlying Se La Group in the Tawang-Mago Chu valley (Rana and Duttagupta, op. cit.). Lithologically, the Thingbu Formation comprises a lower argillaceous unit represented by mica schist and an upper part represented by fine to medium detrital quartz-mica schist and flaggy quartzite. The lower schistose rock contains appreciable amount of amorphous carbon whereas, the upper part has very little or no carbonaceous matter. Garnet has developed towards the basal part of the schist. Garnet crystals occur in two modes - one, sigmoidal type with asymmetric trails and the other deltoid type indicating the presence of a shear couple.

One of the characteristics of the carbonaceous mica schist is the development of cross biotite porphyroblasts on the basis of which the sequence has been compared with the Chekha Formation of Bhutan Himalaya which is known to be a part of the Tethyan sequence. Tourmaline and fine magnetite are found as accessories in the groundmass. Although, no insitu carbonate rocks could be seen, their presence in the upper reaches has been inferred from the boulders of these rocks near Drosar in the Larong Phu section (Rana and Duttagupta, op cit).

### (ii) Biotite Granite (Deed granite / Hawa Pass granite / Tamen gneiss):

The homophanous, porphyritic Deed Granite occurs within the migmatites and gneisses north-west of Hapoli as concordant, large bands measuring 30-100 m in width. Enclaves of metasediments and gneisses showing intricate folding are seen within the Deed Granite. Mineralogically, the granite comprises plagioclase, K-feldspar, biotite, quartz tourmaline with zircon, apatite and opaques as accessories. The Tamen Gneiss of Ziro-Daporijo section has been studied in detail by Bhalla et.al, (1994). This gneiss shows nebulitic to agmatitic texture and pods of leucozones. Enclaves of metasediments of Khetabari Formation show feldspathisation to varying degrees. The medium to coarse grained gneiss consists of zoned plagioclase, perthite, quartz, biotite with zircon, apatite and opaques as accessories. Plagioclase grains are saussuritized and frequently replaced by K-feldspar and quartz.

Some of the geochemical characters of the Himalayan granitoids of Arunachal Pradesh mentioned above are as follows (Bhalla et.al, op. cit.).

i) Tamen Gneiss which shows wide range (67.71% - 78.00%) of $SiO_2$.

ii) Tamen Gneiss which show lower total alkali but higher $Na_2O/K_2O$ ratio (>1).

iii) In the $Na_2O$-$K_2O$ plot, samples from Deed Granite fall in the adamellite field, Taliha and Tamen gneisses in adamellite-granodiorite field.

iv) All the granitoids are characterised by moderate to high Rb content and moderate to low Sr content with Rb/Sr ratio more than 1.

## D. PALAEOZOIC

There is no record of sedimentation during the period from Neoproterozoic to Carboniferous in Arunachal Pradesh. The area received no sediments or other volcanics other than the Pan-African event marked by granitoids (500± ma, i.e. Rilo Granite). The Hercynian orogeny in the Carboniferous period resulted in instability and submergence of the landmass associated with transgression of sea. The short-lived transgression resulted in deposition of a thin sequence of marine deposit (Miri Formation and Bichom Formation) followed by a continental facies (Bhareli Formation) and mafic volcanism (Lichi Volcanism). The rifting in response to the extensional regime resulted in a new cycle of sedimentation in a new sea, the Neotethys.

### (a) LOWER GONDWANA GROUP:

The rocks of the Lower Gondwana Group are exposed in discontinuous patches over a roughly E-W trending belt extending from the Bhutan border in the west to the north of Pasighat in the east. The southern contact of Lower Gondwana Group with the Siwalik Group is faulted. To the north rocks of Bomdila Group is thrusted over Lower Gondwana Group.

### (i) Miri Formation:

Laskar (in Krishnan,1954) described a sequence of cross bedded and ripple marked quartzite, banded in hues of pink, lavender, grey, light green and white, at the confluence of Kamla River and Pepiajuli stream in the Subansiri valley. According to him, Miri Formation includes a unit of quartzite with interbeds of grit and carries a few thin bands of pink slaty shales. He described them as younger to “Buxas” (Bomdila Group) and is quite distinct from Lower Gondwana Group. Stratigraphic status of Miri Formation remained a matter of debate. Jain et.al, (1974) erroneously included a part of Tenga Formation exposed east of Along with the Miri’s and assigned ‘Group’ status to the sequence. Das et.al, (1975) considered the Miri Quartzite as a part of the overlying Bichom Formation (Marine Palaeozoic). Acharyya et.al, (1975) treated it as part of Buxa Formation. Sinha Roy (Tandon et.al, 1979) described presence of palaeo weathered zone at the base of Miri Formation and described laterite clasts from the diamictite of Miri Formation. Grouping of Miri Quartzite with the older Proterozoic rocks discarded by Dhoundial (Nandy et.al, 1975). Kumar and Singh (1974) and Singh and Singh (1983) lowered the status of Miri Group of Jain et.al, (op.cit.) to a Formation and gave a separate identity between the Bomdila Group and the overlying Bichom Formation. In the section exposed at Sododoke on Bame–Daporijo road, Singh and De (1989) and Singh (1993) have shown an unconformable relation of the Miri Formation (Nikte Quartzite) with the underlying Ragidoke Formation. Miri Quartzite lies unconformably over a unit equivalent to Buxa Group represented by dolomite with a basal conglomerate and a laterite horizon at the base.

Best exposures of the Miri Formation are seen in the Bame–Sododoke section. Steeply dipping quartzites of pink and white colours with thin purple shale partings akin to those of the Miri Formation are also exposed in the Bana–Palizi section along Nechiphu–Seppa road. These quartzites show spectacular development of ripple marks and cross bedding of various types. The quartzites in this section are folded around steeply plunging to sub vertical axis. Chakraborty et.al, (2002) described a thrusted contact of Bomdila Group with Miri Formation and a conglomerate unit with interbands of quartzite as the passage of Miri Formation to Bichom Formation (marine Palaeozoic).

The Miri Formation of Sododoke area (Dhoundial et.al, 1989) has been subdivided into four units:

| Member | Lithology |
|---|---|
| D | Purple to pinkish white to greyish white feldspathic quartzite and purple micaceous shale |
| C | Grey to greenish grey diamictite with angular clasts of grey to purple quartzite, slate/phyllite, limestone and granite |
| B | Purple to pinkish and white quartzite/ feldspathic sandstone with purple silty shale |
| A | Oligomictic conglomerate with grit to cobble sized clasts of quartzite |

In Bame-Sododoke section, general trend of the Miri Formation is north-south with steep easterly dips and local overturnings. The unit abuts against Tuting thrust (Tidding suture) to the north.

**(ii) Bichom Formation:**

It is represented by a thick succession of diamictite, dark grey shale/slate and minor quartzite overlying the Miri Formation conformably in the Bame-Igo-Basar section. These rocks were also mapped in the lower reaches of Bichom valley as Bichom Formation (Anon 1974, Das et.al, 1975). However, a sequence comprising pink and purple quartzite akin to the Miri Quartzite is also encountered in the Bana-Palizi sector of Bhareli valley.

Lithostratigraphically, the Bichom Formation has been subdivided into three members-lower, middle and upper by Bhusan (1999). Dhoundiyal et.al, (1989) and Kumar (1997) have also subdivided the Bichom Formation into three member's viz., Rilu, Bomte and Sessa in ascending order. The Rilu Member is dominated by diamictite with subordinate sandstone, shale and grits. The diamictite contains angular to sub-angular clasts of quartzite (30%), dolomite (25%), rock fragments of phyllite, schist, slate (20%), gneiss and granite (20%). The clasts are randomly dispersed in grey argillaceous to calcareous phyllite. The Bomte Member consists of grey to black shale with calcareous and phosphatic cherty nodules. The Sessa Member comprises grey to black tuffaceous (?) shale and impersistant bands of quartzite.

The Rilu Member has yielded radial monosaccate palynomorphs of Lower Permian age (Singh, T, 1979). On the other hand, the Bomte Member is rich in marine fauna and the Sessa Member exposed in the Sessa-Nechiphu and Foot hill-Tenga road sections contain a few ill preserved bryozoa and brachiopods. The faunal assemblage in the marine Gondwana recorded by different authors: (Diener, 1905, Laskar, 1956, Sahni and Srivastava, 1956, Jain and Das, 1973, Acharyya et.al, 1975, Sinha and Mishra, 1984, Laul et.al, 1986)

| | |
|---|---|
| **Bivalve** | *Deltopecten* sp., *Eurydesma aeguale, E. mytiloides, E. Perversum, E. punjabicum, Myalina* sp., *Nucula* sp., *Schizondus* sp., *Aviculopecten* sp., *Goniophora* sp. |
| **Brachiopoda** | *Buxtonia scabriculus, Chonetes* sp., *Cyrtella* sp., *C. Nagmargensis, Dielasma dadanense, D. biplex, Neospirifer fasciger, Oldhamia* sp., *Productus purlulosus, Linoproductus cora, Spirifer* sp., *Spiriferina* sp. *and Subansiri aranganensis* |
| **Bryozoa** | *Fenestella* sp., *Geinitzell* sp. *and Polypora megastroma* |
| **Cephalopod** | *Pseudogartrioceras* sp., *Uraloceras siangense singh.* |
| **Conularids** | *Conularia laskari and panaconularia* sp. |
| **Gastropoda** | *Bellerophon* sp.,*Pleurotomaria* sp., *Straparollus lachiensis, Platyeichum benenssis, P. garuensis and Mourlomia cf. nuda* |

The above faunal assemblage is comparable to the Eurydesma-Deltopecten assemblage of Asselian-Artinskian age (Lower Permian).

The palynofloral studies of the Bichom Formation yielded several palynomorphs and on the basis of their studies Srivastava and Bhattacharya, (1996) have recognised five palynozones in the Bichom Formation as follows:

| | |
|---|---|
| Zone- I | ***Plicatipollenites stigmatus zone*** - characterised by predominance of radial monosaccate pollens (86%) viz. *P. Stigmatus and P. densus*. It is restricted to the Rilu Member. |
| Zone- II | ***Callumispora gretensis* Zone** - characterised by proliferation of *C. gretensis* and appearence of *Microbacalispora tentula and Indotriradites korbaensis* in the basal part of the Bomte Member. |
| Zone- II | ***Crucisaccites indicus* Zone** - characterised by appearance of *Crucisaccites indicus, Brevitriteles levis and Denisosporites solidus* lying in the basal part of the Bomte Member. |
| Zone-IV | ***Pseudoreticulatispora barakarensis* Zone** - It represents in the middle part of the Bomte Member and characterised by the dominance of *P. barakarensis and Paravesicaspora indica;* the latter make their first appearance with *Rhizomaspora.* |
| Zone- V | ***Premuspollenites - Rhizomarpora* Zone** - It is in the Upper part of the Bomte Member and characterised by the acme zone of *P. obscures, R. indica and R. Monosulcata.* |

### (iii) Lichi Volcanics:

In Arunachal Himalaya mafic volcanics have been recorded from various formations viz., the Proterozoic Tenga Formation, Lower Permian Bichom and Bhareli Formations and the Palaeocene- Eocene Yinkiong Group (described later). All these volcanics had been collectively referred as Abor Volcanics (Acharyya et.al, 1983) disregarding their stratigraphic position and age. While the metavolcnics of the Tenga Formation are clearly distinct by virtue of their metamorphosed character and interbedded occurrence with the Along Member, confusion remains regarding the volcanics associated with the Lower Gondwana and those with the Yinkiong Group. To avoid this confusion, the volcanics associated with the Lower Permian Bichom-Bhareli sequence have been separated out from the Abor Volcanics (Coggin Brown, 1912) and referred by Ravi Shanker et.al, (1989) as the Lichi Volcanics named after a village in the Ranga valley (Kimin-Yazali road section). Basic volcanism in similar stratigraphic position has been recorded from the Sikkim Himalaya also. The intertrappeans associated with basic volcanic rocks exposed west of Yinkiong, east and south-east of Dalbuing are known to have yielded Early Permian palynomorphs (Prasad et.al, 1989). These volcanics therefore, may correspond to the “Older Volcanics” of Tripathi and Roychowdhury (1983) and represent a phase earlier than the Abor Volcanics (Tertiary) but coeval with the Lichi Volcanics.

Petrography of the Lichi Volcanics has not yet been studied in details. These volcanics are dark grey to greenish grey in colour and at places amygdaloidal to vesicular in nature and are associated with tuffs and ash beds (Roychowdhury, 1984). The other associations are leucite basalt and trachytes recorded in Ranga valley.

### (iv) Bhareli Formation:

The Bichom Formation is overlain by thick sequence of grey to dark grey feldspathic sandstone and grey shale with lenticular coal beds yielding rich Lower Gondwana floral assemblage. These represent the continental facies of the Lower Permian sequence which have been referred to as the Bhareli Formation, best developed and exposed in the Bhareli valley along Balukpong-Bomdila road between Pinjoli and Sessa. Acharyya et.al, (1975) divided the Lower Permian continental sequence into Khelong Formation and Bhareli Formation and these two along with the Bichom Formation are grouped as Damuda Group. Later works by Laul et.al, (1988) and Bhusan et.al, (1989) have shown that the Khelong Formation and the Bhareli Formation are lithologically and floristically indistinguishable and therefore, retained the name as Bhareli Formation. Bhusan et.al, (1989) have subdivided the Bhareli Formation into a Lower and an Upper Member as shown below:

| | |
|---|---|
| **Bhareli Formation** | **Upper** - Feldspathic sandstone, carbonaceous shale with impersistant lenticular coal |
| | **Lower** - Arkosic silicified sandstone, siltstone, carbonaceous shale with thin impersistant lenticular coal |

The Lower Member has yielded plant fossils of Gangamopteris sp., Glossopteris sp. and Vertebraria sp. and the Upper Member has yielded Schizoneura gondwanensis, Vertebraria indica, Glossopteris longicaulis, Glossopteris indica, Rotundocarpus sp., Cardiacarpus Zeileri, Samaropsis sp., Tryzygia sp., Phyllotheca sp. and Dictyopteridim sp. (Acharyya et.al, 1975; Bhusan et.al, 1989). Besides these, trilete and monolete spores, monosaccate pollen, striate and non-striate disaccate pollens and monocopolate pollens are also reported from the Bichom Formation and Lower Member of the Bhareli Formation (Singh, 1987, 1999; Dutta et.al, 1988; Srivastava and Bhattacharya, 1990). The palynofloral assemblage of the Bichom and Bhareli Formations is suggestive of Lower Permian age comparable to the Lower Karharbari palynoflora of the Peninsular Gondwana (Dutta et.al, 1988).

Sinha and Mishra (1984) reported the presence of Cathaysian elements Lepidostrobus and Lycopods from the Bhareli Formation, but the precise stratigraphic position and description of the specimens are not given and therefore, this record can not be given much importance till it is substantiated by later works.

**(v) Abor Volcanics:**

The Abor volcanic rocks (Abor Volcanic Series, of Coggin Brown, 1912) was first recorded from the Siang valley and were compared with the Rajmahal Trap of the Indian shield of Early Cretaceous in age. The stratigraphic position of the Abor Volcanic rocks and their correlation with other volcanic rocks of the Himalaya has been a subject of debate. These volcanics have been confused earlier with the metavolcanics associated with the Proterozoic Bomdila Group by some workers (Jain and Thakur, 1978). Similar volcanic rocks occuring to the west of the type area of the Abor volcanics in Arunachal Pradesh were considered to be of Permian age by other workers on the basis of their association with fossiliferous Gondwana rocks and correlated with the Panjal volcanics of the northwest Himalaya (Gansser 1964, Bhat 1984). Tripathi and Roychowdhury (1983) suggested the presence of one 'older volcanics' of Permian age and the other 'younger volcanics' of Tertiary age. K/Ar dating of some samples (locality not known) of Abor volcanic rocks has suggested an age of 93 + 3 to 98 ± Ma (Anon, 1986). However, Acharyya and Sengupta (1998), on the basis of foraminiferal assemblage from the sediments immediately underlying the Abor volcanic rocks as well as interlayered with them has inferred a Late Palaeocene to Early Eocene age of the Abor Volcanics.

The Abor volcanic rocks as defined here correspond to the younger volcanics of Tripathi and Roychowdhury (1983) and are intimately associated with the Geku Formation in Siang valley. The Abor volcanic rocks are conformably overlain by the Dalbuing Formation. According to Talukdar and Majumdar (1983), the Abor volcanic sequence in Siang district comprises basaltic to andesitic flows, silicic tuffs, lapillis, agglomerates and aquagene tuffs and sediments. Basalts and andesite occur as highly amygdaloidal flows with greenish base and reddish tops at places. The base and top of individual flows are richer in amygdules than the central part. Amygdules are of stretched, piped and composite types and are generally filled with quartz, carbonate, zeolite and chlorite. Both porphyritic and aphyric types of basalt are found. The groundmass of both the basalt types shows similar mineralogy and consists of plagioclase microlites, clinopyroxene, altered glass, chlorite with epidote, sphene and opaque as accessories and exhibit intersertal to intergranular texture.

The silicic or acidic volcanic rocks constitute a minor part of the Abor volcanic suite and occur as intercalations within the basic flows. Talukdar and Majumdar (op cit.) have identified five localities where acid volcanic rocks are found. The aquagene tuffs and volcanogenic sediments as described by Talukdar and Majumdar (op. cit.) consist of fragments of basalts, fine grained quartzite/ siltstone, angular to rounded quartz and rare plagioclase set in an altered volcanic matrix.

On the basis of geochemical analysis Bhat (1984) has suggested that the basalt is transitional between alkali basalt and tholeiite. Enriched with incompatible elements and high Ti/Y (353-927) and Zn/Y (4.20-6.33) ratios indicate a 'within-plate tectonic setting' of lava eruptions. Sengupta et.al, (1996) carried out detail geochemical studies of ten samples of Abor volcanic rocks. From the analysis of major element oxide composition, trace element data and REE signatures it has been inferred (Sengupta et.al, op cit.) that the Abor volcanic rocks are comparable to both ocean island basalt and continental flood basalt. However, geological evidences in favour of oceanic crustal nature of the Abor basalts are lacking. In contrast, their association with shallow marine shelf sediments and their contemporaneity with the collision between the Tibetan and the Indian Plate indicate that the Abor volcanic suite may represent foreland basin volcanism in a shallow marginal basin of the Himalayan fold-thrust belt south of the collision zone. On the basis of enrichment in incompatible elements and their closely matching ratios it has been inferred that the Abor basalts generated from an enriched source possibly located in the sub-continental lithospheric mantle.

**(vi) Yamne Formation:**

Upper Permian marine fossils have been reported from the southern slope of Dalbuing village in the Yamne nala. This unit designated, as Yamne Formation (Kumar, 1997), is about 5m thick and sandwiched between the underlying Dalbuing Formation containing Early Eocene plant fossils and the overlying Geku Formation hosting Lower Eocene Nummulites. The pale brown ferruginous shale is reported to yield the following marine invertebrate fauna (Sinha et.al, 1986).

| | |
|---|---|
| **Bivalves** | *Aviculopecten* sp., *Burmesia* sp., *Claria* sp., *Eosohizodus* sp., *Etheripecten* sp., *Goniophor*a sp., *Myconcha* sp., *Mysidiopter*a sp., *Nuculana* sp. *Schizodus* sp., *Pterinopecten* sp., *Phestia* sp and S*tuchbaria* sp. |
| **Brachiopoda** | *Neochonetes* sp., *Neospirifer* sp., *Productus* sp. and *Spirifer* sp. |
| **Gastropod** | *Loxonenca* sp., *Meekospira* sp., *Mocrlonia* sp. and *Neilsonia* sp. |

It may be mentioned that subsequent search in the Dalbuing area failed to locate any in situ outcrop of the Permian fossil-bearing-horizon (Singh, 1999). However, Upper Permian marine fossiliferrous shale has been recorded at a place about 50 meters down slope from the Dalbuing village. Singh et.al, (1999) has presumed that the outcrop might be 'concealed under thick soil cover'. It is also probable that this occurs as either a tectonic, or a sedimentary mélange within the Palaeogene sequence.

## E. PALAEOGENE

### (a) YINKIONG GROUP:

A sequence of argillo-arenaceous sedimentary rocks associated with basic volcanics mapped around Yinkiong in the Siang valley was designated as 'Yinkiong Formation' and also was arbitrarily assigned as Precambrian age by Jain et.al, (1974). This sequence is also exposed further south of Yinkiong along the Yamne valley. With the discovery of Lower Tertiary floral remains from the Geku area (Tripathi et.al, 1981a) and Early Eocene foraminifera from Dalbuing (Tripathi et.al, 1981b, Singh & Singh 1983, Tripathi & Mamgain 1986) two distinct facies were recognised - the lower continental facies and the upper marine facies in the "Yingkong Formation" and the stratigraphic rank of this unit was raised to a group (Kumar 1997). The lower unit has been designated as the Geku Formation and the upper one as the Dalbuing Formation. The quartzite-limestone-phyllite sequence exposed east and northeast of Padu in the southern part of Yamne valley was treated as a part of the 'Pongging Quartzite' by Singh et.al, (1999). However, Sengupta et.al, (1996) clubbed the Abor Volcanics, the underlying quartzite and the overlying argillo-areneceous sequence as a thrust bound packet, exposed in an area approximately 2500 sq km in the "Siang Window'. Talukdar and Majumdar (1983), Singh et.al, (1999) and Sengupta op.cit, were registered that this quartzite-carbonate sequence is intimately associated with the Abor volcanics and similar lithologies are also found as intertrappeans in the basal part of the Abor Volcanics. The interbands of calcareous quartzite locally contain rich assemblage of larger foraminifera of Late Palaeocene to Early Eocene age (Acharyya and Sengupta, 1998). Sengupta et.al, (1996) also suggested a gradational contact and contemporaneity of age of the Abor volcanics and the underlying quartzite, the latter containing feeders of Abor Volcanics (Acharyya and Sengupta op. cit.).

The quartzite-sandstone-siltstone-shale sequence exposed in the core of the Siang half window should be included in the Geku Formation with an assigned Late Palaeocene-Late Eocene age. The stratigraphic succession of the Palaeogene sequence of the Siang valley on the basis of age constrained by fossils is as follows:

Dalbuing Formation named by Singh (1984) after the village Dalbuing has a restricted occurrence in the Yamne valley. It occurs as several isolated outcrops in the areas east of Yinkiong, southeast of Dumro and east of Dalbuing.

From the foraminiferal assemblage Singh and Singh (1983) and Tripathi and Mamgain (1986) assigned a Lower Eocene age to the Dalbuing Formation. The assemblage is comparable with that of the Subathu Formation of the northwest Himalaya. Prasad and Dey (1986) reported pterydophytic spores, gymnosperm and angiosperm pollens and phytoplanktons from the Dalbuing Formation. The assemblage is dominated by triporate and tricolporate palynomorphs suggesting an Early Eocene age. Some reworked Lower Gondwana palynomorphs are also recorded in the Dalbuing Formation (Kumar, 1997).

## F. NEOGENE

### (a) TOURMALINE-BEARING LEUCOGRANITE:

The youngest phase of acid intrusive affecting the

**Table 1.1.2: Stratigraphic succession of the Palaeogene rocks of Siang valley**

| GROUP | Formation | Lithology | Fossils | Age |
|---|---|---|---|---|
| Yinkiong Group | Dalbuing | Limestone with shale intercalations | *Nummulites atacious,*<br>*N. maculatus,*<br>*N. pengaroensis,*<br>*Assilina spire,*<br>*A. daviesis.*<br>*A. subassamica,*<br>*Orbitolites cf. complanata* | Early to Mid Eocene |
| | Abor volcanic rocks | Porphyritic and aphyric basalts, andesite, acidic tuffs, agglomerates, aquagene tuffs, volcaniclastic sediments | | |
| | Geku | Purple and pale green shales, sand-stones, black shale, nodular grey shale, quartzite (occasionally calcareous) as limestone, Mafic dykes (feeders? of Abor volcanics) | Dicot plants<br>palynomorphs<br>*Assilina depressa*<br>*A. regularia,*<br>*Orbitosiphon cf, tibetica*<br>*Nummulites thalicus* | Late Palaeocene to Early Eocene |

rocks of the Bomdila Group is represented by unfoliated tourmaline-bearing pegmatite, fine grained aplite and quartz veins. These occur as dykes and veins in the Ziro Gneiss and Khetabari Formation of the Bomdila Group.

The high grade metamorphic rock assemblage of Se La Group is intruded by unfoliated two-mica, medium to coarse grained tourmaline-bearing leucogranite which occurs as large bodies as well as network of dykes. Mineralogically, the rock is composed of microcline perthite, albite, oligoclase and quartz with interstitial muscovite showing inclusions of biotite, tourmaline, zircon and opaques as accessories. On the basis of Rb-Sr isotopic data the Se La leucogranite has been dated as 29+7 Ma (Bhalla et.al, 1990, 1991 & 1994).

**(b) SIWALIK GROUP :**

The Upper Tertiary (Mio-Pliocene) molassic sediments constituting the Siwalik Group occurs as a linear belt along the foothills of Arunachal Pradesh extending from Bhutan to just east of Pasighat where it is overlapped by the alluvium. However, it re-appears on the left bank of Dibang River where it is tectonically overlain by the rocks of the Bomdila Group along the Roing Fault, which according to Ranga Rao (1983) is the continuation of the Mishmi Thrust. The Siwalik Group is bounded to the north by the Main Boundary Fault along which the Pre-Tertiary sequence has been brought over. Its southern limit with the alluvium of the Brahmaputra River is also at places marked by a tectonic plane-the Foot Hill Fault. Karunakaran and Ranga Rao (1979) classified the Tertiary sequence of Arunachal Pradesh foothills into Dafla, Subansiri and Kimin Formations broadly corresponding to the Lower, Middle and Upper sub-divisions of the Siwalik Group of northwestern Himalaya and also considered these to be the northward extension of the Tertiary sequence of Assam. However, Tripathi et.al, (1981a) opined that the sediments of Siwalik Group occur as nearly continuous stretch from Pakistan in the west to Arunachal Pradesh in the east. The Lower, Middle and the Upper Siwalik are separated from each other by reverse faults and the three units are stacked in a reverse stratigraphic order (Joshi and Chakraborty, 2000). A generalised description of the Lower, Middle and Upper Siwaliks is given below:

**(i) Dafla Formation (Lower Siwalik):**

It consists of indurated, medium to fine grained, well sorted, bluish grey sandstone, subordinate feldspathic micaceous sandstone and bluish grey, greenish grey and nodular silty shale. The clastic grains are subangular to sub-rounded. Stringers and small lenses of coal aligned parallel to bedding are noticed frequently. Commonly observed bedforms in the Lower Siwalik are laminated to massive, large trough cross beds, festoon cross beds, planar curved cross beds, tabular cross beds and ripple cross laminations (Joshi and Chakraborty, op. cit.). The palaeocurrent direction deduced from the measurement of cross-beds indicates a unimodal westerly flow (Joshi and Chakraborty, op.cit).

Sandstone and shale of the Lower Siwalik are rich in plant fossils and have yielded dicotyledon leaf impressions, stems and seeds.

The lithological attributes and the nature of various bedforms indicate deposition of the Lower Siwalik sediments in a wandering and meandering fluvial system with possible accretion of point bars over flood plains. Presence of Ampelopteris sp. indicates occurrence of freshwater swamps on river banks (Joshi & Chakraborty, op. cit).

On the basis of arenaceous foraminifera Trochommina sp. (Ranga Rao, 1983) the age of the Lower Siwalik has been deduced as Lower Miocene. The plant fossils and palynomorphs are not age diagnostic as they consist of long ranging forms. No vertebrate fossils, other than a solitary molar of Bos. sp. (Singh, 1975), are recorded in the Lower Siwalik.

**(ii) Subansiri Formation (Middle Siwalik):**

The Middle Siwalik rocks are generally poorly indurated, medium to coarse grained, salt and- pepper textured multistoried sandstone with calcareous concretions of various shapes and sizes and grey shale intercalations. Conglomerate bands are noted in the Foothills-Chaku section and Siku river section. Stringers, flakes and clasts of coal are found occasionally. In Bhalukpong-Sessa section some of the phytoclasts are seen aligned along the cross-stratification. Silicified wood fragments have been recorded in the Pasighat section.

Commonly observed bedforms in the Middle Siwalik are tabular cross beds, amalgamated planar and curved cross beds, plane laminated beds, curved crested and ripple-cross lamination. Soft sediment deformational structures such as convolute lamination, flame structure and clastic dykes are very common. Study of palaeocurrent direction in the Middle Siwaliks of East and West Kameng districts indicated a polymodal current distribution (Joshi and Chakrabarty, 2000). Lithological attributes and nature of bedforms in the Middle Siwalik point to valley fill deposit frequented by ephemeral streams.

The Middle Siwalik rocks have yielded abundant plant fossils (Joshi and Chakrabory op.cit) and (Dutta and Singh, 1980). Some of the palynomorphs are interpreted to be reworked Permian elements.

**(iii) Kimin Formation (Upper Siwalik):**

Best developed sections of the Upper Siwalik are found east of Bhareli River, between Banderdewa and Itanagar and around Kimin and Likabali. The lithology is mainly represented by loosely packed very coarse to fine grained, friable, grey sandstone which is highly limonitised at places. The sandstone is pebbly at places and is intercalated with claystone and shale which are frequently nodular. Occasional boulder beds with sandy matrix are exposed east of River Bhareli. The boulders are of quartzite, gneiss, granite, schist and basic rock. Petrified and carbonised wood fragments upto 2 m in length and charcoal clasts are often found. Bedforms observed in the Upper Siwalik are -

a) plane laminated, often topped by curved, crested ripples,
b) curved cross-bed, often showing brink point and transition to plane laminations,
c) tabular cross bed and
d) rarely very small festoon cross beds.

Liquefaction and soft sediment deformation is displayed by slump folds and convolute laminations. Synaeresis cracks with limonitic stains are found in nodular shales. Palaeocurrent data of the Upper Siwalik indicate a unimodal southerly flow (Joshi and Chakraborty, 2000). Middle Siwalik sediments were deposited in a piedmont fan or outwash fan.

Several isolated thin outcrops of calcareous sandstone have been reported from the area from the south of MBF to the north of MBF at Sissni, Sessa, Rengging near Pasighat (Tripathi et.al, 1981b, and Sinha et.al, 1986). These beds were named as 'Kimi beds' after a village in the Bhareli valley. Although Tripathi et.al, (1981 b) ascribed Triassic age to these beds Sinha and Misra (in Anon 1986) reported Middle to Upper Eocene coccoliths from Sessa and Lower to Middle Eocene nummulites from Garu locality. In this connection it is important to note that Jaiprakash and Patel (1991) also reported the presence of nummulites in a calcareous conglomerate in Subansiri Formation (Middle Siwalik) from the East Siang district and interpreted them as bioboulders of older formation embedded in the Siwaliks. Ranga Rao (op cit.) also contended that the fossils are reworked from the Dalbuing Formation of Eocene age. An alternative explanation is that these Eocene outcrops within the Siwalik may represent 'horses' which travelled by thrust propagation mechanism.

Similar outcrops of Eocene rocks are also found in the Ranga valley within the marine Gondwana rock. Towards the west the Dewalthang beds of Bhutan also occupy similar tectono-stratigraphic position. A tectono-stratigraphic succession involving these Palaeogene and the Neogene sequence is given in table 1.1.3:

**Table 1.1.3. Tectonostratigraphic succession of the Palaeogene-Neogene sequence of Arunachal Himalaya.**

| | |
|---|---|
| | Gondwana Group |
| Permian | ---------- Thrust ---------- |
| Palaeogene | Ringging Formation/ Kimi Beds |
| ---------- | ---------- Main boundary faults ---------- |
| | Lower Siwalik (Dafla Formation) |
| Neogene | ---------- Thrust ---------- |
| | Middle Siwalik (Subansiri Formation) |
| | ---------- Thrust ---------- |
| | Upper Siwalik (Kimin Formation) |
| ---------- | ---------- Main Frontal Fault ---------- |
| Quaternary | Assam Alluvium |

## G. QUATERNARY

## QUATERNARY SEDIMENTS:

The post-Siwalik Quaternary sediments of Arunachal Pradesh are represented by fluvial deposits. The fluvial deposits occur as two to three cycles of valley fill deposits exposed at different levels on either side of almost all the river valleys. These are broadly classified into an Older Alluvium co-eval with the Older Alluvium of the Brahmaputra Plain (Middle to Upper Pleistocene) and a Newer Alluvium of Holocene to Recent age.

### (i) Older Alluvium:

This is represented by one to two levels of terrace deposits. In the upper reaches of the major rivers, only one level of terrace is usually developed. Two levels of terraces are seen along the Rivers Dikrang, Tenga, Pappu, Passar and Siang. The sediments are unconsolidated and represented by boulders, cobble, pebble, sand and sandy clay beds. Oxidation of the sand and sandy clay is noted at many places.

### (ii) Hapoli Formation (Newer Alluvium):

This is also represented by two levels of terrace deposits comprising unoxidised sediments of the active channels found in all the rivers.

The limnic deposits in Arunachal Pradesh are encountered over a large area around Hapoli in the Ziro valley. The sequence designated as Hapoli Formation comprises sand, clay and peat. One peat sample has yielded a C?? date of 40,000 yrs BP (Kar, et.al, 1997). Peat sample from similar deposit of Tal le valley has given an age of 25,410 ± 750 yrs BP (Kar, et.al, op.cit.). The Hapoli Formation is considered equivalent to the Karewa Group of Kashmir valley.

★★★

# *1.2: Geology of the Trans Himalayan Belt*

In the Upper Siang, Upper Dibang and Lohit valley areas the NNW-SSE trending rocks of the Trans-Himalayan belt are juxtaposed against the rocks of the Himalayan belt along the Tidding Suture. The Trans-Himalayan belt comprises two distinct lithopackages viz, i) the suture package comprising Yang Sang Chu Formation and Tidding Formation with serpentinites and metavolcanics and ii) the Lohit Granitoid Complex and the Etalin Formation, the latter occuring as restites. The total assemblage of the suture package resembles an ophiolitic mélange. The tectono-stratigraphic succession of the Trans-Himalayan belt is as follows:

**Table 1.2.1: Tectonostratigraphic succession of the Trans-Himalayan belt**

| **Rock Unit** | **Lithology** |
|---|---|
| Lohit Granitoid Complex (LGC) | Diorite, granodiorite, tonalite, 2-mica leucogranite, metanorite, anorthosite |
| Etalin Formation | Garnet-kyanite gneiss, amphibolite, schist, quartzite, marble |
| ------------------------------------------------------------------- Lohit Trust (?) ------------------------------------------------------------------- | |
| Tidding Formation | Tuting meta-volcanics, serpentinites, intrusive granodiorite, crystalline limestone, graphitic phyllite / schist |
| ------------------------------------------------------------------- Gradational / sheared ------------------------------------------------------------------- | |
| Yang Sang Chu Formation ( YSC Formation ) | Chlorite-phyllite lenses of serpentinite garnet ± sillimanite ± staurolite + graphite schist, quartz-muscovite schist, garnetiferous amphibolite |
| ------------------------------------------------------------------- Tiding Suture ------------------------------------------------------------------- | |
| Bomdila Group | |

### (i) YANG SANG CHU FORMATION:

This unit comprising mostly by graphitic metapelite is best developed in the Yang Sang Chu valley (Singh and Malhotra, 1983b). In Dibang valley area it has also been described as Annelih Formation or Myodia Formation. The YSC Formation consists of garnetiferous graphitic phyllite, schist and schistose amphibolite. Development of staurolite and sillimanite are noted in the lower part of the sequence and one of the characteristics of the YSC Formation is that it displays upward decrease in grade of metamorphism (Kumar, et.al, 2000). Minor occurrences of garnetiferous amphibolite showing weakly developed gneissosity are found in the Siang river section (Kumar, et.al, op .cit.) and south of Salamgam in Lohit valley section.

Mineral assemblages of major lithotypes of the YSC Formation are as follows:

| | |
|---|---|
| Graphitic schist | Quartz ± Mica ± garnet ± graphite ± sillimanite (fibrolite) ± staurolite |
| Amphibolite | Hornblende ± andesine ± sphene ± actinolite ± epidote ± quartz |
| Amphibolite gneiss | Quartz ± feldspar ± garnet ± cummingtonite ± grunerite |
| Chlorite schist | Quartz ± chlorite ± epidote ± leucoxene |

Although the Taliha Formation of the Se La Group and the Khetabari and Chilliepam Formations of the Bomdila Group contain graphitic / carbonaceous horizons, they are not correlated with the YSC Formation mainly because of the following reasons i) graphitic / carbonaceous rock is a major constituent in the YSC Formation, ii) overall lower grade of metamorphism of the

YSC Formation than the Taliha Formation, iii) decrease in grade of metamorphism towards top of the sequence in YSC Formation in contrast to the Se La and the Bomdila Groups where the grade metamorphism increases upward and iv) association of ultramafics in the YSC Formation.

### (ii) TIDDING FORMATION:

It conformably overlies the YSC Formation and incorporates the Hunli Formation of the Dibang valley and Tuting meta-volcanics of the Upper Siang valley (Singh, 1983). However, in the Upper Siang valley its contact with the underlying YSC Formation is locally sheared (Kumar, et. al, 2000). It is limited to the north by the Lohit Granitoid Complex (LGC). The contact between the Tidding Formation and the LGC has been interpreted as a thrust (Lohit Thrust) by Nandy and Basak (1966-67), whereas Chattopadhyay and Chakraborty (1980) interpreted the contact as intrusive. According to Kumar, et. al, 2000 the contact is tectonic in the Siang and Dibang valleys but in the Lohit valley the tectonic nature of the contact is not clearly discernible and minor intrusive bodies of diorite, akin to that of LGC, are frequently found.

The Tidding Formation comprises meta-volcanics (Tuting meta-volcanics) showing varying degree of alteration to chlorite-phyllite or chlorite-actinolite-phyllite associated with thin crystalline limestone and carbonaceous phyllite. Dykes and sills of ultramafics and amphibolites are noted occasionally. Minor intrusions of granodiorite are also recorded, particularly in the vicinity of the LGC. Lenticular bands of magnesite associated with the ultramafics have been noticed in area west of Hunli (Ray and Dutta, 1982, Kumar, et.al, 2000). The ultramafics show alteration to serpentinite which are well exposed at Tidding and also mapped near Myodia Pass, Mayi hills (Babu and Das, 1990), north of Tuting and Rayalli (Kumar, 2000). The ultramafics of Myodia area occur as remnant of a thrust sheet (nappe) overlapping the gneisses of the Bomdila Group (Kumar, et.al, 2000).

Petrographically, the ultramafics are essentially made up of olivine, chlorite, tremolite, actinolite and asbestos. The serpentinite is composed of antigorite, lizardite and epidote. The Tuting meta volcanics are frequently interbanded with grey crystalline limestone, graphitic schist, minor chert, rhythmite and conglomerate. Lenses of serpentinised ultramafics and talc schist occur as tectonic slivers. The conglomerate lenses are noticed near the confluence of Yang Sang Chu and the Siang Rivers. The polymictic conglomerate contains pebbles of basalt (glassy and vesicular), granite, gabbro and ultramafic rocks set in a chloritic matrix.

Synthesis of major oxides of the metabasics of the Yang Sang Chu Formation and the Tuting meta-volcanics indicates composition range from basalt to andesite of calc-alkaline affinity. However, plot in the MnO-TiO2-P2O5 diagram of Mullen indicates that these are mostly island arc related tholeiite basalts (Kumar, et. al., 2000). The variations of Al2O3, Na2O and K2O, CaO, MgO and Fe2O3 against SiO2 of Tuting-Hunli metabasics point to magmatic evolution through the process of fractional crystallisation (Kumar, et.al, op cit.)

### (iii) LOHIT GRANITOID COMPLEX (LGC):

The LGC forms the most conspicuous unit in the eastern Arunachal Pradesh extending from Namcha Baruwa in the northwest to Dapha Bum in southeast abutting against the Naga-Patkoi ranges along Mishmi Thrust. It consists of multivariant plutonic rocks of multiphase character with several restites of high grade metasediments. These high grade restites are designated as Etalin Formation in the Dibang valley area (Nair and Shanker, 1981; Kumar, 1997). The granitoids include diorite, granodiorite, tonalite, hornblende-biotite granite and leucogranite. Descriptions of the granitoids and the Etalin Formation are given below:-

**Granitoids:**

Diorite is the most dominant lithotype in the Lohit valley. The width of the body decreases towards north and in Tuting area, these occur as patches within the biotite granite. In general, the rock is mesocratic and foliated with variable proportion of felsic and mafic constituents. Mineralogically the diorites comprise andesine, hornblende, epidote and quartz. Several outcrops of metanorite within the diorite are encountered between Kongra and Changreilang in Lohit valley (Kumar et.al, 2000). The metanorite mainly comprises calcic plagioclase (labradorite) and pyroxene. Orthopyroxene dominates over the clinopyroxene and the pyroxene and the plagioclase grains at places show cumulate texture.

The granodiorite of the LGC is mostly gneissic and the gneissosity is defined by alternate bands of the quartzo-feldspathic and ferromagnesian minerals. The mineral assemblage is represented by plagioclase, K-feldspar, quartz, biotite, muscovite, hornblende, pyroxene, chlorite and epidote.

In Lohit area, in addition to several minor occurrences, a major body of biotite granite is exposed between Menjang and Kharoti. The light grey, coarse and equigranular rock comprises anhedral grains of quartz, alkali feldspar and biotite in order of their abundances. Muscovite and zircon are accessories. Field relation shows that the biotite granite is younger phase intrusive into the diorite and granodiorite gneiss. In Tuting area the leucocratic biotite granite dominates over other granitoid. Under microscope, some of the biotite grains contain hornblende and pyroxene in the core.

The youngest plutonic phase of the LGC is represented by coarse to very coarse leucocratic granite exposed at places pegmatic around Walong and further north in the Lohit valley, the rock is often pegmatitic. Mineralogically it comprises quartz, K-feldspar, plagioclase, muscovite and biotite. Minor occurrences of tourmaline-epidote granite and tourmaline pegmatite are noticed near Nayul and Kamlang bridge, respectively (Kumar et.al, 2000).

**Etalin Formation:**

A sequence of high grade metasediments, associated with the LGC exposed around Etalin in Dibang valley has been designated as Etalin Formation. The metasediments are represented by interbanded sequence of migmatitic gneiss, calc silicate gneiss, marble, quartzite, kyanite gneiss, mica-schist and amphibolite. The sequence shows general increase in metamorphic grade as well as proportion of amphibolite towards the north. In Lohit valley the Etalin Formation is exposed in several localities and mostly occupies the zone from south (diorite) to north (leucogranite). In the Upper Siang valley scattered enclaves of marble, quartzite and amphibolite are present in the biotite granite of the LGC (Kumar, et.al, op. cit.).

Amphibolite is one of the major constituents of the Etalin Formation. Strongly schistose to gneissose bands are exposed near Hayuliang and between Pranji and Hala in Lohit valley. The amphibolites often contain garnet porphyroblasts of lilac colour. The mineralogical composition is as follows:

Calcic plagioclase + hypersthene + hornblende + garnet ± epidote ± quartz ± biotite.

The LGC comprising the plutonic assemblage of granite-granodiorite-diorite-gabbro/norite exhibits similarity with the Kohistan-Ladakh arc batholith of Cretaceous age (Searle, et.al, 1999). The bulk geochemical character, calc-alkaline affinity and low $^{87}Sr/^{86}Sr$ ratio indicate their origin from the mantle derivative magma in a destructive plate boundary (Srimal, et.al, 2000). The LGC belt is considered to be the continuation of the Gangdise-Nyainqentanglha batholith of the Lhasa terrain in the north and extends into the eastern part of the Naga Hills to the south (Sheng-Zhou and Wie-Jin, 1983). Selected samples of granodiorite from north of Anini, south of Anini and Angolin plutons were analysed by Srimal, et.al, (2000) for Rb-Sr isotopic studies. A regression line to define an age using Ludwig (1988) programme following the method of York algorithen-II (York,1969) did not define any well constrained age. However, a reference errorchron constituting six data points approximates an age around-140 Ma. This age corresponds to the closure of the Mishmi back are basin and can be related to the Bango Co-Dongquiao Nu river back arc basin ( Sheng-Zhou and Wie-Jin, op. cit.). The metasediment restites of the Etalin Formation which show intrusion of various phases of granitoids may be regarded as Palaeozoic-Mesozoic on the basis of analogy applied to similar rock sequences of the Gangdise-Nyainquentanglha batholithic region.

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# 1.3 Geol0gy of South Eastern Arunachal Pradesh

The Tertiary and Quaternary sediments of the Naga-Patkoi belt extend north-eastward in Changlang and Tirap districts of south-eastern Arunachal Pradesh. The rock sequences as exposed in south-eastern Arunachal Pradesh are summarised in the following table:

**Table 1.3 .1: Rock sequence in south-eastern Arunachal Pradesh**

| Age | Group | Formation | Description | |
|---|---|---|---|---|
| Pleistocene to Recent | | | alluvium and high level terraces | |
| Pliocene | | Dihing | boulder beds and sand | |
| | | Namsang | coarse pebbly sandstone | |
| Mio-Pliocene | Naharkatia | Girujan | variegated clays, minor sand | |
| Miocene | | Tipam/Gandhigram | greenish grey micaceous sandstone, minor lenses of coal | |
| ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ Unconformity ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ | | | | |
| | | | **North of Disang Thrust (Platform facies)** | **South of Disang Thrust (Geosynclinal facies)** |
| Oligocene | Barail | Tikak Parbat | sandstone and coal | Greyish green sandstone with intercalation of greenish shale |
| | | Bargolai | sandstone, clay and minor coal seams | |
| | | Nagaon | hard well bedded sandstone | |
| Eocene | Disang | | Dark grey shales with interbands of hard, fine grained flaggy, sandstone | |
| ---------- Tilung Thrust ---------- | | | | |
| Proterozoic | | Tilung | quartz-chlorite/ mica schist with intercalation of quartzite | |
| ---------- Namdhapa Thrust ---------- | | | | |
| Proterozoic | | Namdhapa Crystalline Complex | biotite granitoid gneiss | |

### (i) NAMDHAPA CRYSTALLINE COMPLEX:

This crystalline complex occupies the highest tectonic level. The main lithological variant of this package is a well foliated, mesocratic, biotite granitoid gneiss which is divisible into three textural types viz. augen gneiss, homophanous gneiss and streaky gneiss. Among these, augen gneiss forms the dominant constituent, banded gneiss is rare. In some localities, particularly in Laboi Hka, profuse developments of migmatites are found. The dominant migmatitic structures in these zones can be termed as phlebitic (vein type injection gneiss), stromatic (banded gneiss), schlierric and nebulitic (in the diatextits of the migmatitic zones). Amphibolite and mica schist are present as enclaves. This litho-package is frequently traversed by late phase leucocratic and pegmatitic granite veins. This late phase activity is particularly prevalent along the sole of this litho-package.

Megascopically the granitoid gneiss exhibits well developed mylonitic foliation throughout the area which is also corroborated by the petrographic studies. The original hypidiomorphic granular texture is not preserved. A reduction of overall grain size as well as relative proportion of porphyroclasts is perceptible from augen gneiss to streaky gneiss. Based on the relative proportion of porphyroclasts, the augen gneiss and the streaky gneiss can be termed as augen mylonite and mylonite. Effects of post crystalline deformation are noticeable prominently in the granitoid gneiss. The augens are commonly made up of feldspar. Quartz porphyroclasts are comparatively rare. The mylonitic foliation which generally warps around feldspar / quartz porphyroclasts is commonly defined by elongation of quartzo-feldspathic grains.

The grain size refinement related to recrystallisation is pronounced within the quartz grains in the granite mylonite. The quartz porphyroclasts display features of intra-crystalline deformation such as undulose extinction, deformation bands and formation of subgrains. Feldspar porphyroclasts are found to be elongated parallel to as well as at an angle with the mylonitic foliation. The variable angles between the mylonitic foliation and the inclusion trails, observed within feldspar porphyroclasts, indicate differential rotation of different grains within the otherwise ductile matrix during the shear regime.

Geochemical study of the granitoid gneiss of the Namdhapa Crystalline Complex has been carried out for chemical characterization of the body. Attempt has also been made to interpret the data in terms of probable petrotectonic and petrogenetic processes involved during the evolutionary path of the granitoid gneiss.

### (ii) TILUNG FORMATION:

Rocks of this formation are disposed in a narrow belt along the central part of the area. To the north it is overlain by the Namdhapa Crystalline Complex whereas to the south it is underlain by rocks of the Gandhi gram Formation (Tertiary age).

This formation is constituted of quartz-chlorite / mica schist with intercalation of quartzite. The proportion of quartzite dominates over schist in upper reaches of the Noa-Dihing valley, particularly along Longhuizilu Hka and Angachidulu Hka. Occasionally this package is traversed by concordant metabasic bodies represented by amphibolite. At places, thin veins of quartz and qaurtz-carbonate are observed. These veins are particularly predominant towards the upper and lower parts. In some sections, lenticular pockets of calc silicate rock also constitute a part of this formation. One such band is well exposed near the confluence between the Noa-Dihing River and the Angachidulu Hka.

The quartz-chlorite / mica schist is medium to fine grained and greenish grey in colour. The dominant mineral constituents are quartz, chlorite, muscovite and biotite. The relative proportion of the phyllosilicate minerals varies from sample to sample. Common accessories include epidote, sphene and opaque. Occasionally, in a hand specimen this schist appears to be gritty. However, from the petrographic study it is found that the rocks are phyllonitic. The larger, still preserved porphyroclasts of quartz, in a pulverized fine grained matrix, giving rise gritty appearance to the rock at places. The quartz-chlorite / mica schist frequently grades to quartzite which is fine grained, greyish-white to greenish-white in colour. The greenish colour is due to presence of chlorite. In some sections (e.g. upper reaches of Noa-Dihing and Laboi Hka) quartzite is found to be thinly bedded. In other sections it is thickly bedded and the bedding is poorly preserved. Generally the quartzite is micaceous. The dominant mineral constituents are quartz-muscovite and rarely chlorite. Accessories include opaque and a few grains of tourmaline. In calc silicate rocks the bulk mineralogy is constituted of quartz, chlorite, carbonate and rarely muscovite. Sphene, epidote and opaque constitute the accessory minerals. Chlorite is mostly present as fine grained pasty material forming bands which alternate with quartzose or carbonate rich bands. Sphene and epidote are frequent and are invariably restricted to chlorite rich zones.

Megascopically as well as under microscope, rocks of this formation are found to be intensely deformed with a prominent development of mylonite foliation. Occasionally, these rocks attain phyllonitic texture. Commonly rocks of this unit are found to be affected by several sets of joints, particularly near its contact with the underlying Gandhigram Formation. In the Laboi Hka section well developed shear bands are observed within this litho-package. Petrographic study reveals presence of S-C fabric within the rocks of this formation. In a hand specimen, down dip mineral lineation is conspicuously developed.

### (iii) DISANG GROUP:

The oldest horizon of Tertiary sequence in Tirap and Changlang districts is represented by the rocks of Disang Group which comprises thick succession of unfossiliferous dark grey compact shales with frequent intercalations of hard massive grey and reddish sandstone. These rocks are abutted in north by Disang Thrust. The shale to arenaceous facies of Disang Group has typical miogeosynclinal depositional facies. South of Bogapani, Disang beds are extensively developed into the southern part of Tirap district. The rocks are repetitively folded and also faulted resulting in an enormous thickness of these sediments. On the basis of presence of Venericardia sp. in the lower part of the Upper Disang and Dictyoconides sp. from the upper part in Nagaland, Sinha and Chatterjee, (1982) considered the unit to range from Palaeocene to Middle Eocene.

There are number of brine / saline wells / springs located in the Disang Group. It is not clearly known whether the source of saline water is in the Disang or in the underlying rocks.

### (iv) BARAIL GROUP :

Rocks of Barail Group occur in two different sedimentological environments in Tirap district. The one occurring to the south of Disang Thrust belongs to the geosynclinal facies, whereas the other found north of it belongs to shelf or platform facies and is coal-bearing. Freshwater terrestrial to deltaic deposits occur as narrow belts under which many intricate thrust sheets occur within the belt of schuppen. In the Naga-Patkoi range, the Barail Group has been subdivided into three formations viz., Nagaon, Bargolai and Tikak Parbat Formations

(Mathur and Evans, 1964). The E-W trending Margherita Thrust running along the foothills of Kuwan Bum range exposes the coal bearing Bargolai Formation, but better coal seams of Tikak Parbat Formation occur in Miao and Namchik-Namphuk areas which are of better quality. There are a number of coal-bearing Barail horizons exposed towards north-eastern side around Rima, Wintog, Longchang and Motongsa villages.

The miogeosynclinal Barails are well exposed in the higher contours of Patkai Bum, south of Khonsa and Longding areas. They are characterised by grey to greyish brown, compact, fine grained sandstones with greyish to greenish grey shale intercalations. The precise facies transition between the coal bearing and the geosynclinal Barail Group is however, not exposed.

**iv. (a) Nagaon Formation:**

The formation is well exposed at Dirak gorge and on both the limbs of Nampong anticline. Enormous thickness of sandstone with thin partings of arenaceous clay having thickness of 20-25 cms are exposed along Lazu-Khonsa road section along the southwestern part of Tirap district. The upper part of Disang Shale can be readily distinguished from the lower part of Nagaon Sandstone by considerably higher ratio of shale and sandstone but the exact boundary between the two formations is uncertain and conjectural. Nagaon Sandstone, on the other hand, is readily distinguishable from the overlying Bargolai Formation by colour and presence of comparatively less carbonaceous material in general. Nagaon Sandstone shows rhythmic alteration of thick sandstone bands (1 to 2 m) and thin shales (1 to 5 cms) with sand to shale ratio 5:1 to 10:1 as measured in different places along Lazu-Khonsa road sections (Ramteke and Chowdhury, 1985).

**iv. (b) Bargolai Formation:**

Bargolai Formation conformably overlies the Nagaon Formation and is in turn conformably overlain by Tikak Parbat Formation. The formation has been folded into a regional Nampong anticline and as a result occurs in two bands. The southern band occupies the higher reaches while the northern band extends from Honkup Bum in the west to new Janpong village in the east. Bargolai Formation comprises alternating sequence of sandstone, shale, silstone, clay, grey shale and coal seams. The sandstone is hard, compact, fine to medium grained and brownish grey to reddish grey in colour.

**iv. (c) Tikak Parbat Formation:**

This formation overlies Bargolai Formation in the type area of Makum Coalfields and occupies the topmost position of the Barail Group. It consists of white to greyish white sandy clay, shale, carbonaceous shale and fine to medium grained brown sandstone. Thick workable coal seams mark the contact of Tikak Parbat Formation and the underlying Bargolai Formation. In Nampong area, a 0.4 m. thick coal seam occurs at the contact with the underlying formation. Besides the basal seam, minor seams ranging in thickness from 10 to 25 cms are traceable towards the middle and the upper part of the formation. The coal seams are invariably associated with greyish white and occasionally ferruginous clay bands, sandy shale and yellow sandstone. The formation has been folded into an isoclinal anticline. The northern band is exposed near New Kamlang village. On the northern slope of Kuwan Bum this formation has attained a thickness of about 600 m consisting of sandstone and greenish sandy clays.

**(V) NAHARKATIA GROUP :**

The post-Barail but pre-Namsang succession which was originally referred as Tipam Group has been redesignated by Baruah et.al, (1992) as Naharkatia Group to avoid the use Tipam both for group and formation. Rocks belonging to Naharkatia Group are exposed North of Bagopani checkpost area where the slaty shales of Disang Group abut against the sandstones. They occur in the form of elongated wedges. Nahorkatia Group comprises Tipam Formation and Girujan Formation.

**v. (a) Girujan Formation:**

It is conformably overlying the Tipam Formation and is mainly clayey in composition. Numerous reworked Permian microfloras have been recorded from the samples of Girujan Clays collected from outcrops southeast of Upper Assam valley (Baruah and Ratnam, 1982). Girujan Clays show a pronounced variation in thickness. Its thickness rapidly decreases towards the northwest from 1261 m in Namrup area to only 1 m in Tenkaghat area. This variation may be due to either the differential erosion of the top of the Girujan Clays followed by deposition or facies changes of a member of the Tipam Sandstone towards the southeast and east into the shale.

**v. (b) Tipam Formation / Gandhigram formation:**

In Arunachal Pradesh it is well exposed north of Disang Thrust around Bagapani in the Dirang valley, in the upper reaches of Namphuk River and Noa Dihing River, where, it unconformably overlies the Barail Group. It is conformably overlain by the Girujan Formation. The Tipam Formation is mainly arenaceous sediments comprising grits, lenses of conglomerate, sandstone and minor shale.

Minor lenses of coal, oil and gas shows are known from the Tipam Formation. One of the characteristic features of this sandstone is the presence of epidote as heavy minerals, whose provenance might be traced to the Lohit Himalaya which might have been uplifted during deposition of Tipam Sandstone. Tipam rocks are thrusted against the Namsang beds within the schuppen zone.

La Touche (1886), Rao, Dias and Limaye (1963-64), Limaye (1964-65) Dutta and Dasgupta (1975), mapped the area form Mao to Chukan pass. They mapped the sedimentary group of rocks designated as Tipam Sandstone. Later Dasgupta, et. al, (1995-96), Kesari and Patel (1996-97) and Ghosh and Kesari (1997-98) adopted local name for different lithopackage of the area. They designated the sedimentary group of rocks of Tertiary age as Gandhigram Formation in the Noa Dihing valley from Mao to Chukan pass. This formation is mainly constituted of coarse to medium grained, greenish grey to buff coloured sandstone with intercalations of greenish grey to grey shale and siltstone bands. Conglomeratic/ gritty layers within the sandstone are particularly frequent towards the upper part of the sequence. Occasionally, lenticular bodies of purple/ maroon coloured shale and siltstone are observed. These are well exposed to the north and west of the confluence between Noa–Dihing and Machipilu Hka and Noa-Dihing and Angachidulu Hka respectively. Besides these, thin intercalations of purple/ maroon coloured sandstone-shale are also noticed. At many other places thin (2-10 cms), discontinuous coaly bands and carbonaceous shaly bands are also found.

Plant and invertebrate fossil bearing horizons are found at five localities within this formation. The fossils are found mostly in dark grey shales which are generally 30-50 cm thick. However, in a locality west of Ramnagar, it is also found in dark grey siltstone.

From the bulk mineral constituent the sandstone can be classified as quartzwacke to lithicwacke. The framework and matrix ratio varies from 70:30 to 50:50. The matrix is commonly arenaceous though in some samples ferruginous matrix is also present. Framework grains are mainly quartz, muscovite, chlorite, biotite and opaque. Feldspar grains are rare compared to rock fragments. However, in some sections grains of glauconite is also present. The presence of glauconite bears some significance. It is formed only in marine water of normal salinity (Cloud, 1955) and requires a slight reducing condition. Under such condition, it is derived from the alteration of phyllosilicate minerals, particularly biotite whose ionic arrangements are closely similar to that of glauconite.

The invertebrate, plant and ichno-fossils are found in several locations. The invertebrates are identified as common Miocene forms, while plant forms indicate a Mio- Pliocene age. However, foraminifers have more restricted age connotation i.e. Middle Miocene age. Thus, the Gandhigram Formation is considered to be of Lower–Middle Miocene age.

### (VI) NAMSANG FORMATION:

Around Deomali area in Namsang and Dibang valleys the mottled clay, sandstone, gritty to conglomeratic sandstone with pebble, coal (derived from Barail) and minor lignite lenses constitute Namsang Formation. They lie over the Girujan Formation unconformably. Namsang Formation consists of a sequence of soft sandstone with thin clay beds, lignite and conglomerate.

### (VII) DIHING FORMATION:

Dihing Formation is the uppermost Tertiary sequence in Tirap and Changlang districts, observed north of Kuwan Bum. It comprises boulder to pebble-sized-clasts of quartzite and gneiss embedded in a matrix of loose sand & clay and sand rock with very soft greenish and bluish clayey beds, carbonized wood fragments and small lenses of lignite. The maximum thickness of about 2500 mt is attained in Mana Bum anticlinal structure.

Dihing Formation is exposed along Noa-Dihing and in Miao, Deomali and Nam Dhapa area. The formation has been subdivided into lower sandstone and an upper boulder bed member. The lower sandstone member is medium to coarse grained, soft with greyish to bluish grey sandy clay lenses which ultimately grades into pebble bed with increasing thickness.

The lower sandstone member passes onto the boulder bed member and is well exposed near Miao. It consists of medium to coarse grained greyish to bluish grey sand. The lower portion of the boulder bed contains small, compact and well sorted pebbles with intercalations of sandy layers and lenses. The boulders and pebbles include fine grained hard and compact quartzite, granitoid gneisses, biotite gneisses and metabasic rocks. The pebbles and gravels of quartz and jasper are also present. In Namsang area occasional lenticels of sand are present in association with pebbles. In Manabum area, the pebbles are rarely present and the matrix is composed mostly of quartz, feldspar and chloritic minerals.

The generalized arrangement of the structural disposition of rock formations in the Tertiary belt, resulting from tectonic disturbance, as seen from NW to SE is given in the following table:

Table 1.3.2: Generalised NW to SE tectonic succession of Naga Patkoi Tertiary rocks in Arunachal Pradesh.

NW______________________

Dihing Formation
Namsang Formation
~~~~~~Unconformity~~~~~~~
Tipam Formation
——— Margherita Thrust ———
Barail Group
Tipam Formation
——— Disang Thrust ———
Disang Group
Barail Group

SE\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

### (viii) ALLUVIUM AND TERRACES:

The Older Alluvium of south-eastern Arunachal Pradesh is usually represented by three levels of terraces occurring close to the hill fronts around Pasighat, Roing and Tezu and extends further south-eastward to Noa Dihng river valley. The township of Tezu and Pasighat are situated on the youngest terraces of this sequence. The Older Alluvium is characterised by oxidation of the sediments.

The Newer Alluvium sediments are subdivisible into alluvial fan, newer terrace alluvium and active channel alluvium. The sediments are unoxidised and overlie the Older Alluvium disconformably or unconformably Dihang (Siang), Dibang and Lohit Rivers, after reaching the plains have laid down the Newer Alluvium sediments over vast areas.

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# 1.4 Structure and Tectonics

Arunachal Pradesh can be divided into three broad structural belts with distinct geological history and structural grains. The three belts are:

1) The Himalayan belt
2) The Trans Himalayan belt of eastern Arunachal Pradesh and
3) Southeastern Arunachal Pradesh which is the extension of the Naga-Patkoi ranges.

**A. Structure of the Himalayan Belt:**

The Himalayan belt comprises several thrust-bound litho-tectonic units. The major tectonic features of the Himalayan belt of Arunachal Pradesh are as follows:

**(i) Main Central Thrust (MCT):**

The MCT separates the high grade metamorphites of the Se La Group in the north from the epi to meso grade rocks of the Lesser Himalayas to the south. The MCT is well defined in north of Dirang in the West Kameng district where the rocks of the Bomdila Group are truncated with conspicuous presence of moderately dipping thrust (Bhusan, 1999). It has been mapped in the Subansiri river section, south of Taliha. The position of the MCT in the East Kameng and Kurung Kume districts and its continuity has been interpreted photogeologically. At the east of Subansiri valley, the MCT swings to NE and abuts against the Tidding suture in the Siang valley.

The rocks of the Dirang Formation occur in contact with the MCT continuously from the western Arunachal Pradesh as well as central Arunachal Pradesh. The Lumla Formation which has been mapped in Tawang district (Kaura and Basu Roy, 1982), and in the Upper Subansiri district lithologically resembles the Dirang Formation and may be interpreted as isolated tectonic windows implying that the MCT is either curviplanar or is folded later. Dirang Formation appears to be physical continuation of the Jaishidanda Formation of Bhutan Himalaya (Dasgupta, 1995).

**(ii) Main Boundary Fault (MBF):**

Main Boundary Fault which demarcates the boundary between the Siwalik Group of rocks to the south and the pre-Neogene rocks, occurring to the north, is a steep, north dipping reverse fault which maintains roughly a WSW-ENE trend. Although most of the workers agree that the MBF abuts against the Roing Fault in the Dibang valley, difference of opinion also exists. For instance, Ranga Rao (1983) considered the MBF to join with the Mishmi Thrust. Acharyya and Sengupta (1998) interpreted uparching of the MBF in the Siang valley and the Upper Cretaceous to Palaeogene sediments. According to them, they are exposed between the uparched MBF and the 'North Pasighat Thrust'. This interpretation is difficult to accept mainly because of the reason that nowhere in the Himalayas such extensive outcrop of Upper Cretaceous-Palaeogene rocks are found to occur south of the MBF. Isolated small occurrences of fossiliferous Palaeocene-Eocene rocks south of MBF may be explained as 'bioboulders' derived from the Dalbuing Formation and the Geku Formation (cf. Ranga Rao, 1983, Jaiprakash and Patel, 1991). In the northwest Himalaya also similar situation exists, where presence of nummulites derived from the Eocene rocks in the Middle Siwalik and that of Cretaceous radiolarian in the Muree Formation are reported by Ranga Rao (1983). In the present interpretation the MBF, as already mentioned, abuts against the Roing Fault and the latter may be a continuation of the Mishmi Thrust (Acharyya, 1986).

**(iii) Roing Fault:**

It is concealed under the alluvium in the lower part of the Lohit valley. In Dibang valley, the rocks of the Bomdila Group are brought over the Quaternary sediments along the easterly dipping Roing Fault indicating neotectonic movement. In the Siang valley, the rocks of the Tenga Formation tectonically overlie the Palaeogene sequence along this fault. The Roing Fault is probably obliterated by the north-south trending Bame Fault to the west of Along with a dextral sense of shear. To the west of Bame Fault various lithounits of the Bomdila Group (Khetabari Formation, Tenga Formation and Chilliepam Formation) come in contact with the Miri Formation along the Roing Fault which finally merges with the MBF, north of Itanagar.

**(iv) Minor Structures:**

Mesoscopic structures related to several deformational episodes have been recorded by various workers. The Proterozoic rocks of the Bomdila Group and the Se La Group show a common plan of deformation - related to four or five episodes (Saha, et.al, 1989; Singh and Ahmed, 1989; Singh et.al, 1989; Bhusan, et.al, 1991; Saha and Manjunath in Jayaprakash et.al, 1988-89). The $F_1$ folds ($D_1$ deformation), usually identifiable in the psammitic rocks, are of tight isoclinal, reclined or recumbent geometry and are often rootless. These folds are tightly appresssed with attenuated limbs and high amplitude: wavelength ratio. The most pervasive planar fabric $S_1$ is developed parallel to the axial plane of the $F_1$ folds and in most places parallel to the So except near hinges of minor $F_1$ folds where the So and $S_1$ intersection gives rise to $L_1$ lineation. Quartz micromullions and mineral lineation also define the $L_1$ lineation. The first folding is accompanied by metamorphism of almandine amphibolite facies ($M_1$) which has been interpreted as a pre-Himalayan event (Neogi, et.al, 1998, Singh and Choudhury, 1999).

The $F_2$ folds developed during the $D_2$ deformation are superimposed over $F_1$ and are tight to moderately open and asymmetrical. These are found on mesocopic, as well as megascopic scale in the rocks of the Bomdila and Se La Groups. Co-axial refolding of the $F_1$ folds producing hook-shaped interferences pattern (Type-III of Ramsay, 1967) on mesocopic scale has been recorded in Shergaon area. In this area crenulations/strain slip cleavage ($S_2$) dipping at moderate to steep angles either towards NW or towards SE has been recorded. The $L_2$ lineation defined by $S_1$-$S_2$ intersection stripping and boudin necklines, plunges 10° -20° mostly towards NE. The $D_2$ deformation was accompanied with acid magmatism and metasomatism. Although Kumar (1997) attributed greenschist metamorphism ($M_2$) with the $D_2$ deformation, Singh and Choudhury (1999), on the basis of their work in the Siang region, have different interpretation. According to them, the syn- $D_2$ metamorphic event ($M_2$) was most intense and most of the garnet and staurolite porphyroblasts developed during this event. They (op, cit) further interpreted that the $D_2$ deformation culminated into large scale thrusting during the Himalayan Orogeny, but the $M_2$ metamorphism reached its zenith before the thrusting took place.

The structures related to $D_3$ deformation are recognisable not only in the Proterozoic but also in the younger sequences ranging in age upto the Early Eocene (Yinkiong Group). These are clearly related to the Himalayan orogenic movements. The structural data from the Siang valley suggests that the $F_3$ folds are pre-MBF (Ranga Rao, 1983). The $F_3$ folds are moderately open having rounded hinge with moderate to steeply plunging axis and are not coaxial with $F_1$ or $F_2$. This folding is accompanied with a strong fracture cleavage ($S_3$).

The signature of $D_4$ deformation is recorded in the form of open and broad cross folds and faults trending NW-SE to N-S. This deformation was probably collision related and the Eastern Syntaxial Bend and the Siang antiform might have probably developed during this deformation.

The Siwalik Group of does not show imprints of $D_1$ to $D_4$ deformations. However, folds developed parallel to the trend of the MBF could be referred as $D_5$ deformation and might be fault-bend folds related to the movement along MBF, Tippi Thrust and Foothill Fault. The Lower, Middle and Upper Siwaliks are stacked over one another in reverse stratigraphic order. The Lower Siwaliks by virtue of proximity to the MBF show development of tight anticlines and synclines (Kunte et.al, 1983) whereas the Middle and Upper Siwaliks are folded into open anticline and synclines eg., the Simna Parbat anticline, Papum syncline and Lao syncline in Bargang-Pachin river sections.

### B. Structure of the Trans-Himalayan Belt

The structure of the Trans-Himalayan Belt comprising the rock sequence east of the Tidding Suture has not been studied systematically. Although two major tectonic features, the Tidding Suture and the Lohit Thrust have been recognised by most of the workers, data on minor structures are available from isolated sectors only.

#### (a) Major Tectonic Features:

#### (i) Tidding Suture:

The Tidding Suture (Tidding lineament of Acharya,, 1982, Tuting-Tidding suture of Acharya, 1987) is a NW-SE trending tectonic lineament considered to mark the boundary between the Indian Plate and the Central Burmese Plate. It has been mapped from south of Tuting in the Siang valley to Dhapa Bum in the southeastern part of the Lohit valley. Although these planes are known to dip steeply towards east (Kumar, 1997), Manoj Kumar, et.al, (2000) described the tectonic plane delineating the boundary between the 'Tuting-Tidding Suture Package' and gneissic formation of the 'Siang Group' (Bomdila Group) as a thrust and referred it variously as Yang Sang Chu Thrust, Rayali/Miodiya Thrust or Lalpani Thrust in the Siang, Dibang and Lohit valley respectively.

#### (ii) Lohit Thrust:

Nandy and Basak (1966-67) while mapping in Telly valley recognised a tectonic plane between the Tidding Formation and the 'Mishmi Granodiorite' which subsequently (Nandy 1973) was described as Lohit Thrust. Nandy and Banerjee (1983) extended it to Dibang valley near Endoline where it is marked at the contact between the diorite gneiss and the underlying low grade schist's and is characterised by shearing and recrystallisation. Continuity of the Lohit Thrust further north-westward upto Arudzu in the Upper Siang valley and its merging with the Yang Sang Chu Thrust is suggested by Nair and Sankar (1981). It has been picked up north of Tuting also (Singh and Malhotra, 1983b). To the south, the Lohit Thrust probably abuts against the Mishmi Thrust near Dapha Bum. The existence of the Lohit Thrust, however, has been doubted by some workers who reported the contact between the metasedimentaries and the diorite-granodiorite-granite complex to be intrusive (Adhikari, 1986, Rajesham and Dutta, 1983; Shrivastava, et.al, 1984; Chattopadhyay and Chakraborty, 1984).

**(b) Minor Structures:**

The Yang Sang Chu Formation, Tidding Formation and Tuting metavolcanics bear signatures of four deformational episodes. The first fold $F_1$ is recorded as tight isoclinal to reclined minor folds in thin quartzite bands associated with the carbonaceous/graphitic schist. These folds have E-W to WNW-ESE axial trends and northerly dipping axial plane schistosity ($S_1$). Kumar et.al, (2000) has reported mineral lineation and deformed pebble lineation related to the $D_1$ deformation in Tuting area. The attitude of the lineation is highly variable.

The second generation folds ($F_2$) are found as puckers of widely varying attitudes. From the study of the asymmetric crenulation cleavage, Manoj Kumar (op.cit) has interpreted that the $F_2$ folds are related to thrusting. $F_3$ folds are developed on regional scale as open antiforms and synforms generally with NNW-SSE axial trends. The Yang Sang Chu and Ahi Rivers follow two antiformal axes whereas the synforms are marked by ridges, e.g., the Miodiya ridge and the Lalpani ridge. The $F_3$ folds of the Trans-Himalayan belt are similar to those of the Himalayan belt and it is most likely that the $D_3$ deformation post dates the main collision event.

$F_4$ folds manifest as broad warps including the Eastern Syntaxial Bend. Several cross faults with NNE-SSW or NE- SW trends reported from Siang, Dibang and Lohit valley areas are interpreted by Kumar (op.cit.) to be related to $D_4$ deformation episode.

The gneissic rocks of the Lohit Granitoid Complex and the restites of the Etalin Formation preserve the imprints of three to four phases of deformation. The secondary foliation or the gneissosity is related to the $D_1$ deformation. The $F_2$ folds ($D_2$) are represented by open to moderately tight folds. The $F_3$ folds of third deformation are open and broad folds and generally follow the regional NW-SE trend. The $F_4$ folds are open, broad cross-folds trending NE-SW with northeasterly plunge.

The $F_1$ and $F_2$ folds are coaxial trending in NW-SE direction and show plunge culmination and depression (Rajesham and Dutta, 1983).

**C. Structure of South Eastern Arunachal Pradesh**

The Tertiary and Quaternary sequence disposed in the Changlang and Tirap districts of Arunachal Pradesh in northerly convex arcuate pattern are continuation of the Naga-Patkoi ranges. All the deformational structures developed in southeastern Arunachal Pradesh trend NE-SW in the southwestern part and gradually swing to southeast in the upper reaches of the Noa Dihing valley where it is delimited to the north by the Mishmi Thrust.

In general, the trend of the bedding varies from E-W to NW-SE. However, east of Vijaynagar it takes a northeasterly swing. Around Vijaynagar-Garrigaon-Ramnagar area, reversals of dips are conspicuous. This swing in bedding as well as reversal of dip delineates presence of a megascopic antiform and synform and related mesocopic folds of the smaller order. The megascopic folds are broad, open and upright type with almost E-W trending axial trace. The synformal axial trace passes through Vijaynagar-Garrigaon area, while the corresponding antiformal axial trace is further north. Northwest of Gandhigram, a broad swing is decipherable in the bedding trend.

In the LANDSAT imagery these thrusts can be traced from the present area towards west up to the vast alluvial cover northeast of Miao. Further north, within the crystalline belt, two more lineaments parallel to the thrust planes can be picked up. In the LANDSAT imagery, the southern belt is characterized by prominent bedding trace which continues up to Miao. South of the Vijayanagar-Ramnagar tract, a megascopic fold with E-W trending axial trace is delineated. The major part of this fold lies in the adjoining terrain of Myanmar. Besides these, two more major folds are decipherable around Gandhigram. East of the Miao three major N-S trending lineaments can be picked up. The swing of the bedding trace, east of Miao, probably caused due to the presence of these lineaments.

The rocks of the Disang, Barail and Nahorkatia Groups are folded into a series of north-easterly plunging folds which swerve towards east. In the western half of Tirap district the rocks are folded into a major isoclinal, overturned, northeasterly plunging anticline, known as the Nampong Anticline (Jhanwar, et.al, 1999). The trend of the axial surface of this fold swerves from NE-SW in the northwestern part to ENE-WSW in the northeastern part near Nampong. Further eastward its trend becomes parallel to the trend of the Mishmi Thrust. The second generation folds are represented by open broad, asymmetrical folds whose axes plunge towards NW or NNW. The Mana Bum Anticline north of Miao Bum is one such anticline whose southern limb is cut off by the ENE-WSW trending Margherita Thrust (Naga Thrust).

Besides the Mishmi Thrust already described, two more major thrusts have been mapped in southeastern Arunachal Pradesh viz., the Disang Thrust and the Margherita Thrust (Naga Thrust).

The Disang Thrust trends NE-SW and runs almost parallel to the axis of the Nampong Anticline. It dips at low angle towards southeast. As a result of this thrusting the Tipam Sandstone is overthrust by the Disang Shale near Kanubari.

The Margherita Thrust, which may be the continuation of the Naga Thrust of Naga Hills, is also a low southerly dipping thrust trending northeasterly near the confluence of Deban and Dihing rivers. Further northeast it appears to be breached by the Mishmi Thrust. The Margherita Thrust cuts the Mana Bum Anticline at high angle and brings rocks of the Tipam and Barail Groups in contact with those of the Dihing Formation (Jhanwar, et.al, 1999).

**(i) Structure of the Northern Crystalline Belt**

Bedding is the only non-diastrophic structure observed within the quartzites of the Tilung Formation.

Within this belt two types of folds are found. Both these types are only observed on minor scale. The earlier type of folds is defined by bedding. These folds are highly appressed and reclined type mylonitic foliation which defines the main pervasive planar fabric of this belt, is axial planar to these folds. This mylonitic foliation has a general NW-SE to WNW-ESE trend with moderate northerly dip. Under microscope this mylonitic foliation is defined by thin phyllosilicate rich laminae as well as by elongation of small recrystallised quartz grains and elongated quartz ribbons. These phyllosilicate rich laminae are anastomosing in nature and warp round the porphyroclasts of quartz and feldspar. The fine grained and the shredded mica flakes along these anastomosing laminae indicate that the phyllosilicate rich laminae acted as movement planes (C-planes). Another set of phyllosilicate laminae which are made up a thin flakes make an acute angle with the C-planes. These two sets of planes delimit lenticular to rhombic fabric domains and are interpreted to represent S-C planes. Such rocks are similar to type I S-C mylonite of Lister and Snoke (1984). The angle between S and C planes decreases with the intensity of deformation. In more deformed mylonite this angle is less compared to its less deformed variety, implying progressive rotation of S- planes towards C- planes in increasing high strain zones. In some exposures on this mylonitic foliation, a prominent down dip mineral lineation, parallel to the axes of the earlier reclined folds, is observed. This lineation is defined by mica streaks and also by elongate clots of quartz and feldspar. In the high strain zones this lineation is considered to be parallel to the movement direction.

The later types of folds have folded the mylonite foliation. At places, these folds are found to be open type with gentle to moderate northwesterly plunge. However, in the high strain zone these folds attain highly appressed and reclined geometry. Commonly an axial planar crenulation cleavage is associated with these folds. The general trend of the crenulation cleavage is NW-SE to WNW-ESE i.e. similar to the earlier described mylonitic foliation. However, the former commonly have steeper northerly dip compared to the latter. At many places, the crenulation cleavage transposes the earlier fabric and hence, a composite fabric defines the main structural grain of the rock. From the microscopic study the crenulation cleavage is found to be zonal type. In the micaceous quartzite of the Tilung Formation as well as in phyllosilicate rich granitoid gneiss of the Namdhapa Crystalline Complex, crudely developed alternate quartzose and phyllosilicate rich bands parallel to crenulation cleavage are seen. Such secondary banding is typically found where the crenulations are asymmetric and the domains in which earlier foliation makes a high angle with crenulation cleavage are quartz rich and those in which angle is low are depleted in quartz. Occasionally these cleavage planes appear as movement planes which cut across sigmoidally curved earlier mylonitic foliation. In such case the later cleavage becomes similar to the extension crenulation cleavage.

The above described earlier and later folds are found to be co-planar as well as co-axial at many places. Moreover, in some exposures the later folds attain similar geometrical forms as that of the earlier folds. Thus, it can be suggested that the bulk strain regime was similar during the formation of both these folds. Hence, it is considered that these folds represent earlier and later part of the same pregerssive deformational episode.

In addition to the already described structural fabrics, a set of shear bands or C-planes found at few places, particularly in Laboi-Hka section. This shear band is represented by thin phyllosilicate rich laminae which cuts across the mylonitic foliation and gives rise to sigmoidal curvature of the latter. The nature of deflection of the mylonitic foliation by the shear bands makes the later comparable to extensional crenulation cleavage. These shear bands have nearly the same strike as the mylonitic foliation but dip more gently towards north.

The general attitudes of the mylonitic foliation are parallel to the major thrust planes and are thus considered to be coeval. Minor folds associated with the mylonitic foliation are considered to be thrust related and are formed due to perturbation in the flow regime. From the macroscopic kinematic indicators, viz. asymmetry of minor folds, S-C fabric, shear bands, and up dip movement of the northern block is deduced along the two major thrust planes. This sense of movement is also corroborated by microstructures like asymmetric pressure trail and book-shelf texture.

**(ii) Tectonic Evolution**

The deformation features developed in the minerals (already discussed) and the presence of mylonitic fabrics within the rocks suggest that the thrust of the northern crystalline belt represents ductile shear zone. In the mylonites formed during the thrusting episode, movement of dislocation is responsible for the ductile behaviour of quartz. The optical strain features including undulose extinction, planar deformation bands, subgrain formation with low angle boundaries, development of quartz ribbons and presence of strain features in the new recrystallised grains indicate that the dislocation and creep-type deformation accompanied by dynamic recrystallisation.

From the present study, the thrusts are not found to be related with any mega scale crustal folds. Hence, they are considered to be comparable with the type-C thrust sheets described by Hatcher and Hooper (1892). According to them, this type of thrust sheets are internally brittle slab of intact crust that detach within the thermally softened ductile-brittle transition and once formed behave as thin skinned thrust sheet. Type-C thrust sheet is considerd to be resultant of continent-continent collision. Thrust sheets of the present area are formed during the main Himalayan Orogeny which is the manifestation of the collision between Indian and Tibetan plates.

The mineral assemblages of the Tilung Formation indicate an overall low grade green schist facies of metamorphism and points towards a shallow depth of burial. The depth of ductile-brittle transition zone varies and depends on heat flow and the amount of fluid present. The ductile-brittle transition may be close to the surface in zones of high heat flow where fluids may be abundant. Similar to such situation the Tilung Thrust sheet might have also originated from ductile-brittle transition zone located close to the surface.

In the present area, the kinematic indicators point towards an up dip movement of the successive structurally higher horizon. These kinematic indicators also indicate a southward tectonic transport of the thrust sheet, corresponding to the regional sense of tectonic transport in the Himalayan Orogeny. It is postulated that the Gandhigram Formation is deposited along the fringe of the rising mountain chain. Initlally Tilung Firmation is thrusted over the Gandhigram Formation, successively a new thrust is generated on the hanging wall side of the already thrusted block and in turn brought the Namdhapa Crystalline Complex over the Tilung Foramtion. Thus the thrusts propagate towards the hinterland in a sense opposite to the tectonic transport direction which is towards the foreland. These types of thrusting commonly results in overlap sequence which is evident in the present area where the narrow belt of Tilung Formation represents the whole Lesser Himalayan package. From the style of folding and nature of deformation it can be tentatively suggested that the main pinnacle of Himalayan Orogency is represented by the formation of thrust sheets of the northern crystalline belt; while the mega folds of the Gandhigram Formation represent the waning phase of this orogeny.

★★★

# 1.5 Mineral Resources

In 1960s, Assam Circle of Geological Survey of India located a few occurrences of limestone and graphite in Lower and Upper Subansiri, West Siang and Lohit districts. Occurrences of clay, beryl and base metals near Potin village in Ranga valley of Lower Subansiri district also received attention because of the indicated cobalt values in pyrite and nickel in pyrrhotite. Investigation for locating limestone-marble was undertaken by officers of GSI which resulted in the discovery of Tidding Limestone and Dora Marble deposits in Lohit district. The coal deposits of Namphuk in Tirap district was investigated by GSI.

After the establishment of Arunachal Pradesh Circle in 1969, a broad geological picture could be quickly built up by GSI through geological traverses, mapping and mineral investigations. These included base metal investigations of Middle Proterozoics in Shergaon, West Kameng district; investigation of pozzolonic clay in East Kameng and Lower Subansiri districts ; plastic clay in Lohit and West Kameng districts; dolomite investigation in West Kameng district; graphite investigation within Khetabari Formation in Upper Subansiri district; investigation of limestone in Dibang valley (Hunli Deposit) in Lohit and West Siang district; and sulphide investigation in Khetabari-Potin Formation in Lower Subansiri and East Kameng districts.

## (i) COAL

Tertiary coals of Northeast India were developed in deltaic, estuarine or lagoonal swamps, along or close to marine coasts, in a tectonically active domain, from semi-aquatic as well as marine vegetation. The depositional environment simulates that of present day mangrove-swamps, where the ecological imprint is more marine than continental. Lensoid bodies of coal formed from accumulated vegetable debris, wherever a swampy depression formed in a continually accumulating pile of sediments over an extensive depositional arena. In such a formative process lensoid coal-bodies (unlike blanket like coal seams as found in Gondwana basins) may develop or occur anywhere within the host rock-formation, singly or in clusters. Only on those favoured locales, where swampy or lagoonal conditions persisted over a larger area and during some length of time, larger number of coal-bodies have formed, some of which have attained sufficient thickness and horizontal spread. Under such a depositional condition, it is theoretically possible to expect a coal-body at any part of the host rock at random. These coal occurrences cannot be called coal-basins sensu-stricto. Those areas, where one or more coal beds or bodies are visibly known to occur over a large area may be called coalfields. In most of these coalfields, the coal bodies have been exposed through the process of erosion or sometimes by excavation for construction. If the entire host formation is systematically drilled from one end to the other, it is quite possible that more hidden coal-bodies or a few more unknown coalfields may be located. However, the terms coal-seams and coalfields are conventionally used to denote the lensoid coal-bodies, irrespective of their dimensions and coal-bearing areas and irrespective of any definable outline.

Lower Gondwana rocks with carbonaceous components have been reported to occur in northeastern region, as a long linear belt in Arunachal Pradesh. Presence of coal with doubtful economic potentiality has been reported from the Arunachal Gondwana belt. All the economically important and workable coal in the northeastern region belongs to the Lower to Middle Tertiary (Eocene to Upper Oligocene) age.

The coal deposits of the northeastern region (excluding the Gondwana outlier of Meghalaya) occur within the geo-tectonic province of Gondwana belt of Arunachal Pradesh as thrust sheets in the foot-hill zone of outer Himalaya, and, in the zone of peri-cratonic downwarp of an epi-continental geosyncline, which has later turned into a zone of "Schuppen" through thrust tectonics, comprising the coal-fields of Upper Assam, eastern Arunachal Pradesh and Nagaland adjacent to Upper Assam. Based on the above criteria, the northeastern coalfields may be classified as:

Coal occurrences in the fresh-water continental Gondwanas occurring with and along the thrust sheets of the outer Himalaya in Arunachal Pradesh.

Coalfields in the zone of "Schuppen" in the geosynclinal domain, comprising Coalfields of Namchik-Namphuk, Arunachal Pradesh.

The coal fields of Arunachal Pradesh and Nagaland fall within the scope of this of the volume.

1. The coals of Gondwana belt in Arunachal Pradesh

A narrow belt of Lower Gondwana rocks, trending ENE-WSW and dipping steeply due north has been traced from Kameng district in west, through Subansiri district to Siang district in East. This belt is demarcated by two high-angle thrusts, all along the northern and southern boundaries, overthrusting Gondwana Group on the Siwalik Group in South and thrust over by the metamorphics and other pre-Gondwana rocks in North. Gondwana rocks rest on a denuded surface of Miri Formation, which possesses Cuddapah and Vindhyan characteristics. Abor Volcanics are underlying and sometimes intercalated with Miri Formation. Regional stratigraphy for Gondwana coal occurrences, as worked out, is given in Table 1.5.1.

**Table 1.5.1: Stratigraphy of Gondwana coal horizons in Arunachal Pradesh**

| Group | Formation | Age |
|---|---|---|
| Lower Gondwana Group | Bhareli Formation/Abor Volcanics | Cretaceous (?) |
| | Gensi Formation | |
| | Garu Formation | |
| | Rangit Pebble Slate | |
| | ~~Hiatus/Unconformity~~~ | |
| | Miri Formation | Lower Palaeozoic |

Coal deposits of Upper Assam and the adjoining parts of Arunachal Pradesh and Nagaland belong to geosynclinal sediments which include an older flysch stage and a younger molasse stage, spanning the entire Tertiary from Eocene to Pliocene. Within this huge geosynclinal pile, coal-measures occupy the lower-middle part i.e. Oligocene. The regional stratigraphic framework of these geosynclinal sediments has been worked out by Evans (1964), and is given in Table 1.5.2.

**Table 1.5.2: Stratigraphy of Tertiary coalfields of northeast India**

| Age | Group and Formation | Thickness (meters) | Lithology |
|---|---|---|---|
| Pliocene | Dihing Group | 1800 | Poorly lithified pebbly sandstones and thin, greyish clay beds |
| ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ Unconformity ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ | | | |
| Mio-Pliocene | Namsang Formation | 800 | Fine to coarse grained sandstone with bands of clay |
| ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ Unconformity ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ | | | |
| Miocene | Tipam Group Girujan Clay | 1800 | Mottled clay with fine grained greyish sandstone |
| | Tipam Sandstone | 2300 | Ferruginous (bluish green) fine grained, micaceous and feldspathic sandstone with fossil wood |
| ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ Unconformity ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ | | | |
| Oligocene | Barail Group Tikak Parbat Formation | 600 | Greyish to yellowish white sandstones, sandy shale and coal seams |
| | Baragolai Formation | 3300 | Greyish to bluish grey and yellowish red mudstones, shaly sandstone, carbonaceous shale and thin coal seams |
| | Nagaon Formation | 2200 | Compact, fine grained, dark grey sandstone with bands of splintery shales. |
| Eocene | Disang Group | 3000 | Splintery, dark grey shales with thin sandstone interbands (flysch sediments) |

The generalised stratigraphic sequence for the belt is given in Table 1.5.2, and appended with details from relevant sections on geology in this and next volume. The mobile geosynclinal belt is characterised by intense orogenic movements and resultant deformations, comprising intense and compact folding, overfolding, dip-reversals, and mega to mesoscopic thrusting, which are high-angle, reverse faults/thrusts. These structures are in addition to intense lateral and vertical facies variations. As a result, the formations are not traceable continuously over the entire belt, having been altered/cut-off/obliterated by thrusts.

This geosynclinal sequence is India's most important on-shore oil repository. The important coal resources of Northeast India are also developed in it. Barail Group constitutes the principal coal measures and comprises

Nagaon, Baragolai and Tikak Parbat Formations, best developed in Upper Assam and adjoining parts of Arunachal Pradesh and Nagaland.

Baragolai Formation gradationally passes into the overlying Tikak Parbat Formation, the principal workable, coal-bearing formation in Upper Assam. On lithological basis, this formation has been divided into a lower, mainly argillaceous member, 120 to 215 meters thick with well developed coal seams, and an upper member, mainly arenaceous, with lesser number of thin seams.

Barail Group is usually succeeded by the Tipam Group with an apparent erosional unconformity in the Schuppen-belt. It is well developed in Namchik-Namphuk, Makum, Dilli-Jeypore and Borjan coalfields. This group has a Lower Tipam Sandstone Formation comprising medium to coarse grained sandstones, bluish to bluish green which weather to brown colour, with occasional conglomerates, clay lenses and carbonised fossil wood, and a lower Girujan Clay Formation comprising variegated clays.

The succeeding Namsang Formation unconformably overlies Girujan Clay Formation. It comprises mainly coarse grained, friable sandstones with clay lenses and occasional coal pebbles.

The youngest Tertiary sequence is Dihing Group comprising alternate pebble beds and loose feldspathic sandstones, occurring in isolated patches in Namchik-Namphuk, Makum and Dilli-Jeypore coalfields. Extensive parts of this group appear to be concealed under Older and Newer Alluvium.

**Description of the Coalfields**

It has been mentioned that the thin lensoid coal bodies of Lower Gondwana rocks in Arunachal Pradesh have neither workability nor economic significance. However, a major Tertiary coalfield is at Namchik (27º25’00")-Namphuk which contains workable coal seams. This is situated in the eastern part of Changlang district, at 27°18' N latitude and between 95°58' and 96°14’E longitude and is an easterly extension of the Makum coal-field, located about 25 km away.

These coal-bearing areas are difficult to reach due to absence of bridges across the Namchik and Namphuk rivers. The area is approachable from the nearest railhead at Lekhapani (NFR) in Assam plains, via Jagun along the extension of N.H. 38, and from Jagun to Namchik village by a 9 km fair-weather road.

The coalfield is within a densely forested rugged terrain with humid summer, high rainfall and fairly cool winter. It forms a part of the Patkai range. Kuwen Bum, Honkap Bum and Miao Bum are important peaks. The average height varies from 700 m. to 925 m.

The field was discovered by Medlicott (1865) and later studied by LaTouche (1866), both of whom located two coal seams 1.2 metres and 1.8 meters thick. Subsequently Pascoe (1912) discovered an 18 m. thick seam. This area was later explored by the officers of the Assam Oil Co. and Oil India Ltd., but no data was published. Munshi (1962), Munshi & Goswami (1959-61) and Munshi & Rao (1962-63) resurveyed the coal-field during 1959-63 investigations by GSI. Later large-scale mapping of the coal-bearing area was carried out by Bose, Chowdhury and Puri in 1970, followed by Mazumdar and Ghosh, (1969-70).

The complete Tertiary sequence from Eocene to Pliocene has developed completely in this field. Tikak Parbat Formation is the main coal-bearing horizon, whose upper member (200 meters to 300 meters thick) is practically devoid of coal, while the lower member (120-215 meters thick) contains eight coal seams varying in thickness from 1.0 m. to 16.4 m., besides thick carbonaceous shale.

This coalfield represents a broad asymmetric syncline with minor anticlines and synclinal folds, which appears to be the eastern extension of the adjacent Namdang Syncline of Makum coal-field. The northern limb of the syncline has been truncated by the Margherita Thrust and the southern limb by the Disang Thrust. The strata dip 15° to 35° southerly with ENE-WSW strike in the northern limb and at 40° to 70° northerly with E-W strike in the southern limb. The coal-bearing strata trends NW-SE with 20°- 30° southerly dips. At places the dips are 60° to almost vertical.

Exploratory drilling by GSI in Kuwen Bum area has revealed the existence of eight coal seams varying in thickness from 1.0 m. to 16.4 m. In Miao Bum area mapping has revealed only two coal seams 7.00 m. and 8.30 m. in thickness. A considerable part of the coalfield is covered by riverine sediments. A borehole South of Kharsang has revealed a sequence of coal seams given Table 1.5.3.

**Table 1.5.3. : Lithostratigraphic sequence of Coal Seams in Kharsang Area, Changlang District, Arunachal Pradesh (After Rao, C.S.R., 1981)**

| Seam No. | Thickness (meters) |
|---|---|
| VIII | 1.3-2.1 |
| Parting | 7.0-8.0 |
| VII | 1.3-2.7 |
| Parting | 2.0-5.0 |
| VI | 0.4-1.2 |
| Parting | 11.0-24.0 |
| V | 1.0-6.3 |
| Parting | 8.0-23.0 |
| IV | 1.3-5.4 |
| Parting | 7.0-39.0 |
| III | 2.4-16.4 |
| Parting | 2.0-31.0 |
| II | 0.5-2.8 |
| Parting | 1.7-18.0 |
| I | 0.25-2.7 |

In addition, there are a few more thin seams varying in thickness from 0.35 meters to 0.80 meters. These seams as well as inter-seam partings frequently thicken and thin out and also split out. The Seam No. III is the most persistent seam with an average thickness of 13 meters in the central part, followed by Seam No. IV, Seam No. VII and Seam No. VIII. The quality of coal from these seams is given in Table 1.5.4.

**Table 1.5.4.: Coal Quality parameters of Kharsang Coalfield Samples, Changlang District, Arunachal Pradesh**

| | | Proximate analysis of air dried samples | |
|---|---|---|---|
| Seam No. | Moist % | Ash % | Total Sulphur % |
| VIII | 2.2-2.6 | 5.9-9.1 | 4.0-4.3 |
| VII | 3.0-3.3 | 10.3-19.3 | 3.6-5.1 |
| VI | 2.7-3.3 | 10.5-24.5 | 3.1-5.6 |
| V | 1.9-3.2 | 5.6-17.1 | 1.6-7.2 |
| IV | 2.1-3.8 | 4.8-21.4 | 3.1-5.1 |
| III | 2.2-3.4 | 3.8-18.9 | 3.0-4.1 |
| II | 1.9-3.7 | 5.6-27.8 | 1.6-4.0 |
| I | 2.0-2.7 | 4.8-24.7 | 1.7-6.3 |

On the basis of mapping, GSI assessed a reserve of 91 million tones for all the seams upto a depth of 600 m. Drilling over a 3 km strike length proved a total reserve of 17 million tones for all the seams above 1.2 meters in thickness. A considerable part of this coalfield is yet to be explored and hence, the potentiality picture seems to be partial. If approach and communications to the area are improved, this coalfield could become a major productive field from its present virgin status.

Coal occurrences in Arunachal Pradesh have been reported from two stratigraphic horizons: Early Permian Lower Gondwana coal in Lesser Himalaya in the western part and the Tertiary Coal fields in the Naga-Patkoi Ranges in eastern part.

**Gondwana coal:**

Occurrences of coal seams in the Gondwana sediments are insignificant and have little or no economic value because of their impersistant nature. The coal seams occur as lenticular bands in the upper part of the Bhareli Formation.

**West Kameng District:**

**Amatulla:**

A 7.5 m thick coal seam has been reported near Amatulla. The coal is generally crushed and powdery. The analyses of this coal indicated moisture 1.6%, ash 12-14%, low sulphur 0.3%, fixed carbon 88.4%-89.4%, hydrogen 5.1-5.3% and volatile matter about 13% and have moderately caking (c.i. 12-15 1355) properties.

**Pinjoli nala section:**

Exploratory drilling in Pinjoli nala has recorded a 4.30 m thick coal seam in one borehole besides the other minor seams. The analytical results indicated 19.1% ash + moisture content, 68.6% fixed carbon and 12.3% volatile matter and has been graded as low volatile sub-bituminous coal.

Besides, there are some other minor occurrences of coal viz. in Bhalukpong-Bomdila section, Garu-Gensi section and Bhareli section having no economic significance.

**Tertiary coal:**

Coal in the Tertiary sediment has been reported from Schuppen zone in the Naga-Patkoi ranges in the eastern part of Arunachal Pradesh.

**Tirap District:**

**Namchik-Namphuk coalfield:**

The only important coalfield of Arunachal Pradesh, Namchik-Namphuk coalfield lies in the eastern part of the Tirap district and is the extension of the Makum Coalfield of Assam. It forms an extensive linear belt extending for over 350 km from Haflong in SW to Namchik Namphuk. in NE. The coalfield lies between 27°18' and 27°28' N latitudes and 95°58' and 96°14' E longitudes. The area is drained by Namchik and Namphuk, two tributaries of the Buri Dihing River and is approachable by a fair weather road from Jagun. The important occurrences of this coalfield are Namchik (27°25':95°58') in the Kuwen Bum area over a stretch of 2.5 km; south of Miao (27°30':96°12') in Miao Bum area and near Jairampur (27°20':96°01').

This coalfield was brought to light by the reconnoitary traverses taken by Medlicott in 1865 and by La Touche in 1886 in the Namchik valley and Miao Bum area respectively. Pascoe (1912) reported the occurrence of a 18 m thick coal seam near Namchik. U. Bose, A. Chowdhury and V.D. Puri have carried out detailed work in the potential coal bearing areas in 1968-69 and made an assessment of the coal resources of this region.

The coal seams of this field are confined to the lower member of the Tikak-Parbat Formation of the Barail Group of Oligocene period. The beds are folded into an asymmetrical syncline, the Namchik syncline, which is the eastern continuation of the Namdang syncline of the Makum Coalfield and is delimited to the north by Margherita Thrust and by the Dirang Thrust in the south. Coal measures are exposed on the northern limb of the syncline striking ENE-WSW with southerly dips varying from 15° to 35°. The rocks of Jairampur form the southern limb of the syncline and in general strike in E-W with northerly dips varying from 40°-70°.

Geological mapping in the area between Namchik and Namphuk Rivers has indicated that the coal seams extend over a strike length of about 10 km in this area. The total reserve assessed to 85 million tones upto a maximum depth of 600 m for all the eight seams. Regional exploration of the most potential portion of this area extending over a strike length of 3 km indicated a proved reserve of 17.1 million tones for seams above 1.2 m thickness. A total of eight coal seams have been established by drilling. The details of their thickness, chemical analyses and reserves of indicated coal seam are given in table 1.5.6.

**Table: 1.5.6: Chemical analyses, thickness and seamwise proved reserves of coal in Namchik-Namphuk area. (after Raja Rao,1981)**

| Coal Seam No. | Thickness (m) | Analyses | | | Reserves (million tones) |
|---|---|---|---|---|---|
| | | Moisture (%) | Ash on air dried basis (%) | Sulphur (%) | |
| VIII<br>Parting | 1.3-2.1<br>7-8 | 2.2-2.6 | 5.9-9.1 | 4.0-4.3 | Not estimated |
| VII<br>Parting | 1.3-2.7<br>2.0-5.0 | 3.0-3.3 | 10.3-19.3 | 3.6-5.1 | Not estimated |
| VI<br>Parting | 0.4-1.2<br>11-24 | 2.7-3.3 | 10.5-24.5 | 3.1-5.6 | Not estimated |
| V<br>Parting | 1.0-2.3<br>8-23 | 1.9-3.2 | 5.6-17.1 | 1.6-7.5 | 1.47 |
| IV<br>Parting | 1.3-5.4<br>7-39 | 2.1-3.8 | 4.8-21.4 | 3.1-5.1 | 4.19 |
| III<br>Parting | 2.4-16.4<br>2-31 | 2.2-3.4 | 3.8-18.9 | 3.0-4.1 | 9.81 |
| II<br>Parting | 0.2-2.8<br>1.7-18 | 1.9-3.7 | 5.5-27.8 | 1.6-4.0 | 0.92 |
| I | 0.25-2.70 | 2.0-2.7 | 4.8-24.7 | 1.7-6.3 | 0.71 |
| | | **TOTAL** | | | **17.10** |

The Seam No. III is the most persistent seam and is likely to continue at depth. The indicated reserve has been estimated at 8.3 million tones for this seam. The reserves of the top three seams are not assessed due to their tendency of pinching and swelling within short distances.

In Miao Bum area two seams, with an aggregate thickness of 10 m, crop out at the surface. The indicated reserves are 6 million tones up to a depth of 200 m down dip.

In Jairampur area a total aggregate thickness of 8 m of coal is reported within the Tikak Parbat Formation, east of Manchik River (Raja Rao, 1981). The coal bed in the southern strip probably continues westwards and is exposed near Wington, NE of Nampong. Nine coal seams, varying in thickness from 0.17 to 7m have been identified during surface mapping and in boreholes sections (Mukherjee, 1990).

### (ii) ARSENOPYRITE

**Lower Subansiri District:**

About 100 m upstream of the confluence of Kale River and Ranga River, arsenopyrite mineralisation is seen in a sheared, 1-m-thick quartzite and quartz veins. Analytical results of samples from this zone have recorded upto 23.37% arsenic, 10.13% sulphur, 100 ppm cobalt and 50 ppm nickel.

### (iii) BASE METALS

Occurrences of base metal mineralisation have been recorded from West Kameng, East Kameng, Upper Subansiri, Lower Subansiri, West Siang, Dibang valley, Lohit and Tirap districts. The mineralisation occurs as strata-bound in the meta-sedimentaries and also in the intrusive quartz veins. It is erratic and poor in grade at most of the places and hence, it has not been economically exploited anywhere.

**West Kameng District**
**Mukatung-Shergaon (83A/8):**

Stratabound sulphide mineralisation is found within the Mukatung Formation (Chilliepam Formation) comprising mainly of phyllite with bands of dolomite and quartzite. The mineralised bands occur in the eastern limb of a regional antiform having NNE-SSW axial trend.

Lead and zinc mineralisation mainly represented by presence of galena and sphalerite occurs within the dolomite bands in the form of disseminations, stringers, veins, fracture fillings, blotches and segregations. The mineralised belt extending for about 9 km length in NE-SW direction has been divided into three blocks, namely Mukatung Block, Amritganga-Vasundhara Block and Shergaon Block. The thicknesses of the dolomite bands vary from 15 m to 100 m. The mineralisation is patchy with highly erratic strike continuity and depth persistence. The average Pb-Zn content is less than 1.5%.

**Table 1.5.7 Analysis of Shergaon lead-zinc mineral deposit samples, West Kameng district, Arunachal Pradesh**

| Element | Galena rich ore | Sphalerite rich ore | Soil |
|---|---|---|---|
| Pb | 4.72 to 84.02% | 900 ppm | 1.12% |
| Zn | 0.1 to 0.32% | 43.5% | 0.79% |
| Ag | <90 ppm | 2 ppm | <10 ppm |
| Cd | <70 ppm | 900 ppm | - |
| Sb | <4000 ppm | - | - |

**Other occurrences in West Kameng district:**

Mineralised zones with pyrrhotite and pyrite have been located between 74 km and 75 km stones (near culverts 71/5 and 69/3) on the Chardwar-Dedza-Bomdila road. The host rock quartzite is associated with carbonaceous phyllites.

Pyrrhotite mineralisation has been noticed in mica schist associated with the dolomite on the Chilliepam-Jigaon road.

A zone with sulphur leaching has been recorded at Dedza (27°12':92°30') in the carbonaceous slates occurring at the base of dolomite.

A 1.5-m-thick mineralised zone consisting of pyrrhotite is recorded in quartzite at Dirang (27°20':92°16')

A few specks of galena and magnetite have been reported from the marble exposed in the Rinkho nala, west of Gocham (27°13':92°19'). Sulphur leaching zone in mica schist has been noticed at the base of dolomite near Jigaon (27°11':92°20').

A 5-m-thick sulphide zone of fine dissemination and small pockets of chalcopyrite, bornite and pyrite is reported from biotite schist located along Lumla-Yabab-Sherbang foot-track, near Gomkangrong Chu (near Lumla ). The visual estimates indicate upto 0.5% content of sulphides. The associated quartzite bands, however, show only pyrite mineralisation. Wide zones of sulphur leaching are observed in the area.

**East Kameng District:**

**Pakro (27°14'05":93°04'10"):**

Sulphide mineralisation in metasedimentaries of Khetabari Formation of Precambrian age is recorded around Pakro area. The sulphide mineral assemblage of pyrite, chalcopyrite and galena occurs in the form of fine disseminations and specks.

Two distinct types of sulphide mineral assemblages are noticed restricted to micaceous quartzite/quartz mica schist, viz., pyrite and chalcopyrite assemblage, considered syngenetic and the other epigenetic galena-pyrite assemblage associated with quartz veins. The Values recorded is not encouraging (Table 1.5.8).

**Table 1.5.8. : Analysis of sulphide mineral assemblages of Khetabari Formation around Pakro, East Kameng district, Arunachal Pradesh**

| Element | Pyrite-chalcopyrite | Galena-pyrite |
|---|---|---|
| Cu | 30 to 400 ppm | <20 to 100 ppm |
| Pb | <100 ppm | 125 to 475 ppm |
| Zn | 30 to 300 ppm | 125 to 475 ppm |
| Ni | <50 ppm | <50 ppm |
| Co | <50 ppm | <50 ppm |
| Cd | <20 ppm | <20 ppm |

**Upper Subansiri District:**

**Bara Rupak (28°00':94°20'):**

A 30 m wide and 3 m thick lense of quartzite exposed in a stream channel at 45 km stone on Daporizo - Gasa road carries stringers and disseminations of pyrrhotite and minor chalcopyrite. The maximum values analysed for Cu, Ni and Co are given in Table 7.3.

**Daporizo:**

Specks of chalcopyrite and malachite stains are seen in a steeply dipping sequence of quartzite and quartz-mica shcist exposed at 4 km from Saddle (27°50':94°10') towards Daporijo.

**Daporijo-Taliha:**

A number of sulphide mineralisation zones are located along the Daporijo-Taliha road. Three such zones, located within a distance of 20 km from Taliha have been sampled. Mineralisation in the zones consists of pyrite and pyrrhotite.

A sulphide zone in graphitic schist extending over a strike length of 500 to 800 m with a width of 40 to 60 m containing pyrite and cobalt bearing pyrite has been located near Taliha (28°15':94°10'). Chemical analysis values of a few samples are given in Table 7.3.

***Lamdak* (27°15':94°15'):**

Sulphide mineralisation in graphitic schist is seen along Daporijo-Tamen road. The results of chemical analysis of samples are not encouraging (Table 1.5.9).

**Table: 1.5.9: Analytical results of samples from Daporijo-Taliha, Bara Rupak and Lamdak areas, Upper Subansiri district, Arunachal Pradesh**

| Element | Bara Rupak | Daporijo-Taliha | Lamdak |
|---|---|---|---|
| Sn | - | 250 ppm | - |
| Co | 0.06% | 0.6% | 250 ppm |
| Ni | 0.02% | 700 ppm | 750 ppm |
| Cu | 0.15% | 600 ppm | 75 ppm |
| V | - | 600 ppm | - |

**Lower Subansiri District:**

**Kamla Valley (82H/12 & 16 and 83E/9 & 13):**

The gneisses and low grade metasedimentaries at Luba, northwest of Gingba and south of Godak Basti carry base metal sulphides represented by pyrrhotite, pyrite, chalcopyrite, bornite and galena.

**Ranga Valley (Potin-Yazali area):**

Polymetallic sulphide mineralisation represented by pyrite, pyrrhotite, chalcopyrite with minor sphalerite and galena associated with Ni, Co, Sn and W has been reported from Potin area between 41 and 45 km stone on Kimin-Ziro road on either side of the Ranga (Panyan) River. The mineralised zone extends over a strike length of 3 km with a width of upto 300 m and occurs in the greenschist to lower amphibolite facies rocks of Potin/ Khetabari Formations of the Bomdila Group. The mineralisation is confined to the magnetite-bearing schistose units of the Potin Formation.

Systematic exploration in this area has helped in delineating three different types of mineralised zones. They are:

a) Cobaltiferous pyrite zone mainly in the north of the Ranga River, having a strike length of 250 m with 0.03% to 0.25% Co.

b) Nickeliferous pyrrhotite zone mainly in the south of the Ranga River having a strike length of 185 m with 0.28% Ni. Sporadic high values of Pb (upto 4.6%) and Zn (upto 2.20%) have been obtained in this zone in one borehole.

c) Two copper rich zones, one extending for about 385 m with average grade of 0.33% Cu and other for about 145 m with upto 0.19% Cu.

A possible reserve of 1.55 million tones of copper ore with an average grade of 0.33% has been tentatively estimated in the area. There are sporadic patches of high Cu (upto 0.5% to 0.66%) values.

**Sagali-Yazali area (83E/ 15):**

Sulphide mineralisation is reported between 16 and 23 km stones on Sagali-Yazali road. Dissemination, stringes and veinlets of pyrite, pyrrhotite and chaclopyrite occur within quartz veins and along fracture planes in quartzite. Stains of malachite and azurite are seen on weathered surfaces.

**Serr area (83E/11):**

In this area, the sulphide mineralisation in the form of disseminations, stringers and veinlets is found with association of quartzite. The sulphide minerals are mainly pyrite, chalcopyrite and pyrrhotite. The analytical results of pyrite, chalcopyrite and pyrrhotite bearing quartzites from the area have indicated Cu<20 to 125 ppm, Pb<100 ppm, Zn<20 to 70 ppm, Co<50 ppm and Cd<20 ppm.

**Tale-Pange area (27°32':94°57', 83E/14):**

A 30 m thick shear zone occurring in quartzite contains pyrrhotite near Tale. A shear zone in the granite near Pange contains profuse malachite stains.

**Yazali-Tago area (83E/15):**

The carbonaceous phyllite and marble occurring as lenticular interbands within the schistose quartzite of Khetabari Formation show presence of sulphide mineralisation, mainly pyrite in the form of fine disseminations, veinlets and stringers near 51 km stone along Kimin-Ziro road, near Tago Power House site and 1.5 km south of Tago Power House site. Analytica result obtained is not encouraging.

Spectrochemical analysis of six samples of carbonaceous phyllite exposed along Yazali-Tago road is given in Table 1.5.10.

**Table 1.5.10: Metal content in carbonaceous phyllites of Khetabari Formation occurring in Yazali-Tago area of Lower Subansiri district, Arunachal Pradesh**

| Element | Value | Element | Value |
|---|---|---|---|
| Cu | 15 to 1000 ppm | Zr | <10 to 150 ppm |
| Pb | <10 to 40 ppm | Ti | 40 to 500 ppm |
| Ni | 45 to 1000 ppm | V | 10 to 400 ppm |
| Sr | 10 to 25 ppm | Ba | 80 to 400 ppm |
| Cr | 30 to 300 ppm | Mn | 60 to 600 ppm |
| Be | 10 to 20 ppm | - | - |

**West Siang District:**

**West of Along:**

Boulders containing pyrrhotite are seen in two streams near Liromoba (28°05': 94°30'). Boulders with pyrrhotite and minor chalcopyrite and copper oxides are reported in three streams near Kambang (28°15':94°15').

**Ragidoke area (82L/12):**

Sulphide mineralisation in the area is confined to quartzites and dolomites and is distributed mainly as fractures filling within quartz veins, dissemination and specks and at places, as irregular patches of segregated grains. It is represented predominantly by pyrite with minor amount of chalcopyrite and pyrrhotite. A total of six mineralised zones are recorded. Results of analyses of surface samples for Cu, Zn and Pb are given in Table 7.5

**Tai-Badak-Tachidoni-Tirbin area (27°57':28°00', 94°30':94°35', 82L/16 & 83I/9):**

The sulphide mineraliasation represented by pyrite, pyrrhotite and chalcopyrite occur as sporadic minor dissemination, fine specks, thin stringers along fracture planes in quartz veins and foliation planes within quartzite, carbonaceous phyllite, magnetite, quartzite and dolomite. The analytical results are not encouraging (Table 1.5.11).

**Table: 1.5.11: Chemical analysis of sulphide incidence in Ragidoke and Tai-Badak-Tachidoni-Tirbin areas, West Siang district, Arunachal Pradesh**

| Element | Ragidoke | Tai-Badak-Tachidoni-Tirbin |
|---|---|---|
| Cu | <20 to 125 ppm | 20 ppm to 0.38% |
| Pb | <100 ppm | 10 to100 ppm |
| Zn | <20 to 30 ppm | 20 to 250 ppm |
| Au | - | 100 ppb |
| W | - | 100 ppm |
| Co | - | 50 to 75 ppm |
| Ni | - | 50 to 100 ppm |

**East Siang District:**

Pugging (28°15':94°55'): In this area the occurrence of chalcopyrite was suspected by LaTouche (1883) on examining of a few boulders in the upper reaches of Sissi nala North of Pugging.

**Dibang Valley And Lohit District:**

**Arunli village (28°35':95°45'):**

Thin stringers of pyrite with specks of chalcopyrite are reported from Arunli village, Eurah valley, in association with actinolite quartz schist within diorite gneiss and about 10 km upstream of Roing. The analyses of a few samples recorded Cu 75 to 125 ppm, Ni 50 to 150 ppm and Co 20 to 125 ppm.

**Mehao lake:**

Incidence of base metal mineralisation in the form of specks and stringers in quartz and pegmatite veins intruding diorite gneiss and amphibolite was recorded in the area between Yatong and Dichu around Mehao lake but results obtained is not encouraging (82P/16, 92A/9 & 13, 92H/3 &4) .Table 1.5.12 gives the base metal values of samples drawn from the deposit.

**Table 1.5.12 : Analysis of samples (7 Nos.) from Yatong-Dichu base metal deposit, West Kameng district, Arunachal Pradesh**

| Element | Content | Element | Content |
|---|---|---|---|
| Cu | 200 ppm to 0.88% | Cd | <20 ppm |
| Pb | <100 ppm | Cr | <10 ppm |
| Zn | 30 to 125 ppm | Mo | <50 ppm |
| Ni | 50 to 300 ppm | Li | <20 ppm |
| Co | <50 to 900 ppm | | |

**Onseam village (28°00':97°00'):**

Stringers and patches of pyrite in a 10 m wide epidote granulite band occurring within hornblende schist have been recorded West of Onseam village (28°00':97°00') in Tellu valley. Analysis recorded a value of 0.32 % for Cu.

**TIRAP DISTRICT:**

Small nodules and veins of pyrite were observed in Disang Shales between Bhogapani (27°09':95°24') and Khonsa (27°06':95°32') along a road cutting and river sections. These occurrences are of academic interest only.

**(iv) GOLD**

**Lower Subansiri District:**

**Gold in Siwaliks:**

Gold panning was recorded from Subansiri River during the time of Ahom Kingdom. Preliminary investigations to find out the auriferous Siwalik rocks were carried out around Doimukh (27°08’30":93°45’25"), Naharlagun (27°06’00":93°41’40"), Pomsa (27°04’45": 93°02’00"), Sonajuli(27°01’45":93°37’40") and Balijan (26°57’30":93°30’40"). On panning, pebbly beds of Upper Siwalik (Kimin Formation) have shown presence of gold in form of fine dust, minute grains and fine flakes as noticed in the streams/sediments/terraces. Bedrock samples analysed less than 50 ppb Au values. In the stream sediment samples Au values vary from 50 ppb to as high as 2.67 ppm and in terrace samples, the Au value recorded is less than 50 ppb.

**Potin Yazali area:**

Incidence of gold has been reported from polymetallic sulphide zone of Potin-Yazali area, Lower Subansiri district. Bedrock samples from the meneralised zone have indicated gold values ranging from <50 ppb to 300 ppb and silver values from <2 ppm to 20 ppm, whereas stream sediment samples from zones of mineralisation have recorded gold values ranging from <50 ppb to 2.1 ppm. The gold is associated with polymetallic sulphide mineralisation represented mainly by pyrite, pyrrhotite with minor chalcopyrite, galena and sphalerite. The host rock for mineralisation is magnetite bearing garnetiferous quartzite and biotite-chlorite schists of Potin Formation (ºKhetabari Formation) of Bomdila Group.

**Tirap District:**

Although no authentic information on the occurrence of gold is available, the historic record of gold panning in Burhi Dihing River is worthy to mention.

**(v) IRON**

**East Kameng District:**

**Bana Basti (27°16':92°52'):**

Occurrence of boulders of micaceous hematite (at places with magnetite as float) on a small ridge on the right flank of Bichom River opposite to Bana Basti camping ground is recorded within quartzite.

**Upper Subansiri District:**

**Lamdak (27°15':94°15') and Godak (27°50':94°10'):**

A number of minor occurrences of iron ore are reported between Lamdak and Godak. Float ore boulders of hematite and magnetite have been observed on the bank of Simmi River. Occurrence of similar ore falling in the strike of ferruginous zone has been observed near Tawa (27°45':94°51') in the Kamala valley.

**Lower Subansiri District:**

**Kimin (27°20':94°06') and Taihing (27°20':94°05'):**

Small rolled boulders of iron ore are reported from the alluvial terraces in Tertiary belt near Kimin and Taihing across the Ranga valley. Occurrence of magnetite has been reported from Biting area in Ranga valley. The zone extends from southern bank of Ranga River to the north bank over a strike length of about 5600 m with a width of 20 m.

**West Siang District:**

**Tirbin (28°00': 94°35') and Late (28°00':94°35'):**

Hematite-magnetite has been found east of Tirbin to Late. It occurs as a vein deposit in the fine grained schist and phyllite. Chemical analysis shows 53.6 to 62.6% of Fe. Minor occurrences are found near village Yomcha (28°00':94°03').

**(vi) MOLYBDENITE**

**Dibang Valley District:**

**Apruni:**

Occurrence of molybdenite within quartzo-felspathic vein near Apruni (28°35': 95°51', 82P/14) was reported. Only one mineralised vein is noticed, which has limited strike extension of about 5 meters. On chemical analysis, the value of Mo is found to be below detection limit. Occurrence of Mo in this area is of academic interest only.

### (vii) PLATINOIDS

**Dibang Valley District:**

The ultramafic bodies intruding the para-metamorphites of Ithun Formation (of Bomdila Group) in Myodia area have been investigated for platinoid group of elements (PGE). The analytical results of 10 samples collected from this area have recorded Pt values ranging from <5 ppb to 50 ppb and Pd value less than 10 ppb.

**Lohit District:**

Investigation for PGE in the serpentinite body occurring along Tidding river section, near Tidding village (92 A/5) was carried out. Analytical results obtained for platinum and palladium in Tidding area are a little higher than that of normal geochemical abundance of platinoids in the lithospheric crust (Table 1.5.13). Analytical results for 12 samples gave higher values of 73 ppb for Pt and one sample showed value of 134 ppb for Pd.

Randomly collected samples gave values ranging from 2 to 30 ppb for Pt and less than 2 to 23 ppb for Pd.

Out of 65 samples collected during field season 1987-88 and 1988-89 results of 15 serpentinite samples were received for platinoid elements. Table 1.5.13 details the concentration of platinum group of elements. The overall average of all the platinoid elements is 25.5 ppb.

**Table 1.5.13: Analytical results of platinum group of elements from samples drawn from serpentinite body occurring near Tidding village, Lohit district, Arunachal Pradesh**

| Element | Concentration (ppb) |
|---|---|
| Pt | 2 to 28 |
| Pd | 3 to 14 |
| Ru | 2 to 10 |
| Lr | 4 to 14 |

### (viii) ASBESTOS

Veins of fibrous actinolite and tremolite asbestos associated with serpentinite have been located 1 km upstream of the confluence of Lohit (Tellu) and Tidding Rivers on Tezu-Hayuliang road in Lohit district, and also at 52 km post on Roing-Hunli road, Dibang Valley district.

A 3.2 m wide zone of chrysotile variety of asbestos associated with a dyke of ultrabasic rock is found near Gamra La (27o 41'32":91o50') in West Kameng district. It is found at the peak of the ridge ∆4624).

### (ix) BERYL

**Tachuli (27°29':93°46'):**

White beryl-bearing pegmatite vein emplaced within gneisses has been reported from Tachuli (27°29':93°46') in Lower Subansiri district.

### (x) CLAY

**West Kameng District:**

**Bhalukpong-Tipi foothill area (83A/12 & 16 and 83B/9):**

The clay beds in the area are grey to steel grey in colour with moderate to good plasticity and generally associated with soft, friable sandstone unit of Upper Siwaliks and sandstone-shale sequence of Middle Siwaliks.

A total of nine occurrences of clay bearing horizons, mainly in the area around Tipi nala, Dippi nala, Mausari nala, Doinera (26o59'24":92o25'22"), Diphuta and Chopai (26o56'20": 92o24'00") have been identified. An inferred reserve of approximately 54,350 tones of clay is estimated for all the 23 bands, of which 2700 tones from six bands are found to be of good quality. Chemical analysis recorded the values of SiO2>40% and SiO2+Fe2O3>70%.

**East Kameng District:**

**Seijussa-Namorah area (83E/4 and 83F/1):**

Occurrence of clay as thin beds and lenses in Upper Siwaliks are reported from Majuli nala, Seijussasu nala, Dikrai nala Tarasu nala, Batibasti nala Giladhari nala, Bargang river section, Gangtunga nala section and Dibru nala. The results of chemical analyses are given in Table 1.5.14

The chemical analysis shows that the clays confirm to pozzolonic clay grade. The inferred reserve of the clay beds in the area is 81,372.62 tones.

**Table 1.5.14: Results of chemical analysis of clay samples drawn from Seijossa-Namorah area, East Kameng district, Arunachal Pradesh**

| Consituents | Assay values |
|---|---|
| $SiO_2 + Al_2O2 + Fe_2O_2$ | <70% |
| $SiO_2$ | 60% to 70% |
| CaO | <5% |
| MgO | <3% |
| $Na_2O + K_2O$ | <3% |
| LOI | <10% |

**Lower Subansiri District:**

**Doimukh-Kheel area (83 E/12 & 16):**

Thin beds and lenses of clay are noticed mainly in the Upper Siwaliks. The important occurrences of clay are reported from left bank of Dikrang River, Rano Juli, Emchi nala, Gulo Juli, East of Midpu village and Gumalo nala areas. The chemical analysis (Table 1.5.15) confirms it to be pozzolonic clay. The inferred reserve of the clay in the area is 63,812 tones.

**Table: 1.5.15: Chemical analysis of clay beds in Doimukh-Kheel area, Lower Subansiri district, Arunachal Pradesh**

| Constituent | Content |
|---|---|
| $SiO_2 + Al_2O_3 + Fe_2O_3$ | >70% |
| $SiO_2$ | >60% |
| CaO | <1% |
| MgO | <3% |
| $Na_2O + K_2O$ | <3% |
| LOI | <10% |

**Nitabol (27°20':93°48'):**

A small pocket of clay is reported in Nitabol along the Ranga valley.

**Dibang Valley District:**

**Roing (28°08':95°49'):**

Occurrence of white clay associated with Upper Tertiary rocks was reported from Roing.

**LOHIT DISTRICT:**

**Chiolbu-Karanu area:**

Occurrence of white to brown clay as very thin bands is reported all along the Mishmi thrust in the foot-hills from Chiolbu (28°12':95°47') to Karanu (28°03':95°57').

**Denning (28°13':96°01'):**

Pink clay with high proportion of grit with ferruginous material associated with Upper Tertiary rock is reported at Denning (28°13':96°01')

**Tezu (83 M / 13 & 92 A / 1):**

Two types of plastic clay is found in the western part of the area investigated in the low level alluvium and has been identified as bottom yellow clay and top whitish grey clay. The clays in the area are highly siliceous and have high colour oxides which are not suited for industrial purpose but are useful for manufacture of bricks and other building material. The estimated reserve of the top whitish grey clay is 0.8 million tones whereas the bottom yellowish brown clay is 4 million tones. The chemical analyses of the two clay horizons are given in table 1.5.16

**Table 1.5.16: Analytical results of white grey clay and yellow clay exposed near Tezu, Lohit district Arunachal Pradesh.**

| Constituent | White Grey Clay | Yellow Clay |
|---|---|---|
| $SiO_2$ | 46.35 to 49.02% | 47.31 to 51.06% |
| $Al_2O_3$ | 8.46 to 10.43% | 15.52 to 16.95% |
| $Fe_2O_3$ | 2.69 to 4.19% | 4.19 to 8.19% |
| MgO | 15.06 to 18.62% | 3.07 to 7.37% |
| CaO | 3.25 to 4.95% | 2.97 to 7.07% |

**(xi) DOLOMITE**

**West Kameng District:**

**Dedza (27°12':92°34'):**

Dolomite occurrences at Dedza are reported over a strike length of 1.5 km with a width of 250 meters. Reserves have been estimated to be 58 million tones. The chemical analyses show CaO-30%, MgO-20% with low insolubles, which specifies that it, is useful for manufacture of refractories and in agriculture and paper industries.

**Rupa area (27°12' 26":94°24'28"):**

The dolomite deposit is located to the southwest and west of Rupa in the form of a down faulted block within the low grade metamorphics of Tenga Formation. The analysis of 3,456 channel samples collected (Table 1.5.17) suggests that the deposit is of SMS and BF grade. A total of 185 million tones of probable reserves have been estimated over an area of 0.66 sq km.

The chemical analysis of the grab samples collected from Rupa area indicates about 1km zone of chemical grade dolomite.

**East Siang District:**

**Tarak (28°13':94°55') and Pangin (28°12':94°55'):**

A number of fine grained grey dolomite limestone outcrops along Siang River between Pasighat (28°05':94°20') and Pugging (28°45') and a few bands of dolomite between Tarak (28°13': 94°55') and Pangin (28°12':94°55') have been reported. Analysis of a few samples is given in Table 1.5.17

**Table 1.5.17: Analyses of dolomite deposits in Tarak-Pangin area, East Siang district and Rupa area West Kameng district Arunachal Pradesh**

| Constituent | Tarak-Pangin | Rupa |
|---|---|---|
| CaO | 27 to 37% | 30% |
| MgO | 11.56 to 20.33% | 20% |
| Insolubles | 1.76 to 16.51% | <18% |
| $R_2O_3$ | 0.72 to 3.40% | <1% |

**(xii) GLASS SAND**

**West Kameng District:**

**Rupa (27°12'26":92°24'28") area:**

White pure quartzite, possibly suitable for glass industry, occurs in association with Tenga Formation in Rupa (27°12'26":92°24'28") area. The Kalaktang Quartzite is suitable for ferrosilicon industry.

**(xiii) GRAPHITE**

**Lower Subansiri District:**

**Khetabari (27°22':93°48'):**

Graphite (amorphous) occurrences as small pockets and as lenses (40 to 80 meter long and 20 to 30 m wide) within a sequence of phyllitic quartzite and calc-silicate rock are reported near Khetabari on Kimin-Ziro road.

The graphite lenses are arranged parallel to the foliation of the country rock and occur over a distance of about 5,000 meter. A probable reserve of 1 million tones has been inferred.

**Upper Subansiri District:**

**Bopi (27°52':94°14'):**

Occurrence of amorphous graphite in grey phyllite is recorded at Bopi. Two lensoidal bodies of graphite with thickness of 2 m and 60 m have been reported. The analysis shows average carbon content of 16.23 %.

**Chuckro nala:**

Flaky graphite occurs in quartz-biotite-sillimanite schist and gneiss in Chuckro nala.

**Bopi-Lamdak (83 I / 1) area:**

Occurrence of amorphous graphite is recorded within the Simi Member of Khetabari Formation of Precambrian age. This member comprises fine grained and compact phyllite with lenses and pockets of graphite. Analytical results indicate very low 6.29% average graphitic carbon with maximum and minimum values of 18.10% (west of Ange Lamdak) and 0.63% (between Lamdak and Ange Lamdak), respectively.

North of Bopi, reserves of graphite-bearing rocks have been calculated as 3,67,175 tones with average graphitic carbon of 8.5%. Southeast of Bopi the reserves are 51.250 tones with 9.9% average graphitic carbon. Graphite bearing rock is reported from the area between Lamdak and Ange-Lamdak. Their reserves are estimated as 41.875 tones with 5.3% average graphitic carbon.

**La-Lamdak (27°51'-27°53':94°13':94°15'):**

It occurs between 105 and 110 km stone on Ziro-Daporijo road. The deposit in La is flaky and amorphous in Lamdak.

Flaky graphite in La area occurs as dissemination and specks within the quartz-albite-sillimanite schist. The graphite bearing lenticular band is persistent over a strike length of 186 meters with an average true width of 2.50 meters. Another minor band has been traced over a strike length of 44 m with an average thickness of 1.25 meters.

The average graphite content is 12 % and the average value of LOI is 16.38 %. The results of beneficiation tests indicate that graphitic carbon could be upgraded to 85 % with 12 % ash. The quality of graphite is suitable for manufacture of crucibles, paint and foundry facings.

Reserve of the main band is estimated at 21,866 tones to a depth of 30 m and the minor band has a reserve of 1,391 tones to a depth of 20 meters.

Amorphous graphite in Lamdak area occurs in association with quartz-mica schist and phyllite. It is intercalated with thin partings of micaceous and carbonaceous materials. The band has been traced over a strike length of 330 m with an average true width of 30 m. The average graphite content of amorphous graphite deposit is about 16.24 % (LOI method). The reserve is estimated at about 330 million tones to a depth of 140 meters.

**Taliha (26°15':94°09'):**

Occurrence of sulphide and graphite bearing sequence is reported at Taliha. Graphite occurs as small flakes and finely crystalline particles disseminated within the quartzite. The graphitic band occurs within a sequence of quartzite, micaceous quartzite and garnetiferous quartz-mica schist with occasional thin bands of coarse crystalline marble. The graphite is almost invariably associated with sulphide minerals, chiefly pyrite.

The main graphite band is exposed along both the banks of Subansiri River and extends over a strike length of about 50 meters. A 30 million tones reserve of graphite has been estimated upto a depth of 90 meters. About 75 samples have been analysed with variable carbon values, the (maximum) being 25.58 %. The graphite is intimately associated with sulphide minerals with significant values of Co, Ni, Cu, W and Sn. The flaky variety of Taliha graphite is amenable to beneficiation for upgrading upto the extent of 85 % for the manufacture of crucible, paints, pencil lead and foundry facings.

**Upper Siang District:**

Ninging: Graphite schist is exposed as three distinct zones between Rubang nala and Ninging village. The first zone has a strike length of 310 m with an average thickness of 11 m with a down dip extension of 300 m. The second and third zones have their strike lengths and thicknesses of 300 m X 20 m, 150 m X 100 m, 10 m X 100 m respectively. A probable reserve of 44.8 million tones has been estimated for these graphite bands. The beneficiation study indicated high content of ash (86-92 %) as well as high volatile matter (4.9-6.8 %).

**West Siang District:**

**Tai (27°59':94°32') and Tachidoni (27°58':94°31'):**

The graphite band of amorphous variety occurs within garnetiferous kyanite-staurolite-mica schist over strike length of 2.04 km with an average width of 11 meters at Tai village. The reserve has been inferred as 10.35 million tones upto a depth of 130 meter. Near Tachidoni, 3 km SW of Tai village, amorphous graphite is exposed in the road section and probably represents the strike continuity of the Tai occurrence.

**Dibang Valley District:**

**Hunli (28°19'15":9558'30"):**

Flaky variety of graphite is occurring within grey phyllite and phyllitic quartzite at Hunli 90 km from Roing (28°08'20": 95°50'50") on Roing-Hunli road. The graphite bearing grey phyllite and phyllitic quartzite is exposed within a width of 800 meters.

**LOHIT DISTRICT:**

**Lalpani (27°56':96°23'):**

The main graphite body, over a strike length of 1,100 m with an average width of 300 m, within the garnetiferous schists has been traced at Lalpani, 50 km from Tezu on Hayuliang road. Graphite occurs as fine to medium size flakes in the schist and also as inclusions and coatings.

Fifteen bands of graphite have been found within garnetiferous kyanite-staurolite schist. The average graphite content of the schist is 5.86 %, determined by LOI method. Reserves of the main graphite schist band are 7.50 million tones up to a depth of 100 m. Reserves of the other minor bands has been estimated at 0.50 million tones.

**(xiv) HOT AND SALINE SPRINGS**

**West Kameng District:**

Three hot springs have been reported around

Dirang (27°21':92°16'), Bishum and Bulu. Springs give a strong sulphurous smell and are located along the thrust contact between Dirang Formation and the Se La Group. The physical and chemical properties of the spring water are tabulated in 1.5.18:

**Table 1.5.18: Physico-chemical properties of spring water of West Kameng district, Arunachal Pradesh**

| | |
|---|---|
| Temperature (F°) | 41-42 |
| pH | 7.75-8 |
| Total Hardness (ppm CaCO3) | 252 |
| HCO3 (ppm) | 286-894 |
| Cl(Mg/Lt) | 145-645 |

**Dibang Valley District:**

Structurally controlled hot springs have been reported from Brani (29° 09' 30'': 95° 09' 00'') from west bank of Dari River along a NW-SE trending fault in biotite schist. The physical and chemical properties of the spring water are given below in Table 1.5.19:

**Table 1.5.19: Physico-chemical parameters of hot springs of Upper Subansiri district, Arunachal Pradesh**

| | |
|---|---|
| Temperature (F°) | 60 |
| Ca(Mg/Lt) | 6 |
| $CaCO_3$ | - |
| Cl | 7.9 |
| F | 1.2 |
| Mg(Mg/Lt) | 0.97 |
| Na(Mg/Lt) | 1.42 |
| NO3 | 0.28 |
| pH | 7.5 |
| $SiO_2$ (Soluble) | 15.45 |
| Total Hardness | 20 |

**Upper Subansiri District:**

About 30 thermal springs have been located in the Subansiri and Kamala valleys. These springs are located at Taksing, Maja, Chetu and Rige (most of the springs are confined to Taksing, Maja and Chetu). The physical and chemical properties of the spring waters are given in Table 1.5.20.

**Table 1.5.20: Physico-Chemical parameters of hot springs of Upper Subansiri district, Arunachal Pradesh**

| **Parameter** | **Locality** | | |
|---|---|---|---|
| | **Taksing** | **Chetu** | **Maja** |
| Temperature (F°) | 51.7° | 37.8° | 37.8° |
| Discharge (litres/sec.) | 90 | 30.60 | NFA |
| pH | 7.2 | 7.1-7.65 | 7.7 |
| Sp.Cond.at 25°C | 816 | 1528-1801 | 960 |
| (m.mho./cm) | | | |
| Total Hardness (ppm $CaCO_3$) | 113 | 362-430 | 158 |
| $HCO_3$ (ppm) | 435 | 269-456 | 353 |
| Ca++ (ppm) | 27 | 127 | 54 |
| Mg ++ (ppm) | 11 | 11-27 | 5 |
| Na + (ppm) | 133 | 150 | 86 |
| K + (ppm) | 10 | 17 | 9 |
| Fe +++ (total ppm) | 1.40 | 0.08 | 6 |
| Cl - (ppm) | 18 | 110-190 | 35 |
| $(SO_4)$ - (ppm) | 28 | 370 | 36 |
| $NO_3$ (ppm) | <0.4 | <0.4 | <0.4 |
| F - (ppm) | 2.1 | 1.06 | tr. |
| $SiO_2$ (soluble, ppm) | 80 | 60 | 40 |

Taksing and Chetu lie on the right bank of Subansiri River and Maja lies on the bank of Tsari Chu, a tributary of Subansiri River. Taksing group of springs are located within a radius of 5 km from Taksing. The main zone of springs lies on the left bank of Subansiri River.

Another group of nine hot springs are located on the left bank of the Subansiri River near Chetu. A group of hot springs are located within a radius of 42 m on the right bank of Tsari Chu, near the Bisa bridge, 5 km North of Maja.

The hot springs at Chetu are located in a zone of shearing and emanate through marble, whereas in Taksing and Maja, they emanate through phyllites.

The residue on evaporation of the spring water showed high concentration of B, Li, V, Sr, Mn and F. From the characteristic high ratio of Li/Na, B/Cl and low ratio of Ca/Na, it is apparent that the spring water contains magmatic components.

**Tirap District:**

Saline springs locally called Sum had been known to the local inhabitants for centuries. These were the only mineral resource, which the local people exploited for salt manufacture in the area, during ancient times.

The principal localities around which such springs are located from south to north are Bunting-Lamsa area (27°00':95°35'), Borduria area (27°02':95°25'), and Namsang Lonkhong area (27°02':95°28'). The springs originate mostly in Disang Beds, but a few are located in Barail rocks also. Although no distinct source of salinity is yet known, it is felt that the source is deeper or below the exposed Disang Shales and the brine represents the connate water in the marine sediments.

The springs are seen invariably at the base of the valley near surface drainage. Water temperature from these wells was recorded as varying from 16 to 18.5° C during the months from November to February. The depth and diameter of the wells vary from 1 to 2.5 m and 1 to 1.5 m respectively. The recharge of saline water varies from 1 to 3 cubic meters per hour.

The salinity of water gradually increases from south to north, as indicated below:

1. Bunting-Jhela-Lamsang area- Moderate
2. Borduria-Pullung-Paniduaria area- Moderately strong

3. Namsang-Lonkhong area- Strong

Na values vary from 128 mgm./ ltr. on the low side to as high as 23,000 mgm./ ltr. K values are low varying from 1.4 mgm./ ltr. to 45 mgm./ ltr. These springs were used for manufacture of salt.

### (xv) LIMESTONE

**East Kameng District:**

Bichom river deposit: A sequence of variegated slate, massive and compact limestone/ carbonates and sandstone is seen exposed along the right flank of Bichom River for about 20 km. The total thickness of the exposed calcareous zone is about 30 meters. The chemical analysis of a few samples is given in Table 1.5.21

**Table 1.5.21: Chemical analysis of Bichom River Carbonate near Banabasti, East Kameng district, Arunachal Pradesh**

| Constituent | Bichom river deposit |
|---|---|
| CaO | 26.77 to 49.50 % |
| MgO | 0.48 to 17.22 % |
| $R_2O_3$ | 0.037 to 0.054 % |
| Acid insolubles | 0.14 to 5.14 % |
| $SiO_2$ | 10.27 to 37.94 % |

Calcareous bands associated with slaty rocks are also present in Bichom River section downstream at Bambasti.

**Upper Subansiri District:**

**Menga (28°06':94°09') limestone and dolomite:**

A band of light to grey dolomite and greyish white to white limestone with occasional pink limestone pockets has been located about 20 km from Daporijo on Taliha road. It is exposed over a distance of approximately 8 km along the road stretch and occupies an area of approximately 20 sq km. It is associated with dark grey to black iron stained shale, siltstone and slate (sometimes phyllitic) and light grey to white and pink, fine to medium grained quartzite.

Analytical results of 15 channel and 70 regular chip samples indicate CaO-52.26%, MgO in trace, and insolubles 0.11 to 2.1%. Some samples analysed high MgO values grading into dolomite composition with low Fe2O3 and insolubles and thus revealing its suitability for manufacture of bleaching powder, soda ash, caustic soda, calcium carbide, paper, fertilizer and Portland cement. Reserves upto a depth of 30 m have been estimated at 3.3 million tones.

**East & West Siang District:**

In Pangin (28o12’45":94o59’30"), Lokpeng, Kabu, Dali and Yemsing (27°07’00": 95°00’30") areas limestone suitable for lime burning occurs as linear, impersistant bands showing variable thickness along the strike. In Pangin area, two limestone bands of 0.45 km and 0.75 km strike lengths, 32 m and 22 m average thickness are located within thickly bedded quartzite and phyllites. In Lokpeng area, the limestone forms a SE plunging syncline. A tentative reserve of 37 million tones has been assessed. The limestone of these areas is suitable for lime making.

**West Siang District:**

**Along (28°12':94°45'):**

The crystalline limestone at Kabu with occasional intercalations of sericite-chlorite-quartz schist occurs over a strike length of 346 m with an average true width of 50 meters. A reserve of 1.49 million tones upto a depth of 50 m has been estimated. The average analyses of 40 chip samples have recorded CaO-42.48 %, MgO-3.94 % and R2O3-1.77 %. The analysis also indicates that there are three high calcic bands varying in thickness from 1.40 to 4.15 m within the limestone. Though the high calcic bands are of cement grade, it may not be possible to exploit these by selective mining. Considering the overall quality and quantity likely to be available, the limestone is useful locally for lime burning.

**Tarak (28°45':94°45') and Pangin (28°10':94°55'):**

A few dolomitic limestone bands occur between Tarak and Pangin along the Along-Pangin road. The analytical results of some bands are given in Table 1.5.22.

**Table 1.5.22: Analytical results of limestone bands occuring between Tarak and Pangin on the Along-Pangin road, West Siang district, Arunachal Pradesh**

| Constituent | Concentration |
|---|---|
| CaO | 27 to 37 % |
| MgO | 11.56 to 20.33 % |
| $R_2O_3$ | 0.72 to 3.40 % |
| insolubles | 1.76 to 6.53 % |

**Dali (27°55':94°45') :**

This deposit occurs at 1.5 km east of Along in the course of Tago River, near 80 km stone on the Likabali-Along road. The carbonate bands comprising dolomite and limestone are overlain by fine grained schists and underlain by phyllites of Tenga Formation.

The carbonate bands have a strike length of 3000 m with an average thickness of 240 meters. The total limestone reserve estimated is 225 million tones. The limestone is siliceous and contains high percentage of acid insolubles and is useful for lime making and agricultural purposes.

**Dibang Valley District:**

**Hunli limestone deposit:**

Hunli limestone deposit is located at about 3 km southwest of Hunli in the proximity of Chippomachi nala. It is exposed between 86 and 87 km road markings on the Roing-Anini road (28°18'-28°19':95°57'-95°58'; 82 P/15).

The main limestone body with a strike length of 1.5 km and thickness varying from 74 to 143 meters with two schistose partings has been delineated at road section near 87 km stone.

The limestone is medium to fine grained, greyish white to dark grey in colour and crystalline in nature. The chemical analysis indicates that the limestone is of cement grade. Limestone reserves of probable category to 30 m and 50 m depths estimated are 13.55 and 22.57 million tones respectively. The chemical analysis of a few samples is given in table 1.5.23

**Table 1.5.23: Chemical analysis of Hunli Limestone deposit, Dibang valley district:**

| Constituent | Concentration |
|---|---|
| CaO | 48 to 53.5% |
| MgO | 0.4 to 2.0% |
| $R_2O_3$ | 1.25% |
| Acid insolubles | 2 to 8 % |
| $SiO_2$ | - |

**Pyunli (28o22'50":95o55'40"):**

A 600 m in strike length and 40 m thick lensoid body of marble, suitable for lime burning occurs within biotite gneiss and amphibolite of Ithun Formation.

**Akobe:**

A band of marble, having 1.1 km cumulative strike length with 110 m average thickness is exposed south of Akobe. A tentaive reserve of 41.5 million tones has been estimated upto 150 m down dip extension along the hill slope. The limestone/marble deposit is suitable for lime burning as well as for cement making.

**Lohit District:**

**Tidding limestone:**

Tidding limestone deposit is located at the confluence of Telu and Tidding Rivers. The limestone occurs within low to medium grade metasedimentaries consisting of chlorite-biotite-amphibolite-schists occasionally calcareous with impure limestone. Concordant band of serpentinite occurs on either side of the limestone. The limestone is bluish grey, medium to fine grained, massive with schistose intercalations, excepting a 5 m band with quartz-biotite-sericite-graphite schist within the limestone. The limestone is of flux grade and useful for manufacture of portland cement.

**Table 1.5.24: Chemical analysis (average) of Tidding Limestone, Lohit district, Arunachal Pradesh**

| Constituent | Concemtration |
|---|---|
| CaO | >40 % |
| MgO | 1.5 % |
| $R_2O_3$ | <1.25 % |
| Acid insolubles | 10 % |
| $SiO_2$ | - |

The thickness of the limestone band varies from 140 to 200 meters (average true width being 170 meters) over a strike length of 2.1 km. The reserves of limestone are estimated at 49 million tones and 91 million tones, upto the road level (Tezu-Hayuliang road) and Tidding river level respectively.

## (xvi) MARBLE

**West Kameng District**

Marble associated with Lumla Formation (ºDirang Formation) is located between Gispu, Lumla, Bakhar, and Namstering. It is white, crystalline, siliceous and occurs as alternate bands with quartzites and mica schists.

**Dirang (27°21':82°16'):**

An occurrence of crystalline limestone is reported from 3 km, east of Dirang along Digging valley. Its analyses and those of two other samples collected from the band of the northern bank of the Dirang are given in Table 1.5.25.

**Table 1.5.25: Analytical results of crystalline limestone exposed on the northern bank of Tellu valley, Bambi village, Lohit district and Digging valley, West Kameng district, Arunachal Pradesh**

| Contituent | Bambi village marble band | East of Dirang | Dirang Northern Bank |
|---|---|---|---|
| CaO | 53.62 % | 54.59 % | 39.71 & 40.47 % |
| MgO | 1.14% | 0.54 % | 9.18 & 8.58 % |
| $R_2O_3$ | 2.53 %($R_2O_3$ + Other oxides + Insolubles) | 7.4 % | 2.15 & 1.86 % |
| Insolubles | - | - | 6.50 & 5.83 % |

**West Siang District:**

**Siyom Valley:**

Occurrences of crystalline limestone near Dapu (28°33':94°36') and Lipshui (28°40':94°15') villages and also further upstream near Mechukha (28°48':94°59') have been reported from upper reaches of Siyom valley. The marble occurs within the crystalline sequence.

**Dibang Valley District:**

Two bands of impure marble of 40 m and 150 m width occur along the Tangan River. Another thin impure marble band is observed along the bank of Ichhi nala near Endolin (28°30':95°51'). A 200 metre thick, white, cross-jointed marble band occurs 3 km north of Granli (28°40':95°56'). The marble contains more than 50 % CaO.

A number of marble bands occur between Tezu and Hayuliang. These are generally coarse grained and siliceous in nature and may be useful for lime processing and building purposes.

**Lohit District:**

Tezu area: Two occurrences of marble are reported within the metamorphic rocks near Tezu. The marble is white, medium grained, jointed and in parts foliated in thin section. It consists predominantly of carbonate and tremolite, the latter being evenly distributed in the rock.

Tezu river deposit: About 13 km northeast of Tezu-Doming road, this deposit occurs as a band over a distance of about 1 km across the Tezu river plain. This lenticular crystalline limestone occurring with the granulite schists is exposed over a length of 1,230 meters with an average thickness of 92 meters. The analysis of the band is given in Table 1.5.26. A total of about 30.3 million tones reserve has been estimated to 50 meters depth.

**Table 1.5.26: Chemical analysis of crystalline limestone band, near Tezu, Lohit district, Arunachal Pradesh**

| Constituent | Concentration |
|---|---|
| CaO | 24.35 to 31.29 % |
| MgO | 0.66 to 12.10 % |
| $R_2O_3$ | o.35 to 1.60 % |
| Insolubles | 19.64 to 47.4 % |

**Dora river deposit:**

Calcareous lenses (875 m x 185 m) within quartz-plagioclase-sericite schist are located 10 km east of Tezu. The physical and chemical properties of these marble bands indicate their utility for lime burning and as building material.

**Tellu valley:**

A 200 m wide marble band with an intervening hornblende schist band of 40 metre width is located west of Bambi village (27°58':96°58'). The results of chemical analyses of this marble band confirm specifications for cement grade.

**Lohit And Dibang Valley Districts:**
**Yasang and Walong:**

Mapping carried out in the area between Yatong and Dichu around Mahao Lake (82 P/16, 92A/9 & 13 and 92H/3 & 4) has recorded presence of eight marble bands between Yasang and Walong, varying in thickness from 5 to 20 meters with CaO percentage more than 50 %.

**(xvii) MICA**
**West Kameng District:**

Mica books in pegmatite are reported from Se La and other areas of Kameng district but occurrences are of academic significance only.

**Lower Subansiri District:**

The pegmatite in granite near Ziro (27°20':95°51'), Pitapol (27°20':93°48'), Potin (27°79':93°48') and Terul Dikrang valley contains highly crumpled, fractured and stained biotite and muscovite books. Similarly, pegmatite veins in quartzite near Meghu (27°53':94°15') contain small books of muscovite. The occurrences are uneconomical.

**West Siang District:**

Mica books are found to occur to the WNW of Boleng, but they do not have any economic significance.

**Lohit District:**

Minor occurrences of biotite and muscovite books in pegmatites of Dibang valley have been reported. These are highly fractured and crumpled. The muscovite books are highly stained.

**(xviii) OCHRE**

**West Siang District:**

Ochre phyllites are exposed at several places between Bame (28°03':94°11') and Along (28°11':94°48'). Some promising pockets of yellow ochres on preliminary testing recorded Fe2O3 content from 19.82 to 30.39 %. In general these are of medium to low grade. Five ochre samples showed nickel values from less than 50 ppm to 350 ppm.

**(xix) OIL AND NATURAL GAS**

Exploration for oil and natural gas is beyond the perview of the Geological Survey of India. However, occurrences of oil have been recorded from a few places in course of exploration for coal and geological mapping in Tertiary basin in Tirap and Changlang districts of Arunachal Pradesh, viz. Namchik-Namphuk Coalfield in Jairampur area, Nampong in Disang Formation and Lungchang in Surma Group.

Various other agencies like OIL, ONGC, AOC etc. have been associated with oil exploration in Arunachal Pradesh. Oil India Ltd. is carrying out extensive surveys in two areas viz. Kumchai and Kharsang where two structural highs are recognised. The Kumchai area is located in Mana Bhum Anticline while Kharsang lies in the thrust zone in continuation of Digboi Oil field. In both the areas oil bearing horizon belongs to Girujan Formation of Naharkatia Group. Details of oil production from these two areas are available with OIL.

**Tirap District:**

Oil seepage has been noticed at 7 km SSE of Kanubari on the right bank of Pangjon nala within Tipam Sandstone.

**(xx) QUARTZITE (REFRACTORY/FOUNDRY GRADE)**

**West Kameng District:**

In Kalaktang (27o06’34":92o07’35") area, three thick horizons of quartzites having average thicknesses of about 130 m, 75 m and 125 m interbedded with schistose phyllite and micaceous quartzite forming basal part of the Rupa Group (ºBomdila Group) have been investigated for its use as refractory /foundry grade material. Three quartzite bands I, II and III with thickness of 25 m, 22 m and 60 m respectively have been delineated. These have been further divided into five blocks. The three blocks of band-I have cummulative mineable reserves of 0.94 million tones with average 97.48 % SiO2 and less then 1.6 %. Al2O3. This quartzite may find its use in manufacturing silica refractory bricks. Of these three blocks, Block-I with 0.37 million tonne of quartzite analysing 98 % SiO2 and <0.9 % Al2O3 satisfies the requirement for the manufacturing of ferrosilicon nodules. The quartzite of band - II (Block-IV) and band-II (Block-V) is slightly inferior in quality and have been estimated as 0.21 million tonne and 4 million tones respectively with average SiO2-96.2 % and Al2O3 < 1.6 %.

### (xxi) ROCK PHOSPHATE

**Subansiri District:**

Samples of dark shale and calcareous band within Gensi area exposed near 30 km stone have recorded P2O5 upto 7 %.

**Siang District:**

Likabali-Along road: Banded phyllites 22 km south of Basar on Likabali-Along road having more than 1.85 km strike length and 250 m width have recorded P2O5 content as 0.4 %.

Pangin: Bluish phyllites near Pangin (28°12':94°50') show insignificant presence of phosphate in the field.

### (xxii) TALC

**West Kameng District:**

Dedza (27º12’00":92º34’08"): A low grade, about 8 meters thick schistose talc band associated with dolomite is located near Dedza.

**Lohit District:**

Talc schist with pyrite has been located at a point near 62.5 km from Roing to Hunli.

### (xxiii) FLUX MATERIAL

**Lohit District:**

Tidding(27º58’00":96º24’44"):: A serpentinite body exposed along the Damwe-Hayuliang road section near Tidding, measuring 3 km in strike length and of 50-100 m width may find its use as flux material in iron and steel industry. The whole rock analysis of serpentinites vis-a vis chemical specification for flux grade ultramafics are given below in Table 1.5.27.

**Table 1.5.27: Whole rock analysis of serpentinites vis-a vis chemical specifications for flux grade ultramafics**

| | $SiO_2$% | MgO% | $Al_2O_3$% | CaO % | Alkali% | $Fe_2O_3$ +FeO% | LOI% |
|---|---|---|---|---|---|---|---|
| Whole rock analysis of serpentinites | 32.98 to 54.90 | 4.50 to 40.00 | 0.18 to 16.62 | 0.70 to 14.00 | 0.13 to 7.23 | 1.59 to 9.20 | 0.44 to 13.70 |
| Chemical specifications for flux grade ultramafics | -Max. 40% -32 to 38% | -Max. 35% -38 to 44% | -Max. 2% -Max. 1% | -Max. 2% -Max. 2% | -Max. 2% -<0.1% | - -5 to 10% (Fe) | - 5 to 15% |

Some of the samples indicated analyses conforming to the specifications. The original rock varies in composition from diorite to peridotite.

### (xxiv) URANIUM AND ATOMIC MINERALS

**Siang District:**

**Boleng area:**

Uranium and thorium mineralisation has been found to be associated with dark heavy mineral bandings along bedding planes in the meta-greywackes, flanking the Abor volcanics. Detrital minerals identified in the mineralised zones are monazite, thorite, xenotime, cassiterite and scheelite. Secondary uranium minerals have been noticed in a thin phyllitic layer associated with the quartzites interbedded with meta-greywackes.

**Igo-Darring area:**

Low order radioactivity has been recorded in the contact zone within Pre-Permian metasediments and Gondwana sediments. Similar low radioactivity has been found in the deep brownish yellow soil.

**Ragidoke area:**

Significant radioactivity has been noticed in the phyllite and the adjoining soil covered area. The mineralisation has been found with oxides and sulphide of iron and galena.

**Subansiri District:**

Radiometric surveys have brought to light important radiometric anomalies in Precambrian granite gneiss and migmatite.

★★★

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