

## PALAEONTOLOGICAL RECORDS FROM THE EASTERN HIMALAYAS: A SYNTHESIS

TRILOCHAN SINGH

### Introduction

The present paper is an attempt to synthesize the published palaeontological data from the Eastern Himalayas to put on record the present state of art in this rather poorly attended area of great geological interest.

The Eastern Himalayas, as referred to here, comprises the Himalayan segment between the eastern border of Nepal and the western border of Myanmar, and includes Darjeeling-Sikkim, Bhutan and Arunachal Pradesh (Fig. 1).

Each portion has been dealt separately for the convenience of discussion. Further, the biota, which include fauna, micro-fauna, flora, palyno-flora, etc., is given suitably from different litho-units. As far as possible, care has been taken to incorporate all the important available published information. It is felt that the concise account of the fauna and flora mentioned in the text will be useful to the workers in knowing the current status of the various litho-units concerning their fossil contents.

The geology of these areas has been given by various workers from time to time, and, thus, is not emphasised here. Broadly the regional geology in all these areas, viz. Sikkim-Darjeeling, Bhutan and Arunachal Pradesh, is more or less the same, except for the easternmost Arunachal Pradesh. The reader is referred to the book by Kumar (1998) for a good summary.

The generalised geological set-up of the Eastern Himalayas from south to north is as follows:

<i>Sikkim-Darjeeling</i>	<i>Bhutan</i>	<i>W-Arunachal Pradesh</i>
Tethyan sequence	Tethyan sequence	not exposed
Darjeeling Gneiss	Darjeeling Gneiss	SeLa Group
Daling Group	Daling Group	Bomdila Group
Buxa Group	Buxa Group	Miri Group
		Abor Volcanics
Gondwana Group	Gondwana Group	Gondwana Group
		Lower Tertiaries
Siwalik Group	Siwalik Group	Siwalik Group

As is clear from the above table, the same litho-tectonic units exist in all the three sectors of the Eastern Himalayas, except for the Tethyan Sequence which is not exposed in Arunachal Pradesh.

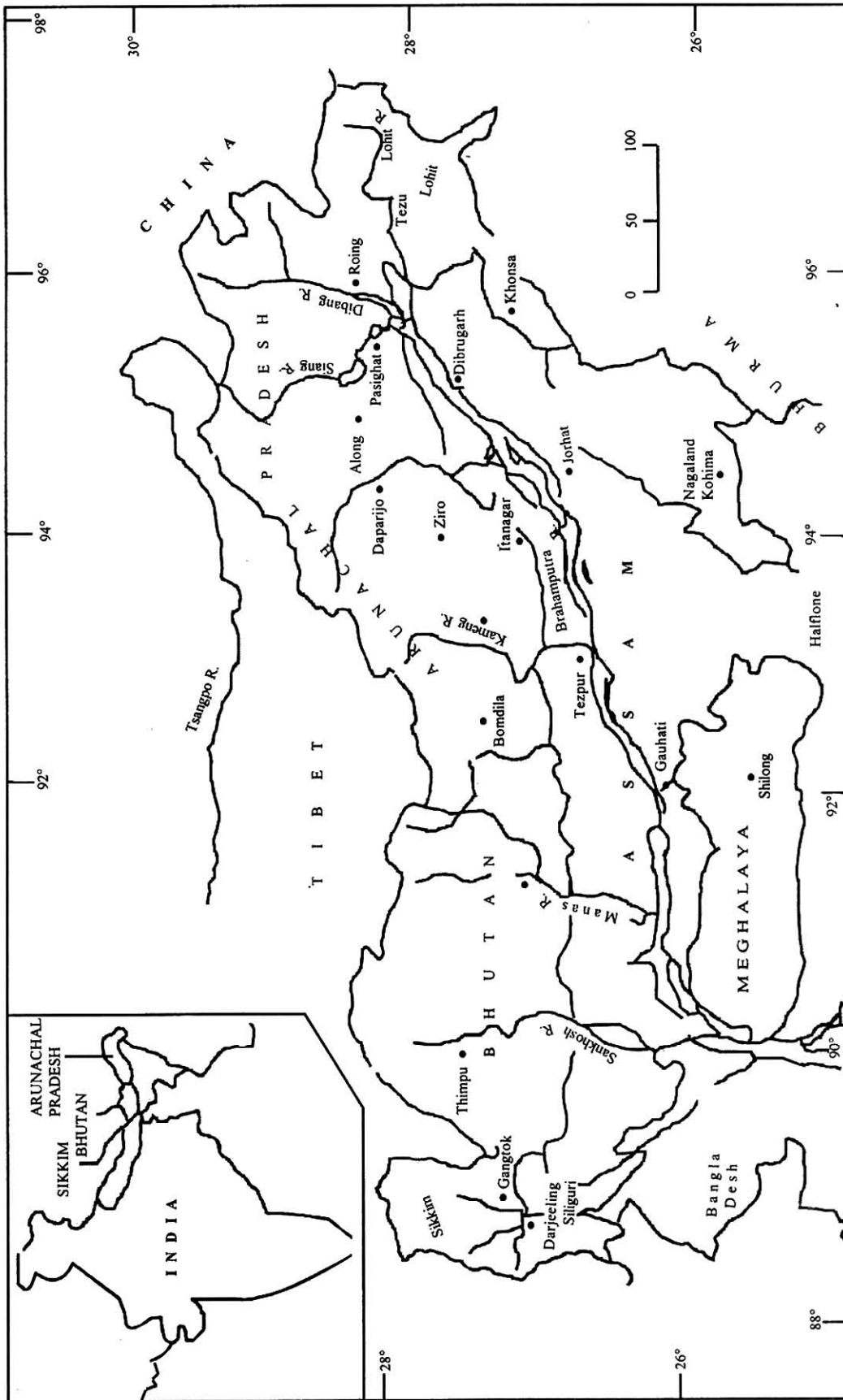


Fig. 1. Administrative Map of the Eastern Himalayas and the Adjoining Northeastern India

Further, the Lower Tertiary sediments and the Abor Volanics are exposed in Arunachal Pradesh, these are absent in the other sectors of the Eastern Himalaya.

### **Darjeeling - Sikkim Himalayas**

The fossils in this sector (Fig. 2) are known from the Siwalik Group, Gondwana Group, Buxa Group and the Tethyan Himalayan zone.

#### ***Siwalik Group***

The first report of fossils from the Siwalik Group of the Darjeeling Himalayas was that of *Venus* sp. by Mallet (vide Oldham, 1883). Thereafter, fresh water molluscs, viz. *Lamellidense* sp., *Planorbis* sp., and *Cerithium* sp., were reported from the marly intercalations in the lower part of the Geabdat sandstone from Darjeeling Foothills (Ray, 1976).

Pathak (1969) described a number of leaf-impressions from the Mahanadi River Section in the foothill region of Darjeeling District. The most common genera are *Castanopsis tribuloides* A. Dc., *Cinnamomum tamala* Nee., *Machilus villosa* Hooker, *Litsea polyantha* Juss., *Bridelia stipularis* Blum, Bijk., *Bridelia verrucosa* Haines, *Mallotus philippinensis* Muell. and *Rhododendron lepidotum* Wall. According to Pathak (1969, p. 384) the fossil bearing bed is supposed to be of the Plio-Pleistocene age. On one hand, he compares this floral assemblage with that of the Karewa of Kashmir, and on the other hand, he assigns the Siwalik an Upper Tertiary age based on field evidence. There appears to be some confusion since the Karewas of Kashmir belong to the Quaternary. It is quite likely that this floral assemblage may have come from the Quaternary sediments exposed in the Mahanadi River Section.

Later, fungal spores were recovered and described by Pathak and Banerjee (1989) from the Upper Tertiary sediments of the Mahanadi River Section. The described fungal remains are: *Inapertisporites* cf. *kedvesii* Elsik, *Inapertisporites* sp., *Monoporisporites keralensis* Ramanujam and Rao, *Diaporisporites curvatus* Ramanujam and Rao, *D. elongatus* Van der Hammen, *Didymoporisporonites psilatus* Sheffy and Dilcher, *Dicellaesporites elongatus* Ramanujam and Rao, *Fusiformisporites keralensis* Ramanujam and Rao, *F. elongatus* Ramanujam and Rao, *Dyadosporonites schwabii* Elsik, *D. denticulatus* Ramanujam and Rao, *Multicellaesporites ellipticus* Sheffy and Dilcher, *M. sp.*, *A. M. sp. B.*, *Pluricellaesporites* sp., *Alternariaites* sp., *Lirasporis intergranifer* Potonie and Sah, *Microthallites cooksonii* Rao and Ramanujam, and *Kutchiathyrites eccentricus* Kar.

#### ***Gondwana (Permian) Group***

The Gondwana sediments in Sikkim-Darjeeling Himalayas are well developed at two localities; one lies in the frontal part of the Lesser Himalayas in a narrow linear belt and the other in a tectonic window in the Rangit Valley, referred to as the Rangit Window in Sikkim, about 12 miles (19km) north of Darjeeling. Marine fossils, plant fossils and palynomorphs are known from this unit.

*Marine Fossils.* The first reference to the Permian marine fossils in this area was made by Ghosh (1952), who recorded the occurrence of *Spirifer* and fragments of Permian - Carboniferous marine brachiopod and bivalve casts and shells from the Rangit Valley in Sikkim. Subsequently, Jacob and Banerjee (1954) referred to a fossil collection (not *in situ*) made by Banerjee from Khemgaon near Namchi in the Rangit Valley. Amongst the fossils mentioned by them are *Spirifer* (?*Neospirifer*) cf. *moosakhailensis*, *Productus*, *Fenestella* (?*Fenestrellina*).

Sahni and Srivastava (1956), however, doubted this identification and emphasized the need for revision. They further described a collection from Khemgaon Chorten and Wak localities of South



Sikkim made by Shri G.N. Dutt. The faunal assemblage described by Sahni and Srivastava includes *Eurydesma cordatum* var *mytiloides* Reed, *Eurydesma* cf *globosa* Dana, *Eurydesma subdepressa* Sahni and Srivastava, *Eurydesma austini* Sahni and Srivastava, *Eurydesma subtriangularis* Sahni and Srivastava, *Ambikella fructiformis* Sahni and Srivastava, *Spirifer papillionate* Sahni and Srivastava, *Spirifer duttai* Sahni and Srivastava, *Syringothyris?* sp. indet, and *Protoretrepora* cf *ampla* Lonsdale.

Since then, there was no new record of Permian fossils from this area for nearly two decades. In 1972, Acharyya made a significant discovery of the Lower Permian marine fossils from the Rangit Pebble Slate of Darjeeling Foothills at Tindharia locality. It includes *Eurydesma* sp. (provisionally identified as cf *E. cordata* var *mytiloides* Reed, cf *E. subdepressa* Sahni and Srivastava), *Sanquinolites* sp. or *Praeundulomya* sp., ?*Wilkingia* sp., *Leptodesma* sp., or *Merismopteria* sp. together with a few other Pholadomyacea, Nuculanidae and other fragmentary bivalve remains. This fauna, however, could not be recovered by any subsequent worker. The author of the present review too failed to get the marine fauna from Tindharia locality in Darjeeling, though, collected a few fossils from Khemgaon and Wak localities in Sikkim which is under study.

Raina (1982, p. 38) collected ill preserved fossils belonging to the genera *Spiriferina* and Pectanaceae from a conglomerate band on Khemgaon-Ranguthang hill section in Sikkim.

*Plant Fossils.* The occurrence of *Glossopteris* sp., *Vertebraria indica*, *Phyllothea* sp. and *Sphenophyllum* sp. was first reported by Hooker (1854) and Mallet (1875) from Pankhabari area in Darjeeling District. Subsequently, Dutt and Sen (vide Jacob and Banerjee, 1954, p. 54-55) located plant-bearing Gondwana beds in the Rangit Valley. The plant fossils collected by Dutt about 2 miles west of Asangthang include *Schizoneura*, *Vertebraria indica*, and a doubtful *Glossopteris* (?*Gangamopteris*). Whereas, the plant fossils collected by Sen from a locality about 2 miles north-east of the junction of the Rangit River and Roathak Kholā, north of Naya Bazar, include an imperfect specimen of *Glossopteris*, probably *Glossopteris indica*. Later, a number of workers recorded plant fossils. However, no one attempted the systematic description of these fossils.

Recently, T. Singh and Bajpai (1990) described systematically a few plant fossils from the Eastern Himalayas. Of these, the species from Sikkim-Darjeeling include Equisetalean axes, *Phyllothea* sp., *Glossopteris* sp. cf *G. leptoneura* Bunbury, *Glossopteris syaldiensis* Chandra and Surange, and *Vertebraria indica* Royle from a locality about 2 km from Naya Bazar on Naya Bazar-Legship Road Section in South Sikkim District, and *Glossopteris formosa* Feistmantel from Tindharia in Darjeeling District.

*Palyno Fossils.* The palyno-stratigraphic succession of the Permian sediments, specially of the coal and associated sediments has been described by T.K. Ghosh (1973, 1983).

T.K. Ghosh (1983) recorded 36 miospores from the Lower Gondwana (Permian) coals from Tindharia and Rangtong localities in Darjeeling District. These include Monolete - *Laevigatosporites* (Ibr.) S.W. and B., *Thymospora* Wilson and Venkatachala; Trilete - *Leiotriletes* (Naum.) Potonie and Krotov, *Calmospora* S.W. and B., *Callumispora* Bharadwaj and Srivastava, *Hennellysporites* Tiwari, *Acanthotriletes* (Naum.) Potonie and Krotov, *Apiculatisporis* (Ibr.) Potonie and Krotov, *Cyclogranisporites* Potonie and Krotov, *Cyclobaculisporites* Bharadwaj, *Lophotriletes* (Ibr.) Potonie and Krotov, *Horriditriletes* Bharadwaj and Saluja, *Microfoveolatispora* Bharadwaj, *Indospora* Bharadwaj; Monosaccate - *Parasaccites* Bharadwaj and Tiwari, *Plicatipollenites* Lele, *Cannanoropollis* Potonie and Sah, *Densipollenites* Bharadwaj, *Divarisaccus* Wilson; Bisaccate Nonstriate - *Cuneatisporites* Leschik, *Vasicaspora* (Schmel) Wilson and Venkatachala, *Scheuringipollenites* Tiwari; Bisaccate Striate - *Rhizomaspora* Wilson, *Schizopollis* Venkatachala and Kar, *Striatites* (Pant) Bharadwaj, *Verticopollenites* Bharadwaj, *Hindipollenites* Bharadwaj, *Lahirites* Bharadwaj, *Crescentipollenites* Bharadwaj, Tiwari and Kar, *Striatopodocarpites* (Zorisch and Sevoda)

Bharadwaj, *Faunipollenites* Bharadwaj, *Distriatites* Bharadwaj and Saluja; Polyplicate - *Welwitschiapites* Bolch, *Gnetaceaeapollenites* Thiergart; Monocolpate - *Vittatine* (Luber) Wilson, *Gingocycadophytus* Samoil.

Srivastava *et al.* (1988) while synthesizing the Permian palyno-fossils from the Eastern Himalayas have recorded the palynological assemblages demarcating the Coal Measures in Darjeeling District. The Lower Coal Measures show the *Parasaccites* - Assemblage, *Lophotriletes* - Assemblage, and *Faunipollenites* + *Striatopodocarpites* - Assemblage, while the Upper Coal Measures show Striate Disaccate - Assemblage. The *Parasaccites* - Assemblage is characterized by abundance of monosaccate pollens (56%), non-striate disaccate pollens (29%), striate disaccate pollens (8%) and rare trilete spores. The important elements are *Parasaccites*, *Scheuringipollenites*, *Crucisaccites*, *Caheniasaccites*, *Ibisporites* and *Vesicaspora*. The *Lophotriletes* Assemblage is rich in trilete spores and striate disaccate pollens. The characteristic elements are *Lophotriletes*, *Horriditriletes*, *Brevitriletes* and *Cyclogranisporites*. The *Faunipollenites* + *Striatopodocarpites* - Assemblage show overall dominance of striate disaccate pollens, with less of trilete spores. *Faunipollenites*, *Striatopodocarpites* and *Lahirites* are the chief constituents. The Striate Disaccate - Assemblage is rich in striate disaccate pollen grains and also show a sizeable percentage of trilete and monoete spores. The significant pollens and spores include *Striatites*, *Verticipollenites*, *Crescentipollenites*, *Striatopodocarpites*, *Indospora*, *Thymospora*, *Verticipollenites*, *Crescentipollenites*, *Distriatites* and *Gnetaceaeapollenites*. From Sikkim, they have shown the presence of the trilete spores (35%), non-striate disaccate (21%), monoete spore, colpate pollen and aleate spores. The important elements include *Striatites*, *Brevitriletes*, *Scheuringipollenites* and *Lophotriletes*.

Srivastava and Bhattacharyya (1992) listed a palynofossil assemblage containing 21 genera and 26 species from the Permian sediments (Sikkim Member of the Namchi Formation) exposed in the Jorethang - Namchi Section. The assemblage include *Leiotriletes tenuis*, *Lophotriletes minimus*, *Horriditriletes curvibaculosus*, *Brevitriletes unicus*, *Cyclogranisporites* sp., *Laevigatorporites vulgaris*, *Striatites varius*, *S. solitus*, *S. alius*, *S. communis*, *Striatopodocarpites decorus*, *Faunipollenites varius*, *F. minor*, *Verticipollenites debilis*, *Lahirites* sp., *Crescentipollenites* sp., *Vesicaspora indica*, *Scheuringipollenites tentulus*, *S. maximus*, *Ephedripites* sp., *Weylandites lucifer*, *Gingocycadophytus vetus* *Gondwanaeaplicates bharadwajii*, *Leisphaeridia* sp., *Parasaccites invisus*, *Trochosporites* sp. According to them the assemblage is dominated by Striate disaccate pollen (35%) and trilete spores (34%).

### ***Buxa (=Miri) Group***

No fossil has so far been reported from the Buxa (=Miri) Group of rocks in the Sikkim-Darjeeling Himalayas, except algal stromatolites. Although systematic description of these stromatolites is lacking, these are very commonly mentioned as passing references by several workers in this area.

Sinha Roy (1972) has reported the following forms of algal stromatolites : *Anomalophycus compacta*, *Collenia* sp., and *Proliferum* sp., from the Buxa Group in the Rangit Window.

Acharyya (1974, p. 110) stated that the algal stromatolites are rather sporadic in occurrence and less well developed within the Buxa Dolostone of the Jainti area compared to the window zone in Sikkim. These include stratiform, nodular and also columnar types. These are recognised from Romphu, a tributary of river Raiduk, and Mechia Khola about 2 km east-north-east from Jainti.

Srikantia (1980, p. 184) recorded *Colonnella*, *Kussiella*, and *Platella* from Tatapani area in Rangit Window.

Raha (in Raha and Sastry, 1982, p. 309) stated that the biostrome I of the Jammu Limestone, comprising *Colonnella discreta*, *C. laminata* and *Kussiella kussiensis*, has been found to be associated with the Buxa Dolostone exposed on the right bank of the Rangit River; and that about 4 km north of

at *Colonnella riasiensis* and *Kussiella magna* occur in close association, indicating a correlation with biostrome II of the Jammu Limestone.

Raina (1982, p. 41) has mentioned about the presence of ill-preserved and limonitised casts of bivalves within the calcareous purple phyllites and slates belonging to the Buxa Group, reported by Dutt in the upper reaches of the Ranji Khola in the Rangit Valley.

### **Tethyan Sequence**

The first ever reference of fossils from the Tethyan Sequence of North Sikkim came from Hooker (1854, p. 176) who described an isolated outcrop of fossiliferous limestone, rising above the alluvial flats on the eastern side of the Tso Lhamo. Fossils were described later by Oakley (in Muir-Wood and Oakley, 1941: 73-76). This includes: Foraminifera: *Monogenerina* sp., Hydrozoa; gen. et sp. indet, *Bryozoa*: gen. et sp., indet, and Algae: *Solenopora (Parachaetetes) hookeri* Oakley.

Wager (1939) collected a rich faunal assemblage from the Lachi Ridge in North Sikkim, which lies in between Gordamah (Gurudongmar) Lake and Tso Lhamo. This assemblage was described by Muir-Wood and Oakley (1941) who recognised two fossiliferous horizons, viz. the Middle or Upper Carboniferous and the Upper Permian. The fossils include : CARBONIFEROUS - Brachiopods: *Productus* sp. indet (part of dorsal valve), *Athyrid* (fragment of ventral valve), *Spiriferellina* sp.; *Anthozoa*: gen. et sp. indet; *Gastropoda*: *Straparollus lachiensis* Oakley; and *Crinoidea*: *Ellipsellipsora* sp. PERMIAN - Brachiopods: *Orthotetid*, *Chonetes wageri* Muir-Wood, *Dictyoclostus cf subcostatus* (Waagen), *Dictyoclostus cf graciosus* (Waagen), *Linoproductus of cora* (d'Orbingny), *Marginifera himalayaensis* Diener, *Pustula* sp., *Waagenoconcha purdoni* (Davidson), *Camarotoechia* sp., *Ucinunellina jabiensis* (Waagen), *Neospirifer moosakhailensis* (Davidson), *Spiriferella rajah* (Salter), *Syringothyris lydekkeri* (Diener); *Bryozoa*: *Batostomella (Geinitzella)* sp., *Fenestrellina aff fossula* (Lonsdale), *Goniocladia* sp., *Rhombopora cf circumcincta* Reed; *Bivalves*: *Nuculana* sp., *Parallelodon aff tenuistriatum* (Meek and Worthen), *Pleurophorus* sp., *Aviculopecten hyemalis* Salter, *Aviculopecten cf leniusculus* (Dana); *Gastropoda*: *Pleurotomarium aff orientalis* Roemer (non Krotow); *Crinoidea*; *Poteriocrinus* sp.

Sastry and Mathur (1962) reported middle Triassic fauna (Anisicar), characterized by *Paraceratites trinodosus*, from the Tso Lhamo Formation of North Sikkim.

Thereafter, Chandra and Sen (1982) described a Carboniferous trilobite from North Sikkim, which was collected from a westerly running gully south-southeast of the Dosgila Peak, and north-westerly running gully southwest of the Mashya Camping ground. This trilobite which is a new genus sp. nov, is named as *Lachenia bispinosa* Chandra and Sen. The other fauna associated with this trilobite are- *Gastropods*: *Bellerophon (Bucania) kattaensis* Waagen, *Pleurotomaria (Wortheniopsis) eulkaiensis* Reed; *Bryozoans*: *Poteriocrinus* sp. (stem ossicles), *Fenestella assumpta* Reed; *Fenestella elusa* Reed; and *Bivalve*: *Nuculana* sp. Other fauna, about 20 m above the *Lachenia* horizon, include *Fenestella elusa* Reed, *Pleurotomaria* sp., *Nuculana* sp., and *Phillipsia* sp. Of these, the trilobite genus has been described in length, while other fauna have only been listed.

### **Bhutan**

Various litho-units in Bhutan are in strike continuation from those in the Sikkim-Darjeeling Himalayas and are shown in fig. 2.

### **Siwalik Group**

The thick sequence of the Neogene sediments forms a continuous autochthonous belt of varying thickness except for two gaps in Bhutan, viz. Jaldhaka-Torsa gap in the west and Sarbhang-Mao Khola gap in the east. There is no record of any fossils from here except for an elephant molar tooth from the

Siwaliks of Buxa Duars by Godwin-Austen (1868). However, Biswas *et al.* (1979, pp. 293-294, 299-300) have mentioned about the presence of palynofossils (*Palmepollenites* sp., *Polypodisporites* sp., *Leptolepidites* sp.), carbonised wood, dicot plant leaf, flower and fruit impressions, and occasional wood fragments from the Siwalik sediments of Bhutan. But details of these fossils are lacking. Guha Sarkar (1979, p. 374) has also mentioned the plant fossil-bearing Siwalik sediments that occur along Kalapani (Kalanadi) River, Nonai River and Jia Bar River sections, north of Rangia Railway Station in Eastern Bhutan Foothills.

The first systematic description of fossil leaf-impressions from the Siwalik sediments (Miocene-Pliocene) was given by Banerjee and Das Gupta (1979). These fossils come from Darranga and Lakshmi sections in the eastern part of Bhutan and include *Siwalikiphyllum accuminatum* Banerjee and Das Gupta, *Dilcher ellipticalis* Banerjee and Das Gupta, *Ghosia furcata* Banerjee and Das Gupta, *Pseudopaxilletophyllum ellipticalis* Banerjee and Das Gupta, *Darrangiophyllum ellipticum* Banerjee and Das Gupta, *D. elongatum* Banerjee and Das Gupta, and *D. auriculatum* Banerjee and Das Gupta. Banerjee (1985) recorded *Heliospermopsis* Nagy (*Oudhkusumites* Srivastava) from the Miocene sediments of Darjeeling foothills and Bhutan in the Eastern Himalaya, giving emended diagnosis. Subsequently, Banerjee (1986) recorded *Botryococcus*, *Pediastrum*, and microplankton from the same sediments from which she recorded *Heliospermopsis* (*Oudhkusumites*) earlier.

### **Gondwana (Permian) Group**

The Gondwana Group consists of medium to coarse-grained sandstones, carbonaceous shale, seams and lenses of crushed coal, grey to dark grey quartzitic sandstone, carbonaceous sandstone, carbonaceous shale and diamictites.

*Marine Fossils.* Except for passing remarks by Acharyya *et al.* (1975a) that the Fenestellid bryozoa and gastropods have been located in Dewathang area, East Bhutan, there was no record of any marine fossil till when Joshi (1990) and Joshi *et al.*, (1990) reported and illustrated well preserved marine fossils from the Sankosh Valley along the Seti Khola in Bhutan Lesser Himalaya. The provisionally identified species include : *Neospirifer* cf. *fasciger* (Keyserling), *Neospirifer* sp., *Trigonotreta* sp., *Platyteichum* sp., *Protoretetpora* cf. *ampla* Lonsdale, *Orthotetes* sp., *Waagenoconcha* cf. *vagans* (Reed), *Waagenoconcha* cf. *humboldti* (d'Orbigny) and *Waagenoconcha* sp.

*Plant Fossils.* Although the Gondwana sediments are known to occur in Bhutan ever since 1906 (Pilgrim, 1906), however, the fossils were reported only in 1979 simultaneously by Acharyya and Sastry (1979), and Biswas *et al.* (1979) who recorded *Glossopteris* sp., *Gangamopteris* sp., and *Vertebraria* sp. Later Guha Sarkar *et al.* (1983) reported the occurrence of *Glossopteris* sp., *Gangamopteris* spp., *Vertebraria* sp., *Schizoneura* spp., and fossil wood (without giving illustrations and description of these fossils).

*Palyno Fossils.* Biswas *et al.* (1979, p. 294) reported a few micro-flora, viz. *Acanthotriletes*, *Sulcatisporites*, *Verticypollenites*, and *Faunipollenites*.

Banerjee and Das Gupta (1983) and Banerjee *et al.* (1986), gave the palynological account of the Gondwana sediments from Darranga - Dewathang traverse section, nearly 4 km west of Dewathang in East Bhutan. The assemblage is dominated by non-striated disaccates and apiculate triletes, which include *Leiotriletes* Naum., *Psilalacinites* Kar, *Punctatisporites* Ibr., *Calamospora* S.W. and *B. Granulatisporites* Ibr., *Cyclogranisporites* Potonie and Krotov, *Apiculatisporis* Ibr., *Lophotriletes* Naum., *Acanthotriletes* Naum., *Didecitriletes* Venkatachala and Kar, *Microfoveolatispora* Bharadwaj, *Cirratriradites* Wilson and Coe., *Laevigatosporites* Ibr., *Densipollenites* Bharadwaj, *Limitisporites* Leschik, *Labiisporites* Leschik, *Scheuringipollenites* Tiwari, *Cuneatisporites* Leschik, *Platysaccus*

Naum., *Primuspollenites* Tiwari, *Striatites* Pant, *Striatopodocarpites* Sedova, *Lunatisporites* Leschik, *Faunipollenites* Bharadwaj, *Marsupipollenites* Balme and Hennelly, *Gnetaceaepollenites* Thiergart, *Vittatina* Luber, and *Ginkgocycadophytus* Samoil.

### ***Buxa (=Miri) Group***

The occurrence of stromatolites in the foothills zone of the Bhutan Himalayas within the Buxa Group was first reported by Sen Gupta and Raina (1978). Subsequently, Raha and Sastry (1982, p. 309) reported *Tungussia* and *Poludia*, a late Riphean - Vendian stromatolite assemblage from the Buxa Dolostone of Bhutan.

### ***Tethyan Sequence***

*Marine Fossils.* P. Singh (1973) located a few fossiliferous localities in Bhutan. These include : (i) slates near Riphakha in Paya Chu Valley; (ii) silty limestone near Kobja in Tang Chu Valley; and (iii) green shale and thinly bedded limestone south of Taphu on way to Wachi La and Black Mountains. The slates of Paya Chu Valley are included in the Tang Chu Formation and have yielded *Spirifer* sp., *Fenestella* sp., *Fenestrellina* sp. and *Protoretetpora ampla*. The silty limestones of the Tang Chu Valley are also included in the Tang Chu Formation and contain small gastropods. The rocks of Taphu are included in the Black Mountain Formation, which have yielded abundant brachiopod fauna, chiefly *Spirifer*, *Spiriferina*, *Marginifera himalayensis*, Orthids and Productids. Though, these fossils have not been fully identified, P. Singh (1973) has however, assigned an age between the Carboniferous and Permian. Chaturvedi *et al.* (1983, p. 36), however, stated that no Permo - Carboniferous rocks are present in the Wachi La area, and that they have collected rather a number of fossils of the Ordovician age. Gansser (1983, p. 57), too, observed that the age assigned by P. Singh seems to be uncertain since his (Gansser) specimens, are of the Devonian age.

Termier and Gansser (1974) described a small faunal assemblage of the Middle to Upper Devonian age from the Tang Chu Basin of Central Bhutan, which includes : brachiopods - *Atrypha* cf *reticularis*, *Elita* sp., *Torynifer* nov. gen. sp., *Cyritina* sp.; bryozoa - *Fenestella* ? sp.; trilobite - family Phacopidae ?; echinoderms and crinoids - *Hexacrinites* ? sp., *Nodale* ? indet.

Gokul (1982) reported several fossiliferous horizons in Bhutan Tethys Himalayas. The fossils recorded are : *Fenestella* sp., *Fenestrellina* sp. and *Polypora* sp. of the Permo-Carboniferous age from about 4 km north of Yale La belonging to the Tang Chu Series; *Nechoceras nalikanta* of the Triassic age about 1 km south of the Yale La around Lingshi Dzong belonging to the Lingshi Series; and *Pseudomonotis* sp., *Cardita* sp. (Bivalve), Hoplitidae and Hopliteceans (Ammonoids) of the Jurassic to Cretaceous age from the Yale La Series.

Chaturvedi *et al.* (1981, 1983) gave systematic account of fossils of the Ordovician to the Devonian age from the Tethyan Palaeozoic sequence of the Black Mountain Region, Central Bhutan. The fossils have been collected from : A - Mane Ting - Wachi La area (north-west part of Black Mountain Range) - (i) Nearly 2.5 km south of 4136 m peak and 3 km N 65 W of 4497 m peak (Wachi La) along foot track (= possibly the fossil locality of P. Singh, 1973); (ii) Nearly 1.5 km south of 4462 m. peak, in the nala; (iii) About 1.5 km south-south-east of 4461 m peak, along foot track towards lake; (iv) south-east of 4373 m peak; (v) 1 km south-south-west of 4461 m peak near second mound; (vi) 1 km south-west of 4136 m peak; B - Kha Khola area (southern Black Mountain Range) - (vii) About 200 m north-west of 1705 m, in dry nala; and (viii) Along foot track near the crest of the ridge between Siran Khola and Gong Khola. The fossils identified from the first five localities are : Brachiopods - *Orthis* sp., ?*Strophomena* sp., *Leptaena rhomboidalis* (?), *Rafinesquina cratera* Salter, *Strophomena* sp.; Trilobites - ?*Gallagnostus* sp., *Prosopiscus* sp., ?*Illiaenus yeosinensis*, ?*Phacopida*; ill preserved ? Fenestelloidea bryozoans; fragmentary crinoids; Plants - ? *Psilophyton* sp. The fossils from locality (vi) are : Brachiopods -

*Glossella* sp., *Lingulella* sp.; Bivalves - ? *Ctenodonta* sp., ? *Palaeoneilo* sp., *Cycloconcha* sp., ? *Nuculoidea* sp.; The fossils from locality (vii) are : Brachiopods - *Sericoidea* sp., *Sowerbyella* sp.; and from locality (viii) are : ill preserved trilobite fossils - *Asaphacea* and *Illaeonacea*. The fossil assemblages suggest a middle to upper Ordovician age for the rocks of the Mane-Ting Formation.

Gansser (1983, p. 41) while describing the Bhutan Tethyan sediments of the Lingshi Basin, specially on its southern side from the Wang Chu to Shodu and further northwards over the Yale La into the centre of the Lingshi Basin, reported (p. 41) that the first fossil traces appear in the higher part of the section in the coarse grained limestones mostly as small undeterminable lumachelles and some crinoids which may possibly be the Palaeozoic forms of the Camerata type. Well preserved negatives of the Norian ammonite *Parajuvavites* are identified by Hanny (vide Gansser, 1983, p. 42). In the deeper part of the Lingshi Basin, however, Gansser (p. 43) observed sandy to silty micaceous horizons containing fragments of *Perisphinctus* and bivalves which resemble *Pseudomontis* and *Cardita*, possibly of the Jurassic age. The fossiliferous black spathia limestone layers occurring in black shales in the northwest of Lingshi contain several bivalves (*Trigonia*) and ammonites, of which *Hoplitaceae* and *Hoplitidae* suggest an Albian age. Another Cretaceous fauna is also reported (p. 43) in platy siltstones of Nak Chu La with ammonites probably representing *Probysteroceras* (*Goodhallites*?) and other small compressed forms, possibly *Mortoniceras* or *Hyseroceras* which also suggest the Albian age. In the eastern Lingshi Basin around Jhari La, Gansser reported (p.45) fossiliferous limestone containing shell remnants, crinoids and sponge needles and also badly preserved primitive arenaceous foraminifers. Though no age is assigned to this poor fauna, he assumed a Palaeozoic age on the basis of associated lithology. Gansser, further, observed (p.43) that the Lingshi Basin is certainly an area where detailed stratigraphic studies are warranted.

Ganesan *et al.* (1986) while describing the geology of the Lingshi Basin reported the occurrence of marine and plant fossils from various formations. Of these, the marine fossils include turritelid gastropods of probable Devonian age from the middle part of the Barishong Formation, and *Spirifer* sp., *Products* sp., *Syringothyris* sp., *Favosites* sp., *Fenestella* sp., *Polypora* sp., *Dogaddanella* sp., and *Rhombopora* sp., of Carboniferous age from the upper part of the Barishong Formation; *Spirifer* sp., *Products cora*, *Marginifera himalayensis*, *Ingerella* sp., *Fenestella* sp., *Polypora* sp. and *Rhombopora* sp. of Carboniferous to Permian age from the Shodug Formation; and *Trigonia costata*, *Ancella spitiensis*, *Nucula spitiensis*, *Nuculana* sp., *Homomya tibetica*, *Rhynchonella trinodosi*, *Linella* sp. and *Odontodiscus* sp. of Middle to Upper Jurassic age from the Chebesa Formation.

**Plant Fossils.** Ganesan *et al.* (1980, 1982) reported the occurrence of plant remains of the Jurassic age from the Mo Chu Formation from near Yale La in the Lingshi Basin of the Bhutan Himalaya. These were later described in detail by Ganesan and Bose (1982). The fossil bearing shales lie about 4 km north of the Yale La and are included in the Mo Chu Formation. Although the fossils are rather poorly preserved, the species identified are : *Pachypteris* cf. *indica* (Oldham and Morris) Bose and Roy, *Ptilophyllum acutifolium* Morris, *Elatocladus jabalpurensis* (Feistmantel) Halle, *Pagiophyllum* sp. A, *Pagiophyllum* sp. B, *Conifero-caulon* cf. *rajmahalensis* Gupta, cf. *Cladophlebis* sp., and a fragment of *Ptilophyllum* leaf. This assemblage is considered to be of middle to late Jurassic age, and resembles certain plant assemblages known from the Upper Gondwanas of India. Chaturvedi *et al.* (1983, p.44) have mentioned the presence of a ?*Psilophyton* sp. from the Mane Ting - Wachi La area.

### Western Arunachal Pradesh

The geological interest in Arunachal Pradesh dates back to 1825 when Wilcox made some observations in the Lohit District. The subsequent knowledge of the geology of the interior region of the mountains bordering the plains of Upper Assam has mainly come from the punitive expeditions conducted from

time to time against one or the other hostile tribes inhabiting the region. Notable amongst those are Godwin Austen (1875), La Touche (1885), MaClaren (1904), and Coggin-Brown (1912). The discovery of mega fossils in the early years of the present century, however, generated much interest especially because these provided direct evidence for the age and depositional environment of beds which contained them.

The first reference to the occurrence of fossils in the region was made by MaClaren (1904) from the mouth of the Subansiri gorge near Dreper. These fossils were described systematically by Diener (1905) who assigned an Anthracolithic age to the fossiliferous boulders collected by MaClaren (1904). Subsequently, Coggin-Brown (1912) reported badly preserved crinoid ossicles from the rolled boulders of arenaceous limestone in the Siang River in Abor Hills (Siang District). Thereafter, Sahni and Srivastava (1956) described Permian fauna from Subansiri District, which was collected by Laskar in 1954 (vide Krishnan, 1958). The plant fossils were, however, first reported by Jacob and Banerjee (1954).

It is significant to note that attention had remained only on the Permian fossils ever since the first record of fossils from Arunachal Pradesh was made. It was only after mid seventies, that the occurrence of fossils in other stratigraphic horizons (litho-units) came into light. The significant discovery was the record of the Eocene fossils from the Dihang Valley.

The generalised geological setup of the western part of Arunachal from south to north is as follows: Siwalik Group, Gondwana Group, Miri Group, Bomdila Group, and Se La Group. Beside these, the Eocene rocks occur at two different positions, the one in juxtaposition with the Siwalik and Gondwana Groups at the frontal margin of the Lesser Himalayas, and the other in a tectonic window in the Lesser Himalayas. The other group of rocks are the Abor Volcanics which occur associated with the rocks of the Gondwana and Miri Groups. These two groups have not been assigned any formal stratigraphic nomenclature.

Fossils in this region (Fig. 3) are known to occur in the Siwalik, Gondwana and Eocene sediments, as well as from the inter-trappean sediments in the Abor Volcanics, and some trace fossils from the Miri Group.

*Siwalik Group:* The Siwalik Group has been well studied (Karunakaran and Ranga Rao, 1979; Hazarika, 1984; Hazarika and Das, 1984; T. Singh *et al.*, 1979; and Kumar and Singh, 1982). The fossil content in the Siwalik sediments is poor in the Eastern Himalayas as compared to the Western Himalayas which are prolific at least in vertebrate fauna. The fossils in the Arunachal Siwaliks known so far, are restricted to the plant fossils, palyno fossils, a few arenaceous foraminifera and a lone vertebrate fossil.

*Vertebrate Fossil.* There are only two records of the vertebrate fossils. The first one dates back to 1865, when Medlicott (1865, p. 436, *vide* MaClaren, 1904, p. 193) quoted an interesting discovery "a fossil elephant tooth found by Bryan Comber, Esq., in the gorge of the Deijmoo, north of Dibrugarh". The other record came after more than a century when G. Singh (1975, 1983) reported an isolated occurrence of a molar tooth of *Bos* sp., from the Upper Tertiary rocks in the Burai River Section about 1.5 Km upstream of Ramghat in the Subansiri District. He correlated it with the Pinjore Stage (Lower Pleistocene) of the Upper Siwalik. This discovery remained a matter of controversy, as it could not be reproduced inspite of rigorous efforts.

*Micro Fossils.* Karunakaran and Ranga Rao (1979) and Ranga Rao (1983) have mentioned that certain clay samples have yielded a few arenaceous foraminifera, which resemble those from the Bokabil Formation of the Lower Miocene age. However, they have not given the list of fauna except *Trochommia* sp. by Ranga Rao (1983, p. 131). Kunte *et al.* (1983, p. 126) have mentioned that except for an arenaceous foraminifer similar to the one occurring in Bokabil Formation of Assam, the Dafla Formation (Upper Tertiary) is devoid of any index fossil.

*Plant Fossils.* The dicotyledenous fossil plants and silicified wood fragments are invariably found in the sandstones and shale bands. However, T. Singh and Uttam Prakash (1980) were first to describe

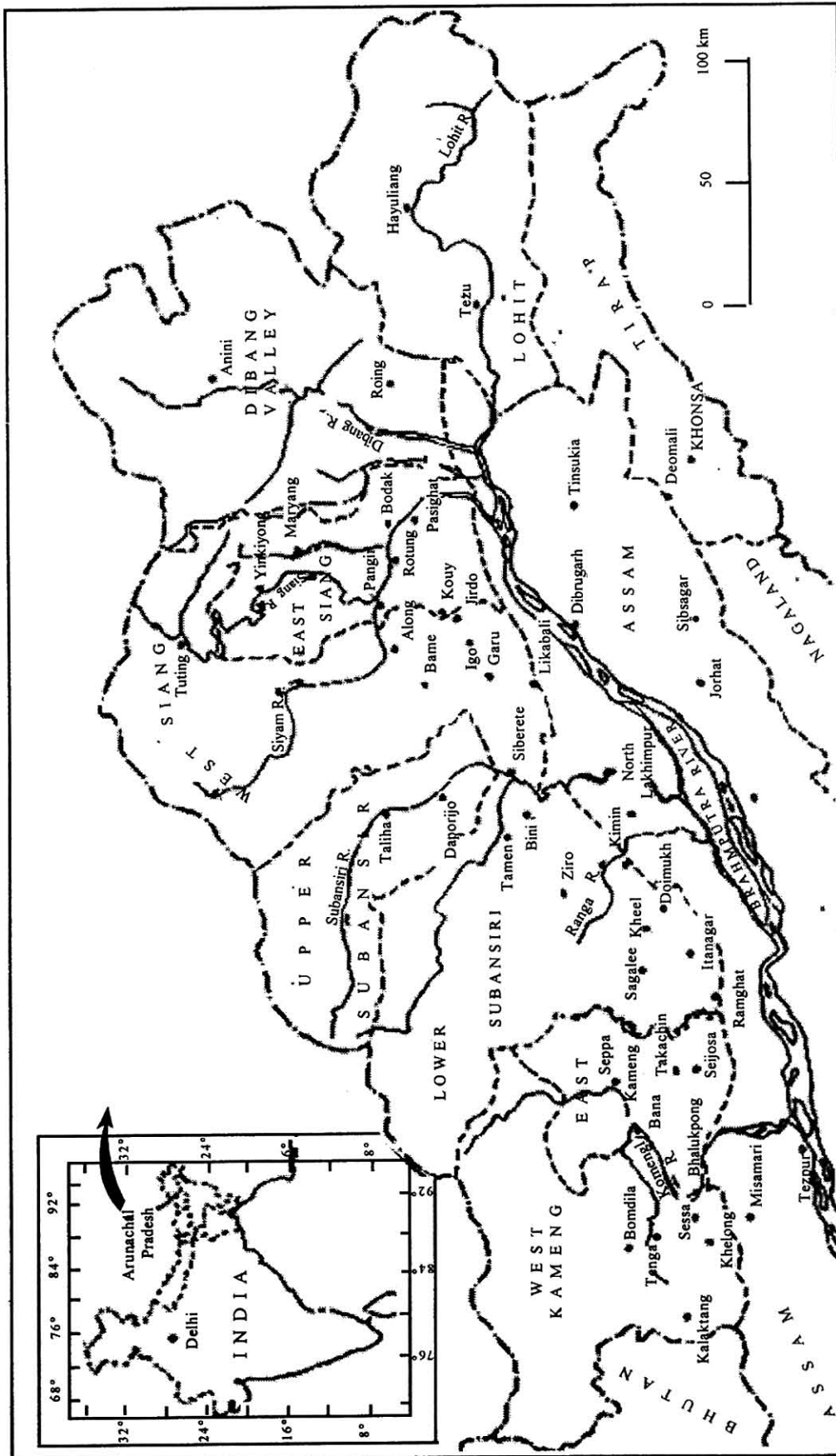


Fig. 3 . Sketch Map of Arunachal Himalayas Showing Localities Used in the Text

the leaf-impressions from Pasighat in Siang District. They identified *Zizyphus indicus* Singh and Uttam-Prakash, and *Dicotylophyllum dioscoreoides* Singh and Uttam-Prakash. Subsequently, Ranga Rao (1983) while giving the palaeontological features of the Arunachal Upper Tertiaries mentioned the presence of *Zizyphus* sp. and *Sigigium* sp. However, he neither illustrated nor described the specimens.

*Palyno Fossils.* The first ever account of the palynological studies was made by Dutta and Singh (1980) and Dutta (1980) from the Siwalik sediments of the Kameng District from two different localities. This mioflora is listed and illustrated. However, Dutta (1980) described two forms in detail in addition to the listed and illustrated forms.

Dutta and Singh (1980) reported the palynotaxa from Bhalukpong - Bomdila Section. Their palynological composition shows a copious mioflora, containing elements of the Permian, Eocene and Miocene ages. It includes : *Cuneatisporites* spp., *Sulcatisporites* spp., *Striatopodocarpidites* spp., *Veliasaccites* spp., *Cyclogranisporites* spp., *Striapollenites* spp., *Densipollenites* spp., *Faunipollenites* spp., *Parasaccites* spp., *Deltoidospora* sp., *Inaperturopollenites* sp., *Monolites* sp., *Lygodiumsporites lakiensis* Sah and Kar, *Alsophilidites* sp., *Osmundacidites* sp., *Nyssapollenites barooahi* Sah and Dutta, *Palmidites plicatus* Singh, *Palmidites* sp., *Retipilonapites* sp., *Cicatricosisporites dorogensis* Potonie and Gelleit, *Cyathidites australis* Couper, *Dandotiaspora dilata* Sah, Kar and Singh, *D. telonata* Sah, Kar and Singh, *Rugulatisporites* sp., *Pharagmothyrites edwardsii* Kar, Sah and Singh, *P. eocenicus* Edward, *Notothyrites paddapakarensis* Jain and Gupta, *Cycadopites* sp., *Proxapertites assamicus* Singh, *Pinuspollenites* sp., *Meliapollis* sp., *Notothyrites paddapakarensis* Jain and Gupta, *Todisporites* sp., *T. minor* Couper, *Cicatricosisporites* sp., *Cicatricosisporites macrocostatus* Sah and Dutta, *Palmaepollenites* sp., *Granulatisporites* sp., *Echinotriletes* sp., *Tricolporites* sp., *Couperipollis brevispinosus* Venkatachala and Kar, C, sp., and *Strotersporites* sp.

Dutta (1980), on the other hand, listed and illustrated the palynotaxa, from the Misamari-Chaku Section in the western part of Kameng District. The palynological assemblage also shows mixed type of flora having Tertiary elements mixed with the Permian, indicating a recycled deposit. The indigenous palynotaxa suggests a middle Miocene age for these sediments. The characteristic palynotaxa recorded are : *Polypodiaceoisporites* sp., *Striatriletes susannae* van der Hammen, *Leptolepidites assamicus* Dutta, *Punctatisporites gretensis* Balme and Hennelly, *laevigatosporites colliensis* (Balme and Hennelly) Venkatachala and Kar, *Tiwariasporis gondwanensis* (Tiwari) Maheshwari and Kar, *Cannanoropollis obscurus* (Lele) Bose and Maheshwari, *Platysaccus papilionis* Potonie and Klaus, *P. densus* Kar, *Striatites ornatus* Venkatachala and Kar, *Lahirites raniganjensis* Bharadwaj, *Strotersporites decorus* (Bharadwaj and Saluja) Venkatachala and Kar, *S. magnificus* (Bharadwaj and Saluja) Venkatachala and Kar, *Scheuringipollenites maximus* (Hart.) Tiwari, *Leptolepidites assamicus* Dutta, Microplankton type-1, and Microplankton type-2.

Ranga Rao (1983) listed a few recycled Lower Gondwana taxa from the Upper Tertiary sediments of Arunachal Himalayas without giving the precise locality. This include : *Plitipollenites*, *Nuskoisporites*, *Ananthotriletes*, *Pinuspollenites*, *Podocarpidites*, and *Queroidites*. This assemblage is comparable with the Surma-Tipam micro-flora of the Upper Assam Plains and Naga Hills.

T. Singh and Tripathi (1990) carried out palynological studies from the Bhalukpong-Sessa Section in Kameng District, Itanagar-Doimukh-Kheel Section and Kimin-Ziro Section in Subansiri District, and Likabali-Garu Section and Pasighat-Koyu Section in Siang District. Although they did not give the taxonomic description, but have given the palynological composition with quantitative analysis and illustrated a few palynotaxa, and attempted the palynological comparison with extinct plants to determine the palaeovegetation, palaeoclimate and environment of deposition.

The palynological assemblage of T. Singh and Tripathi (1990) comprises of angiospermous pollen, pteridophytic spores, fungal remains, gymnospermous pollen, dinoflagellate cysts, acritarchs and

reworked Permian spores and pollens. The various palynotaxa are as follows: *Lycopodiacidites dextrus* Kar and Kumar, *Lycopodiacidites* sp., *Lycopodiumsporites* sp., *Monolites mawkmaensis* Sah and Dutta, *Dictyophyllidites* sp., *Lygodiumsporites eocenicus* Dutta and Sah, *Intrapunctisporis subtriangularis* Kar and Singh, *Todisporites major* Couper, *Striatriletes attenuatus* Singh and Tripathi, *Striatriletes susannae* van der Hammen emend Kar, *Pteridacidites* sp., *Podocarpidites meghalayaensis* Rao, *Podocarpidites* sp., *Pinuspollenites* sp., *Abiespollenites* sp., *Laricoidites* sp., *Palmidites maximum* Couper, *P. applicatus* Kar and Kumar, *P.* sp., *Couperipollis magnus* (Dutta and Sah) Kar and Kumar, *P.* sp., *Couperipollis* sp., *Dicolpopollis* sp., *Longapertites klinkenbergii* Rao and Ramanujam, *Proxapertites assamicus* (Sah and Dutta) Singh, *Ctenolophonidites costatus* Van Hoeken-Klinkenberg, *Tricolporopollis rubra* Dutta and Sah, *Lakiapollis assamicus* Tripathi and Singh, *Meliapollis* sp., *Liliacidites* spp., *Collospermumpollis laevigatus* Tripathi and Singh, *Loranthipites* sp., *Malvacearumpollis paucibaculatus* Venkatachala and Rawat, *Verruletes assamicus* Singh and Saxena, *Verruletes* sp., *Assamiapollenites ghoshii* Singh and Saxena, and *Collumospaera* sp.

### ***Eocene Sequence***

A significant breakthrough in the Cenozoic stratigraphic and palaeontological records of the Eastern Himalayas occurred with the discovery of the Lower Tertiary sediments. Although, Acharyya *et al.* (1975a) and Ray and Acharyya (1976) interpreted the possible existence of Palaeogene-Lower Neogene shelf miogeosynclinal sediments along the frontal zone and further north below the pre-Tertiary sediments in the Eastern Himalayas, Bhandari *et al.* (1974, p. 646) and the Geological Survey of India (1974, p. 11) indicated the presence of the Lower Tertiary sediments in the Arunachal Himalayas, on the basis of seismic data and stratigraphy, respectively. However, it was Jain and Dutta (1978), who first recorded definite Lower Tertiary (probably Eocene) palynological assemblage from Siang District in Arunachal Pradesh. Almost simultaneously, the reports of the fossiliferous Early Eocene sequence with abundant foraminifers from Siang District were published by C. Tripathi *et al.* (1978, 1979a, 1979c, 1981a, 1981c). Their locality lies 2 Km south-east of the Rengging village near Pasighat in the Siang District. Subsequently, T. Singh & P. Singh (1983) located another horizon of late Early Eocene strata which contains larger foraminiferids. This horizon was located nearly 19 Km south-east of Yinkiyong near Dalbing village in the Yamne Valley in Siang District. Simultaneously, C. Tripathi & S. Singh (1983) recorded the occurrence of *Nummulite*-bearing horizon not only from this locality (i.e. near Dalbing village) but also from the nearby Gobuick village.

*Marine Fossils.* The fossils described by S. Singh (1984) from Dalbing, which he considered to be of the Permian age, in fact belong to the Eocene age. Likewise, a few of the fossils listed by Sinha *et al.* (1986) may also be the Eocene.

*Micro Fossils.* The foraminiferal fauna reported by C. Tripathi *et al.* (1978, 1979a, 1979c, 1981a) from the Rengging locality in the Pasighat area of Siang District, was later described by C. Tripathi *et al.* (1981c) who assigned it a Upper Paleocene to Lower Eocene age. The fauna included: *Nummulites atacicus* Leymerie, *N. lahirii* Davies and Pinfold, *N. wadii* Davies, *N. thalicus* Davies, *N. nuttalli* Davies, *N. globulus* Laymerie, *Assilina granulosa* (d' Archiac), *A. dandotica* Davies and Pinfold, *A.* sp., *Miscellanea miscella* d' Archiac and Haime, *M.* sp., *Lockhartia conditi* (Nuttall), *L. haime* (Davies), *L.* cf. *conica* Smout, *Lepidocyclina (Polylepidina)* sp., and *Globorotalia*. Besides these, larger foraminifers, viz., *Globorotalia*, *Miliolid*, and *Textularia* were also reported. Other than these, some forms of microgastropods, corals, an ostracod *Xestoleberis* sp., and fish teeth were also reported.

T. Singh and S. Singh (1983), while recording the foraminiferal assemblage near Dalbing locality, commented that the identification of the fauna given by C. Tripathi *et al.* (1981c) is not correct. They

concluded (T. Singh and P. Singh, 1983, p. 144) that the specimens described by Tripathi *et al.* (1981c) represent only *Nummulites atacicus* and *Nummulites globulus*, and that rest of the specimens assigned to other genera are referable to one or the other species of *Nummulites* as mentioned above. The fauna of T. Singh & P. Singh (1983) included *Nummulites (Assilina) dandotica* Davies, *N. (A.) daviesi* Cizancourt, *N. (A.) laminosa* Gill, *N. (A.) spinosa* Davies, *N. (A.)* sp. A, a few bivalves and gastropod shells. This assemblage suggested a late early Eocene age.

Other passing references of the Eocene fauna were made by Ranga Rao (1983), C. Tripathi and S. Singh (1983), S. Singh (1984), S. Singh & De (1984), and Sinha *et al.* (1986).

Ranga Rao (1983) listed the fauna recovered by the ONGC geologists from Rengging and Dalbing localities. It included : i) *Nummulites* aff. *atacicus*, *N. cf. globulus*, *Operculina* sp., Rotalids, a Globigerinid (?), *Orbitolites* sp., echinoid spines, etc., and ii) *Discocyclina* sp., *Lockhartia* sp., *Nummulites atacicus*, *N. globulus*, *N. beaumonti*, *N. sp.*, *Assilina* sp., and *Dictyoconoides* sp., respectively. It is, however, difficult to comment on the authenticity of identification of these forms in view of lack of systematics and illustrations.

C. Tripathi and S. Singh (1983) noted that the *Nummulites* are deformed into ellipses. They also made a unique study of strain-estimates on these *Nummulites*, and concluded that the deformed *Nummulites* of Gobuick area have suffered 73.41% of local stretching during the Himalayan Orogeny (post-Eocene tectonic movements). They opined that undeformed behaviour of *Nummulites* of nearby Dalbing area could be ascribed due to distant disposition from thrusting areas.

S. Singh (1984) listed the Eocene faunal assemblage of Dalbing. The assemblage included *Nummulites atacicus*, *N. lahirii*, *N. obtusus*, *N. discorbinus*, *N. acutus*, *Assilina dandotica*, *A. granulosa*, *A. spinosa*, *A. sub-spinosa*, *Assilina* sp., *Spiroculina* sp., *Quinquoloculi* sp., *Operculina* cf. *salsa*, *Rotalia trochidiformis* and a bryozoa *Biselenaria* sp. He also reported the occurrence of the Permian fossils from the same area and interestingly from the same formation, i.e. Yinkiyong Formation. This included : brachiopods- *Chonetes* sp., *Chonetina* sp., *Marginifera* sp., bivalves (and not cephalopods as mentioned by S. Singh, p. 36) - *Nucula* sp., *Nuculana* sp. The present author examined a part of the collection and the lithology in which the aforementioned fossils were reported to occur, and is of the opinion that the identification of these fossils by S. Singh is not correct, which in fact are of the Eocene age: It may be noted that S. Singh also stated (on page 37) it to be difficult to differentiate the Eocene rocks from the Permian rocks. He introduced a new term "Dalbing Formation" to designate the *Nummulites*-bearing rocks of the Lower to Middle Eocene age, and retained the term "Yinkiyong Formation" for the lower Palaeozoic rocks.

S. Singh & De (1984) reported foraminifers of the Lower (?) to Middle Eocene age from calcareous sandstone exposed in a new locality near P. W. D Inspection Bungalow in Garu Village along the Likabali-Along road (at 5 km stone) and 1 km west of Garu Village along the Garu-Gensi road. The forams included *Nummulites* sp., *Discocyclina* sp., *Assilina*, *Pelatispira* sp. and *Rotalia* sp. The authors gave additional information on fossils from the Rengging area, and reported bryozoans- *Callopora* sp., cf. *Idomonea* sp.; and coral - *Dasmomlia* sp.

Sinha *et al.* (1986) mentioned about the Eocene foraminifers and plant fossils as reported by C. Tripathi *et al.* (1979b, 1981b), and also those of the Permian fossils.

*Plant fossils.* A significant contribution to the palaeontology of the Eocene beds in Arunachal was made by C. Tripathi *et al.* (1979b, 1981b), who reported the Lower Tertiary plant fossils from near Geku Village in the Dihang Valley, Siang District. They identified five genera- *Apocynophyllum* sp., *Canavalia* sp., *Hicoria* sp., *Grewiopsis* sp., and *Sophera* sp., and assigned a lower Eocene age. The systematic description of these leaf impressions is lacking, and only the illustrations were published. Sinha *et al.* (1986, p.55) reported leaf impressions of an Oak, *Quercus* sp. from the same locality. They however, neither described nor illustrated the material.

*Palyno Fossils*. As mentioned earlier, the first record of the Eocene fossils from the Arunachal Himalayas, was that of palynomorphs (Jain and Dutta, 1978). The assemblage, characterised by predominance of dinoflagellates, fungal bodies, pteridophytic spores, gymnospermous pollen grains, and subdominance of angiospermous (palmae) pollen grains, was recovered from a limestone sample from near Garu Village on the Likabali-Along road in Siang District. The various forms described are : Algae-Dinoflagellates - *Hystrichokolpona rigaudae* Deflandre and Cooksan, *Homotryblium tenuispinosum* Davey and Williams, *H. pallidum* Davey and Williams, *H. plectilum* Drugg and Loeblich, *Cyclonephelium pastielsii* Deflandre and Cooksan, *C. intricatum* Eaton, *Polysphaeridium* sp. cf. *giganteum* Caro, *Impletosphaeridium multispinosum* Benedek, *Spiniferites ramosus* subsp. *gracilis* (Davey and Williams) Lentin and Williams; Fungi - only two badly preserved specimens belonging to micro-hyriaceous fungi; Pteridophytic spores and Gymnospermous pollen grains - a single bisaccate pollen grain and a few trilete spores; Angiospermous pollen grains - *Couperipollis wodehousei* (Biswas) Venkatachala and Kar, *C. grandis* Jain and Dutta, *Lakiapollis* sp. A, *Malvacearumpollis* sp. A, *Polycolpites* sp. A, *Triorites* sp. A, and *Polygonacidites* sp. A.

Prasad and Dey (1986) recorded Early Eocene palynotaxa from the Lesser Himalayan sediments exposed in Dalbing and Yinkiyong localities in Siang District. The palynomorphs recorded are : Pteridophytic spores - *Cyathidites minor* Couper, *Cyathidites* sp. cf. *C. australis* Couper, *Stereisporites formosus* Saluja, Kindra and Rehman, *S. ambiguus* Saluja, Kindra and Rehman, *Polypodiaceoisporites* sp., *Dandotiaspora* sp., *Foveotriletes pachyexinus* Datta and Sah, *F. eocenicus* Mehrotra and Sah, *Malayaeaspora costata* Triwedi; Ambwani and Kar, *Malayaeaspora* sp., *Ceratoporites* sp., *Anapiculatisporites* sp., *Osmundacidites cephalus* Saxena, *Hymenozonotriletes raris* Saluja, Kindra and Rehman, *Laevigatosporites* sp. and *Schizaeoisporites* sp.; Gymnosperm pollen - *Prastriopollenites triangulatus* Maheshwari, *Virkkipollenites mehtae* Lele, *Parasaccites korbaensis* Tiwari, *Podocarpidites* sp., *Scheuringipollenites barakarensis* Tiwari, *Illinites* sp., *Platysaccus* sp., *Lueckisporites elongatus* Lele and Karim, *Crescentipollenites gondwanensis* Bhardwaj, Tiwari and Kar and *Abiespollenites* sp.; Angiosperm pollen - *Inaperturopollenites mirabilis* Saluja, Kindra and Rehman, *Spinainaperturites* sp., *Spinizonocolpites echinatus* Muller, *Spinizonocolpites* sp., *Pistillipollenites* sp., *Palmaepollenites kutchensis* Venkatachala and Kar, *P. ovatus* Sah and Kar, *P. eocenicus* Sah and Dutta, *Liliacidites maximus* Saxena, *L. kutchensis* Saxena, *Liliacidites* sp., *Couperipollis* sp., *Mauritidites* sp., *Cupuliferoipollenites* sp., *Dicolpopollis proprius* Saluja, Kindra and Rehman, *Dicolpopollis* sp., *Tricolpites* sp., *Retitrescolpites assamicus* Sah and Kar, *Stephanocolpites* sp., *Bacustephanocolpites nadhamunii* Saxena, *Retistephanocolpites coramandeliensis* Venkatachala and Rawat, *Polycolpites* sp., *Rhoipites* sp., *Araliaceoipollenites* sp., *Retidiporites magnus* Baksi and Dev, *Retidiporites* sp., *Proteacidites protrudus* Sah and Kar, *P. bellus* Samoiloivitch, *Proteacidites* sp., *Myricipites* sp., *Cupanieidites cauveriensis* Venkatachala and Rawat, *Margocolporites* sp., *Favitricolporites magnus* Sah and Datta, *Trisyncolporites* sp. and *Striatocolporites* sp.; Phytoplanktons - *Micrhystridium modestus* Saluja, Kindra and Rehman and *Hystrichosphaeridium* sp.

S. K. M. Tripathi and T. Singh (1992) systematically described the Early Tertiary (Eocene) palynotaxa from Rengging, Dalbing and Gobuick localities of Siang District. The represented taxa are - *Tricolporopollis matanamadhensis* (Venkatachala and Kar) Tripathi and Singh, *Lakiapollis ovatus* Venkatachala and Kar, *Pellicieropollis langenheimii* Sah and Kar, *Pellicieropollis* sp., *Ctenolophonidites costatus* (van Hoeken-Klinkenberg) van Hoeken-Klinkenberg, *Ligulifloraedites pilatus* Kar and *Incrotonipollis* sp.

### **Gondwana Group (Permian)**

The Gondwana Permian Group of sediments forms more or less a continuous linear belt from the Kameng District in the west to the Siang District in the east, where it is truncated by a fault along Dibang River.

This linear belt over rides over the Siwalik sediments and in turn was thrust over by the rocks of the Miri Group and/or Bomdila Group in the north. In Arunachal it comprises of three formations (T. Singh, 1993) : Rangit Formation, Garu Formation and Bhareli Formation, ranging in age from the Lower to the Upper Permian. The rocks of this group are rich in fossils including invertebrates fossils, micro-fossils, plant-fossil, and palyno-fossils.

*Marine fossils.* MaClaren (1904) was the first to collect a good number of fossiliferous fragments of the Permian age from boulders at Derpai in the Subansiri gorge. Although the specimens were not found *in situ*, MaClaren (1904) opined that the source beds could not be very far from Assam Plain. The fossils were later described by Diener (1905). He identified the following fossils and assigned an Anthracolithic age - Brachiopods : *Productus* cf. *pustulosus* Phill., *Productus* div. sp. indet., *Spiriferina* sp. indet., *Reticularia* cf. *inaequilateralis* (?) Gemmellaro, *Dielasma* sp. indet. aff. *uralico* Krotow, *Dielasma* sp. indet. ex aff. *biplex* Waagen, *Dielasma* sp. indet., *Chonetes* cf. *carbonifera* Keyserling; Bivalves: *Myalina* sp. indet., *Monopteria subansirica* Diener; Gastropods: *Loxonema* sp. indet., *Pleurotomaria* sp. indet. aff. *punjabica* Waagen, *Bellerophon* sp. indet. ; Bryozoa : *Fenestella* sp. indet.

Coggin-Brown (1912) while traversing the upper course of Sireng River in the Abor Hills (Dihang Valley, Siang District) obtained dark bluish-grey arenaceous limestone rolled boulders in the Upper Sireng stream with indeterminable fossil remains including badly preserved crinoid ossicles and opined that these belonged undoubtedly to the base of the Gondwana Series.

Lasker (vide Jacob and Banerjee, 1954, p. 56) located a bluish fossiliferous limestone bed in the Ranga River Basin, about 32 Km south-west of MaClaren's locality and a few hundred meters from the Tertiary belt lying to the south (north of the Siwalik Group). The only identifiable fossil was a poorly preserved *Chonetes* cf. *carbonifera* Keyserling. Subsequently, Lasker (1959) found intercalations of finely laminated, impure limestone and thick beds of dark carbonaceous slaty shales in the Dihang River gorge. The shales yielded numerous dark argillaceous to slightly calc syngenetic pyritic nodules and concretions containing invertebrate fossils. These nodules and concretions were similar to those obtained from the Subansiri, Per, Ranga and Dikrong valleys, some of which contained marine fossils, viz., *Chonetes* sp., *Spirifer* sp., *Productus* sp. and crinoid remains.

The fossils collected from the Bighu Nala in the Ranga Valley, Subansiri District, by Lasker (1954) were described by Sahni and Srivastava (1956). The described and illustrated fauna include *Conularia laskeri* Sahni and Srivastava, *Chonetes carbonifera* var. *lata* Sahni and Srivastava, *Chonetes carbonifera* var. *sulcata* Sahni and Srivastava, *Subansiria ranganensis* Sahni and Srivastava, *Sringothyris* cf. *nagmargensis* (Bion), *Productus* (? *Linoproductus*) sp. indet. An Anthracolithic age was assigned to this fauna, as Sahni and Srivastava (1956) found it difficult to assert with confidence a more precise (Carboniferous or Permian) age in view of the small number of determinable species.

After more than a decade of silence, the interest in this remote area was revived when Chandra (1972) located three new localities in the coal bearing Lower Gondwana of Arunachal Pradesh in the Kameng and Subansiri districts. He collected brachiopods and bivalves from the black calcareous argillites with phosphate nodules and pyritous specks at 28.5 Km stone marker on the Kimin-Ziro road in Subansiri District. Subsequently, many workers started exploring this area palaeontologically.

Das (1973) identified a *Linoproductus* sp. from the Side Nala Section near Tatamari Village in Siang District. Jain and Das (1973) discovered some bryozoans along the Foothill-Tenga Road Section at about 100 m west of Sissni Camp in Kameng District. The bryozoans recorded are *Fenestella* sp., *Protoretetepora* cf. *ampla* (Lonsdale), and ? *Polypora megastoma* de Koninck. They inferred Upper Carboniferous to Lower Permian age.

T. Singh (1973) for the first time described the *in situ* marine fauna from the Subansiri District. The fauna, recovered from near 32 km stone on the Kimin-Ziro road near Lichi Village, included : Brachiopods

- *Subansiria* sp., *Martinia dispar* Diener, *Chonetes carbonifera* var. *sulcata* Sahni and Srivastava; Conularids - *Conularia laskeri* Sahni and Srivastava, Bivalves - ?*Goniophora* sp., *Nucula* sp.; Gastropods - *Pleurotomaria* cf. *brenensis* Reed. This faunal assemblage, which was to be indicative of Middle to Upper Carboniferous age by T. Singh (1973), in fact indicates a Lower Permian age. The specimen of *Subansiria* sp. was later restudied by the author himself (T. Singh, 1978a), and named it as *Subansiria ananti* Singh.

T. Singh (1975) reported fossils from two localities in Siang District, one in the Sijik stream near Tatamari Village, and the other in the Sigen stream near Gensi Village. These are *Deltopecten*, *Stephanoviella*, ? *Ambikella*, *Subansiria*, *Pleurotomaria*, *Warthia*, *Buccania*, *Uralorthoceras*, *Pseudogastriceras*, fenestellids and crinoidal remains. The study by present author at Bureau of Mineral Resources, Canberra in Australia revealed the presence of a new species of *Megadesmus* (Dickins and T. Singh, Ms).

Acharyya *et al.* (1974a, 1974b, 1975a, 1975b) recorded *Geinitzella* sp., squashed brachiopods (orthotetid and spiriferid affinity); *Eurydesma* sp., *Schizodus* sp., other bivalves and some trace fossils from Khuppi area in Kameng District. They also recorded marine fauna from the Tatamari - Daring area in Siang District which included: *Linoproductus* sp., *Stepanoviella* sp., *Terrakea* sp., *Neochonetes* sp., *Neospirifer* sp., *Cyrtella* sp., and other brachiopods; *Mourloniopsis* sp., *Peruvispira* sp., *Warthia* sp. and other gastropods; ? *Myonia* sp., *Deltopecten* sp., and a few other bivalves; *Paraconularia* sp., *Calceolispongia* sp., crinoid stems, *Fenestella* sp. and other bryozoans and corals. They also mentioned about the presence of a Late Permian forms *Oldhamina* sp. in the Ranga Valley, Subansiri District (collected by B. Kakoti and identified by S.C. Shah). This fauna was only listed and a few forms were illustrated, without giving any systematic account. Hence, it is difficult to comment on this fauna.

T. Singh (1976) took up the task of systematically describing the fauna collected from a narrow linear belt extending from Tatamari village in the west to Daring village in the east in Siang district. He also made collections from various points all along the foot-track between Tatamari and Siberette villages. upto the Subansiri river. Towards the east, the collections were also made from the Pasighat area around Rengging village. The fauna described by T. Singh represented: **Bryozoans** (T. Singh, 1976) - *Fenestella* sp., *Polypora* sp.; **Crinoids** (T. Singh, 1976) - ?*Calceolispongia* sp.; **Conulariids** (T. Singh, 1976) - *Conularia laskeri* Sahni and Srivastava, and *Paraconularia* sp.; **Brachiopods** (T. Singh, 1978b) - *Chonetes* sp., *Lissochonetes carbonifera* (Keyserling), *Linoproductus cora* (d'Orbigny), *Subansiria rangansensis* Sahni and Srivastava, *Subansiria* sp. indet., *Neospirifer fasciger* (Keyserling), *Neospirifer fasciger* cf. var. *paucicostulata* Reed, *Neospirifer* sp. indet., and *Ambikella konincki* (Etheridge); **Gastropods** (T. Singh, 1978c) - *Warthia* cf. *intermedia* Dickins, *Straparollus lachiensis* Oakley, *Platyteichum brenensis* (Reed), *Platyteichum garuensis* Singh, *Mourlonia* (*Mourlonia*) cf. *nuda* (Dana), *Ptychomphalina* (?) sp. indet., Incertae sedis type A; **Bivalves** (T. Singh, 1978c) - *Anthraconeilo kansana* (Tasch), *Quadratonucula australiensis* Dickins, *Phestia* cf. *lyonsensis* (Dickins), *Eurydesma cordatum* Morris, *Eurydesma* (?) sp. indet., *Aviculopecten* sp. indet., *Aviculopecten* (?) sp. indet., *Deltopecten mitchelli* (Etheridge and Dun), *Neoschizodus* cf. *australis* Runnegar, *Astartila* cf. *blatchfordi* (Hosking), *Oriocrassatella* (?) sp. indet. These specimens alongwith some additional material are being studied (Dickins and T. Singh, Ms). These included *Warthia* cf. *intermedia* Dickins, *Peruvispira yachungii* n. sp., *Mourlonia* (*Mourlonia*) *siangensis* n. sp., ?*Nuculopsis* sp. indet., *Quadratonucula garuensis* n. sp., *Phestia* sp. nov., *Atomodesma mytiloides* Beyrich, *Streblopteria* sp., *Deltopecten* sp., ?*Oriocrassatella* sp., *Myofossa waterhousei* n. sp. and *Megadesmus himalayensis* n. sp.; **Cephalopods** (T. Singh, 1978d) - *Sueroceras bomtense* Singh, *Sueroceras* sp. indet., *Uraloceras siangense* Singh, *Uraloceras* cf. *irwinense* Teichert and Glenister, *Uraloceras* sp. indet. Significantly, the cephalopods were recorded for the first time from the Eastern Himalayan region and that the find of the genus *Uraloceras* was the first record of the Lower Permian ammonoid in the Himalayas, where so far only the Upper Permian ammonoids were known.

Later, T. Singh (1981) analysed the age and affinity of the faunal assemblage from the Garu Formation. He showed that brachiopods dominate over other groups of fossils, next follow gastropods, bivalves, cephalopods, bryozoans, crinoids and conularids. He assigned the Sakmarian and Artinskian stages of the Lower Permian age on the basis of the faunal assemblage. He further suggested that the Garu fauna of Arunachal Pradesh has close affinity with the fauna of South Sikkim, Darjeeling, Garhwal, Agglomeratic Slate of Kashmir, Lahaul and Spiti, Dandot and Amb formations of the Salt Range in the Himalayan region and *Eurydesma* fauna of Bap, Manendragarh and Daltonganj in the Peninsular India, and also show striking resemblance with the Australian fauna, specially Western Australia. T. Singh (1987) analysed the palaeoclimatic significance of the fauna from the Garu Formation of Siang District, and reported that the fauna is indicative of cool climatic conditions.

Subsequently T. Singh and Archbold (1993) re-studied the brachiopods described by T. Singh (1978b) with some additional material. The significant study on the specimens designated as *Ambikella konincki* by T. Singh (1978b) revealed it to be a new species of *Tomiopsis* on the basis of micro-ornaments, and was supported by the additional specimens. Thus, all the specimens described under *Ambikella konincki* (Etheridge) by T. Singh (1978b) were named as *Tomiopsis siangensis* by T. Singh and Archbold (1993). Other brachiopod fauna described were *Tivertonia tatamariensis* sp. nov., *Strophalosioides* indet., *Costatumulus sahnii* sp., *Cyrtella* sp. cf. *c. nagmargensis* (Bion), *Subansiria* sp. *Tomiopsis siangensis* sp. nov., *Fredericksia?* sp., *Trigonotreta orientensis* sp. nov. Simultaneously, Archbold and T. Singh (1993) commented on the palaeogeographical implications of this brachiopod fauna, specially on the provincial relationship with Australia. They demonstrated significant and strong links of this fauna, thus, contradicting the reviews that imply relationships between the Early Permian faunas of the Indo-Himalayan and Western Australian are not as strong as the relationships between Indo-Himalayan and Eastern Australian regions during the Late Sakmarian.

Santra (1979) collected well preserved fossils of bivalves and brachiopods from a fossiliferous nodular band, about 2.4 Km south-east of Rengging. The fossils described were: *Strophalosia* sp., *Parallelodon* sp. and *Mourlonia* cf. *frenyensis*.

G. Singh and Tiwari (1980) recorded *Modiolopsis* sp. from Kimin-Ziro Road Section (between 27 to 32.5Km), and *Martinia* sp. from Kheel Nala on Doimukh - Sagalee Road Section, both in Subansiri District.

C. Tripathi and Roy Chowdhury (1981) while analysing different litho-units of the Gondwan of Arunachal Pradesh, listed the faunal assemblage of Black Shale Facies (= Garu Formation of T. Singh, 1981) from Tatamari-Daring area. This included *Linoproductus* sp., and *Stepanoviella* sp., *Terrakea* sp., *Cyrtella* sp., *Neochonetes* sp., *Mourloniopsis* sp., *Peruvispira* sp., *Warthia* sp., *Paraconularia* (?), *Myonia* sp., *Deltopecten* sp., *Calceolispongia* sp., *Fenestella* sp. This fauna was neither described systematically nor illustrated. A significant observation of these authors (p. 86) is the suspected occurrence of a Mesozoic form *Inoceramus* in the Ranga Valley, Subansiri District.

Sinha and Mathur (1982) described a faunal assemblage from the Kimin-Ziro Road Section. This included : **Bivalves** - *Eurydesma aequale* Reed, *E. mytiloides* (Reed), *E. perversum* (Reed), *E. punjubicum* var. *elongata* Reed, *E.* sp. indet.; **Brachiopods** - *Pustula pustulosa* (Phillips), *Buxtonia scabriculus* (Sowerby), and *Dielasma dadanense* Reed.

S. Singh (1984) reported the occurrence of the Permian fossils from the Dalbing area. This included: Brachiopods - *Chonetes* sp., *Chorinetina* sp., and *Marginifera* sp ; Bivalves - (and not cephalopods as mentioned by S. Singh, 1984) - *Nucula* sp., *Nuculana* sp. The present author examined a part of this collection and is of the opinion that this fauna appears to be of the Eocene age and not the Permian, as mentioned earlier also under the Eocene Sequence.

Sinha *et al.* (1986) reported a rich faunal assemblage from the shales exposed below Dalbing village, which included: Bivalves - *Aviculopecten*, *Burmesia*, *Claraia*, *Eoschizodus*, *Etheripecten*, *Goniophora*,

*Myoconcha, Mysidioptera, Nuculana, Nuculopsis, Palaeoneilo, Phestia, Pterinopecten, Schizodus* and *Stutchburia*; Brachiopods - *Neochonetes, Neospirifer, Productus* and *Spirifer*; and Gastropods - *Loxonema, Meekospira, Mournalonia* and *Neilsonia*. In view of lack of illustrations and systematic description, it is difficult to comment on the authenticity and identification of this fauna. They have also referred to the fauna of Sinha and Mishra, 1982 (reference not given by Sinha *et al.*, 1986) from about 1 km south of a bridge on the Igo River in the West Siang District. This fauna included *Linoproductus, Marginifera, Neochonetes, Pustula, Bellerophon* and *Protoretetpora*.

*Micro Fossils.* Except for some passing remarks about the presence of micro-fossils (foraminifers, etc.) by a few workers, no detailed account has yet been published. The present author has recovered a rich assemblage of foraminifers and a few ostracodes from the Permian sediments of Siang District. This faunal assemblage is currently under study.

*Plant Fossils.* Jacob and Bannerjee (1954) were first to firmly establish the Lower Gondwana age by recording and describing two specimens of *Glossopteris* fronds from slaty beds in a road section below Flat Two (Elephant Flat) in the Sela sub-Agency, N.E. Frontier, Assam (now named as West Kameng District, Arunachal Pradesh). The described specimens are *Glossopteris* cf. *indica* and *G. indet.*

Later, Acharyya *et al.* (1975b) listed a rich assemblage of plant fossils from the Khelong and Bhareli Formations in Kameng District. The flora included: *Glossopteris indica* Schimper, *G. communis* var. *stenoneura* Feistmantel, *G. damudica* Feistmantel, *G. angustifolia* Brongniart, *G. longicaulis* Feistmantel, *G. conspicua* Feistmantel, *G. formosa* Feistmantel, *Gangamopteris* cf. *cyclopteroides* Feistmantel, *Dictyopteridium* sp., *Vertebraria indica* Royle, *Phyllothea* sp., *P. griesbachi* Zeiller, *Schizoneura* sp., *S. gondwanensis* Feistmantel and *Samaropsis* sp. This floral assemblage was only listed and not described. However, Acharyya *et al.* (1975b) compared the floral assemblage of the Khelong and Bhareli formations broadly with the Barakar and Raniganj flora of the Peninsular India.

T. Singh and Bajpai (1990) systematically described the *Glossopteris* flora from the Eastern Himalayas, of which the flora from Arunachal Pradesh comes from around the Elephant Flat area on Bhalukpong-Bomdila Road Section and around Khuppi area in Kameng District. It included: *Equisetalean axes, Glossopteris stenoneura* Feistmantel, and *G. communis* Feistmantel.

Recently, Bajpai and T. Singh (1997) have described the occurrence of a wood-fossil, viz. *Megaporoxyton maheshwari* n. sp. from the Garu formation near 1.25 km from Garu PWD Inspector Bungalow on Garu-Gensi-Road in Siang District. Significantly it is the first report of a Permian wood-fossil from Eastern Himalayas.

*Palyno Fossils.* Chandra (1972) examined coal samples of the Siang District and noted microscopic flora represented by pteridophytic and gymnospermic pollen grains with lot of cuticles and other woody matter. He also observed monosaccate, bisaccate and trilete spores. The genera identified are: *Candidispora, Crucisaccites, Virkkipollenites, Punctatisporites, Apiculatisporites, Microreticulatisporites, Ciratriradites, Verrucosisporites, Lahirites* and *Strialites*. He assigned a Lower Permian (Barakar) age to the assemblage.

Das (1973) mentioned about the spores of the Barakar affinity (Early Permian) from some of the coal seams and lenses.

Srivastava and Dutta (1977) recorded a rich miofloral assemblage consisting of Pteridophytic spores, gymnospermous pollen grains and alete miospores from Siang District. Twenty-three important spore pollen genera which they encountered in the mioflora are: *Callumispora, Lycopodiumsporites, Brevitriletes, Lacinitriletes, Microbaculispora, Indotriradites, Jayantisporites, Parasaccites, Virkkipollenites, Plicatipollenites, Stellapollenites, Rugasaccites, Crucisaccites, Divarisaccus, Caheniasaccites, Potonieisporites, Illinites, Platysaccus, Striatites, Faunipollenites,*

*Striatopodocarpites*, *Vesicaspora* and *Scheuringipollenites*. The alete forms assignable to 'Acritarchs' included *Pilasporites*, *Schizosporis*, *Hemisphaerium*, *Balmeella*, *Maculatasporites*, *Quadrisporites*, *Leiosphaeridia*, *Spongocystia?*, *Botryococcus*, *Foveofusa*, Sponge spicule like structures and spinose acritarchs. The over all association of various palynotaxa indicated the occurrence of two distinct miofloral zones, which are comparable to the Talchir and the Lower Karharbari mioflora of the Peninsular India.

T. Singh (1979) recovered two distinct assemblages from the Rilu Member (= Rangit Formation) and Bomte Member (= Garu Formation) in the Siang District. The palynological assemblage of the Rangit Formation shows maximum dominance of radial monosaccates. The palynomorphs reported in order of dominance are: *Parasaccites*, *Plicatipollenites*, *Virkkipollenites*, *Pilasporites*, *Divarisaccus*, *Potonieisporites*, *Limitisporites* and *Illinites*. The palynological assemblage of the Garu Formation shows the radial monosaccates as the dominant group but *Callumispora* becomes the most prominent genus. Other genera are *Parasaccites*, *Potonieisporites*, *Plicatipollenites*, *Indotriradites*, *Vesicaspora*, *Caheniasaccites*, *Hemisphaerium*, and *Microbaculispora*. The two miofloral assemblages correspond to the Talchir and the Lower Karharbari assemblages, respectively. Later, T. Singh (1987) analysed palaeoclimatic significance of this mioflora which indicated cool climatic conditions.

Srivastava *et al.* (1988) while synthesising the Permian palyno-fossils from the Eastern Himalayas have shown the presence of trilete spores, chiefly *Callumispora* associated with *Parasaccites*, *Plicatipollenites*, *Caheniasaccites* and *Indotriradites* in the Permian sediments exposed around Elephant Flat area in Kameng District. They also reported similar assemblage from near Kheel in Subansiri District. However, in Siang District, they have shown three assemblages. Of these two are the same as described by Srivastava and Dutta (1977), and T. Singh (1979), while the third is a new one which is recovered from the carbonaceous sediments of the Garu Formation near Takaso (Tasko) Village. This assemblage is dominated by *Scheuringipollenites*, while radial monosaccate pollen and trilete spores show decrease, and striate and non-striate disaccates record increase in their percentage.

Dutta *et al.* (1988) recovered the palyno-fossils from the Bhareli Formation around Elephant Flat area in Kameng District, which included trilete, monosaccates, disaccate and alete forms. The mioflora are: *Leiotriletes* sp., *Hennellysporites diversiformis* (Balme and Hennelly) Tiwari, *Callumispora barakarensis* Bharadwaj and Srivastava, *C. tenuis* Bharadwaj and Srivastava, *C. tenuis* var. *minor* Bharadwaj and Srivastava, *Microbaculispora tentula* Tiwari, *Indotriradites korbaensis* Tiwari, *I. surangei* Tiwari, *Dentatispora* sp., *Divarisaccus* sp., *Caheniasaccites ovatus* Bose and Kar, *Parasaccites obscurus* Tiwari, *P. distinctus* Tiwari, *P. bilateralis* Tiwari, *Plicatipollenites indicus* Lele, *P. maculatus* Lele and Karim, *Plicatipollenites* sp., *Virkkipollenites orientalis* Tiwari, *Potonieisporites subtilis* Sinha, *Vestigisporites densus* Singh, *Illinites* sp., *Limitisporites diversus* Lele and Karim, *Faunipollenites varius* Bharadwaj, *Striatopodocarpites brevis* Sinha, *Maculatasporites punctatus* Peppers, *Leiosphaeridia indica* Lele and Chandra.

Srivastava and Bhattacharyya (1990) reported a palynofossil assemblage comprising 21 genera from the Permian sediments exposed near Kheel on Doimukh-Sagalee Section in Subansiri District. The genera included *Leiotriletes*, *Callumispora*, *Brevitriletes*, *Apiculatisporis*, *Horriditriletes*, *Granulatisporites*, *Cyclobaculisporites*, *Psilalacinites*, *Indotriradites*, *Dentatispora*, *Parasaccites*, *Plicatipollenites*, *Virkkipollenites*, *Caheniasaccites*, *Sahnites*, *Vestigisporites*, *Alisporites*, *Scheuringipollenites*, *Paravesicaspora*, *Striatites*, and *Striatopodocarpites*. According to them the assemblage is rich in trilete spores (52%) and monosaccate pollens (31%), while nonstriate disaccate (6%) and striate disaccate pollen (2%) are poor in occurrence.

### **Miri Group**

The Miri Group consists of slaty shales and phyllites, limestone, variegated quartzites and conglomerates. No megafossil has so far been found in the Miri Group except trace fossils. Stromatolites which are

reported from Sikkim-Darjeeling Himalayas, have not been recorded from Arunachal, but these are likely to be present here also.

Acharyya (1974) first reported the trace fossils, in forms of tubular subvertical to L-shaped burrows about 1-2 cm wide and upto 45-50 cm deep in the quartzites of Tatamari-Gensi area in Siang District. Subsequently, Laskar and Roy Chowdhury (1979) and Laskar (1983, p.111) reported "Ichno-fossils" in the form of *Skolithos* burrows (max. length 20 cm) in the Miri Quartzite and worm-tracks in the associated red shales.

Tandon *et al.* (1979) documented two trace fossils out of the stray samples of the Miri Quartzite from the Siang District. The described Ichnogenera are *Skolithos* Haldemann, and *Planolites* Nicholson.

C. Tripathi and Kaura (1980) reported Middle Devonian early vascular plant remains resembling *Rhynia* in the black carbonaceous slate/phyllite of the Salari Formation in the Salari Window in the Kameng District. The Salari Formation is believed to represent the upper part of the Bichom Group. The stratigraphic status of the Bichom Group is uncertain, as part of it belongs to the Permian rocks and a part to the Miri Group (for a different opinion, see Kumar, this volume and Kumar (1998)). The presence of *Rhynia* is interpreted here to have recovered from the rocks of the Miri Group.

### Abor Volcanics

The occurrence of volcanics in the Arunachal Himalayas was first reported by Coggin-Brown (1912) from the Dihang Valley (Siang District), and named the "Abor Volcanic Series". The age of the Abor Volcanics remained a subject of controversy, since there was no fossil control. Roy Chowdhury (1977) for the first time reported the occurrence of the Permian sporomorphs from the intertrappean black shales, but unfortunately he did not give any reference of sample, locality and photographic illustrations. Later, Prasad *et al.* (1989) located the presence of intertrappean beds at three localities, viz., Yinkiyong, Dalbing and Maryang in Siang District, and recovered rich micro-floral assemblages of the Early Permian age. From Yinkiyong, the microfloral assemblage included *Punctatisporites indicus* Tiwari, *Cyclogranisporites* sp., *Horriditriletes curvibaculosus* Bhardwaj and Saluja, cf. *H. unicus* Tiwari, *Acanthotriletes filiformis* Tiwari, *Laevigatosporites* sp., *Parasaccites korbaensis* Bharadwaj and Tiwari, *P. bilateralis* Tiwari, *Plicatipollenites gondwanensis* Lele, *P. indicus* Lele, *Parastratipollenites rajmahalensis* Maheshwari, *Virkkipollenites mehtae* Lele, *V. obscurus* Lele, *Striatopodocarpites gondwanensis* Lakhanpal, Sah and Dube, *Crescentipollenites fuscus* Bharadwaj, Tiwari and Kar, *Scheuringipollenites tentulus* Tiwari, and *Podocarpidites* sp. The microflora from Dalbing included *Punctatisporites indicus* Tiwari, *Lophotriletes* sp., *Dictyotriletes* sp., *Laevigatosporites colliensis* Venkatachala and Kar, *Parasaccites distinctus* Tiwari, *Virkkipollenites mehtae* Lele, *V. obscurus* Lele, *Scheuringipollenites barakarensis* Tiwari, *Platysaccus* sp., *Crescentipollenites fuscus* Bharadwaj, Tiwari and Kar, and *Striatopodocarpites tiwarii* Bharadwaj and Tripathi. The microfloral assemblage from Maryang included *Punctatisporites uniformis* Tiwari, *Microfoveolatispora* sp., *Lophotriletes rectus* Bharadwaj and Saluja, *Indotriradites* sp., *Potonieisporites* sp., *Scheuringipollenites barakarensis* Tiwari, *Platysaccus* sp., *Striatopodocarpites* sp., *Crescentipollenites gondwanensis* Bharadwaj, Tiwari and Kar, and *Striatites parvus* Tiwari.

### Eastern Arunachal Pradesh

The tectono-stratigraphic succession of the Eastern Arunachal Pradesh, which includes Lohit and Tirap districts, is quite different from that of the Western Arunachal Pradesh, mainly because of the so called Eastern Syntaxis. The metamorphites of this region overlie the alluvium directly, and are in contact with the Ophiolitic Melange. Higher up in the north are the Basic and Ultra Basic rocks. The Gondwana (Permian) and Miri Groups are altogether absent in this part. In Tirap District, however, the Tertiary sediments are present but are different from those of the Western Arunachal Pradesh where they

represent Siwalik (Upper Tertiary) and marine Eocene sequence. In Tirap District of Eastern Arunachal Pradesh, the Tertiary sediments are the continuation of the Assam Tertiaries.

### *Tertiary Sequence*

In Tirap District of Arunachal Pradesh, the Tertiaries of the Tipam, Disang and Dihing formations trending NE-SW represent northern continuation of the Naga Patkai Ranges. They are thrust over at right angle to their trend by the northwest-southeast trending Crystalline Thrust Sheets of the Central Crystallines of Lohit District.

### **Ophiolitic Melange**

No fossils have been reported from this unit, which is exposed in Lohit District. However, Dhoundial *et al.* (1976) indicated the presence of some ill-preserved casts, which are beyond specific identification. They suspect these to be of pre-Permian (Palaeozoic) age.

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## APPENDIX

## LIST OF LOCALITIES USED IN THE TEXT

<i>Locality Name</i>	<i>Area</i>	<i>Horizon</i>
Abor Hills	Siang (A.P.)	Abor Volcanics/Gondwana
Along	Siang (A.P.)	Gondwana
Asangthan (=Rangit Valley)	Sikkim	Gondwana
Bhalukpong	Kameng (A.P.)	Gondwana*/Siwalik
Black Mountains	Bhutan	Tethyan Sequence
Bomdila	Kameng (A.P.)	Gondwana*/Siwalik*
Buxa Duars	Darjeeling/Bhutan	Miri/Siwalik*
Chaku	Kameng (A.P.)	Gondwana*
Dalbing (=Dalbuing)	Siang (A.P.)	Eocene*/Gondwana*/ Abor Volcanics*
Daring	Siang (A.P.)	Gondwana
Darranga	Bhutan	Siwalik
Dewathang (=Deothang)	Bhutan	Gondwana
Dihang River (=Siang River)	Siang (A.P.)	Gondwana/Miri/Eocene
Dikrang River (Tributary of Subansiri River)	Subansiri (A.P.)	Gondwana*/Siwalik
Doimukh	Subansiri (A.P.)	Gondwana*
Dosgila Peak	North Sikkim	Tethyan Sequence
Elephant Flat	Kameng (A.P.)	Gondwana
Garu	Siang (A.P.)	Gondwana/Eocene/Siwalik
Geku	Siang (A.P.)	Eocene
Gensi	Siang (A.P.)	Gondwana
Gobuick (=Gobuk)	Siang (A.P.)	Eocene
Gong Khola (In Black Mountains)	Bhutan	Tethyan Sequence
Gurudongmar Lake (=Gordamah Lake)	North Sikkim	Tethyan Sequence
Igo	Siang (A.P.)	Gondwana
Jainti	Darjeeling/Bhutan	Miri
Jaldhaka River	Bhutan	Siwalik*
Jhari La (In Lingshi Basin)	Bhutan	Tethyan Sequence
Jia Bar River	Bhutan	Siwalik*
Kalapani River (=Kalanadi River)	Bhutan	Siwalik*
Kha Khola (In Black Mountains)	Bhutan	Tethyan Sequence
Kheel	Subansiri (A.P.)	Gondwana/Siwalik
Khemgaon (=Khemgaon Chorten)	Sikkim	Gondwana
Khuppi	Kameng (A.P.)	Gondwana
Kimin	Subansiri (A.P.)	Gondwana*/Siwalik*
<i>Locality Name</i>	<i>Area</i>	<i>Horizon</i>

<i>Locality Name</i>	<i>Area</i>	<i>Horizon</i>
Koyu	Siang (A.P.)	Siwalik
Lachi Ridge	North Sikkim	Tethyan Sequence
Legship	Sikkim	Gondwana*
Lichi	Subansiri (A.P.)	Gondwana*
Likabali	Siang (A.P.)	Gondwana*/Siwalik/Eocene*
Lingshi Basin (Dzong)	Bhutan	Tethyan Sequence
Mahanadi River	Darjeeling	Siwalik
Mane Ting (In Black Mountain)	Bhutan	Tethyan Sequence
Mao Khola (In Black Mountain)	Bhutan	Siwalik*
Maryang (=Mariang)	Siang (A.P.)	Eocene/ Abor Volcanic
Mashya Camping Ground	North Sikkim	Tethyan Sequence
Misamari	Kameng (A.P.)	Gondwana*/Siwalik
Nak Chu La (=Lingshi Basin)	Bhutan	Tethyan Sequence
Namchi	Sikkim	Gondwana
Naya Bazar	Sikkim	Gondwana
Nonai River	Bhutan	Siwalik*
Pankhabari	Darjeeling	Gondwana
Pasighat	Siang (A.P.)	Siwalik/Gondwana/Eocene
Paya Chu Valley (In Lingshi Basin)	Bhutan	Tethyan Sequence
Per River (Tributary of Subansiri River)	Subansiri (A.P.)	Gondwana
Rangit Valley (Rangit River/Rangit Window)	Sikkim	Gondwana
Ranguthang (Near Namchi)	Sikkim	Gondwana
Raiduk River	Bhutan	Miri*
Ramghat	Subansiri (A.P.)	Siwalik
Ranga Valley/River (Tributary of Subansiri River)	Subansiri (A.P.)	Gondwana
Rangtong	Darjeeling	Siwalik/Gondwana
Rengging	Siang (A.P.)	Gondwana/Eocene*
Roathak Nala	Sikkim	Gondwana
Sagalee	Subansiri (A.P.)	Gondwana*
Sankosh Valley	Bhutan	Gondwana
Sarbang (=Sarbang/=Sarbhong)	Bhutan	Siwalik/Gondwana
Sessa	Kameng (A.P.)	Gondwana/Siwalik*
Seti Khola (North of Jainti)	Bhutan	Gondwana
Siberrette	Siang (A.P.)	Gondwana
Siran Khola	Bhutan	Tethyan Sequence
Sireng River	Siang (A.P.)	Gondwana
Sissni	Kameng (A.P.)	Gondwana
Subansiri River (Subansiri Valley/Subansiri Gorge)	Subansiri (A.P.)	Siwalik/Gondwana
Takaso (=Tasko/=Takso)	Siang (A.P.)	Gondwana
Tang Chu Basin	Bhutan	Tethyan Sequence
Taphu	Bhutan	Tethyan Sequence

<i>Locality Name</i>	<i>Area</i>	<i>Horizon</i>
Tatamari	Siang (A.P.)	Gondwana
Tatapani (Near Legship)	Sikkim	Gondwana/Miri
Tenga	Kameng(A.P.)	Gondwana*
Tindharia	Darjeeling	Gondwana
Torsa	Bhutan	Siwalik
Tso Lhamo Lake	North Sikkim	Tethyan
Wachi La (=Wanchi La) (In Black Mountain)	Bhutan	Tethyan
Wak	Sikkim	Gondwana
Yale La (In Lingshi Basin)	Bhutan	Tethyan
Yamne Valley	Siang (A.P.)	Eocene
Yinkiyong	Siang (A.P.)	Eocene*/Abor Volcanic*
Ziró	Subansiri (A.P.)	Gondwana*/Siwalik*

\*-indicates that the given locality name is used in that particular horizon in the text.