Palynostratigraphy of the Tertiary sediments of Meghalaya, Northeastern India – Present status and gaps

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ABSTRACT


Thick and extensive Tertiary sediments, belonging to both shelf and geosynclinal facies, occupy the southern part of the Meghalaya Plateau. The basal part of these sediments is represented by the Langpar Formation which is followed by Jaintia (Therria, Sylhet Limestone and Kopili formations), Barail (Laisong, Jenam and Renji formations), Surma (Bhuban and Bokabil formations), Tipam (Tipam Sandstone and Girujan Clay formations), Dupitila and Dihing groups. In Garo Hills, these sediments are classified into various other differently named formations. A considerable amount of palynological information has so far been published from these sediments, which provides useful data for biostratigraphic zonation, correlation and age determination and for interpreting palaeoclimate, palaeogeography and environment of deposition. An effort has been made, in the present paper, to synthesize the published palynological work on these sediments in order to understand the present status of the Tertiary palynostratigraphy of Meghalaya. It has been noticed that the various palynozones established in the Tertiary sequence of Meghalaya can be recognized by their peculiar palynofossil assemblages. This is particularly useful in the correlation of homotaxial stratigraphic units in Garo, Khasi and Jaintia Hills and in the interbasinal correlation. In spite of a good deal of palynodata available, there are plenty of gaps in our knowledge regarding Tertiary palynostratigraphy of Meghalaya that deserve attention of palynologists. These gaps have been identified for the future studies.

Key-words—Palynology, Palynostratigraphy, Tertiary, Meghalaya, Northeastern India.

पूर्वोत्तर भारत के मेघालय प्रान्त के दर्शायरी अवसादों की परामाणुपुस्तकी – वर्तमान अवस्था एवं अवकल्प

रमेश कुमार सशेना

सारांश

मेघालय के पश्चिम के दक्षिण अंड में उपत्तीय तथा भूभौतिक डोंडों से समन्वित झूल एवं बिस्तर दर्शायरी अवसाद उपस्थित हैं। इन अवसादों का आवागमन अंडा लोमापर जैलसमुद्र द्वारा निर्देशित है, जिसके प्रवाह कुशल: जयन्तिया (थरिया, तिसरट चूरा जल तथा कौल्हल जैलसमुद्र), जिल (सीलगं, जौलम एवं रैमी जैलसमुद्र), धराक (चुराएवं बोकरियन जैलसमुद्र), दीम (राजप बालपार एवं निजलाल मुलिका जैलसमुद्र), दुपितिला एवं बिस्तर रामस में आते हैं। नागरी पहाड़ियों में इन अवसादों को विभिन्न अंडा जैलसमुद्र के नामों से वर्गीकृत किया जाता है। इन अवसादों के साथी माट्र भी परामाणुविक सूचनाएं अभी तक प्रकाशित हो गई हैं, जिनसे जैविक अवसादी अनुसंधान वर्गीकरण, सहस्त्रसन्ध्या एवं अद्व नियुक्ति
THE state of Meghalaya, comprising Garo, Khasi and Jaintia Hills, covers an area of approximately 23,000 sq km. It is bordered to its northwest, north, east and southwest by the state of Assam and to its southwest and south by Bangladesh. The southern portion of Meghalaya is occupied by a thick sequence of Cretaceous-Tertiary sediments, which remained a centre of attraction for geologists because of rich deposits of limestone, clay, glass sand and coal. Pioneering geological studies and mapping of this region have been done by Bedford (1842, in Medlicott 1868), Oldham (1859), Medlicott (1868, 1869, 1874), LaTouche (1882, 1883a, b, 1884, 1887, 1889, 1890a, b), Hayden (1897), Pinfold (1919), Palmer (1923), Fox (in Heron 1937), etc. Raja Rao (1981) published an account of the coalfields of Northeastern India.

Evans (1932) published a detailed study of the Tertiary sediments of Northeast India and proposed a stratigraphic classification, which received a wide acceptance. He opined that the Tertiary succession of this region is developed in two distinct facies, the shelf and the geosynclinal. Chakraborty (1972) and Chakraborty and Baksi (1972) realized that Evans' stratigraphic units are not applicable to the sediments developed in Garo Hills and western Khasi Hills of Meghalaya and proposed another lithostratigraphic classification for the Cretaceous-Tertiary sequence of this region. Director General, Geological Survey of India (1974) and Murthy et al. (1976) proposed yet another classification. They redefined some of the earlier stratigraphic units and also proposed a few new ones.

INTRODUCTION

The oldest rocks, represented by the Gneissic Complex (Archaean), are exposed in the central and northern parts of Meghalaya. These are believed to be the northeastern extension of the Indian Peninsular Block, separated from it by the Garo-Rajmahal Trough Fault. The Gneissic Complex is unconformably succeeded by the Shillong Group (Precambrian), which is exposed in the central and eastern parts of the Meghalaya Plateau. The Shillong Group is mainly composed of quartzite with subordinate phyllite, quartz-sericite schist, conglomerate, etc. These rocks are intruded by ultramafic and acidic sills and dykes. A patch of Lower Gondwana (Permian) sediments, containing streaks and lenses of coal and impressions of *Vertebraria indica*, is exposed at Singrimari in West Garo Hills. Along the southern border of Meghalaya Plateau are exposed Sylhet Traps (?Jurassic) which form a narrow, east-west strip, about 80 km long and 4 km wide. They unconformably overlie the Precambrian rocks and are unconformably overlain by the Late Cretaceous-Palaeogene sediments. The Late Cretaceous sediments are represented by Gumaghat and Mahadeo formations.

The basal unit of the Tertiary succession of Meghalaya is represented by the Langpar Formation (Danian). This formation overlies the Mahadeo Formation (Late Cretaceous) in the Umsohryngkew River Section in Cherrapunji area. The deposition of these sediments marks the beginning of the table shelf conditions. The Langpar Formation is succeeded by the Therria Formation (Palaeocene). Equivalents of the Therria Formation are known as Tura Formation (in part) in Garo Hills and Cherra Formation in Khasi Hills. Singh R.Y (1982) observed that the Cherra Formation merges laterally into the Langpar Formation in Therriaghata area and that the former may be a lateral equivalent of the latter. The lithological difference between the two may merely be an expression of facies change. The Therria Formation is overlain by the Sylhet Limestone Formation (Early-Middle Eocene), which is made up of alternations of limestones and sandstones and is divided into five members, viz., Lakadong Limestone, Lakadong Sandstone, Umlatadoh Limestone, Nurpuh Sandstone and Prang Limestone. The lower two members of this formation may be equivalent to the upper part of the Tura Formation. In Garo Hills, the limestone, overlying the Tura Formation, is much reduced and is known as Siju Formation. Director General, Geological Survey of India (1974) and Murthy et al. (1976) included both Therria and Sylhet Limestone/Siju formations together into the Shella Formation. Overlying the Sylhet Limestone/Shella Formation is Kopili Formation (Late Eocene). In Garo Hills, equivalent of the Kopili Formation is known as Rewak Formation. The Langpar, Therria, Sylhet Limestone and Kopili formations together constitute the Jaintia
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<th>Evans, 1932</th>
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Fig. 1—Tertiary stratigraphy of Meghalaya.

Group. The equivalent of this group in geosynclinal facies is known as the Disang Group (in part). The Kopili Formation is overlain by the Barail Group (= Simsang Formation/Kherapara Formation) of Oligocene age. The Meghalaya Plateau witnessed considerable sinking during Oligocene resulting into thick deposition of the Barail Group. The Barail Group of geosynclinal facies is divided into three formations, viz., Laisong Formation (2400 m), Jenam Formation (1200 m) and Renji Formation (1000 m) whereas the same belonging to the shelf facies, exposed in the western part of the Shillong Plateau, is comparatively much thinner (1200 m). Chakraborty and Baksi (1972) introduced a new name - Kherapara Formation for the Barail Group sediments of Garo Hills. These are nearly 1900 m thick and are divisible into a lower, mainly arenaceous Darik Member and an upper, more argillaceous Inoligiri Member. The close of Barail sedimentation in this region witnessed a period of uplift, nondeposition and erosion. The Barail Group is unconformably overlain by the Surma Group (Early Miocene) which is divisible into two formations, viz., Bhuban and Bokabil. The lower and upper parts of the Bhuban Formation (= Baghmara Formation/Boldamgiri Formation) are arenaceous with subordinate shales whereas the middle part is mainly argillaceous with thinly bedded sandstones. In Garo Hills, equivalent of the Bhuban Formation is known as Boldamgiri Formation. The Bhuban Formation is overlain by the Bokabil Formation (= Chengapara Formation/Angartoli Formation). The Surma Group is overlain by the Tipam Group, which is divisible into two formations, viz., Tipam Sandstone and Girujan Clay. This group is poorly exposed in the eastern part of Meghalaya. In Garo Hills, the Angartoli (=Bokabil) Formation is unconformably overlain by the Bilkona (= Dupitila) Formation. The Dupitila Group (Mio-Pliocene) is composed of mottled clays and siltstones, gritty sandstones and conglomerates. In Garo Hills, the Bilkona (= Dupitila)
Formation is unconformably overlain by the isolated outcrops of Dalu and Rangapani formations. Both these formations are equivalents of the Dihing Group and are overlain by the Older and Newer Alluvia of Pleistocene and Recent ages respectively (Fig. 1).

TERTIARY PALYNOSTRATIGRAPHY

A considerable amount of palynological information is known from the Tertiary sediments of Meghalaya, which has been successfully applied in biostratigraphy and in deducing palaeoclimate and environment of deposition. The Tertiary palynofossil localities in Meghalaya are shown in Fig. 2. A synthesis of the palynological work done on these sediments is presented below with the objectives to understand the present status of the Tertiary palynostratigraphy of Meghalaya and to identify gaps in our knowledge that need be bridged in the future studies.

Garo Hills

Palaeocene—Early Eocene


Singh R.Y. and Singh H.P. (1978) studied palynoflora from the subsurface Palaeocene sediments (= Tura Formation) in Nongwal Bibra (= Nangwalibbra) area of Darranggiri Coalfield. This assemblage closely compares with that recorded from the Tura Formation in type area by Singh (R.Y. 1977a). Singh H.P. et al. (1976) recognized Dandoliaspora telonata Cenozone in borehole NS-1 and Dandoliaspora telonata Cenozone and Palmidites plicatus Cenozone in borehole NS-5. In these boreholes, Dandoliaspora telonata Cenozone is better developed than that of the type area and is divisible into finer units. In borehole NS-1, Singh et al. (1976) recognized four subzones, viz., Polycolpites cooksoniae Subzone, Palmalepollenites communis Subzone, Lycopodiumspores palaeocenicus Subzone and Dandoliaspora telonata Subzone. In borehole NS-5, the lower two subzones are not traceable because of the poor recovery of spores and pollen grains. However, this part is rich in fungal remains and has been termed as 'Zone of fungal elements'. Overlying this zone, the upper two subzones encountered in borehole NS-1 were clearly recognized.

Ambwani (1993) recorded a palynoflora from the three coal seams of Rekmgirgi Coal Mine of Garo Hills. Based on palynofloral assemblage, he concluded that the lower two coal seams are of Palaeocene age and the top coal seam is of Early Eocene age.

Saxena et al. (1996) also studied palynoflora from the Tura Formation of Nangwalbibra area in East Garo Hills and recognized two informal palynozones. The lower zone, characterized by the dominance of Proxapertites spp., Tricolporopollis spp., Granulastephanocopolites cooksoniae, Palmidites spp., Tricolporopollis matamahdensis, etc., corresponds to the Assamiales enendatus Cenozone whereas the upper zone, characterized by Lycopodiumspores spp., Dandoliaspora spp., Foveospores triangulus, Todispores spp., etc., corresponds to the Dandoliaspora telonata Cenozone.

Tripathi et al. (2000) studied palynoflora from the Tura Formation exposed along Tura-Dalu Road in West Garo Hills and recognized three palynozones, viz., Lanagiopollis spp. Assemblage-zone, Palmidites spp. Assemblage-zone and Tricolporopollis spp. Assemblage-zone. The Lanagiopollis spp. Assemblage-zone is characterized by Lanagiopollis emarginatus, L. nanggalaensis, L. retisaeae, Dandoliaspora telonata and Paleococalpiniaepites eocenica. The Palmidites spp. Assemblage-zone is characterized by the dominance of dinoflagellate cysts along with Palmidites plicatus, P. naviculus, P. granulatus and P. punctatus. The Tricolporopollis spp. Assemblage-zone is characterized by the dominance of Tricolporopollis uniformis, T. tectatus and T. robustus.
Middle-Late Eocene

The Middle Eocene sediments in Garo Hills are represented by the Siju Formation. Baksi (1962) designated Simsang Palynological Zone I as representing the palynoflora of the Sylhet Limestone (= Siju Formation) of Simsang River Section. Its main elements are pollen of Palmae and Caesalpiniaceae together with inaperturate and polycolporate pollen and a large number of hystrichosphaerids. Sah and Singh R.Y. (1977a) recorded a scanty spores-pollen assemblage from the Siju Limestone, which includes Retipilonapites sp., Neocouperipollis brevispinosus, Cyathidites minor, Palmidites plicatus and Polycopites cooksoniae. Polycopites-Monosulcites (Colocasioideaepifes) assemblage Zone designated by Baksi (1974) from the Simsang River Section represents the Early-Middle Eocene palynoflora.

Baksi (1962) recognized Simsang Palynological Zone II in the Rewak Formation exposed along Simsang River Section. The principal constituents of this zone are Laevigatosporidites kopilia, Gilkgopites dubia, Silsangia trispinosa, Molocolpites broadcolpusi and Acolpompites spinulosa and dinoflagellate cysts. Saluja et al. (1972) described palynoflora from the Palaeogene sediments (Tura, Siju, Rewak and Darik formations) of Garo Hills. However, they did not mention occurrence of palynotaxa formation-wise.

Oligocene

Baksi (1962) established Simsang Palynological Zone III in the Barail Group (Kherapara Formation) exposed along Simsang River Section. This zone is characterized by the abundant occurrence of Meyeripollis naharkotensis, appearance of Baunina burdwanensis, frequent occurrence of Polypodiisporites tuberculensis, Leitrotiletes garoensis, Spinospites acolporata, Tricolpopites spinosa, T. prolati, T. shorti, Tricolpopites minima, Schizaeaceaesporutes knoxii, etc.

Mishra et al. (1996) studied palynoflora and animal fossils from the post-Kopili succession of the Tura-Dalu Road Section, West Garo Hills. He recognized Biostratigraphic Zone I in the Simsang (=Kherapara) Formation which is characterized by Meyeripollis naharkotensis, Polypodiisporites tuberculensis, Schizaeaceaesporutes knoxii, Spinospites acolporata, Polypodiaceaesporutes sp., Lycopodiumisporutes sp., Corrugatisporutes sp., Retistephanocolpites sp. and Ginkgopites dubia.

Miocene

Palynological work on the Surma Group has been carried out by Baksi (1962), Banerjee (1964a), Nandi and Sharma (1984) and Saxena and Rao (1996). Baksi (1962) recognized Simsang Palynological Zone IV representing the Surma sediments (Miocene). This zone is characterized by the abundance of conifer pollen (Coniferinges garoensis, C. abiesimilis, C. wilsonii and C. chattacharai), frequent occurrence of schizaeaceous (Aeimia type) and parkeriaceous (Caratopferis type) spores and Denseinoxisporites minuta, first occurrence of Polygonaceaesporites zonoides and occurrence of
Tricolopites radistriae, T. granulosa, Triporipites crescentipora and some dinoflagellate cysts.

Banerjee (1964a) also studied the Surma palynoflora from the above section and described spore-pollen types. He noticed a broad division of the sediments into two parts based on the presence and absence of certain types with restricted range and occurrence of coniferous pollen only in the upper part.

Nandi and Sharma (1984) studied palynoflora from the Boldamgiri Formation (=Bhuban Formation, Early Miocene) exposed along Tura-Damalgiri Road Section in West Garo Hills and divided the sequence into two subzones. According to them, these subzones constitute the lower part of the Coniferites-Cicatricosisporites Assemblage Zone of Baksí (1974). The lower subzone, viz., Cicatricosisporites-Palmaepollenites Assemblage Subzone is marked by frequent occurrence of Cicatricosisporites macrocostatus, C. dorogensis, Magnastratiotes howardii, Palmaepollenites eocenicus, P. communis, Dicocolpollis kockeli, Striatopollis bellus, Striocolpites grandioratus, Striatocolpites grandis, Tricolpites rectulatus, T. minutus, etc. with more or less high frequency of bisaccate pollen and presence of Rhostites nitidus, R. communis, R. psilatus, Araliaceoipollenites euphorii, A. psilatus, Margocolpites tsukadae, Meyeripollis nakharkotensis, Neocouperipollis brevispinosus and N. rarispinatus. The upper subzone, viz., Polygonaceaepites zonoides Assemblage Subzone is characterized by the significant occurrence of Polygonaceaepites zonoides and P. ghoshii, high frequencies of Polypodiisporites spp., Polypodiaceoepites simplex, Nyssapollenites baroohali, N. pseudocruicus, Bombacacoidites assamicus and Myricipites dubius, comparatively higher percentage of Corongatisporites turritus, Lygodiumsporites adriennis, Foreotriletes pachyexinus, low frequencies of Cicatricosisporites macrocostatus, Magnastratiotes howardii, Pinuspollenites labdaucus, Podocarpidites ellipticus, Striatocolpites grandis, Palmaepollenites eocenicus, P. communis, etc. and restricted occurrence of Achnipollenites verus and Chenopodipollis multiplex. The palynoflora indicates tropical-subtropical climate, swampy environment of deposition having brackish water influence and elevated topography surrounding the basin of deposition.

Saxena and Rao (1996) studied palynoflora from the Boldamgiri Formation exposed along Adogiri-Purakhasia Road near Boldamgiri in West Garo Hills. This assemblage is dominated by Striatolesus susaanae (20%), Pinuspollenites foveolatus (12%), Lygodiumsporites lakiensis (10%), Bireisporites convexus (8%), etc. The Boldamgiri Formation is divided into two informal zones. The lower zone is characterized by the restricted occurrence of Lygodiumsporites pachyexinus, Bireisporites convexus, Striatolesus pseudocostatus, S. punctatus, Pinjoriaipollis lanceolatus, Palaeosantalaceaeepites minutus, Meyeripollis nakharkotensis, Varispinitripores ratatiaensis, Echistephanoipollites spp. and Chenopodipollis sp. On the other hand, the upper palynozone has restricted occurrence of Foreotriletes garoonensis. Osmandicidites sp., Pilamonoletes excellens, Triporipollites robustus, Favicipolpites magnus and Pieridicidites sp. The Boldamgiri assemblage of Garo Hills is largely comparable to that recorded from the Bhuban Formation of Jaintia Hills (Saxena et al., 1987).

Mishra et al. (1996) recognized Biostratigraphic Zone 2 in the Baghmara Formation (=Boldamgiri Formation) exposed along Bugi River in West Garo Hills. This zone is characterized by Pinuspollenites spp., Coniferipites abiesinilis, Abiespollenites sp., Lygodiumsporites sp., Polypodiisporites sp., Gleicheniellses sp. and fungal remains. Biostratigraphic zones 3, 4 and 5 in the Chengapara Formation have been recognized on the basis of animal fossils.

No palynological information is so far available from the sediments younger than Boldamgiri (=Bhuban/Baghmara) Formation.

Khasi Hills

Palaeocene

The Langpar Formation (Danian) constitutes the basal stratigraphic unit of the Tertiary stratigraphic sequence in Khasi Hills. This formation has yielded spores, pollen, phytoplanktons and foraminifers. The palynofloral assemblages from this formation have been recorded by Sah et al. (1970), Sah and Dutta (1974), Jain et al. (1975), Singh R.Y. and Tewari (1978) and Saluja and Kindra (1981). Sah and Singh R.Y. (1977) recognized Assamialetes enedatus Cenozone within this unit which includes the following characteristic palynotaxa: Dendrosispora dilata, D. telonata, Sestosporites dettmanianae, Lycopodiumsporites palaeoecenicus, L. speciosus, Assamialetes enedatus, Proxaperites assamicus, P. crassinurus, Palmaepollenites communis, P. eocenicus, Liliacidites major, L. microreticulatus, Neocouperipollis brevispinosus, Tricolpites levis, Tricolporipollis matanogadensis, Meliapollis ramannjani, Polypolpites speciosus, P. cocksoniae, Trioripollites communis and Drosiderites parvus. The occurrence of spores and pollen, in association with phytoplanktons, indicates a shallow marine depositional environment.

Jain et al. (1975) studied palynoflora from the Langpar Formation of Dawki and Cherrapunji areas. This assemblage is dominated by dinoflagellate cysts and acritarchs (95%) with meagre representation of spores-pollen (5%). Significant taxa of the Langpar assemblage of Dawki area are Codoniella (18%), Ceratiopsis (10%), Deflandrea (4%), Palaeocystadinium (10%), Cordosphaeridium (6%), Cyclonephelium (19%) and Leiofusa type (reworked, 20%) whereas the same of the Cherrapunji area is dominated by Lauternospheauridium (60%) and Cordosphaeridium (30%). The dominant taxa of the underlying Gumagh (Jadukata)
and Mahadek formations, viz., *Dinogynium* and *Ariadnaeasporites*, are absent from the Langpar Formation.


Kar (1997) recognized *Acrnostichusporites meghalayaensis* Subzone in the Langpar Formation (Danian) exposed at Therrighat on the Um-Sohryngkew River section in Khasi Hills. It is characterized by *Acrnostichusporites meghalayaensis*, *Proxapertites operculatus*, *P. cursus*, *Matanomadhiasulcites maxillius*, *Spillizollocolpitcs echinatus*, *Saturna enigmatus* and *Terscissllis grandis*.

The Cherra Formation is overlain by the Syllhet Limestone Formation. The lower two members of this formation, viz., Lakadong Limestone and Lakadong Sandstone, pertain to Palaeocene. The Lakadong Limestone has yielded dinoflagellate cysts and foraminifers indicating Late Palaeocene age. The spores and pollen are not known from this member. From the Lakadong Sandstone Member, Dutta and Sah (1970) and Sah and Dutta (1974) recorded a spore-pollen assemblage and designated this sequence as the Lakadong Palynological Zone. This zone is characterized by the appearance of *Lycopodiumsporites crassimurus* and *Dandotiaspora spp.* Kar and Kumar (1986) studied palynoflora from the Lakadong Sandstone, exposed in six stratigraphic sections in Khasi Hills. They divided the sequence into two cenozones, viz., *Lycopodiumsporites speciosus* Cenozone and *Kielmeyeralloporites syncinalporatus* Cenozone. The former is characterized by *Lycopodiumsporites speciosus*, *L. unstedwensis*, *L. parvireticulatus*, *Dandotiaspora dilata*, *D. telenata*, *Pteridacidites meghalayaensis*, *P. robustus*, *Proxapertites crassimurus*, *P. emendatus*, *Matanomadhiasulcites maxillius*, *Neocouperipollis kutchensis*, *N. wodehousei*, *Tricolpites reticulatus*, *Tricolporallolites matanomadhensis* and *Araucariacites australis* whereas the latter is characterized by *Dandotiaspora dilata*, *D. telenata*, *Polypodisporites unstewensis*, *Lycopodiumsporites lakiensis*, *Lycopodiumsporites concavus*, *Palmitides psilatus*, *Psilastophacoporites psilatus*, *P. subcirculatus*, *Retestephanocolpites multirimatus* and *Polymargocolpites mawlaensis*.

Mandal (1990) recorded a rich palynoflora from three coal seams in the Lakadong Sandstone exposed at Thanjinath, about 12 km southeast of Cherrapunji. The lower coal seam is rich in pteridophytic spores (*Lycopodiumsporites spp.* and *Lycopodiumsporites ssp.*); the middle coal seam is characterized by the dominance of angiospermous pollen (*Neoucouperipollis spp.*, *Kielmeyeralloporites concavus*, *Tricolpites spp.* and *Proxapertites spp.*), *Lycopodiumsporites spp.* and fungal remains; and the upper coal seam has dominance of *Lycopodiumsporites spp.*, *Proxapertites spp.*, *Rhophites kutchensis* and *Recenocolpites spp.*

Singh R.S. (1990) recorded a rich palynoflora from 5 coal seams in Langrin Coalfield in West Khasi Hills. These coal seams are associated with the Tura Formation. Coal seam 1 and 2 are dominated by *Lycopodiumsporites palaeoceicus*, *L. speciosus*, *Proxapertites spp.*, *Dandotiaspora spp.*, *Matanomadhiasulcites maxinun* and *Tricolporallolites tuber*. Coal seam 3 has slight dominance of angiospermous pollen (with predominance of *Kielmeyeralloporites concavus*). Coal seam 4 is dominated by angiospermous pollen with first appearance of *Lycopodiumsporites unstewensis*, *Schizaeispores crassimurus*, *Polypodisporites mawlaensis*, *Spinizonocolpites indicus*, *S. echinatus*, *Psilastophacoporites psilatus*, *Polymargocolpites mawlaensis* and *Triangularites bellus*. The assemblage of coal seam 5 is more or less similar to that of coal seam 4 but for the overwhelming representation of *Spinizonocolpites*.

Palynofloras from the sediments younger than Lakadong Sandstone are not known.

**Jaintia Hills**

**Palaeocene**

Palynofloras from the Therria Formation (Palaeocene), exposed along Jowai-Sonapur Road, have been recorded by Tripathi and Singh H.P. (1984a, 1985) and Singh H.P. and Tripathi (1986, 1987). On the basis of this palynoflora, Tripathi and Singh H.P. (1984b) divided this formation into three zones, viz., *Lycopodiumsporites psilatus* Cenozone, *Palmitides obtusus* Cenozone and *Apectodinium homomorphum* Cenozone. The *Lycopodiumsporites psilatus* Cenozone has been equated with the lower two zones of Tura (Garo Hills), Cherra (Khasi Hills) and Mikir (North Cachar Hills) formations whereas *Palmitides obtusus* and *Apectodinium homomorphum* cenozones together have been equated with the third zone (from bottom upwards) of these formations. *Lycopodiumsporites psilatus* Cenozone is characterized by the restricted occurrence of *Lycopodiumsporites*
Limestone Formation (Microplankton Assemblage C) from Adnalosp! Laeridiul1l viltalum assemblage from the Prang Limestone Member of the Sylhet Formation.

Dutta and Jain (1980) recorded dinoflagellate cysts and acritarchs from the Sylhet Limestone and Kopili formations in the area around Lumshnong. The Lakadong Limestone (Microplankton Assemblage A) has abundance of Collinmosphaera fraticosa (71%) along with Operculodinium major, O. centrocarpum, Polysphaeridium subtile, Adnatosphaeridium spp., Homotryblium spp., Codoniella langparesanis, Cordosphaeridium multispinosum and Operculodinium spp. along with spore-pollen taxa. The high representation of dinoflagellate cysts indicates a transgressive phase.

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The Late Eocene sediments in Jaintia Hills are represented by the Kopili Formation. This formation overlies the Sylhet Limestone Formation. Palynofloras from the Kopili Formation have been recorded by Sein and Sah (1974), Tripathi and Singh H.P. (1984a, b, 1985), Singh H.P. and Tripathi (1986, 1987) and Trivedi (1985). Sein and Sah (1974) differentiated the Kopili sediments from the overlying Barail sequence in Jowai-Badarpur Road Section, on the basis of Monolites mawhnaensis, Lycopodiumsporites sp., and Tricolpites sp. characterising the former and their absence from the latter. The Barail sequence is also characterized by the abundance of Cicatricosisporites macrocosatus and Meyeriellum yaharkotenss.

Dutta and Jain (1980) recorded dinoflagellate cysts from the Kopili Formation (Microplankton Assemblage D) from near Lumshnong. This assemblage has dominance of Hystrichokolporna rigidae (21%) followed by Cordosphaeridium exilimurum (14%), Glaphyrocysta divaricata (12%), Operculodinium spp. (14%), etc.

Kar (1992) recorded palynoflora from the Prang Formation (=Prang Limestone Member of the Sylhet Formation) exposed near 132 km post on Jowai-Badarpur Road. The palynoflora is represented by Todisporites kutchensis, Lygodiumsporites lakiellsis, Osmondicadites kutchensis, Cyathidites minor, Striatrilettes susannae, Podocarpidites khasiensis, Polypodiaceaesporites ekatterji, Polypodiisporites repandus, Lakiapollis ovatus and Pellicieropollis langenheimii.

Eocene

The Theriia Formation is overlain by the Sylhet Limestone Formation (Early-Middle Eocene). Tripathi and Singh H.P. (1984b) recorded a scanty palynoflora from this formation, which includes Neocouperopollis brevispinosus, Lillicidites gigantis, Dandotiaspora telenata, Tricolporopollis ruber, Operculodinium major and Tricolpites aleoalus.

Dutta and Jain (1980) recorded dinoflagellate cysts assemblage from the Prang Limestone Member of the Sylhet Limestone Formation (Microplankton Assemblage C) from near Lumshnong. This assemblage has dominance of Hystrichokolporna rigidae (21%) followed by Cordosphaeridium exilimurum (14%), Glaphyrocysta divaricata (12%), Operculodinium spp. (14%), etc.

Kar (1992) recorded palynoflora from the Prang Formation (=Prang Limestone Member of the Sylhet Formation) exposed near 132 km post on Jowai-Badarpur Road. The palynoflora is represented by Todisporites kutchensis, Lygodiumsporites lakiellsis, Osmondicadites kutchensis, Cyathidites minor, Striatrilettes susannae, Podocarpidites khasiensis, Polypodiaceaesporites ekatterji, Polypodiisporites repandus, Lakiapollis ovatus and Pellicieropollis langenheimii.
Striatriletes paucicostatus and Densiverrupollenites eocenicus.

Oligocene

Saluja et al. (1974) published palynoflora from the Palaeogene sediments of Khasi-Jaintia Hills. However, they did not mention occurrence of palynotaxa formation-wise. Palynological work on the Barail sediments of Jowai-Badarpur Road Section (Sein & Sah 1974) shows that the frequency of Striatriletes increased from 38% in the Laisong Formation to nearly 98% at the top of sequence. Detailed palynological study of the Barail (Oligocene) and Surma (Early Miocene) groups exposed in Jaintia Hills has been made by Rao (1983, 1986), Saxena and Rao (1984), Rao et al. (1985), Singh H.P. et al. (1986, 1987) and Rao and Singh H.P. (1987) which enabled Saxena et al. (1987) to divide the Barail Group into three cenozones, viz., Polysphaeridium subtile Cenozone, Todisporites major Cenozone and Lygodiumsporites eocenicus Cenozone. The lower two cenozones together correspond to the Laisong Formation whereas the upper cenozone corresponds to the Jenam and Renji formations. The Polysphaeridium subtile Cenozone is characterized by the dominance of Adnatosphaeridium vittatum, Polysphaeridium subtile, Cordosphaeridium inodes, Implesporella insolutum, Homotrebiurn floripes, Striatriletes susannae, Lygodiumsporites lakiensis, L. eocenicus, Cyathidites minor and Pinuspollenites foveolatus and restricted occurrence of Adnatosphaeridium vittatum and Tricolpites sp. The Todisporites major Cenozone is characterized by the dominance of Cordosphaeridium multispinosum, C. fibrospinosum, Polysphaeridium subtile, Striatriletes susannae, Todisporites major, Birepisporites oligocenicus, Lygodiumsporites lakiensis, L. eocenicus, Polyadopollenites sahlit and Echistephanococpile meghalayaensis and restricted occurrence of Birepisporites oligocenicus and Cordosphaeridium multispinosum. The Lygodiumsporites eocenicus Cenozone is characterized by the dominance of Striatriletes susannae, S. pachycaulus, Todisporites major, Polyadopilineaeaeosporites tertiarus, Podocarpidites meghalayaensis, Laricodites punctatus and Polyadopollinates sahlit and restricted occurrence of Striatriletes pachycaulus and Dictyophyllidites indicus.

Singh R.Y et al. (1986) recorded a rich palynoflora from the Barail Group exposed around Sonapur, on Jowai-Badarpur Road, and divided the Barail Group into three zones, viz., Eximispora meghalayaensis Zone, Polyadopilineae Abundance Zone and Striatriletes Abundance Zone. The lower, Eximispora meghalayaensis Zone (corresponding to the Laisong Formation) is characterized by Eximispora meghalayaensis, Todisporites plicatus, Polyadopilineaeasporites tertiarus, Tricolporopollis matamadhehensis, Neocouperipollis brevispinosus, Striatriletes discontinuous, S. susannae, etc.; the middle, Polyadopilineae Abundance Zone (corresponding to the Jenam Formation) is characterized by Jaintiapollenites plicatus, Sahiapollis arcuatae, Todisporites granulatus, T. crassilaesusurus, Polyadopilineaeasporites indicus, P. meghalayaensis, P. punctatus, Striatriletes indicus, S. juxtacostatus, S. susannae, etc.; and the upper, Striatriletes Abundance Zone (corresponding to the Renji Formation) is characterized by Striatriletes indicus, S. juxtacostatus, S. discontinuous, S. susannae, Todisporites granulatus, T. crassilaesusurus, Polyadopilineaeasporites meghalayaensis, P. punctatus, Scantigranutules trianguulus, Cyathidites minor, etc.

Miocene

The Surma Group is divisible into Bhuban and Bokabil formations. Saxena et al. (1987) recognized three palynostratigraphic zones in the Bhuban Formation. The lower zone, viz., Striatriletes sinuosus Cenozone is characterized by the restricted occurrence of Striatriletes sinuosus and significant representation of Cordosphaeridium inodes, Homotrebiurn floripes, Striatriletes susannae, Lygodiumsporites lakiensis, L. eocenicus, Cyathidites australis, Polyadopilineaeasporites chalterii, Polyadopollinates favus, Abiespollenites surahensis, Pinuspollenites foveolatus, Neocouperipollis robustus, Polyadopollenites sahlit, Echistephanococpile meghalayaensis and Malvaeaurnpollis sp. This zone is marked by the dominance of Striatriletes (62%) and gymnospermous pollen (up to 20%). The middle zone, viz., Pinuspollenites foveolatus Cenozone is characterized by Cordosphaeridium inodes, Todisporites minor, Lygodiumsporites eocenicus, L. lakiensis, Striatriletes susannae, Polyadopilineaeasporites tertiarus, P. chalterii, Pinuspollenites foveolatus, Abiespollenites surahensis and Malvaeaurnpollis sp. Gymnospermous pollen constitute about 33% of the assemblage of this cenozone. The upper zone, viz., Malayaeaspora costata Cenozone is characterized by the restricted occurrence of Malayaeaspora costata, Surmaspora sinuosa, Lygodiumsporites donaensis, Lancodopilineae abdunans and Fiveatrites sp. along with the significant representation of Striatriletes susannae, Monolites major, Pinuspollenites foveolatus, Abiespollenites suraensis, Assaniapollenites sp. and Malvaeaurnpollis sp. The Bhuban palynoflora is dominated by pteridophytic spores and gymnospermous pollen followed by dinoflagellate cysts, fungal remains and angiospermous pollen. The phytoplanktons indicate a near-shore depositional environment whereas gymnospermous pollen suggest the presence of high land nearby.

Comparatively less palynological information is available from the Bokabil Formation (Saluja et al., 1973; Saxena et al., 1987). This formation is characterized by the predominance of Magnasaltrites mirabilis, Polyadopollinates speciosus, Striatriletes susannae and Triporopollinates triquetus and presence of Lygodiumsporites lakiensis, Polyadopilineaeasporites tertiarus, Sinozonotritiles amplus.
**GAPS IN OUR KNOWLEDGE**

A perusal of the foregoing account shows that a large amount of palynodata has so far been generated from the Tertiary sediments of Meghalaya. However, there are considerable gaps in our knowledge which require urgent attention of palynologists. It is suggested that the objectives of the future studies need be directed towards bridging these gaps. Some of the gaps have been identified and are being mentioned below.

1. Although a detailed palynostratigraphic investigation of the Paleocene-Early Eocene sediments of shelf facies of Meghalaya has been carried out, the same on their geosynclinal equivalents (Disang Group) still awaits attention of palynologists.

2. Palynological information from the Siju/Sylhet Limestone Formation is meagre and a detailed palynological study of these formations (particularly the limestone members) is yet to be carried out. These sediments contain a good assemblage of dinoflagellate cysts along with spores-pollen, which may be extremely useful in biostratigraphic zonation and dating of these sediments and in deducing environment of deposition.

3. The Kopili Formation in Jaintia Hills has been worked out in detail. The zones established there need to be traced westwards to recognize potential of palynofossils in basinal and interbasinal correlations.

4. The Barail Group exposed along Jowai-Badarpur Section in Jaintia Hills has been divided into three palynozones. It is yet to be established whether or not these zones extend into the Kherapara Formation of Garo Hills.

5. The Bhuban Formation in Jaintia Hills and its equivalent Boldamgiri Formation in West Garo Hills have been worked out in detail. Efforts should be made to study its equivalent in South Garo Hills (Baghmarra Formation) and in Khasi Hills.

6. The Bokabil/Angartoli palynoflora is poorly known. These sediments yield rich palynoassemblages and have good prospects for future studies.

7. The palynological information from the post-Bokabil/Angartoli/Chengapara sediments, viz., Tipam Sandstone, Girjana Clay, Dupitila/Bilkona and Dihing/Rangapani and Dalu, of Meghalaya is not yet available. Systematic efforts are needed to generate palynodata from these sediments. Such studies will be helpful in establishing palynozonation and correlation of these sediments and also in recognizing Neogene/Quaternary Boundary in Meghalaya.

**CONCLUDING REMARKS**

Palynological studies carried out on the Tertiary sediments of Meghalaya resulted into records of rich palynofloras and their application in biostratigraphic zonation, correlation and dating of the sediments and in inferring palaeoclimate and depositional environment. Various palynozones established in these sediments can be recognized by their peculiar palynofossil assemblages which are useful in the correlation of homotaxial stratigraphic units in Garo, Khasi and Jaintia Hills and also in the interbasinal correlation. A synthesis of the palynodata from these sediments presents state-of-the-art of the Tertiary palynostratigraphy of Meghalaya and identifies gaps therein to be filled in future studies. It has been noticed that better palynological information is available from the Palaeogene sediments than the same from the Neogene.

It is strongly felt that the palynodata gathered so far require more precision. To achieve this, a synergistic approach should be adopted. Palynodata need be tagged, as far as possible, with data obtained from other disciplines in order to get better and more dependable results and conclusions. It has been observed that in a number of cases palynofloras have been recorded from the grab samples. This makes them of limited value in biostratigraphic studies. It is therefore necessary that palynological samples should be collected on measured stratigraphic sections with the precise location of their positions in the stratigraphic column. Use of obsolete and invalid names of palynotaxa create problems and should be avoided. It is advised that only those palynotaxa, that are prevalent, should be used. Character evaluation of palynotaxa...
and standardisation of morphotaxonomy are therefore very important in palynostratigraphic studies. It has been observed that in some cases palynological assemblage zones (cenozones) are loosely proposed. These are formal biostratigraphic units and therefore their proposal need be in accordance with the requirements laid down in the International Stratigraphic Guide (Hedberg, 1976). Lastly, it is recommended to study subsurface sections, in addition to outcrop sections, as they provide uninterrupted stratigraphic sequences and fresh samples almost completely unaffected by weathering agencies.

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