Palaeobotanist 49 (2000) : 281-292
0031-0174/2000/281-292 $2.00

Palynostratigraphy of the Tertiary sediments in North-East India with comments on the Terminal Eocene events

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(Received 24 September 1999; revised version accepted 15 February 2000)

ABSTRACT

Kar RK 2000. Palynostratigraphy of the Tertiary sediments in North-east India with comments on the Terminal Eocene events. Palaeobotanist 49 (2) : 281-292.

The Tertiary rocks in North-East India rest unconformably on the granitic basement. They represent more or less a continuous sequence except a post Barail unconformity. The palynological assemblage is more or less known from all the formations. The assemblage by and large is dominated by the pteridophytic spores in all the formations followed by the angiospermic pollen. The gymnospermic pollen are rare in Palaeocene-Middle Eocene and are found in Late Eocene onwards and occur in good numbers in Miocene-Pliocene rocks. The index fossils for each formation have been marked. The Terminal Eocene events have been analysed. It has been observed that during that time India was enjoying a tropical climate and there was no cooling effect as has been advocated from the other parts of the world.

Key-words—Palynology, Palynostratigraphy, Tertiary, North-east India.

सीमान्त इओसीन युगीन घटनाओं के परिप्रेक्ष्य में उत्तर-पूर्वी भारत में टर्शियरी युगीन अवसादों की परागाणुस्तरिकी

रंजीत कुमार कर

सारांश

उत्तर-पूर्व भारत के टर्शियरी शैल ग्रेनाइटी आधार पर असमविन्यासी अवस्था में अवसादित हैं. ये उत्तर बराइल असमविन्यास को छोड़कर प्रायः न्यूनाधिक रूप से एक सतत् अनुक्रम को निरूपित करते हैं. परागाणु समुच्चय प्रायः सभी शैलसमूहों से ज्ञात हुए हैं. समुच्चय के सभी शैलसमूहों में दूर-दूर तक टेरिडोफाइटी बीजाणुओं की प्रचुरता है, तत्पश्चात क्रमशः आवृतबीजी परागकण आते हैं. पेलियोसीन मध्य इओसीन युग में आवृतबीजी परागकण प्रायः अनुपस्थित हैं. ये अन्तिम इओसीन युग के पश्चात पाए गए हैं तथा मायोसीन-प्लायोसीन शैलों में अच्छी मात्रा में उपस्थित हैं. प्रत्येक शैलसमूह के लिए पादपाश्म सूचकांक अंकित किए गए हैं तथा सीमान्त इओसीन घटनाओं का विश्लेषण किया गया है. यह देखा गया है कि इस काल के दौरान भारत में उष्णकटिबन्धीय जलवायु थी तथा विश्व के अन्य भागों की भाँति यहां से कोई शीतलन प्रभाव, जिसे पहले कल्पित किया गया था, प्राप्त नहीं हुआ है.

संकेत शब्द—परागाणुविज्ञान, परागाणुस्तरिकी, टर्शियरी, उत्तर-पूर्व भारत.

INTRODUCTION

OF the seven states of North-East India viz., Assam, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram and Tripura palynological investigation has been extensively carried out in Assam, Meghalaya and Tripura in comparison to other states. For this reason, the present assessment is mainly based on these three states.

The state of Assam is a part of the Assam-Arakan Basin, its foreland shelf zone of the Upper Assam valley is covered by alluvium. The Naga and Margherita thrusts separate the outcrops of rock along the Naga-Patkai hills from the Upper Assam valley and provide a geological succession mostly of the Late Tertiary sediments.

In Meghalaya, the Cretaceous and Early Tertiary rocks rest unconformably on the Precambrian granitic basement.

The oldest sedimentaries in Tripura comprise Bhuban Subgroup (Early Miocene) overlain conformably by Bokabil Subgroup (Middle Miocene). It is differentiated from Bhuban Subgroup by the absence of well bedded argillaceous sandstones. The Bokabil Subgroup occurs on Rokhia, Baramura and Gojalia anticlines. This is overlain conformably by Tipam Group (Middle Miocene). The latter is distinguished from Brokabil by its predominance of arenaceous sediments.

The geology of North-East India was mainly worked out by Oldham (1858), Medlicott (1871), Palmer (1923), Ghosh (1940), Baksi (1962), Biswas (1962), Evans (1964), Bagchi (1964), Dutta and Sah (1970), Handique and Dutta (1981), Samanta and Raychowdhury (1983), Handique and Mallick (1989) and others.

GENERAL GEOLOGICAL SUCCESSION

As mentioned earlier, the Tertiary rocks are lying unconformably over the granitic basement. According to Oil India geologists the oldest Tertiary sediments are of Late Palaeocene in age and are represented by Langpar Formation. Pandey (1981) however, considers that Langpar Formation exposed in Meghalaya is of Early Palaeocene in age. This formation having calcareous shale at the base is underlain by Mahadeo Sandstone (Late Cretaceous) and overlain by Therria Formation (Early-Middle Palaeocene). Pandey (1981) postulates that the Upper Member of Mahadeo Formation at Therriaghat consists of light to dark grey and greenish grey silty shales associated with calcareous and noncalcareous sandstone. The Therria Formation is characterized by the first appearance of arkosic, whitish sandstone with leaf impressions.

The Eocene sediments are very well developed and are mostly represented by Jaintia Group. This group is divided into Lower Sylhet Formation and Upper Kopili Formation. The Sylhet Formation comprises Lakadong Member, Narpuh Member and Prang Member. The Kopili Formation is also divided into Lower Member, Middle Member and Upper Member. The Oligocene rocks are represented by Barail Group. This group is divisible into Tinali Formation and Moran Formation. Tinali Formation, according to Oil India Limited, forms the uppermost part of Eocene. There is a big unconformity between Oligocene and Miocene. The Miocene rocks are represented by Nahorkatiya Group which is divisible into Tipam Formation and Girujan Formation. The Namsang Formation rests unconformably on Girujan Formation and is overlain unconformably by Dhekiajuli Formation (Pliocene) (Fig. 1).

Langpar Formation

This formation is exposed mostly at Therriaghat on the Umshoringkew River, Meghalaya. It is mostly represented by shale and is rather poor in spores-pollen content but very rich in phytoplankton. Kar (1992a, b) recovered *Cyathidites, Lygodiumsporites, Acrostichumsporites, Contignisporites, Schizaeoisporites, Matanomadhiasulcites, Dracaenoipollis, Proxapertites, Saturna, Tercissus, Araucariacites, Schizosporis* and *Phragmothyrites*. Some Permian reworked genera viz., *Striatites, Rhizomaspora* and *Densipollenites* were also noted in the assemblage.

Amongst the recovered spores and pollen, the pteridophytic elements are common and are generally represented by *Lygodiumsporites lakiensis, Cyathidites minor* and *Acrostichumsporites meghalayaensis*. Among the angiosperms the common forms are: *Saturna enigmatus, Proxapertites cursus* and *Matanomadhiasulcites maximus*.

The presence of *Acrostichumsporites meghalayaensis* in considerable number indicates that the deposition took place in a back mangrove swamp.

Lakadong Member

The lower part of this member is made up of limestone whereas the upper part constitutes the sandstone. Within the sandstone there are few workable coal seams. The palynological investigation of this horizon was made by Biswas (1962), Sah and Dutta (1966), Dutta and Sah (1970), Singh (1974, 1975) and Kar and Kumar (1986) and others.

Kar and Kumar (1986) divided the Lakadong palynological assemblage into lower *Lycopodiumsporites speciosus* Cenozone and upper *Kielmeyerapollenites syncolporatus* Cenozone. The former cenozone is characterised by the common occurrence of *Lycopodiumsporites speciosus, L. umstewensis, L. parvireticulatus, Dandotiaspora dilata, D. telonata, Cyathidites minor, Pteridacidites meghalayaensis, P. robustus, Proxapertites crassimurus, P. emendatus, Matanomadhiasulcites maximus, Neocouperipollis kutchensis, N. wodehousei, Tricolpites reticulatus, Retitribrevicolporites matanomadhensis* and *Araucariacites australis*. Whereas the latter cenozone is recognised by the common occurrence of *Kielmeyerapollenites syncolporatus, Dandotiaspora dilata,*

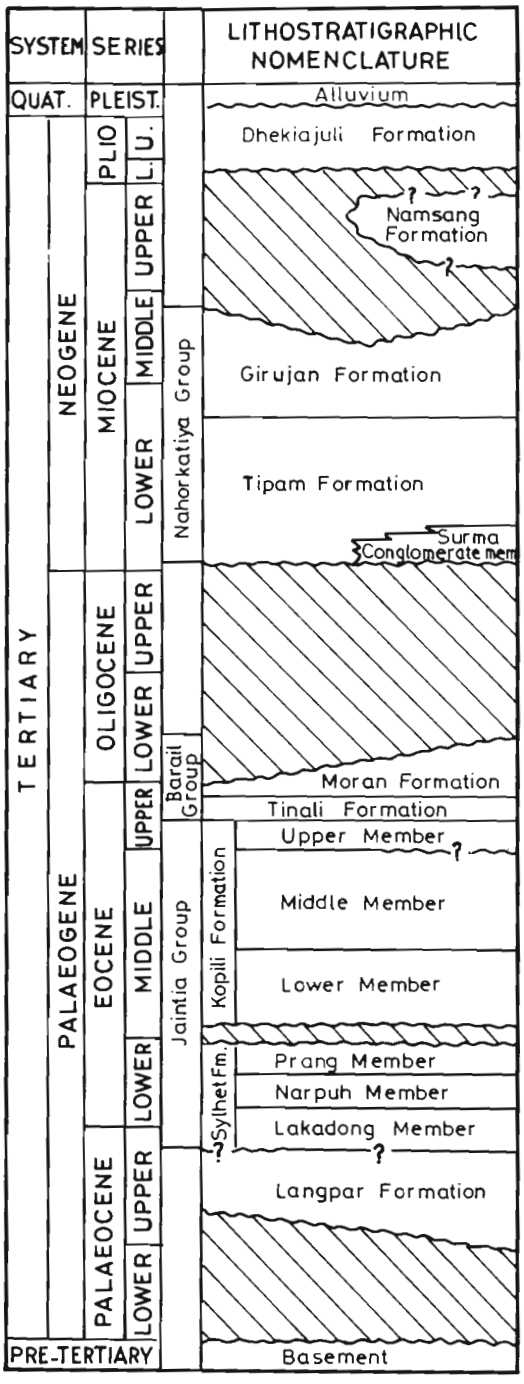

Fig. 1—General geological succession of the Tertiary rocks in north-east India (after Oil India Ltd)

D. telonata, Polypodiisporites umstewensis, Lygodiumsporites lakiensis, Lycopodiumsporites lakiensis, Lycopodiumsporites concavus, Palmidites plicatus, P. excellensus, Triangulorites triradiatus, Psilastephano-colporites psilatus, P. circularis, Retistephanocolpites multirimatus and *Polymargocolporites mawlensis*.

Prang Member

The geological investigation on this member was carried out by Evans (1932), Wilson and Metre (1953), Nagappa (1959), Das Gupta (1977), Biswas (1962), Murthy *et al.* (1976) and Samanta and Raychaudhury (1983). Kar (1992a) studied the palynology of this member exposed on Jowai-Badarpur Road near 132 km post from a fresh cutting near the bridge. He recovered 31 genera and 37 species. The common species are: *Laevigatosporites lakiensis, Todisporites kutchensis, Lygodiumsporites lakiensis, Cyathidites minor, Biretisporites convexus, Lakiapollis ovatus, Osmundacidites wellmanii, O. kutchensis, Dandotiaspora plicata, Pellicieroipollis langenheimii, Seniasporites verrucosus, Striatriletes multicostatus, S. paucicostatus, Podocarpidites densicorpus, P. khasiensis, Pinuspollenites crestus, Polypodiaceaesporites levis, P. chatterjii, P. major, Polypodiisporites repandus* and *Phragmothyrites eocaenica.*

The assemblage is overwhelmingly dominated by the pteridophytic spores, both the triletes and monoletes are equally represented. The angiospermic pollen are occasionally found while the gymnosperms are consistently found in small percentage.

Kopili Formation

Evans (1932) coined this name after the river Kopili. It is well exposed on the Kopili river, Jowai-Badarpur road section, Therriaghat and adjacent localities in Meghalaya. Geological investigations of this formation were carried out by Evans (1932), Wilson and Metre (1953), Nagappa (1959), Murthy *et al.* (1976), Das Gupta (1977), Saxena and Tripathi (1982), Samanta and Raychaudhury (1983), Kar (1992), Kar *et al.* (1994) and others. Rao and Singh (1986), Trivedi (1985) and Kar *et al.* (1994) carried out palynological investigation on the Kopili Formation. The important palynological taxa of this formation are: *Operculosculptites globatus, Osmundacidites wellmanii, O. kutchensis, Scantigranulites sparsus, Striatriletes susannae, S. multicostatus, S. microverrucosus, S. paucicostatus, S. aidaensis, Polypodiisporites repandus, P. ornatus, Pilamonoletes excellensus, Polypodiaceaesporites levis, P. chatterjii, Pinuspollenites crestus, Abiespollenites cognatus, Neocouperipollis kutchensis, Spinizonocolpites echinatus, Palmaepollenites nadhamunii, Proxapertites assamicus, P. microreticulatus, Tricolpites parvireticulatus, Retitrescolpites assamicus, Acanthotricolpites brevispinosus, Ratariacolporites plicatus, Margocolporites tsukadi, Dermatobrevicolporites dermatus, Rhoipites kutchensis* and *Retipilonapites cenozoicus.*

The assemblage is dominated by pteridophytic spores and poorly followed by angiosperms and gymnosperms.

Disang Formation

This formation is exposed on Silchar-Halflong Road. The shales are generally black to dark, steel-grey, weathering to reddish brown. This is laminated, highly fissile to splintery. The Disang shales are assumed to be fluvial, non-marine flood plain deposits formed in a narrow trough. They are not related to the carbonate and clastic deposits of Kopili Formation though they are also presumably of Late Eocene age.

Kar (1990) recovered the following taxa from this formation : *Cyathidites minor, Todisporites major, Dictyophyllidites dulcis, Intrapunctisporis intrapunctis, Lygodiumsporites lakiensis, Striatriletes susannae, S. paucicostatus, S. multicostatus, S. microverrucosus, Osmundacidites wellmanii, Polypodiaceaesporites chatterjii, P. tertiarus, P. levis, Polypodiisporites repandus, Psilosclizosporis psilata, Podocarpidites khasiensis, Pinuspollenites crestus, Piceapollenites excellensus, Neocouperipollis achinatus, Margocolporites tsukadai, Pellicieroipollis langenheimii* and *Palaeomalvaceaepollis mammilatus.*

The assemblage is rather poor in diversity and the pterodophytic spores roughly contribute 70% of the total assemblage, the angiosperm and gymnosperm each represents less than 10%.

Kar (1990) placed the whole assemblage into *Striatriletes microverrucosus* Cenozone having the dominance of *Cyathidites minor, Striatriletes microverrucosus, Polypodiaceaesporites tertiarus, Pinuspollenites crestus* and *Phragmothyrites eocaenica.*

Barail Group

The Oil India geologists divide Barail Group into Tinali Formation and Moran Formation, whereas the other geologists divide this group into Laisong, Jenam and Renji for the geosynclinal facies and Nagaon, Bara Golai and Tikak Prabat for the shelf facies.

The Laisong Formation at the basal portion comprises sandstone with frequent beds of shale. The sandstone is grey to dark grey, reddish brown, medium to coarse grained, thick bedded, hard and compact. It has yielded *Haplophragmoides* sp., *Trochimina* sp. and *Bathysiphon* sp. (Kumar, 1994).

The Jenam Formation is predominantly an argillaceous unit comprising mainly shale alternating with sandstone. Kar (1990) remarked that at Silchar-Halflong Road section sandstone is also well developed. The shales are dark grey to grey, laminated and carbonaceous at places. According to Kumar (1994) there is also coaly matter, angiospermic leaf impression and arenaceous foraminifera viz., *Trochimina* sp., *Ammobaculites* sp. and *Haplophragmoides* sp.

The topmost Renji Formation is made up of entirely sandstone with occasional thin bands of highly fissile silty shale. The sandstones are dirty grey to greenish-grey with specks of violet, occasionally pinkish weathering to yellowish brown. The dicot leaf impressions are commonly found in this formation. Besides, arenaceous foraminifera e.g., *Trochimina* sp., *Haplophragmoides* sp. are also present.

Sinha and Sastri (1973) studied the heavy mineral suits of Disang and Barails and opined that Disang sedimentation was geosynclinal in nature. Ganguli (1984) remarked that these sediments were originated in a "plate edge" geosyncline and were evolved due to convergent dynamic system resulting from the oblique subduction of the Indian Plate under the Eurasian Plate of Burma. Acharyya *et al.* (1989) remarked that the emplacement of Naga Hills ophiolite during Middle Eocene was probably due to the collision of an ocean island chain with the subduction zone beneath the central Burmese continent (Fig. 2).

PALYNOLOGICAL ASSEMBLAGES

Laisong Palynological Assemblage

The common taxa of this assemblage according to Kar (1990) are: *Cyathidites minor, Todisporites major, Dictyophyllidites dulcis, Lygodiumsporites lakiensis, Intrapunctisporis apunctis, I. intrapunctis, Lycopodiumsporites palaeocenicus, L. globatus, Osmundacidites wellmanii, Striatriletes susannae, S.paucicostatus, S. multicostatus, S. microverrucosus, Malayaeaspora costata, Polypodiaceaesporites tertiarus, P. chatterjii, Polypodiisporites repandus, Podocarpidites khasiensis, Pinuspollenites crestus, Neocouperipollis achinatus, Palaeomalvaceaepollis mammilatus* and *Pellicieroipollis langenheimii.*

The assemblage is absolutely dominated by the pteridophytic spores and very poorly followed by the gymnospermic elements. Some reworked Permian palynomorphs particularly *Dulhuntyispora dulhuntyi* is also occasionally found in this assemblage. This genus is so far known from Australia and Africa and is a Late Permian marker fossil. According to Venkatachala and Kar (1990) turbidity currents were possibly responsible for the reworking of this fossil along with Permian sediments from Australia to north-east India when the Indian and the Australian Plates were juxtaposed.

Kar (1990) proposed *Osmundacidites wellmanii* Cenozone to accommodate Laisong palynological assemblage with the common forms like: *Cyathidites minor, Osmundacidites wellmanii, Striatriletes microverrucosus, Polypodiaceaesporites tertiarus, Pinuspollenites crestus* and *Inapertusporites kedvesii.*

Jenam Palynological Assemblage

This assemblage is rich in spores and pollen. Kar (1990) recorded 49 genera and 42 identifiable species. He divided

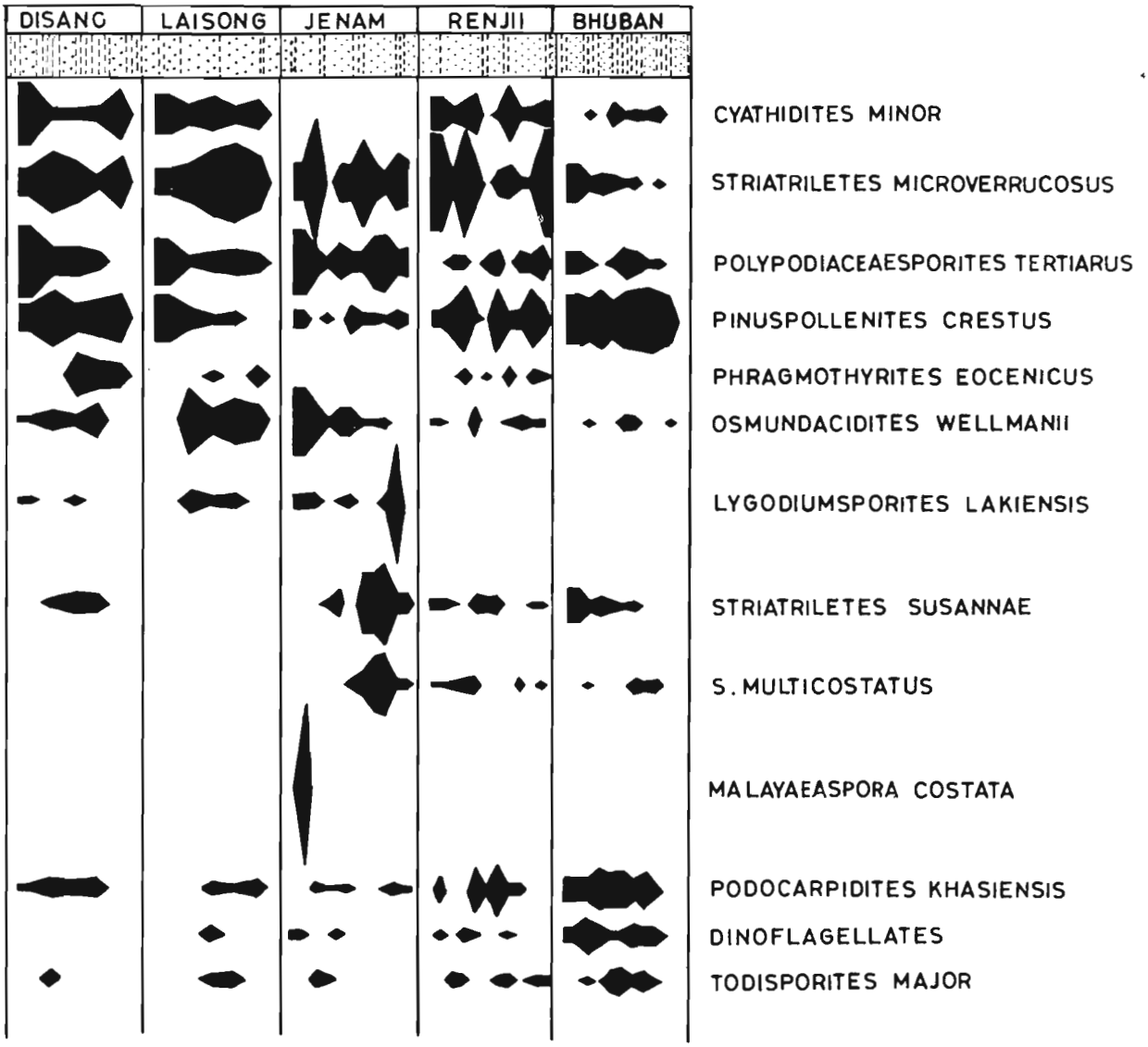

Fig. 2—Distribution of stratigraphically important palynological species in Disang, Laisong, Jenam, Renji and Bhuban formations (after Kar, 1992).

the whole assemblage into three palynological cenozones viz., *Malayaeaspora costata* Cenozone, *Polypodiaceaesporites tertiarus* Cenozone and *Striatriletes susannae* Cenozone.

Malayaeaspora costata Cenozone has the dominance of *Malayaeaspora costata, Striatriletes microverrucosus, Osmundacidites wellmanii* and *Polypodiaceaesporites tertiarus. Polypodiaceaesporites tertiarus* Cenozone is recognized by the abundance of *Polypodiaceaesporites tertiarus, Striatriletes microverrucosus, Phragmothyrites eocaenica* and *Notothyrites setiferus. Striatriletes susannae* Cenozone has the fair representation of *Striatriletes susannae, Striatriletes multicostatus, Striatriletes microverrucosus, Lygodiumsporites lakiensis* and *Polypodiaceaesporites tertiarus*.

Along with the typical Oligocene palynological assemblage there are lots of reworked older Tertiaries, Mesozoic and Permian palynomorphs in Renji Formation. The common palynotaxa are: *Striatriletes susannae, S. multicostatus, S. microverrucosus, S. paucicostatus, Cyathidites minor, Todisporites major, Lycopodiumsporites globatus, Osmundacidites wellmanii, Polypodiaceaesporites tertiarus, Podocarpidites khasiensis, Pinuspollenites crestus, Notothyrites setiferus* and *Phragmothyrites eocaenica.*

Kar (1990) proposed *Cyathidites minor* Cenozone for this assemblage with the common occurrence of *Cyathidites minor, Striatriletes microverrucosus, S. paucicostatus, Pinuspollenites crestus* and *Podocarpidites khasiensis.*

Tikak Parbat Palynological Assemblage

Mandaokar (1993, 1995) worked out the palynology of the Tikak Parbat Formation (Late Oligocene) of Dibrugarh District, Assam. The assemblage comprises 41 genera and 63 species. The pteridophytic spores and angiospermic pollen are found in good numbers and the gymnospermous pollen are absent. The common elements are: *Osmundacidites wellmanii, Gleicheniidites senonicus, Lycopodiumsporites globatus, Schizaeoisporites crassimurus, Striatriletes susannae, Polypodiaceaesporites levis, Pellicieroipollis langenheimii* and *Tricolpites medius*. *Meyeripollis naharkotensis* is the index fossil for the Tikak Parbat Formation. This species is, however, absent in the Late Oligocene sediments of Jowai-Badarpur Road, Meghalaya.

Surma-Tipam Palynological Assemblage

Kar (1990-91) investigated many samples from Rokhia bore hole core no.1, Gojalia 1 and Baramura 2 drilled in Tripura through Surma-Tipam succession by the Oil and Natural Gas Commission, Dehra Dun. The palynological assemblages from Rokhia 1 consist of 114 genera and 164 species, from Gojalia 1, 65 genera and 85 species and Baramura 2, 64 genera and 84 species.

However, the stratigraphically important species are: *Cyathidites minor, Deltoidospora* sp., *Dictyophyllidites dulcis, Pteridacidites fistulosus, P. tripuraeusis, Crassoretitriletes vanraadshooveni, Malayaeaspora costata, Striatriletes susannae, S. microverrucosus, S. multicostatus, S. aidaensis, Polypodiaceaesporites tertiarus, P. levis, Pilamonoletes excellensus, P. moderatus, Operculosculptites globatus, O. rokhiaensis, Podocarpidites* sp., *Pinuspollenites crestus, Piceapollenites excellensus, Palaeomalvaceaepollis mammilatus, Phragmothyrites eocenica, Inapertusporites kedvesii, Operculodinium centrocarpum, Cleistosphaeridium cephalum, Spiniferites mirabilis, Tuberculodinium vancampoae, Azolla aglochidia* and *Lycopodiumsporites globatus*.

There are many reworked Palaeocene-Eocene, Mesozoic and Permian forms in the samples. Some of the important forms are: *Dandotiaspora dilata, Aequitriradites spinulosus, Densoisporites velatus, Rhizomaspora costa, Crescentipollenites fuscus, Verticipollenites secretus* and *Scheuringipollenites maximus*.

Kar (1990) divided the whole palynological assemblage into three cenozones-*Aplanosporites robustus* Cenozone, *Striatriletes susannae* Cenozone and *Pinuspollenites crestus* Cenozone. *Aplanosporites robustus* Cenozone is marked by the dominance of dinoflagellates. The characteristic forms are: *Operculodinium centrocarpum, Cleistosphaeridium cephalum, Spiniferites mirabilis, Oligosphaeridium* sp. and *Tuberculodinium vancampoae*. The other species frequently found in the cenozone are: *Striatriletes microverrucosus, S. multicostatus, Pinuspollenites crestus, Polypodiisporites repandus, Polypodiaceaesporites tertiarus, Phragmothyrites eocenicus* and *Inapertusporites kedvesii*.

Striatriletes susannae Cenozone is dominated by the various species of *Striatriletes* and gymnospermous pollen. The common species are: *Striatriletes microverrucosus, S.susannae, S.multicostatus* and *S.aidaensis*. Other pteridophytic spores found in perceptible percentage are: *Cythidites minor, Polypodiisporites repandus, Polypodiaceaesporites tertiarus, Malayaeaspora costata* and *Pteridacidites tripuraensis*. Of the gymnosperms, *Pinuspollenites crestus* is more common.

Pinuspollenites crestus Cenozone has the dominance of gymnospermous pollen grains. *Striatriletes* and dinoflagellates are hardly encountered in this zone. *Pinuspollenites crestus* is most common and followed by *Podocarpidites khasiensis, Cyathidites minor* and *Inapertusporites kedvesii*. The other species which are frequently found are: *Polypodiisporites repandus, Polypodiaceaesporites tertiarus, Operculosculptites globatus* and *Operculosculptites* sp.

Palynological Assemblage from Girujan and Namsang Formations

Kar (1990-91) palynologically investigated Lakwa 27 bore hole core supplied by the Oil and Natural Gas Commission, Dehra Dun. The samples were ranging from 2445-50 m to 1150-1200 m. Of these 2445-50 - 2175-2200 m was marked as Girujan and 1600-1605 to 1150-1200 m as Namsang. Kar *et al.* (1994) also studied Nahorkatiya bore hole core no.1, Nahorkatiya 263 and 268, Kharsang 2 and 3 supplied by the Oil India Limited, Duliajan. These bore hole cores had also Girujan and Namsang sediments (Fig. 3).

The samples are, however, poor in palynological contents. The species recovered are: *Cyathidites minor, Todisporites major, Deltoidospora* sp., *Dictyophyllidites kyrtomatus, Dictyophyllidites dulcis, Intrapunctisporis apunctis, Lycopodiumsporites globatus, Lycopodiacidites* sp., *Osmundacidites wellmanii, Striatriletes susannae, S. multicostatus, S. microverrucosus, S. paucicostatus, Polypodiaceaesporites tertiarus, Psiloschizosporis psilatus, P. scabratus, Podocarpidites khasiensis, Pinuspollenites crestus, Piceapollenites excellensus, Pellicieroipollis langenheimii, Phragmothyrites eocenica, Notothyrites setiferus, Inapertusporites kedvesii, Bicellaesporites* sp., *Lirasporis intergranifer* and *Pediastrum* sp.

It was observed that palynological demarcation between Girujan and Namsang formations could be made by the relative dominance of *Pinuspollenites crestus, Lycopodiumsporites globatus, Osmundacidites wellmanii, Striatriletes susannae, S. pseudocostatus* and *Psiloschizosporis costata*. The other species which are also common are *Lycopodiumsporites*

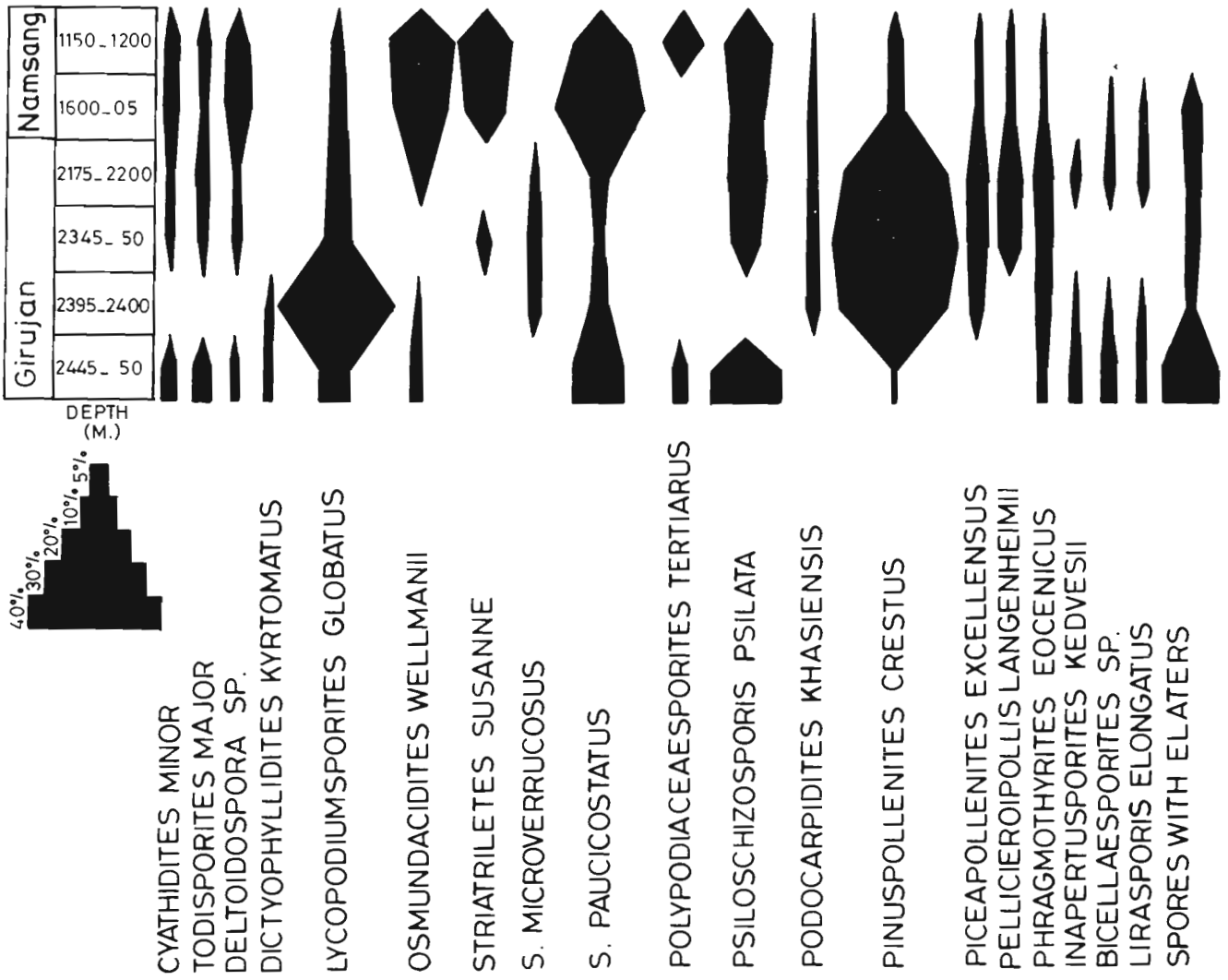

Fig. 3—The distribution of various spore pollen species in Girujan and Namsang formations (after Kar, 1992).

globatus, Psiloschizosporis psilata and some spores with elaters.

In Namsang Formation (1605-1200 m), the gymnosperms are poorly represented and the pteridophytes are found in abundance. *Osmundacidites wellmanii, Striatriletes susannae, S. paucicostatus* and *Polypodiaceaesporites tertiarus* are well represented.

DISCUSSION

Tertiary rocks are well developed in North-East India. Palaeocene to Pliocene rocks are exposed almost in continuous sequence except post Barail unconformity. The palynological taxa are also found in good numbers from all the formations. This helps to assess the marker fossils from the different horizons.

Tertiary Index Species in North-east India

More than 100 genera and 150 species have been recorded from the various formations. Most of them are, however long ranging and thus have no significance as stratigraphic markers. Kar (1992) selected 27 palynological taxa as index species of the different Tertiary formations (Fig. 4).

Of these, *Saturna enigmatus, Tercissus* sp., *Acrostichumsporites meghalayaensis* are restricted to Early Palaeocene sediments. *Diporoconia* sp. is the only marker species for Middle Palaeocene. *Lycopodiumsporites speciosus* and *Dandotiaspora dilata* are confined to Middle-Late Palaeocene. *Matanomadhiasulcites maximus* originates in Early Palaeocene and becomes extinct in Early Eocene. *Tripilaorites triangulus* is also not found after Early Eocene. *Kielmeyerapollenites eocenicus* is restricted to Middle

Palaeocene to Late Palaeocene. *Tricolporopilites robustus* and *Tricolporocolumellites pilatus* are found only in Middle Eocene. In the Terminal Eocene, *Dermatobrevicolporites dermatus, Spinizonocolpites echinatus, Triangulorites bellus, Lakiapollis ovatus* and *Retibrevicolporites matanomadhensis* disappear. Five taxa are confined to Oligocene and Miocene. These are: *Bombacacidites triangulus, Crassoretitriletes vanraadshoovenii, Pinuspollenites crestus, Abiespollenites cognatus* and *Piceapollenites excellensus. Azolla aglochidia* and *Hibisceaepollenites splendus* stand for the Miocene sediments.

Terminal Eocene Events

There was a major change in planktonic foraminifera, radiolaria, ostracoda, nannoplankton and other forms of life from Eocene to Oligocene (Killer, 1986; Pomerol & Premoli-Silva, 1986; Shackleton & Kennett, 1975; Haq, 1981).

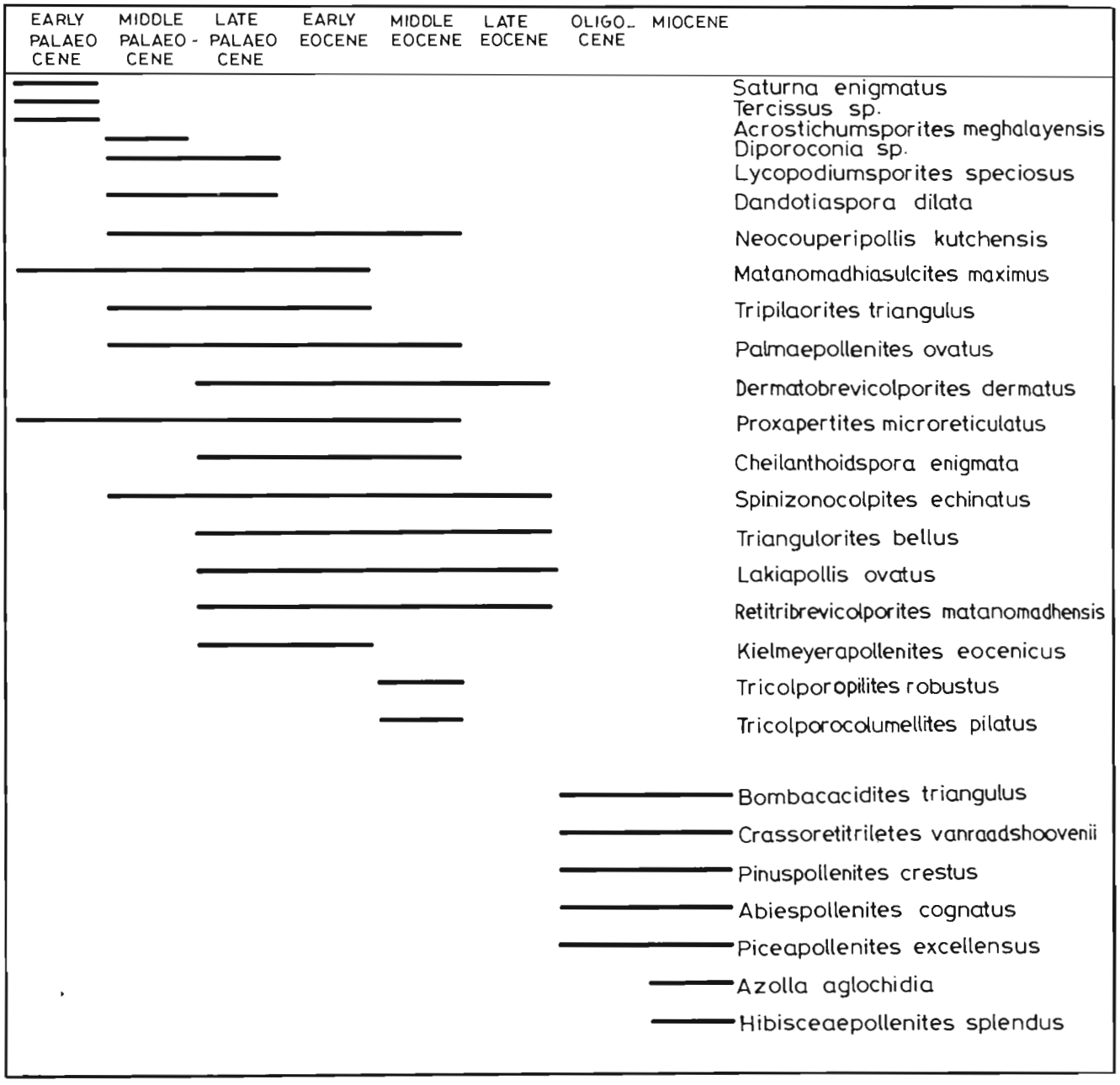

Fig.4—Distribution of index species in the Tertiary formations of north-east India.

Biostratigraphic events based on terrestrial vegetation are not that sensitive as those of fauna but has significance at least on regional scale. Floral changes at Eocene-Oligocene transition were worked out by Wolfe (1978) in North America, Chateauneuf (1986) in north-western Europe, Akhmetiev *et al.* (1986) in Kazakhastan, Krasheninnikov *et al.* (1986) in Armenia.

Pomerol and Premoli-Silva (1986) analysed these diversified data and noted that the vegetation markedly changed world wide during Eocene-Oligocene transition due to cooling of the climate. Wolfe (1978) pointed out that at the end of Eocene, mid and high latitude areas in North America which were supporting broad-based evergreen forest were replaced by temperate broad-leaved deciduous forest.

Kar *et al.* (1994) worked out the Eocene-Oligocene transition on the bore hole core nos. Nahorkatiya 1, 263 and 268. The overwhelming dominance of pteridophytic spores and the paucity of angiospermic and gymnospermic pollen both in quality and quantity mark the Eocene-Oligocene transition in North-East India. Among the pteridophytes, *Striatriletes* is the most common genus. This genus according to Kar (1992) occurs in very insignificant numbers in Palana Formation (Early Eocene) of Rajasthan, found frequently in the Middle Eocene sediments of Kutch and Prang Formation of Meghalaya and contributes maximum in Barails in North-East India (Fig. 5).

The fossil spores of *Striatriletes* which are tagged with the extant genus *Ceratopteris* belong to the family Parkeriaceae. This fern taxon grows throughout the tropics in quiet waters. The abundance of fossil spores of *Ceratopteris* in Eocene-Oligocene transition in India points out that during this time India was enjoying a tropical climate and there was no cooling effect as has been advocated from the other parts of the world. The leaf impression studied by Lakhanpal and Guleria (1981) from the Early Eocene of Kutch and by Awasthi and Mehrotra (1995) from the Oligocene of Assam indicates that in both the periods tropical evergreen to deciduous forest was present.

Reason for Warmer Climate

The position of India during Eocene-Oligocene transition was approximately around the equator. Barron *et al.* (1981) placed India on the 40 million year palaeogeographic reconstruction between 10°S to 20°N. The southern tip of India was approximately around the present Chagos Archipelago during that time. Being placed in the equatorial belt, India naturally was enjoying a tropical climate.

The DSDP sites 214 and 218 drilled in the Indian Ocean and Laccadive Island respectively indicate that carbonate accumulation was relatively low throughout the Late Eocene-Early Oligocene interval (Thunell & Corliss, 1986). This perhaps points out that water in these two regions were not cool as in other parts of the globe during that time (Fig. 6).

At the Eocene-Oligocene transition, Tethys turned shallow and emergence of land on a higher scale took place on the eastern side blocking the passage of cool water to India (Dercourt *et al.*,1985; Ricou *et al.*,1986).

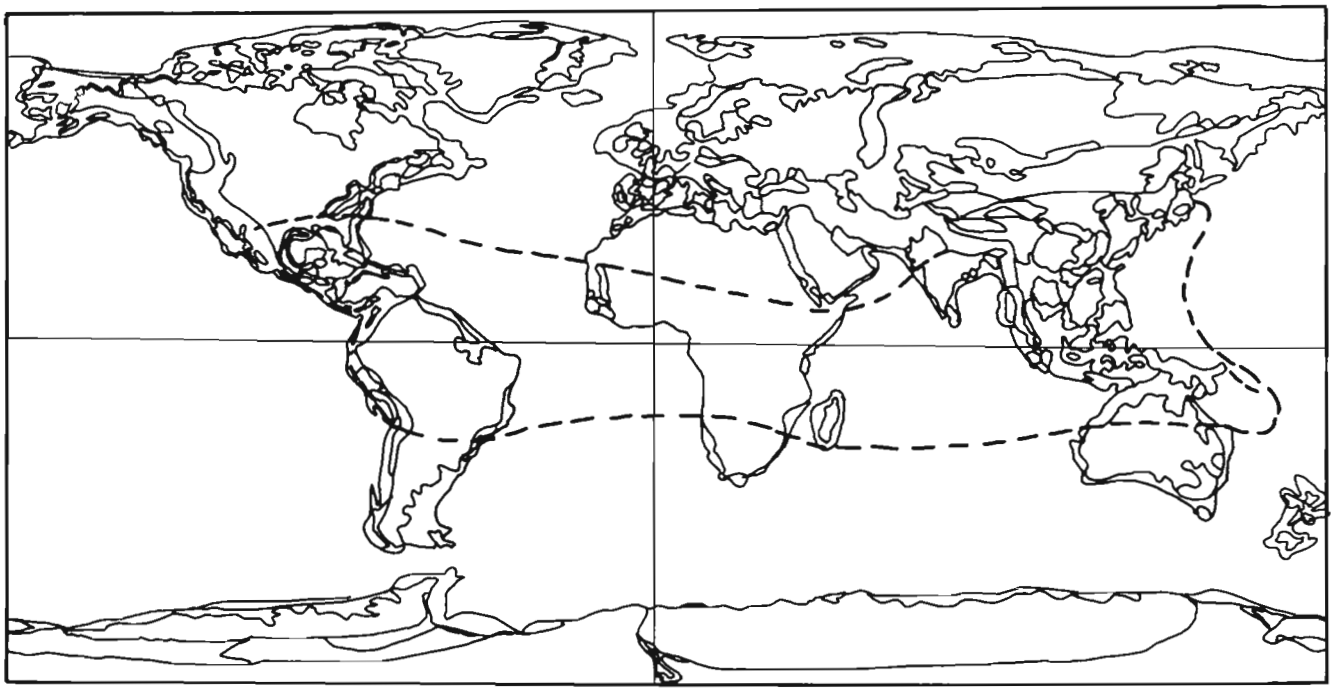

Fig. 5—The present day distribution of *Ceratopteris*.

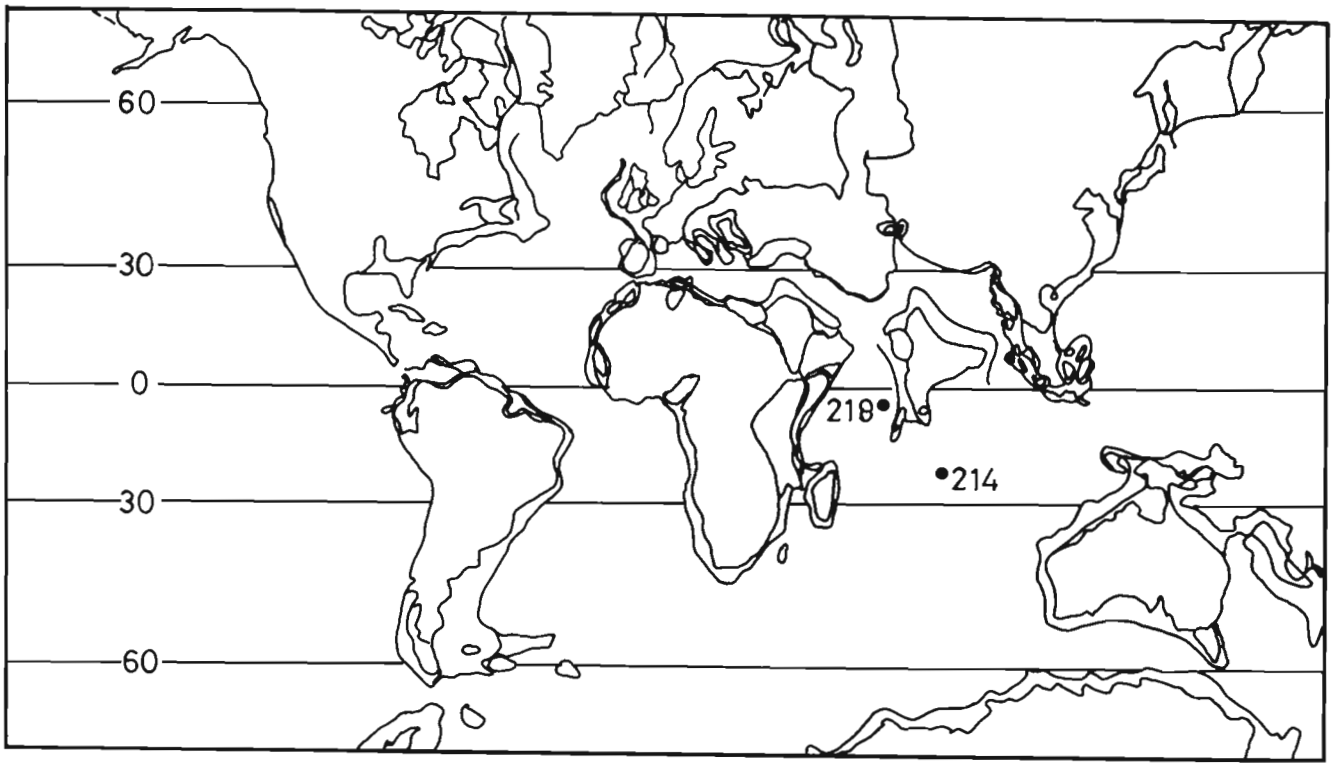

Fig. 6—The position of India during Eocene-Oligocene and the DSDP sites 214 and 218.

Biswas (1983) investigated the Tertiary sediments in Tripura and Assam regions. He remarked that Laisong rocks exposed on Silchar-Halflong Road section contain illite and kaolinite persistently. Chlorite is also common and montmorillonite is found only in certain lithounits. This indicates that the climate of south Assam region was tropical in most of the Early Oligocene time.

Acknowledgements—*Sincere appreciation is expressed to the Department of Science and Technology, New Delhi for sanctioning a project entitled "Deccan Intertrappean palynoflora and its implication for the demarcation of K/T boundary" (ESS/CA/A4-16/96). The author is thankful to Prof Anshu K Sinha, Director, Birbal Sahni Institute of Palaeobotany, Lucknow for providing infrastructural facilities.*

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