Stratigraphical implications of Tertiary palynological succession in north-eastern and western India

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Cretaceous and Tertiary sedimentary rocks are found overlying a Precambrian granite basement or occasionally the Sylhet Trap (Late Jurassic) in north-east India whereas in Kutch, western India, the Tertiary rocks rest on the Deccan Trap and its derivatives. In north-east the Tertiary succession is almost complete whereas in Kutch the Early and Middle Palaeocene and Late Eocene sediments are missing. More than 150 spores and pollen genera are described from the Tertiary sediments but except about 20 all are long ranging. The Early Tertiary palynological succession in north-east and Kutch is more or less similar and all the marker taxa are found simultaneously in the equivalent formations in both the regions. In north-east India, throughout the Tertiary succession, the pteridophytic spores are found in abundance whereas in Kutch they are found in meagre percentage. The distribution of marker taxa throughout the Tertiary has been shown with the help of a chart. It is assumed that during Palaeocene to Eocene the plants grew in tropical, coastal swamps whereas from Oligocene onwards the deposition was mostly riverine in the eastern region.

Key-words—Palynology, Palaeoecology, Tertiary, North-eastern India, Western India.

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सारांश

उत्तर-पूर्वी एवं पश्चिमी भारत में तृतीयक युगीन परागाणविक अनुक्रम का स्तरिकीय महत्व

रंजीत कुमार कर

क्रीटेशी एवं तृतीयक युगीन चट्टानें कम्बिय-पूर्व ग्रेनाइट अथवा कभी-कभी उत्तर-पूर्व भारत में सिल्हट ट्रैप (अनंतिम जूराई) के ऊपर स्थित पाई जाती हैं जबकि पश्चिमी भारत में कच्छ में तृतीयक चट्टानें दक्खिन ट्रैपों एवं इनसे सहयुक्त चट्टानों पर स्थित हैं। उत्तर-पूर्व में तृतीयक अनुक्रम लगभग पूर्ण है जबकि कच्छ में प्रारम्भिक एवं मध्य पुरानूतन तथा अनंतिम आदिनूतन अवसाद अनुपस्थित हैं। तृतीयक अवसादों से 150 से भी अधिक बीजाणु एवं परागकण प्रजाति वर्णित की गई हैं लेकिन इनमें से लगभग 20 को छोड़कर सभी लम्बी अवधि तक मिलती हैं। उत्तर-पूर्व एवं कच्छ में प्रारम्भिक तृतीयक परागाणविक अनुक्रम प्रायः एक जैसे ही हैं तथा दोनों क्षेत्रों में सूचक प्रजातियाँ समतुल्य शैल-समूहों में साथ-साथ मिलती हैं। उत्तर-पूर्व भारत में तृतीयक अनुक्रम में टेरीडोफ़ाइटी बीजाणुओं की बाहुल्यता है जबकि कच्छ में इनकी काफी कम संख्या है। इस कल्प में विभिन्न वर्गकों का वितरण एक चार्ट के द्वारा प्रदर्शित किया गया है। ऐसा अनुमान है कि पुरानूतन से आदिनूतन कल्प तक पौधे उष्णकटिबन्धीय, तटीय दलदल में विद्यमान थे जबकि ओलिगोसीन और उसके बाद उत्तरी क्षेत्र में निक्षेपण का वातावरण नदीय था।

TERTIARY rocks are very well developed in north-eastern and western India. In north-east, Palaeocene to Pliocene rocks are found almost in continuous sequence except the post-Barail (Oligocene) unconformity. In western India, well exposed Tertiary sediments are mostly confined in Kutch, Gujarat, but the Early-Middle Palaeocene and Late Eocene rocks are missing.

North-east India

The north-east India comprises Assam, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram and Tripura. Of these states, palynological work has mostly been carried out in Assam, Meghalaya and Tripura. The paper is based mostly on the information of these three states.

The alluvium covered foreland shelf zone of Upper Assam Valley, which is a part of the major Assam-Arakan Basin, forms the north-eastern corner

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of the Indian sub-continent. Outcrops of rocks all along the Naga-Patkai Hills separated from the Upper Assam alluvial plain by the major Naga and Margherita thrusts provide a geological succession of the Late Tertiary sediments in the region.

The Cretaceous and Early Tertiary sediments, on the other hand, are found in Meghalaya unconformably overlying on the Precambrian granitic basement. A general lithological succession is given in Text-figure 1 following the Oil India Limited, Duliajan. The geology of this region has mainly been worked out by Oldham (1858), Medlicott (1869), Palmer (1923), Ghosh (1940), Baksi (1962), Biswas (1962), Evans (1964), Bagchi (1964), Dutta and Sah (1970), Handique and Dutta (1981), Samanta and Raychaudhuri (1983), Handique and Mallick (1989) and others.

Langpar Formation

This formation exposed at Therriaghat on the Umshoringkew River, Meghalaya is not rich in spores and pollen and instead the phytoplanktons are quite common. The spores and pollen genera recovered are: *Cyathidites, Lygodiumsporites,* spores of *Acrostichum, Contignisporites, Schizaeoisporites, Matanomadhiasulcites, Dracaenoipollis, Proxapertites, Saturna, Tercissus, Araucariacites, Schizosporis* and *Phragmothyrites.* Besides, some reworked Permian genera, e.g., *Striatriletes, Rhizomaspora* and *Densipollenites* are also recorded.

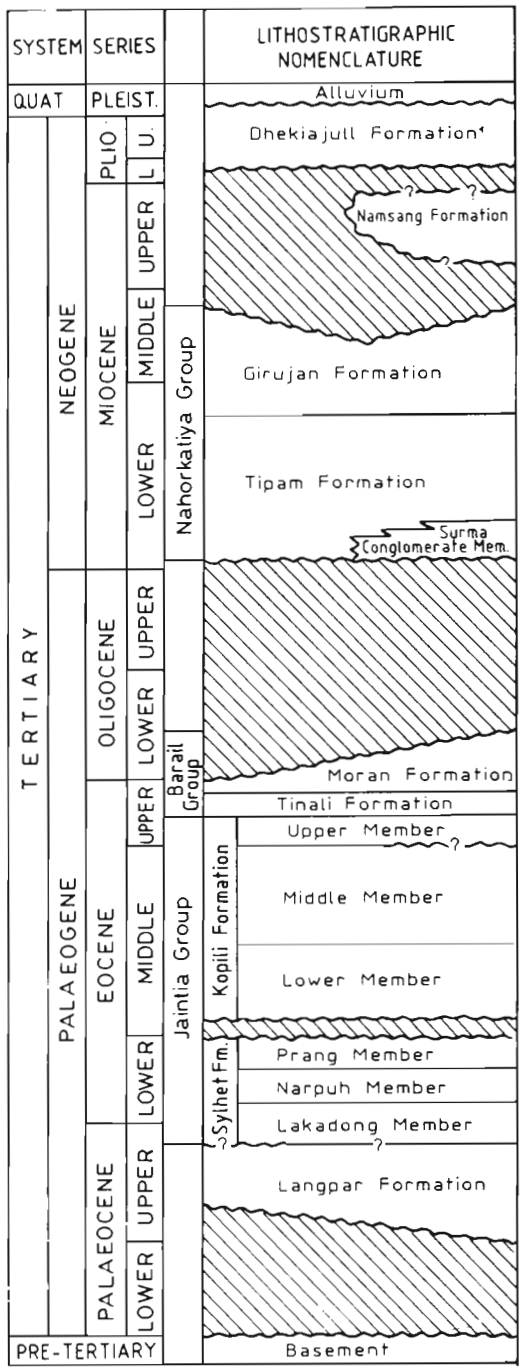
Presence of *Saturna* and *Tercissus* in this formation claims special attention. The genus *Saturna* (Salard-Cheboldaeff, 1978) is so far known from Africa, while *Tercissus* is recorded from U.S.A., western Venezuela (Tschudy, 1970) and Africa (Kieser & Jan du Chêne, 1979; Boudouresque, 1980; Caratini *et. al.,* 1991).

The assemblage is dominated by pteridophytic spores, mostly represented by *Lygodiumsporites lakiensis, Cyathidites minor* and spores of *Acrostichum.* Among angiosperm pollen *Saturna enigmatus, Proxapertites cursus* and *Matanomadhiasulcites maximus* are occasionally met with. *Araucariacites* represents the gymnosperms.

Presence of the spores of *Acrostichum* in appreciable percentage at Therriaghat indicates that the deposition took place in a back mangrove swamp. Occurrence of Permian striate and monosaccate genera in the sediments provides testimony to the erosion of Permian rocks in the sediments.

Therria Formation

Therria Formation witnessed the emergence of some important marker spore-pollen genera for



Text-figure 1

Palaeocene and Lower Eocene. Notable amongst them are: *Lycopodiumsporites, Dandotiaspora, Palmaepollenites, Neocouperipollis, Diporoconia, Spinizonocolpites* and *Tripilaorites. Lycopodiumsporites, Diporoconia* and *Tripilaorites* occur from the lower part of the formation, whereas *Dandotiaspora dilata* appears from the middle. *Spinizonocolpites* and other palm pollen are found almost in all the samples.

The pteridophytic spores out number the

angiospermous pollen. Amongst the pteridophytes, *Dictyophyllidites* spp., *Lycopodiumsporites speciosus, Lygodiumsporites lakiensis* and *Cyathidites minor* are quite common. Among the angiosperms, *Verrucolporites verrucus, Matanomadhiasulcites maximus, Diporoconia* sp., *Spinizonocolpites echinatus* and *Palmaepollenites ovatus* are frequently found. *Spiniferites* and other phytoplanktons are also encountered often.

Lakadong Formation

Sah and Dutta (1966), Dutta and Sah (1970) and Kar and Kumar (1986) studied the sediments of Lakadong Sandstone Member exposed at Laitryngew and Mawlong coalfields, Sohrarim, Mawmluh and Shillong-Cherrapunji road section, Khasi Hills, Meghalaya. The assemblage consists of 45 genera and 86 species, of them 15 genera and 31 species belong to pteridophytes and 30 genera and 55 species to angiosperms.

Kar and Kumar (1986) divided the assemblage into *Lycopodiumsporites speciosus* Cenozone and *Kielmeyerapollenites syncolporatus* Cenozone. *Lycopodiumsporites speciosus* Cenozone is recognized by the common occurrence of *Lycopodiumsporites speciosus, Dandotiaspora dilata, Dandotiaspora telonata, Lycopodiumsporites parvireticulatus, Pteridacidites meghalayensis, Pteridacidites robustus, Proxapertites crassimurus, Neocouperipollis wodehousei, Neocouperipollis kutchensis* and *Retitribrevicolporites matanomadhensis.*

Kielmeyerapollenites syncolporatus Cenozone is characterised by the good representation of *Kielmeyerapollenites syncolporatus, Dandotiaspora dilata, D. telonata, Polypodiisporites umstewensis, Lygodiumsporites lakiensis, Palmidites plicatus, P. excellensus, Psilastephanocolporites psilatus, P. subcircularis, Retistephanocolporites multirimatus* and *Polymargocolporites mawlensis.*

Prang Formation

Spores and pollen grains are not known from the Prang Formation so far. Kar (Ms) recovered an assemblage from near 132 km post on Jowai-Badarpur Road, Meghalaya, which consists of 28 genera and 34 species. Pteridophytes are represented by 17 genera and 24 species, gymnosperms by 2 genera and 3 species, angiosperms by 9 genera and 7 species. The pteridophytic spores are mainly represented by *Todisporites kutchensis, Lygodiumsporites lakiensis, Osmundacidites kutchensis, Cyathidites minor, Striatriletes susannae, Podocarpidites khasiensis, Polypodiaceaesporites chatterjii* and *Polypodiisporites repandus.* The angiospermic pollen are occasionally found and generally represented by *Lakiapollis ovatus* and *Pellicieroipollis langenheimii.*

Kopili Formation

Trivedi (1985) investigated Kopili Formation exposed at 136 km post on Jowai-Badarpur Road, Meghalaya. The assemblage is dominated by pteridophytic spores comprising only *Striatriletes susannae* Cenozone. It includes *Striatriletes susannae, Striatriletes paucicostatus, Striatriletes microverrucosus, Polypodiaceaesporites tertiarus, Laevigatosporites lakiensis, Dermatobrevicolporites verrucosus* and *Cleistosphaeridium heteracanthum.*

Barails

The Barails in the geosynclinal facies of north east India are subdivided into Laisong, Jenam and Renji formations. Sein and Sah (1974), Salujha, Kindra and Rehman (1972, 1974), Saxena and Rao (1984), Rao and Singh (1986) and others worked on the palynology of the geosynclinal sediments. Kar (1990) studied in detail the palynofossils of these formation exposed on Silchar-Half Long Road.

Palynotaxa of Laisong Formation consist of 30 genera and 28 identifiable species. Kar (1990) proposed *Osmundacidites wellmanii* Cenozone for this formation, which has a good representation of *Osmundacidites wellmanii, Cyathidites minor, Striatriletes microverrucosus, Polypodiaceaesporites tertiarus, Pinuspollenites crestus* and *Inapertusporites kedvesii.*

Jenam Formation is populated by 49 genera and 42 identifiable species. Kar (1990) divided 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 shows the abundance of *Polypodiaceaesporites tertiarus, Striatriletes microverrucosus, Phragmothyrites eocaenica, Notothyrites setiferus* and *Polyadopollenites* spp. The characteristic species of *Striatriletes susannae* Cenozone are: *Striatriletes susannae, Striatriletes multicostatus, Striatriletes microverrucosus, Lygodiumsporites lakiensis* and *Polypodiaceaesporites tertiarus.*

Cyathidites minor Cenozone stands for Renji Formation and has good percentage of *Cyathidites minor, Striatriletes microverrucosus, Striatriletes paucicostatus, Pinuspollenites crestus* and

Podocarpidites khasiensis.

In Upper Assam, Barails are divided into Naogaon, Baragolai and Tikak Parbat formations. Palynological knowledge on Naogaon and Baragolai formations is scanty. The palynological assemblage of Tikak Parbat Formation due to its richness in coal is well known. Mandaokar (Ms.) has divided the assemblage into *Schizaeoisporites crassimurus* Cenozone, *Meyeripollis naharkotensis* Cenozone and *Osmundacidites wellmanii* Cenozone. *Schizaeoisporites crassimurus* Cenozone has the dominance of *Schizaeoisporites crassimurus, Surmaspora sinuosa, Crassoretitriletes vanraadshoovenii, Polypodiaceaesporites major, Polypodiisporites speciosus, Striatriletes susannae* and *Cucurbitariaceites bellus. Meyeripollis naharkotensis* Cenozone is associated with *Meyeripollis naharkotensis, Polypodiisporites miocenicus, Polypodiisporites oligocenicus, Retitricolpites robustus, Pteridacidites vermiverrucatus* and *Osmundacidites wellmanii. Osmundacidites wellmanii* Cenozone is characterised by *Osmundacidities wellmanii, Striatriletes susannae, Polypodiaceaesporites levis, Lygodiumsporites lakiensis, Polypodiisporites turbinatus* and *Crassoretitriletes vanraadshoovenii.*

Tipam-Surma units

Kar (1990) studied the samples of Tipam-Surma units from Rokhia bore-hole no. 1, Gajalia bore-hole no. 1 and Baramura bore-hole no. 2 drilled in Tripura by the Oil and Natural Gas Commission, Dehradun.

The assemblage comprises 114 genera and 164 species and is divisible into three cenozones, viz., *Aplanosporites robustus* Cenozone, *Striatriletes susannae* Cenozone and *Pinuspollenites crestus* Cenozone. Significant species of *Aplanosporites robustus* Cenozone are: *Operculodinium centrocarpum, Cleistosphaeridium cephalum, Spiniferites mirabilis, Oligosphaeridium complex, Tuberculodinium vancampoae, Striatriletes multicostatus, Polypodiisporites ornatus, Lycopodiumsporites lakiensis* and *Pinuspollenites crestus. Striatriletes susannae* Cenozone constitutes *Striatriletes susannae, Striatriletes multicostatus, Striatriletes aidaensis, Osmundacidites cephalus, Azolla aglochidia, Lycopodiumsporites globatus, Pilamonoletes excellensus, Conitricolporites triangulus, Pinuspollenites crestus* and *Operculosculptites globatus.* The important species of *Pinuspollenites crestus* Cenozone are: *Pinuspollenites crestus, Operculosculptites globatus, Palaeomalvaceaepollis mammilatus, Pteridacidites tripuraensis, Polypodiisporites ornatus, Lycopodiumsporites globatus* and *Lygodiumsporites lakiensis.*

Pinuspollenites crestus Cenozone also holds good for the Bhuban Formation (Surma) exposed near Bandarkhal on Silchar-Half Long Road, Assam. *Operculosculptites globatus,* which is one of the dominant forms in subsurface of Tripura, is almost absent in Bhuban. Besides, presence of reworked Permian and Cretaceous forms in appreciable percentage in this formation also helps to identify this cenozone in Meghalaya.

In Duarmara bore-hole no. 2 and Nahorkatiya bore-hole nos. 263 and 268 (Assam) the reworked Permian and Cretaceous palynomorphs are very negligible in Tipam-Surma. Besides, gymnospermous bisaccate pollen are found in low percentage.

In Arunachal Pradesh, as evidenced by Kharsang bore-hole nos. 2 and 3, the gymnospermous pollen are found in abundance in Tipam-Surma.

Girujan Clay Formation

The palynological assemblage of this formation is known from the bore-hole nos. Lakwa 27, Duarmara 2 and Kharsang 2 and 3. The assemblage consists of 25 genera and 37 species. In Lakwa 27 and Kharsang 2, Girujan is dominated by gymnospermous pollen whereas in Duarmara bore-hole no. 2 the pteridophytes are abundant and many species of angiosperms are also met with (Kar *et al.*, MS).

In Lakwa bore-hole 27, Girujan is overwhelmingly dominated by *Pinuspollenites crestus.* The other associated significant species are: *Lycopodiumsporites globatus, Psiloschizosporis psilata* and some spores with elaters.

Namsang Sandstone/Clay Formation

In Lakwa bore-hole no. 27, the gymnosperms are poorly represented while the pteridophytes are found in good numbers. They are mostly represented by *Osmundacidites wellmanii, Striatriletes susannae, Striatriletes paucicostatus* and *Polypodiaceaesporites tertiarus.*

In Kharsang 2, Namsang exhibits the abundance of *Crassoretitriletes vanraadshoovenii* and *striatriletes susannae.* Besides, frequent presence of *Palaeomalvaceaepollis mammilatus, Palaeomalvaceaepollis rudis, Acanthotricolpites* sp., *Compositoipollenites conicus, Compositoipollenites tricolporatus, Palaeosantalaceaespites primitiva* and *Monoporopollenites* sp. marks Namsang in the bore-hole.

WESTERN INDIA

The Tertiary sediments in western India

exposed in the district of Kutch represents exposures from Palaeocene to Pliocene. The outcrops are mostly confined in the south-western coastal plain of Kutch between Guvar and Khari rivers. The geology of this area has been worked out by Grant (1840), Wynne (1872), Vredenburg (1925), Nuttal (1926), Tewari (1952, 1957), Poddar (1959, 1963), Sen Gupta (1959, 1964), Tandon (1962), Bhatt (1968), Biswas (1971), Biswas and Deshpande (1970), Biswas and Raju (1971, 1973), Hardas and Biswas (1973), Sahni and Misra (1975), Mishra (1980) and others. However, the rock-stratigraphic classification of Biswas and Raju (1971, 1973) for the Tertiary sediments of Kutch has been followed as under:

FORMATION	MEMBER		AGE
Sandhan		Pliocene	
Vinjhan Shale	Siltstone	Miocene	Langhian
	Chhasra		Burdigalian
Khari Nadi			Aquitanian
Maniyara	Ber Moti		Chattian
	Coral	Oligocene	Rupelian
	Limestone		Lattorfian
	Lumpy clay		
	Basal Member		
Fulra Limestone			Luttetian
Harudi		Eocene	
Naredi			Ypresian
Matanomadh		Palaeocene	
Deccan Trap		Upper Cretaceous to Palaeocene	

Matanomadh Formation

This formation is best exposed around the village Matanomadh. The lithology is extremely variable and comprises trap wash, ash, agglomerate, variegated white and tuffaceous shales, red tuffaceous sandstones with occasional layers of lignite.

Kar (1985) divided this formation into five palynological cenozones. These in the ascending order are: (i) Barren zone, (ii) *Dandotiaspora dilata* Cenozone, (iii) *Tricolpites minutus* Cenozone, (iv) *Neocouperipollis kutchensis* Cenozone, and (v) Sponge spicules Zone.

Dandotiaspora dilata Cenozone has the following significant species: *Dandotiaspora dilata, Dandotiaspora plicata, Lygodiumsporites lakiensis, Lygodiumsporites pachyexinous, Todisporites major, Intrapunctisporis apunctis, Proxapertites microreticulatus, Psilastephanocolpites guaduensis, Tricolpites retibaculatus, Tricolpites crassireticulatus, Proteacidites protrudus, Cyathidites australis* and *Liliacidites matanomadhensis. Tricolpites minutus* Cenozone is characterised by *Tricolpites minutus, Tricolpites brevis, Phragmothyrites eocaenica, Osmundacidites microgranifer, Cyathidites australis, Dandotiaspora plicata, Palmaepollenites nadhamunii, Palmaepollenites ovatus, Sonneratioipollis bellus* and *Inapertusporites kedvesii. Neocouperipollis kutchensis* Cenozone has *Neocouperipollis kutchensis, Tricolpites minutus, Phragmothyrites eocaenica, Lakiapollis matanomadhensis, Meliapollis ramanujamii, Palmaepollenites kutchensis, Neocouperipollis robustus, Kielmeyerapollenites eocaenicus, Neocouperipollis achinatus, Polycolpites flavatus, Polypodiaceaesporites levis* and *Lakiapollis ovatus.*

Naredi Formation

This is made up of three members—the lower Gypseous Shale Member, the middle Assilina Limestone Member and the upper Ferruginous Claystone Member. This formation rests on the Deccan Trap in the type locality but at other places it rests unconformably on the Matanomadh Formation.

The palynological assemblage has been divided by Kar (1985) into two cenozones—the lower *Lakiapollis ovatus* Cenozone and the upper *Lygodiumsporites lakiensis* Cenozone. *Lakiapollis ovatus* Cenozone has the association of *Lakiapollis ovatus, Neocouperipollis kutchensis, Proxapertites microreticulatus, Meliapollis ramanujamii, Palmaepollenites kutchensis, Umbelliferoipollenites ovatus, Inapertusporites kedvesii, Botryococcus palanaensis, Pellicieroipollis langenheimii* and *Lygodiumsporites lakiensis. Lygodiumsporites lakiensis* Cenozone has *Lygodiumsporites lakiensis, Dandotiaspora plicata, Intrapunctisporis apunctis, Palmaepollenites kutchensis, Proxapertites microreticulatus, Neocouperipollis kutchensis, Lakiapollis ovatus* and *Inapertusporites kedvesii.*

Harudi Formation

This consists of green-greenish grey, splintery shale with limnotic partings in the lower part and calcareous claystone, siltstone with layers of gypsum and carbonaceous shale in the upper part.

Proxapertites microreticulatus Cenozone and *Cheilanthoidspora enigmata* Cenozone are the two cenozones proposed by Kar (1985) for this formation. *Proxapertites microreticulatus* Cenozone has common occurrence of *Proxapertites microreticulatus, Palmaepollenites kutchensis, Cyathidites minor, Neocouperipollis kutchensis, Scantigranulites sparsus, Palmaepollenites ovatus, Seniasporites verrucosus* and *Laevigatosporites cognatus.* The significant species in *Cheilanthoidspora enigmata* Cenozone are: *Cheilanthoidspora enigmata, Striatriletes susannae,*

Neocouperipollis kutchensis, Oligosphaeridium complex, Striatriletes multicostatus, Polypodiaceaesporites strictus, Palmaepollenites kutchensis, Proxapertites microreticulatus and *Lakiapollis ovatus.*

Fulra Limestone

It comprises massive to thickly bedded, cream to dirty white foraminiferal limestone with numerous animal fossils comprising mostly *Discocyclina* and *Nummulites.* No palynological assemblage is known from this formation.

Maniyara Fort Formation

This is divisible into (i) Basal Member characterised by alternating beds of foraminiferal, glauconitic-siltstone and calcareous to gypseous claystone, (ii) Lumpy Clay Member has cement coloured to brownish calcareous lumpy claystone with intercalation of thin bands of limestone and marlite, (iii) Coral Limestone Member consists of dirty white nodular limestone alternating with calcareous claystone, and (iv) Ber Moti Member comprises mostly brown argillaceous sandstone and thin bedded hard, foraminiferal limestone.

The three cenozones recognised by Kar (1985) are: *Operculodinium centrocarpum* Cenozone, *Trisyncolpites ramanujamii* Cenozone and *Aplanosporites robustus* Cenozone. *Operculodinium centrocarpum* Cenozone is dominated by microplankton, e.g., *Operculodinium centrocarpum, Cleistosphaeridium heterocanthum, Tuberculodinium vancampoae, Inapertusporites kedvesii* and *Phragmothyrites eocaenica.*

Trisyncolpites ramanujamii Cenozone has a high percentage of *Trisyncolpites ramanujamii, Leptolepidites chandrae, Striatriletes susannae, Laevigatosporites lakiensis, Polypodiaceaesporites chatterjii, Polypodiisporites constrictus, Podocarpidites cognatus* and *Palaeosantalaceaepites ellipticus.* The species associated with *Aplanosporites robustus* Cenozone are: *Aplanosporites robustus, Operculodinium centrocarpum, Cleistosphaeridium heterocanthum, Inapertusporites kedvesii* and *Phragmothyrites eocaenica.*

Khari Nadi Formation

This formation is composed of laminated, mottled to variegated siltstone with occasional bands of grey-brown, gypseous claystone.

This formation is represented by *Cordosphaeridium cantharellum* Cenozone, *Striatriletes susanne* Cenozone and *Operculodinium israelianum* Cenozone. The important taxa belonging to *Cordosphaeridium cantharellum* Cenozone are: *Cordosphaeridium cantharellum, Operculodinium centrocarpum, Striatriletes susannae, Operculodinium israelianum, Aplanosporites robustus, Cordosphaeridium exilimurum, Podocarpidites densicorpus* and *Piceapollenites excellensus. Striatriletes susannae* Cenozone comprises *Striatriletes susannae, Azolla aglochidia, Podocarpidites densicorpus, Striatriletes aidaensis, Striatriletes paucicostatus, Khariasporites densus, Abiespollenites cognatus, Piceapollenites excellensus* and *Tsugaepollenites velatus. Operculodinium israelianum* Cenozone includes *Operculodinium israelianum, Cordosphaeridium cantharellum, Operculodinium centrocarpum, Tuberculodinium vancampoae, Spiniferites bulloideus, Millioudinium unicarpum, Cordosphaeridium exilimurum* and *Abiespollenites cognatus.*

Vinjhan Shale

The grey and khaki coloured, laminated, gypseous shales and claystones with alternation of argillaceous limestones are the characteristic lithology of this formation. No spores and pollen could be recovered from this formation.

Sandhan Formation

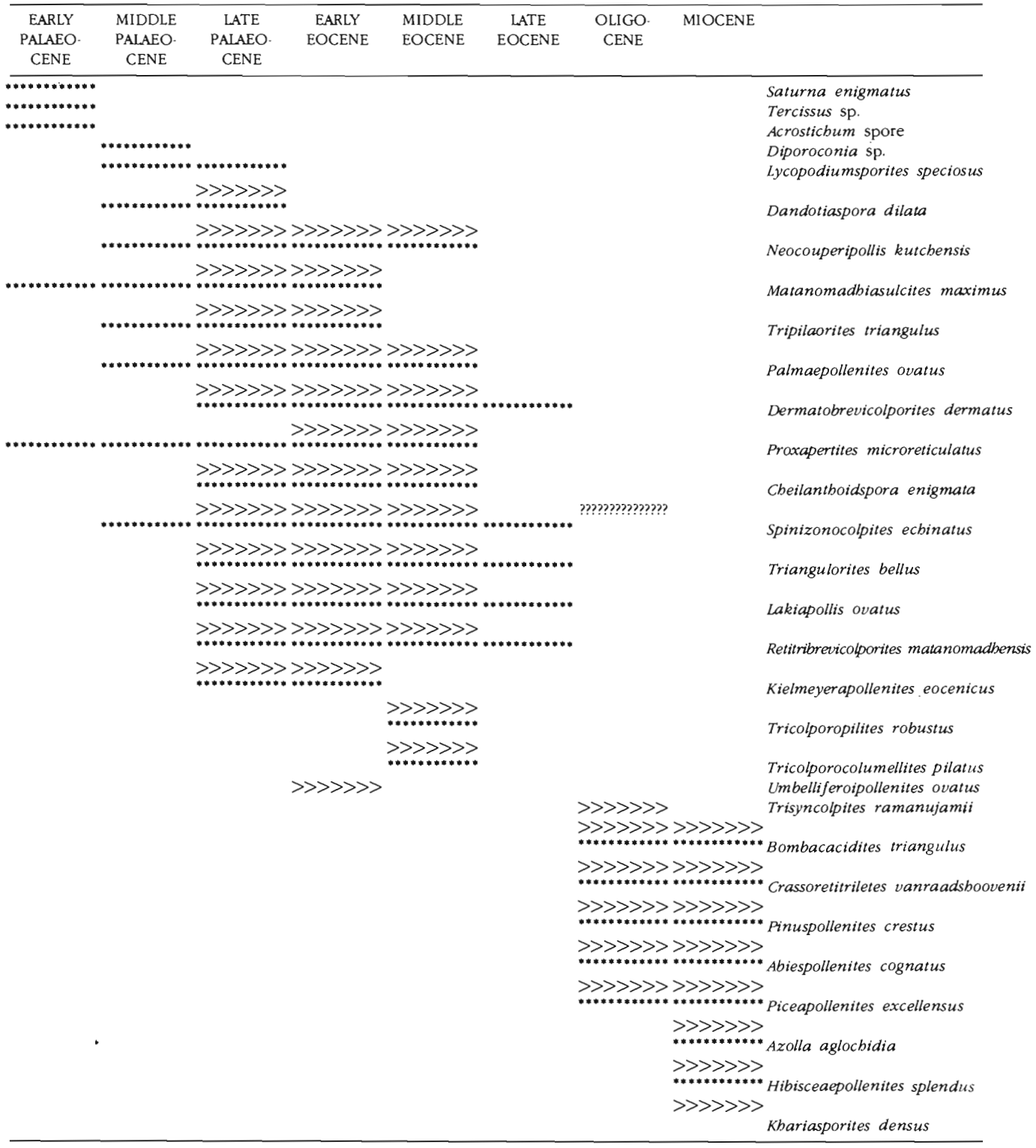
The basal part of this formation consists of coarse grained massive sandstone and laminated sandstone while the upper part has generally hard calcareous grit. Palynological fossils are absent in this formation.

DISCUSSION

The Tertiary palynological assemblages of north-east and western India show broad similarity. The appearance and disappearance of some of the marker forms also indicate striking similarity. *Dandotiaspora dilata, D. telonata, D. auriculata* and *D. densicorpa* in both the regions are restricted to Palaeocene. Likewise, *Matanomadhiasulcites maximus, Kielmeyerapollenites syncolporatus, Tripilaorites triangulus, Triangulorites bellus, Spinizonocolpites echinatus* and *Neocouperipollis kutchensis* are confined to Palaeocene-Lower Eocene. *Striatriletes* makes its first appearance in Middle Eocene both in north-east as well as western India and maintains its prominence in Oligocene and Miocene. Gymnospermous pollen mostly represented by *Pinuspollenites crestus, Piceapollenites excellensus, Abiespollenites cognatus* and *Podocarpidites densicorpus* are commonly found in Miocene in the two areas. In the terminal Eocene all the marker palynofossils disappear except for *Spinizonocolpites echinatus* which is rare in the

Oligocene. In Kutch, Late Eocene Period is absent while in north-east India *Dermatobrevicolporites dermatus, Spinizonocolpites echinatus, Triangulorites bellus, Lakiapollis ovatus* and *Retitribrevicolporites matanomadhensis* do not continue in Oligocene. *Umbelliferoipollenites ovatus, Tricolporopilites robustus* and *Tricolporocolumellites pilatus* are the index species

Table 1—Distribution of some Index species in Tertiary Period in India



for Eocene. *Umbelliferoipollenites ovatus* is confined to Lower Eocene in Kutch while the other two species are found only in the Middle Eocene in both the regions. *Trisyncolpites ramanujamii* is an index fossil for Oligocene and found so far only in western India. *Bombacacidites triangulus, Crassoretitriletes vanraadshoovenii, Pinuspollenites crestus, Abiespollenites cognatus* and *Piceapollenites excellenus* are found in both the regions in Oligocene and Miocene. *Azolla aglochidia, Hibisceaepollenites splendus* and *Khariasporites densus* are the marker species for Miocene (Table 1)

There are, however, some differences in the palynological consituents of the two regions. In north-east India, pteridophytic spores are found in abundance in all the formations. The various species of *Lycopodiumsporites* and *Dandotiaspora* are the marker fossils for the Upper Palaeocene. *Lycopodiumsporites* is hardly found in the Upper Palaeocene rocks in Kutch. Similarly, *Osmundacidites, Polypodiaceaesporites, Polypodiisporites* and *Malayaeaspora* which play decisive role in demarcating different formations in north-east India are either insignificant or absent in western India.

This disparity in palynofossils may perhaps be explained due to different physiographic features of the two regions. It may be recalled that due to continental drift, north-east India came into direct contact with the Asian Plate and a substantial part of it was subducted under it. Further, due to upliftment of the Himalaya many hills came into existence in this area with an access to the open sea on the south and south-eastern side. Shillong Plateau should also not to be forgotten in this context. It was a high land surrounded by sea in the Early Tertiary time and must have harboured many pteridophytes. The spores got deposited in nearby swamps and shores resulting high frequency in the assemblage.

Kutch and adjacent area on the other hand was far away from the Asian Plate and the rising of the Himalaya did not imprint any direct signature on it. Moreover, during pre-Tertiary time it witnessed intense volcanic eruption and the existing flora must have been perished. Non depositional period continued for a long time which caused erosion and weathering of the traps.

The transgression and regression pattern of sea in these areas are also different. In north-east India deposition in shelf areas continued from Palaeocene-Upper Eocene resulting huge accumulation of limestone. The sea regressed mostly from north-east India thereafter. In Kutch, major transgression took place in Middle Eocene but the sea was in proximity even in Oligocene and Miocene. Climax of vegetation pattern is also different in both the parts. In north-east India, coal is found in abundance in Upper Palaeocene and Oligocene. Tectonic disturbance due to Himalayan uplift, Naga and Margerita thrusts transformed the vegetative matter into good quality of coal and also gave rise to oil. In Kutch, lignite occurs in Lower Eocene but this was not transformed into coal due to lack of sufficient overburden and tectonic activity.

In Meghalaya, Permian reworked fossils are known from Palaeocene. During Upper Oligocene and Miocene they are very common in Arunachal Pradesh also. They are, however, hardly found in north-east Assam indicating perhaps thereby different source materials. In Kutch, reworked palynofossils are hardly encountered.

The deposition in north-east India started with Langpar Formation in back mangrove swamp, from Therria to Kopili formations the deposition was mostly coastal swamps and shelf. But from Barails onwards it seems to be riverine. In Kutch throughout the Tertiary, the sedimentation took place in coastal and coastal swamps.

In north-east India, the flora is rich in diversity throughout the Tertiary culminating in two highs in Palaeocene and Oligocene. In Kutch, the flora is well represented in Palaeocene and Eocene, starts dwindling in Oligocene and becomes scanty in Miocene. It seems that Kutch enjoyed favourable climate up to Eocene which gradually altered into an inhospitable climate allowing no room for luxuriant vegetation.

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