Late Cretaceous and Tertiary palynological succession in India

R.K. Kar


The Late Cretaceous and Tertiary palynological assemblages of India are divided into several phytogeoprovinces and cenozones. The Senonian palynoflora of India is clubbed with Brazil and West African palynoflora as Constantintsporls phytogeoprovince characterized by the presence of Constantintsporls, Victorisporls and Andriseporls. The Danian to Middle Eocene palynoflora of India are placed under pantropical Proxaper1ites opereulatus zone and this is further subdivided into Acrostichumgonits mehalayensis subzone, Dendrocladopera dilata subzone, Kielmeyera pollenites synscolopera subzone, Lakiapolitis ovatis subzone, Tricolporopillites robustus subzone and Pel/leleroipolitis langenheimii subzone. The Oligocene and Miocene palynofossils are placed under Trensycolpites ramanujamii subzone and Hibisceapollenites robustuskipnus subzone respectively and come under Stransrites susannae pantropical zone. A comparison of the Indian palynological succession with Borneo, Caribbean and Atlantic Tertiary palynological assemblages reveals that the trans-Atlantic palynological assemblages have closer similarity than others.

Key-words—Palynology, Late Cretaceous, Tertiary palynozones (India).

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INDIA indeed is a land of floral diversity. With its 8°-36°N latitudinal spread sporting a varied temperature condition ranging from desert to ice cold region, receiving hardly to highest rainfall of the world, flat, monotonous plain to mightiest mountains, India harbours a rich and varied flora which differs according to its habitat.

The moist tropical forests of India nurse different species of Dipterocarpus, Hopea, Artocarpus and Mangifera. The Western Ghat flora exhibits the as-
associations of *Cullenia-Palaquium, Palaquium-Mesua, Mesua-Calophyllum* and *Vateria-Cullenia*. In Cachar tropical evergreen forest, *Dipterocarpus turbinatus, Artocarpus chaplasha* and *Michelia montana* offer a majestic view. *Pterocarpus dalbergioides, Terminalia bilata, Canarium euphyllym, Sterculia campanulata* rise from the sea level to lofty height in the Andaman Islands.

In contrast to this luxuriant vegetation, Rajasthan desert thorn forest adorns *Prosopis spicigera*. In Himalayan wet temperate forest, *Machilus edulis, Michelia cathcartii, Beilsheimadia* spp. etc. are found. *Quercus* and different species of *Rhododendron* thrive amongst *Abies, Cedrus, Picea, Tsuga* and *Pinus* in the moist temperate forest of Himalaya. Lastly, in the Alpine forest of the same region *Abies, Juniperus, Pinus, Betula utilis* and *Rhododendron* sp. flourish (Champion, 1936). The angiosperms outnumber the gymnosperms and pteridophytes and show maximum diversity. In the northeast India alone there are presumably more than 4,000 species of flowering plants.

The plethora of the angiospermic flora in India commands respect and rapt attention. How and when this diversified flora reached India is an enigma to the palaeobotanists, plant geographers and systematic botanists. Was India only at the receiving end or also cradled and nursed some groups of plants to contribute to the world is a question to ponder. The paucity of palaeobotanical fossils hinders enormously to solve this quest. However, from the present state of knowledge, an attempt has been made to trace the evolution and development of Indian Late Cretaceous and Tertiary flora on the basis of palynology.

![Text-figure 1—Showing the position of India during Santonian (Late Cretaceous) in the cylindrical equidistant map (after Smith, Hurley & Briden, 1981).](image1)

![Text-figure 2—Showing the position of India during Palaeocene in the cylindrical equidistant map (after Smith, Hurley & Briden, 1981).](image2)

![Text-figure 3—Showing the position of India during Late Eocene in the cylindrical equidistant map (after Smith, Hurley & Briden, 1981).](image3)
POSITION OF INDIA DURING LATE CRETACEOUS-MIOCENE

Palaeogeographic maps showing the position of wandering India were depicted by Smith and Briden (1977), Smith, Harley and Briden (1981), Owen (1983), etc. Smith, Hurley and Briden (1981) placed India around 15° S during Santonian in the cylindrical equidistant map. During Palaeocene, India was in between equator and 15° S. In Late Eocene, according to them major part of India crossed the equator and was below 15° N. In Early Miocene, even the southern tip of India was at the verge of crossing the line of equator and India was stationed in between the equator and 15° N (Text-figures 1-3).

Constantinisporis Phytogeoprovince

According to Srivastava (1981) this is characterized by the presence of porotrichotomosulcate, small pollen with 3 pores placed at the apical ends on one surface. Constantinisporis, Victorisporis and Andreisporis are the typical examples of this group of pollen. This phytogeoprovince is found during the Senonian in Brazil, West Africa and India and is distinguished from the Nothofagidites phytogeoprovince comprising southern tip of South America, southern part of South Africa, Australia, New Zealand and Antarctica. During this time the Normapolles phytogeoprovince includes North America, Central Europe and China and the Aquilapollenites phytogeoprovince consisting of northern and western part of North America and Russia.

Zaklinskaya (1977), on the other hand, divided the Late Cretaceous-Early Palaeogene Central Atlantic palynoflora into Proxapertites-Proteaceae province and the Australian-Antarctic palynoflora into Nothofagidites-Proteaceae province. Her Normapolles province includes California-Kazakhstan. The Aquilapollenites province has Khatanga-Lena, Yenisey-Amur and Primorsky-Sakhalin basins (Text-figure 4).

Smith and Briden (1977) depicted land and sea distribution during the Senonian placing Brazil, Central Africa and India in the same latitudinal belt. This perhaps gave rise to common Constantinisporis flora in this region. Belsky et al. (1965), and Jardine and Magloire (1965) recorded this flora from West Africa, Regali et al. (1974a, 1974b) and Herngreen (1975) from Brazil and Venkatachala and Sharma (1974) from India.

Venkatachala and Sharma (1974) worked on the palynology of a number of wells from the subsurface
of Vridhachalam area, Cauvery Basin. They found Early Senonian palynological assemblage in the Puvanur well and designated the assemblage into \textit{Constantinisporis jacquei} Cenozone. This zone is characterized by the presence of \textit{Constantinisporis}, \textit{Andreisporis}, \textit{Victorisporis} in association with \textit{Tricolpites}, \textit{Cupanieidites}, \textit{Turonipollis}, \textit{Liliacidites}, \textit{Tricolpopollenites}, \textit{Intratricolpopollenites}, \textit{Proteacidites}, \textit{Vacuopollis} and \textit{Ulmoidipites}.

\textbf{Mixing of \textit{Constantinisporis} and \textit{Aquilapollenites} flora—} During the Cenomanian-Maastrichtian, the identity of \textit{Constantinisporis} phytogeoprovince is blurred as many species of hitherto known Normapolles and \textit{Aquilapollenites} phytogeoprovince enter into its realm as the dominant elements. Nandi (1983, 1990) recorded predominance of Normapolles pollen in some of these cenozones which are dated as Cenomanian from the Gumaghat Formation of Meghalaya. She noted \textit{Plicapollis serta} Pflug 1953, \textit{Pseudoplicapollis} ssp., \textit{Nudopollis endangulatus} Pflug 1953, \textit{Minorpol­lis minimus} Krutzsch 1959, \textit{Basopollis orthobasalis} Pflug 1953, \textit{Extratriporopollenites spumoides} Pflug 1953, \textit{Vacuopollis pyramis} Pflug 1953, \textit{Vacuopollis semiconca­vus} Pflug 1953, \textit{Pseudotrudopollis pseudo­aloides} Krutzsch 1967, \textit{Pecakipollis sernoensis} Krutzsch 1959, \textit{Oculopollis lapillus} Pflug 1953, etc.

Banerjee and Misra (1968) first reported \textit{Aquilapollenites} from the subsurface of Cauvery Basin. Venkatachala and Sharma (1981) also recorded 2 species of this genus from the subsurface in the Palk Bay, Cauvery Basin. The assemblage is dated as Senonian and besides \textit{Aquilapollenites} has \textit{Myrtacidites} ssp., \textit{Turonipollis} ssp., \textit{Sapotaceoidapolleni­tes} ssp., \textit{Polyvestihulopollenites} ssp., \textit{Triporoletes reticulatus} and \textit{Dinogymnium} sp. Maheshwari and Jain (1982) also recorded \textit{Aquilapollenites} from the Dalmaipuram Formation (Late Cretaceous), Tamil Nadu. Baksi and Deb (1976) recognised \textit{Aquilapol­lenites bengalensis} Cenozone in the Late Cretaceous subsurface sediments of Bengal Basin. Nandi (1979) observed that Normapolles and \textit{Aquilapollenites} occur together with \textit{Dinogymnium} in the Gumaghat Formation of Meghalaya. Prakash, Singh and Sahni (1990) and Mathur and Sharma (1990) recorded \textit{Aquilapollenites bengalensis} in the Deccan Intertrappeans (Maastrichtian) of Madhya Pradesh.

Occurrence of Normapolles and \textit{Aquilapollenites} is not restricted to India in the Late Cretaceous. Regali \textit{et al.} (1974a, 1974b) observed its presence in Brazil and Jardine and Magloire (1965) in West Africa. Ked-
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Text-figure 6—Senonian phytogeoprovinces shown on equal area projection and the different phytogeoprovinces: 1 = Aquilapollenites Province, 2 = Normapolles Province, 3 = Constantinisporis Province, 4 = Nothofagidites Province (after Srivastava, 1981).

Evans (1971) and Ela (1978) recorded Senonian Normapolles from Egypt.

Srivastava (1981) opines that a severe marine regression during the Late Maastrichtian opened several land routes between the different phytogeoprovinces obliterating the characteristic of the said provinces.

The Late Cretaceous epeiric sea situated in North America was withdrawn in the Late Maastrichtian opening new land areas in the western interior. This enabled land connection between the Normapolles and Aquilapollenites provinces providing mixing of floras (Text-figure 5). Nothofagidites phytogeoprovince, however, could maintain its identity throughout the Tertiary as Australia, New Zealand and Antarctica remained separated from other continents due to the deep sea (Text-figure 6).

Batten (1981), however, opined that the occurrence of Normapolles outside its normal province is mostly found in the Tertiary and need not be thought bewildering. He thinks that it is possible that the morphophytes were produced by more than one plant genus and eventually might have found ecological niches in the Aquilapollenites/Triproyectacites province. Kar (1993) recorded Normapolles type of pollen from the Miocene sediments of India.

Tertiary rocks—The Tertiary sediments are well exposed in north-eastern, northern and western parts of India. In north-east, the Tertiary succession is almost complete from Palaeocene to Pliocene except the post Barail (Oligocene) unconformity. In Kutch, western India, Early-Middle Palaeocene and Late Eocene rocks are missing whereas the Siwaliks in north India mostly represent the Mio-Pliocene sediments. In south India, the Tertiary exposures are generally found along the west and east coasts. Palynological investigations have been carried out from all the major formations by different workers in last four decades (Kar, 1992). A wealth of information has been thus accumulated which enabled us to evaluate the floristic trends, the appearance and disappearance of some species and their subsequent spread in other regions.

Pantropical palynological zones—Germeraad, Hopping and Muller (1968) proposed few pantropical palynozones for the Tertiary rocks of the tropical areas covering South America, West Africa and Borneo after working roughly for twenty years. The zones in the ascending order are Proxapertites operculatus zone, Monoporites annulatus zone, Verrucatosporites usmensis zone, Magnastriatites howardi zone, Crassoretirules vanraadshoveni zone and Echitricolporites spinosus zone.

The Proxapertites operculatus zone—It ranges from Senonian to Early Eocene and is characterized by the presence of Proxapertites operculatus, Proxapertites cursus, Spinizonocolpites echinatus and Echitriporites trianguliformis. The Monoporites annulatus zone is identified by the first appearance of Monoporites annulatus and is confined to Middle Eocene. The Verrucatosporites usmensis zone is restricted to Late Eocene and is marked by the regular appearance of Cicatricosisporites dorogensis and Verrucatosporites usmensis. The Magnastriatites howardi zone covers entire Oligocene and Early Miocene and is indicated by the first appearance of Magnastriatites howardi. The Echitricolporites spinosus zone is found in the Middle and Late Miocene as well as Pliocene. The regular occurrence of Echitricolporites spinosus is the indication of this zone. These pantropical zones are again subdivided by Germeraad, Hopping and Muller (1968) into several Atlantic, Caribbean and Borneo zones.

Comparison between pantropical and Indian palynological zones—In India, only two pantropical
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zones are recognizable, i.e., Proxapertites operculatus and Striatriletes susannae (= Magnastriatites howardi) zones. The genus Magnastriatites Germeraad, Hopping and Muller 1968 is regarded as a synonym of Striatriletes van der Hammen 1956. Proxapertites operculatus zone ranges from Langpar Formation (Danian) of north east to Harudi Formation (Early-Middle Eocene) of Kutch. The Proxapertites operculatus zone is subdivided into Acrostichusporites meghalayensis subzone, Dandotiaspora dilata subzone, Kielmeyerapollenites syncolporatus subzone, Lakiapollis ovatus subzone, Triloculporitites robustus subzone and Pellicierospolls langenheimii subzone. Striatriletes susannae zone has only two subzones—the lower Trisyncolpites ramanujamii subzone stands for the Oligocene and the upper Hibiseaepollenites robustispinosus subzone generally represents the Miocene.

Acrostichusporites meghalayensis subzone—Acrostichusporites meghalayensis subzone is confined to the Langpar Formation (Danian) exposed at Therriaghat on the Umshoryngkew River, Meghalaya. The assemblage is characterized by the presence of Proxapertites operculatus, Proxapertites cursus, Matanomadbiasulcites maximus, Spinizonocolpites echinatus, Saturna enigmaticus and Terscissus grandis.

The unique feature of this subzone is that all the important species are pantropical in distribution. Acrostichusporites sp. is reported by Caratini et al. (1991) from Walalane bore-hole, Senegal. Matanomadbiasulcites maximus is recorded from Senegal (Caratini et al., 1991), Niger (Boudouresque, 1980), Nigeria (Sonuga, 1987), Cameroun (Salard-Cheboldaef, 1977), Colombia (Guzmán, 1967). Matanomadbiasulcites evolves in Maastrichtian, occurs commonly in Palaeocene and continues up to Early Eocene. Saturna enigmaticus is recovered from Cameroun (Salard-Cheboldaef, 1977) and Senegal (Caratini et al., 1991). Terscissus grandis is observed in Late Cretaceous-Palaeocene of U.S.A. (Kieiser & Jan du Chêne, 1979; Caratini et al., 1991) and Niger (Boudouresque, 1980). Matanomadbiasulcites maximus according to Caratini et al. (1991) is comparable to the pollen of Annona though Muller (1981) rejected its affinity with this genus. Others contemplate it to be a monocot (see Caratini et al., 1991). The pantropical distribution of Proxapertites and Spinizonocolpites is well known.

Dandotiaspora dilata subzone—Dandotiaspora dilata subzone starts from the Therri Formation (Late Palaeocene) of Meghalaya and ends in Matanomad Formation (Late Palaeocene) of Kutch. Dandotiaspora, Lycopodiumsporites, Palmeapollenites, Neocouperipollis, Diporoconia, Tripilaortes, Triangulorities and some other genera appear for the first time in this subzone.

In north east India, different species of Lycopodiumsporites are found in abundance. This genus is, however, rather rare in west and so the subzone is named after Dandotiaspora dilata. Kar and Mandal (1984) studied the spore morphology of 23 species of Lycopodium growing in India. They noted that the spores of extant Lycopodium growing in India are mostly foveolate-fossulate whereas the Palaeocene species generally have reticulate type of ornamentation. They also observed that Lycopodiumsporites assamicus Mehrrota & Sah 1980 described from the Palaeocene of Mikir Hills closely resembles the spores of Lycopodium veitchii.

Dandotiaspora dilata subzone is recognized by the presence of Dandotiaspora dilata, Dandotiaspora densicorpa, Dandotiaspora auriculata, Dandotiaspora telonata, Lycopodiumsporites speciosus and Lycopodiumsporites parvireticulatus. These species do not range beyond Palaeocene. The other species which are also commonly found are Neocouperipollis kutchensis, Neocouperipollis wodebouseti, Palmeapollenites ovatus, Proxapertites cursus and Retitribrevicolporites matanomadensis.

Dandotiaspora dilata is found in Dandot, Pakistan (Vimal, 1952) and Colombia (Guzmán, 1967). The author could also recover a few specimens from the Palaeocene of Senegal. Regarding its affinity, Kar (1985) remarked that the spores of Gymnosphaera glabra illustrated by Kremp and Kawasaki (1972, p. 66, fig. 129) comes close to Dandotiaspora dilata in general appearance but has smaller size.

Kielmeyerapollenites syncolporatus subzone—It has the association of Kielmeyerapollenites eocenicus, Psilastephanocolpites psilatus, Psilastephanocolpites subcircularis, Retis-
tepghanocolporites multirrimatus, Polycolporites indicus, Polycolpites flavatus and Lakiapollis ovatus. Besides, various species of Dandotiaspora, Palmæpollenites, Neocouperipollis and Lycopodiumsporites are also present in the assemblage.

The presence of tetrad pollen genus Kielmeyerapollenites and polycolpate-polycporate pollen in good numbers distinguish this subzone from others. The genus Kielmeya grows in the tropical forest of Brazil today. The pollen of this genus is found only up to Early Eocene (Sah & Kar, 1974) in India and afterwards it became extinct. Polycolpate and polycporate pollen are produced by number of families like Acanthaceae, Euphorbiaceae, Lamiaceae and Scrophulariaceae; so it is difficult to tag the fossil species with the living ones. Kar (Ms.), however recovered fossil pollen very close to extant Ocimum pollen from the Early Eocene of Rajasthan polycolpate and polycporate pollen are also occasionally found in Early Eocene and gradually they become rare. So at the end of Palaeocene, most of the species of Dandotiaspora, Lycopodiumsporites, Polycolporites, Palæpollenites and Retis tephanocolporites become extinct or only rarely met with. Matanomadhisasulcites, Triangularites, Triripolaretes, Lakiapollis, Retivirevicolporites, Palmæpollenites and Neocouperipollis continue in the Early Eocene.

Lakiapollis ovatus subzone—This subzone has Retitribrevicolporites matanomadhinensis, Meltapollis ramanujamii, Umbelliferopollenites ovatus, Pellicieroipollis langenheimii and Lygodiumsporites lakensis as the distinguishing elements. This zone is confined to the Early Eocene.

Tricolporopilites robustus subzone—The Middle Eocene is characterized by the development of brevitricolporate type of pollen already ushered by Lakiapollis ovatus and Retitribrevicolporites matanomadhinensis. Tricolporopiltes robustus and Tricolporocolumellites pilatus are the marker species for the Middle Eocene. Retipollenites confusius also generally found in association with these species.

Amongst the pteridophytes, Striatriletes starts coming in good numbers. Kar (1984) advocated its origin in India during the Middle Eocene, but recently he could recover a few specimens of Striatriletes in the Early Eocene assemblage of Palana, Rajasthan, described by Sah and Kar (1974). Osmundacidades wellmamii and Osmundacidades kuicbhis are at their zenith during this time. Polypodiaceous spores represented by Polypodiaceaesporites, Sentiasporites and Polypodiisporites are also common.

Pellicieroipollis langenheimii subzone—The Late Eocene palynology has not been extensively worked out except Trivedi (1985) and Tripathi (1988), on Jowai-Badarpur road, Meghalaya. Striatriletes establishes itself firmly in Kopili Formation, but the general depletion of the angiospermic pollen is noticed. Lakiapollis ovatus, Retivirevicolporites matanomadhinensis, Dermatobrevicolporites dermatus, Triangularites bellus, Spinizonocolpites ecbinitus, Acanthotricolpites bulbosinuosus and Pellicieroipollis langenheimii are occasionally met with. Oercululoscliptes globatus, Oercululoscliptes robianensis and Pilamonoletes excellensus appear for the first time.

New Innovations in spore pollen morphology—In the Middle Eocene, some new innovations in spore-pollen morphology are observed. Amongst angiosperms, tribrevicolporate forms with subquatorily placed apertures are common. Lakiapollis, Retivirevicolporites, Tricolporopilites, and Tricolporocolumellites are the examples of this trend. Besides, heavily ornamented forms become more prevalent. Tricolporopilites robustus and Retipollenites confusius may be cited as examples. Of the pteridophytes, Osmundacidades wellmamii, Osmundacidades kuicbhis, Sentiasporites verrucosus, Polypondisporites repandus, Operculoscliptes globatus, Operculoscliptes robianensis and Pilamonoletes excellensus are all heavily ornamented.

The testimony of this trend is perhaps best exemplified in Verrudandotiaspora verrucata. Like Dantodiaspora dilata, it has warts on the distal side at each ray end but unlike Dantodiaspora, it has verrucae all over the distal surface. Perhaps sensing the drastic consequences, the lineage of Dandotiaspora also developed verrucae in the Middle Eocene due to some environmental pressure. The strongly costate Striatriletes may be another type of expression in this direction. This kind of developmental tendency is in striking contrast with the
Palaeocene-Early Eocene forms which are broadly aperturate and less ornamented. The various species of *Dandotiaspora* are almost laevigate except the presence of wart at each ray end as in *Dandotiaspora dilata*. The species of *Lycopodiumsporites* are either mildly reticulate with thin muri or foveolate-fossulate. *Lygodiumsporites lakensis*, another common form in the Early Eocene, is also laevigate.

Palaeocene and Early Eocene angiospermic genera are mostly longiaperturate in contrast to the breviperturate Middle Eocene forms. *Proxapertites*, *Spinizonocolpites* and *Saturna* are zonisulate, *Matanomadhiasulcites*, *Palmaepollenites* and *Neocouperipollis* are broadly monocolpate. Polycolporate forms, e.g., *Psilastephanocolporites*, *Retistephanocolporites*, *Meliapollis*, *Polycolpites* and *Polycolporites* also possess long apertures, laevigate or less ornamented exine.

Irrespective of other different modes of innovation most of the marker taxa of Eocene disappeared at the terminal Eocene including *Lakiapollis ovatus*, *Retitribrevicolporites matanomadhensis*, *Tricolporopilites robustus*, *Tricolporocolumellites pilatus* and *Verrudandotiaspora verrucata*. Only *Pellicieroipollis langenheimii*, *Marginipolliskutchensis* and *Acanthotricolpites bulbospinosus* survived the onslaught and occasionally found in the Oligocene.

However, in the pteridophytic front the story is not that dismal. *Striatriletes*, *Osmundacitites*, *Polypodiaceaeasporites*, *Polypodiisporites*, *Pilamonoletes* and *Seniasporanot* only continue their existence but also turn to be the dominant elements. *Oerculosculptites* is also common.

*Striatriletes susanannae* zone—This pantropical zone is found above the *Cicatricosisporites dorogensis* zone. According to Germeraad et al., (1968) an Oligocene age is assigned to this zone on the presence of smaller foraminifera, viz., *Globigerina ampliapertura*, *G. ciperoensis*, *Globorotalia opina opina* and *G. kugleri*. Trivedi et al., (1981) pointed out that the specimen assigned to *Cicatricosisporites dorogensis* by Germeraad et al., (1968, pl. 2, fig. 2) in all probability belong to *Malayaeaspora* Trivedi et al., (1981).

The first appearance of *Striatriletes susanannae* is the lower limit of this zone in Paz Del Rio section, Colombia and Benin West-1, Nigeria. Germeraad, Hopping and Muller (1968) opine that this zone starts from the Early Oligocene in Caribbean, Nigeria and Borneo and continues up to Pliocene. Kar (1984) pointed out that in India the occurrence of *Striatriletes* is noted from the Middle-Late Eocene of Kutch, Gujarat. Kar (1992) also recorded it from the Middle Eocene sediments of Meghalaya and Early Eocene of Rajasthan which led him to postulate that Ceratopteris—the fern producing *Striatriletes* spores was evolved in India. In the Indian sediments, *Striatriletes* appear as a common element in Middle Eocene, shows its maximum development in Oligocene and Miocene and dwindles down in Pliocene.

*Trisyncolpites ramanujamii* subzone—The extinction of hitherto prevalent Eocene genera gave rise to new forms in Oligocene. These are *Trisyncolpites ramanujamii*, *Crassoretirilites vanraadshoveni*, *Bombacacidites triangulatus*, *Compositoipollenites tricolporatus*, *Meyeripollis nabarkotensis*, *Graminites granulatus*, *Verrupolyforites globosus*, *Polyporina multiporosa* and *Polyadopollenites* sp.

A perusal of these forms reveals that most of them are heavily sculptured and the same morphological expression is noted in pteridophytes as well as in angiosperms. *Trisyncolpites ramanujamii*, *Crassoretirilites vanraadshoveni*, *Compositoipollenites tricolporatus*, *Meyeripollis nabarkotensis* and *Verrupolyforites globosus* are examples. Another characteristic feature of the Oligocene assemblage is the occurrence of polyporate forms represented by *Verrupolyforites globosus* and *Polyporina multiporosa*.

It may, however, be cited here that *Cryptopolyporites cryptus*—another polyporate form, was recorded in the Early Eocene but it was never a common element and disappeared soon.

The introduction of trisyncolporate pollen in Oligocene in the form of *Trisyncolites ramanujamii* reminds long forgotten porotrichomosulate pollen of the *Constantinispora* phytogeopzone. *Trisyncolites* resembles *Constantinispora*, *Victorisporis* and *Andreisporis* in trichotomosulate condition and the position of the pores at the apices. *Trisyncolites* is, however, much bigger in size and heavily ornamented with bacula and pila. The reappearance of this apertural form was restricted to this genus only and it did not extend beyond Oligocene.
The appearance of bisaccate pollen in Oligocene also ushered a new vista of the palynological assemblage. *Pinuspollenites cretus, Abiespollenites cognatus* and *Picea-pollenites excellens* are the species which are generally met with. The upliftment of the Himalayas introduced these plants in the northern highlands and the air borne pollen also put their signature at the depositional sites of the plain. The frequent presence of *Polyadopollenites* is also characteristic of Oligocene. After the tetrad genus *Kielmeyerapoliten* of Palaeocene-Early Eocene, the *meyerapollenites shooveni* zone is subdivided in South America into *Polyadopollenites* and *Multimarginites volcanicus* subzones. The transatlantic Early Miocene *Verrutricolporites rotundiporis* zone is further divided into *Jandufouria* and *Psiladiporites minimus* subzones. Similarly, the *Cassinitritriletes vanraardenbooveni* zone is subdivided in South America into *Multimarginites vanderhammeni* and *Grimsdalea margiclavata* subzones. Except rare occurrence of *Jandufouria*, most of the other genera are not found in the Tertiary rocks of India.

**COMPARISON WITH OTHER TROPICAL ASSEMBLAGES**

Borneo palynological zones—Except for broad similarities, Borneo palynoassemblages are quite distinct and exhibit the dominance of some local plants. Oligocene and Miocene epochs witness the emergence of *Florschuetzia* and subdivided by Germeraad et al. (1968) into *Florschuetzia trilobata, Florschuetzia semilobata, Florschuetzia levipoli* and *Florschuetzia meridionalis* zones. The pollen grains assignable to *Florschuetzia* are almost absent in the Tertiary sediments of India.

Caribbean palynological zones—The pantropical *Proxapertites operculatus* zone is subdivided in Caribbean region by Germeraad et al. (1968) into *Foveotriletes margaritae, Cenolophonidites lismae* and *Foveotrilocolpites perforatus* subzones. All these zones are confined to Palaeocene. The Middle Eocene pantropical *Monoporites annulatus* zone is subdivided into *Psiladiporites crassus*, *Psiladiporites triangularis* and *Retirulripolites guianensis*. The transatlantic Early Miocene *Verrutricolporites rotundiporis* zone is further divided into *Jandufouria* and *Psiladiporites minimus* subzones. Similarly, the *Cassinitritriletes vanraardenbooveni* zone is subdivided in South America into *Multimarginites vanderhammeni* and *Grimsdalea margiclavata* subzones. Except rare occurrence of *Jandufouria*, most of the other genera are not found in the Tertiary rocks of India.

Thus in comparison to Borneo and Caribbean regions, the transatlantic palynological assemblage comes somewhat closer to the Indian Tertiary assemblage.

**REFERENCES**


Kar RK 1979. Palynostratigraphy of the Naredi (Lower Eocene) and the Harudi (Middle Eocene) formations in the district of Kutch, India. Palaeobotanist 24(1-3): 161-177.


