The Palaeogene vegetation of peninsular India (Megafossil evidences)

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The Palaeogene represents the age of spread and diversification of angiosperms in the Indian sub-continent. A comprehensive knowledge of the Palaeogene flora of peninsular India is, therefore, necessary to decipher the history of the modern flora of India. The Palaeogene plant megafossils of this region can broadly be considered under (i) Deccan Intertrappean flora, (ii) Eocene flora of Kutch, (iii) Eocene plant fossils described from the Fullêr's earth deposits near Barmer in Rajasthan, and (iv) Eocene plant records from Meghalaya.

The flora as a whole is characteristically tropical in character. It consists of taxa belonging to marine, estuarine, freshwater, and terrestrial habitat with both evergreen and deciduous forms. It is suggestive of an equable warm and moist tropical climate over the whole of peninsular India during the Palaeogene. The existence of this type of climate was the result of (i) a more or less equatorial position of peninsular India during the Palaeocene-Eocene period, and (ii) a warm sea which not only surrounded the peninsula from all the sides but also intruded into the landmass.

Most of the plants recovered from the Palaeogene localities of peninsular India still continue to grow in various forests of this region. Part of this flora, thus, can be considered to be the ancestral stock for the present day flora of India. Occurrence of some African, Madagascarian, Australian and South American elements in this flora suggests India's past connections with these Gondwanaland countries.

Key-words—Plant megafossils, Palaeoecology, Phytogeography, Palaeogene, Peninsular India.

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सारांश

प्रायद्वीपीय भारत की पूर्व-तृतीयक वनस्पति (गुरुपादपाश्म प्रमाण)

मोहन बलवंत बाँडे

भारतीय उपमहाद्वीप में पूर्व-तृतीयक कल्प आवृतबीजीयों के विस्तार एवं विभिन्नता को प्रदर्शित करता है। अतएव भारत के वर्तमान वनस्पतिजात का इतिहास सुनिश्चित करने हेतु प्रायद्वीपीय भारत के पूर्व-तृतीयक वनस्पतिजात की यथार्थता जानना आवश्यक है। इस क्षेत्र के पूर्व-तृतीयक गुरुपादपाश्म मोटे तौर पर चार समूहों में विभाजित किये जा सकते हैं: (i) दक्खिन अन्तर्ट्रेपी वनस्पतिजात, (ii) कच्छ का आदिनूतन वनस्पतिजात, (iii) राजस्थान में बाड़मेर के पास फुलर अर्थ निक्षेपों से वर्णित आदिनूतन अश्मित पौधे, तथा (iv) मेघालय से आदिनूतन पौधों के अभिलेख। यह वनस्पतिजात कुल मिलाकर उष्णकटिबन्धीय है। इसमें समुद्री, सरोवरी, स्वच्छजलीय तथा स्थली स्वभाव वाले सदाहरित एवं पर्णपाती प्रकार के अवयव विद्यमान हैं। पूर्व-तृतीयक कल्प में समूचे प्रायद्वीपीय भारत में ये अवयव सामान्य गर्म एवं नम उष्णकटिबन्धीय जलवायु का होना इंगित करते हैं। पुरानूतन-आदिनूतन काल में इस प्रकार की जलवायु का होना प्रायद्वीपीय भारत की प्राय: भूमध्यरेखीय स्थिति का द्योतक है तथा इस समय गर्म सागर ने प्रायद्वीप को चारों ओर से घेर ही नहीं रखा था अपितु भू-भाग में अन्दर तक प्रवेश किये हुए था।

प्रायद्वीपीय भारत की पूर्व-तृतीयक संस्थितियों से उपलब्ध पौधों में से अधिकतर अभी भी इस क्षेत्र के विभिन्न वनों में उगते हैं। अत: इस वनस्पतिजात का कुछ भाग भारत के वर्तमान वनस्पतिजात का पूर्वज कहा जा सकता है। इस वनस्पतिजात में कुछ अफ्रीकी, मेडागास्करी, आस्ट्रेलियाई तथा दक्षिण अमेरिकी अवयवों की उपस्थिति अतीत में इन गोंडवाना देशों से इसके सम्बन्ध व्यक्त करती है।

THE Palaeogene has been considered as the age of spread and diversification of angiosperms in the Indian sub-continent. During this period the Indian Plate broke away from the main land-mass of the Gondwanaland but it had not yet joined with the

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Asian Plate. A critical analysis of the Palaeogene flora of the peninsular India is, therefore, necessary to decipher the history of the modern flora of the Indian sub-continent. The evidence of fossil plants can also be made use of to reconstruct the palaeoclimate and palaeogeography of peninsular India during the Palaeogene.

Geographically, peninsular India consists of the triangular peninsula including the Shillong Plateau in the north-east and the Kutch-Kathiawar region in the west. The Palaeogene flora of this region as a whole can be treated under the following four assemblages:

1. Deccan Intertrappean flora,
2. Eocene flora of Kutch,
3. Eocene plant fossils described from the Fuller's earth deposits near Barmer in Rajasthan, and
4. Eocene plant records from Meghalaya.

The age of the Deccan Intertrappean flora has been a matter of discussion since several decades. The main controversy being whether the flora is Upper Cretaceous or Early Tertiary in age. This problem is linked with the problem of the age and span of the Deccan volcanism. On the basis of radiometric dating the span of Deccan volcanism has been suggested to be as long as 70 Ma, i.e., between 100 to 30 Ma (Alexander, 1981) to as short as 1 Ma at the Cretaceous-Tertiary boundary (Courtillot *et al.*, 1986, 1988; Duncan & Pyle, 1988a, 1988b). On the basis of palaeontological evidence, especially on the evidence of dinosaur fossils recovered from the Intertrappean beds of Takli and Naksal, Sahni *et al.* (1988) have supported the later view. However, ^{39}Ar-^{40}Ar dates obtained for the basalt flow underlying the fossiliferous intertrappean bed at Takli has given an age of 63.6 ± 0.2 Ma, i.e., Palaeocene (Shukla *et al.*, 1988). Thus, the possibility cannot be ruled out that the dinosaurs in India might have survived even up to Palaeocene. Similar view has also been expressed by Mathur (1987). Survival of the Dinosaurs in the Palaeocene has also been envisaged in North and South America as well as in China (Gauthier *et al.*, 1990). The evidence of the Intertrappean plant fossils described from around Nagpur-Chhindwara and Mandla is in favour of an Early Tertiary age for the flora rather than the Upper Cretaceous (Bande *et al.*, 1988). Under the circumstances, the Deccan Intertrappean flora has been treated to be of Palaeogene age for the present discussion.

The Neyveli lignite deposits have been traditionally considered to be of Neogene age (Ramanujam, 1966, 1966-67). On the basis of palynofossils a Palaeocene-Eocene age has been advocated for these deposits (Deb, Bakshi & Ghosh, 1973; Venkatachala, 1973; Siddhanta, 1986; Saxena, 1992). A Neogene age has been suggested on the basis of megafossil evidences (Guleria, 1992). Singh *et al.* (1992) have also supported the later view. The flora of these deposits therefore, has not been included in the present discussion.

FLORAL RECORD

Deccan Intertrappean Flora

The Deccan Intertrappean flora can be considered to be the most important and thoroughly studied flora of the Indian Palaeogene. Constituted by the plant fossils preserved in the sediments deposited between successive lava flows, the flora consists of woods, leaves, flowers, fruits and other organs representing all the major groups of Plant Kingdom. Besides, the stray reports of fossil plants described from various localities distributed all over the vast area of the Deccan Trap country, and the charophytes described from Gurmatkal, the flora can be studied under four different assemblages:

i. Rajahmundry assemblage,
ii. Nagpur-Chhindwara assemblage,
iii. Bombay-Malabar-Worli Hills assemblage, and
iv. Mandla assemblage.

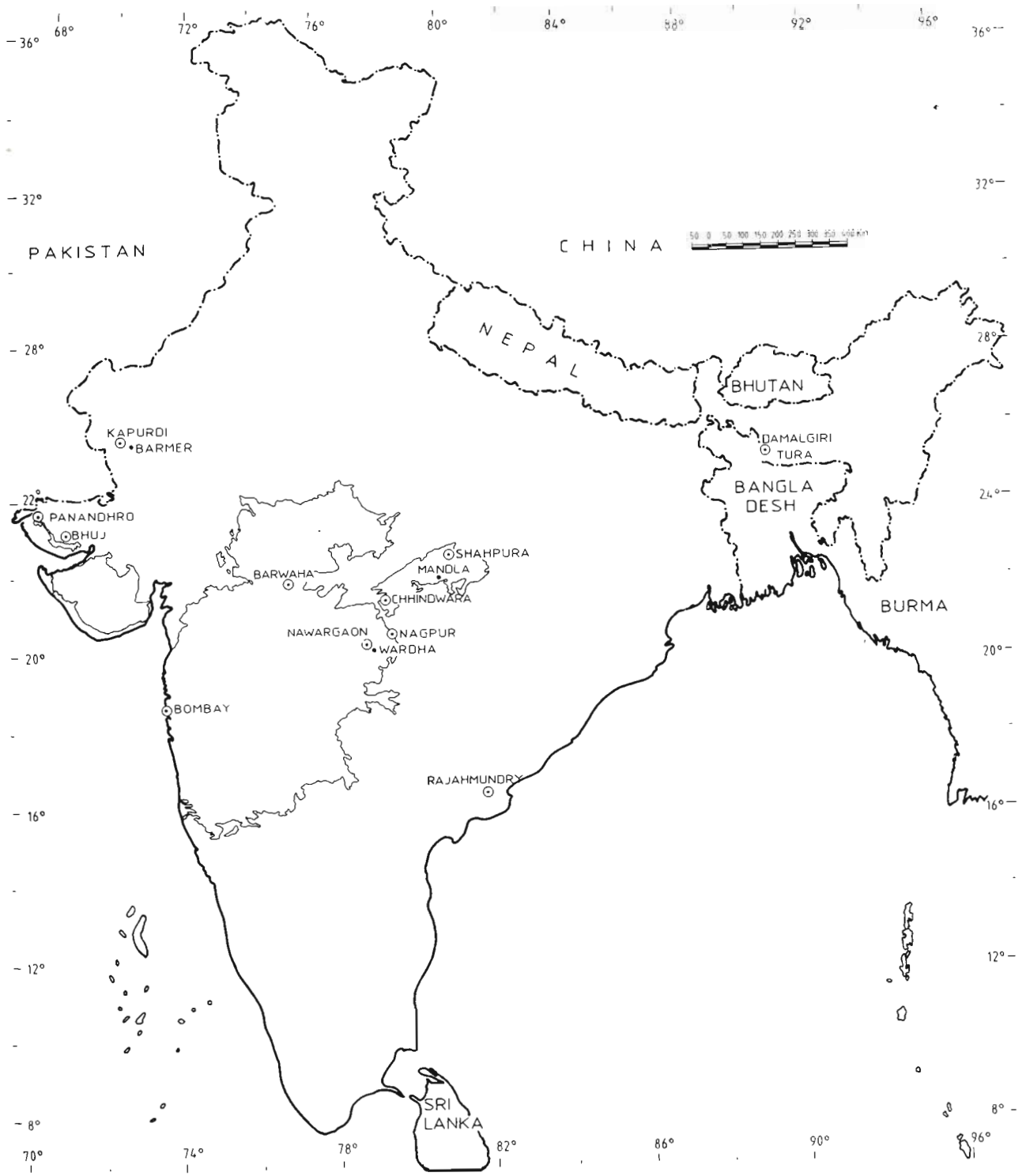
A comprehensive review of the plant taxa described from all these assemblages has recently been made by Bande *et al.* (1988). A summary of the available information is given below.

Rajahmundry Assemblage—This assemblage is mainly dominated by a number of algal taxa of estuarine habitat and thirteen species of charophytic gyrogonites. Important algal genera are *Helimeda, Dissocladella, Terquemella, Acetabularia, Neomeris, Holosporella* and *Acicularia.*

Three gymnospermous woods, viz., *Taxaceoxylon kateruense, Mesembrioxylon fusiforme* and *M. dudukurense* representing Taxaceae and Podocarpaceae have been described. *Rhizopalmoxylon sundaram* and *Palmoxylon sundaram* (showing affinities with the extant genus *Cocos*) and *Sonneratioxylon dudukurense* are indicative of a mangrove habitat.

Nagpur-Chhindwara Assemblage—The important fossiliferous localities are Mohgaonkalan and Keria near Chhindwara and Sausar, Mahurzari and Takli near Nagpur. Many fossil taxa are common to these different localities. The important floral elements of the assemblage are:

Algae—Fresh water elements are represented by *Spirogyrites, Oedogonites* and *Westielopsis* from Mohgaonkalan and *Ulothrix*-like filaments from Sausar. *Chara sausari*, the only fossil record of a gyrogonite of *Chara* with attached vegetative filament, is known from Sausar. Three more species



Map 1—Showing important Palaeogene fossiliferous localities of peninsular India.

of charophytic gyrogonites, viz., *Platychara raoi, P. sahnii* and *Microchara* sp. have also been described from the Gitti Khadan area near Nagpur. Two marine algae *Peyssonnelia antiqua* and *Distichoplax raoi* have been described from Mohgaonkalan. Recently, Mehrotra (1989) has described yet another marine alga *Solenopora* from the same beds.

Fungi—Some fungal forms, viz., *Shuklania, Diplodia rodei* and *Tetracosporium* are from Mohgaonkalan, while *Palaeosordaria* and *Perisporacites varians* have been described from Sausar.

Bryophytes—The record of bryophytes is very poor. An anthocerotaceous capsule—*Shuklanites deccani* has been described from Mohgaonkalan. *Riccia chitaleyii*, a thallus similar to *Riccia*, is also known from the same beds.

Pteridophytes—The pteridophytic elements in this assemblage are mainly composed of fresh water ferns. The important genera described are *Azolla, Rodeites, Marsilea* and *Salvinia. Rodeites* probably has affinities with the southern American fern *Regnelidium.* A strobilus resembling that of *Selaginella* has been reported from Mohgaonkalan.

Gymnosperms—The gymnosperms are mostly represented by cones, e.g., *Takliostrobus alatus, Indostrobus bifidolepis* and *Pityostrobus crassitesta*, all described from Takli. *Pityostrobus crassitesta* shows affinities with the family Abietineae. The other two cones possess characters of Abietineae as well as Podocarpaceae. *Mohgaonstrobus sahnii*, described from Mohgaonkalan, shows affinities with the modern Araucariaceae. Presence of both Araucariaceae and Podocarpaceae in these sediments is also confirmed by fossil woods of these families described from the same locality. Another gymnospermous cone, *Harrisostrobus intertrappea* with uncertain affinities, is known from Mohgaonkalan. A cycadean ovule is also recorded from the same locality.

Angiosperms—Both monocotyledons and dicotyledons are recorded. Besides palms, the other important monocot family is Musaceae. While the fossil fruit and the pseudostem (*Musocaulon*) have been assigned to the genus *Musa*, the leaf *Musophyllum* has been assigned to the family Musaceae. Yet another noteworthy genus is *Cyclanthodendron sahnii* which is said to possess affinities with the South American family Cyclanthaceae. Woods, fruits, petioles and roots of palms are of frequent occurrence. *Palmoxylon sundaram* is of special interest as it is comparable to *Cocos* and indicative of a coastal habitat. *Nipa*, a characteristic floral element of estuarine habitat, is also recorded from Mohgaonkalan.

Tricoccites, Viracarpon and *Monocotylostrobus* are well-preserved fruit genera with uncertain affinities in the assemblage. The structure and affinities of *Viracarpon hexaspermum* have been recently restudied and new interpretations given (Bande & Awasthi, 1986). Earlier the affinities of this fruiting axis were suggested to be with the Pandanaceae. However, Bande and Awasthi (1986) have questioned its affinities with Pandanaceae with the remarks that they still remain to be ascertained.

Dicotyledons are well-represented by a number of flowers, fruits and woods. Amongst these, the flower *Sahnianthus parijai* and the fruit *Enigmocarpon parijai* have affinities with *Sonneratia apetala* and *S. acida.* Other noteworthy flowers and fruits are *Sahnipushpam, Chitaleypushpam, Harrisocarpon* and *Sahniocarpon.* The affinities of these taxa are not known.

Fossil woods are mostly known from Keria and Mahurzari, the most common species being *Ailanthoxylon indicum.* The other known genera are *Simarouboxylon, Boswellioxylon, Bridelioxylon, Mallotoxylon, Tetrameleoxylon*, etc. from Keria and *Grewioxylon, Elaeocarpoxylon, Leeoxylon, Barringtonioxylon*, etc. from Mahurzari. *Aeschynomenoxylon* is comparable to the extant genus *Aeschynomene* indicative of a marshy habitat. A peduncle showing affinities to the aquatic family Nymphaeaceae is also described.

Further south of Nagpur, the intertrappeans near Nawargaon in Wardha, Maharashtra contain a rich floral assemblage. It is difficult to assess its relationship with the Nagpur-Chhindwara assemblage at present. The fossils so far described include five species of *Palmoxylon*, important amongst which is *Palmoxylon livistonoides* showing affinities with the extant genus *Livistona.* A palm petiole *Palmocaulon hyphaeneoides* showing similarities with the living genus *Hyphaene* has also been described. The dicotyledonous woods show affinities with the extant genera *Evodia* (Rutaceae), *Amoora* (Meliaceae), *Sonneratia* (Sonneratiaceae), *Ardisia* (Myrsinaceae), *Heterophragma* (Bignoniaceae), *Gmelina* (Verbenaceae), *Phyllanthus* (Euphorbiaceae) and *Aristolochia.*

Bombay-Malabar-Worli Hills Assemblage—The plant fossils described from the Intertrappeans of this area are limited and consist of a fossil wood of bamboo, leaflets similar to those of *Acacia* and seeds similar to *Artabotrys.* A fossil wood of Podocarpaceae has also been recorded.

Mandla Assemblage—Extensive palaeobotanical studies on the Deccan Intertrappean localities in the Mandla District have substantially added to our knowledge of the Deccan Intertrappean flora. The monocotyledons are exclusively represented by woods of palm and a fruit attributed to the modern branched palm *Hyphaene indica.* Recognizable modern genera in the assemblage are *Arenga, Licuala, Chrysalidocarpus, Hyphaene, Polyalthia, Homalium, Hydnocarpus, Garcinia, Sterculia, Grewia, Elaeocarpus-Echinocarpus, Atalantia-Limonia, Bursera, Canarium, Gomphandra (Stemonurus), Heynea, Aglaia, Walsura, Dracontomelum, Ailanthus, Lophopetalum, Artocarpus, Syzygium, Eucalyptus, Melaleuca-Tristania, Barringtonia, Sonneratia, Bischofia* and *Drypetes.*

Recently, some doubts have been raised against

the presence of mangrove, coastal and marine taxa like *Nipa, Sonneratia, Cocos, Distichoplax* and *Peyssonellia* in the Deccan Intertrappean flora around Nagpur-Chhindwara and Mandla (Borkar, 1987). As the occurrence of these taxa in the Deccan Intertrappean assemblage is very significant in reconstructing the palaeoenvironment of this area, the objections raised by Borkar (1987) are briefly discussed below:

Presence of *Nipa* in the Deccan Intertrappean sediments is based on a well-preserved fruit described by Sahni (*in* Sahni & Rode, 1937) from Mohgaonkalan. In fact, the similarity of this specimen, both morphological and anatomical, with the modern *Nipa* fruit is so close and convincing that Sahni (1937, p. 167) had no hesitation in referring the fossil to *Nipa*. Borkar (1987) makes no observation on the structure and affinities of this particular fossil. The minor differences referred to by Borkar (1987, pp. 38, 39) in no way alter the generic affinities of this fossil with *Nipa*. Recent discovery of *Nipa* pollen from the Deccan Intertrappean sediments of Padwar on Jabalpur-Mandla road (Tanu Prakash *et al.*, 1990), further confirms the presence of this genus in the Deccan Intertrappean flora. Occurrence of *Sonneratia* in the Deccan Intertrappean flora is envisaged not only on the evidence of *Sahnianthus parijai* and *Enigmocarpon parijai* which bear affinities with Sonneratiaceae but also on the evidence of well-identified fossil woods exhibiting very close affinities with *Sonneratia* described from Mohgaonkalan, Nawargaon and recently from near Shahpura in Mandla District (Mehrotra, 1988). Borkar has mentioned not a single character on the basis of which the identification of these woods can be doubted.

It should be noted here that *Barringtonia*, a genus often found in association with *Nipa* and *Sonneratia*, has been well documented from the Deccan Intertrappean beds of Nagpur-Chhindwara as well as of Mandla District.

Regarding *Cocos*, although Borkar suggests the occurrence of this genus in the Deccan Intertrappean flora as doubtful, he does not give a single reason against accepting its presence in this assemblage.

The identification of the marine algal genera *Distichoplax* and *Peyssonnelia* (Bande *et al.*, 1981) from Mohgaonkalan has also been questioned by Borkar (1987, p. 41). In doubting the identification of *Distichoplax* the above author refers to the observations of Kundal (1987) but makes no mention of the work of Varma (1962) in which the structure of *Distichoplax* has been discussed in detail. The identification of *Distichoplax* described by Bande *et al.* (1981) is based on the work of Varma (1962). Incidentally, under the references provided by Borkar, Kindal's work finds no place!

Lastly, although Borkar (1987, p. 41) himself admits that the anatomical structures of *Peyssonnelia antiqua* described by Bande *et al.* (1981) are closely comparable to those of the modern genus *Peyssonnelia*, he questions on its identification merely on the basis of a comment made by a third person and that too in personal communication. Recent finding of yet another marine alga of Solenoporaceae (Mehrotra, 1989) from Mohgaonkalan Intertrappeans is another evidence in favour of the presence of marine algae in this assemblage.

It should thus be clear that the objections raised by Borkar against the presence of *Nipa, Sonneratia, Cocos, Distichoplax* and *Peyssonnelia* in the Deccan Intertrappeans are not tenable. Occurrence of coastal and marine environment around Nagpur during Deccan Intertrappean sedimentation is also supported by palaeontological evidence (Sahni, 1983, 1984; Bhattacharya *et al.*, 1990).

Eocene flora of Kutch

The available information on the Eocene flora of Kutch has been reviewed at length by Lakhanpal *et al.* (1984). The flora consists of three species of calcareous red algae and a variety of angiospermous leaf-impressions. The algae, described from the locality of Babbia Hills (23°42′30″ N : 68°47′ E) situated at a distance of 122 km north-west of Bhuj and 5 km north-west of Panandhro, are representatives of the subfamily Melobesoideae of the family Corallinaceae (Kar, 1979). The species described are *Lithothamnium* sp. cf. *L. validum* Foslie, *Lithothamnium* sp. cf. *L. bofilli* Lemoine and *Lithophyllum* sp.

All the leaf-impressions described so far under this assemblage are from the lignite deposits near the village Panandhro (23°41′45″ N : 68°47′22″ E) situated at a distance of 126 km north-west of Bhuj on Bhuj-Narayan Sarovar Road. Palaeocene-Eocene leaf-impressions have also been reported from the localities of Matanomadh, Baranda and Sherdi (Lakhanpal *et al.*, 1984). However, no genera and species have been identified from these localities.

The Panandhro assemblage consists of leaves assigned to *Terminalia panandhroensis, Syzygium kachchhense, Lagerstroemia patelii, Cinnamomum eokachchhensis, Ficus kachchhensis* and *Pandanus eocenicus* belonging to the families Combretaceae, Myrtaceae, Lythraceae, Lauraceae, Moraceae and Pandanaceae respectively. Three species of

Dicotylophyllum, viz., *Dicotylophyllum cordatum, D. panandhroensis* and *D. quadrinervatum* have also been described from these deposits (Lakhanpal *et al.*, 1984).

Recently, the carbonised woods resembling *Terminalia calamansanai* and *Sonneratia apetala* have been described from the Rajpardi lignite mine, district Bharuch, Gujarat of Eocene age (Guleria, 1991).

Eocene plant fossils from the Fuller's earth deposits

A small fossil assemblage has also been described from the Fuller's earth bed at Kapurdi (25°54′30″ N : 70°21′30″ E), a village about 18 km from Barmer in Rajasthan. The assemblage, considered to be Middle Eocene in age, consists of leaf and fruit-impressions belonging to *Mesua* (cf. *M. ferrea*), *Garcinia* and *Calophyllum* of Guttiferae (Lakhanpal & Bose, 1951) and a fruit of *Cocos* (Kaul, 1951). The leaves of *Mesua* and *Garcinia* were later assigned to the species *Mesua tertiara* and *Garcinia barooahii* (Lakhanpal, 1964).

Eocene plant records from Meghalaya

From the Lower to Middle Eocene beds near Cherrapunji (25°17′ N : 91°44′ E) and Laitryngew (25°21′ N : 91°44′ E) in Meghalaya fossils of the mangrove palm *Nipa* and *Calophyllum* (Guttiferae) have been described (Bhattacharya, 1967). A few leaf-impressions have also been described from the Middle Eocene beds near Damalgiri in the Garo Hills, Assam (Lakhanpal, 1954, 1955). The locality (25°32′ N : 90°7′ E) lies about 18 km west of Tura. The leaves described from these beds are *Nelumbium* sp. (Nymphaeaceae), *Trema garoensis* (Ulmaceae), *Neolitsea sahnii* (Lauraceae), *Grewia foxii* (Tiliaceae) and *Bombacites orientalis* (Bombacaceae). The modern taxa comparable to these forms are *Nelumbium, Trema orientalis, Neolitsea zeylanica, Grewia tilifolia* and *Eriodendron anfructuosum/Bombax* sp.

A palm leaf referred to the genus *Sabalites* has also been reported from near Laitryngew near Shillong (Bose & Sah, 1964). However, as it is a feather palm, it should be referred to the genus *Phoenicites* Brongniart and not to *Sabalites*. From some other Lower to Middle Eocene localities of Garo Hills Bhattacharya (1979, 1983, 1985) has described a number of angiospermous leaf, flower and fruit-impressions. Locality-wise, the forms described are:

(i) West Daranggiri (25°28′ N : 90°42′ E)—*Nelumbo* Adans. affinity *Nelumbo nucifera*.

(ii) Rongrenggiri (25°34′ N : 90°33′ E), Nangalbibra (25°28′ N : 90°42′ E)—*Nipa sahnii, Poacites* sp., *Nelumbo nangalensis, Litsea* sp., *Phoebe sublanceolata, Artocarpus garoensis, Triumfetta rhomboideocarpa, Heteropanax* sp., *Osmanthus eocenicus, Ligustrum turaensis, Antholithes oleaceaeformis* and *A. campanulatus*. The modern genera identified in this assemblage are *Nipa* (Palmae), *Nelumbo* (Nymphaeaceae), *Litsea* (Lauraceae), *Phoebe* (Lauraceae), *Artocarpus* (Moraceae), *Osmanthus* (Oleaceae) and *Ligustrum* (Oleaceae).

(iii) Garo Hills, Meghalaya (25°31′ N : 90°15′ E)—Five species of leguminoceous fruits—*Leguminocarpon*, viz., *L. desmodioides, L. derrisoides, L. millettioides, L. pongamioides* and *L. albizioides* have been described. The comparable modern taxa are *Desmodium triquetrum, Derris cuneifolia, Millettia rubiginosa, Pongamia pinnata* and *Albizia lucida*.

PALAEOENVIRONMENTAL ANALYSIS

Because any plant community is the result of interaction between the plant and surrounding environment, the evidence of fossil plants has been made use of to reconstruct the palaeoclimate and palaeogeography of different areas of peninsular India during the Palaeogene (Lakhanpal, 1970; Lakhanpal *et al.*, 1984; Prakash, 1973; Bande & Prakash, 1982; Bande *et al.*, 1988). The data have also been used to reconstruct the vegetation around Nagpur-Chhindwara and Mandla during the Deccan Intertrappean sedimentation (Bande & Chandra, 1990).

As mentioned earlier, most of our information regarding the Deccan Intertrappean flora, the oldest of the Indian Palaeogene is from the Rajahmundry assemblage, the Nagpur-Chhindwara assemblage and the Mandla assemblage. Occurrence of estuarine algae and *Cocos* in the Intertrappean beds of Rajahmundry indicates the existence of sea shore which was a little more inland than the present shore line.

The Nagpur-Chhindwara assemblage is typically tropical in character in which a number of ecological facies can be recognized. These are:

(i) marine—indicated by *Distichoplax, Peyssonnelia* and Solenoporaceae

(ii) mangrove—indicated by *Sonneratia* and *Nipa*

(iii) coastal—indicated by *Cocos*

(iv) fresh water lakes, ponds, streams marshes—indicated by fresh water algae, water ferns, aquatic angiosperms—*Barringtonia, Syzygium, Aeschynomene*

(v) terrestrial and upland—indicated by Araucariaceae, Podocarpaceae and other arborescent angiosperms.

Although occurrence of conifers is usually taken to be indicative of a high altitude, both Araucariaceae and Podocarpaceae show a wide range of altitudinal distribution and can as well grow at the sea level (Florin, 1963). Most of the modern comparable taxa of this assemblage are presently found in the evergreen to semi-evergreen forests of Western Ghats and north-east India with some forms occurring in the dry deciduous forest. Thus, the assemblage indicates a depositional site at the mouth of a river in the near vicinity of sea.

Compared to the Nagpur-Chhindwara assemblage, the Mandla assemblage is exclusively angiospermous dominated by arborescent species. Similar to the Nagpur-Chhindwara assemblage this assemblage is also characteristically tropical in character with most of its modern equivalent taxa growing in the evergreen to semi-evergreen forests of Western Ghats and north-east India. The genera constituting the assemblage are *Hyphaene, Chrysalidocarpus, Licuala, Arenga, Polyalthia, Homalium, Hydnocarpus, Garcinia, Sterculia, Grewia, Echinocarpus, Atalantia-Limonia, Bursera, Canarium, Gomphandra* syn. *Stemonurus, Heynea, Walsura, Dracontomelum, Lophopetalum, Syzygium, Eucalyptus, Tristania, Sonneratia, Bischofia, Drypetes* syn. *Putranjiva* and *Artocarpus*.

Taking into consideration the habit and habitat of the modern equivalents it has been deduced (Bande & Chandra, 1990) that the forest was constituted by water loving forms, like *Syzygium, Drypetes* and *Barringtonia*, low trees or shrubs like *Garcinia, Gomphandra, Grewia, Heynea, Atalantia-Limonia, Tristania, Polyalthia,* etc., moderate to large-sized trees like *Bischofia, Bursera, Dracontomelum, Hydnocarpus* and *Walsura*, and some very large trees like *Artocarpus, Canarium, Lophopetalum* and *Sterculia* with their crowns projecting up in the sky through the main forest canopy. The palm genera like *Chrysalidocarpus, Licuala* and *Arenga* must have constituted the understorey but *Hyphaene* must have occupied some open area. Presence of *Sonneratia* indicates brackish water conditions, most probably at some distance from the main forest.

Analysing the Nagpur-Chhindwara and the Mandla assemblages together, Bande and Prakash (1982) have envisaged in central India a climate similar to the present day climate of the Western Ghats. It has been postulated that the area enjoyed a humid tropical climate with an annual rainfall over 2000 mm, an uniform temperature throughout the year and a long duration of rainy season. The factors responsible for the occurrence of such a type of climate were : (i) almost equatorial position of the area during that period, (ii) presence of sea in near vicinity, and (iii) probable absence of Western Ghats as main barriers in the path of the southwest monsoon currents. The northward drift of the Indian Plate, the withdrawl of the sea and uplifting of the Western Ghats in the post-trappean times resulted in the establishment of the present day climate and tropical dry deciduous to moist deciduous vegetation in central India against a tropical wet evergreen to semi-evergreen forest of the past (Bande & Prakash, 1982).

Similar to the Deccan Intertrappean flora, the Panandhro assemblage has also been analysed to decipher the palaeoenvironment around the basin during the Lower Eocene (Lakhanpal *et al.*, 1984). The occurrence of marine algae indicates that there was transgression of sea in the Kutch area during the deposition of these sediments. The modern comparable forms for the angiospermous species described from Panandhro are: *Terminalia crenulata, Syzygium* sp., *Lagerstroemia speciosa, Cinnamomum zeylanicum, Ficus tomentosa, Pandanus diversus, P. furcatus* and *P tectorius*. The occurrence of these taxa is suggestive of a moist evergreen to deciduous vegetation around Panandhro. Further, the littoral and swampy elements like *Lagerstroemia speciosa, Syzygium* sp. and *Pandanus tectorius* are indicative of marshes around this locality in which the vegetation got buried and resulted in the formation of lignite in due course of time (Lakhanpal *et al.*, 1984).

In continuation of the Lower Eocene, the poorly known Middle Eocene flora of Kapurdi, Rajasthan is also typically tropical in character. Presence of *Mesua* cf. *M. ferrea, Garcinia* and *Calophyllum* clearly indicates that a moist tropical climate with evergreen forest flourished around Kapurdi at the time of deposition of the Fuller's earth bed. Presence of *Cocos* in addition, further suggests that the shoreline was not far away from Kapurdi during the Middle Eocene.

The small assemblage of fossil plants described from near Damalgiri in the north-east suggests presence of evergreen to semi-evergreen vegetation and a tropical to sub-tropical climate around Damalgiri during the Middle Eocene. Of the various plant taxa identified from these deposits, *Trema orientalis* and *Neolitsea zeylanica* are small to middle-sized evergreen trees, *Grewia tilifolia* is distributed in east tropical Africa and peninsular and northeastern parts of India and *Nelumbium* is a well known aquatic plant of the tropics. *Eriodendron*

mostly occurs in America but *E. anfructuosum* is a moderate-sized deciduous tree occurring in Burma, Andamans, Malaya Peninsula and the Archipelago, western parts of Indian Peninsula and tropical America. *Bombax malabaricum*, another comparable form, is well distributed in tropical Himalayas and throughout the warmer forests of India to Burma and Ceylon, also in Java and Sumatra. *Bombax insigne*, yet another species of the genus, is a common tree of mixed deciduous forests extending into evergreen to semi-evergreen forests. It is essentially a tropical tree occurring in Burma, Andamans, Chittagong, Malay Peninsula and the Western Ghats of India (Lakhanpal, 1954).

Presence of *Nipa* in the Lower to Middle Eocene beds around Cherrapunji and Garo Hills indicates an estuarine condition in both these areas. Similarly, occurrence of *Nelumbo* suggests the presence of fresh water lakes and ponds. In addition, occurrence of terrestrial trees, shrubs, and herbs like *Calophyllum, Artocarpus, Litsea, Phoebe, Ligustrum* and *Osmanthus*, all of which are tropical to sub-tropical in habitat, suggests a depositional site, especially around Rongrengiri and Nangalbibra in Garo Hills, very similar to that around Mohgaonkalan during the Deccan Intertrappean sedimentation. It should be noted that at least four families, viz., Palmae, Guttiferae, Nymphaeaceae and Moraceae and two genera *Nipa* and *Artocarpus* are common in the Deccan Intertrappean flora of central India and the Lower to Middle Eocene assemblage of Meghalaya. Lastly, the evidence of the fossil fruits comparable with different genera of Leguminosae also suggests that the assemblage was composed of trees, shrubs, herbs and woody climbers growing in and around the banks of streams in tropical to sub-tropical moist deciduous forest (Bhattacharya, 1985

An overview of the Palaeogene flora of India broadly suggests that the wet evergreen to semi evergreen forest and humid tropical climate in central India, prevalent during Early Palaeogene—i.e. during the Deccan Intertrappean sedimentation, continued to prevail in the west as well as north-east India at least till the Middle Eocene. It was only in the post-Palaeogene period, after the joining of the Indian Plate with the Asian Plate, that the Indian sub-continent started acquiring its present day topography resulting in the onsetting of the current vegetational and climatic pattern of this sub-continent.

PHYTOGEOGRAPHICAL CONSIDERATIONS AND PLANT MIGRATIONS

As mentioned earlier, in the history of the Indian sub continent the Palaeogene represents a period when the Indian Plate had already broken away from the rest of the continents of the Gondwanaland but had not yet joined with the Asian Plate. It is, therefore, but natural to expect, in the Palaeogene flora of peninsular India, at least a few taxa showing affinities with those presently confined to the other countries belonging to Gondwanaland of the past. An analysis of the Indian Palaeogene flora, especially the Deccan Intertrappean flora, brings out some interesting evidences in support of this assumption. Affinities of *Rodeites*, described from Mohgaonkalan intertrappeans, have been traced to *Regnellidium* a water fern of Brazil. Similarly, *Cyclanthodendron* and *Simarouboxylon* bear resemblance with the tropical American genera *Cyclanthus* and *Simarouba*, respectively. Although the affinities of all these fossils are not beyond doubt, their presence does indicate the possibility of the presence of some tropical American genera in the Indian Palaeogene. From the Intertrappean beds of Mandla District, a fossil fruit exhibiting close affinity with the fruit of the branched palm *Hyphaene* has been described (Bande *et al.*, 1982). A palm petiole belonging to this genus has also been described from the Intertrappean beds of Nawargaon, district Wardha (Shete & Kulkarni, 1980). Only a single species of *Hyphaene—H. indica* is found in India which is distributed all along the western coast up to Goa. The other 41 species are distributed in tropical and sub-tropical areas of Africa and Arabia. From the same assemblage, yet another palm—*Chrysalidocarpus*, a genus native of Madagascar, has been described.

Occurrence of some Australian taxa like *Eucalyptus, Tristania-Melaleuca* (Bande *et al.*, 1986) is also interesting. It is essential to rethink regarding the position of India in relation to Australia in the past. Further, if the view proposed by some that before the Gondwana break-up Australia and India were in juxtaposition to each other is accepted (Bande *et al.*, 1988, p. 100), then what was the time of separation of India and Australia? Even after the separation took place, were these two landmasses inter-connected through some land bridges till as late as the Palaeogene ? Can it be presumed that during the Palaeogene the present day tropical America, Africa, Madagascar, India and Australia enjoyed a similar type of climate permitting the existence of at least some common plant taxa on them? It should be interesting to note that atleast a few Indian Palaeogene families like Myrtaceae, Lauraceae, ?Sterculiaceae, etc. have been recorded from the Palaeogene deposits of Antarctica also (Birkenmajer & Zastawniak, 1986).

The extant flora of India is usually termed as Indo-Malayan. However, it should be born in mind

that the flora of this region acquired its present composition only after the Indian Plate joined with the Asian Plate and establishment of land connections between India and South-east Asia (Bande & Prakash, 1986). A detailed comparison of the Palaeogene flora of India vis-a-vis Palaeogene as well as Neogene floras of South-east Asia has already been made to understand the migration of various plant taxa between these two land masses (Bande & Prakash, 1986). Some of the genera which appear to have migrated from India to South-east Asia during the Neogene are: *Sterculia, Grewia, Polyalthia, Gomphandra, Lophopetalum, Syzygium* and *Sonneratia*. Similarly, the most important taxa which were added to the Indian flora from South-east Asia during the post-Palaeogene are, Dipterocarpaceae and many genera of Leguminosae.

The Palaeogene flora of peninsular India, thus, can be considered as the parental stock for the present day flora of India. To this stock the elements of South-east Asia, Africa and also Europe were added during the post-Palaeogene period ultimately resulting in the evolution of the modern Indian sub-continent flora.

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