Early Tertiary vegetational reconstructions around Nagpur-Chhindwara and Mandla, central India

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The Deccan Intertrappean flora represents a stage in the vegetational history of India when majority of forms constituting the modern vegetation of this subcontinent had attained a stability in their morphological characters. Most of the information regarding this flora is derived from the assemblages from Nagpur-Chhindwara region and Mandla District in central India. The Nagpur-Chhindwara assemblage is constituted by taxa representing all major groups of the Plant Kingdom belonging to marine, estuarine, fresh water, marshy and terrestrial habitats. The Mandla assemblage, mainly comprising plant fossils from the localities around Shahpura, is exclusively angiospermous constituted mostly by palms and arborescent dicotyledons. Based on the available data of fossil plants from these areas, Early Tertiary vegetational reconstructions have been attempted. The evidence of the Deccan Intertrappean plant fossils suggests the occurrence of evergreen to semi-evergreen forests in central India during Early Tertiary, similar to the present day forests of Western Ghats.

Key-words—Deccan Intertrappeans, Vegetational reconstructions, Nagpur-Chhindwara, Mandla, Early Tertiary (India).

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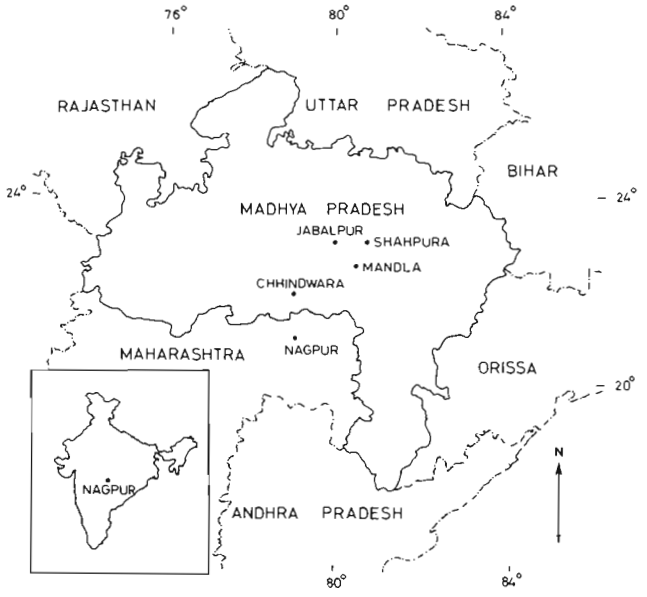
सारांश

केन्द्रीय भारत में नागपुर-छिंदवाड़ा एवं मंडला के आस-पास प्रारम्भिक तृतीयक युगीन वनस्पतिक निर्मितियाँ

मोहन बलवंत बाँडे एवं शैला चन्द्रा

भारत के पुरावनस्पतिक इतिहास में दक्खिन अन्तर्ट्रेपी वनस्पतिजात उस चरण का निरूपण करता है जब इस उपमहाद्वीप की वर्तमान वनस्पति के अधिकतम अवयव अपने आकारिकीय लक्षणों में स्थायीत्व प्राप्त कर चुके थे। इस वनस्पतिजात से सम्बन्धित अधिकतर जानकारी केन्द्रीय भारत में मंडला जनपद तथा नागपुर-छिंदवाड़ा क्षेत्र से उपलब्ध समुच्चयों से निष्कर्षित की गई है। नागपुर-छिंदवाड़ा समुच्चय में पादप जगत के सभी प्रधान समूहों के वर्गक अर्थात् समुद्री, सरोवरी, स्वच्छ जलीय, दलदली एवं स्थलजात, विद्यमान हैं। मंडला समुच्चय, जिसमें शाहपुरा के आस-पास के अश्मित पौधे सम्मिलित हैं, में मुख्यतः ताड़ एवं वृक्षीय द्विबीजपत्री आवृतबीजी पौधो के अवयव विद्यमान हैं। इन क्षेत्रों से उपलब्ध अश्मित पौधों के आधार पर प्रारम्भिक तृतीयक युगीन वनस्पतिक स्वरूप को साकार करने का प्रयास किया गया है। दक्खिन अन्तर्ट्रेपी पौधों के प्रमाणों से प्रस्तावित होता है कि प्रारम्भिक तृतीयक कल्प में केन्द्रीय भारत में पश्चिमी घाट के वर्तमान वनों की तरह सदाहरित से अर्धसदाहरित वन विद्यमान थे।

THE Deccan Intertrappean flora occupies a unique position in the vegetational history of India. The flora, which has been assigned a Palaeocene-Eocene age, represents a stage when majority of the forms constituting the modern vegetation of this subcontinent had attained a stability in their morphological characters, at least at the generic level. Embedded in the lacustrine and fluviatile sediments, deposited between the successive lava flows, the fossil flora is constituted by well preserved woods, leaves, fruits, flowers, etc representing all major plant groups. Leaving aside the stray reports of fossil plants from various localities distributed all over the Deccan Trap country, most of the information regarding this flora comes from the assemblages described from the Intertrappean beds exposed around Rajahmundry in Andhra Pradesh, Nagpur-Chhindwara in Maharashtra/Madhya Pradesh and in the Mandla District of Madhya Pradesh (Map 1). Of these, the Rajahmundry assemblage is characterized by the occurrence of marine algae and charophytic



Map 1

fructifications, in the Nagpur-Chhindwara assemblage all the major plant groups are represented, while the Mandla assemblage is exclusively angiospermous where dicotyledons and palms are frequent.

It is now established that majority of Tertiary plant fossils are assignable to extant genera and species. This being the case with the Deccan Intertrappean fossils also, the evidence of fossil plants from the Nagpur-Chhindwara area and the Mandla District has already been analysed to reconstruct the palaeoclimate and palaeogeography in central India during the Early Tertiary. It has been postulated that at the time of the Deccan Intertrappean sedimentation this area was covered by forests similar to the extant evergreen to semi-evergreen forests of Western Ghats and northeast India (Lakhanpal, 1970; Prakash, 1973; Bande & Prakash, 1982; Bande *et al.*, 1988). The area enjoyed a humid tropical climate with almost uniform temperature throughout the year and annual rainfall above 2,000 mm per year and a long rainy season. The occurrence of this type of climate has been attributed to an equatorial position of peninsular India at that time, presence of sea in near vicinity and probable absence of Western Ghats as barrier in the path of the southwest monsoon (Bande & Prakash, 1982). Taking into account the evidence of fossil plants, an attempt has been made in the present paper to reconstruct Deccan Intertrappean vegetation around Nagpur-Chhindwara (Plate 1) and Mandla (Plate 2).

A prerequisite for such reconstruction is to collect as much data as possible regarding the habit and habitat of the extant genera and species represented in a fossil assemblage. The height of individual trees (in case of arborescent forms), length and width of their clear boles, presence or absence of buttresses, colour and characters of bark, shape of the crowns, shape and size of the leaves, etc. are other important features which also need consideration. While preparing illustrations of the past vegetation around Nagpur-Chhindwara and Mandla information concerning extant taxa represented in these two assemblages was collected by studying them in their natural habitat and also from various published data (Beddome, 1978; Blatter, 1926; Brandis, 1971; Blasco, 1975; Champion & Seth, 1968; de Wit, 1967; Everett, 1969; Florin, 1963; Hora, 1981; McCurrach, 1960; Pearson & Brown, 1932). This information has been provided in Table 1 and 2.

Table 1—Significant extant taxa (Gymnosperms & Angiosperms) in the Deccan Intertrappean flora of Nagpur-Chhindwara with their habit, habitat and distribution

Extant Taxa (1)	Habit, Habitat & Distribution (2)	Comparable Fossil Taxa (3)
Araucariaceae		
Araucaria	Trees, distributed in different countries of the southern hemisphere. Some species grow in the temperate conditions. In New Caledonia the genus occurs in moist forests from sea shore up to an elevation of 2,600 m.	*Mohgaostrobus sahnii* Prakash 1956
Agathis	Up to 75 m tall forest trees growing at medium to heigh altitudes in tropical and sub-tropical regions in New Zealand, the coast of Queensland, Australia, New Caledonia, Vanuatu, Santa Cruz, Islands, and Fiji, Soloman Islands and New Guinea to the Philippines as well as Sumatra and the Malay Peninsula. Altitudinal range 0-2100 m.	*Araucarioxylon* sp. Lakhanpal, Prakash & Bande 1977

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Podocarpaceae		
Podocarpus	Shrubs or large trees. Two species in India *P. nerifolia*—A tall tree, branches whorled. Nepal, Sikkim, evergreen forests of the outer hills ascending to about 900 m. Assam, Khasi hills, Cachar, Chittagong in Bangla Desh, Andamans at the bottom of the valleys, not on the hills, often gregarious. *P. wallichianus*-large trees, Khasi hills, Cachar, Martaban and Tenasserim. Tinnevelli ghats, 10 to over 1500 m, Malaysian Peninsula, Java.	*Podocarpoxylon deccanensis* Trivedi & Srivastava 1989
Musaceae		
Musa sp.	Tree like herbs with thick stems composed of convolute leaf sheaths. A genus of the Old World tropics. In India occurring in Western Ghats, Bihar, Assam, Meghalaya, Mizoram, Arunachal, Nagaland, Eastern Himalaya, also in Nepal, Sri Lanka, Burma, Malaysia.	*Musa cardiosperma* Jain 1964 *Musocaulon indicum* Jain 1964 *Musophyllum indicum* Prakash, Bande & Ambwani 1979
Palmae		
Cocos nucifera	Unarmed monoecious palms. Cultivated in the hot damp regions of India, Burma and Sri Lanka especially near the sea.	*Palmoxylon sundaram* Sahni var *vidarbhai* Rao & Menon 1964, *Cocos intertrappeansis* Patil & Upadhye 1984
Phoenix rupicola	Trees, trunk 4 to 6 m high, 20 to 25 cm in diameter The entire stem closely covered by the more or less rhomboidal bases of petioles. Occurs in Sikkim on steep cliffs near the Tista and Mahanadi rivers.	
Phoenix robusta	Stem 3.5 to 6 m, diameter 30-40 cm, tessellated with persistent rhomboidal leaf bases. Western Ghats, gregarious on the flat top trap hills.	*Palmoxylon* cf. *Phoenix* Mahabale 1959
Nipa fruticans	From a stout-branching rhizome creeping either underground or along the surface spring tufts of huge pinnate leaves 3 to 7.5 m long, leaflets numerous, 60-120 cm long. Found in estuaries or rivers and tidal swamps, Sunderbans, Andamans, Chittagong in Bangla Desh, Burma coast, Sri Lanka, Malaysian Peninsula and Archipelago, Australia.	*Nipa hirtdi* Sahni & Rode 1937 *Rhizopalmoxylon indicum* Sahni 1938
Nymphaeaceae		
Nymphaea sp.	Aquatic perennial herbs with long petioled floating leaves and creeping root-stocks. Flowers of various colours. Common throughout warmer parts of India and many other countries.	*Nymphaeocaulon intertrappeum* Trivedi & Ambwani 1971
Tiliaceae		
Grewia laevigata	A small to medium sized tree with a stem about 60-90 cms in girth and 4 m bole. Found in the outer Himalaya, from the Jamuna eastwards ascending to over 900 m in both the peninsula.	*Grewioxylon mahurzariense* Prakash & Dayal 1965
Grewia tiliaefolia	Moderate to large tree, straight, fairly cylindrical stem, 1 to 1.5 m in girth, 4.5 to 6 m bole, in central India. On the west coast, Karnataka, Coorg, etc. Large trees 2 m and over in girth, 9 m bole.	*Grewioxylon indicum* Prakash & Dayal 1965

Contd.

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PLATE 1

Reconstruction of vegetation around Nagpur-Chhindwara area during Early Tertiary.


TETRAMELES
BOSWELLIA
AILANTHUS
BARRINGTONIA
NIPA
SONNERATIA
PHOENIX
SYZYGIUM
SONNERATIA
AILANTHUS
ARAUCARIACEAE
PODOCARPUS
COCOS
NYMPHAEACEAE
MUSA
PALM

PLATE 1

PLATE 1

Elaeocarpaceae

Elaeocarpus sp.	A large genus of medium to large evergreen trees, majority of the species distributed in the Indo-Malayan region. Nearest comparable species *Elaeocarpus ferrugineous* is moderate sized tree, about 12 m, height with a clear bole of 3 m, and about 90-120 cm girth. Occurs in Western Ghats, Nilgiris, Anamalais, Pulney hills as well as high hills of Travancore. Another anatomically similar species *E. tuberculatus* is a large tree 2 m in girth and 25 m high. Buttressed. Found in Karnataka southwards through the Western Ghats, Coorg, Mysore, Travancore, common in evergreen forests of Garisoppah of Karnataka.	*Elaeocarpoxylon antiqum* Prakash & Dayal 1964

Simaroubaceae

Ailanthus malabarica	A lofty tree with tall cylindrical trunk, found in the evergreen forests of Western Ghats from the Konkan-southwards, from the coast to about 900 m.	*Ailanthoxylon indicum* Prakash 1959

Burseraceae

Boswellia serrata	A deciduous middle-sized tree with a spreading flat crown, bole up to 3.5 to 4.5 m, girth 1 to 1.5 m. Found in the sub-Himalayan tracts, from Sutlej eastwards and throughout the drier parts of the western Peninsula to within 10-20 km of the Western Ghats. Often gregarious, forming open forests.	*Boswellioxylon indicum* Dayal 1966

Ampelidaceae

Leea	Large herbs or erect shrubs, stems and branches generally furrowed. Different species distributed in Sikkim, Assam, Manipur, Andamans, Bengal, west peninsula, Konkan, Chotanagpur etc.	*Leeoxylon multiseriatum* Prakash & Dayal 1964

Leguminosae

Aeschynomene	The Indian species *Aeschynomene aspera* is a tall, erect water plant of marshy habitat, attaining up to 3.5 m. Occurs in Bengal, rare in the western peninsula.	*Aeschynomene tertiara* Prakash 1962

Myrtaceae

Syzygium cumini	Medium to large-sized evergreen tree occurring throughout India usually along water courses.	*Syzygioxylon chhindwarense* Patil & Singh 1974

Lecythidaceae

Barringtonia acutangula	A middle-sized evergreen tree found in sub-Himalayan tract from the Ganges eastwards, Bengal and central India, the peninsula and Burma, chiefly on the banks of streams and in moist places.	*Barringtonioxylon deccanense* Prakash & Dayal 1965
Barringtonia pterocarpa	An evergreen tree found in Pegu and Martaban in Burma	*Barringtonioxylon eopterocarpum* Prakash & Dayal 1965

Sonneratiaceae

Sonneratia acida & *S. apetala*	Glabrous trees. Sunderbans and along the coastal and tidal waters of peninsular India	*Sahnianthus parijae* Shukla 1944 *Enigmocarpon parijae* Sahni 1934

Datiscaceae

Tetrameles nudiflora	A very tall fast growing deciduous tree. Trunk straight 30 to 40 m to the first branch, 9 m in girth, often much buttressed. Terai and outer hills, Darjeeling District, ascending to 900 m, Andamans, Western Ghats and Nilgiris in Sholas and evergreen forests. Evergreen to semi-evergreen and low lying plain forests and Burma.	*Tetrameleoxylon prenudiflora* Lakhanpal & Verma 1966

Euphorbiaceae

Mallotus philippensis	A large shrub or a small to moderate-sized tree, branching low with a short, sometimes fluted or	*Mallotoxylon keriense* Lakhanpal & Dayal 1964

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	otherwise irregularly shaped stem 60 to 90 cm in girth. Found in the sub-Himalayan tract from Punjab eastwards, ascending to over 1,300 m in Bengal, central India, both the peninsulas.	

Table 2—Significant extant taxa in the Deccan Intertrappean flora of Mandla District with their habit, habitat and distribution

Extant taxa (1)	Habit, Habitat & Distribution (2)	Comparable Fossil Taxa (3)
Palmae		
Hyphaene indica	Branched palm distributed all along the western coast up to Goa.	*Hyphaeneocarpon indicum* Bande, Prakash & Ambwani 1982
Chrysalydocarpus lutescens	About 7.5 m tall palm with unarmed stem and pinnate leaves found in Malagassy.	*Palmoxylon ghuguensis* Ambwani & Prakash 1983
Licuala peltata	2.5 to 4.5 m, usually gregarious, marked below with leaf scars, leaves orbicular, 0.9 to 1.5 m in diameter, peltate. Found in Sikkim, deep hot valleys near the Teesta River, Assam, Khasi Hills, Cachar, woody mountainous country to the coast and near Chittagong in Bangla Desh, Burma in damp ravines of Pegu Yoma and in Andaman islands.	*Palmoxylon shahpurensis* Ambwani 1983
Arenga sp.	Tall stout palms. Indian species *Arenga wightii* occurs in north Karnataka, evergreen forest of the Western Ghats, very common near the falls of Gairsoppah, Nilgiris and Travancore.	*Palmostroboxylon arengoidum* Ambwani 1984
Anonaceae		
Polyalthia simiarum	An evergreen, tall, rather slender tree up to 1.2 m in girth with a tall cylindrical stem. Found in the moist forest of Orissa, Mayurbhanj, in lower hill forests in North Bengal, Assam, Chittagong hill tracks in Bangla Desh and Burma.	*Polyalthioxylon parapaniense* Bande 1973
Flacourtiaceae		
Homalium tomentosum	A large tree up to 2.7 m girth with a 15 m cylindrical straight stem. Found in the deciduous forest from Chittagong in Bangla Desh to Martaban in Burma, Ganjam.	
Homalium zeylanicum	A lofty tree found in the Western Ghats from North Karnataka southwards in evergreen forests.	*Homalioxylon mandlaense* Bande 1974
Hydnocarpus wightiana	A tall straight tree common along the Western Ghats from Konkan southwards ascending to over 600 m, also below the Ghats in Malabar and Karnataka.	*Hydnocarpoxylon indicum* Bande & Khatri 1980
Hydnocarpus alpina	Small to moderate-sized tree, 90 to 120 cm girth with 6 to 9 m bole. Found in the Nilgiris up to nearly 1,800 m, Sri Lanka (low country).	
Guttiferae		
Garcinia cowa	A large tree with drooping branches found in Assam, Chota Nagpur, Nilgiris and elsewhere in the peninsula, and Chittagong in Bangla Desh.	*Garcinioxylon tertiarum* Bande & Khatri 1980
G. xanthochymus	A moderate-sized tree with dense dark green shining foliage. Sikkim ascending up to over 900 m, Assam, Khasi hills, Andamans, western peninsula in the Circars but chiefly in the evergreen forests along Western Ghats from north Karnataka southwards, Chittagong hills in Bangla Desh and Burma.	
Sterculiaceae		
Sterculia foetida	A large deciduous tree found on the west coast	

Contd.

	at low elevations from Konkan southwards, Sri Lanka and Martaban in Burma.	
Sterculia guttata	A medium-sized tree found in the evergreen forests of Western Ghats to Travancore, ascending up to 600 m in Assam and Tenasserim in Burma.	*Sterculioxylon deccanensis* Lakhanpal, Prakash & Bande 1978 & *Sterculioxylon shahpurensis* Bande & Prakash 1980.
Sterculia campanulata	A large deciduous tree upto 30 to 40 m in height with a smooth cylindrical stem 2.5 to 3 m in girth. Found in eastern Peninsula, slopes of the Pegu Yoma and Martaban in Burma, Nicobars, Malaysian Peninsula.	
Sterculia angustifolia	A small to medium sized tree found in Lower Burma.	
Tiliaceae		
Grewia laevigata	A small to medium-sized tree with a stem about 60-90 cm in girth and 4.5 m bole found in the outer Himalaya from the Jamuna eastward ascending to about 900 m in both the peninsulas.	*Grewioxylon* sp. in: Lakhanpal, Prakash & Bande 1978
Elaeocarpaceae		
Echinocarpus sigun	A large tree growing in Khasi hills and Burma.	
Echinocarpus assamicus	A large tree occurring more or less gregariously on river banks throughout Assam, also in Sikkim.	*Elaeocarpoxylon mandlaensis* Lakhanpal, Prakash & Bande 1979
Rutaceae		
Atalantia monophylla	A small evergreen tree or a glabrous shrub found throughout the mountain region of south India, Bihar, Orissa Assam and Sri Lanka, extending to the Andamans and Burma	
Limonia acidissima	A small tree or a glabrous shrub growing in the sub-Himalayan tract from Ravi eastwards throughout hill forests of Punjab, Uttar Pradesh, Maharashtra, Karnataka, Tamil Nadu, Andhra and Upper Burma.	*Atalantioxylon indicum* Lakhanpal, Prakash & Bande 1978
Burseraceae		
Bursera serrata	A large evergreen tree with a straight cylindrical stem upto 2 m in girth and 9-12 m clean bole. Occurs in Assam, Cachar, Chotanagpur, Orissa extending to Eastern Ghats especially in valleys and along water courses, also in Chittagong in Bangla Desh.	*Burseroxylon preserratum* Bande & Prakash 1982
Canarium	Medium-sized to large trees distributed in the evergreen forests of Western Ghats, north Bengal and Assam extending up to Burma. *C. strictum* the south Indian species is a very large tree, with a straight cylindrical stem up to 30 m in height, 2.5 m in girth.	*Canarioxylon shahpurensis* Trivedi & Srivastava 1985
Meliaceae		
Heynea trijuga	A small tree or a shrub, up to 6-12 m in height, 90 cm girth with 4.5 to 6 m clear bole. Found in sub-Himalayan tract from Kumaon eastwards to north Bengal, plain and hill forests of Assam, Eastern Ghats, Western Ghats, etc.	*Heyneoxylon tertiarum* Bande & Prakash 1982
Walsura glauca	A tree up to 24 m in height occurring in South Tennasserim in Burma.	
W. piscida	A middle-sized tree up to 25 m in height and 60 cm in diameter. Found in Western Ghats from North Karnataka southwards to the Anamalais and Travancore; also in dry evergreen forests of Mysore, Andhra, Orissa and Southern Bihar.	*Walsura deccanensis* Mehrotra 1989

Contd.

PLATE 2

Reconstruction of vegetation around Mandla during Early Tertiary. →


PALM
LICUALA
ARTOCARPUS
POLYALTHIA
SYZYGIUM
PALM
PALM
DRYPETES
HYPHAENE
LICUALA
STERCULIA
ARENGA
POLYALTHIA
CHRYSALIDO-
CARPUS
PALM

PLATE 2

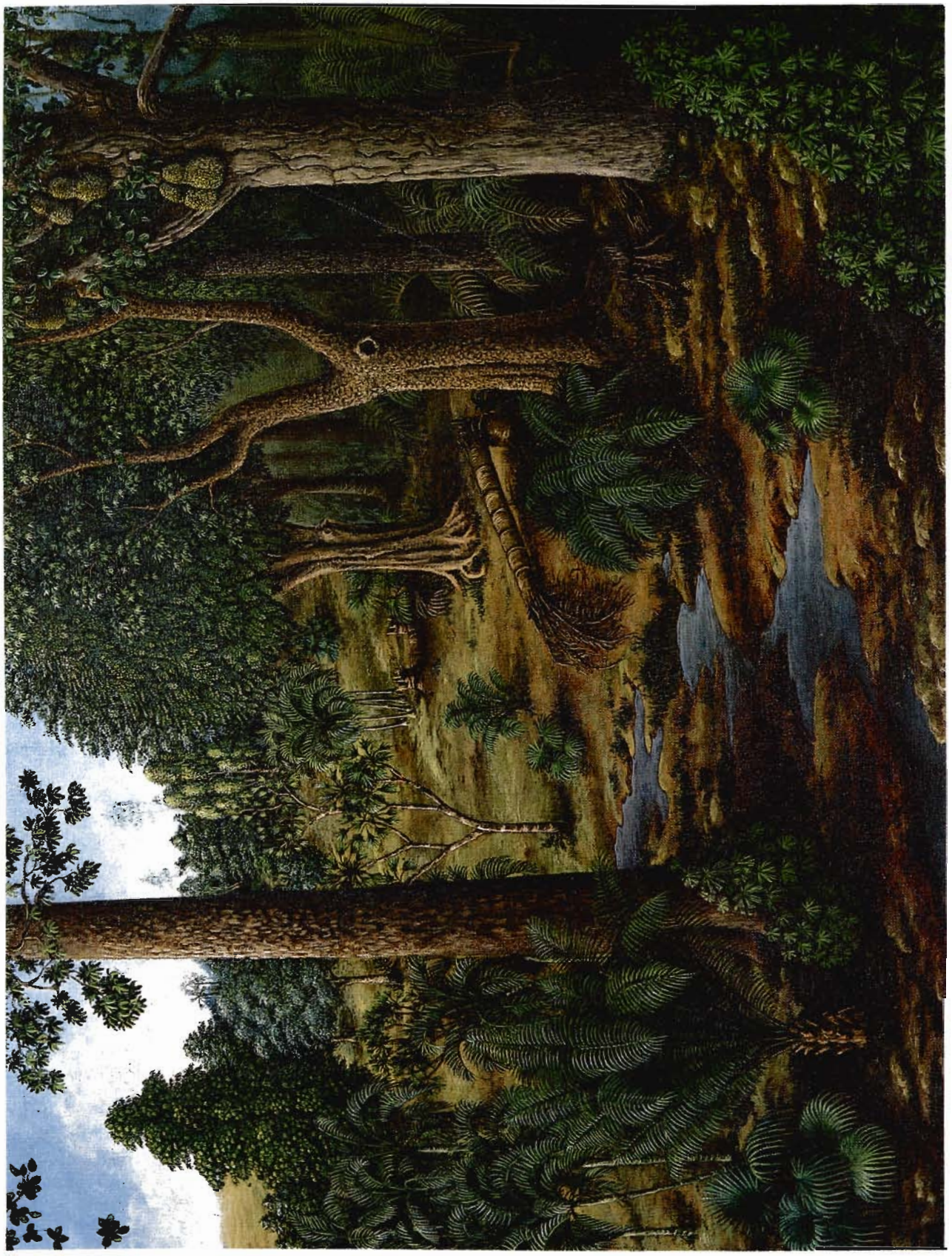

PLATE 2

W. villosa	A moderate-sized tree 9 to 15 m in height fairly common in Upper and Lower Burma.	
Aglaia andamanica	Tall evergreen trees found in the Andamans.	*Aglaioxylon mandlaense* Trivedi & Srivastava 1982
Icacinaceae		
Gomphandra tetrandra	A large shrub or a small tree growing in the Western Ghats from North Karnataka southwards, Nilgiris and Anamalais, also in Sri Lanka.	*Gomphandroxylon samnapurensis* Bande & Khatri 1980
Celastraceae		
Lophopetalum littorale	A large tree growing in Pegu and Tenasserim especially on low lands along rivers.	*Lophopetalumoxylon indicum* Mehrotra, Prakash & Bande 1984
Anacardiaceae		
Dracontomelum mangiferum	A tall handsome evergreen tree, 15-30 m high and 1.5 to 3 m in girth, usually in damp places along the streams. Distributed in Burma, Andaman and Nicobar Islands, Malaysian Peninsula.	*Dracontomelumoxylon mangiferumoides* Bande & Khatri 1980
Myrtaceae		
Syzigium cumini	A medium to large sized evergreen tree occurring throughout India usually along water courses.	*Syzygioxylon mandlaense* Ingle 1972
Eucalyptus	A genus of medium to lofty trees mainly distributed in Australia, very variable in habitat. Flourishing in areas with 300 to 3,000 mm annual rainfall and from sea level up to the Snow line.	*Eucalyptus dharmendrae* Bande, Mehrotra & Prakash 1986
Tristania conferta	Evergreen trees or tall shrubs found in North Australia, Queensland and New South Wales. The genus as a whole is distributed in Malaysia, New Caledonia, Australia, Fiji and northeast part of India.	*Tristania confertoides* Bande, Mehrotra & Prakash 1986
Lecythidaceae		
Barringtonia acutangula	A middle-sized evergreen tree found in sub-Himalayan tract from the Ganges eastwards, Bengal and central India, the peninsula and Burma chiefly on banks of streams and in moist places.	
Barringtonia pterocarpa	An evergreen tree found in Pegu and Martaban in Burma	*Barringtonioxylon mandlaensis* Bande & Khatri 1980
Sonneratiaceae		
Sonneratia	Glabrous trees. Sunderbans and along the coastal and tidal water of peninsular India.	*Sonneratioxylon preapetalum* Awasthi 1969
Euphorbiaceae		
Bischofia javanica	A large to very large deciduous tree generally with straight, cylindrical up to 7.5 m bole and 3.5 m girth. Found in the sub-Himalayan forest and outer hills from Jamuna eastwards ascending to 4,000 ft. in Chotanagpur, western peninsula, Assam, Chittagong in Bangla Desh, Upper and Lower Burma, chiefly is shady ravines and on the banks of the streams.	*Bischofinium deccanii* Bande 1974
Drypetes	Shrubs and trees mostly in Assam. *D. venusta* occurs in Western Ghats. Branches drooping. *Putranjiva roxburghiana* included under *Drypetes* by many authors is a middle-sized evergreen tree with hanging branches occuring throughout tropical India in damp evergreen forests and on the banks of streams.	*Euphorbiocarpon drypeteoides* Mehrotra, Prakash & Bande 1983
Moraceae		
Artocarpus heterophyllus	Large to very large evergreen tree in the dense forests along the Western Ghats.	*Artocarpoxylon deccanensis* Mehrotra, Prakash & Bande 1984

While attempting such reconstructions, it is not possible to depict all the known fossil taxa described from any particular area. In addition to the limited number of taxa which can be accommodated in such reconstructions another constrain is that in many cases affinities of the fossil taxa are doubtful. It, therefore, becomes unavoidable to base such reconstructions on the evidence of only those fossil taxa whose affinities are reasonably certain.

Irrespective of the area to which a wet tropical evergreen forest (tropical rain forest) may belong or the taxa which might constitute the forest, there are certain characteristic common features of these forests all over the world. These have been discussed in detail by Richards (1981) and briefly mentioned by Champion and Seth (1968, p. 57) in specific relation to the southern tropical evergreen forests of India. A characteristic feature of such forests is the dominance of tall evergreen trees up to 45 m or more in height. Some of these trees occupying the top storey may be with clear boles 30 m long and 5 m or more in girth and may be briefly deciduous without affecting the evergreen nature of the forest. The canopy is extremely dense and, apart from the scattered giants projecting well above the general canopy the differentiation into definite canopy layers probably does not exist. Epiphytes, like aroids ferns, mosses and orchids are common but climbers are more frequent in the semi-evergreen forest. The ground vegetation may be totally absent or it may consists of a carpet of *Strobilanthes* or *Selaginella* or ferns; grasses are absent. The undergrowth consists of canes, creeping bamboo and palms. The trees are usually with long cylindrical boles with thin smooth bark but plank buttresses are frequent. The leaves are thick and glossy and often white or pink when young. Cauliflory may be relatively common. It was found profitable to keep in mind these characteristic features of the southern evergreen forests of India while attempting these reconstructions.

PALAEOVEGETATIONAL RECONSTRUCTIONS

Nagpur-Chhindwara area

The important fossiliferous localities of this area are Mohgaonkalan and Keria situated near Chhindwara and Sausar, Mahurzari and Takli near Nagpur. Many fossil taxa are common to these localities. A complete list of plant fossils known from these localities has recently been furnished by Bande *et al.* (1988). Although in many cases the affinities of the fossil taxa are not known, the important recognizable extant taxa in this assemblage are as follows:

Amongst algae, the fresh water element is represented by *Spirogyrites, Oedogonites*, etc. from Mohgaonkalan and *Ulothrix*-like filaments from Sausar. *Chara sausari*, the only fossil record of a gyrogonite of *Chara* with attached vegetative filament, has been described from Sausar. Charophytic gyrogonites have also been recorded from Gitti Khadan near Nagpur. Two marine algal taxa, *Peyssonnelia antiqua* and *Distichoplax* have been described from Mohgaonkalan. Recently, Mehrotra (1989) has described yet another marine alga *Solenopora* from these beds.

The fungi are mostly known as dispersed spores. The records of bryophytes are meagre and consist of a capsule assignable to Anthocerotaceae and a thallus, similar to *Riccia*.

The extant pteridophytic genera identified in this assemblage are water ferns, *Azolla, Marsilea* and *Salvinia*. Another genus *Rodeites* possesses probable affinities with the South American aquatic fern *Regnellidium*. A strobilus resembling that of *Selaginella* has also been recognized.

The gymnosperms are represented both by cones as well as woods. The two families which can be identified with certainty are Araucariaceae (*Araucaria/Agathis*) and Podocarpaceae (*Podocarpus*).

Amongst angiosperms, both monocotyledons and dicotyledons are recorded. Palms are of frequent occurrence and the most important genera are : (i) *Nipa*—the characteristic floral element of estuarine habitat, and (ii) *Cocos*—a form of coastal environment. Yet another palm *Phoenix* has also been recorded. The other important monocot genus of this assemblage is *Musa* whose fruit, petiole as well as leaf have been described from Mohgaonkalan.

The dicotyledonous element is represented by a number of flowers, fruits and woods. The affinities of the flower *Sahnianthus parijae* and the fruit *Enigmocarpon parijae* have been traced to the mangrove genus *Sonneratia*. Fossil woods showing affinities with this genus have also been recorded from this area. Some other genera recognized are *Ailanthus, Boswellia, Bridelia, Mallotus, Tetrameles, Elaeocarpus, Leea, Syzygium, Barringtonia,* etc. *Aeschynomene*, a plant of marshy habitat, has also been reported from Mohgaonkalan. A peduncle showing affinities with Nymphaeaceae is also described (for a detailed review of the flora see Bande *et al.*, 1988).

The Nagpur-Chhindwara assemblage is typically tropical in character. Following ecological facies, however, can be distinctly marked in this assemblage :

(i) Marine	—as indicated by *Distichoplax, Peyssonnelia, Solenopora*
(ii) Mangrove	—*Sonneratia, Nipa*
(iii) Coastal	—*Cocos*
(iv) Fresh-water lakes, ponds,	—fresh water algae, water ferns, aquatic angios-

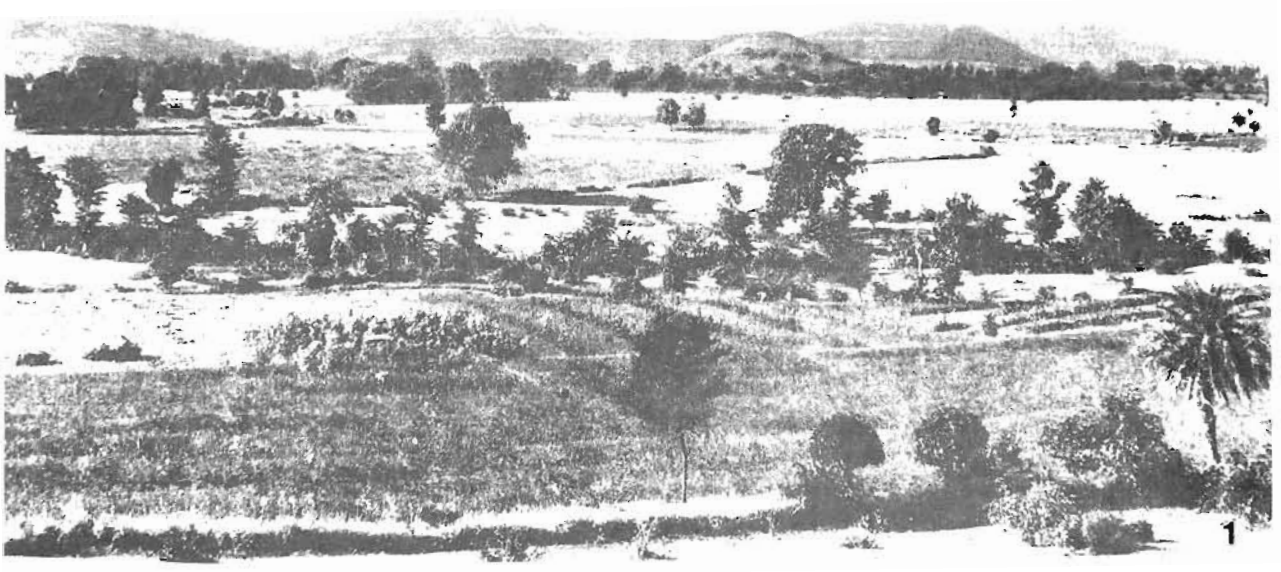

PLATE 3

1 Present day topography around Nagpur-Chhindwara (from Sahni & Rao, 1943)

2. Present day topography around Shahpura, Mandla District, Madhya Pradesh

streams and marshes	perms, *Barringtonia, Syzygium, Aeschynomene*
(v) Terrestrial and upland	—Araucariaceae, Podocarpaceae, other arborescent angiosperms

Although occurrence of conifers is usually taken to be indicative of high altitude, the Podocarpaceae and Araucariaceae show a remarkable range of vertical distribution and may as well grow at the sea level (Florin, 1963). The habit, habitat and present day distribution of the modern equivalents of the fossil taxa of this assemblage have been presented in Table 1. To get a better idea of the composition of this assemblage, it should be interesting to examine their distribution in various forest types of India. Champion and Seth (1968) have classified the Indian forests into (i) wet-evergreen forest, (ii) semi-evergreen forest, (iii) moist deciduous forest, (iv) littoral or swamp forest, (v) dry

deciduous forest, (vi) thorn forest, and (vii) dry evergreen forest.

The wet evergreen forests are composed of almost entirely evergreen species, in the semi-evergreen forests the dominant elements include deciduous species also, but the evergreens predominate. The comparable modern taxa of this fossil assemblage (Table 1) are distributed in the following forest types:

Evergreen to semi-evergreen forest	—*Araucaria/Agathis, Podocarpus, Musa, Cocos, Elaeocarpus, Ailanthus malabarica, Leea* sp., *Tetrameles nudiflora*
Dry deciduous forest	—*Phoenix, Grewia, Boswellia serrata, Mallotus phillipensis.*

Of the remaining forms, *Syzygium cumini* and *Barringtonia* are evergreen trees usually found on the banks of the streams and *Sonneratia* and *Nipa* are the genera of mangrove habitat. In addition, *Aeschynomene*, a genus of fresh water swamps, and aquatic angiosperms (Nymphaeaceae) can also be recognized in the assemblage. An overview of the assemblage indicates a depositional site at the mouth of a river (delta) in the near vicinity of sea. The assemblage is dominated by evergreen forms with some dry deciduous elements which might have been growing on the upland area.

With this background, the scene depicted in Plate 1 shows a portion of the vegetation near the mouth of a river just before merging with the sea. Taking into account the salinity tolerance of various mangrove taxa, *Sonneratia* has been shown nearest to the sea followed by *Nipa* and *Barringtonia*. *Syzygium cumini* which usually prefers water courses, has been shown accordingly. A cluster of the coastal palm *Cocos* can be recognized near the sea shore and *Phoenix* on the dry upland. Towards the left side of the picture a portion of a pond with Nymphaeaceae has been shown with a thicket of *Musa* nearby. Such ponds must have provided suitable environment for the growth of fresh water algae, water ferns and other aquatic angiosperms. The arborescent forms which can be identified in the illustration are the giant tree *Tretrameles nudiflora* with plank buttresses, *Ailanthus* which is a medium-sized tree with dropping compound leaves and *Boswellia* on the dry upland. *Podocarpus* and Araucariaceae have been shown in the left upper corner at some distance from the mouth of the river.

Area around Mandla

During the past 15 years, significant contributions have been made on the Deccan Intertrappean flora of this area. The fossiliferous localities are Parapani, Samnapur, Mohgaon and Umaria and Ghughua near Shahpura. The last two localities are especially rich in fossils providing major information. A list of the plant taxa so far described from all these localities has recently been published by Bande *et al.* (1988). Although silicified woods are of common occurrence, fruits showing affinities with those of *Drypetes* and the branched palm *Hyphaene* have also been described.

Compared to the Nagpur-Chhindwara assemblage, the Mandla assemblage is more uniform in nature dominated by arborescent species. The assemblage is exclusively angiospermous where palms and dicotyledons occur in equal frequency. The modern genera which have been identified in the assemblage are *Hyphaene, Chrysalidocarpus, Licuala, Arenga, Polyalthia, Homalium, Hydnocarpus, Garcinia, Sterculia, Grewia, Echinocarpus, Atalantia-Limonia, Bursera, Canarium, Gomphandra* syn. *Stemonurus, Heynea, Aglaia, Walsura, Dracontomelum, Lophopetalum, Syzygium, Eucalyptus, Tristania, Sonneratia, Bischofia, Drypetes* syn. *Putranjiva* and *Artocarpus*. The extant species of most of these genera comparable to the fossil taxa of this assemblage are found in the evergreen to semi-evergreen forests of India (Table 2). The comparable species of *Lophopetalum, Syzygium, Bischofia* and *Barringtonia* are evergreen trees usually growing on the banks of the streams. The assemblage is dominated by evergreen to semi-evergreen species.

An analysis of the habit and habitat of the modern equivalents of this assemblage (Table 2) indicates that the forest was constituted by water-loving forms, like *Syzygium, Drypetes/Putranjiva* 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, Aglaia* 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. While most of the palms, e.g., *Chrysalidocarpus, Licuala* and *Arenga* must have constituted the understorey of the forest, the branched palm *Hyphaene* must have occupied an open area at the forest boundary. The presence of *Sonneratia* in the assemblage is indicative of

brackish water conditions, may be at some distance from the main forest.

Plate 2 shows a portion of the forest near its edge with a portion of sea at a distance in the left upper corner. The palm in the foreground forming two thickets with characteristic palmate leaves is *Licuala*. A few plants of *Chrysalidocarpus* can be seen on the left and also in the centre. A single plant of *Arenga* with large pinnate leaves has been shown growing near a large tree of *Sterculia*. A few plants of *Hyphaene* with characteristic dichotomous branching and palmate leaves can easily be marked out in the picture. The tree on the right hand with large fruits attached on its stem is obviously *Artocarpus*. Some other trees which can well be recognized are *Polyalthia, Syzygium* and *Drypetes*. The ground vegetation has been shown mostly constituted by a variety of palms.

CONCLUDING REMARKS

Reconstruction of past vegetation around any particular area, as attempted in this paper, provides an opportunity to study the present day ecology and plant cover of that area in comparison to the environmental conditions of the past and to ponder over the reasons for the change in environment that took place. Testimony of the intertrappean fossils has clearly indicated in central India (around Nagpur-Chhindwara and Mandla) the existence of a humid tropical climate with a uniform temperature throughout the year and annual rainfall above 2,000 mm per anum distributed over a prolong rainy season during the Palaeocene-Eocene period (Bande & Prakash, 1982). Compared to this, there is a considerable variation in the present annual range of daily maximum and minimum temperatures at Mandla, Chhindwara and Nagpur and the annual rainfall is also not more than 1,400 mm. Today, the area is covered by dry deciduous to moist deciduous forest unlike the evergreen to semi-evergreen forest of the past. The factors suggested to be responsible for the occurrence of a much different type of climate and plant cover during the Early Tertiary period were (i) position of the Indian Plate at the equator, (ii) presence of sea in the vicinity, and (iii) probable absence of Western Ghats as barriers in the path of the southwest monsoon currents. In due course of time the Indian Plate drifted toward the north, regression of sea occurred from central India and the Western Ghats came into existence cutting off the Deccan Plateau from the main onslaught of the monsoon currents (Bande & Prakash, 1982).

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