PALAEOCLIMATE AND PALAEOGEOGRAPHY OF CENTRAL INDIA DURING THE EARLY TERTIARY*

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ABSTRACT

An attempt has been made to reconstruct the early Tertiary palaeo-environments of Central India from the study of plant fossils known from the Deccan Intertrappean beds of Nagpur-Chhindwara and Mandla regions. This flora indicates a warm tropical climate with heavy rainfall, a long duration of rainy season and an uniform temperature throughout the year in the Deccan Trap country as against a comparatively dry, subtropical climate at the present time. Presence of such a humid climate may be attributed to the almost equatorial position of peninsular India and the sea shore conditons near Nagpur-Chhindwara area during the Palaeocene-Eocene times as shown by the fossils of *Cocos*, *Nypa*, *Sonneratia* and a marine alga *Peyssonnelia* in the Deccan Intertrappean beds of this region.

INTRODUCTION

One of the basic aims of palaeobotanical studies, especially on megafossils, is to reconstruct the past vegetation. Because any plant community is the result of interaction between the plants and surrounding environment, the vegetation of an area is a good indicator of its climate which is mainly governed by the position of a land-mass in relation to the equator in that particular period and the distribution of land and sea in that area. Besides, the distribution of neighbouring mountain chains also affects the climate. Thus, the above three factors are finally responsible for the annual rainfall, mean annual temperature and wind currents of that region. The palaeoecologist reads, from the fossil remains, the type of community which they represented, the climate which controlled the community and the topography which controlled the climate. Reconstruction of palaeoclimate becomes increasingly difficult beyond the Tertiary due to lack of similarity of plant fossils of those times with the present day forms; but from the beginning of the Tertiary Period such resonstructions become possible mainly due to the fact that these plant fossils can be compared and identified with the modern taxa. However, in case of early Tertiary floras only some broad conclusions can be drawn, as it is not always possible to compare the fossil plants with modern species. But such reconstructions become more and more accurate with the successive younger floras.

The Indian Tertiary floras are usually divided into two, viz. the Palaeogene and the Neogene floras. The most important flora of the Indian Palaeogene is the Deccan Intertrappean flora which has been of great interest to palaeobotanists, geologists and others all over the world since the beginning of nineteenth century. Many attempts have been made during these years to reconstruct the palaeovegetation, palaeogeography and the palaeoclimate of the Deccan Trap country during the early Tertiary times. Important contributions in this respect are by Sahni (1940), Lakhanpal (1970, 1973, 1974a), Prakash (1960, 1972), and Mahabale (1966, 1979). While attempting these reconstructions, the main emphasis was usually given on the plant fossil assemblages

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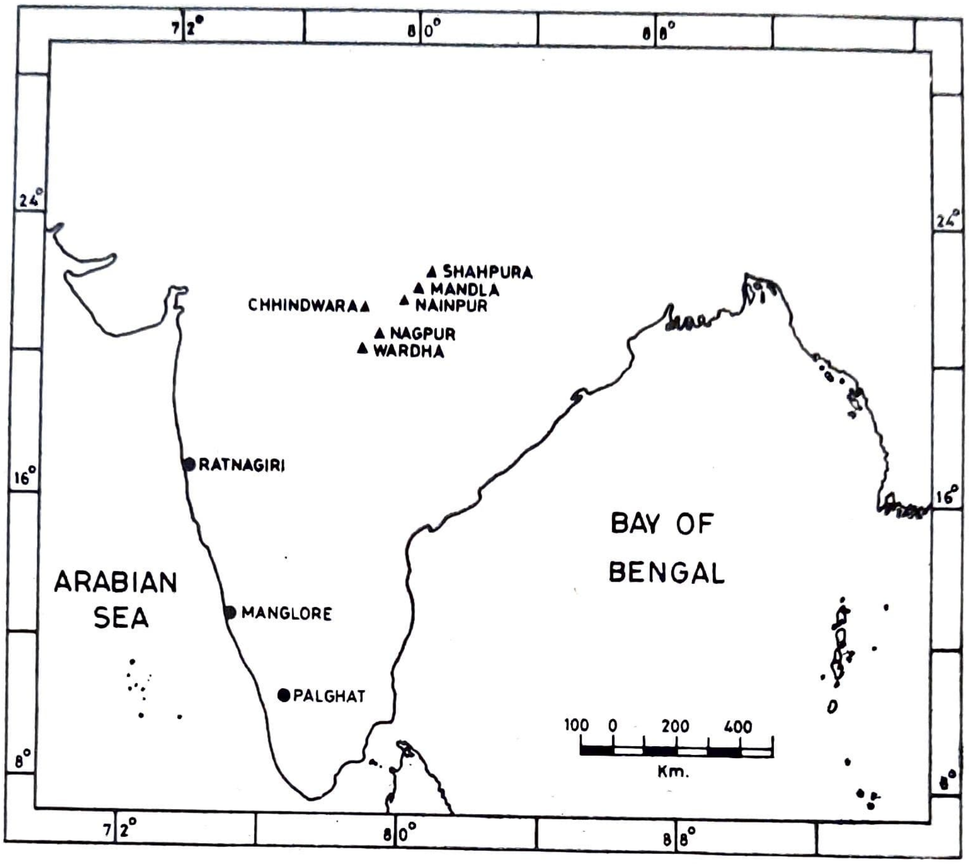
from the Rajahmundry and the Nagpur-Chhindwara regions. The Rajahmundry assemblage being mainly marine in nature, the conclusions were usually drawn on the basis of plant fossil assemblages occurring in Nagpur-Chhindwara region. However, during the last few years a good number of plant fossils have been described also from the Deccan Intertrappean beds of Mandla District in Madhya Pradesh (BANDE & KHATRI, 1980; BANDE & PRAKASH, 1982, 1982a) due to which it has become necessary to review the observations of the earlier workers in the light of these findings. Thus, while dealing with the palaeovegetation and palaeoclimate of Central India during the Deccan Intertrappean times, the flora has been broadly considered under following two assemblages:



Map 1—Map of peninsular India showing position of Nagpur-Chhindwara-Mandla area and comparable west coast localities.

(1) Nagpur-Chhindwara Assemblage
(2) Fossil Assemblage from Mandla District

(1) *Nagpur-Chhindwara Assemblage*

The flora of Nagpur-Chhindwara has attracted maximum attention of palaeobotanists working on the Deccan Intertrappean beds of India. There are a number of fossiliferous localities (like Mohgaonkalan, Keria, Mahurzari, Takli, Sausar, etc.) in this region and because many of the forms are common to these localities, the fossil flora of this region has been treated as a single assemblage. Most of the plant fossils described from this area have already been listed by PRAKASH (1960, 1972) and LAKHANPAL (1973). PRAKASH (1972, p. 193) has also given a detailed distribution of the modern comparable species of the fossil taxa described from these beds. Based on the fossil flora of this region both LAKHANPAL (1970, 1973, 1974a) and PRAKASH (1972) have successfully reconstructed the probable palaeoenvironment of this region. Without going into details, their conclusions can be summarised as follows :

There were sea-shore conditions as indicated by the occurrence of fossils similar to those of *Cocos*, *Nypa*, *Sonneratia*, etc. from this area. This conclusion is further supported by the recent finding of a marine alga *Peyssonnelia* from Mohgaonkalan by BANDE, PRAKASH AND BONDE (1981). The presence of marshy habitat with some lakes and ponds can also be visualized by the occurrence of fossils like *Enigmocarpon*, *Tricoccites* (which show presence of air spaces), *Aeschynomene* and the water ferns. There are many fossil species, the comparable modern forms of which are presently growing in moist places like Western Ghats, Ceylon, Assam, Meghalaya, Mizoram, Nagaland, Burma, etc. (as shown by PRAKASH, 1972, p. 193). These forms indicate the presence of an evergreen to semi-evergreen forest close to the sea-shore. However, the dry deciduous comparable forms of the fossils, like *Boswellia serrata* and *Mallotus philippinensis*, would appear to occupy low dry hills of the Deccan Traps further away from the watershed. In general, the flora indicates a typical tropical climate with more humidity than today. But the presence of the temperate genus *Sparganium* in Mohgaonkalan goes against this general nature of the flora. Probably this fossil deserves reinvestigation as regards its true affinities.

Recently, based on a single wrongly identified record of a so-called dipterocarpaceous fossil wood from Mahurzari, *Shoreoxylon mahurzarii* by PARADKAR (1972), both MEHER-HOMJI (1978) and MAHABALE (1979) have accepted the presence of Dipterocarpaceae in the Deccan Intertrappean flora of India. MAHABALE (1979, p. 206) has even suggested that "....in the early Deccan Intertrappean forests *Shorea* must be growing on a larger scale than *Tectona*". How Mahabale has deduced this conclusion is difficult to understand as no fossils of *Tectona* have so far been described from the Indian Tertiary, and the history of this genus is still an unsolved problem. Occurrence of Dipterocarpaceae in the Deccan Intertrappean flora also seems highly improbable as the Indian fossil record shows that this family is characteristic of Neogene age in India. Thus, before the presence of Dipterocarpaceae in the Indian Palaeogene is accepted, it is necessary to critically check the identification of the fossil form on which its presence is accepted in the Deccan Intertrappean flora. A study of the anatomical characters of *Shoreoxylon mahurzarii* (PARADKAR, 1972, pp. 19-25, pl. 1, figs. 1-6, text-figs. 1-5) clearly shows that it has been wrongly identified. The most important anatomical characters of Dipterocarpaceae are the presence of vasicentric tracheids and gum canals. As none of these features is present in the fossil wood described by PARADKAR (1972), it is obvious that the fossil does not belong to Dipterocarpaceae.

Geological history of Dipterocarpaceae has been discussed in detail by LAKHANPAL (1974). It is generally believed that this family originated in Western Malaysia and entered the Indian subcontinent during the middle Tertiary only after the Indian Plate joined the Asian Plate. So the presence of this family in the Deccan Intertrappean flora is highly improbable.

MEHER-HOMJI (1978, pp. 21, 22) has also accepted the presence of the extant genera *Machilus* and *Vitex* in the Deccan Intertrappean flora on the evidence of fossil genera *Machilusoxylon* (INGLE, 1974) and *Vitexoxylon* (INGLE, 1972), respectively. Affinity of *Machilusoxylon* with the modern wood of *Machilus* is doubtful as the fossil does not show the presence of oil cells, a characteristic feature of Lauraceae. Similarly, identification of *Vitexoxylon* has also been doubted by PRAKASH (1974, p. 134). Hence the presence of *Machilus* and *Vitex* in the Deccan Intertrappean flora should not be accepted till more evidence is available. MEHER-HOMJI (1978, p. 21) has also included some fossils, like *Oleoxylon* (PARADKAR & JOSHI, 1971) and *Perrottetioxylon* (CHITALEY, PATIL & HUNNARGIKAR, 1971) under the Deccan Intertrappean flora. Both these taxa are reported without a detailed description, photographs or text-figures. As it is difficult to ascertain their affinities, such taxa should not be taken into consideration while reconstructing the palaeovegetation and the palaeoclimate of the Deccan Intertrappean flora.

Beside the fossiliferous localities discussed above, one more locality in this area from where plant fossils have been described is Nawargaon in Wardha District of Maharashtra. The area lies about 50 km south-west of Nagpur and appears to be an extension of the Nagpur-Chhindwara assemblage. The fossils described from this area include both dicot woods and palms. Palms are represented by four species of *Palmoxylon*, important amongst which is *Palmoxylon livistonoides* (PRAKASH & AMBWANI, 1980) said to possess affinities with the extant genus *Livistona*. The latter is represented in India by a single species *L. jenkinsiana* which grows in the evergreen forests of Upper Assam, but most plentiful in the Nowgong District, Naga Hills and Lower hills, and outer valleys of Sikkim. However, *Palmoxylon livistonoides* has been shown to possess similarities with *Livistona chinensis* which is indigenous to China and Japan and not with *Livistona jenkinsiana*. As mentioned by PRAKASH AND AMBWANI (1980), it seems quite likely that a somewhat anatomically similar species of *Livistona* might have been growing in the Deccan Trap country during the Intertrappean times. The other important palm fossil described from this locality is *Palmocaulon hyphaeneoides* by SHETE AND KULKARNI (1980) showing nearest affinity to the extant palm genus *Hyphaene* which is represented in India by a single species *Hyphaene indica* restricted to the western coast.

The fossil dicot woods described from this locality are *Aristolochioxylon prakashii* KULKARNI & PATIL (1977), *Evodinium indicum*, *Amooroxylon deccannensis* and *Sonneratioxylon nawargaoensis* (BANDE & PRAKASH 1982) showing affinities with woods of Aristolochiaceae and the modern taxa *Evodia roxburghiana*, *Amoora rohituka—A. walichii*, and *Sonneratia* sp., respectively. *Evodia roxburghiana* is a small to medium-sized tree common in the hills of Southern India upto 2,150 m, Assam, Sibsagar, Nowgong, Khasi and Jaintia Hills at 1,200 m, and also in the forests of Tennasserim, the Andamans and Ceylon at 600-1,800 m from M. S. L. Both the species of *Amoora*, viz. *Amoora rohituka* and *A. walichii*, occur in the evergreen forests of north-east India. Lastly, the modern genus *Sonneratia* is a mangrove tree, four species of which occur in the coastal forests of India. The present day distribution of all these comparable species suggests that the climate near Nawargaon was much more humid during the Deccan Intertrappean period as compared to the present day.

(2) *Fossil Assemblage from Mandla District*

As mentioned earlier, a good number of fossils have now been described from the Deccan Intertrappean beds of Mandla District in Madhya Pradesh. Four fossiliferous localities have so far been discovered from this area, the relative positions of which have recently been given by BANDE AND PRAKASH (1982a). A list of fossil taxa so far described from this area alongwith the distribution of their modern comparable species is given in table 1. However, in this table only those forms have been included whose comparison with the modern taxa appears to be correct. A study of the above table clearly indicates that most of the species represented in this fossil assemblage do not occur now-a-days in Mandla region. Rather, they are presently distributed in the more moist forests of Western Ghats and north-east India.

With the above mentioned palaeobotanical data available from the various Deccan Intertrappean assemblages of Central India it may be interesting to reconstruct the past climate of these areas and compare it with their present day climate. The climatological data which has been compared includes details regarding month-wise mean of daily maximum and minimum temperature, month-wise mean of rainfall and the number of rainy days per year. This data has been taken from the Climatological Tables of the Observatories published by Indian Meteorological Department. Thus, climatological details from Nagpur, Chhindwara and Mandla were readily available, and they have been reproduced here in tables 2, 3 and 4, respectively.

For a reconstruction of the early Tertiary climate of Central India the next logical step is to select a few representative localities where modern plant assemblages similar to the fossil are found. The climatological details of these localities can be considered to indicate the past climate of the fossiliferous area. The past and the present climatological data from these areas can then be compared so as to understand changes in the climate of the fossiliferous area and also to visualize the probable reasons for these changes.

A look at the modern distribution of the comparable extant species of Nagpur-Chhindwara-Nawargaon and Mandla assemblages indicates that most of these forms are now-a-days distributed in the wet evergreen to semi-evergreen forests of the Konkan and those of the Western Ghats (COOKE, 1958) in Karnataka. In the Mandla assemblage the modern species thus represented are: *Hyphaene indica*, *Homalium zeylanicum*, *Hydnocarpus wightiana*, *Garcinia xanthochymus*, *Sterculia foetida*, *S. guttata*, *Grewia laevigata*, *Atalantia monophylla*, *Limonia acidissima*, *Gomphandra tetrandra*, *Gomphandra polymorpha*, *Heynea trijuga*, *Barringtonia acutangula*, *Bischofia javanica* and *Syzygium cumini*. *Bursera serrata* although not represented in the modern flora of these areas is known to occur in the eastern moist zone of Bengal, Assam, Orissa, Chittagong and tropical forests of Upper and Lower Burma and in Rajahmahal hills, extending to Eastern Ghats especially in valleys and along the water cources. Similarly, *Polyalthia simiarum*, also an evergreen tree, inhabits the moist forests of Orissa, Mayurbhanj, in the lower hill forests of North Bengal, Assam, Chittagong hill tracks and Burma. Another comparable modern species *Dracontomelum mangiferum* is now restricted to the Andaman and Nicobar Islands and Burma. However, this species has been described from the Neogene localities of the Siwaliks and West Bengal (PRAKASH, 1979 ; GHOSH & ROY, 1979), thus indicating that it was well represented in India in the past but has become restricted to Burma and Andaman-Nicobar Islands due to changes in the climatic conditions.

In the Nagpur-Chhindwara-Nawargaon assemblage, the modern comparable taxa which occur in the wet evergreen forests of Konkan and Western Ghats are *Musa* sp., *Sonneratia apetala*, *Elaeocarpus ferrugineus*, *Ailanthus malabarica*, *Barringtonia acutangula*, *Tetrameles nudiflora*, *Amoora rohituka* and *Evodia roxburghiana*. Thus it appears that the fossil assemblages of Nagpur-Chhindwara-Nawargaon area and the Mandla District suggest a forest type in Central India comparable to the one found today in the Konkan and the Western Ghats. However, the Mandla assemblage shows a greater percentage of evergreen species than the Nagpur-Chhindwara-Nawargaon assemblage.

Table 1—Distribution of modern comparable species of fossil taxa from the Deccan Intertrappean beds of Mandla District

Fossil Species	Modern comparable species	Habit and distribution in Indian region
PALMAE		
Hyphaeneocarpon indicum Bande, Prakash, & Ambwani, 1982	Probably *Hyphaene indica*	A branched palm distributed all along the western coast upto Goa.
ANONACEAE		
Polyalthioxylon parapaniense Bande, 1973	*Polyalthia simiarum*	An evergreen tall tree in the moist forests of Orissa, Mayurbhanj, in lower hill forests of North Bengal, Assam, Cittagong hill tracks and Burma.
FLACOURTIACEAE		
Homalioxylon mandlaense Bande, 1974	*Homalium tomentosum* & *Homalium zeylanicum*	*H. tomentosum*—A large deciduous tree common in Upper and Lower Burma, and scattered in Chittagong and in the Ganjam District of Tamilnadu. *H. zeylanicum*—In the evergreen forests of Western Ghats.
Hydnocarpoxylon indicum Bande & Khatri, 1980	*Hydnocarpus alpina* & *H. wightiana*	*H. alpina*—A small to medium-sized tree growing in the hill forests of Western Ghats from South Kanara to Travancore upto 1,800 m, also in the low hills of Ceylon. *H. wightiana*—A moderate-sized tree common along the Western Ghats from Konkan southwards ascending to 600 m, also below the Ghats in Malabar and Kanara.
GUTTIFERAE		
Garcinioxylon tertiarum Bande & Khatri, 1980	*Garcinia cowa* & *G. xanthochymus*	*G. cowa*—A large tree growing in Assam ascending to 900 m, Chittagong, Andamans and Burma, rarely found in North Bengal, Bihar, and Orissa. Also in the Nilgiris and elsewhere in the Peninsula. *G. xanthochymus*—A moderate-sized tree growing in North Bengal up to 1500 m, evergreen forests of Assam, Chittagong, Burma, Andamans, Orissa, Andhra Pradesh, Western Ghats from North Kanara southward.
STERCULIACEAE		
Sterculioxylon deccanensis Lakhanpal, Prakash & Bande, 1979	*Sterculia foetida* & *S. angustifolia*	*S. foetida*—A large deciduous tree on the west coast at low elevations from Konkan southwards, Ceylon and Martaban and Upper Tenasserim in Burma. *S. angustifolia*—A small to medium-sized tree found in Lower Burma from Martaban to Tenasserim.
Sterculioxylon shahpurensis Bande & Prakash, 1980, 1982a	*Sterculia foetida*, *S. guttata* & *S. campanulata*	*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

Fossil Species	Modern comparable species	Habit and distribution in Indian region
		S. campanulata—A large tree found in Lower Burma from Mertaban to Margui, Tenasserim and Andamans.
TILIACEAE		
Grewioxylon sp. cf. *G. mahurzariense* Lakhanpal, Prakash & Bande, 1979	*Grewia laevigata*	A small to medium-sized tree found in the outer Himalayas from the Jamuna eastwards to Bengal, in Chittagong, Assam, central and southern India, the Andamans and Burma, ascending upto 900 m.
ELAEOCARPACEAE		
Elaeocarpoxylon mandlaensis Lakhanpal, Prakash & Bande, 1979	*Echinocarpus sigun* & *Echinocarpus assamicus*	*E. sigun*—A large tree growing in Khasi hills and Burma at elevations from 900-1500 m.
		E. assamicus—A large tree occuring more or less gregariously on river banks throughout Assam, also in Sikkim.
RUTACEAE		
Atalantioxylon indicum Lakhanpal, Prakash & Bande, 1979	*Atalantia monophyla* & *Limonia acidissima*	*A. monophylla*—A small evergreen tree found throughout the mountain regions of South India, Bihar, Orissa, Assam and Ceylon, extending to the Andamans and Burma. *L. acidissima*—A small tree growing in the sub-Himalayan tract from Ravi eastwards ascending to 12,00 m throughout the dry hill forests of Punjab, Uttar Pradesh, Maharashtra, Karnataka, Tamil Nadu, Andhra and Upper Burma.
BURSERACEAE		
Burseroxylon preserratum Prakash & Tripathi, Bande & Prakash, 1982a	*Bursera serrata*	A tree of eastern moist zone of Bengal, Assam, Orissa, Chittagong and tropical forests of Upper and Lower Burma, in Rajmahal hills, extending to Eastern Ghats especially in valleys and along water courses.
ICACINACEAE		
Gomphandroxylon samnapurensis Bande & Khatri, 1980	*Gomphandra tentrandra*	A large shrub or small tree growing in the Western Ghats from North Kanara southwards, Nilgiris and Anamalais upto 1,800 m elevation, also in Ceylon.
MELIACEAE		
Heyneoxylon tertiarum Bande & Prakash, 1980, 1982a	*Heynea trijuga*	A small tree found in sub Himalayan tract upto 1500 m from Kumaon eastwards to North Bengal. Plain and Hill forests of Assam. Eastern Ghats, Western Ghats, Burma, Southern China, Thailand, Malay Peninsula and Sumatra.
ANACARDIACEAE		
Dracontomelumoxylon mangiferumoides Ghosh & Roy, Bande & Khatri, 1980, Bande & Prakash, 1982a	*Dracontomelum mangiferum*	A tall evergreen tree common especially in damp places along the streams in the Andaman and Nicobar Islands. In Burma found in Myitkiyana, Katha and Mergui.

Table 1—(*Contd.*)

Fossil Species	Modern comparable species	Habit and distribution in Indian region
MYRTACEAE		
Syzigioxylon mandlaense Ingle, 1972a	*Syzigium cumini*	A tree growing throughout India.
LECYTHIDACEAE		
Barringtonioxylon mandlaensis Bande & Khatri, 1980	*Barringtonia acutangula* & *B. pterocarpa*	*B. acutangula*—a middle-sized evergreen tree found in sub-Himalayan tract from the Ganges eastwards, Bengal, Central India, the Peninsula and Burma, chiefly on banks of streams and in moist places. *B. pterocarpa*-an evergreen tree found in Pegu and Martaban in Burma.
EUPHORBIACEAE		
Bischofinium deccanii Bande, 1974	*Bischofia javanica*	A large deciduous tree found in the sub-Himalayan forests and outer hills, from Jamuna eastwards, ascending to 4,000 ft in Chhota Nagpur, Western Peninsula, Assam, Chittagong, Upper and Lower Burma. Chiefl in shady ravines and on the banks of the streams.

In order to get a more clear idea of the climate in Central India during the Deccan Intertrappean times it is now desired to compare the climatological details of Mandla, Chhindwara and Nagpur with those from some representative places of Konkan and the Western Ghats. Three such places, viz. Ratnagiri, Mangalore and Palghat have been selected for this purpose and the details of temperature and rainfall from these places have been reproduced in tables 5, 6 and 7. A comparison between the rainfall and temperature of these west coast localities and the fossiliferous area brings out some interesting conclusions.

The most important observation is the difference in the past and the present annual rainfall. At Ratnagiri and Mangalore, the annual rainfall is more than 3,000 mm and at Palghat it is about 2,000 mm (Tables 5-7). Compared to this the annual rainfall at Chhindwara and Nagpur is much less being about 1,100 mm and at Mandla it is about 1,400 mm (Tables 2-4). The number of rainy days per year in the above west coast localities are much more as compared to those at the fossiliferous areas. The number of rainy days per year are 101 at Ratnagiri, 122 at Mangalore and 107 at Palghat. Compared to this the number of rainy days per year at Mandla, Chhindwara and Nagpur are 73, 62, and 60 respectively. Similarly the number of months with nearly 100 mm or more of rainfall per month is much more in the west coast localities than at the fossiliferous areas. At Palghat the monthly rainfall is more than 100 mm in eight months of a year (Table 7), at Mangalore 100 mm or more rainfall per month occurs in six months of a year (Table 6) and at Ratnagiri the rainfall is more than 100 mm per month in five months of a year (Table 5). Comparatively at Mandla, Chhindwara and Nagpur the rainy season is restricted to only four months of a year when the monthly rainfall is more than 100 mm. The above comparison indicates a much longer duration of rainy season in Central India during the Intertrappean times as compared to today.

Table 2—Climatological data from Nagpur

Place—Nagpur	Lat. 21°06′N	Long. 79°03′E Height above M.S.L. 310 m		
Month	Air temperature		Rain fall	
	Daily max.°C	Daily min.°C	Monthly total mm	No. of rainy days
January	28.6	12.7	15.14	1.3
February	32..5	15.1	1.9	0.4
March	36.4	19.1	24.5	2.0
April	39.7	23.9	20.2	1.9
May	42.8	28.4	9.9	0.6
June	38.4	26.9	174.3	8.2
July	31.2	24.0	351.5	16.9
August	30.4	23.7	277.1	14.0
September	31.5	23.1	180.5	10.6
October	31.9	20.0	61.6	4.1
November	29.9	14.1	8.7	0.4
December	28.7	12.1	1.7	0.1
Annual total or mean	33.5	20.3	1127.3	60.5

Table 3—Climatological data from Chhindwara

Place—Chhindwara	Lat. 22°06′N Long. 79°E	Height above M.S.L. 685 m		
Month	Air temperature		Rainfall	
	Daily max.°C	Daily min.°C	Monthly total mm	No. of rainy days
January	25.5	10.6	23.2	1.8
February	29.0	12.8	1.7	0.3
March	32.9	17.0	12.9	1.8
April	36.4	21.9	12.5	1.3
May	39.4	26.1	13.3	1.1
June	35.2	24.9	146.4	9.4
July	28.4	22.4	319.4	16.6
August	27.7	21.9	283.3	14.4
September	29.0	21.3	188.3	11.0
October	29.3	17.7	69.1	4.3
November	27.7	11.8	21.5	0.3
December	26.3	9.8	2.5	0.3
Annual total or mean	30.6	18.2	1094.1	62.6

Table 4—Climatological data from Mandla

Place—Mandla	Lat. 22°35′N Long. 80°22′E Height above M.S.L. 443 m			
Month	Air temperature		Rainfall	
	Daily max.°C	Daily min.°C	Monthly total mm	No. of rainy days
January	26.0	8.8	28.7	2.7
February	29.3	10.1	15.3	1.7
March	3.7	14.1	27.6	2.1
April	37.9	19.1	13.9	1.9
May	41.3	24.3	7.7	0.9
June	37.5	25.3	131.7	8.7
July	30.1	23.3	480.4	20.2
August	29.2	23.1	419.5	18.9
September	30.2	22.3	213.7	11.6
October	30.5	17.6	70.6	3.9
November	28.1	9.9	8.7	0.2
December	26.6	7.8	2.8	0.3
Annual total of mean	31.7	17.1	1420.6	73.1

Table 5—Climatological data from Ratnagiri

Place—Ratnagiri	Lat. 16°59′N Long. 73°20′E Height above M.S.L. 35 m			
Month	Air temperature		Rainfall	
	Daily max.°C	Daily min.°C	Monthly total mm	No. of rainy days
January	30.9	19.4	0	0
February	30.7	19.8	0	0
March	31.4	22.6	0	0
April	32.1	25.6	2.6	0.2
May	32.7	26.8	31.7	3.1
June	30.5	25.2	915.7	19.5
July	28.6	24.7	969.1	27.4
August	28.3	24.1	661.0	25.7
September	29.1	23.8	238.6	15.8
October	30.8	23.6	169.3	7.3
November	32.4	21.4	33.7	1.8
December	32.0	20.0	1.5	0.1
Annual total of mean	30.8	23.1	3023.2	101.1

Table 6—Climatological data from Mangalore

Place—Mangalore	Lat. 12°52′N	Long. 74°51′E	Height above	M.S.L. 22m
Month	Air temperature		Rainfall	
	Daily max.°C	Daily min.°C	Monthly total mm	No. of rainy days
January	31.4	21.7	4.7	0.3
February	31.1	22.8	1.9	0.1
March	31.7	24.5	8.9	0.5
April	32.4	26.1	40.0	2.3
May	32.1	26.0	232.7	8.8
June	29.4	23.9	981.6	25.0
July	28.5	23.5	1058.6	28.7
August	28.5	23.6	576.9	24.3
September	28.7	23.5	267.0	16.5
October	29.8	23.8	205.9	10.5
November	31.1	23.2	70.6	4.6
December	31.7	21.9	18.2	1.1
Annual total or mean	30.5	23.7	3467.0	122.7

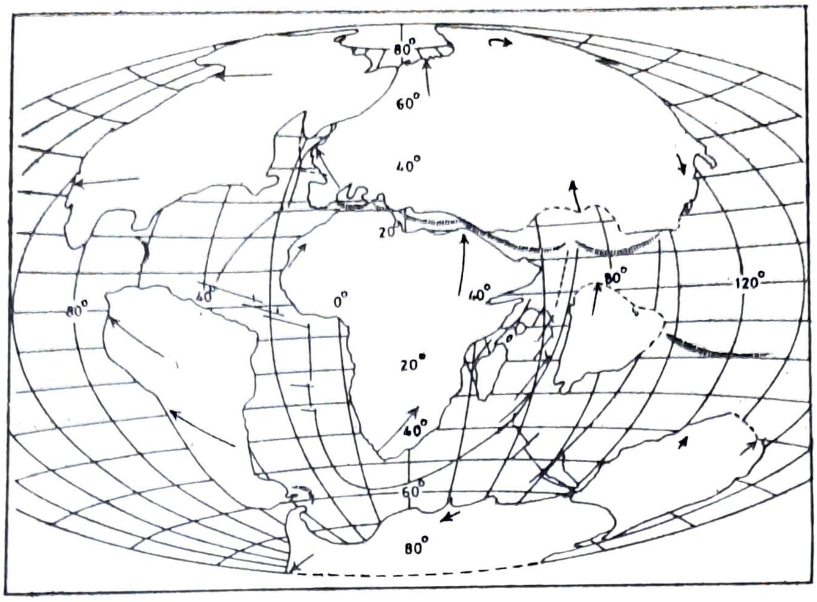
Table 7—Climatological data from Palghat

Place—Palghat	Lat. 10°46′N	Long. 76°39′E	Height above M.S.L. 97 m	
Month	Air temperature		Rainfall	
	Daily max.°C	Daily min.°C	Monthly total mm	No. of rainy days
January	33.5	22.3	3.8	0.3
February	35.7	23.0	5.5	0.6
March	37.4	24.5	17.2	1.5
April	36.0	25.3	106.7	5.6
May	33.4	24.8	192.3	9.4
June	29.3	23.3	414.1	20.7
July	28.1	22.6	546.2	21.0
August	28.8	23.1	274.1	18.4
September	30.3	23.1	125.5	10.4
October	30.7	23.4	242.8	12.7
November	31.8	23.0	112.0	6.3
December	32.1	22.2	18.4	1.0
Annual total or mean	32.3	23.4	2058.6	107.9

Another important observation is the range of variation in the daily minimum and maximum temperatures at the west coast localities as compared to the fossiliferous areas. A study of the temperature data from Ratnagiri, Mangalore and Palghat clearly indicates an almost uniform warm climate throughout the year with practically no winters. The range of daily maximum temperature throughout the year at Ratnagiri and Mangalore is 28°-33°C (Tables 5, 6) and at Palghat 28°-37.5°C (Table 7). Similarly the range of daily minimum temperature is 19°-27°C at Ratnagiri, 21°-26°C at Mangalore and 22°-26°C at Palghat. Compared to this there is much more variation in the annual range of daily maximum and minimum temperatures at Mandla, Chhindwara and Nagpur. At Mandla the daily maximum temperature ranges from 26°-41.5°C and the daily minimum between 7° to 26°C with at least four months having daily minimum temperature around 10°C (Table 4). At Chhindwara the range of daily maximum temperature is 25° to 40°C and daily minimum 9° to 26°C (Table 3). Lastly, at Nagpur the range of daily maximum temperature is 28° to 43°C and daily minimum between 13° to 29°C (Table 2). The above comparison of the temperature data from the fossiliferous localities and the comparable modern areas clearly indicates that the climate in Central India during the Intertrappean times was much more uniform throughout the year with winters almost totally absent or very mild. This factor alongwith a much higher rainfall must have been responsible for the growth of a tropical evergreen forest very similar to the modern forests of the Konkan and Western Ghats during the Palaeocene-Eocene times in Central India. However, while Nagpur-Chhindwara-Nawargaon area is presently covered by a tropical, dry deciduous forest, a tropical moist deciduous forest occurs at Mandla today (CHAMPION & SETH, 1968).

Having reconstructed a humid tropical climate with an uniform temperature throughout the year and an annual rainfall above 2,000 mm per year in Central India during the Palaeocene-Eocene period, it is now desirable to search for an explanation for the occurrence of such a climate in this area and its subsequent change. Two factors must have been mainly responsible for this, viz., (*a*) the position of the Indian subcontinent during the late Cretaceous-early Eocene times, and (*b*) the distribution of land and sea in this area during this period. Considering the position of the Indian Plate during the late Cretaceous to early Tertiary times as indicated in the palaeogeographical maps given by various workers (DIETZ & HOLDEN, 1973 ; SEYFERT & SIRKIN, 1973; SCHÜSTER, 1972), it becomes quite evident that the Peninsular India was occupying a much southern latitudinal position at that time as compared to today (Map 2). The Nagpur-Chhindwara-Mandla area which is presently located between about 21° to 23.5° north of equator was almost equatorial in position during the Palaeocene-Eocene times. This equatorial position of present day Central India must have been one of the main causes for the presence of a typical tropical climate in this area during the early Tertiary time.

Another factor which must have influenced the past climate was the presence of coastal environment in Central India during the Palaeocene-Eocene times. Based on the presence of fossils of coastal plants like *Cocos*, *Nypa*, *Sonneratia* etc. from Mohgaonkalan, LAKHANPAL (1970, 1974a) has envisaged the presence of an arm of Tethys sea in Central India during this period. This suggestion finds further support in the recent findings of a marine alga *Peyssonnelia* from Mohgaonkalan beds by BANDE, PRAKASH AND BONDE (1981). Thus the presence of a sea in the near vicinity alongwith the equatorial position of the Indian peninsula resulted in a much uniform warm humid tropical



Map 2—Map showing position of different continents at the end of the Cretaceous Period (From Dietz & Holden, 1973, p. 827).

climate in Central India during the Palaeocene-Eocene times. Yet another factor which also must have influenced the climate of this region is the formation of Western Ghats. With the elevation of these mountain chains in the post-trappean times the main land mass of the Deccan Plateau was cut off from the main onslaught of the south-west monsoon resulting in the decrease in rainfall in this area. Thus the withdrawl of sea from Central India, the northward drift of the Indian Plate, and the formation of Western Ghats in the post-trappean times were cumulatively responsible for the establishment of present day tropical, dry deciduous to moist deciduous vegetation in Central India as against a tropical, wet evergreen forest of the past.

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