A PRELIMINARY APPRAISAL OF THE TERTIARY MEGAFLORA OF KACHCHH DISTRICT, GUJARAT, WESTERN INDIA

R. N. LAKHANPAL & J. S. GULERIA

Birbal Sahni Institute of Palaeobotany, 53, University Road, Lucknow-226 007

ABSTRACT

As known at present the Tertiary megaflora of Kachchh in Gujarat consists of three florules : (i) Lower Eocene, (ii) Lower Miocene, and (iii) Pliocene. Collectively, it comprises 38 species of 26 genera, representing 10 dicot families, 2 monocot families and one gymnosperm. There are indications of the African and Arabian elements occurring along with the Indian in the Tertiary flora of Kachchh.

In the light of distribution of their modern comparable forms, all the components of the Tertiary flora of Kachchh are tropical. Because of the occurrence of moist evergreen as well as deciduous taxa, the flora can be placed under the category of "moist tropical semi-evergreen to deciduous forests". The environment of deposition seems to have been mainly lacustrine and fluviatile. The overall vegetation of Kachchh during the Tertiary period was more luxuriant than the scrubby vegetation there today. Obviously the present xeric conditions are a result of post-Pliocene changes in the climate in this area. Even during the Teritiary, there were periodic changes in the climate. Starting from moist during the early Eocene, it became comparatively drier during the early Miocene, and again became moist towards the end of Miocene.

INTRODUCTION

In a recent paper (LAKHANPAL & GULERIA, 1981) we referred to all the known publications on the Tertiary plant fossils of *Kachchh. Since then, a few more papers have come out (AWASTHI *et al.*, 1982; LAKHANPAL & GULERIA, 1982) and some are expected shortly (GULERIA, in press, a & b). The published record shows that although considerable work has been done on the plant microfossils leading to stratigraphic conclusions, comparatively much less information is available about the megafossils. Nevertheless, a stage has come when it is possible to draw some conclusions regarding the Tertiary palaeoecology and phytogeography of the Kachchh area based on the collective evidence of the hitherto known plant megafossils. The same are being discussed in the present paper.

AVAILABLE DATA

Physiography and Climate of the Area—District Kachchh, which forms the northwestern part of the Gujarat State, lies between Lat. 22° 44′—24°42′ N and Long. 68°08′—71° 46′ E (see Map—1). The district consists of Kachchh main land, Wagad highland and four detached islands, viz. Patcham, Khadir, Bela and Chorar. The total area of the district is 45, 652 sq km. It consists mainly of flat dry land whose monotony is broken by ranges of elevated ridges comprising scattered naked hills and isolated hillocks besides valleys, rivers, nalas and tracts of pasture land. Amongst the dominant physiographic features of regional importance, are the three east-west trending anticlinal ridges. The other important landmarks of the area are the traps extending from near Panan-

*In the earlier literature spelt as Cutch or Kutch.

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dhro in the West to Anjar in the east in the form of several flat-topped hillocks separating the northern hilly tract from the southern coastal plain.

The east-west running central hill ranges do not exceed a height of 300 metres and are not capable of supporting a permanent river system. The entire area is exclusively dependant on seasonal rains. Lying beyond the course of south-west monsoon it falls in the zone of scanty rainfall. The streams and nalas flow only during rains. For the greater part of the year the climatic conditions in Kachchh remain dry. The average annual rainfall is about 35 cm, of which about 90 per cent precipitates between June and September. The annual average temperature ranges between 20°C and 33°C. (Climatological Tables of Observatories in India, 1931-1960). These circumstances have a great influence on the character of the local vegetation.

Present Vegetation—The most striking feature of Kachchh is the barrenness of the country. Its flora has a predominantly xerophytic character. PALIN (1880) was perhaps the first person to give a list of plants of the Kachchh District. It was BLATTER (1908, 1909) who first studied the flora in detail and enumerated 431 species belonging to 81 families. Later THAKAR (1926) described 508 species belonging to 71 families, including some exotics also. In 1954, KAPADIA added about a dozen grass species to this flora. PURI AND JAIN (1958) and PURI *et al.* (1959) prepared a comprehensive flora of this area and listed 640 species belonging to 363 genera distributed amongst 93 families, including all indigenous species and those exotics which are now well established. The ten dominant families referred to are Leguminosae, Gramineae, Compositae, Malvaceae, Convolvulaceae, Euphorbiaceae, Cyperaceae, Acanthaceae, Amaranthaceae and Cucurbitaceae. Further additions to the flora of Kachchh have been made by JAIN (1960), JAIN AND DESHPANDE (1960), JAIN AND KANODIA (1960), DESHPANDE (1961), and BHANDARI (1965).

Phytogeographically Kachchh is very significant as it is the meeting ground for the arid African and Arabian elements with those of India (BHARUCHA & MEHER-HOMJI, 1965; CHATTERJEE, 1940, 1962; PURI, 1960; LEGRIS, 1963; MAHABALE, 1966). The flora of Kachchh shows resemblance with that of Sind as well as of Gujarat, though the affinities with the former are more pronounced. BLATTER (1909) has pointed out that out of 345 species, about 200 are common with those of Sind and 160 with those of Gujarat. It is interesting to observe that more and more plants reported from Sind are now being found in Kachchh and many of them do not extend east of Kachchh.

The thorny scrub jungle forms the dominant vegetation of Kachchh. It is composed of *Acacia nilotica* (L.) Willd. ex Del. ssp. *indica* (Benth.) Brenan (Syn. *A. arabica* Willd.), *A. leucophloea* Willd., *A. senegal* Willd., *Balanites aegyptica* Delile, *Calotropis gigantea* R. Br., *Capparis decidua* Edgew., *C. grandis* L. f., *Cassia auriculata* Linn., *Commiphora mukul* Engl., *Euphorbia neriifolia* Linn., *E. tirucalli* Linn., *Grewia flavescens* Juss., *G. tenax* Fiori, *G. villosa* Willd., *Indigofera* spp., *Mimosa hamata* Willd., *Premna resinosa* Schau., *Zizyphus mauratiana* Lam., *Z. nummularia* (Buran. f.) W. & A.

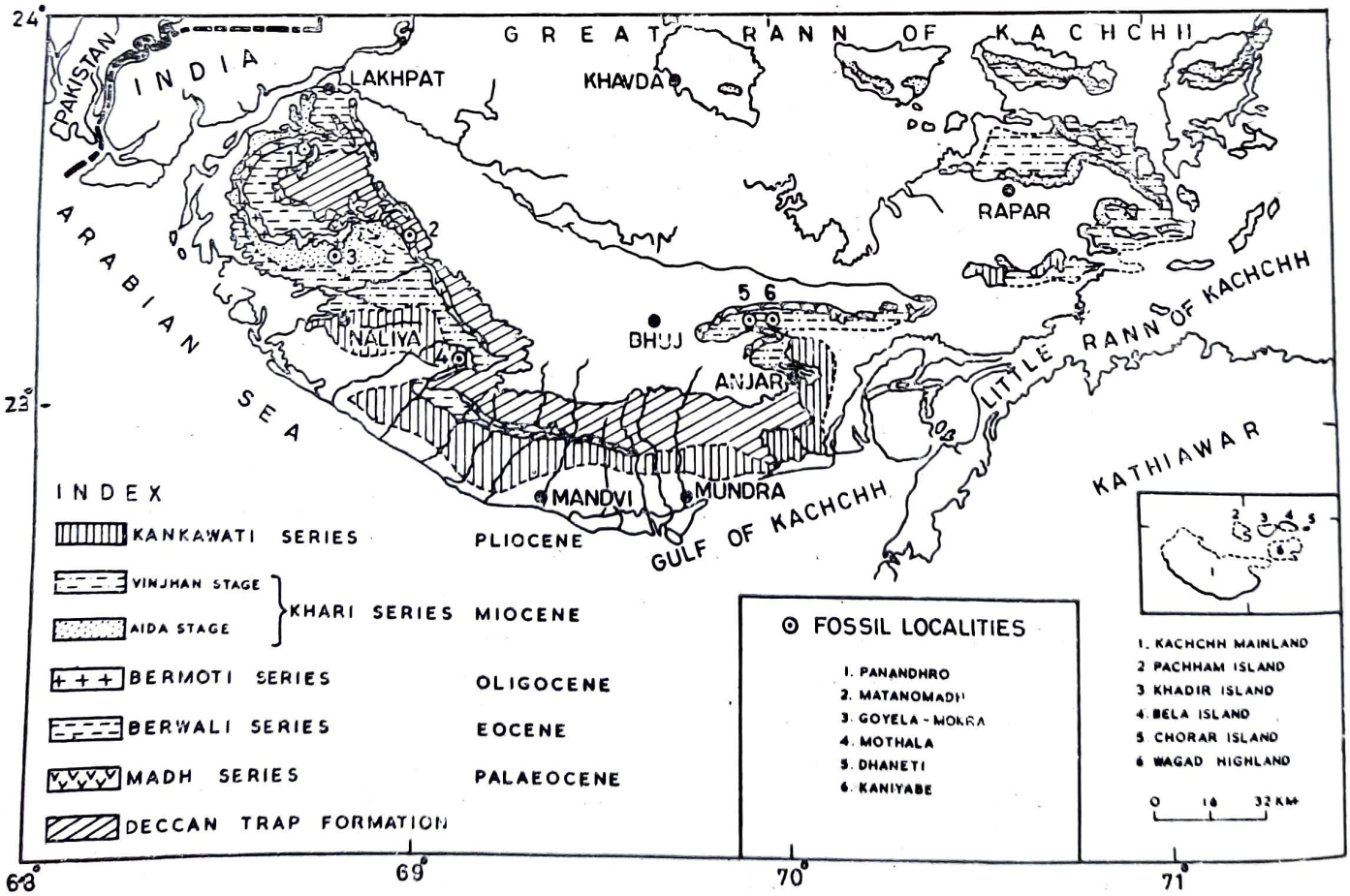
In the protected and moister situations, such as valleys of the hills at Dhinodhar, Kala Dungar and Motadhola, the vegetation tends to develop into good deciduous tracts which resemble the typical dry deciduous forests of Deccan traps, with such species as *Bauhinia racemosa* Lam., *Cordia dichotoma* Forst. f., *C. myxa* Linn., *C. rothii* Roem. & Schult., *Ehretia laevis* Roxb., *Ficus* sp., *Gymnosporia montana* Benth., *Lannea coromandelica* Merr., *Lawsonia inermis* Linn., *Moringa oleifera* Lam., *Odina wodier* Roxb., *Salmalia malabarica* Schott. & Endl., *Sterculia urens* Roxb. and *Vitis trifolia* Linn.

Rocky habitat with poor shallow soil and waste lands, is colonized by abun-

dant growth of *Cassia* spp. Dense colonies of *Echinops echinatus* Roxb. occur in freshly exposed hard rocky soils along the railway lines. The climbers in the area are few, such as *Abrus precatorius* Linn., *Cardiospermum halicacabum* Linn., *Cissus quadrangularis* Linn., *Clitoria ternatea* Linn., *Cocculus hirsutus* Diels., *C. pendulus* Diels., *Daemia extensa* R. Br., *Ipomoea pilosa* Sweet and *Tragia* sp. The saline tracts and the riverain areas have sparse scrub forests of *Calotropis procera* R. Br., *Salvadora oleoides* Decne., *S. persica* Wall., and *Tamarix* spp.

There is paucity of aquatic plants because there are very few fresh water habitats. *Typha angustata* Bory & Chaub. is the conspicuous plant in the marshy areas. Mangroves occur all along the coast, mostly poor and disturbed. *Avicennia alba* Bl. is the commonest mangrove plant. The other mangrove trees are *Aegiceras corniculatum* Blanco., *Avicennia officinalis* Linn., *Bruguiera conjugata* Merr., *Rhizophora candelaria* DC., and *R. mucronata* Lam. The scrubs and prostrate herbs include *Cressa cretica* Linn., *Haloxylon recurvum* Bunge., *Juncus maritimus* Lam., *Salicornia brachiata* Miq., *Salsola foetida* Del., *S. fruticosa* Linn., *Suaeda nudiflora* Moq. and *Urochondra setulosa* (Trin) Hubb. The sandy bank along sea-creeks have dense growth of *Asparagus dumosus* Baker, *Crotalaria burhia* Ham., *Aelurophus lagopoides* (L.) Trin. ex. Thwaites, and several grasses. Some epiphytes and ground parasitic plants also grow in the area.

Tertiary Geology and Fossil Localities—The Tertiary of Kachchh is represented by a complete sequence from Palaeocene to Pliocene (see Map 1). It is best developed in south-western Kachchh where it attains a thickness of about 650 m (Biswas & Raju, 1973) and has been the subject of detailed studies in recent years (for references please see Guleria, 1978). The sediments were deposited on the eroded surface of Deccan



Map 1. Map of Kachchh showing Tertiary formations and megafossil localities (based on Biswas & Deshpande, 1970).

Trap flows and the Mesozoic sedimentary rocks. The stratigraphical classification followed here is that of BISWAS AND RAJU (1973).

The fossils investigated have been collected from the Lower Eocene (Berwali Series) beds of Panandhro lignite mine; Lower Miocene (Khari Series) beds near Goyela—Mokra and *Pliocene beds (Kankawati Series) near Dhaneti, Kanaiyabe and Mothala (Map-1). In addition, leaf-impressions were also collected from the Palaeocene beds (Madh Series) around Matanomadh but being highly fragile and tuffaceous, they could not be worked out.

TERTIARY FLORULES: All the hitherto collected Tertiary plant megafossils of Kachchh can be grouped into 3 florules on the basis of their age, viz. (1) Lower Eocene florule of Panandhro; (2) Lower Miocene florule of Goyela-Mokra (Khari Nadi Bed) and (3) Pliocene florule of Dhaneti, Kanaiyabe and Mothala. The first two florules are represented by impressions and the third by petrifactions. All the three florules consist of a variety of fossil forms comparable to modern plants as listed below:

1. *Lower Eocene florule of Panandhro*

The Panandhro florule is based only on leaf-impressions (LAKHANPAL & GULERIA, 1981; GULERIA & LAKHANPAL, in press). It consists of 9 species, out of which 6 have been identified with 6 modern genera. The remaining three, which could not be identified with any modern genus but are decidedly dicotyledonous, have been placed under the form genus *Dicotylophyllum* Saporta. The composition of this florule is as follows:

FAMILY	FOSSIL TAXA	MODERN COMPARABLE TAXA
Combretaceae	*Terminalia panandhroensis*	*Terminalia crenulata* Heyne ex. Roth.
Myrtaceae	*Syzygium kachchhense*	*Syzygium* sp.
Lythraceae	*Lagerstroemia patelii*	*Lagerstroemia speciosa L.* Pers.
Lauraceae	*Cinnamomum eokachchhensis*	*Cinnamomum zeylanicum* Breyn
Moraceae	*Ficus kachchhensis*	*Ficus tomentosa* Roxb.
Incertae Sedis	*Dicotylophyllum cordatum*	Dicot.
	D. panandhroensis	Dicot.
	D. quadrinervatum	Dicot.
Pandanaceae	*Pandanus eocenicus*	*Pandanus diversus* John *P. furcatus* Roxb. *P. tectorius* Solander

2. *Lower Miocene florule of Goyela-Mokra (Khari Nadi Bed)*

This florule consists of impressions of leaves and a few fruits and seeds, belonging to 5 families, 10 genera and 11 species (LAKHANPAL & GULERIA, 1982) listed as below:

FAMILY	FOSSIL TAXA	MODERN COMPARABLE TAXA
Rutaceae	*Murraya khariensis*	*Murraya paniculata*(Linn.) Jack
Leguminosae	*Bauhinia kachchhensis*	*Bauhinia phoenicea* Heyne *B. purpurea* Linn.

*In Table 1, showing the stratigraphic classification of the Tertiary sediments of Kachchh, BISWAS AND RAJU (1973, p. 39) have given the age of Kankawati Series as Pliocene though on page 45 they have mentioned that "Probable Pliocene age is suggested" for Sandhan Formation which consists of Kankawati Series. Recently Dr. S. K. Biswas has communicated to one of us (J.S.G.) that fossil woods of the Kankawati Series may belong either to the lowermost Pliocene or the uppermost Miocene. However, we are referring them here to Pliocene according to the published record.

	Cassia miokachchhensis	*Cassia* sp.
	Leguminocarpon khariensis	Fruit cf. Leguminosae
	Leguminophyllum khariensis	Leaflets cf. Leguminosae
	Leguminosites khariensis	Seed cf. Leguminosae
	Millettia asymmetrica	*Millettia ovalifolia* Kurz
	M. miocenica	*M. auriculata* Baker *M. macrostachya* Coll. & Hemsl.
Lauraceae	*Cinnamomum miokachchhensis*	*Cinnamomum zeylanicum* Breyn.
Moraceae	*Ficus khariensis*	*Ficus infectoria* Roxb.
Palmae	*Palmacites khariensis*	Palm

3. *Pliocene florule of Dhaneti, Kanaiyabe and Mothala*

This florule consists entirely of petrified woods. They have been described by LAKHANPAL *et al.* (1975), AWASTHI *et al.* (1980, 1982) and GULERIA (in press, a, b). They belong to 7 families, 14 genera and 18 species as enumerated below :

FAMILY	FOSSIL TAXA	MODERN COMPARABLE TAXA
Podocarpaceae	*Podocarpoxylon kutchensis*	*Podocarpus wallichianus* C. Presl.
Dipterocarpaceae	*Dipterocarpoxylon malavii*	*Dipterocarpus dyeri* Pierre ex De Laness
	D. pondicherriense	*D. indicus* Bedd.
Sterculiaceae	*Pterospermoxylon kutchensis*	*Pterosperomum glabrescens* W.&A. *P. reticulatum* W. & A. *P. rubiginosum* Heyne
	Sterculinium kalagarhense	*Sterculia coccinea* Roxb. *S. oblonga* Mast *S. rhinopetala* K. Schum.
Sapindaceae	*Euphorioxylon indicum*	*Euphoria longana* Lamk.
	Schleicheroxylon kachchhensis	*Schleichera oleosa*(Lour.) Oken
Leguminosae	*Millettioxylon indicum*	*Millettia pendula* Benth. *M. prainii* Dunn *Pongamia pinnata* (Linn.) Pierre
	Pahudioxylon sahnii	*Afzelia-Intsia*
	P. assamicum	*Afzelia-Intsia*
	Cynometroxylon holdenii	*Cynometra polyandra* Roxb. *C. ramiflora* Linn.
	Isoberlinioxylon congoense	*Isoberlinia angolensis* (Welw.) Hoyle & Brenan *I. niembaensis* Duvingn
	Dialiumoxylon indicum	*Dialium* sp.
	Albizinium eolebbekianum	*Albizia lebbek* Benth.
	A. pondicherriensis	*Albizia amara* Boivin *A. odoratissima* Benth.
Combretaceae	*Terminalioxylon felixii*	*Terminalia arjuna* Bedd. *T. tomentosa* W. & A.
	T. burmense	*T. tomentosa* W. &. A.
Palmae	*Palmoxylon kachchhensis*	Palm

Palaeophytogeography—From the general survey of the meg flora it is seen that out of the known modern comparable genera, viz. *Afzelia-Intsia, Albizia, Bauhinia, Cassia, Cinnamomum, Cynometra, Dialium, Dipterocarpus, Euphoria, Ficus, Isoberlinia, Lagerstroemia, Millettia, Millettia-Pongamia, Murraya, Pandanus, Podocarpus, Pterospermum, Schleichera, Sterculia, Syzygium* and *Terminalia*, only *Bauhinia, Cassia, Ficus* and *Sterculia* are represented in the present day flora of Kachchh. These four genera are found in protected and limited places in Kachchh. It is obvious from the above data that the other genera were much wider in their distribution and extended up to Kachchh in the western part of the country during the Tertiary Period. Amongst these *Cinnamomum, Dipterocarpus, Euphoria, Murraya, Pterospermum, Schleichera, Isoberlinia* and *Podocarpus* are the important genera from the phytogeographical point of view. Out of them, the first six are primarily Indo-Malayan in distribution. *Isoberlinia* is restricted to Tropical Africa and *Podocarpus* is a relict southern hemisphere plant. It shows that the mixing of eastern and western elements had already taken place in India during the Tertiary and Kachchh had been the meeting ground particularly for the African and Arabian elements with the Indian.

On comparing the Kachchh mega-flora, specially the Pliocene florule, with the modern forest types of the neighbouring areas it can be observed that almost all the elements of the Pliocene florule are found south of Kachchh along the western coast. It seems that with the later deterioration in climatic conditions, this flourishing florule died down in Kachchh while its counterparts countinued southwards along the western coast of India.

Palaeoecology—In general, the composition of the Lower Eocene, Lower Miocene and Pliocene florules, considered in the light of distribution of their modern comparable forms, indicates a tropical climate in which these florules had flourished. CHAMPION AND SETH (1968, p. 54) have divided the tropical vegetation of India into the following 7 forest types on the basis of moisture conditions :

(i) Wet evergreen forests;
(ii) Semi-evergreen forests;
(iii) Moist deciduous forests;
(iv) Littoral and swamp forests;
(v) Dry deciduous forests;
(vi) Thorn forests;
(vii) Dry evergreen forests.

The modern equivalents of the Lower Eocene florule are distributed in the following types of tropical forests :

TAXA	TROPICAL FOREST TYPES						
	Wet evergreen forests	Semi evergreen forests	Moist deciduous forests	Littoral & swamp forests	Dry deciduous forests	Thorn forests	Dry evergreen forests
Cinnamomum zeylanicum	+	+					
Ficus tomentosa	+	+	+		+		
Lagerstroemia speciosa			+	+			
Pandanus diversus		+					
P. furcatus	+						
P. tectorius			+	+			
Syzygium sp.	+	+	+	+	+		+
Terminalia crenulata			+				

The modern comparable forms of the Lower Miocene elements are distributed in the following types of tropical forests :

TAXA	TROPICAL FOREST TYPES						
	Wet ever-green forests	Semi-ever-green forests	Moist deci-duous-forests	Littoral & swamp forests	Dry deci-duous forsets	Thorn forests	Dry ever-green forests
Bauhinia phoenicea	+						
B. purpurea	+	+	+				
Cinnamomum zeylanicum	+	+					
Cassia sp.			+		+	+	
Ficus infectoria			+		+		
Millettia auriculata			+		+		
M. ovalifolia					+		
Murraya paniculata		+	+		+		

The modern corresponding elements of the Pliocene florule are distributed in the following types of tropical forests :

TAXA	TROPICAL FOREST TYPES						
	Wet ever-green forests	Semi-ever-green forests	Moist deci-duous forests	Litto-ral & swamp forests	Dry deci-duous forests	Thorn foretsts	Dry ever-green forests
Afzelia bijuga				+			
Albizia amara					+	+	+
A. odoratissima			+		+	+	
A. lebbek	+	+	+		+		
Cynometra polyandra	+	+					
C. ramiflora				+			
Dialium sp.	+						
Dipterocarpus dyeri	+						
D. indicus	+						
Millettia pendula			+		+		
M. prainii			+				
Pongamia pinnata				+	+		
Euphoria longana	+						
Isoberlinia angolensis					+		
I. niembaensis							
Podocarpus wallichianus	+						
Pterospermum rubiginosum							
P. glabrescens	+	+					
P. reticulatum							
Schleichera oleosa	+	+	+		+		
Sterculia sp.	+	+	+				
Terminalia arjuna			+	+	+		
T. tomentosa		+	+		+		

From the foregoing account it is clear that the modern equivalents of fossil genera are not confined to a particular type of tropical forest in any of the three florules. Broadly speaking, the above noted floristic assemblages are climatically an admixture of evergreen to deciduous elements.

From the components of the Lower Eocene florule it is plausible to conclude that moist evergreen to deciduous vegetation was then prevalent around Panandhro. Further the littoral and swampy elements indicate the occurrence of marhses around this locality in which the vegetation got buried and in due course resulted in the formation of lignite.

Climatic conditions must have become less moist during the Lower Miocene as is indicated by the majority of elements of the Goyela-Mokra florule, which belong to moist deciduous to dry deciduous forests. This view is further substantiated by the smaller size of leaves and dominance of legumes. The semi-evergreen plants might have been growing in pockets.

It is important to note that the leaves of both Lower Eocene and Lower Miocene florules are entire-margined. The entire-margined leavesand leaf lets are predominantly found in arctic, alpine, xeric and tropical rainforest environments. The percentage decreases to near equality in the upland tropics and subtropical forests, while the leaves of temperate forests are mainly non-entire as has been pointed out by SINNOTT AND BAILEY (1915), BAILEY AND SINNOTT (1916), CHANEY AND SANBORN (1933) and WOLFE (1977). Thus on the basis of the morphology of leaves (which provides an additional tool to decipher the climatic conditions of the plants growing in a particular region) it can be safely concluded, keeping in view the vegetational complexes of the Lower Eocene and Lower Miocene florules, that they represent a tropical type of vegetation rather than arctic, alpine or xeric.

During Pliocene, conditions must have again become favourable for the growth of comparatively luxuriant vegetation. The occurrence of evergreen elements like *Dipterocarpus*, *Euphoria*, *Podocarpus* and *Pterospermum*, indicates hot and humid conditions with plenty of rainfall. Along with these are also moist deciduous forms like *Albizia*, *Millettia Schleichera* and *Terminalia*. Thus it seems that, in general, the prevalent vegetation might have been semi-evergreen to moist deciduous. Further, around the streams and ravines some marshy vegetation must also have existed as indicated by the littoral and swampy elements of this florule.

It is important to mention here that the ecological amplitude of *Podocarpus*, the largest genus of all the present day Conifer families, is considerable. The podocarps mostly occur in montane tropical forests, but a few also grow in lowland forests and even descend to sea level. Generally they do not form pure forests and are said to be found mixed with angiosperms in rich lowland tropical forests. Hence, the presence of *Podocarpus* in Kachchh in association with other evergreen elements is not at all surprising and is quite in accordance with its modern habitat.

In view of the occurrence of both moist evergreen as well as deciduous taxa, the Kachchh flora can be placed under the category of the "moist tropical semi-evergreen to deciduous forests".

Thus, in contrast to the dominant scrubby vegetation of today, the vegetation of Kachchh during the early Eocene, early Miocene and the Pliocene was much better and luxuriant. All this provides a strong evidence to the view that the present xeric conditions in this part of India is the result of post-Pliocene changes in the climatic conditions.

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