
Late Cenozoic plant-impressions from Mahuadanr Valley, Palamu District, Bihar

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Impressions of leaves, fruits and a flower have been described from the Late Cenozoic beds from near Mahuadanr, Palamu District, Bihar. The assemblage consists of 25 species belonging to 22 genera and 16 families of the dicotyledons. Family Asclepiadaceae and the genera *Spondias*, *Erythrina*, *Combretum*, *Mitragyna*, *Alstonia* and *Cryptolepis* have been described for the first time from the Cenozoic of India. The data have been used to decipher the palaeoecology and depositional environment of the region. A comparison of this flora with other Neogene floras of India has also been made.

Key-words—Megafossils, Plant-impressions, Dicotyledons, Late Cenozoic, India.

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सारांश

बिहार में पलामु जनपद में महुआडाँड़ घाटी से अनंतिम नूतनजीवी पादप-अवशेष

मोहन बलवंत बाँडे एवं गजेन्द्र प्रताप श्रीवास्तव

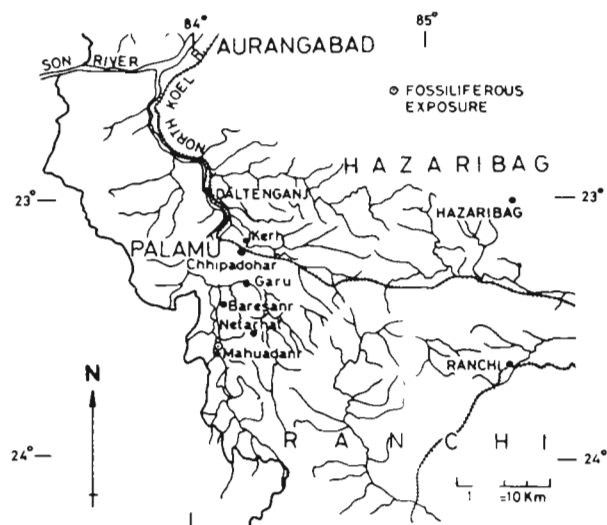
पलामु जनपद (बिहार) में महुआडाँड़ के पास स्थित अनंतिम नूतनजीवी संस्तरो से पत्तियों, फलों एवं फूलों की छाप उपलब्ध हुई हैं। इस समुच्चय में 16 द्विबीजपत्री कुलों से सम्बद्ध 22 प्रजातियों की 25 जातियाँ विद्यमान हैं। भारत के नूतनजीवी कल्प से *एस्क्लीपियेडेसी* कुल एवं *स्पोन्डियास*, *एरिथ्राइना*, *क्रेन्डीटम*, *मित्रागाइना*, *आल्सटोनिया* एवं *क्रिप्टोलेपिस* का इस शोध-पत्र में पहली बार वर्णन किया गया है। इस क्षेत्र की पुरापास्थितिकी एवं निक्षेपणीय वातावरण को सुनिश्चित करने में उपलब्ध आँकड़ों का उपयोग किया गया है। भारत के अन्य पश्चिमी युगीन वनस्पतिजातों से भी उक्त पुरावनस्पतिजात की तुलना की गई है।

ANGIOSPERMOUS Plant fossils from the Late Cenozoic beds near Mahuadanr, Palamu District, Bihar were first reported by Puri (1976). The plant fossils so far described from these beds are very meagre and consist of leaf-impressions of *Grewia*, *Murraya*, *Schleichera*, *Mangifera* and *Vitex* (Bande, Srivastava & Mishra, 1989). Impressions of flowers and fruits, besides those of fishes, birds and insects, have also been reported from these beds (Puri & Misra, 1982). In the present paper impressions of leaves, fruits and a flower have been described. In all, this assemblage comprises 25 species belonging to 22 genera of 16 families of the dicotyledons.

The present investigation has added a number of new taxa to the Late Cenozoic flora of Bihar on the basis of which palaeovegetation, palaeoclimate, and palaeoecology of this region during the Late

Cenozoic period have been reconstructed. In almost all the cases the leaf-impressions have been found to resemble the modern leaves of the plants growing in the vicinity of the fossiliferous locality. For the description of leaf-impressions the terminology given by Hickey (1973) and Dilcher (1974) has been adopted with certain amendments.

Geography—The area of investigation is Chhechari Valley. It is also known as Mahuadanr Valley and is situated in Chotanagpur plateau region of south Bihar in Palamu District (Survey of India toposheet no. 73A/3: North latitudes 23°24'00" and 23°27'30" and East longitudes 84°06'20" and 84°09'10"). Mahuadanr is the largest village in this area and situated about 116 km south of Daltonganj. The nearest railway station is Chhipodohar on Gomoh-Dehri-on-Sone loop line of the Eastern



Map 1—Locality map of Mahuadanr, Bihar.

Railway (Map 1). The Chotanagpur plateau mostly consists of hilly tracts with an average altitude of 600-650 m. It is deeply dissected around its edges giving rise to the ghats (steep escarpments). The subplateaus of Ranchi, Hazaribagh and Surguja throw out long spurs and hill ranges far into Palamu District on which are situated the Baresand, Betla and other reserve forests. Another important feature of this area is a number of isolated, flat topped, steep sided and laterite covered pats which rise above 1,000 m from sea level. The fossiliferous area (Mahuadanr Valley) lies at an altitude of 655-680 m above sea level and forms a part of flat Chhechari basin surrounded on all sides by hills rising up to a height of about 1,070 m. The usual direction of hill ranges is from East to West (Bhagat, 1980; Misra, 1979, 1982). The area is drained by several *nalas* and *nadis* (rivers). Burha is the main and perennial river of the valley, which flows into the North Koel River at Begum Champa near Kutku.

Climate—The area enjoys a tropical climate characterised by a dry and comparatively cool season (winter) from the middle of October to middle of February, a dry and hot season (summer) from the middle of February to sometime in May-June and a warm and wet season (rainy) from June to September. The low lying lands at the foot of the main hill ranges and narrow valleys on the higher plateau occasionally experience frost during the winter. The rainfall is derived mainly from the Bay of

Bengal currents of monsoon. The occurrence of rains is of bixeric type.

Vegetation—The vegetation of Chotanagpur region, except its southern part and valleys of Baresand, is of deciduous Sal—*Shorea robusta*-forest type. Obviously, *Sal* is the dominant species. The associates vary from place to place according to their ecological requirements (Meher-Homji, 1971).

The floristic studies of the Chotanagpur region have been carried out by Anderson (1863), Wood (1903), Haines (1910), Mooney (1944), Kapoor (1964-65), and Paul (1984). Some of these workers have also made some ecological observations on the forest types of this region. Mooney (1944) recognised only one type—Plateau *Sal*-forest. Rao and Panigrahi (1961) recognised moist and dry deciduous forests of tropical stock. Kapoor (1964-65) divides the forests under low hill regions and higher hill regions. In both these types *Shorea robusta* stands as the main type. Meher-Homji (1971) recognised the vegetation of Chotanagpur plateau as of the deciduous *Shorea robusta* forest type consisting of *Shorea-Cleistocalyx operculatus-Toona-Symplocos* type (occurring mainly where the rainfall is bixeric and over 1,500 mm; length of dry season of six months and mean temperature of the coldest month being in the vicinity of 10°-15°C and 15°-20°C) and *Shorea-Terminalia-Adina* type (occurring where rainfall is between 1,300-1,500 mm; length of dry season being seven months and mean temperature of the coldest month 15°-20°C). Champion and Seth (1968) broadly described two types of forests, viz., moist tropical forests and dry tropical forests in the Daltenganj South Forest Division.

Geology—The present area of investigation comes under Chotanagpur granite gneiss terrain (Roy Chowdhury *in West*, 1948). The geology of this area has been worked out in detail by Puri and Misra (1982). The sedimentary formations in the area, forming an outlier within the Pre-cambrian Chotanagpur granite Gneiss country, are exposed over a length of about 2.6 km and a width of 1.5 km along Birha River and its tributaries (Map 2) between Rajdanda (84°07'30" : 23°25'43") and Mahuadanr (84°06'40" : 23°23'15") villages. Pyroclastic sediments, conglomerates, sandstones and shales occur as the rock types.

The stratigraphic sequence proposed by Puri

PLATE 1

Shorea robusta Gaertn. f.

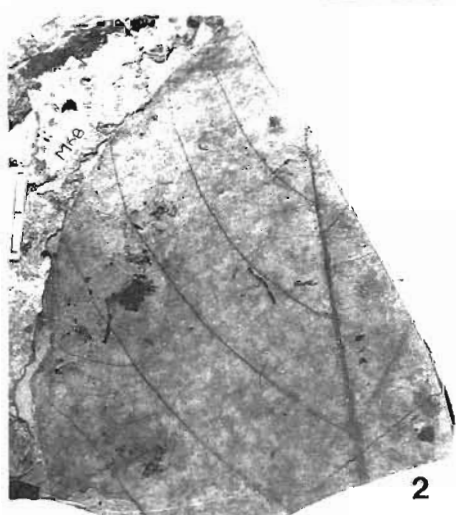
1. Fossil leaf in natural size; Specimen no. BSIP 36272.
2. Another fossil specimen. × ½; Specimen no. BSIP 36273.

3. Modern leaf, natural size.

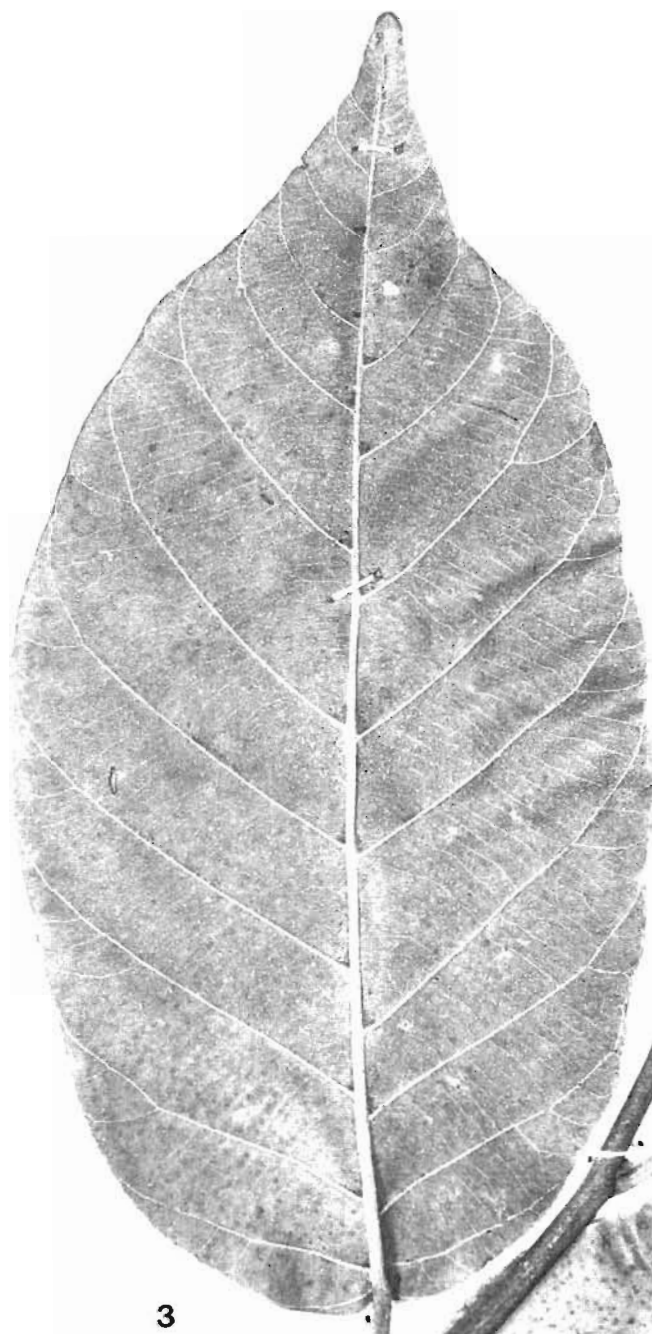
4. Venation pattern of fossil leaf (fig. 2) near midrib. × 7.
5. Venation pattern of fossil leaf (fig. 2) near margin. × 7.



1



2



3

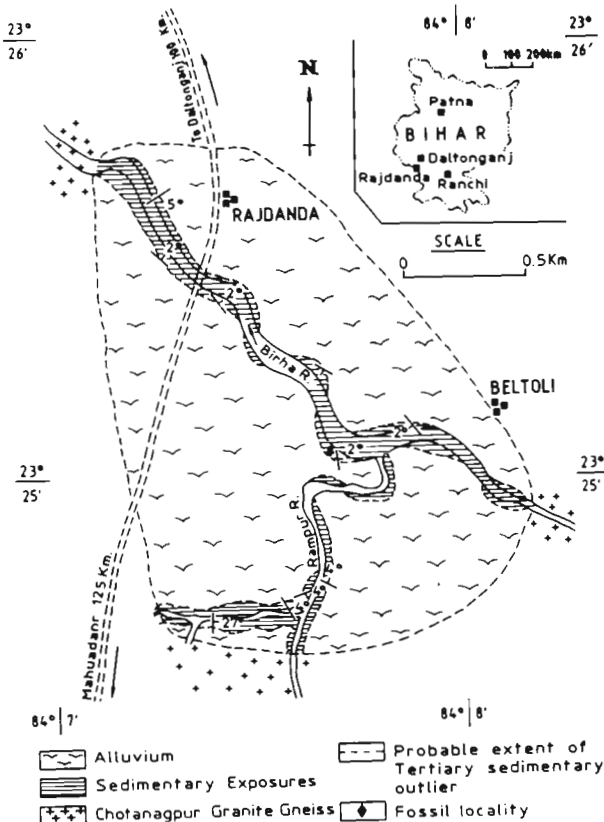


4



5

PLATE 1



Map 2—Geological map showing fossiliferous locality near Mahuadanr, Palamu District, Bihar.

and Misra (1982) for the rocks exposed in the area is as under:

		Maximum thickness
Recent	Loose pebbles, soil etc.	3.4 m
Unconformity.....	
	Shale bed	3.2 m
Upper Tertiary	Sandstone bed	3.0 m
	Conglomerate bed	2.0 m
Unconformity.....	
	Pyroclastic rocks	6.0 m
Unconformity.....	
Pre-cambrian	Chotanagpur granite gneiss	

The fossiliferous shales with plant and animal fossils are prominently exposed on the left bank of the Birha River south of Rajdanda Village and partly in the adjoining Rampur nala. Among the sedimentary rocks exposed in the area, the shales have yielded provided fossils of fishes, birds, leaves, flowers, fruits and insects while petrified woods have been recovered from the conglomerate/sandstones.

LEAF-IMPRESSIONS

Family—Dipterocarpaceae

Genus—Shorea Roxb.

Shorea robusta Gaertn. f.

Pl. 1, figs 1, 2, 4, 5

Material—Two incomplete leaf-impressions, one showing the basal part of leaf and the other with a part near the apex. Preservation satisfactory; insect eaten holes visible.

Description—Leaf simple, length 9.7 and 13 cm, maximum width on one side of the midrib 8 and 7.5 cm respectively; nothing could be said about form and apex; base cordate; margin entire; texture chartaceous; glands not visible; petiole normal; venation pinnate, craspedodromous, simple; primary vein (1°) stout, straight; secondary vein (2°) with acute (moderate) angle of divergence, variation in divergence angle nearly uniform, moderate, in some secondaries bifurcation near the margin present, both inter-secondary and intramarginal veins absent; tertiary veins (3°) AO, percurrent, mostly simple (at places forked also), relationship with midvein oblique, constant, predominantly alternate and closely spaced; highest vein order of leaf (4°), it is also the highest vein order showing excurrent branching, quaternary veins thin, orthogonal, marginal ultimate venation incomplete; areoles well-developed, oriented, quadrangular to pentagonal (mostly quadrangular), veinlets none.

Discussion—Craspedodromous venation with some forked secondary veins near the margin and percurrent tertiaries are the important characters of the fossil leaves. The impressions show resemblance with the modern leaves of *Anthocephalus cadamba*, *Terminalia tomentosa*, *Schleichera oleosa*, *Shorea*

PLATE 2



Sterculia villosa Roxb.

- 1. Fossil leaf. × 1/2; Specimen no. BSIP 36274.
- 2. Modern leaf. × 1/2.

Combretum decandrum Roxb.

- 3. Fossil leaf, natural size; Specimen no. BSIP 36275.
- 4. Modern leaf, natural size.

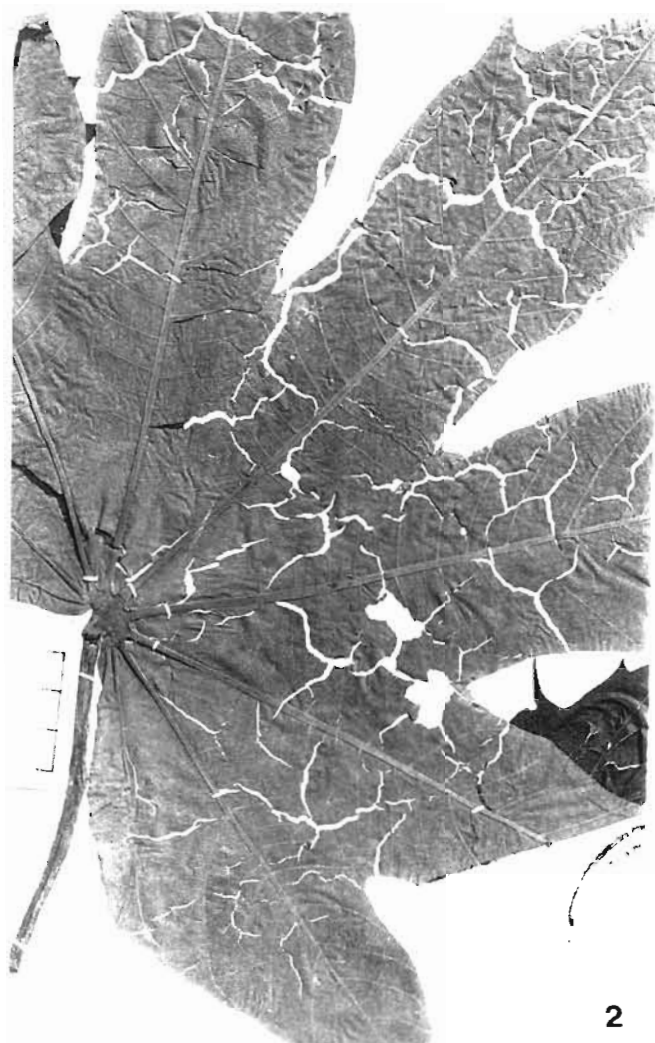
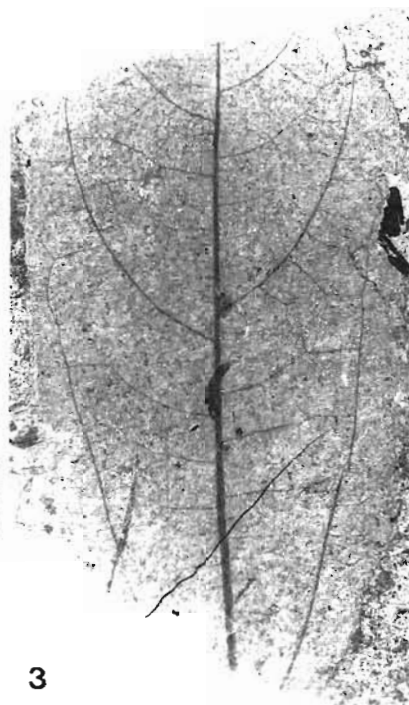
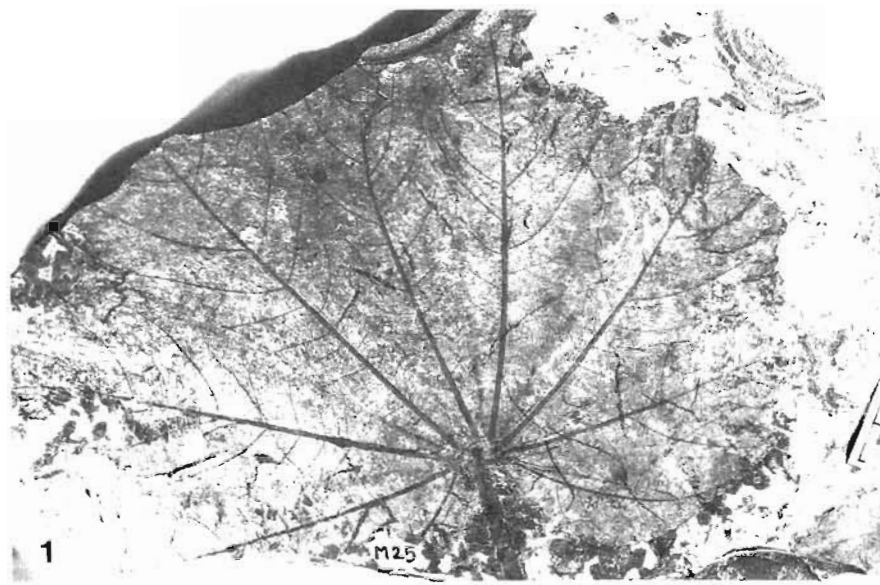


PLATE 2

robusta and *Buchanania lanzan*. However, a close similarity of these leaves is with those of *Shorea robusta* Gaertn. f. (F.R.I. Herbarium sheet no. 138303; Pl. 1, fig. 3).

Only fossil woods of *Shorea*, described under the generic name *Shoreoxylon* Berger, are known from various Tertiary localities of India, viz., Cuddalore sandstones, Tipam sandstones, Tertiary formations of West Bengal, Dupitila Series and the Siwalik beds (Lakhanpal *et al.*, 1976; Awasthi, 1982; Bande & Prakash, 1984). About 13 species of *Shoreoxylon* are so far known from the Tertiary of India but only two of them, i.e., *Shoreoxylon robustoides* described by Roy and Ghosh (1981) from West Bengal and *Shoreoxylon evidens* described by Eyde (1963) from the Tipam sandstones have been shown to bear close affinity with the woods of *Shorea robusta*.

Shorea Roxb. includes about 167 species which are widely distributed in the Old World from Sri Lanka and India on the West and throughout Burma, China, western Malaysia, Moluccas and Sunda Islands in the East (Willis, 1973). Out of these, nearly 100 species of trees grow throughout the tropical parts of Indo-Malayan region (Pearson & Brown, 1932). *Shorea robusta*, the Sal, is a large gregarious tree. The distribution of Sal in India is of considerable interest because it indicates the north-western limit of the family Dipterocarpaceae. In India, the area occupied by *Shorea robusta* forms two irregular but fairly defined belts, separated by the Gangetic plain. The northern sub-Himalayan belt extends from the Kangra Valley in Punjab to Darrang and Nowgong districts in Assam. The southern or central Indian belt extends from Coromandel coast west to the Pachmarhi sandstone hills and south to the Godavari River (Brandis, 1906; Chowdhury & Ghosh, 1958). In the Chotanagpur region, this is the most dominant species of the forest, both on the top of hills as well as in valleys. However, it is also well distributed in rest of the area (Wood, 1903; Haines, 1910; Meher-Homji, 1971; Paul, 1984).

Family—Sterculiaceae

Genus—*Sterculia* Linn.

Sterculia villosa Roxb.
Pl. 2, fig. 1

Material—Two incomplete specimens, counterpart of one of the specimens is also present.

Description—Leaves simple, length 12 cm and 4.5 cm, width 22 cm and 8.5 cm respectively; lamina and base symmetrical, ovate and lobed, apex not preserved; base cordate; margin entire; texture coriaceous; glands not visible; petiole normal; venation actinodromous, nine primaries arising from a single point, basal, perfect, marginal; primary veins (1°) appear to be stout, the middle primaries are almost straight whereas lateral primaries are markedly curved; secondary veins (2°) with angle of divergence varying from right angle or so to acute, upper pairs of secondary veins more acute than pairs below, secondaries arising from middle primaries seen uniting with secondaries arising from adjacent primaries in the basal part of the leaf, the secondaries arising from the lower most primary veins are seen forming loops, otherwise in general no loop formation; both intersecondary and intramarginal veins absent; tertiary veins (3°) AR, reticulate; highest vein order of leaf 4° , highest vein order showing excurrent branching 3° ; quaternary veins thin, orthogonal, marginal ultimate venation incomplete; areoles well developed, oriented, quadrangular in shape; veinlets none.

Discussion—Actinodromous venation with nine primaries arising from a single point, stout petiole and joining of basal secondaries of one primary vein with secondary veins of adjacent primary vein are the important characters of the fossil leaves, which show near resemblance with the modern leaves of *Sterculia*, *Pterygota* and *Firmiana*. However, a detailed comparison with the modern leaves of *Sterculia foetida*, *Sterculia urens*, *S. villosa*,

PLATE 3

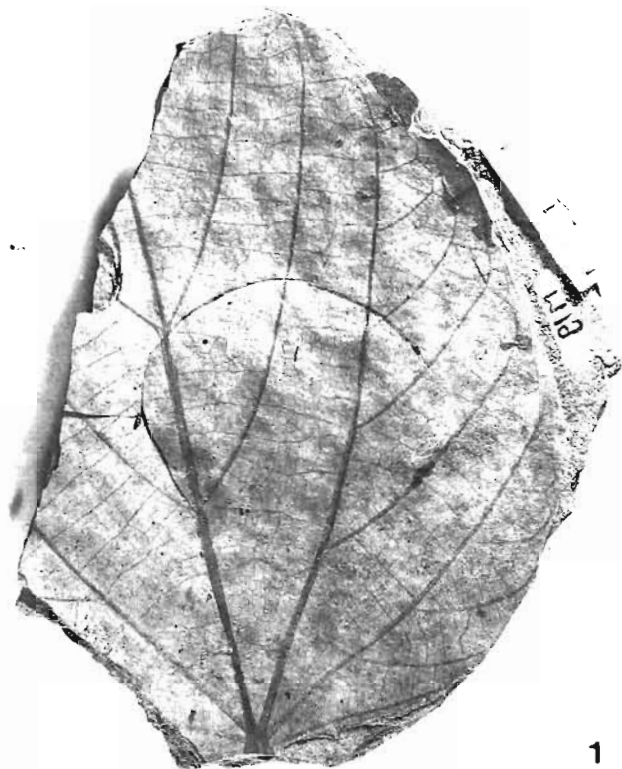


Pterygota alata (Roxb.) R. Br.

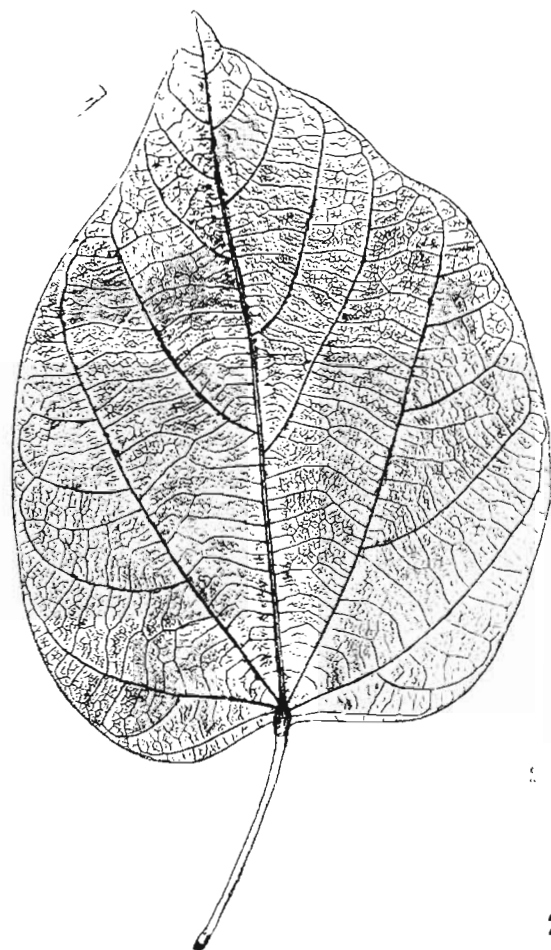
1. Fossil leaf, natural size; Specimen no. BSIP 36276.
2. Line drawing of modern leaf showing similar shape and size.
3. Fossil leaf showing venation details near middle primary.
× 7.
4. Venation details of fossil leaf showing higher order venation.
× 2.5.

Garuga pinnata Roxb.

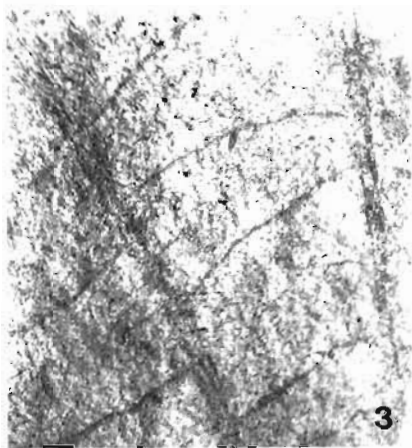
5. Fossil specimen, natural size; Specimen no. BSIP 36277.
6. Venation details of fossil leaflet (Pl. 4, fig. 6) near margin.
× 7.
7. Venation details of fossil leaflet (Pl. 4, fig. 6) near midvein. × 7.



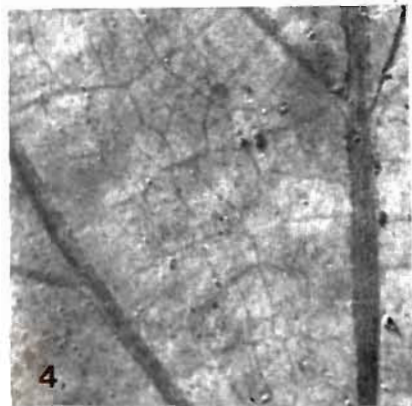
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2



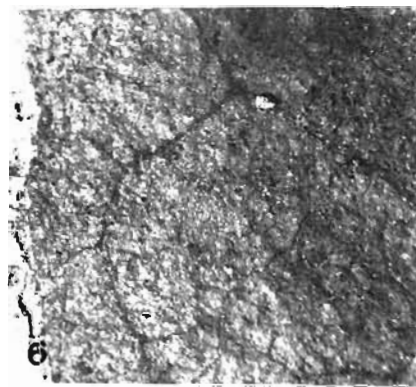
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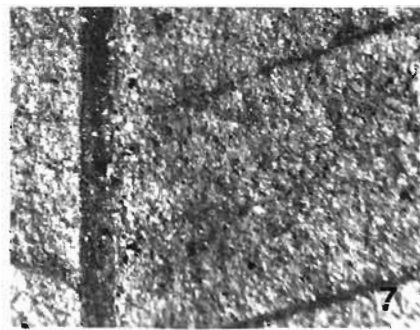
4



5



6



7

PLATE 3

Firmiana pallens syn. *Sterculia pallens* and *Pterygota alata* syn. *Sterculia alata* shows their closest resemblance with the leaves of *Sterculia villosa* (F.R.I. Herbarium sheet no. 5520/3173; Pl. 2, fig. 2).

Although the present finding forms the first record of the leaf-impression, fossil woods of *Sterculia* are known from various Tertiary localities of India, viz., the Deccan Intertrappean beds, Siwaliks beds, Cuddalore sandstones, Tipam sandstones and Namsang beds (Guleria, 1983; Lakhanpal *et al.*, 1984). All of them were earlier described under the generic name *Sterculioxylon* Kräusel 1939 but Guleria (1983) while describing fossil woods from Kachchh instituted another genus *Sterculinium* for the fossil woods of *Sterculia* and allied genera. Of the various species of *Sterculinium* so far described from India only *S. dattai* (Prakash & Tripathi) Guleria from Tipam sandstones shows a close similarity with the wood of *Sterculia villosa*.

The genus *Sterculia* Linn. consists of about 300 species (Willis, 1973) distributed throughout the tropics and reaches its best development in tropical Asia (Pearson & Brown, 1932). *Sterculia villosa* is a moderate-sized deciduous tree found in the sub-Himalayan tract and outer hills from the Indus eastward, ascending to 900 m, Punjab, Oudh, Central Provinces, Chotanagpur, western Peninsula, Sikkim, Assam, Khasi, Andamans and Burma (Wood, 1903; Brandis, 1906; Haines, 1910; Paul, 1984).

Genus—*Pterygota* Schott & Lendl.

Pterygota alata (Roxb.) R. Br. syn.

Sterculia alata Roxb.

Pl. 3, figs 1, 3, 4

Material—A single incomplete leaf-impression with good preservation. The apex and base both are not preserved.

Description—Leaf simple, length 9.4 cm, width 6.5 cm; margin entire; texture chartaceous; glands absent; petiole present, inflated; venation actinodromous, suprabasal, perfect; primary veins (1°) moderate, middle primary straight, lateral primary veins markedly curved; secondary veins (2°) with acute (moderate) angle of divergence, nearly uniform, moderately thick, curved abruptly, joining

with superadjacent secondary at right angle; tertiary veins (3°) RR to RA, percurrent, simple, relationship with midvein oblique, decreasing outward, predominantly alternate, closely spaced; highest vein order 4° which also shows highest vein order of the leaf showing excurrent branching, quaternary veins thin, orthogonal, marginal ultimate venation looped; areoles well-developed, oriented, quadrangular, veinlets none.

Discussion—Actinodromous suprabasal venation, with loop formation by secondary veins and percurrent tertiaries are the important characters of the fossil leaf. A comparison with a large number of modern leaves indicates that it shows somewhat near resemblance with the modern leaves of *Mallotus philippensis*, *Oroxylum indicum*, *Moghamia chappar*, *Pterygota alata*, *Ougenia oojeinensis*, *Kleinbovia hospita* and *Sterculia urens*. However, it shows close resemblance with that of *Pterygota alata* (N.B.R.I. Herbarium sheet no. 19027; Pascal & Ramesh, 1987, p. 200; Pl. 3, fig. 2).

Lakhanpal *et al.* (1981) described a fossil wood *Sterculioxylon varmaii* from the Namsang beds of Arunachal Pradesh which was later renamed by Guleria (1983) as *Sterculinium varmaii* (Lakhanpal *et al.*) Guleria. The fossil wood was shown to bear close resemblance with the modern woods of *Pterygota alata* syn. *Sterculia alata*. The present study constitutes the first record of fossil leaf of *Pterygota alata* from the Cenozoic beds of India.

The genus *Pterygota* consists of about 200 species and is distributed throughout the tropics of the Old World (Willis, 1973), out of which only one species *Pterygota alata* is known to occur in India (Santapau & Henry, 1973). It is found in the evergreen forests of North-east India and in the Western Ghats from North Canara to Kerala up to 900 m but reaches its best development in Chittagong (Bangla Desh), Burma and Andamans (Chowdhury & Ghosh, 1958). It is also found in the forests of Chotanagpur region (Wood, 1903; Haines, 1910).

Family—Rutaceae

Genus—*Evodia* Forst.

Evodia meliaefolia Benth.

Pl. 4, figs 1, 2, 4, 5

PLATE 4 →

Evodia meliaefolia Benth.

1. Fossil leaflet showing unequal base, natural size; Specimen no. BSIP 36278.
2. Another specimen showing symmetrical base, natural size; Specimen no. BSIP 36279.
3. Modern leaf, natural size.

4. Venation details of fossil leaflet (fig. 2) near midvein. $\times 7$.
 5. Venation details of fossil leaflet (fig. 2) near the margin. $\times 7$.
- Garuga pinnata*
6. Another fossil specimen, natural size, BSIP specimen no. 36280.
 7. Modern leaflet, natural size.

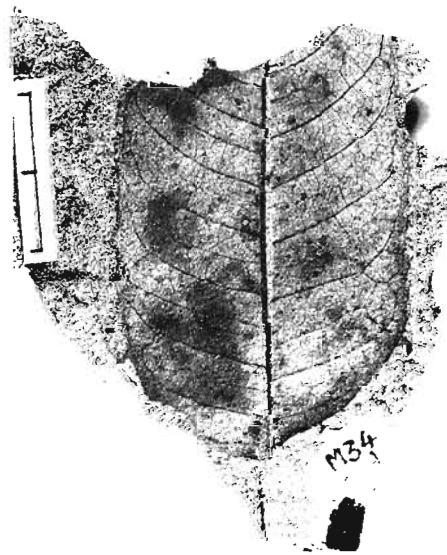
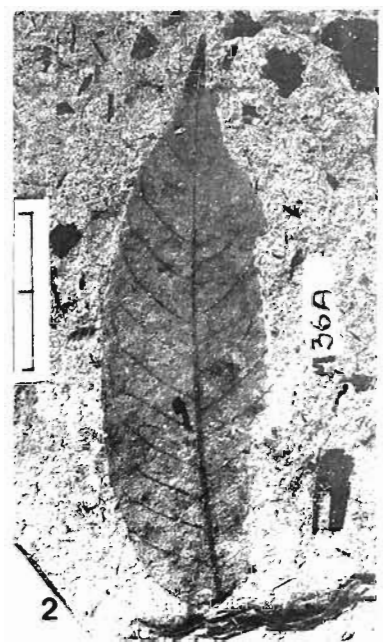
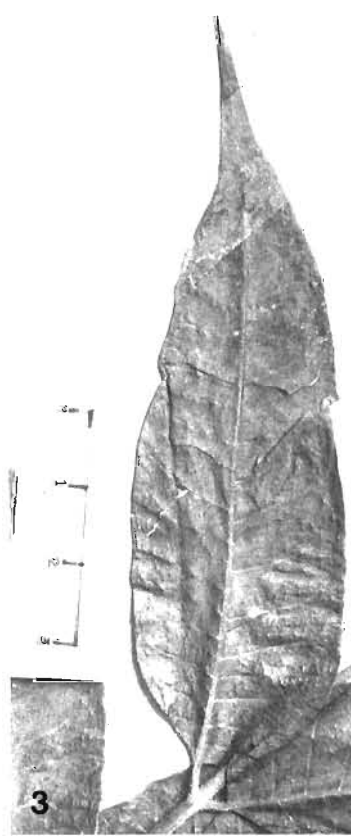
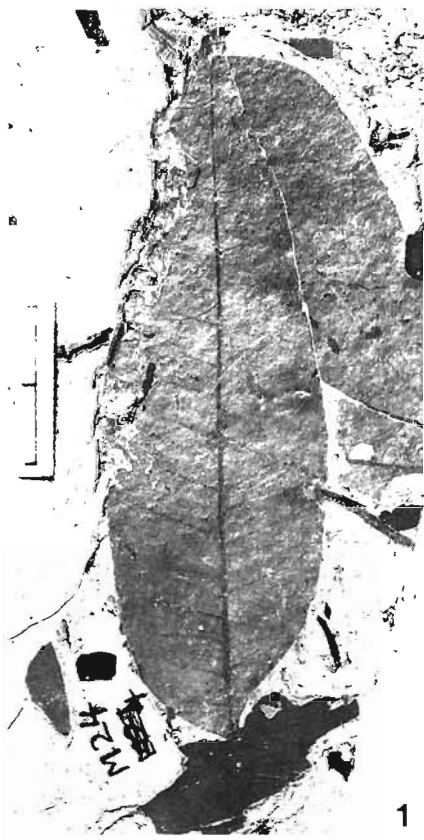


PLATE 4

Material—Two almost complete well-preserved leaflet-impressions.

Description—Leaf compound, leaflet length 7.6 and 9 cm, width 2.3 and 3 cm respectively, lamina and base in one specimen asymmetrical, whereas in the other it is symmetrical, oblong (narrow oblong), apex attenuate, base obtuse in one, obtuse (oblique) in the other specimen; margin entire; texture chartaceous; petiole normal; venation pinnate, camptodromous—brochidodromous; primary vein (1°) stout, markedly curved; secondary veins (2°) with acute (moderate) angle of divergence, uniform, moderate, curved abruptly joining superadjacent secondary at right angle, intersecondary and intramarginal veins both absent; tertiary veins (3°) RR, reticulate, orthogonal; highest vein order of leaf 4°, highest vein order showing excurrent branching 3°; quaternary (4°) veins moderate, orthogonal, marginal ultimate venation incomplete; areoles well-developed, oriented, mostly quadrangular to rectangular in shape.

Discussion—Asymmetrical to symmetrical lamina, obtuse (oblique) base, attenuate apex and brochidodromous venation are the important characters of the present leaflets which show near resemblance with the modern leaves/leaflets of *Vitex negundo*, *Evodia meliaefolia*, *Toona ciliata*, *Garuga pinnata* and *Pistacia integririma*. However, they show strong resemblance with the leaflets of *Evodia meliaefolia* (F.R.I. Herbarium sheet no. 81222; Pl. 4, fig. 3). A large number of herbarium sheets of *Evodia meliaefolia* were consulted and it was observed that the base of leaflets is a variable character in this species. It may be either symmetrical or asymmetrical (unequal) as is also in the fossil leaflets.

Fossil record of the genus *Evodia* is very meagre. Bande and Prakash (1984a) described a fossil wood *Evodinium indicum* (modern comparable form *Evodia roxburghiana*) from the Deccan Intertrappean beds of Nawargaon of Maharashtra. Shete and Kulkarni (1982) also described a fossil wood of *Evodia* from the same locality.

The genus *Evodia* Forst. consists of about 50 species distributed mainly from Madagascar through

South East Asia to Australia and Pacific islands (Willis, 1973; Negi, 1963). Only four species are known from India, out of which only *Evodia melifolia*, a large tree, grows in the forests of Chotanagpur region (Wood, 1903; Haines, 1910; Santapau & Henry, 1973). Besides Chotanagpur region, this species is also found in Assam, Cachar and China (Brandis, 1906).

Family—Burseraceae

Genus—*Garuga* Roxb.

Garuga pinnata Roxb.

Pl. 3, figs 5-7; Pl. 4, fig. 6

Material—Two leaflet-impressions with good preservation.

Description—Leaf compound, leaflets length 6.4 cm and 5 cm, width 2.2 cm and 3.6 cm respectively; whole lamina and base slightly asymmetrical, ovate (lanceolate); apex attenuate, base obtuse; margin toothed-serrate, serrate axis inclined to the tangent of the margins, apical angle acute, serration convex/concave, sinuses angular, spacing regular, teeth simple, basal part of leaf without serration; texture chartaceous; glands craspedodromous-semicraspedodromous, brochidodromous in other specimens without sinuses; primary vein (1°) massive, straight, slightly curved near the apex; secondary veins (2°) with acute (wide) angle of divergence, variation in angle of divergence nearly uniform, moderately thick, curved abruptly joining superadjacent secondary at acute angle, one branch enters in the sinuses when present, inter-secondary and intramarginal veins absent; tertiary veins (3°) RR, reticulate, orthogonal; highest vein order of leaf 4°, highest vein order of leaf showing excurrent branching 3°, quaternary veins thin, orthogonal, marginal ultimate venation incomplete; areoles well-developed, random, quadrangular to pentagonal, veinlets none.

Discussion—The important diagnostic features of the fossil leaflets indicate their near resemblance with the modern leaves/leaflets of *Boswellia serrata*, *Garuga pinnata*, *Pistacia integririma* and *Azadirachta indica*. However, a detailed comparison

PLATE 5

→

Spondias pinnata (L.F.) Kurz.

1. Fossil leaflet, natural size; Specimen no. BSIP 36281.
2. Another specimen, natural size; Specimen no. BSIP 36282.
3. Line drawing of modern leaflet (from Pascal & Ramesh, 1987).

4. Venation details of fossil leaflet (fig. 2) near midvein. × 7.

5. Venation details of fossil leaf (fig. 2) near margin. × 7.

Erythrina suberosa Roxb.

6. Fossil leaflet, natural size; Specimen no. BSIP 36283.

7. Modern leaflet, natural size.

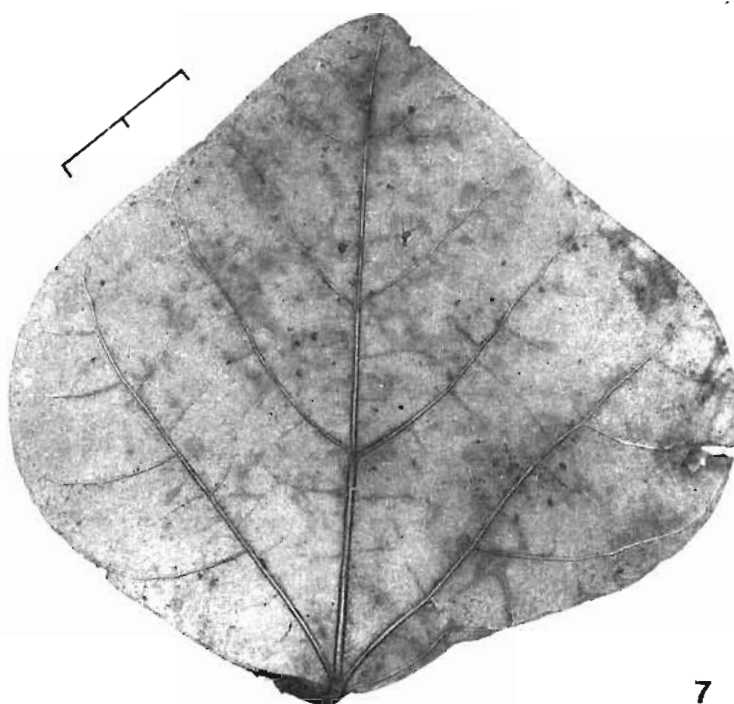
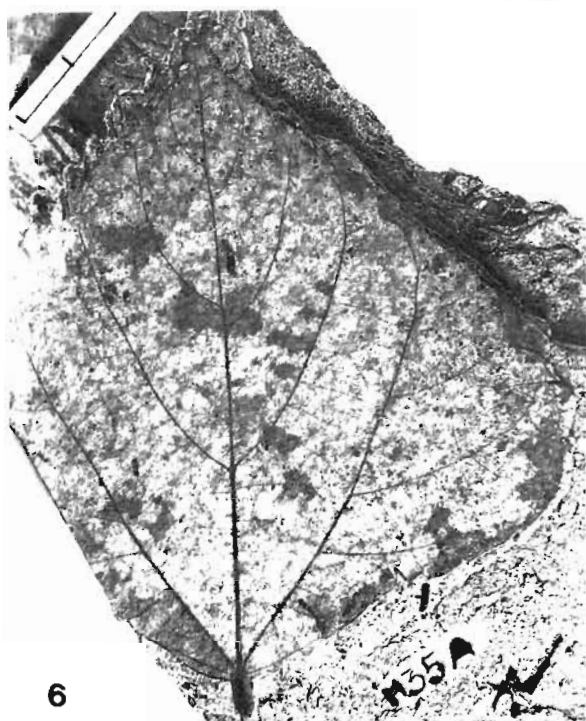
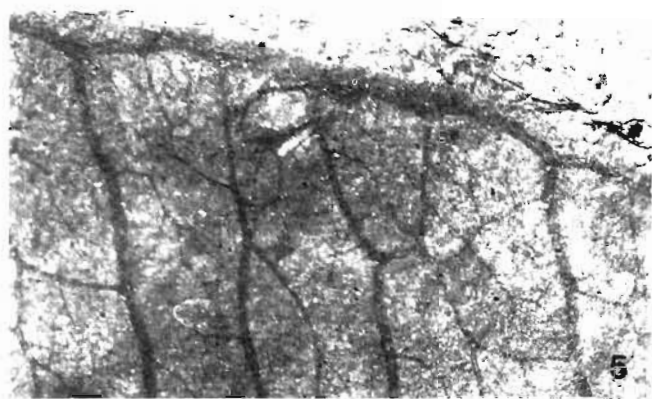
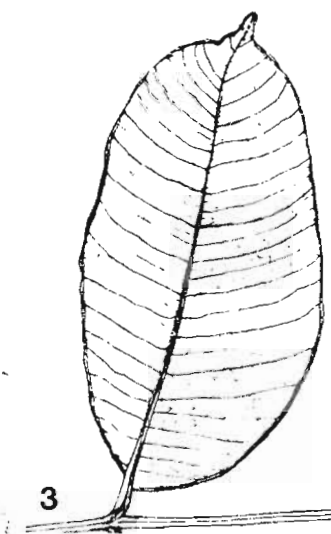
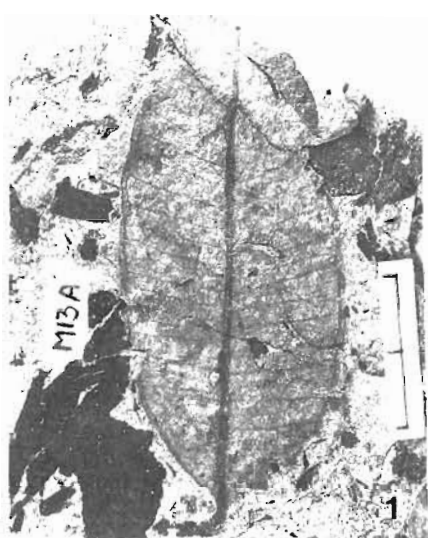


PLATE 5

shows close resemblance with the modern leaflets of *Garuga pinnata*. The leaflets of *Garuga pinnata* show dentate margin which is a variable character. In some of the leaflets the dentation is restricted to the apical region whereas in others there is no dentation (F.R.I. Herbarium sheet nos. 57030, 76120; Pl. 4, fig. 7; BSIP coll. no. 14088).

Fossil woods comparable to *Bursera/Garuga* have been described from the Tertiary of India. Woods of *Garuga* and *Bursera* are nearly similar (Lakhanpal *et al.*, 1981) and have been described under the generic name *Burseroxylon* Prakash & Tripathi 1975. *Burseroxylon preserratum* (modern comparable form *Bursera serrata*) has been described by Prakash and Tripathi (1975) from the Tipam sandstones of Assam and Bande and Prakash (1983) from the Deccan Intertrappean beds. Lakhanpal *et al.* (1981) described *Burseroxylon garugoides* from the Namsang beds of Arunachal Pradesh and compared it with the modern wood of *Garuga pinnata* Roxb.

Garuga Roxb. is a small genus of about five species of medium-sized trees, distributed in Madagascar, India, South East Asia, north-western Australia and the Pacific Islands (Willis, 1973). Two species are indigenous to India (Pearson & Brown, 1932; Santapau & Henry, 1973). *Garuga pinnata* is widely distributed from sub-Himalayan tract and outer valleys, ascending to about 1,100 m from Yamuna eastward, often mixed with Sal. It is a common tree in the dry deciduous forests of Madhya Pradesh, Chotanagpur, Andhra Pradesh, Karnataka and extends into the moist zone of Western Ghats and Satpuras. It is also found in Andaman Islands, Bangla Desh (Chittagong) and Burma in mixed forests (Wood, 1903; Haines, 1910; Ghosh *et al.*, 1963).

Family—Anacardiaceae

Genus—*Spondias* Linn.

Spondias pinnata (L.f.) Kurz. syn.

S. mangifera Willd.

Pl. 5, figs 1, 2, 4, 5

Material—Two incomplete leaflet-impressions

with a counterpart of one of them. Apex is not preserved.

Description—Leaves compound, leaflet length 6.1 cm, width 3.5 cm of both the specimens; lamina and base symmetrical, oblong; apex not preserved; base acute (normal); margin appears to be revolute; texture coriaceous; glands not seen; petiole normal; venation pinnate, camptodromous—brochidodromous; primary vein (1°) stout, straight; secondary veins (2°) with angle of divergence right angle or so, nearly uniform, fine to hair-like, curved, joining superadjacent secondary at obtuse angle, intersecondary veins absent; intramarginal vein present; tertiary veins (3°), RO, random reticulate; highest vein order of leaf 4°, highest vein order of leaf showing excurrent branching 3°, quaternary veins thick, orthogonal, ultimate marginal venation fimbriate; areoles well-developed, oriented, quadrangular in shape, veinlets none.

Discussion—Oblong form, brochidodromous venation, fine to hair-like secondary veins joining superadjacent secondary veins at obtuse angle and fimbriate marginal venation are the important characters of the fossil leaflets. A detailed comparison shows that the fossil leaflets indicate near resemblance with the modern leaves/leaflets of *Alstonia scholaris*, *Spondias indica*, *S. pinnata*, *Syzygium obovatum*, *Mimusops elengii* and *Cryptolepis buchmanii*. However, they bear a close affinity with the modern leaflets of *Spondias pinnata* (Pascal & Ramesh, 1987, p. 76; Pl. 5, fig. 63; N.B.R.I. Herbarium sheet no. 19027).

As per authors' information there is no previous fossil record of the genus *Spondias* from India. However, fossils of *Gluta*, *Melanorrhoea*, *Mangifera*, *Swintonia*, *Lansea*, *Dracantomelum* and *Holigrana* of Anacardiaceae are known from various Tertiary localities of India (Awasthi, 1982; Bande & Prakash, 1984; Guleria, 1984).

The genus *Spondias* L. comprises about 12 species distributed mainly in the Indo-Malayan region, southeast Asia and tropical America (Willis, 1973). In India, only four species are known to occur (Santapau & Henry, 1973). *Spondias pinnata* is a large deciduous tree, found in the sub-Himalayan tract and outer valleys up to 850 m, from Chenab

PLATE 6



Baubinia sp. cf. *B. purpurea* Linn.

1. Fossil leaf, natural size; Specimen no. BSIP 36284.

2. Modern leaf, natural size.

Millettia auriculata Baker ex. Brandis

3. Fossil leaflet, natural size; Specimen no. BSIP 36285.

4. Modern leaflet, natural size.

Ougenia oojinensis (Roxb.) Hochr.

5. Fossil leaflet, natural size; Specimen no. BSIP 36286.

6. Modern leaflet, natural size.

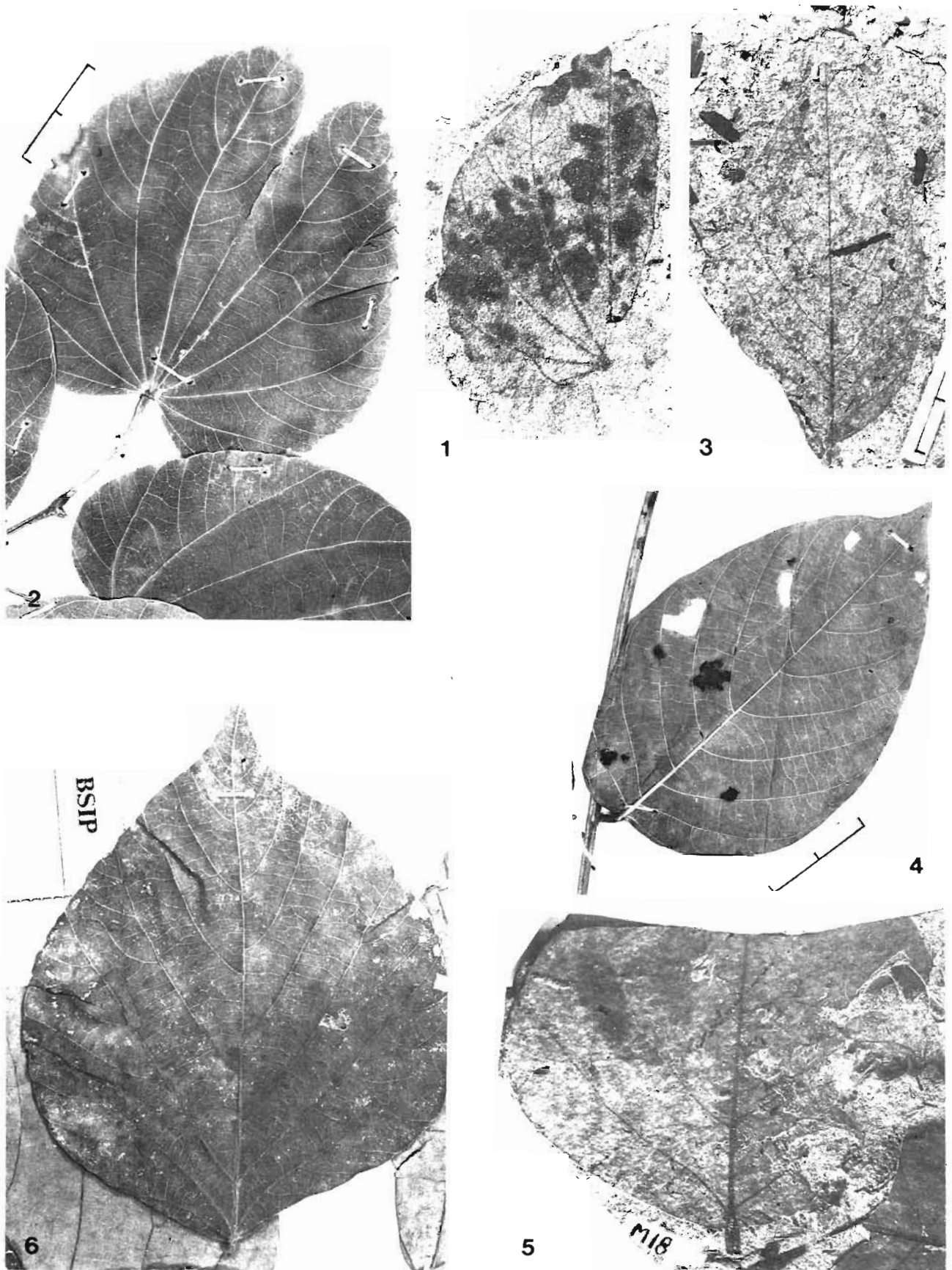


PLATE 6

eastwards, Salt Range in Pakistan, deciduous forests of Burma and the western Peninsula, Chotanagpur region and Sri Lanka (Wood, 1903; Brandis, 1906; Haines, 1910).

Family—Leguminosae (Fabaceae)

Genus—*Erythrina* Linn.

Erythrina suberosa Roxb.

Pl. 5, fig. 6

Material—A single almost complete, well-preserved leaflet-impresion with its counter part.

Description—Leaf compound, leaflet length 9.0 cm and maximum width on one side of the midrib 4.5 cm; lamina and base both symmetrical, wide ovate; apex acute; base rounded; margin entire, texture coriaceous; glands could not be seen; petiole inflated; venation acrodromous, position of primaries basal, perfect, marginal; primary veins (1°) weak, middle primary vein straight and lateral primaries markedly curved; secondary veins (2°) with acute (moderate) angle of divergence, lowest pair of secondaries which arises from the point of divergence of primaries more obtuse than pairs above, thick, abruptly curved, joining superadjacent secondary at acute angle, intersecondary veins absent; tertiary veins (3°) AR to RR, percurrent, retroflexed, relationship with midvein oblique, decreases towards margin, predominantly alternate, distantly spaced; highest vein order of leaf 4° , showing highest vein order with excurrent branching; quaternary veins thick, orthogonal, marginal ultimate venation incomplete; areoles well-developed, oriented, irregular but mostly quadrangular, veinlets none.

Discussion—Wide ovate lamina, inflated petiole, acrodromous venation and percurrent tertiary veins are the important characters of the present fossil leaflet which has been compared with the leaves/leaflets of *Ougenia oojeinensis*, *Erythrina suberosa*, *Mallotus philippensis* and *Oroxylum indicum*. However, it shows closest resemblance with the leaflets of *Erythrina suberosa* (B.S.I.P. Herbarium sheet no. 11302; Pl. 5, fig. 7).

As far as the authors are aware, no fossil of

Erythrina is so far known from India. However, several fossils of Leguminosae have been recorded from various Tertiary localities of the country (Bande & Prakash, 1984; Awasthi, 1982).

The genus *Erythrina* consists of about 100 species of trees and shrubs distributed in the tropics and subtropics of the World (Willis, 1973). *Erythrina suberosa* is a middle sized tree, found in the sub-Himalayan tract from Ravi to Sharda ascending to 900 m, Oudh forests, Burma, Chotanagpur, Kumaon, Sikkim (Wood, 1903; Brandis, 1906; Haines, 1910).

Genus—*Millettia* Wight & Arn.

Millettia auriculata Baker ex Brandis

Pl. 6, fig. 3

Material—Two incomplete leaflet-impresions with fair preservation.

Description—Leaf compound, leaflets length 7 and 5 cm, width 3.6 and 6.3 cm; lamina and base asymmetrical, ovate; apex acute, base obtuse, unequal; margin entire; texture chartaceous; glands not visible; petiole present, normal, only partly preserved; venation pinnate-camptodromous-eucamptodromous; primary vein (1°) moderate, straight; secondary veins (2°) with acute (moderate) angle of divergence, variation in angle of divergence nearly uniform, moderately thick, secondaries upturn and gradually diminishing inside the margin connected to superadjacent secondaries by series of cross-veins; both intersecondary and intramarginal veins present; tertiary veins (3°) with RR, reticulate to percurrent, reticulate orthogonal, percurrent, straight to retroflexed, oblique, constant, predominantly alternate, closely spaced; highest vein order of leaf 4° , further details could not be studied due to preservational factor.

Discussion—Ovate form, eucamptodromous venation, upturning and gradual diminishing of secondary veins near the margin, and presence of reticulate and percurrent tertiaries are the important characters of the present fossil leaflets which show near resemblance with the modern leaves/leaflets of *Mitragyna parvifolia*, *Psychortia truncata*, *Millettia auriculata* and *Aglaia exstipulata*. However, a detailed examination of fossil leaflets indicates a

PLATE 7



Terminalia tomentosa Wt. & Arn.

1. Fossil leaf, natural size; Specimen no. BSIP 36287.
2. Details of venation of fossil leaf near margin. $\times 7$.
3. Details of venation near midvein. $\times 7$.
4. Modern leaf, natural size.

Mitragyna parvifolia (Roxb.) Korth.

5. Fossil leaf, natural size; Specimen no. BSIP 36288.
6. Details of venation near midvein. $\times 7$.
7. Further details showing higher order venation. $\times 7$.
8. Modern leaf, natural size.

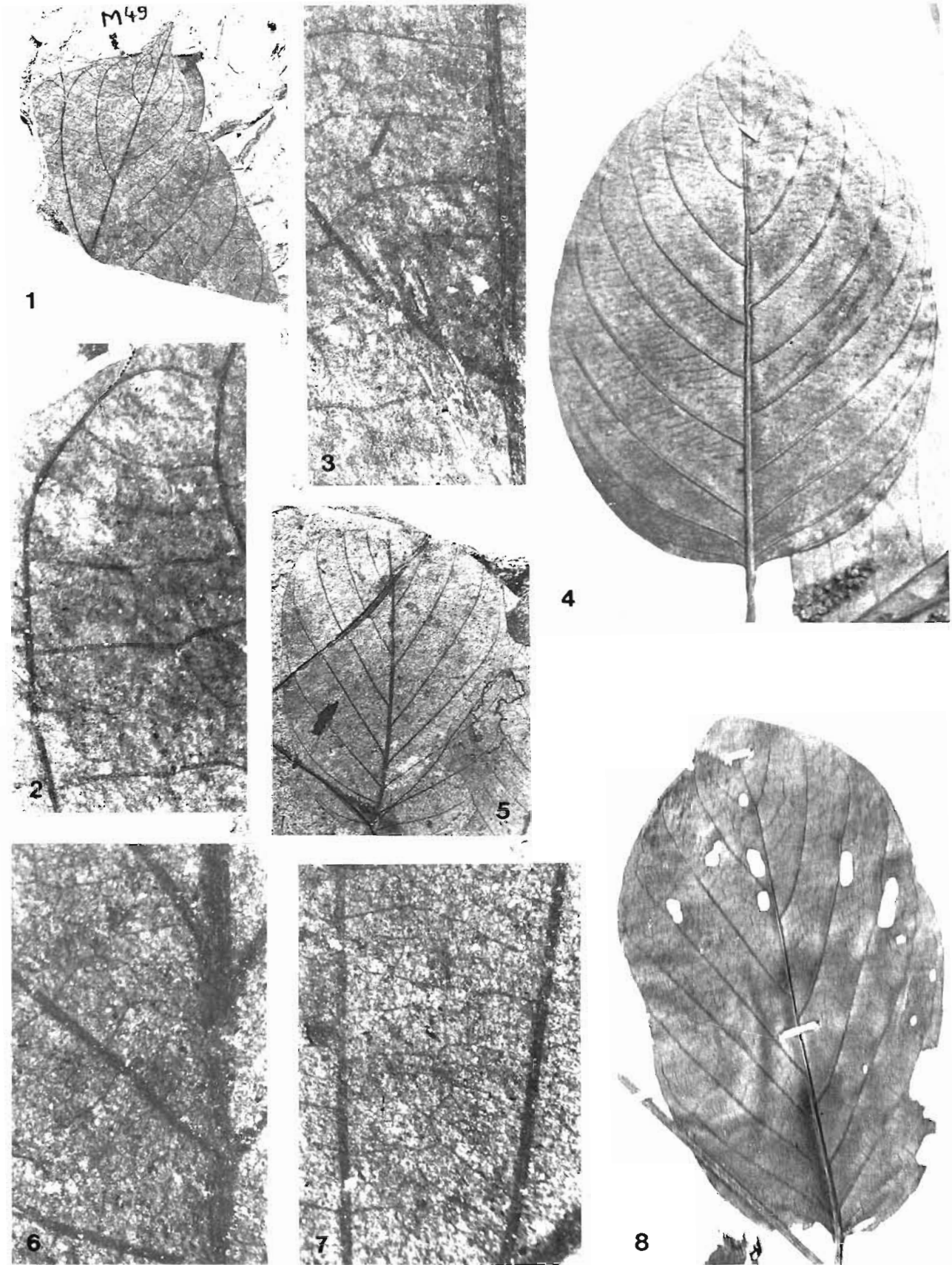


PLATE 7

close resemblance with those of *Millettia auriculata* (BSIP Herbarium sheet no. 14024; Pl. 6, fig. 4), although the shape, form and base of the leaflets vary considerably in the modern species.

The genus *Millettia* is fairly well-represented in the Tertiary of India known both by fossil woods as well as leaf-impressions. The fossil woods have been described under the generic name *Millettioxylon* Awasthi 1967 which represents the fossil woods of both *Millettia* and *Pongamia* as they are anatomically indistinguishable. Awasthi (1967) described *Millettioxylon indicum* (modern comparable form *Millettia pendula*) from the Cuddalore sandstones. Prakash (1975, 1978) described *Millettioxylon pongamiensis* (modern comparable form *Millettia prainii*) from the Siwalik beds of Nalagarh, Himachal Pradesh. The same species was later on described by Bande and Prakash (1980) from West Bengal. Ghosh and Roy (1979) also described one more species *Millettioxylon bengalensis* (modern comparable form *Millettia prainii*) from West Bengal. Lakhanpal *et al.* (1981) described *Millettioxylon palaeopulchra* (modern comparable form *Millettia pulchra*) from the Dupitila Series of Arunachal Pradesh. *Millettioxylon indicum* Awasthi 1967 was also reported by Lakhanpal *et al.* (1984) from Kachchh and compared with *Millettia pendula*, *M. prainii* and *Pongamia glabra*.

Fossil leaf-impressions, so far known, have been described under the generic name *Millettia* with four species. These are *Millettia asymmetrica* (modern comparable form *Millettia pendula*, *M. prainii*, *Pongamia glabra*) and *M. miocenica* (modern comparable form *Millettia auriculata* and *M. macrostachya*) described by Lakhanpal and Guleria (1982) and Lakhanpal *et al.* (1984) from Kachchh, *Millettia koilabasensis* (modern comparable form *Millettia macrostachys*) and *Millettia siwalicus* (modern comparable form *Millettia ovalifolia*) described by Prasad (1986) from the Siwalik beds of Koilabas, Nepal.

The genus *Millettia* consists of 180 species of trees, shrubs and woody climbers, distributed in the warmer regions of Africa, Asia and Australia (Willis, 1973). Twelve species occur in India (Santapau & Henry, 1973). *Millettia auriculata* is a woody

climber found in the sub-Himalayan tract from Sutelej eastward, Bihar, central India, south to the Godavari and commonly occurs in Sal forest (Brandis, 1906). It is also very common in the forests of Chotanagpur region (Wood, 1903; Haines, 1910).

Genus—*Ougenia* Benth.

Ougenia oojeinensis (Roxb.) Hochr. syn.

O. dalbergioides Roxb.

Pl. 6, fig. 5

Material—A single incomplete leaflet-impression, the apical half of the leaflet not preserved.

Description—Leaf compound, leaflet length 6.0 cm, width 8.00 cm, appears symmetrical, ovate; apex not preserved; base rounded; margin entire; texture chartaceous; petiole present, inflated; venation pinnate, craspedodromous, simple; primary vein (1°) weak, straight, secondary veins (2°) with acute (moderate) angle of divergence, slightly recurved near the point of divergence, nearly uniform, curved uniformly, the lowest pair of secondary vein more obtuse and arise from the base of midvein; tertiary veins (3°) RO, further details not visible due to bad preservation.

Discussion—Ovate form, craspedodromous venation and inflated petiole are the important characters of the fossil leaflet which show its near affinity with the modern leaves/leaflets of *Erythrina suberosa*, *Pterygota alata*, *Ougenia oojeinensis*, *Oroxylum indicum* and *Mallotus philippensis*. However, it shows close resemblance with the leaflets of *Ougenia oojeinensis* (BSIP Herbarium sheet no. 14030; Pl. 6, fig. 6). The base and form of leaflets are variable in this species.

The only fossil wood of *Ougenia* from India is *Ougenioxylon tertiarum* described by Prakash and Tripathi (1977) from the Tipam sandstone of Assam and compared with *Ougenia oojeinensis*.

Ougenia Benth. is a monotypic genus distributed only in India (Willis, 1973; Santapau & Henry, 1973). It is found from Ravi eastward to Bhutan, not common in Bihar and Orissa except in Sambalpur, occurring throughout the central provinces, central India, Rajputana, Khandesh,

PLATE 8

Madhuca indica J. F. Gmel.

1. Fossil leaf, natural size; Specimen no. BSIP 36289.
2. Another specimen, natural size; Specimen no. BSIP 36290.
3. Fossil leaf (fig. 2) magnified to show details of venation. ×

1.5.

4. Fossil leaf (fig. 1) magnified to show details of venation. ×
- 1.5.

5. Modern leaf, natural size.

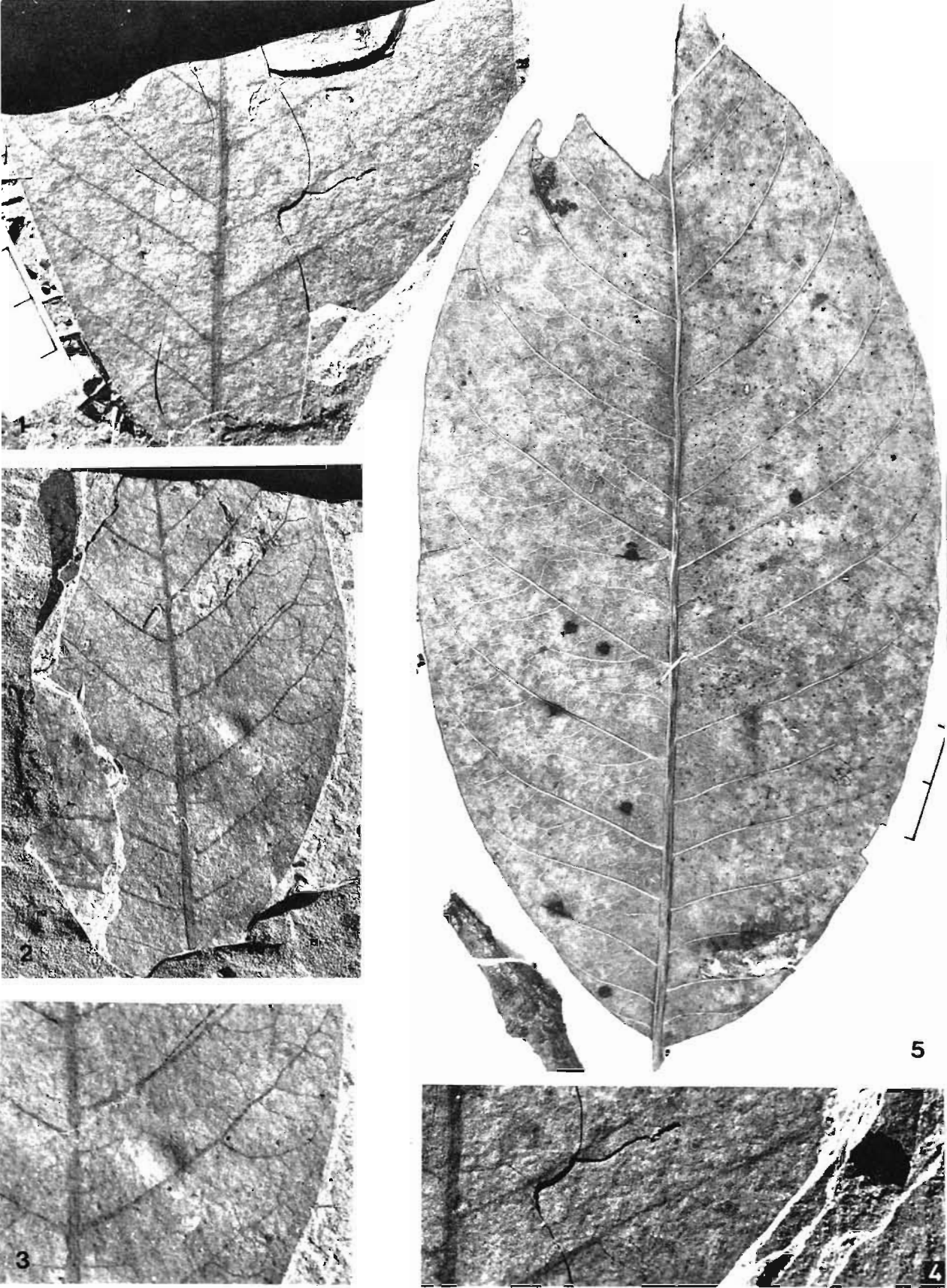


PLATE 8

Bombay, Deccan, Panch Mahalls, Deccan and North Kanara. It is not so common in south India, though found in central and north Coimbatore, Ganjam, Madura, Coorg, Hyderabad and Mysore (Pearson & Brown, 1932). It is also found in the forests of Chotanagpur region (Wood, 1903; Haines, 1910).

Family—Leguminosae (Caesalpinaceae)

Genus—*Baubinia* Linn.

Baubinia sp. cf. *B. purpurea* Linn.

Pl. 6, fig. 1

Material—A single leaf-impression with its counterpart. Preservation at places is fair. The specimen represents a folded leaf and the tertiary veins are only visible at some places.

Description—Leaf simple, length 5.5 cm, width 3.5 cm; lamina and base both asymmetrical, ovate; apex rounded; base also approximately rounded; margin entire, texture coriaceous; glands not visible; petiole not preserved, venation acrodromous, position of primaries basal, perfect; primary veins (1°) weak, one of the primary veins straight, while remaining four markedly curved; secondary veins (2°) with acute (moderate) angle of divergence, variation in angle of divergence nearly uniform, moderately thick, loop formation visible in the apical part, joining the superadjacent secondary at right angle, intersecondary and intramarginal veins absent; tertiary veins (3°) RO, reticulate, orthogonal; highest visible vein order of leaf 3° , highest vein order showing excurrent branching 3° , further details not visible.

Discussion—Acrodromous venation and entire margin are important features of the fossil leaf. The specimen is a folded leaf or may be one half of the leaf as clearly indicated by one of the margins of the fossil leaf which is running almost straight like an edge, whereas the other margin of the leaf shows curvature. Hence, it indicates that the fossil leaf has been folded up from the side of sharp straight edge. This type of leaf is found in *Hardwickia* Roxb. and *Baubinia* Linn. The leaves of *Hardwickia binata* although show some resemblance with the fossil leaf, differ in having almost acute apex. Thus the leaves of *Baubinia* species namely *Baubinia retusa*,

B. purpurea and *B. vablii* show somewhat close resemblance with the fossil, amongst which *B. purpurea* is the closest. Because of poor preservation the fossil is being described as *Baubinia* sp. cf. *B. purpurea* (NBRI Herbarium sheet no. 52236).

Both leaf-impressions and petrified woods of *Baubinia* have been reported from various Neogene localities of India. Rawat (1964-65) described *Baubinioxylon indicum* from the Siwalik beds of Mohand near Dehradun but because there are no figure and description, it was discarded as an invalid name, according to ICBN. However, fossil woods of *Baubinia* have also been described from the Siwalik sediments of Uttar Pradesh by Prakash and Prasad (1984) and Trivedi and Panjwani (1986). Ramanujam and Rao (1966) described a fossil wood of *Baubinia* from the Cuddalore sandstones but its affinities are doubtful. According to Prakash and Prasad (1984) it might belong to *Millettia*. Guleria (1986) has reported the occurrence of a fossil wood of *Baubinia* from the Tertiary of Rajasthan. Recently a fossil wood of *Baubinia deomalica* has also been described from the Namsang beds in Arunachal Pradesh (Awasthi & Prakash, 1986).

Lakhanpal and Awasthi (1984) described fossil leaves of *Baubinia siwalika* from the Siwalik beds of Bihar (modern comparable forms—*B. diptera*, *B. hookeri*, *B. tomentosa* and *B. corymbosa*). Lakhanpal and Guleria (1982) described *B. kachchhensis* (modern comparable forms *B. phoenicea* and *B. purpurea*) from the Miocene of Kachchh, Gujarat. A *Baubinia* type of leaf was reported by Lakhanpal (1970) from the Siwalik beds but it was not substantiated by any description and photograph.

Genus *Baubinia* Linn. consists of about 300 species of shrubs, small trees and woody climbers widely distributed throughout the tropics of the World (Ramesh Rao & Purkayastha, 1972; Willis, 1973) and about 30 species occur in India and Burma (Brandis, 1906).

Baubinia purpurea which compares closely with the fossil leaf, is a moderate-sized tree found from the Indus eastwards in the forests of sub-Himalayas to Assam, in Chittagong (Bangla Desh), hills of Upper Burma, throughout the forests of Bihar

PLATE 9



Diospyros montana Roxb.

1. Fossil leaf, natural size; Specimen no. BSIP 36291.
2. Details of venation near midvein. $\times 7$.
3. Details of venation near margin. $\times 7$.
4. Modern leaf, natural size.

Alstonia scholaris Brown

5. Fossil leaf, natural size; Specimen no. BSIP 36292.
6. Modern leaf, natural size.
7. Fossil leaf (fig. 5) further enlarged to show details of venation. $\times 2$.

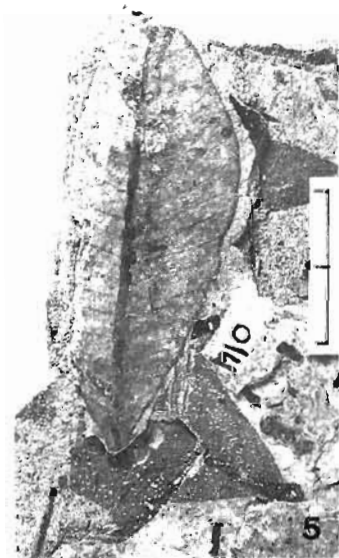
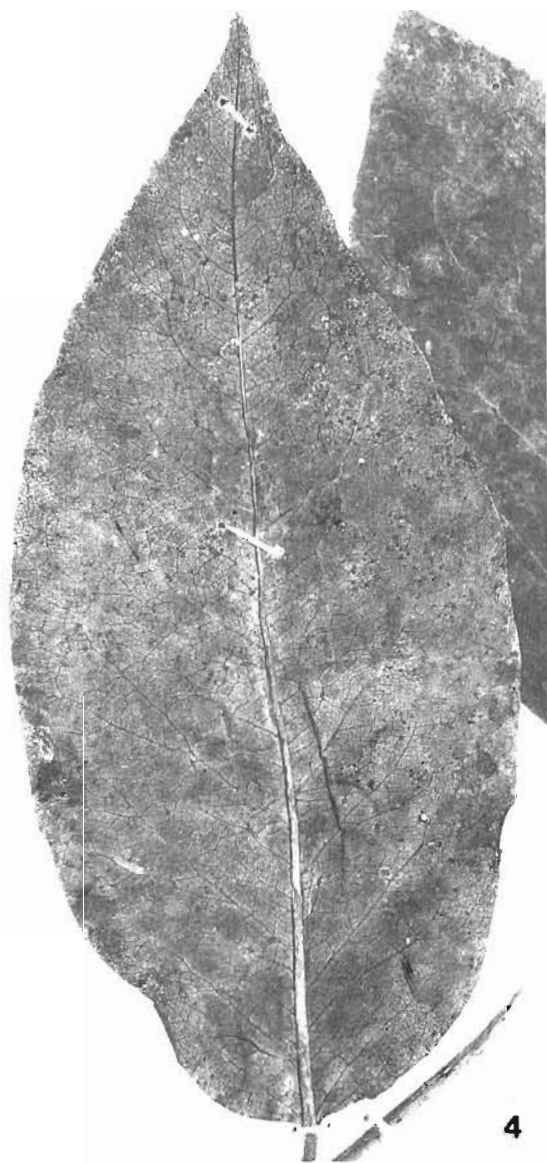
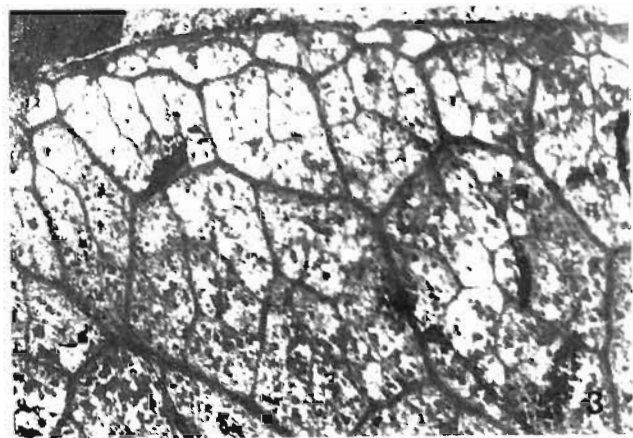


PLATE 9

and Orissa, the central Provinces, Khandesh, Deccan, Konkan, Northern Circars, Karnataka and on the West Coast in the drier areas. It is also found in the forests of Chotanagpur region (Wood, 1903; Brandis, 1906; Haines, 1910).

Family—Combretaceae

Genus—*Combretum* Loeft.

Combretum decandrum Roxb.

Pl. 2, figs 1, 3

Material—Two incomplete fairly well-preserved leaf-impressions.

Description—Leaf simple, length 12.00 cm and 8.4 cm, width 3.5 and 5 cm respectively; lamina and base symmetrical, oblong (narrow oblong); apex not preserved, base acute normal; margin entire; texture chartaceous; glands not visible; petiole normal; venation pinnate-camptodromous-eucamptodromous; primary vein (1°) stout, markedly curved; secondary veins (2°) with acute (narrow) angle of divergence, uniform, thick, upturned and gradually diminishing inside the margin connected to superadjacent secondary by a series of cross veins, enclosed by arches of 3° ; tertiary veins (3°) RR, percurrent, retroflexed, approximately at right angle, predominantly alternate; closely spaced; highest vein order of leaf 4° ; highest vein order showing excurrent branching 4° ; quaternary veins thick, orthogonal, marginal ultimate venation looped; areoles well-developed, oriented, quadrangular to pentagonal, veinlets none.

Discussion—Oblong form, eucamptodromous venation and percurrent tertiary veins are the important characters of the fossil leaves which show its near resemblance with the leaves of various genera of Lauraceae, *Cocculus* spp., *Ryparosa kunstleri* and with *Combretum decandrum*. However, in details of leaf architecture they show close resemblance with the modern leaves of *Combretum decandrum* (BSIP Herbarium sheet no. 11025; Pl. 2, fig. 4).

As per our information no fossil of *Combretum* has been described so far from India, although fossils of *Anogeissus*, *Terminalia* and *Calycopteris* of

the family Combretaceae are known to occur from the Tertiary of India (Bande & Prakash 1984; Prasad, 1986).

The genus *Combretum* comprises about 260 species found in the tropical and subtropical regions of the old and new world, the majority in Africa (Brandis, 1906). *Combretum decandrum* is a large climbing shrub, found in the sub-Himalayan tract from Jamuna eastwards, Sikkim up to 650 m, Assam, Chittagong (Bangla Desh), Burma, Bihar, central Provinces, northern Circars and the northern Deccan (Brandis, 1906). It is also a common climber in the forests of Chotanagpur region (Wood, 1903; Haines, 1910).

Genus—*Terminalia* Linn.

Terminalia tomentosa Wight & Arn.

Pl. 7, figs 1-3

Material—Single incomplete leaf-impression with apical half preserved.

Description—Leaf simple, length 4.4 cm, width 4.5 cm, nothing could be stated about the balance, form and base of the leaf as only the apical half of the leaf is preserved; apex acuminate; margin entire; texture chartaceous; glands not visible; petiole not preserved; venation pinnate-camptodromous-eucamptodromous; primary vein (1°) straight; secondary veins (2°) with acute (moderate) angle of divergence, variation in angle of divergence nearly uniform, moderately thick, secondaries upturned and gradually diminishing apically inside the margin, connected to the superadjacent secondaries by a series of cross veins without forming prominent marginal loops; intersecondary and intramarginal veins absent; tertiary veins (3°) with angle of divergence AR, percurrent, retroflexed, relationship with midvein oblique, constant, alternate to opposite in about equal numbers, closely spaced; highest vein order of leaf 4° , highest vein order showing excurrent branching 4° , quaternary veins thick, orthogonal, marginal ultimate venation looped; areoles well-developed, oriented, quadrangular to pentagonal (mostly quadrangular), veinlets none.

PLATE 10

→

Cryptolepis buchbanani Roem. & Schult.

1. Fossil specimen, natural size; Specimen no. BSIP 36293.
2. Another fossil specimen, natural size; Specimen no. BSIP 36294.
3. Counterpart of fig. 2.
4. Details of venation of fossil leaf (fig. 2) near margin. $\times 7$.

5. Details of venation of fossil leaf (fig. 1) near midvein. $\times 7$.

6. Modern leaf, natural size.

Mallotus philippensis Muell-Arg.

7. Fossil leaf natural size; Specimen no. BSIP 36295.
8. Details of venation of fossil leaf. $\times 7$.
9. Modern leaf, natural size.



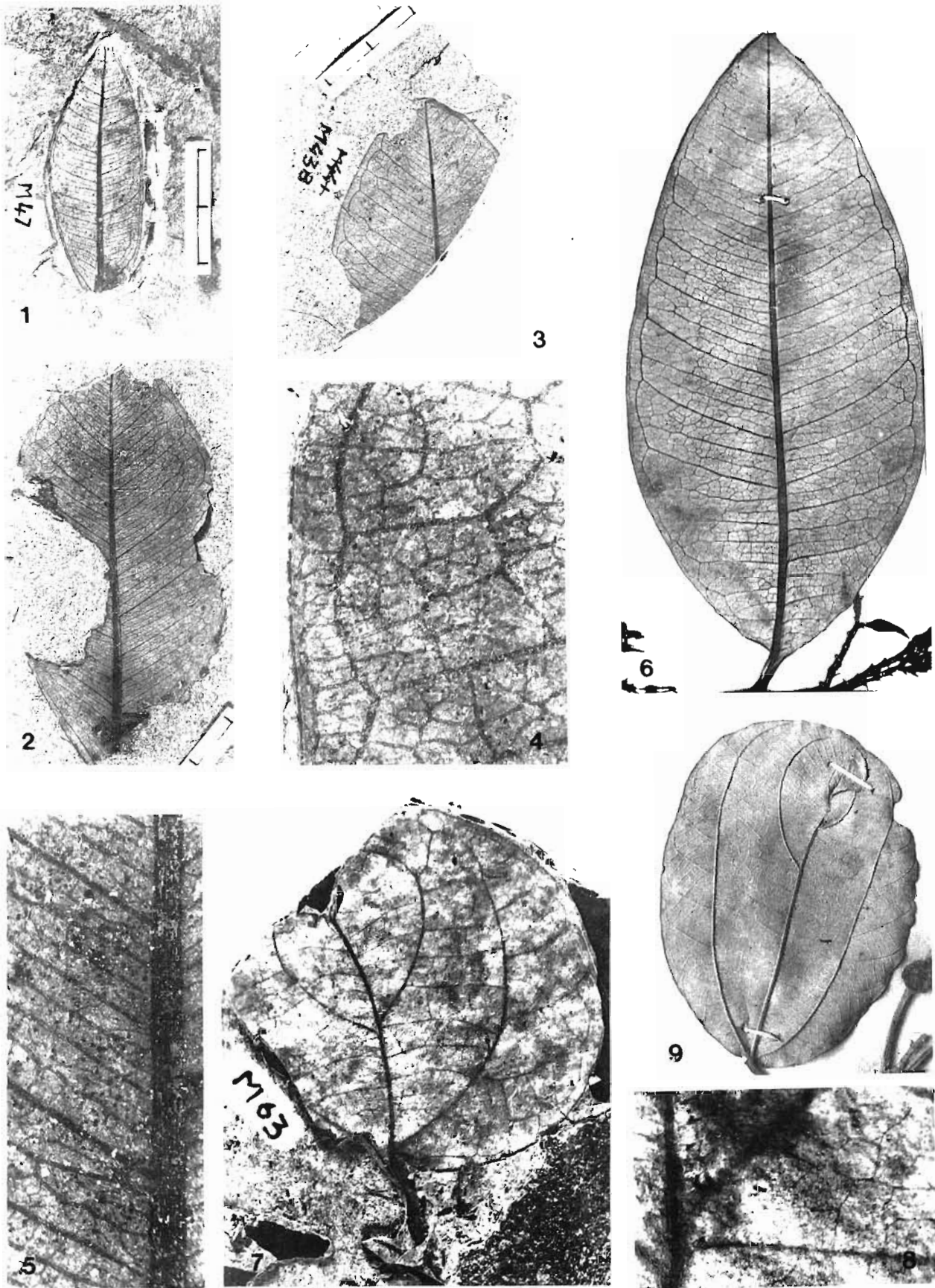


PLATE 10

Discussion—Eucamptodromous venation with percurrent tertiary veins are the important features of the fossil leaf. Such characters have been found in the leaves of *Terminalia* spp., *Anthocephalus cadamba* and *Artocarpus chaplasi*. However, the leaves of *Anthocephalus cadamba* differ from the present fossil in having predominantly alternate arrangement of tertiaries which are distantly spaced. In *Artocarpus chaplasi* the secondaries are with prominent marginal loops which distinguish it from the fossil leaf. A detailed examination reveals that it only shows close resemblance with the modern leaves of *Terminalia tomentosa* in almost all characters (F.R.I. Herbarium sheet no. Kef. III; Pl. 7, fig. 4).

Both fossil woods and leaf-impressions of *Terminalia* are known from various Tertiary localities of India. Most of the fossil woods have been described under the generic name *Terminalioxylon* Schonfeld of which 16 species are known from different Indian Cenozoic horizons, viz., Cuddalore sandstones, Tipam sandstones, Dupitila series of Arunachal Pradesh, the Siwalik beds, Tertiary beds of West Bengal, Andhra Pradesh, Kachchh, Ghala (Surat District of Gujarat) and from Kerala (Mahabale & Deshpande, 1965; Prakash, 1966; Ramanujam, 1966; Awasthi, 1982; Guleria, 1983; Bande & Prakash, 1984; Lakhanpal *et al.*, 1984). Out of these, *Terminalioxylon felixii*, *T. tertiarum*, *T. tomentosum* and fossil wood of *Terminalia tomentosa* have been shown to bear close resemblance with the modern woods of *Terminalia tomentosa*.

Fossil leaves of *Terminalia* have been described under the modern generic name. Lakhanpal (1970) has reported a leaf-impression resembling *Terminalia* from the Siwalik beds of Himachal Pradesh. Lakhanpal and Guleria (1981) and Lakhanpal *et al.* (1984) have described two species, viz., *Terminalia panandbroensis* (modern comparable form *T. crenulata*) and *T. kachchhensis* (modern comparable form *T. chebula*) from Tertiary of Kachchh. Tripathi and Tiwari (1983) have described a leaf-impression cf. *T. arjuna* from the Siwalik beds of Koilabas. Recently Prasad (1986) has also described *T. koilabasensis* (modern comparable form *T. angustifolia* Jacq.) and *T. siwalica* (modern

comparable form *T. pyrifolia*) from the Siwalik beds of Koilabas, Nepal.

The genus *Terminalia* comprises about 250 species (Willis, 1973). They are large trees distributed widely in the tropics of the world. In India, 12 species are known to occur (Santapau & Henry, 1973). The species which grow wild in the Chotanagpur region are *Terminalia catappa*, *T. belerica*, *T. chebula*, *T. arjuna* and *T. tomentosa*. *Terminalia tomentosa* is a large tree found in the sub-Himalayan tract from Ravi eastward, ascending up to 1,300 m, commonly throughout India including Chotanagpur region (except in arid regions) and Burma. It thrives best in heavy clay soil (Brandis, 1906).

Terminalia tomentosa has been described as a complex in various publications by atleast four authors, viz., Beddome, Clarke, Cooke and Wight and Arnold (Ramesh Rao & Purkayastha, 1972). This complex comprises several plant groups showing wide range of variation. Hitherto botanists and foresters were generally content to regard this plant complex as one species. However, a critical examination of this complex by Parkinson (1937) shows that *Terminalia tomentosa* auct. div. is actually a mixture of: (i) *Terminalia crenulata*, (ii) *T. coriacea*, and (iii) *T. alata*.

Family—Rubiaceae

Genus—*Mitragyna* Korth.

Mitragyna parvifolia (Roxb.) Korth.

Pl. 7, figs 5-7

Material—Single incomplete leaf-impression, apex is not preserved.

Description—Leaf simple, leaf length 5.6 cm, width 3.8 cm, lamina and base slightly asymmetrical, oblong (wide oblong); apex not preserved; base appearing rounded, one side seems cuneate; margin entire; texture chartaceous; glands not visible; petiole not preserved; venation pinnate-camptodromous-eucamptodromous; primary vein (1°) moderate, almost straight; secondary veins (2°) with acute (narrow) angle of divergence, lowest pair of secondary veins more obtuse than pairs above; secondaries gradually diminishing apically inside

PLATE 11



Mallotus philippensis Muell-Arg.

1. Another fossil leaf specimen, natural size; Specimen no. BSIP 36296.

2. Venation details of fossil leaf. × 7.

Ficus foveolata Wall. ex Miq.

3-5. Fossil leaves, natural size; Specimen nos. BSIP 36297, 36298, 36299.

6. Details of venation of fossil leaf (fig. 3) near midvein. × 7.

7. Details of venation of fossil leaf (fig. 3) near margin. × 7.

8. Modern leaf, natural size.

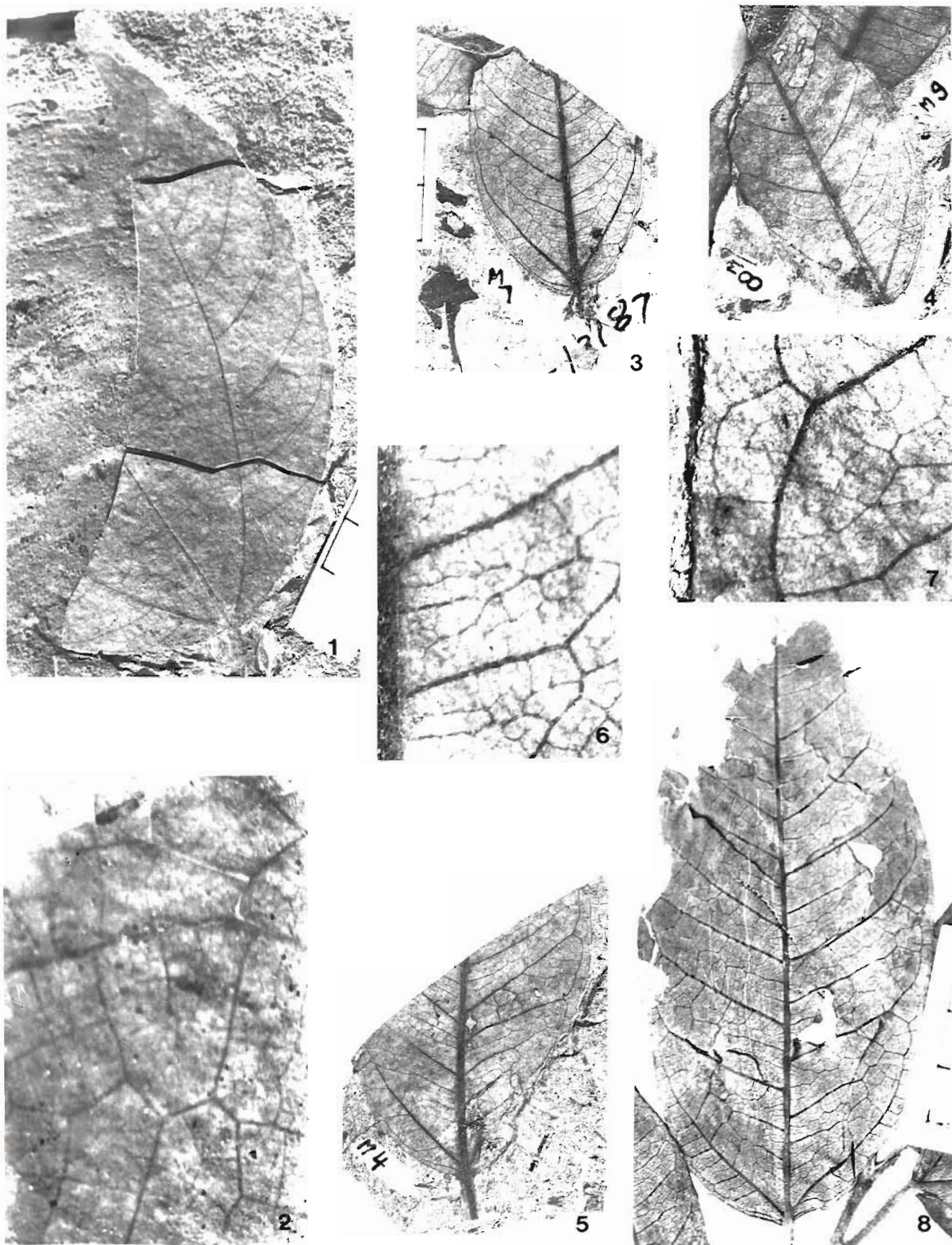


PLATE 11

the margin, connected to the superadjacent secondary by a series of cross veins without forming prominent loops, intersecondary and intra-marginal veins absent; tertiary veins (3°) RA, reticulate and percurrent both, reticulate orthogonal, retroflexed, percurrent retroflexed, oblique, constant, closely spaced; highest vein order of leaf 4° ; highest vein order showing excurrent branching 3° , quaternary veins thin, orthogonal, marginal ultimate venation incomplete; areoles well-developed, oriented, mostly quadrangular, veinlets none.

Discussion—Wide oblong leaf with eucamptodromous venation without loop formation by secondary veins and reticulate as well as percurrent tertiaries are the important characters of fossil leaf. It indicates near resemblance with the leaves of *Millettia auriculata*, *Shorea robusta*, *Mitragyna parvifolia* and *Psychortia truncata*. However, it shows close resemblance with that of *Mitragyna parvifolia*. The shape and base of leaf is quite variable in this species (F.R.I. Herbarium sheet nos. 105400, 1343/111465; Pl. 7, fig. 8; BSIP Herbarium sheet no. 14080).

From the Tertiary of India, only two genera of family Rubiaceae are known. Lakhanpal and Awasthi (1984) described a leaf-impression of *Gardenia palaeoturgida* (modern comparable form *Gardenia turgida*) from Siwalik beds near Bhikhnathoree, West Champaran District, Bihar; while Prasad (1986) described a leaf-impression of *Randia miowallichii* (modern comparable form *Randia wallichii*) from the Siwalik beds of Koilabas.

The genus *Mitragyna* comprises about 15 species of trees and shrubs distributed from tropical Africa through the Indo-Malayan region to New Guinea (Willis, 1973; Pearson & Brown, 1932). Three species are known to occur in India (Santapau & Henry, 1973). *Mitragyna parvifolia* is a large deciduous tree found throughout India, distributed from foot- and outer hills of north-west Himalaya from Bias eastwards, ascending to 1,250 m, Bihar, central India, common in both peninsulas (Brandis, 1906). It is also common in the forests of Chotanagpur region, often gregarious in moist places (Wood, 1903; Haines, 1910).

Family—Sapotaceae

Genus—*Madhuca* J. F. Gmel.

Madhuca indica J. F. Gmel.

Pl. 8, figs 1-4

Material—Two incomplete leaf-impressions without base and apex. Preservation is fair enough to reveal the finer details of the leaf architecture.

Description—Leaf simple, length 6.5 and 8 cm, maximum width on one side of midrib 5 and 3 cm respectively; nothing can be stated about the base and apex, the leaf appears to be elliptic; margin entire; texture chartaceous, glands not visible; petiole not preserved; venation pinnate-camptodromous-eucamptodromous; primary vein (1°) massive, straight; secondary veins (2°) with acute (moderate) angle of divergence, variation in angle of divergence uniform, moderately thick, secondaries upturned and gradually diminishing inside the margin connected to superadjacent secondaries by a series of cross veins without forming prominent loops, intersecondary veins present, simple intra-marginal vein absent; tertiary veins (3°) with angle of divergence AA, pattern generally reticulate but few tertiaries also show exmedial ramified pattern, predominantly alternate, closely spaced; highest vein order of leaf 4° which also shows the highest vein order showing excurrent branching, quaternary veins thin, orthogonal, marginal ultimate venation looped; areoles well-developed, random, quadrangular to rectangular, veinlets none.

Discussion—Eucamptodromous venation, massive primary vein, and some tertiaries with exmedial ramified pattern are the important characters of the fossil leaves, which show a near resemblance with the leaves of various species of *Terminalia*, *Dipterocarpus tuberculatus*, *Madhuca indica*, *Anthocephalus cadamba* and *Semecarpus anacardium*. However, the detailed comparison shows their close similarity with that of *Madhuca indica* (BSIP Herbarium sheet no. 14041; Pl. 8, fig. 5).

So far, only fossil wood of *Madhuca* is known

PLATE 12



Ficus glaberrima Blume

1. Fossil leaf, natural size; Specimen no. BSIP 36300.
2. Modern leaf, natural size.

3. Details of venation of fossil leaf near midvein. $\times 7$
4. Details of venation of fossil leaf near margin. $\times 7$

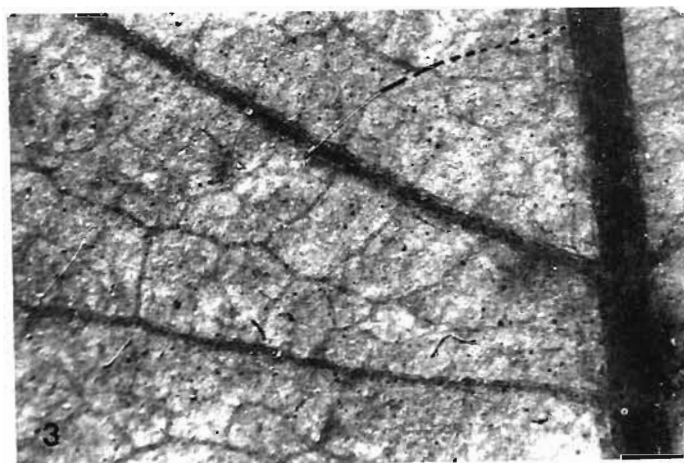
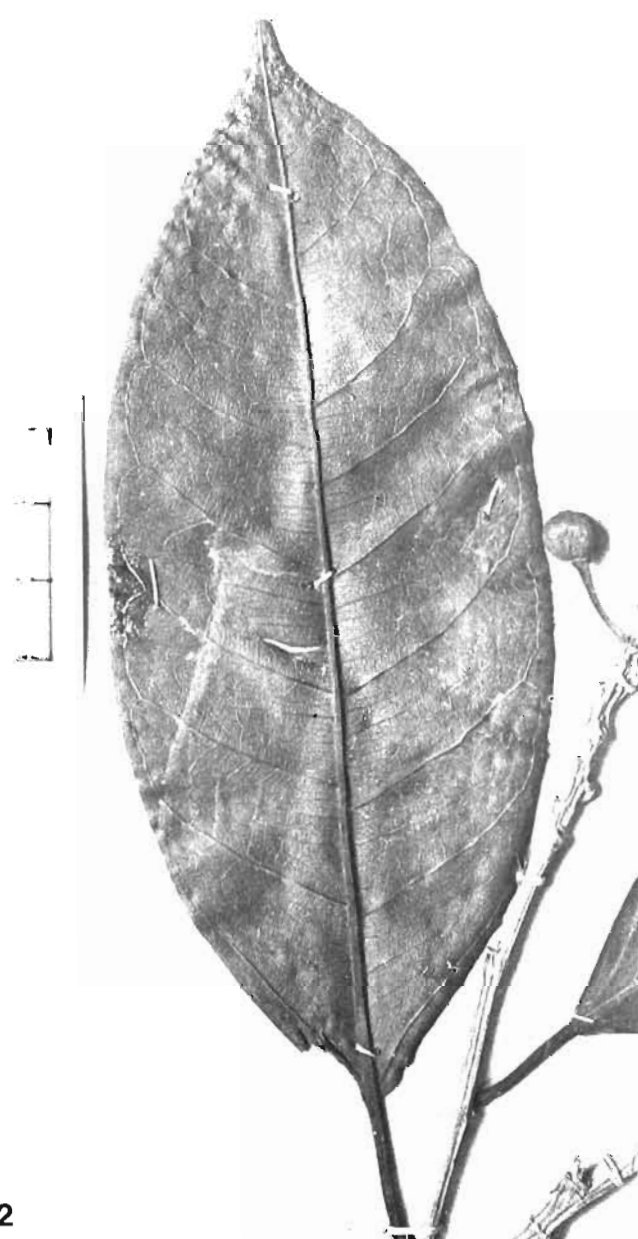
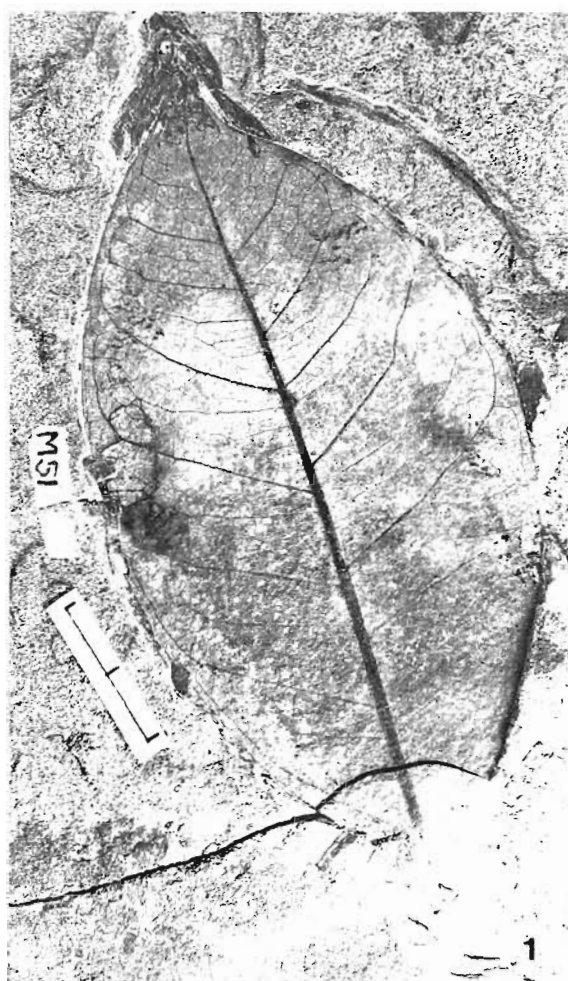


PLATE 12

from India. Prakash and Tripathi (1977) described *Madhucoxylon cacharensense* (modern comparable form *Madhuca butyracea*) from the Tipam sandstones of Assam.

The genus *Madhuca* consists of 85 species distributed in Indochina, Indo-Malayan region especially in West Malaysia and Australia (Willis, 1973). Only five species are known to occur in India (Santapau & Henry, 1973), out of which two including *M. indica* grow in the Chotanagpur region (Wood, 1903; Haines, 1910; Paul, 1984). *Madhuca indica* is a large tree found from Ravi eastward, in Oudh and Kumaon in the foot-hills of Himalayas, extending to Chotanagpur and Orissa; throughout central Provinces, Khandesh, Gujarat, Konkan and Deccan; scarce in Kanara, north Circars especially in Godavari, southward Salem and Coimbatore. It is also, widely cultivated (Pearson & Brown, 1932).

Family—Ebenaceae

Genus—*Diospyros* Linn.

Diospyros montana Roxb.
Pl. 9, figs 1-3

Material—Single incomplete leaf-impresion, only the upper half of the leaf with apex present. Preservation is fair.

Description—Leaf simple, length 5.3 cm, width 3.5 cm, nothing can be stated about balance, form and base of the leaf, as the whole leaf is not preserved; apex acute; margin entire; texture chartaceous; glands absent; petiole not preserved; venation pinnate-camptodromous-cladodromous; primary vein (1°) moderately thick, markedly curved; secondary veins (2°) with acute angle of divergence, variation in angle of divergence nearly uniform, fine to hair-like, curved abruptly, secondaries freely ramified toward the margin, intersecondary veins present, composite; tertiary veins (3°) RR to RO, reticulate; orthogonal; highest vein order of leaf 4°, highest vein order showing excurrent branching 3°, quaternary veins moderate, orthogonal, marginal ultimate venation looped; areoles appear to be well-developed.

Discussion—Cladodromous venation with fine to hair-like secondary veins freely ramified towards the margin are the important characters of the fossil leaf, which show its near resemblance with the leaves of *Garcinia gummigutta*, *Garcinia indica*, *Diospyros montana*, *Schefflera stellata*, *Cyathocalyx zeylanicus* and *Chloroxylon swietenia*. However, in the details of leaf architecture the fossil shows strong resemblance with the modern leaves of *Diospyros montana* (BSIP Herbarium sheet no. 14070; Pl. 9, fig. 4)

The genus *Diospyros* is fairly well known from various Tertiary localities of India both in the form of fossil woods and leaf-impresions. The woods assignable to *Diospyros* have been described under the generic name *Ebenoxylon* Felix whereas fossil leaves have been described under *Diospyros*. From the Lower Siwalik sediments Prakash (1978, 1981) described two species *Ebenoxylon miocenicum* (modern comparable form *Diospyros kurzii*) and *E. siwalicus* (modern comparable form *D. disiana*), from Tipam sandstones Prakash and Tripathi (1970) described *Ebenoxylon kartikcheriense* (modern comparable form *D. ebretioides*), from Cuddalore sandstones Awasthi (1970) described *Ebenoxylon arcotense* (modern comparable form *Diospyros assimilis*), and from Dupitila Series Ghosh and Kazmi (1958) described *Ebenoxylon indicus* (modern comparable form *Diospyros* sp.). However, leaf-impresions are known only from the Siwalik beds. Prasad (1986) described two fossil leaves namely *Diospyros koilabasensis* (modern comparable form *D. montana*) and *D. pretoposia* (modern comparable form *D. toposia*).

The genus *Diospyros* consists of about 500 species of trees, rarely shrubs, distributed in tropical and mild temperate regions of the world (Willis, 1973). About 40 species are known from India, out of which 10 including *D. montana* occur in the Chotanagpur region (Wood, 1903; Haines, 1910; Santapau & Henry, 1973; Paul, 1984). *Diospyros montana* is a small or moderate-sized tree growing throughout most parts of India and Burma from Ravi eastward along the Himalayas, in central, western and southern India (Gamble, 1922).

Family—Apocynaceae

Genus—*Alstonia* R. Brown

Alstonia scholaris Brown
Pl. 9, figs 5, 7

Material—Single incomplete leaf-impresion; preservation satisfactory.

Description—Leaf simple, length 4.5 cm, maximum width on one side of midrib 1.4 cm, lamina and base symmetrical; narrow obovate; apex nearly obtuse; complete base not preserved, appears to be acute (cuneate); margin revolute; texture chartaceous; petiole not preserved; venation pinnate-camptodromous-brochidodromous but the loops are not prominent; primary vein (1°) stout, straight; secondary veins (2°) arising at acute (wide) angle, variation in angle of divergence nearly uniform, fine, curved, bending in arc uniform, loop forming branches joining superadjacent secondary at

an obtuse angle; intersecondary veins not visible, intramarginal vein absent; tertiary veins (3°) with angle of divergence RR, more prominent on exmedial side, pattern ramified (admedial) predominantly alternate, closely spaced; highest vein order visible 3° , highest vein order showing excurrent branching 3° , marginal ultimate venation fimbriate; areoles well-developed, oriented, quadrangular to pentagonal, veinlets none.

Discussion—Important characters of the fossil leaf are narrow obovate form, revolute margin, wide acute secondaries and ramified (admedial) pattern of tertiary veins. These characters of the fossil show its resemblance with the modern leaves of *Holigarna beddomei*, *Semecarpus anacardium*, *Spondias pinnata*, *Alstonia scholaris* and *Garcinia travancorica*. But on the basis of all important characters it closely resembles the modern leaf of *Alstonia scholaris* (F.R.I. Herbarium sheet no. 7123; Pl. 9, fig. 6).

As far as the authors are aware there is no fossil record of the genus *Alstonia* from India. The only fossil of the family Apocynaceae known from India is *Tabernaemontana precoronaria* from the Siwalik sediments by Prasad (1986). This fossil leaf according to author shows closest affinity with the modern leaves of *Tabernaemontana coronaria* Willd.

The genus *Alstonia* consists of over 30 species of trees or rarely upright shrubs mostly distributed through the Indo-Malayan region, Australia and Polynesia. Only one species occurs in the tropical Africa (Willis, 1973). *Alstonia-scholaris* is a very large tree found mostly in deciduous forests, from the Yamuna eastwards through Uttar Pradesh, Bengal, Assam, scarce in Bihar, Orissa and Chotanagpur but common in the west coasts. It also extends to Sri Lanka in south and in the east up to Philippines through Burma and Malay Peninsula and Archipelago (Brandis, 1906; Pearson & Brown, 1932).

Family—Asclepiadaceae

Genus—*Cryptolepis* R. Br.

Cryptolepis buchmanii Roem. & Schult.
Pl. 10, figs 1-5

Material—Two leaf impressions with their counterparts. Preservation is excellent.

Description—Leaf simple, length 8.0 and 4.5 cm, width 4 and 1.6 cm respectively; lamina and base both symmetrical, elliptic, apex acute; base not fully preserved but appears to be normal acute; margin entire; texture coriaceous; petiole not preserved; venation pinnate-camptodromous-brochidodromous; primary vein (1°) stout, straight, secondary

veins (2°) with acute (moderate) angle of divergence, variation in angle of divergence nearly uniform, moderately thick, curved abruptly, joining superadjacent secondary at obtuse angle, intersecondary veins present, composite, intramarginal vein absent; tertiary veins (3°) with angle of divergence AR to RR, orthogonal, reticulate; highest vein order 4° , highest vein order showing excurrent branching 3° , quaternary veins thick, orthogonal, marginal ultimate venation looped; areoles well-developed, random, irregular in shape (mostly quadrangular), veinlets none.

Discussion—Elliptic form, acute apex, brochidodromous venation and looped marginal ultimate venation are the prominent characters of the fossil leaves which indicate their near resemblance with the leaves of *Syzygium cumini*, *Cassia fistula*, *Cryptolepis buchmanii*, *Ochna squamosa* and *Ficus microcarpa* syn. *F. retusa*. However, on the basis of leaf architecture they closely resemble *Cryptolepis buchmanii* (BSIP Herbarium sheet no. 14014, F.R.I. Herbarium sheet no. 9/11837; Pl. 10, fig. 6).

As per authors' information, so far there is no fossil record of the family Asclepiadaceae from the Tertiary of India.

The genus *Cryptolepis* consists of about 15 species and is confined to the tropics of Asia, Malaysia, and Pacific Islands (Willis, 1973). According to Santapau and Henry (1973), three species are known from India *Cryptolepis buchmanii* is a climbing shrub found throughout India and common in the sub-Himalayan tract and outer hills from Kashmir eastward, ascending to 1,600 m, Oudh, Bihar (including Chotanagpur), central provinces, Singhbhum and western Peninsula (Wood, 1963; Brandis, 1906; Haines, 1910).

Family—Euphorbiaceae

Genus—*Mallotus* Lour.

Mallotus philippensis Muell-Arg.
Pl. 10, figs 7, 8; Pl. 11, figs 1, 2

Material—Two incomplete well-preserved leaf impressions, one of them with its counterpart; apex in none of the specimens present.

Description—Leaf simple, length 10.5 and 4 cm, maximum width on one side of the midrib 5.1 and 2.8 cm respectively; ovate, lamina appears to be symmetrical; base symmetrical, rounded; apex not preserved; margin entire; texture chartaceous; glands not visible; petiole present, normal; venation acrodromous, basal, perfect; primary veins (1°) with middle primary vein moderately thick, markedly

curved in one whereas straight in the other specimen; secondary veins (2°) originate from one side (marginal side) of lateral primaries and from the upper half of middle primary, with acute (moderate) angle of divergence, nearly uniform, moderately thick, curved abruptly, joining superadjacent secondary at obtuse angle, also enclosed by secondary arches of 3° near the margin, intersecondary and intramarginal veins absent; tertiary veins (3°) RR, percurrent, simple (the tertiaries which arise from the middle are at right angle with the middle primary while the marginal tertiary veins are oblique in relationship with the midvein); angle of divergence varies from right angle to oblique, predominantly alternate, closely spaced; highest vein order of leaf 4° , highest vein order showing excurrent branching 4° , quaternary veins thick, orthogonal, marginal ultimate venation looped; areoles well-developed, random, quadrangular to polygonal, veinlets none.

Discussion—Ovate form, acrodromous venation, loop forming secondary veins and percurrent tertiary veins are the important characters of the fossil leaves. These indicate their near resemblance with the modern leaves of *Pterygota alata*, *Mallotus philippensis*, *Moghamia chappar*, *Erythrina suberosa* and *Oroxylum indicum*. However, a detailed comparison shows their close resemblance with those of *Mallotus philippensis* (F.R.I. Herbarium sheet no. 8649; Pl. 10, fig.9). The shape and size in the leaves of *Mallotus philippense* vary to a great extent.

Fossil woods as well as leaf-impressions of *Mallotus* are known from India. Fossil woods have been described under the generic name *Mallotoxylon* Lakhanpal & Dayal 1964, whereas leaf-impressions are known under the generic name *Mallotus* itself. Lakhanpal and Dayal (1964) described *Mallotoxylon kerienne* (modern comparable form *Mallotus philippensis*) from the Deccan Intertrappean beds of Keria in Chhindwara District of Madhya Pradesh and Prakash and Tripathi

(1975) described *Mallotoxylon assamicum* (modern comparable form *M. philippensis*) from the Tipam sandstones of Assam. Later, Roy and Ghosh (1982) described *Mallotoxylon cleidinoides* from the Tertiary beds of Shantiniketan in West Bengal and traced the affinities of their fossil wood with *Cleidion javanicum*.

Leaf-impressions of *Mallotus* have so far been described only from the Siwaliks and the Karewa beds. Puri (1947a) described leaf-impressions of *M. philippensis* from the Karewa beds of Kashmir, whereas Pathak (1969) described the same species from the Siwalik beds of Mahanadi River Section near Darjeeling, West Bengal. Mathur (1978) also described leaf-impressions resembling *Mallotus* sp. from the Siwalik beds near Jawalamukhi, Himachal Pradesh.

The genus *Mallotus* Lour. consists of about 150 species confined to the tropical Africa, Madagascar, East and south-east Asia, Indo-Malaya to New Caledonia, Fiji and north-east Australia (Willis, 1973). In India, 20 species are found (Santapau & Henry, 1973). *Mallotus philippensis* is a large shrub or small tree found in the sub-Himalayan tract from Punjab eastwards ascending to 1,400 m, Bengal, central provinces and in both peninsulas (Brandis, 1906). It also occurs in the forests of Chotanagpur region and is considered to be a close associate of *Shorea robusta* (Wood, 1903; Haines, 1910).

Family—Urticaceae (Moraceae)

Genus—*Ficus* Linn.

Ficus foveolata Wall. ex Miq.
Pl. 11, figs 3-7

Material—Two incomplete leaf-impressions, one of them with its counterpart. Apex is absent in both the specimens. Preservation is good.

Description—Leaf simple, length of leaves 4.8 and 4 cm, width 3.2 and 3 cm, lamina and base

PLATE 13

Ficus tomentosa Roxb.

1. Fossil leaf, natural size; Specimen no. BSIP 36301.
2. Modern leaf, natural size.
3. Venation details of fossil leaf. $\times 2$.
4. Higher order venation details. $\times 7$.

Dalbergia sissoo Roxb.

5. Fossil fruit cf. *Dalbergia sissoo*, natural size; Specimen no. BSIP 36302.
6. Modern fruit, natural size.

Zizyphus mauritiana Lamk.

7. Fossil fruit cf. *Zizyphus mauritiana*, natural size; Specimen

no. BSIP 36303.

8. Modern seed, natural size.
Zizyphus xylopyrus Willd

9. Fossil fruit cf. *Zizyphus xylopyrus*, natural size; Specimen no. BSIP 36304.

10. Modern fruit, longitudinal section, natural size.

11. Dicot flower, natural size; Specimen no. BSIP 36305.

Dillenia sp.

12. Fossil fruit cf. *Dillenia* sp. natural size, Specimen no. BSIP 36306.

13. Modern fruit of *Dillenia*, natural size.

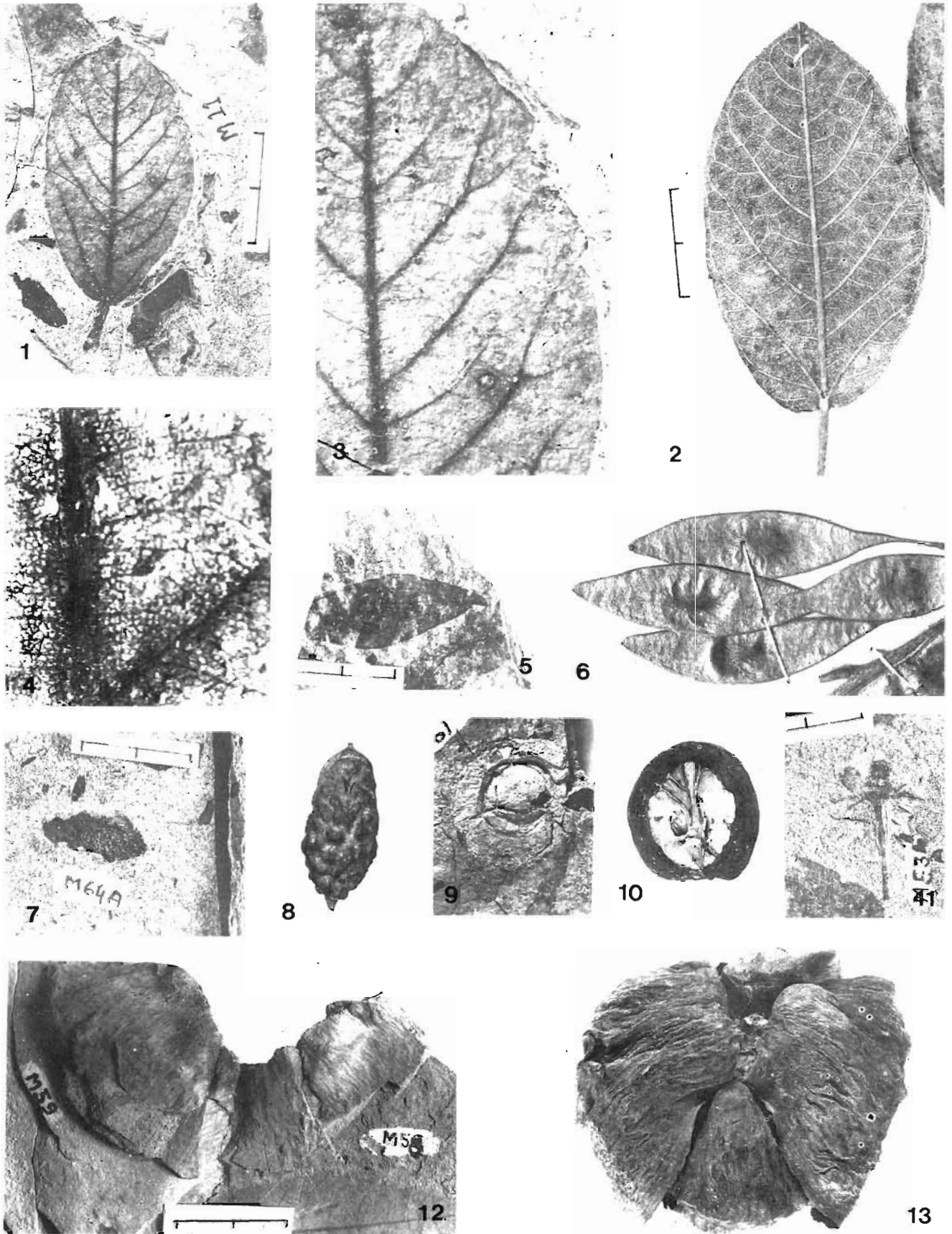


PLATE 13

symmetrical, elliptic; apex not preserved; base rounded; margin entire; glands not seen; texture coriaceous; petiole normal, venation pinnate-camptodromous-brochidodromous; primary vein (1°) massive, straight; secondary veins (2°) acute (wide), lowest pair of secondary veins more acute than pairs above, distance between lowest pair and pair above is much more than in the remaining pairs, moderate, curved abruptly, joining superadjacent secondary at right angle, also enclosed by secondary arches of 3° , intersecondary veins present, simple, tertiary veins (3°) RR, orthogonal, reticulate, predominantly alternate, closely spaced; highest vein order of leaf 4° , highest vein order showing excurrent branching 3° , quaternary veins normal, orthogonal, marginal ultimate venation looped; areoles well-developed, oriented, quadrangular to pentangular, veinlets none.

Discussion—Chartaceous leaf with elliptic form, brochidodromous venation with lowest pair of secondary veins more acute than pairs above, wide gap between the lowest pair of secondaries and the pair above are the most important characters of fossil leaves which indicate their near resemblance with the modern leaves of *Croton oblongifolius*, *Mallotus philippensis* and with various species of *Ficus*. However, they show strong resemblance with those of *Ficus foveolata* (F.R.I. Herbarium sheet no. nil; Pl. 11, fig. 8).

Quite a good number of fossil leaves belonging to *Ficus* are known from India. Puri (1947, 1948) described two fossil leaves resembling *Ficus cunia* Buch-Ham. and *F. nemoralis* Wall. from the Karewa beds of Kashmir. Lakhanpal (1968) described *Ficus precunia* (modern comparable form *F. cunia*) from the Siwalik beds of Jawalamukhi. Later, Gupta and Jiwan (1972) also described *Ficus cunia* from the Siwalik beds of Bilaspur, Himachal Pradesh. *Ficus arnotiana* Miq. and *F. glomerata* Roxb. were described by Mahajan and Mahabale (1973) from the Quaternary deposits of Maharashtra. Lakhanpal and Guleria (1981) described *Ficus kachchhensis* (modern comparable form *Ficus tomentosa* Roxb.) from the Eocene of Kachchh and again in the year (1982) they described *Ficus khariensis* (modern comparable *Ficus infectoria*) from the same beds. Lakhanpal and Awasthi (1984) described another species *Ficus champarensis* (modern comparable form *Ficus cunia*) from the Siwalik beds from near Bhikhnathoree in West Champaran District, Bihar. Recently, Prasad (1986) has also described three species of *Ficus*, viz., *Ficus retusoides* (modern comparable form *Ficus retusa*), *Ficus precunia* (modern comparable form *F. cunia*) and *Ficus nepalensis* (modern comparable form *Ficus*

glaberrima) from the Siwalik beds of Koilabas near Indo-Nepal border.

The genus *Ficus* Linn. consisting of about 800 species (Willis, 1973) is widely distributed throughout the tropics of both hemispheres but most abundant in the islands of Indian Archipelago and the Pacific Ocean. A few species are extended beyond the tropics into the southern Florida (U.S.A.), Mexico, Argentina, southern Japan and China, the Canary Islands and South Africa. About 70 species are reported to occur in India (Santapau & Henry, 1973), out of which about 18 species including *Ficus foveolata* grow in Chotanagpur region (Wood, 1903; Haines, 1910) *Ficus foveolata* is a creeping or climbing shrub rooting at nodes, sometimes erect and is distributed from Himalaya (Hazara) eastward ascending up to 850 m, Assam, Khasi Hills, Bihar (including Chotanagpur) up to Bangla Desh (Chittagong), Burma, China and Japan (Wood, 1903; Brandis, 1906; Haines, 1910).

Ficus glaberrima Bl. syn. *F. infectoria* Roxb.
Pl. 12, figs 1, 3, 4

Material—Single complete leaf-impression with good preservation showing all the architectural details of the leaf.

Description—Leaf simple, length 11 cm and width 5.5 cm, lamina and base symmetrical, elliptic; apex acuminate; base acute, normal; margin entire; texture coriaceous; glands not visible; petiole present, normal; venation pinnate, camptodromous-brochidodromous; primary vein (1°) stout, markedly curved; secondary veins (2°) with acute (moderate) angle of divergence, lowest pair more acute than the pairs above, moderately thick, curved abruptly joining superadjacent secondary at right angle, loop forming branches are also enclosed by secondary arches of 3° , inter-secondary veins present, composite; tertiary veins (3°) AO, reticulate, orthogonal; highest vein order of leaf 4° , highest vein order showing excurrent branching 3° , quaternary veins moderate, orthogonal, marginal ultimate venation looped; areoles well-developed, oriented, quadrangular to pentagonal, veinlets none.

Discussion—The important morphological details of the leaf indicate its affinity with the modern leaves of various species of *Ficus* Linn., amongst which it closely resembles the leaves of *Ficus glaberrima* Bl. (F.R.I. Herbarium sheet no. 1902; Pl. 12, fig. 2).

The fossil records of the genus *Ficus* in India has already been discussed in detail while describing the leaf of *Ficus foveolata*. Lakhanpal and Guleria (1982) and Prasad (1986) have described *Ficus khariensis* and *F. nepalensis* from Kachchh,

western India and from the Siwalik beds of Koilabas, Nepal respectively. Both these forms have been shown to bear close resemblance with the leaves of *Ficus glaberrima* syn. *F. infectoria*.

Ficus glaberrima is a large deciduous tree found in sub-Himalayan tract from Yamuna eastward, common in northern India, central Provinces, Berar, western Peninsula; Khasi Hills, Bangla Desh (Chittagong), Burma (Tenasserim), Andamans and Malayan Archipelago (Brandis, 1906).

Ficus tomentosa Roxb.

Pl. 13, figs 1, 3, 4

Material—Single complete well-preserved leaf-impression.

Description—Leaf simple, length 5.0 cm, width 2.5 cm; whole lamina and base both symmetrical, elliptic; apex mucronate; base obtuse (normal); margin entire; texture coriaceous; glands not seen; petiole present, normal; venation pinnate, craspedodromous, mixed; primary vein (1°) stout, straight; secondary veins (2°) with acute (moderate) angle of divergence, lowest pair of secondary veins more acute than pairs above, curved uniformly, the secondaries bifurcate near the margin and in the apical region take part in loop formation, intersecondary veins present, composite; intramarginal vein absent; tertiary veins (3°), AR, reticulate to percurrent, reticulate orthogonal, percurrent veins straight, oblique with midvein, alternate to opposite in equal numbers, closely spaced; highest vein order of leaf 4° , highest vein order showing excurrent branching 4° ; quaternary veins orthogonal, marginal ultimate venation incomplete; areoles well-developed, oriented, quadrangular, veinlets none.

Discussion—Elliptic form, mixed craspedodromous venation, more acute angle of divergence of lowest pair of secondaries, bifurcation of secondaries near the margin and well-developed areoles are the important characters of the fossil leaf which indicate its close affinity with the leaves of *Ficus tomentosa* Roxb. (BSIP Herbarium sheet no. 14056; Pl. 13, fig. 2).

The fossil record of *Ficus* in India has already been discussed in the previous pages. Of the various species of *Ficus* leaves described from the Cenozoic of India, only *Ficus kachchensis* belonging to the Eocene of Kachchh has been shown to possess close affinity with *Ficus tomentosa* (Lakhanpal & Guleria, 1981).

Ficus tomentosa is a large shady tree found in Bundelkhand, Banda, Bihar, Chotanagpur, central provinces and western Peninsula (Brandis, 1906).

IMPRESSIONS OF FLOWER AND FRUITS

The assemblage has yielded a dicot flower and four types of fruit-impressions. It has been possible to identify the fruit-impressions while the impression of the flower could not be identified with certainty. Hence, it has been described as a dicotyledonous flower.

Dicot Flower

Pl. 13, fig. 11

Flower pedicellate, length of pedicel 1.7 cm with hypogynous insertion of floral organs; calyx polysepalous with four preserved sepals, each sepal thick at the base and pointed towards the apex, sepals appear to have valvate aestivation; corolla polypetalous with two preserved petals, which are elliptic in shape.

Dicot Fruit Type-1

cf. *Dillenia* sp.

Pl. 13, fig. 12

The study is based on a single incomplete impression of the persistent calyx; the length of preserved sepals 2.6 cm and width 2.8 cm.

In a number of fruits like those of *Dillenia*, *Physalis* and *Shorea*, etc., the calyx is not only persistent but also grows in size. On detailed comparison it was found that in the structure of calyx the fossil resembles the fruits of *Dillenia*. In the forests of Chotanagpur region three species of *Dillenia* are found, viz., *Dillenia indica*, *D. aurea* and *D. pentagyna*. On the basis of fruits these species can not be differentiated.

From India, only fossil leaf *Dillenia palaeoindica* (modern comparable form *D. indica*) has been described by Prasad and Prakash (1984) from the Siwalik beds of Koilabas, Nepal.

The genus *Dillenia* consists of 60 species of trees and shrubs distributed widely in the tropical regions of the world, the largest number of species being confined to India and South-east Asia. About 11 species of trees are known to grow in the Indian region (Chowdhury & Ghosh, 1958).

Dicot Fruit Type-2

cf. *Ziziphus xylopyrus* Willd

Pl. 13, fig. 9

The study is based on a complete fruit-impression. The fruit is a drupe and all the three layers of fruit wall are present. The mesocarp is fibrous, 0.35 cm in thickness, while the endocarp is stony. Such type of fruits occur in *Mangifera indica*, *Prunus domestica*, *P. persica*, *P. armenia* and

various species of *Ziziphus*. On detailed comparison it has been found that the fossil fruit shows near resemblance with the modern fruit of *Ziziphus xylopyrus* (BSIP Herbarium sheet no. 14027; Pl. 13, fig. 12).

From India only fossil leaves of *Ziziphus* are so far known. Lakhanpal (1965, 1967) described *Ziziphus siwalicus* from the Siwalik beds of Balugoloa near Jawalamukhi, Himachal Pradesh. Singh and Prakash (1980) described *Ziziphus indicus* (modern comparable form *Z. mauritiana*) from the Siwalik beds of Arunachal Pradesh.

The genus *Ziziphus* includes about 100 species widely distributed in tropical America, Africa, Mediterranean, Indo-Malaya and Australia (Willis, 1973). *Ziziphus xylopyrus* is a large struggling shrub or small tree found in the forest of north-west Himalaya, central India and western peninsula (Brandis, 1906). It is also found in the forests of Chotanagpur region (Wood, 1903; Haines, 1910).

Dicot Fruit Type-3

cf. *Ziziphus mauritiana* Lamk.

Pl. 13, fig. 7

The study is based on an incomplete fruit-impression. The fruit is drupe, mesocarp is partially preserved, while the endocarp with rough surface is well preserved. The impression shows its near resemblance with the modern fruit of *Z. mauritiana* in shape and size and a rough endocarp too.

The fossil record of *Ziziphus* has already been given while dealing with the fruit-impression Type-2. *Ziziphus mauritiana* is a small tree and is found throughout India from north-west Frontier, Sindh, base of Himalaya to Sri Lanka and Malacca. It is also found in Afghanistan, tropical Africa, the Malaya Archipelago, China and Australia (Hooker, 1872). In the forests of Chotanagpur region, six species of *Ziziphus* are met with including *Z. mauritiana* (Wood, 1903; Haines, 1910).

Dicot Fruit Type-4

cf. *Dalbergia sissoo* Roxb.

Pl. 13, fig. 5

The study is based on a single complete fruit-impression which is elliptic in shape. The fruit is a pod with a single seed. The length of preserved specimen is 3.5 cm and width 1.2 cm.

The family Leguminosae is characterized by the presence of pod-like fruits. Amongst Legumes, the fossil fruit has been found to bear a near resemblance with the modern fruits of *Dalbergia sissoo* in shape and size (F.R.I. Herbarium sheet no. 11055; Pl. 13, fig. 6).

Both fossil fruits and leaves of *Dalbergia* have

been described from the Siwalik beds. Lakhanpal and Dayal (1966) described the fossil fruit of *Dalbergia sissoo* from the Siwalik beds from near Jawalamukhi in Himachal Pradesh. In 1984, Lakhanpal and Awasthi described a fossil leaf of *Dalbergia* sp. from the Siwalik beds from near Bhikhnathoree, West Champaran District, Bihar. Recently, Prasad (1986) described *D. miosericea* (modern comparable form *D. sericea*) from the Siwalik beds of Koilabas, Nepal.

The genus *Dalbergia* Linn. f. consists of 120 species of trees or climbing shrubs, distributed in tropical regions of the world (Willis, 1973), out of which about 36 species are reported to occur in India (Gamble, 1922). *Dalbergia sissoo* is a large deciduous tree found in the sub-Himalayan tract and in the outer valleys from Indus to Assam, ascending generally to 950 m, at places to 1,650 m, extending far into the plains along river banks, Baluchistan Suleman range (Brandis, 1906).

DISCUSSION

Considering the large number of plant taxa recovered from these beds it would be interesting to analyse the floral composition of this assemblage and use it in deciphering palaeoecology, depositional environment and age of these deposits. In addition to the taxa described above from these fossiliferous shales, leaf-impressions of *Grewia tiliacifolia* (Tiliaceae), *Murraya paniculata* (Rutaceae), *Schleichera oleosa* (Sapindaceae), *Mangifera indica* (Anacardiaceae) and *Vitex negundo* (Verbenaceae) have also been described by Bande, Srivastava and Misra (1989, in press). From the underlying sandstone unit petrified woods of *Sindora siamea* (Leguminosae, Prakash *et al.*, 1988), *Terminalia tomentosa* (Combretaceae) and *Lagerstroemia* sp. (Lythraceae) have been recovered (unpublished personal collection).

Floristic composition—The present study is the first detailed work on the fossil flora of this area. Including the taxa described by earlier workers (Prakash *et al.*, 1988; Bande, Srivastava & Misra, 1989) so far 32 species belonging to 29 genera and 20 families of dicotyledons have been recovered from these fossiliferous beds. Monocotyledons are totally absent.

Leguminosae (with five genera) is the most dominant family in this assemblage. Dominance of Leguminosae and presence of Dipterocarpaceae clearly indicate that the assemblage is post Palaeogene (Lakhanpal, 1970) in age. Thus comparison of the Mahuadant assemblage with the

different Neogene megafossil floras of India is pertinent. The Neogene floras are widely distributed all over the country, viz., Tipam sandstones, Dupitila Series and Tertiary of West Bengal in the East; Tertiary of Kachchh, Gujarat and Rajasthan in the West; Siwalik beds in the North and Cuddalore sandstones, Neyveli lignites and Varkala beds of Kerala coast in the South.

A comparison of the present assemblage with these various Indian Neogene floras indicates that it is closely comparable to the Lower Siwalik flora. Thirteen genera—*Dillenia*, *Shorea*, *Sterculia*, *Ziziphus*, *Mangifera*, *Dalbergia*, *Millettia*, *Baubinia*, *Terminalia*, *Diospyros*, *Vitex*, *Mallotus* and *Ficus* are common in both. This assemblage is also comparable to the flora recovered from the Tipam sandstones wherein 9 genera are common. They are: *Shorea*, *Sterculia*, *Mangifera*, *Ougenia*, *Terminalia*, *Madhuca*, *Diospyros*, *Vitex* and *Mallotus*. Only four genera, viz., *Shorea*, *Mangifera*, *Millettia* and *Terminalia* are common with the Tertiary flora of the peninsular region of the adjoining West Bengal.

It is interesting to note that fossils of *Spondias*, *Erythrina*, *Combretum*, *Mitragyna*, *Alstonia* and *Cryptolepis* are reported for the first time from the Cenozoic of India. The occurrence of *Cryptolepis buchmanii* constitutes the first fossil record of family Asclepiadaceae from India. Amongst rest of the genera, *Grewia* is known from the Palaeogene (Deccan Intertrappean beds and Eocene of Assam) and from the Karewa beds of Kashmir, while *Evodia* is known only from the Deccan Intertrappean beds.

Palaeoecology—Plant communities especially the climax vegetation reflects an achievement of harmony or a balance with the environment. Thus the study of any fossil assemblage can be used to reconstruct the palaeo-environmental conditions. Reconstruction of palaeoclimates and palaeoedaphic conditions is also possible by a judicious study and interpretation of fossil floras. This inferential information is useful in understanding the sequential development of the present day phytogeography.

The present assemblage can be subdivided into two divisions: (i) silicified woods recovered from the sandstone unit, and (ii) impressions of leaves, flowers and fruits recovered from the shale unit. Only three genera are represented in the form of silicified woods, viz., *Sindora*, *Terminalia* and *Lagerstroemia*. *Sindora siamea* is a typical element of the tropical wet evergreen forests and is found only in Thailand (Ridley, 1967). The other two taxa, *Terminalia tomentosa* and *Lagerstroemia* sp. cf. *parviflora* are common constituents of the tropical forests in the country. This indicates that till the

deposition of the sandstone unit the vegetation was wet evergreen in nature. On the contrary the present day distribution of the genera and species recovered from the shale unit indicates that all of them still grow in the nearby forests of Chotanagpur plateau.

Champion and Seth (1968) have divided the tropical forests of India into (i) wet evergreen forests, (ii) semi-evergreen forests, (iii) moist deciduous forests, (iv) littoral and swamp forests, (v) dry deciduous forests, (vi) thorn forests, and (vii) dry evergreen forest types on the basis of moisture conditions.

The South Daltenganj Forest Division under which the fossiliferous beds are exposed has both moist and dry deciduous forests. Both types of forests can be met within the same area depending on the site, etc. The distribution of various taxa constituting the present fossil assemblage in the moist as well as dry deciduous forests of Chotanagpur plateau is as follows :

Table 1

	Moist deciduous forest	Dry deciduous forest
<i>Dillenia</i> sp.	+	+
<i>Shorea robusta</i>	+	+
<i>Sterculia villosa</i>	+	-
<i>Pterygota alata</i>	+	+
<i>Grewia tiliaefolia</i>	+	-
<i>Murraya paniculata</i>	+	-
<i>Evodia meliaefolia</i>	+	-
<i>Garuga pinnata</i>	+	+
<i>Ziziphus xylopyrus</i>	+	+
<i>Ziziphus</i> sp. cf. <i>Z. mauritiana</i>	+	+
<i>Schleichera oleosa</i>	+	+
<i>Mangifera indica</i>	+	-
<i>Spondias pinnata</i>	+	+
<i>Dalbergia sissoo</i>	+	+
<i>Erythrina suberosa</i>	-	+
<i>Millettia auriculata</i>	+	-
<i>Ougenia oojeinensis</i>	+	-
* <i>Sindora siamea</i>	-	-
<i>Baubinia purpurea</i>	+	+
<i>Combretum decandrum</i>	+	+
<i>Terminalia tomentosa</i>	+	+
<i>Lagerstroemia parviflora</i>	+	+
<i>Mitragyna parvifolia</i>	+	+
<i>Madhuca indica</i>	+	+
<i>Diospyros montana</i>	-	+
<i>Alstonia scholaris</i>	+	+
<i>Cryptolepis buchmanii</i>	+	+
<i>Vitex negundo</i> var. <i>incisa</i>	-	+
<i>Mallotus philippensis</i>	+	+
<i>Ficus foveolata</i>	+	+
<i>F. glaberimma</i>	+	+
<i>F. tomentosa</i>	+	+

*Found in wet evergreen forest

Thus, it is evident that the elements of both

moist and dry deciduous forests were also growing together during the past in the Chotanagpur region. This evidence of fossil plants also indicates that the climate around this basin was subtropical at the time of deposition of shales from which these impressions have been described. It must have been relatively more moist at the time of deposition of underlying sandstone unit from which *Sindora siamea*, a characteristic evergreen species, has been described. Since the deposition of these shales the same tropical climate has continued around this valley without any significant change.

Depositional environment—The fossiliferous beds of the area are composed of two units—the sandstone and shale. The sandstone unit overlying the conglomerates is fine to medium grained and attains a thickness varying from 1 to 3 m. It contains thin intercalations of sandy shales and siltstone. The shales are thinly bedded, grey coloured, somewhat arenaceous and attain a maximum thickness of about 3.2 m in which sand rich and clay rich bands alternate. From the pattern of depositional sequence it may be inferred that these fossiliferous shales were alternately deposited by high energy sedimentation followed by low energy sedimentation. Both sand rich and clay rich bands in the shale unit suggest that the sand rich bands are the result of annual flooding while clay rich bands are due to the deposition in a quiet body of water. The thinly bedded nature of shale unit further indicates that the deposition took place in rhythmic conditions in a shallow body of water, probably a lake, under stable conditions. Most of the plant fossils are well-preserved and do not show much disturbance. Besides, the presence of well-preserved flowers indicate that the material was not transported from a long distance before deposition.

Age—Fox (1923) was the first to record the presence of shales and other sedimentary beds near Mahuadanr. The fossiliferous nature of the beds was first recorded by Roy Chowdhury (in West, 1948, p. 22). Puri (1976) collected from them a fossil fish alongwith some leaf-impressions and assigned an Upper Tertiary or Quaternary age to these beds. Later, Puri and Mishra (1982) further mapped this area in detail and reported the occurrence of fossil fishes, birds and insects alongwith impressions of angiospermous leaves and petrified woods. Although animal fossils have been collected from the shales, they are not of much use in deciphering their age. However, the evidence from the fossil flora can be of some use as we know that the similarities of the fossil forms with modern taxa are inversely proportional to the age of the beds. Close similarity of fossil taxa up to specific level with the modern

forms suggests that the beds are not of great antiquity.

Presence of *Sindora siamea* in the sandstone unit of these beds is interesting in this context. *Sindora* has so far been reported from the Mio-Pliocene (Cuddalore Sandstone, Tipam Sandstone, Siwalik beds and Rajasthan) of India (Prakash, Misra & Srivastava, 1988). This suggests that the sandstone unit is in all probability Mio-Pliocene in age and obviously the shales are younger. However, more evidences, especially from the radiometric dating and organic matter maturation studies, are required to decide the absolute age of these beds.

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