

PLANT REMAINS FROM THE MIOCENE OF KACHCHH, WESTERN INDIA

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ABSTRACT

The paper deals with a few impressions of leaves, fruits and seeds belonging to 5 families, 10 genera and 11 species collected from the Khari Series (Aida Stage — Lower Miocene) of Kachchh. They have been described here as *Murraya khariensis* sp. nov. of Rutaceae, *Millettia symmetrica* sp. nov., *M. miocenica* sp. nov., *Bauhinia kachchhensis* sp. nov., *Cassia miokachchensis* sp. nov., *Leguminocarpon khariensis* sp. nov., *Leguminophyllum khariensis* sp. nov. and *Leguminosites khariensis* sp. nov. of Leguminosae, *Cinnamomum miokachchensis* sp. nov. of Lauraceae, *Ficus khariensis* sp. nov. of Moraceae and *Palmacites khariensis* sp. nov. of Palmae. The assemblage suggests moist to dry deciduous vegetation in this area.

Key-words — Plant remains, Rutaceae, Leguminosae, Lauraceae, Moraceae, Palmae, Khari Series, Lower Miocene (India).

सारांश

कच्छ (पश्चिमी भारत) में मध्यनूतन युग के पादपावशेष — राजेन्द्र नाथ लखनपाल एवं जसवंत सिंह गुलेरिया

प्रस्तुत शोध-पत्र में कच्छ की खारी श्रेणी (एँडा चरण—अधर मध्यनूतन) से एकत्रित कुछ पर्णों, फलों एवं बीजों की छापों का, जो कि पाँच कुलों, 10 प्रजातियों एवं 11 जातियों से सम्बद्ध हैं, वर्णन किया गया है। इन्हें रुटेसी कुल के मुराया खारीयेन्सिस न० जा०, लैग्यूमिनोसी कुल के मिलेट्टिया ऐसिमेट्रिका न० जा०, मि० मायोसेनिका न० जा०, बाँहीनिआ कच्छेन्सिस न० जा०, कैसिया मायोकच्छेन्सिस न० जा०, लैग्यूमिनोकार्पेन खारीयेन्सिस न० जा०, लैग्यूमिनोफिल्लम खारीयेन्सिस न० जा० एवं लैग्यूमिनोसाइटिस खारीयेन्सिस न० जा०, लॉरिसी कुल के सिन्नामोमम मायोकच्छेन्सिस न० जा० मोरेसी कुल के फाइकस खारीयेन्सिस न० जा० तथा पाल्मी कुल के पाल्मासाइटिस खारीयेन्सिस न० जा० से नामांकित किया गया है। यह समुच्चय इस क्षेत्र में नम से शुष्क पर्णपाती वनस्पति का होना इंगित करता है।

INTRODUCTION

LAKHANPAL and Guleria have recently (1981) summarized the work done so far on the Tertiary flora of Kachchh. Since then a few hitherto unknown impressions of leaves, seeds and fruits have been collected from the Miocene beds (Aida Stage — Aquitanian) of Kachchh (Biswas & Raju, 1973; Tewari & Singh, 1977) and described in the present paper. These beds are exposed along the Khari Nadi (23°25'30" : Lat., 68°52' Long.) about 2.5 km south of the village Goyela, district Kachchh,

Gujarat. The locality lies on the southern bank of Khari Nadi about 100 m east of the road where it cuts the river bed. Goyela is about 125 km north-west of Bhuj on the Matanomadh-Naliya route via Rampur. The impressions preserved in arenaceous and light fawn coloured shales are totally devoid of cuticles.

In contrast to the leaf-assemblage described from the Eocene of Kachchh by the authors (1981), the present assemblage consists of smaller leaves of which a large number belong to the family Leguminosae. They seem to indicate relatively drier

conditions during the Lower-Miocene of Kachchh.

For the description of leaf-impressions the system of terminology given by Hickey (1973, 1974) and Dilcher (1974) has been followed.

The authors are thankful to the authorities of the Forest Research Institute, Dehradun for allowing them to consult their herbarium for identifying the fossils.

DESCRIPTION OF IMPRESSIONS

FAMILY — RUTACEAE

Genus — *Murraya* Koen. ex L.

Murraya khariensis sp. nov.

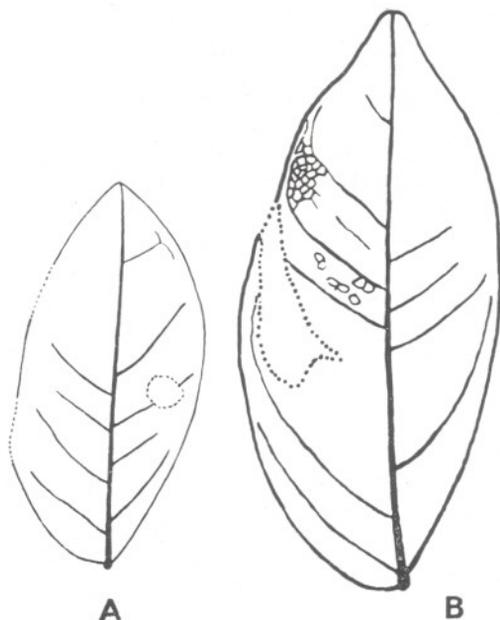
Pl. 1, figs 1, 2; Text-fig. 1A, B

The present species is based on two impressions of leaflets — 3.4 and 4.9 cm long respectively.

Description — Leaflets asymmetrical, elliptic; lamina about 3.4 to 5.0 cm in length and 1.6 to 2.4 cm in width; apex blunt acute to short acuminate; base asymmetrical; margin entire; texture thick smooth; petiolule hardly preserved; venation pinnate, eucamptodromous to brochidodromous, preservation poor; primary vein (1°) single, size moderate, slightly curved; secondary veins (2°) — angle of divergence acute, 50° - 60° , fine, curved, rarely branched; tertiary veins (3°) forming fine meshes, pattern random to orthogonal reticulate; areoles well-developed, appearing triangular to pentagonal; veinlets not seen.

Discussion — The important features of the present fossil are: (i) asymmetrical shape, (ii) small size, (iii) smooth margin, (iv) blunt acute to short acuminate apex, (v) thick smooth texture, and (v) pinnate venation.

The leaves of some of the genera of the families Meliaceae, Euphorbiaceae, Salvadoraceae, Leguminosae and Rutaceae show apparent resemblance with the present fossil in having one or more of the above mentioned characters. The common feature which the leaves of Meliaceae show with the fossil is the asymmetrical shape. However, they differ in other characters. In shape the small leaves of *Drypetes roxburghii* Wall. (*Putranjiva roxburghii* Wall.) of Euphorbiaceae show similarity with the present fossil but they differ in having finely serrated margin. The leaves of *Azima tetracantha*



TEXT-FIG. 1 — A, B, *Murraya khariensis* sp. nov., leaflets, $\times 1.5$.

Lamk. of Salvadoraceae show resemblance in shape and size but they differ in the pattern of venation and in having distinct mucronate apex. In Leguminosae the leaflets of *Millettia ovalifolia* Kurz show apparent resemblance with the present fossil but the leaflets of *M. ovalifolia* differ in having greater width and weakly retuse apex. Of the family Rutaceae the leaves or leaflets of some of the species of *Zanthoxylum* Linn. and *Paramignya beddomei* Tanaka, *Aegle marmelos* Correa, *Murraya koenigii* Spreng. and *M. paniculata* (Linn.) Jack (syn. *M. exotica* Linn.) show better resemblance with the present fossil. The leaflets of *Zanthoxylum* spp. and leaves of *Paramignya beddomei* differ in having longer apex than the present fossil. Further, in *P. beddomei* the petiole is longer. The leaflets of *Aegle marmelos* show resemblance with the fossil but differ in having crenate margin. Similarly, the leaflets of *Murraya koenigii* though showing general similarity with the fossil yet differ in relatively longer apex and serrated margin. Further, the leaflets in *M. koenigii* are chartaceous. The leaflets of *M. paniculata* show the nearest similarity with the present fossil in its shape, size, form, etc. However, they differ in having bigger petiolule

Fossil Records and Comparison—The authors are unaware of any fossil record of the leaflet of *Murraya* except a doubtful species of *Murraya*, i.e. *Murraya* sp. (?), simply recorded by Puri (1948, p. 118) without any description and photograph from the Lower Karewa (Pleistocene) beds of India. Obviously, this is for the first time that fossil leaflets of *Murraya* are being described under the binomial *Murraya khariensis* sp. nov., the specific epithet indicating the locality (Khari Nadi bed) from where the fossil specimens have been collected.

Present Distribution—The genus *Murraya* consists of 12 spp. (Willis, 1973, p. 766), distributed in East Asia, Indo-Malaya and Pacific islands. In India, only two species, viz., *Murraya paniculata* and *M. koenigii* are found.

Murraya paniculata, with which the present fossil shows the nearest resemblance, is a large shrub or small evergreen tree, distributed from Ravi eastwards to Assam, ascending to 1,350 m in Uttar Pradesh, Bihar, Orissa, South and West India; usually common in the underwood in ravines and forests, throughout the hotter parts of India, Burma, the Andamans and Ceylon. It also occurs in China, Australia and the Pacific islands.

Holotype—B.S.I.P. Museum no. 35416.

Paratype—B.S.I.P. Specimen no. 35417.

Locality—Khari Nadi bed, about 2.5 km south of village Goyela, district Kachchh, Gujarat.

Horizon & Age—Khari Series (Aida Stage—Aquitanian); Lower Miocene.

FAMILY—LEGUMINOSAE

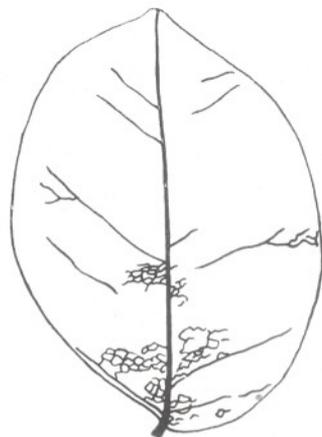
Genus—*Millettia* Wight & Arn.

Millettia asymmetrica sp. nov.

Pl. 1, figs 4-6; Text-fig. 2

The present species is based on three leaflet impressions, 3.1 cm, 3.4 cm and 3.9 cm long. The impressions are fairly well-preserved.

Description—Leaflets asymmetrical, elliptic-wide elliptic; lamina length 3.0-3.9 cm, maximum width 1.6-2.7 cm; apex shortly acuminate?; base asymmetrical; margin entire; texture appearing somewhat coriaceous; petiolule short, 0.1 cm in length; venation pinnate, eucamptodromous, poorly preserved; primary vein (1°) single, size moderate slightly curved; secondary veins (2°) angle of divergence acute, 60° - 50° , thick-



TEXT-FIG. 2 — *Millettia asymmetrica* sp. nov., leaflet, $\times 1.5$.

ness fine, curved; smaller veins forming fine meshes; pattern random to orthogonal reticulate; areoles well-developed, shape appearing to be quadriangular; veinlets not seen.

Discussion—The important features depicted by the present fossil are: (i) asymmetrical shape, (ii) small size, (iii) smooth margin, (iv) shortly acuminate? apex, (v) small petiolule, and (vi) eucamptodromous venation.

These characters can be seen in the leaves of various genera of a number of families as given on page 280. However, the present specimens show better resemblance with the members of Leguminosae, such as *Dalbergia sissoo* Roxb., *D. latifolia* Roxb., *Pongamia pinnata* (Linn.) Pierre (Syn. *P. glabra* Vent.) and *Millettia ovalifolia* Kurz. The leaflets of both the species of *Dalbergia* are broadly elliptic-orbicate-ovate. Also the apex of the leaflet in *D. sissoo* is relatively long acuminate. The leaflets of *Pongamia pinnata* show near similarity. However, in them the angle of secondaries is relatively acute. The fossil shows close resemblance with the leaflets of *Millettia ovalifolia* in its shape, size, form and petiolule length.

Fossil Records and Comparison—The authors are aware of only 3 species of *Millettia* (based on leaflets). *Millettia impressa* Harms, was reported by Menzel (1920) from Kamerun, West Africa (Age—Uncertain, Recent to Tertiary). Other two species have been described from Japan, viz., *M. notoensis* Ishida (1970) from Eocene and *Millettia* sp. Huzioka & Takahasi (1970) from the

Mid-Eocene. As *Millettia impressa* is not accompanied by its description and photograph, it is not possible to compare this species with the present fossil. *M. notoensis* differs from the present fossil in shape and form. *M. notoensis* is ovate in form and more or less symmetrical in shape. *Millettia* sp. distinctly differs from the present fossil in form and size. It is lanceolate in form and 7 cm long as compared to present fossil which is elliptic-wide elliptic in form and 3.1-3.9 cm long.

Obviously, the present species differs from all the known fossil species of *Millettia*, based on the leaflets and hence a new name *Millettia asymmetrica* is assigned to this species, indicating the asymmetric shape of the fossil.

Millettia ovalifolia, with which the specimen shows resemblance, is a tree species found in dry forests of Burma (Kurz, 1877, p. 356; Brandis, 1906, pp. 220, 706).

Holotype — B.S.I.P. Museum no. 35418.

Paratypes — B.S.I.P. Specimen nos. 35419 and 35420.

Locality — Khari Nadi bed, about 2.5 km south of village Goyela, district Kachchh, Gujarat.

Horizon & Age — Khari Series (Aida Stage — Aquitanian); Lower Miocene.

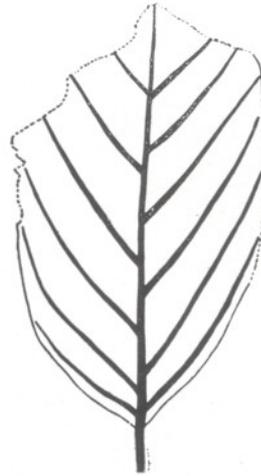
Millettia miocenica sp. nov.

Pl. 1, fig. 9; Text-fig. 3

The present description is based on a single fairly well-preserved 6.2 cm long specimen, whose apical portion is broken.

Description — Leaflet symmetrical, seeming oblong; lamina length 5.6 cm, maximum width 3.2 cm; apex broken; base acute, normal; margin entire; texture chartaceous; petiolule short, 0.6 cm in length; venation pinnate, seemingly eucamptodromous; primary vein (1°) single, stout, slightly curved, unbranched; secondary veins (2°) — angle of divergence acute, moderate, 45°-50°, lowest pair more acute than pairs above, arrangement alternate, number of preserved secondaries six on either side of midrib, relatively less thick than the primary vein, uniformly curved, unbranched; intersecondary veins absent, tertiary veins (3°) and higher order venation not preserved.

Discussion — The important features of the fossil are: (i) symmetrical shape, (ii) oblong form, (iii) acute base, (iv) entire margin, (v) pinnate, eucamptodromous vena-



TEXT-FIG. 3 — *Millettia miocenica* sp. nov., leaflet, $\times 1$.

tion, and (vi) small petiolule. All these characters could be seen in the leaflets of *Desmodium* Desv., *Millettia* Wight & Arn. and *Pterocarpus* Linn. of the family Leguminosae.

The frequency of secondary veins is more in those species of *Desmodium* and *Pterocarpus* which resemble the present fossil. Further, intersecondaries are present in the *Pterocarpus* spp., which are absent in the present fossil.

Among the various examined species of *Millettia* only *Millettia auriculata* Baker, *M. macrostachya* Coll. & Hemsl. and *M. pachycarpa* Benth. show similarity with the fossil. *M. pachycarpa* differs distinctly from the present fossil in the angle of divergence of the lowermost secondaries, which is more acute in the fossil as compared to *M. pachycarpa*. The leaflets of *M. auriculata* and *M. macrostachya* show very close similarity with the fossil and with each other, hence it is not possible to distinguish them on mere morphological basis. However, taking into consideration the present distribution of *M. auriculata* and *M. macrostachya*, it is presumed that the present fossil is likely to show closer affinities with *M. auriculata*, rather than with *M. macrostachya*.

Fossil Records and Comparison — The authors are aware of 4 fossil species of *Millettia*, viz., *M. impressa* Harms from West Africa, *M. notoensis* Ishida and *Millettia* sp. Huzioka & Takahasi from Japan and *M. asymmetrica* (see pp. 281-282) from India. Since *M. impressa* is un-

accompanied by any description or photograph, it is not possible to compare it with the present fossil. *M. notoensis* differs in its shape and angle of divergence. The shape of *M. notoensis* is ovate, whereas it is oblong in the present fossil. *Millettia* sp. from Japan differs from the present fossil in having lanceolate shape and inequilaterally obtuse base. Similarly, *M. asymmetrica* differs from the present fossil in shape and form. As the present specimen is different from all the known species of *Millettia*, a new specific name is assigned to this, viz., *Millettia miocenica* sp. nov. The specific name indicates the age of the beds from which the fossil has been collected.

Present Distribution — The genus *Millettia* comprises 180 spp. (Willis, 1973, p. 746) of trees, shrubs and woody climbers, distributed in the warmer regions of Africa, Asia and Australia. Approximately 30 species (Ramesh Rao & Purkayastha, 1972, p. 114) are reported to occur in the Indian region, chiefly in Burma.

M. auriculata, a woody climber, is found in sub-Himalayan tract, from Sutlej eastward, Bihar, Central India, south to the Godavary, common in Sal forests. It is also common in the deciduous forests of Upper and Lower Burma. *M. macrostachya*, a tree is found in the southern Shan hills

(Burma). As regards climbers, it is important to note that the same species may sometimes be described as an erect shrub. According to Brandis (1906, p. 219), "In the deep shade of the forest *Millettia auriculata*, *Derris scandens* and other climbers remain stunted shrubs, but when light is given overhead, the internodes lengthen out; the shoots seek the light, and begin to climb, attaching themselves to other shrubs and trees. Again, in the open, exposed to the sun, climbing species may remain shrubby for want of supports to lean upon".

Holotype — B.S.I.P. Museum no. 35421.

Locality — Khari Nadi bed, about 2.5 km south of village Goyela, district Kachchh, Gujarat.

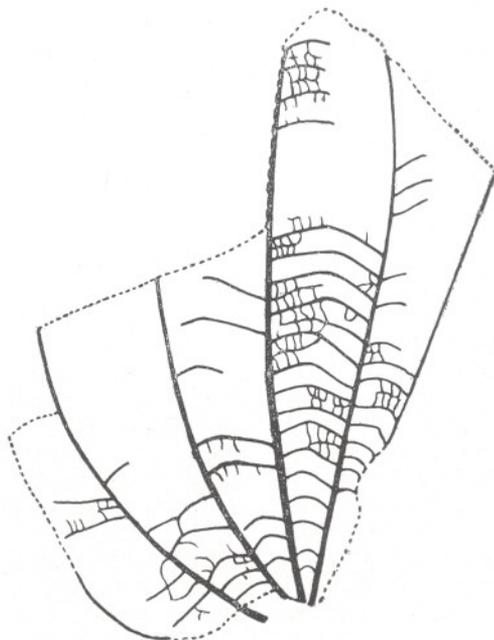
Horizon & Age — Khari Series (Aida Stage — Aquitanian); Lower Miocene.

Genus — *Bauhinia* Linn.

Bauhinia kachchhensis sp. nov.

Pl. 2, figs 10, 12, 13; Text-fig. 4

The present species is based on five specimens of incomplete leaf-impressions, out of which one shows very well-preserved details of venation. The specimens in all likelihood represent folded leaves.



TEXT-FIG. 4 — *Bauhinia kachchhensis* sp. nov., leaf, $\times 1.5$.

Description — Leaf appearing symmetrical, composed of two wide obovate lobes; lamina length 5.0 cm, maximum width 4.0 cm; lobes rounded; apex not preserved; base? cordate; margin entire; texture appearing to be thick chartaceous; petiole not preserved; venation acrodromous; primary vein (1°) four to six in one half, arranged as series of veins of relatively equal thickness, weak, markedly curved; secondary veins (2°) numerous between the two primaries and joining the adjacent primaries, fine, curved to wavy; tertiary veins (3°) pattern random to reticulate, distant to closely arranged; areoles well-developed, arrangement oriented, triangular to pentagonal, size medium; veinlets not seen.

Discussion — The most important feature of the fossil is the acrodromous venation with entire margin of the leaf. That the specimen is a folded leaf or it is one half of the leaf is clearly indicated by one of the margins of the fossil leaf, which is running almost straight like an edge (thereby, abruptly marking the end of lamina on that side) whereas the other margin of the leaf is showing clear curvature, and hence indicates that the fossil leaf has got folded up from the side of sharp straight edge. This folding of the leaf provides a very strong circumstantial evidence that the leaf must have had emarginate apex, as it has been observed that the leaves normally do not get folded up unless the apex is emarginate or the leaf is incompletely or completely bilobed. This type of leaf having emarginate apex or incompletely to completely lobed lamina with entire margin and acrodromous venation is found in *Hardwickia* Roxb. and *Bauhinia* Linn.

Of the two species of *Hardwickia* found in India only the leaves of *H. binata* Roxb. show some resemblance with the fossil. However, leaves in *H. binata* are relatively smaller in size and almost completely bifoliate. Due to bilobation, both the margins of each lobe exhibit curvature, as compared to the present fossil, in which one margin shows curvature, whereas the other margin is almost straight. Further, the orientation of the secondary venation in *H. binata* also differs from the present fossil.

Leaves of a large number of *Bauhinia* species were compared with the fossil. Of them, *Bauhinia purpurea* Linn. and *B. phenicea* Heyne show very close similarity

with the fossil and it is difficult to differentiate these two species from one another on the basis of leaf morphology.

Fossil Records and Comparison — From India Lakhanpal and Awasthi (in press) have reported the fossil leaf of *Bauhinia* from the Siwalik beds of West Champaran District, Bihar. From abroad, the fossil leaves of *Bauhinia* have been described under two genera, viz., *Bauhinia* Linn. and *Bauhinites* Seward & Conway (1935). The earliest record of *Bauhinia* leaf is known from the Middle-Cretaceous of Bohemia (Velenovsky, 1885). Besides one species of *Bauhinites*, *B. groenlandica* Seward & Conway (1935), the authors are aware of 17 spp. of *Bauhinia*, viz., *B. alabamensis* Berry (listed in Berry, 1916), *B. cretacea* Newberry (1886, 1895), *B. destructa* Unger (1850), *B. ecuadorensis* Berry (1945), *B. europaea* Engelhardt (listed in Muller, 1934), *B. germanica* Heer (1859), *B. (?) gigantea* Newberry (1895), *B. marylandica* Berry (1908), *B. olympica* Unger (1867), *B. parschlugiana* Unger (1850), *B. pseudocotyledon* Cockerell (listed in Knowlton, 1919), *B. ripleysensis* Berry (1916), *B. siwalika* Lakhanpal & Awasthi (in press), *Bauhinia* sp. Knowlton (listed in Knowlton, 1919), *B. wadii* Berry (listed in La Motte, 1952), *B. weylandi* Chaney (1933) and *B. wyomingana* Brown (1956d). These species have been reported from Austria, Bolivia, Czechoslovakia, Ecuador, West Germany, Greece, Greenland, India, North Vietnam, Uganda, U.S.A. and U.S.S.R.

All the records available to the authors have been compared here. *Bauhinia siwalika* can easily be distinguished from the present fossil. The former is smaller in size (1.5-4 cm in length and 1-3 cm in width) as compared to the fossil (up to 5.0 cm in length and 4.0 cm in width). Further, the number of primaries are only 3-4 in *B. siwalika* as compared to 4-6 in the present fossil. *Bauhinia ecuadorensis* shows some resemblance. However, the angle and course of the second pair of lower primaries in *B. ecuadorensis* is entirely different from the present fossil. *B. cretacea* differs from the present fossil in having only one to two lateral primaries in each lobe of the leaf. Moreover, the inner primaries bifurcate several times. Similarly, *B. ripleysensis* differs in having only one lateral primary in each lobe. Like the

present fossil, *B. (?) gigantea* is also based on one lobe of the leaf. Nevertheless, it differs from the fossil in its size and in the number of primaries. It possesses only one lateral primary, against four to six in the present fossil. In *B. wyomingana* primaries arise from different points, contrary to the present fossil in which primaries arise from single basal point. Berry (1945) does not regard *B. pseudocotyledon* from the Miocene of Florissant, Colorado, as representing *Bauhinia*. According to him *B. europaea* and *B. germanica* are more likely referable to the genus *Hymenaea* Linn. as they possess well defined midvein in each leaflet, unlike in the genus *Bauhinia*. The pinnate venation in *B. destructa* and *B. parschlugiana* differentiate these from the present fossil. *Bauhinites groenlandica* can also be differentiated by its relatively smaller size and in having 3 primaries in each lobe, as against 4 or more in the present fossil.

Thus the present fossil is distinct from all previously known fossil *Bauhinias* and is assigned to a new species, *Bauhinia kachchhensis*. Its specific name is after the area from where the material was collected.

Present Distribution — The genus *Bauhinia* comprises 300 spp. (Willis, 1973, p. 127) and is found throughout the tropics of the world. These consist of trees, shrubs, vines and gigantic lianes. Brandis (1906) has enumerated 30 spp. from India and Burma, of which 6 attain tree size.

Of the two comparable species, *B. phoenicea* Heyne is a gigantic climber and *B. purpurea* Linn. is a medium-sized tree. The former is common on the Ghats of South Kanara, Wainad and also found in the evergreen forests of Coorg and Travancore. The latter is found in sub-Himalayan tract, from the Indus eastwards, ascending to 1,600 m in Assam, Khasi Hills, Chittagong, western Peninsula, in deciduous forests.

Holotype — B.S.I.P. Museum no. 35422.

Paratypes — B.S.I.P. Specimen nos. 35423-35425.

Locality — Khari Nadi bed, about 2.5 km south of village Goyela, district Kachchh, Gujarat.

Horizon & Age — Khari Series (Aida Stage — Aquitanian); Lower Miocene.

Genus — *Cassia* Linn.

Cassia miokachchhensis sp. nov.

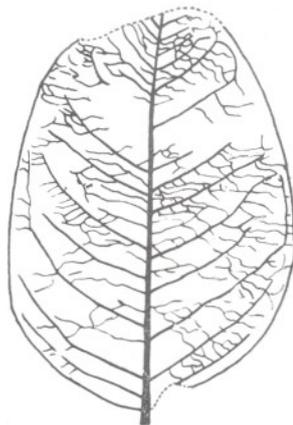
Pl. 2, fig. 11; Text-fig. 5

The present species is represented by three fairly well-preserved leaflets. However, the apices of leaflets in all the specimens are broken.

Description — Leaflet almost symmetrical, ovate; lamina length 3.5 cm, maximum width 2.6 cm; apex broken; base obtuse; margin entire; texture seemingly chartaceous; attachment of petiolule normal, petiolule 2.0 cm long; venation pinnate, eucamptodromous; primary vein (1°) simple, stout, slightly curved; secondary veins (2°) — angle of divergence acute (70°-50°), 70° near the base and gradually decreasing upwards, thickness fine, curved upwards, appears unbranched; intersecondaries present, simple; tertiary veins (3°) still finer, pattern random reticulate, simple, distant to close; quaternaries forming fine net work, course orthogonal to randomly oriented; areoles well developed, oriented, shape appears quadrangular, size small; veinlets not seen.

Discussion — The important characters of the present fossil are: (i) small size, (ii) almost symmetrical shape, (iii) ovate form, (iv) obtuse base, (v) entire margin, (vi) short petiolule, (vii) eucamptodromous venation, and (viii) chartaceous texture.

The petiolule and the small size of lamina of the present fossil suggest that it is a



TEXT-FIG. 5 — *Cassia miokachchhensis* sp. nov., leaflet, × 1.5.

leaflet of some leguminous plant, thereby ruling out all other families from consideration. In the family Leguminosae the leaflets of *Dalbergia* Linn. f., *Pterocarpus* Linn. and *Cassia* Linn. show the above noted characters. The leaflets of *Pterocarpus* spp. which show apparent resemblance with the present fossil, however, differ in the angle of divergence of secondaries. Among the large number of *Dalbergia* spp. examined, the leaflets of *D. latifolia* Roxb. and *D. sissoo* Roxb. show some resemblance. However, they differ in having broadly-elliptic-orbiculate-ovate form. Moreover, they differ in being coriaceous as compared to chartaceous texture of the present fossil. The fossil thus shows the nearest approach to *Cassia* leaflets.

Fossil Records and Comparison — Leaflets of *Cassia* have been reported under two genera, namely *Cassia* Linn. and *Cassiophyllum* Geyler (1887). The authors are aware of about 100 species of leaflets of *Cassia* and one species of *Cassiophyllum* (LaMotte, 1952; Guleria, 1978). They have been reported from different parts of the world such as Australia, Bolivia, Czechoslovakia, Germany, Greenland, Indonesia, Italy, Japan, New Zealand, Switzerland, U.S.A. and U.S.S.R.

So far there is no record of leaflets of *Cassia* from India. However, a fruit said to be comparable to *Cassia* has been described by Carter (1854) from Takli (Deccan Intertrappean Series), near Nagpur, Maharashtra. This is perhaps the earliest record of the so-called *Cassia* from India. Lately, a legume fruit comparable to Carter's (1854) specimen has been reported by Shivarudrappa (1976) from the Intertrappean beds of Burjapalli area of Gulbarga District, Karnataka.

Present Distribution — *Cassia* is a large genus of 500-600 spp. of herbs, shrubs and trees and grows in tropical and warm temperate (excluding Europe) regions of the world (Willis, 1973, p. 211). The genus includes some of the most beautiful flowering trees and shrubs, planted in avenues and gardens. Brandis (1906) enumerates 12 spp. of *Cassia* from the Indian region.

As no fossil species of leaflets of *Cassia* is known from India, the present leaflet is assigned to a new species, *Cassia miokachchensis* sp. nov., the specific name suggesting the age and the place from where the present fossil was collected.

Holotype — B.S.I.P. Museum no. 35426.
Paratypes — B.S.I.P. Specimen nos. 35427 and 35428.

Locality — Khari Nadi bed, about 2.5 km south of village Goyela, district Kachchh, Gujarat.

Horizon & Age — Khari Series (Aida Stage — Aquitanian); Lower Miocene.

Genus — *Leguminocarpon* Goeppert, 1855

Leguminocarpon khariensis sp. nov.

Pl. 3, figs 16-18, 20

This species is represented by a number of fragmentary impressions of pods.

Description — Pods fragmentary; dehiscent; 1.6-7.0 cm long, 1.4-2.4 cm broad, terminating into a short pointed apex; margin wavy due to shallow constrictions setting apart lobes; each lobe containing a single somewhat rounded seed; suture lines visible close to the margins; texture coriaceous.

Since the pods undoubtedly belong to the family Leguminosae and it is difficult to determine the affinity of these pods beyond family level at present, they are placed under the artificial genus *Leguminocarpon* Goeppert (1855) which is the earliest instituted genus for the fossil fruits referable to Leguminosae. The specific epithet *Leguminocarpon khariensis* sp. nov. is after the locality, Khari Nadi bed.

Holotype — B.S.I.P. Museum no. 35429.

Paratypes — B.S.I.P. Specimen nos. 35430-35433.

Locality — Khari Nadi bed, about 2.5 km south of village Goyela, district Kachchh, Gujarat.

Horizon & Age — Khari Series (Aida Stage — Aquitanian); Lower Miocene.

Genus — *Leguminosites* Bowerbank, 1840

Leguminosites khariensis sp. nov.

Pl. 3, figs 19, 21

Description — The species is based on two leguminous seeds. One of them is split open into two parts. Both the specimens are round to circular in form, 1.0-1.9 cm in diameter.

Since these seeds have been found in close association with leaflets and pods they

are therefore considered to be leguminous. Hence they are placed under the artificial genus *Leguminosites* Bowerbank (1840) which represents the fossil seeds belonging to Leguminosae. The specific name is after the locality.

Holotype — B.S.I.P. Museum no. 35434.

Paratype — B.S.I.P. Specimen no. 35435.

Locality — Khari Nadi bed, about 2.5 km south of village Goyela, district Kachchh, Gujarat.

Horizon & Age — Khari Series (Aida Stage — Aquitanian); Lower Miocene.

Genus — *Leguminophyllum* Lemoigne, Beauchamp & Samuel, 1974

Leguminophyllum khariensis sp. nov.

Pl. 2, fig. 14; Pl. 3, fig. 22; Text-fig. 6

The present species is based on a few impressions of leaflets.

Description — Leaflets asymmetrical, oblong to narrow ovate; 1.3-1.8 cm long, 0.6 cm wide; apex appearing obtuse to mucronulate; base oblique; margin entire; texture chartaceous; petiolule absent; venation pinnate; primary vein (1°) single stout, slightly curved, unbranched; secondary veins (2°) preserved only in the basal region, angle of divergence acute, 50°, fine, curving upwards; tertiary veins and higher order venation not clear.

Discussion — The small size, asymmetric shape and the absence of petiole/petiolule doubtlessly indicate that the present specimens are the leaflets of compound

leaves. The leguminous pods found in close association with these leaflets provides additional support to the fact that these are the leaflets of leguminous plant. Such leaflets are found in a large number of modern genera of Leguminosae. As the present leaflets are indubitably leguminous in their affinity they are placed under the artificial genus *Leguminophyllum* Lemoigne *et al.* (1974), which perhaps accommodate all the fossil leaflets of legumes whose affinities cannot be ascertained definitely beyond the family level. The present leaflets are assigned the specific name *Leguminophyllum khariensis* sp. nov., the specific name indicating the locality from where the material was collected.

It seems that *Leguminocarpon khariensis* sp. nov., *Leguminosites khariensis* sp. nov. and *Leguminophyllum khariensis* sp. nov. may belong to one and the same plant as the leaflets, pods and seeds are preserved in close association though not in actual organic connection. Similar type of leaflets and pods are present in various species of a number of modern leguminous genera such as *Abrus*, *Acacia*, *Albizia*, *Caesalpinia*, *Dalbergia*, *Gleditsia*, *Parkia*, *Peltaphorum*, *Schizolobium*, *Tamarindus*, etc. Thus it is hazardous to commit anything about the exact generic affinities of the above described leaflets, pods and seeds.

Holotype — B.S.I.P. Museum no. 35436.

Paratypes — B.S.I.P. Specimen nos. 35437 and 35438.

Locality — Khari Nadi bed, about 2.5 km south of village Goyela, district Kachchh, Gujarat.

Horizon & Age — Khari Series (Aida Stage — Aquitanian); Lower Miocene.

FAMILY — LAURACEAE

Genus — *Cinnamomum* Schaeffer

Cinnamomum miokachchhensis sp. nov.

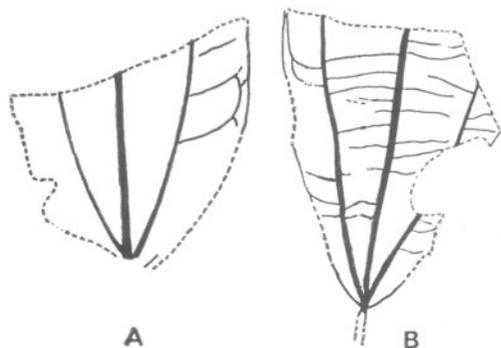
Pl. 1, figs 3, 7, 8; Text-fig. 7A, B

The present species is based on four incompletely preserved specimens. Preservation, however, is poor.

Description — Leaves appearing symmetrical, elliptic to narrow-ovate; preserved lamina length 4.25-6.75 cm, maximum width 2.7-3.5 cm; apex broken; base acute to



TEXT-FIG. 6 — *Leguminophyllum khariensis* sp. nov., leaflet, $\times 3$.



TEXT-FIG. 7 — A, B, *Cinnamomum miokachchhensis* sp. nov., leaves, $\times 1$.

sometimes obtuse, margin entire; texture seemingly chartaceous; petiole unpreserved; venation basal acrodromous, (?) perfect; primary veins (1°) three, moderate to stout, more or less straight, two lateral primaries slightly curved, unbranched; secondaries (2°) very fine, running approximately at right angles (forming ripples) to acute angles, sometimes branched, emerging from the median primary and joining the two laterals, also arising from the outer side of the two lateral primaries at acute angles moving upward and forming fine intramarginal veins, prominent secondaries (seen in specimen nos. 35440 and 35441) moving upwards at acute angles; tertiaries still finer forming numerous fine meshes; areoles imperfect; veinlets not seen.

Discussion — As discussed elsewhere by the authors (1981), the overall characters of these fossils indicate that they belong to the genus *Cinnamomum*. Hitherto, three species of *Cinnamomum*, based on their leaves, are known from India, i.e. *Cinnamomum* sp. cf. *C. tamala* Nees, described by Pathak (1969) from the Upper Tertiary (Middle Siwalik) of West Bengal, *C. palaeotamala* cf. *C. tamala* reported by Lakhanpal & Awasthi (in press) from near Bhikhna-thoree (Indo-Nepal border) in West Champaran District, Bihar and *C. eokachchhensis* described by the authors (1981) from the Eocene of Kachchh. The presence of intramarginal veins and the absence of prominent secondaries at the basal region differentiate the present fossils from *Cinnamomum tamala* described by Pathak (1969). Similarly, *C. palaeotamala* can be easily differentiated from the present fossil. In the former

lateral primaries are suprabasal in origin as compared to their basal origin in our specimens. Further, intramarginal vein is present in our specimens whereas it is not seen in *C. palaeotamala*. *C. eokachchhensis* differs in its bigger size, coriaceous texture, obtuse to almost round base and in the absence of prominent secondaries as compared to the smaller size, relatively thin texture, normally acute base and the presence of prominent secondaries in the present fossil.

Thus the present fossil differs from the earlier known Indian species of *Cinnamomum*. Therefore a new binomial, viz., *Cinnamomum miokachchhensis* sp. nov. is assigned to it. The present fossil in all likelihood is a variant of *Cinnamomum zeylanicum* Breyn.

Cinnamomum zeylanicum is a large tree and is found in Western Ghats and adjoining hill ranges, from Konkan southwards and also in Tenasserim (Brandis, 1906, p. 533).

Holotype — B.S.I.P. Museum no. 35439.

Paratypes — B.S.I.P. Specimen nos. 35440 and 35441.

Locality — Khari Nadi bed, about 2.5 km south of village Goyela, district Kachchh, Gujarat.

Horizon & Age — Khari Series (Aida Stage — Aquitanian); Lower Miocene.

FAMILY — MORACEAE

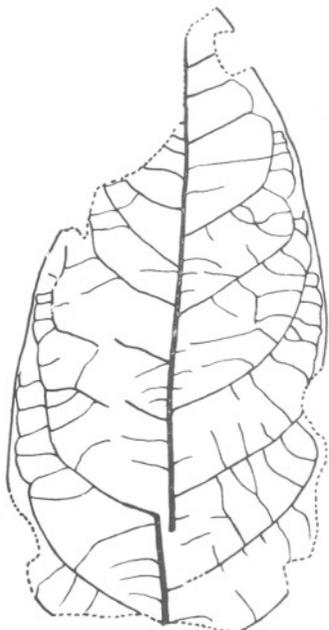
Genus — *Ficus* Linn.

Ficus khariensis sp. nov.

Pl. 2, fig. 15; Text-fig. 8

The present species is based on a single fairly well-preserved leaf-impression. The specimen is, however, incomplete.

Description — Leaf symmetrical, narrow ovate to lanceolate; preserved lamina length 7.7 cm, maximum width 4.1 cm; apex not preserved; base unpreserved (however, appearing to be symmetrical); margin entire, slightly wavy; texture seemingly thick chartaceous; petiole unpreserved; venation pinnate, brochidodromous; primary vein (1°) single, stout, slightly curved; secondary veins (2°) angle of divergence acute (75° - 60°), 75° near the basal region and gradually decreasing upwards, moderately thick, curved, branched, forming loops near the margin, loop forming branches joining superadjacent



TEXT-FIG. 8 — *Ficus khariensis* sp. nov., leaf, $\times 1$.

secondary at wide acute angle; intersecondary veins present, simple; tertiary veins (3°) angle of origin usually RR to OR, pattern percurrent to reticulate, sometimes joining primary, mostly obliquely arranged in rela-

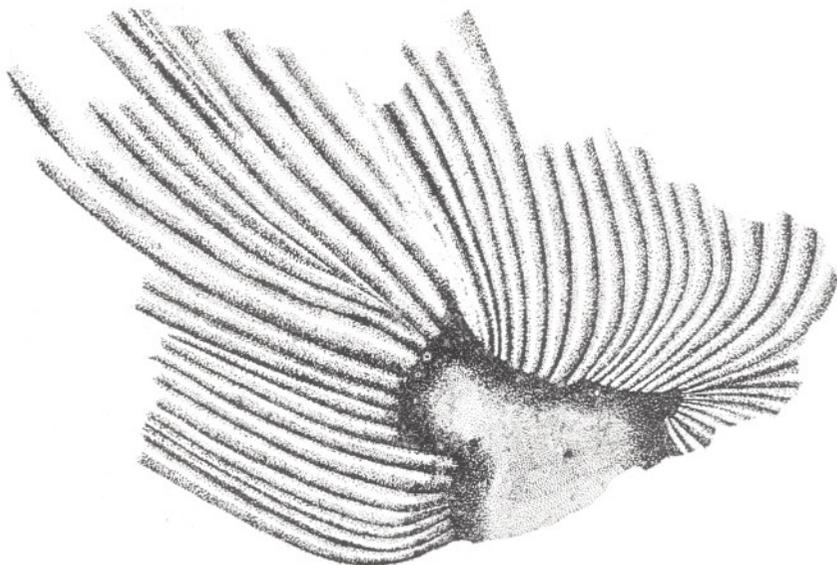
tion to midvein, arrangement seems alternate, distant to close, forming arches just inside the margin enclosing loops formed by secondaries; higher order venation not seen; areoles and veinlets not preserved.

Discussion — The overall characters of the fossil indicate that it belongs to the genus *Ficus*. The leaves of *Ficus infectoria* Roxb. show apparent resemblance with the present fossil.

Among the fossil leaves of *Ficus* from India (Lakhanpal & Guleria, 1981) only *Ficus arnottiana* Miq. and *F. glomerata* Roxb. described by Mahajan and Mahabale (1973) from the Quaternary deposits of Maharashtra show some resemblance with the present fossil. *F. arnottiana* is bigger in size, moreover the angle of divergence in it is less than 60° as compared to the present fossil in which the angle of divergence varies from 60° - 75° . In *F. glomerata* the secondaries bifurcate below the margin at an angle of 30° and less than 30° as compared to the present fossil where the corresponding angle is greater than 30° .

Thus, the present specimen differs from the known Indian fossil leaves of *Ficus*. Therefore, a new specific name *Ficus khariensis* sp. nov., is assigned to it. The specific epithet refers to the locality, Khari Nadi bed, from which the specimen was collected.

Ficus infectoria is a large deciduous tree found in sub-Himalayan tract and outer



TEXT-FIG. 9 — *Palmacites khariensis* sp. nov., $\times 1$.

hills up to 1600 m, common in northern India, the Central Provinces, Berar and the western Peninsula (Brandis, 1906, p. 602.)

Holotype — B.S.I.P. Museum no. 35442.

Locality — Khari Nadi bed, about 2.5 km south of village Goyela, district Kachchh, Gujarat.

Horizon & Age — Khari Series (Aida Stage — Aquitanian); Lower Miocene.

FAMILY — PALMAE

Genus — *Palmacites* Brongniart, 1822

Palmacites khariensis sp. nov.

Pl. 3, fig. 23; Text-fig. 9

The present species is based on about half a dozen specimens of leaf-impressions, of which two are quite big. The preservation is fairly good.

Description — Preserved lamina length 9.0 cm, maximum preserved width 9.0 cm; form palmate; petiole thick, broad, incomplete, preserved length 2.5 cm, distal end irregularly rounded with impression of a shallow ridged hastula, costa not seen; lamina consisting of a large number of plicate segments, about 45 preserved, width of segments varying from 0.1-0.5 cm, segments fused (the specimen consisting of the basal region of the leaf), each segment with a midrib in the middle; further details indistinct.

Discussion — Read and Hickey (1972) in their revised classification of fossil palm and palm-like leaves have pointed out that "numerous similarities in the form and gross external features of palm leaves make it difficult or impossible to assign them to modern genera based only on their external morphology (except *Phoenix* Linn.). Since it is difficult to identify specimens of modern palms accurately from their leaves alone, no attempt should be made to place fossil palm fragments in genera of modern palms unless unquestionably identifiable with them".

Keeping the above observation in view, the present specimen can only be identified in a broad sense, i.e. it belongs to a true palmate palm as is obvious by the presence of hastula in the present specimen (Tomlinson, 1961, p. 24). The true palmate leaves are confined to two subfamilies of the family-Palmae, i.e. Coryphoideae and Lepido-

caryoideae (Corner, 1966, pp. 347, 349, 351). Only three genera of Lepidocaryoideae possess palmate leaves, viz., *Mauritia* L.f., *Mauritiella* Burret, and *Lepidocaryum* Mart. but these are confined to America (Corner, 1966, p. 349). Hence, the present specimen possibly belongs to subfamily Coryphoideae of the Palmae. To know whether the present fossil shows some similarity with the leaves of any Indian member of Coryphoideae, the leaves of modern Indian genera of this subfamily have been compared with the fossil.

The subfamily Coryphoideae consists of 33 genera (Corner, 1966, p. 347) of which only *Corypha* Linn., *Licuala* Thunb., *Livistona* R. Br., *Nannorhops* Wendl. and *Trachycarpus* are found in India (Brandis, 1906, p. 644). Among these 5 genera, the leaves of *Corypha*, *Livistona* and *Nannorhops* are costapalmate and hence are incomparable with the present fossil. The genera *Licuala* and *Trachycarpus* are represented by 2 spp. each, the former by *Licuala peltata* Roxb. and *L. spinosa* Wurm. and the latter by *Trachycarpus martiana* Wendl. and *T. takil* Becc. (Blatter, 1926).

The leaves of aforesaid species of *Licuala* and *Trachycarpus* are much bigger in size (about 90-152.5 cm in diameter) as compared to the present fossil. Moreover, *Trachycarpus* spp. are confined to the Himalayan region from 1,220-2,440 m, where trees are often covered with snow. Thus, the leaves of none of the modern Indian palms show similarity with the fossil. Hence, the generic similarity of the present fossil could not be ascertained.

Indian Fossil Records and Comparison — The earliest record of palm leaves are from the Deccan Intertrappean Series. These are *Palmophyllum dakshinense* Achuthan (1968), *P. mohgaonense* Mahabale (1966), and a palm leaf described by Trivedi and Chandra (1971). In addition to these, palm leaves have also been reported from the Eocene and Miocene beds of Kashmir and Himachal Pradesh. These are *Sabalites microphylla* Sahni (1964), *Sabalites* sp. Sahni (1964), *Palmophyllum* sp. Chaudhri (1969) and a fan-palm reported by Sahni and Bhatnagar (1958). *Palmophyllum dakshinense* is based on the anatomical features of a fragment of lamina. *P. mohgaonense* is unaccompanied by its description. *Palmophyllum* sp. Chaudhari (1969) differs from

the present fossil in its narrow width and the palm leaf described by Trivedi and Chandra is very big in size, besides having much broader segments. Obviously none of them is similar to the present fossil. *Sabalites microphylla* differs in its small size (3.0×2.5 cm) as compared to the bigger size (9.0×9.0 cm) of the present fossil. Moreover, the number of segments in the present fossil are many more than in *S. microphylla*. *Sabalites* sp. Sahni (1964) differs from the present fossil in having much broader segments. The fan palm of Sahni and Bhatnagar shows only the apical portion of the segments as seen in the photographs and the portion near the base is missing. Consequently, it is not comparable with the present fossil.

Following Read and Hickey's recent classification (1972) of fossil palm and palm-like leaves, the present fossil falls under the genus *Palmacites* Brongniart. Since it is quite different from the known Indian fossil species of palm leaves, a new specific name, *Palmacites khariensis* sp. nov., is assigned to it. The specific epithet indicates the locality from where the fossil was collected.

Holotype — B.S.I.P. Museum no. 35443.

Locality — Khari Nadi bed, about 2.5 km south of village Goyela, district Kachchh, Gujarat.

Horizon & Age — Khari Series (Aida Stage — Aquitanian); Lower Miocene.

GENERAL DISCUSSION

The above data have brought to light an important point that the Neogene megafloora of Kachchh is quite rich in legumes unlike the Palaeogene megafloora of this region from where no legume has so

far been recorded (Lakhanpal & Guleria, 1981).

The components of the florule, in the light of distribution of their modern comparable forms, indicate a tropical climate in which it had flourished. The modern comparable forms of this Lower Miocene assemblage are distributed in the following types of tropical forests (see Table 1).

From this distribution it is clear that the modern equivalents of the fossil forms are not confined to a particular type of tropical forests. The climatic conditions must have been moderate (neither very moist nor very dry) as indicated by the majority of elements of this florule belonging to moist deciduous to dry deciduous forests. This view is further substantiated by the smaller size of the leaves and dominance of legumes. The semi-evergreen plants might have been growing in pockets.

From the general survey of the florule, it is seen that out of the known modern comparable genera, namely *Bauhinia*, *Cassia*, *Ficus*, *Cinnamomum*, *Millettia* and *Murraya*, the first three are found in the present day flora of Kachchh. Thus it is obvious that the last three were much wider in distribution during the Tertiary period. Of these, *Cinnamomum* and *Murraya* are the important genera from the palaeophytogeographical point of view. In the modern flora both these genera are confined to East Asia and Indomalaya. The latter, however, extends to Pacific islands (Willis, 1973, pp. 255, 766). *Cinnamomum zeylanicum* Breyn, the modern comparable species, is found in India confined to Western Ghats and adjoining hill ranges from Konkan southwards (Brandis, 1906, p. 533). It is quite likely that this species might have been growing all along the western coast up to Kachchh during Eocene

TABLE 1—TROPICAL FOREST TYPES

TAXA	WET EVER GREEN FORESTS	SEMI- EVER GREEN FORESTS	MOIST DECIDUOUS FORESTS	LITTORAL AND SWAMP FORESTS	DRY DECIDUOUS FORESTS	THORN FORESTS	DRY EVER GREEN FORESTS
<i>Bauhinia phoenicea</i> }	+						
<i>Bauhinia purpurea</i> }			+				
<i>Cinnamomum zeylanicum</i>	+	+					
<i>Cassia</i> sp.			+		+	+	
<i>Ficus infectoria</i>			+		+		
<i>Millettia auriculata</i>			+		+		
<i>Millettia ovalifolia</i>					+		
<i>Murraya paniculata</i>		+	+		+		

to Lower Miocene times and subsequently died out from Kachchh on appearance of unfavourable conditions there. The modern comparable ally of *Murraya khariensis*, viz., *M. paniculata* L. (syn. *M. exotica* L.) is found east of Ravi, ascending up to 1,350 m in Uttar Pradesh, Bihar, Orissa, West and

South India including the Andamans, usually common in the underwood, in ravines and forests throughout the hotter parts of India. Its occurrence in the Lower Miocene of Kachchh indicates that *Murraya* perhaps had its westward extension in the past up to Kachchh.

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EXPLANATION OF PLATES

PLATE 1

1. *Murraya khariensis* sp. nov., leaflet. × Natural size.
2. Another specimen of *M. khariensis* sp. nov., leaflet. × Natural size.
3. *Cinnamomum miokachchensis* sp. nov., leaf. × Natural size.
- 4-6. *Millettia asymmetrica* sp. nov., leaflets, showing variations in shape and size. × Natural size.
7. Another specimen of *Cinnamomum miokachchensis* sp. nov., leaf. × Natural size.
8. A third specimen of *C. miokachchensis* sp. nov., leaf × Natural size.
9. *Millettia miocenica* sp. nov., leaflet. × Natural size.

PLATE 2

10. *Bauhinia kachchensis* sp. nov., leaf. × Natural size.

12. Another specimen of *B. kachchensis* sp. nov., leaf × Natural size.
13. Enlarged photograph of fig. 10, showing details of venation. × 2.
11. *Cassia miokachchensis* sp. nov., leaflet. × Natural size.
14. *Leguminophyllum khariensis* sp. nov., leaflet. × 2.
15. *Ficus khariensis* sp. nov., leaf. × Natural size.

PLATE 3

- 16, 18. *Leguminocarpon khariensis* sp. nov., pods. × Natural size.
- 17, 20. *L. khariensis* sp. nov., pods, showing enclosed seed. × Natural size and × 2 respectively.
- 19, 21. *Leguminosites khariensis* sp. nov. × 2.
22. *Leguminophyllum khariensis* sp. nov., leaflets. × Natural size.
23. *Palmacites khariensis* sp. nov., leaf. Natural size.

