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LEAF-IMPRESSIONS FROM THE EOCENE OF KACHCHH, WESTERN INDIA

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ABSTRACT

An assemblage of leaf-impressions is described here from the Tertiary beds of Kachchh. It consists of 8 species out of which 5 have been identified with 5 modern genera and the remaining three which could not be assigned to any modern genus but are dicotyledonous, have been placed under the form genus *Dicotylophyllum* Saporta. The five species which are comparable with modern genera are *Terminalia panandhroensis* sp. nov., *Syzygium kachchhense* sp. nov., *Lagerstroemia patelii* sp. nov., *Cinnamomum eokachchhensis* sp. nov. and *Ficus kachchhensis* sp. nov. The three *Dicotylophyllum* species are: *Dicotylophyllum cordatum* sp. nov., *D. panandhroensis* sp. nov. and *D. quadrinervatum* sp. nov.

The collective evidence of the above taxa suggests that moist evergreen to deciduous tropical vegetation was growing around the site of this fossil assemblage during the Lower Eocene period.

Key-words — Leaf-impressions, *Lagerstroemia*, *Dicotylophyllum*, *Terminalia*, *Syzygium*, *Cinnamomum*, *Ficus*, Eocene, Kachchh (India).

सारांश

पश्चिमी भारत में कच्छ के ईओसीन कल्प से पर्ण-मुद्राश्म – राजेन्द्र नाथ लखनपाल एवं जसवंतसिंह गुलेरिया

कच्छ के टरशरी संस्तरों से पर्ण-मुद्राश्मों के एक समुच्चय का वर्णन किया गया है। इसमें आठ जातियाँ हैं जिनमें से पाँच का वर्तमान प्रजातियों से अभिनिर्धारण किया गया है तथा शेष तीन जातियाँ, जिनको कि किसी भी वर्तमान प्रजाति से अधिन्यस्त नहीं किया जा सका लेकिन द्विबीजपत्री होने के कारण इन्हें अनंतिम प्रजाति डाइकोटिलोफ़िलम् सॅपोर्टा के अन्तर्गत् रखा गया है। ये पाँच जातियाँ, टर्मिनेलिया पनान्ध्रोयेन्सिस न० जा०, सिन्नेमोमम् ईओकच्छेन्सिस न० जा०, साइज़ीगियम् कच्छेन्से न० जा०, लेजरस्ट्रोमिया पटेलाई न० जा० तथा फ़ाइकस कच्छेन्सिस — वर्तमान प्रजातियों से तुलनीय हैं। डाइकॉटिलोफिलम् की तीन जातियाँ, डा० कोर्डेटम् न० जा०, डा० पनान्ध्रोयेन्सिस न० जा० तथा डा० क्वाड्रिनर्वेटम् न० जा०, हैं।

उपरोक्त वर्गकों का सामूहिक प्रमाण व्यक्त करता है कि अधर ईओसीन काल में इस समुच्चय के आस-पास नम-सदाहरित एवं उष्णकटिबंधीय पर्णपाती वनस्पति विद्यमान थी।

INTRODUCTION

ALTHOUGH Wynne had reported the occurrence of plant fossils in the Tertiary beds of Kachchh as early as 1872, hardly any attempts were made to study them until the middle of the present century. Of late considerable work has been done on plant microfossils from the Tertiary succession of Kachchh. Algal and fungal remains have been described by Kar (1977, 1978, 1979), Kar and Saxena (1976), Mathur (1964, 1966, 1972), Mathur and Mathur (1969), Pal and Ghosh (1974), Pant and Mamgain (1969), Singh (1978a, b), Venkatachala and Kar (1969b) and Vimal (1953). Pteridophytic, gymnospermous and angiospermous spores and pollen grains have been described by Kar (1977, 1978, 1979), Mathur (1964, 1966, 1972), Mathur and Mathur (1969), Mathur and Pant (1973), Sah and Kar (1969, 1970), Saxena (1978, 1979, 1980) and Venkatachala and Kar (1968, 1969a).

In contrast, very little work has been done on the plant megafossils. Ghosh and Ghosh (1959) described *Dipterocarpoxylon malavii* from the Pliocene beds of

Mothala; Prakash and Dayal (1968) reported the fossil wood of *Terminalia* from near Ratnal Railway Station. Lakhanpal *et al.* (1975) described *Podocarpoxylon kutchensis* from the Pliocene of Dhaneti. Lately, Awasthi *et al.* (1980) described *Pterospermoxylon, kutchensis* from the Pliocene of Mothala. In addition to these, two palm woods — *Palmoxylon mathuri* and *P. seriatum*, believed to have come from the Cretaceous of Kachchh have been described by Sahni (1932, 1964). Further, cylindrical reed like stems belonging to Gramineae have also been described by Sahni (1964) as *Culmites cutchensis*. However, the age of these three monocot fossils is doubtful and may most probably be Tertiary.

From the above brief review it is clear that the study of Tertiary leaf-impressions from Kachchh have long been neglected. Consequently this study has recently been undertaken by us and a leaf-impression of *Pandanus* has already been described (Guleria & Lakhanpal, in press) from the Berwali Series of Panandhro Lignite mine. The material of the present assemblage also comes from the same locality which is about 114 km north-west of Bhuj on the Bhuj Narayan Sarovar road. Well-preserved leaf-impressions consisting of several different types were collected from this place. The fossil leaves are preserved as impressions on chocolate coloured shales. They are devoid of cuticles though some specimens do indicate some carbonaceous material. However, efforts to obtain leaf-transfers and cuticles from these samples did not yield any satisfactory results.

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

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

SYSTEMATIC DESCRIPTION OF IMPRESSIONS

FAMILY — COMBRETACEAE

Genus — *Terminalia* Linn.

Terminalia panandhroensis sp. nov.

Pl. 1, fig. 1

This species is based on a single specimen. Although the specimen is incomplete (11.5 cm in length) its preservation is good.

Description — Leaf appears to be symmetrical, elliptic, preserved lamina length 11.5 cm, maximum preserved width 9.5 cm, maximum width on one side of the midrib 5.2 cm; apex and base not preserved; margin entire, slightly wavy; texture seemingly chartaceous; venation pinnate, eucamptodromous; primary vein (1°) massive; secondary veins (2°) appearing to run along the midrib for a short distance before diverging out, moderately thick, angle of divergence varying from 80° in the lower region to 60° in the upper, upturned very near the margin; tertiary veins (3°) fine, angle of origin OR or OA; pattern percurrent, prevalently unbranched, rarely branched, obliquely arranged in relation to mid-vein, arrangement predominantly opposite, close; higher order venation not seen.

Discussion — The type of shape, large size, massive primary vein, prominent secondaries with angle of divergence 60°-80° and their characteristic emergence from the primary (they appear to run parallel to the primary for a short distance before diverging from it), and oblique arrangement of tertiaries are the important features of the fossil. These characters have been noticed in the leaves of *Terminalia* Linn. of the family Combretaceae and *Anthocephalus* A. Rich. of Rubiaceae.

The leaves of *Anthocephalus cadamba* Miq. show apparent similarity with the present fossil. However, on careful examination it differs from the present fossil in having predominantly alternate arrangement of tertiaries. Further, the tertiaries are comparatively more distantly placed.

The leaves of a large number of *Terminalia* species were compared with the present fossil. *T. alata* Heyne ex Roth., *T. crenulata* Heyne ex Roth. and *T. coriacea* (Roxb.) W. & A. were found to show resemblance with the fossil. Of the above three species the angle of divergence of secondaries in *T. alata* is more acute than in the fossil. *T. crenulata* and *T. coriacea* show the closest resemblance with the present fossil in almost all the characters except the arrangement of tertiaries which is opposite to alternate in these two species whereas in the fossil their arrangement is predominantly opposite. Going through a number of herbarium sheets of *T. coriacea* and *T. crenulata* it was observed that it is difficult to separate the leaves of these two

species merely on the morphological basis. However, the two species can be differentiated on the basis of texture of leaves. They are coriaceous in *T. coriacea* and thinner in *T. crenulata*. Thus the fossil comes closest to the leaves of *T. crenulata*.

Fossil Records — The fossil leaves of *Terminalia* are known under three generic names, viz., *Terminalia* Linn., *Terminaliphyllum* Velenovsky and *Terminaliophyllum* Geyler. *Terminaliphyllum* is represented by a single species, i.e. *T. rectinerve* Velenovsky (1884, 1889) from the Upper Cretaceous of Bohemia whereas *Terminaliophyllum* is represented by three species, viz., *Terminaliophyllum* sp. Geyler (1887) from the Eocene of Borneo, *T. keayi* Puri (1966) and *T. faggei* Puri (1966) from the post-Eocene sediments of Nigeria.

After scanning the vast amount of available literature, we could gather the following 21 species of fossil *Terminalia* leaves:

Terminalia cf. *cattapa* Linnaeus (listed in Nemejc, 1975)
T. claibornensis Berry (listed in LaMotte, 1952)
T. elegans Heer (listed in Schimper, 1874)
T. estimina MacGinitie, 1941
T. europea (Web.) Weyland, 1943
T. fenzliana Unger (listed in Nemejc, 1975)
T. gypsorum Saporta (listed in Schimper, 1874)
T. indiocola Ball, 1931
T. italica Principi (listed in Principi, 1915)
T. laurina Krasser, 1903
T. lesleyana (Lesq.) Berry, 1916
T. mioceniea Unger (listed in Unger, 1850)
T. pannonica Unger (listed in Nemejc, 1975)
T. phaeocarpoides Berry (listed in LaMotte, 1952)
T. radobojana Unger, 1867
T. rottensis Weyland, 1943
T. tallyana Ettingshausen (listed in Schimper, 1874)
T. trinitense Berry (listed in LaMotte, 1952)
T. ungeri Ettingshausen (listed in Nemejc, 1975)
T. (?) sp. Hollick, 1936
T. sp. Matsuo, 1970

As we did not have access to all the publications pertaining to fossil *Terminalia* leaves nor the opportunity to investigate them critically, this above is by no means a complete list of its valid records. However, it serves to show that the genus has had a long and wide-spread geological history.

From the geological distribution of fossil Terminalias it is evident that its earliest record *Terminaliphyllum rectinerve* goes back to the Upper Cretaceous (Cenomanian) of Bohemia (Velenovsky, 1884). The fossil leaves have been reported from various countries such as, Bolivia, Brazil, Czechoslovakia, France, Greece, Indonesia, Italy, Japan, Nigeria, Spain and U.S.A. So far no fossil leaf of *Terminalia* has been described from India although leaf impressions resembling *Terminalia* have been reported by Lakhanpal (1970) from the Siwaliks. Thus, it is obvious that the genus *Terminalia* has continued from the Upper Cretaceous to the present day and most probably had relatively wider distribution in the past than at present.

Present-day Distribution of Terminalia crenulata — The genus *Terminalia* comprises 250 species (Willis, 1973, p. 1136). They are large trees widely distributed in the tropics of the world. Although Brandis (1906) has enumerated 16 species of *Terminalia* from India and Burma, there is no unanimity among taxonomists about the exact number of species occurring in India. The differences are mainly with regard to the widely distributed *Terminalia chebula* complex and *T. tomentosa* complex. *T. tomentosa* complex consists of several plant groups showing a wide range of variation. Hitherto, the botanists and foresters were generally content to regard this complex as one species. However, a critical examination of this complex by Parkinson (1937) shows that *T. tomentosa auct. div.* is actually a mixture of (i) *Terminalia crenulata*, (ii) *T. coriacea*, and (iii) *T. alata*. *Terminalia crenulata* is distributed in the central, southern and western India, Bihar, Orissa, Bengal, Assam and Burma (Ramesh Rao & Purkayastha, 1972, p. 199).

The fossil is assigned a new name, *Terminalia panandhroensis* sp. nov., the specific name indicating the name of the locality. This is the first description of a fossil *Terminalia* leaf from India.

Holotype — B.S.I.P. Museum no. 35385.

Locality — Lignite mine at Panandhro, district Kachchh, Gujarat.

Horizon — Berwali Series (Kakdi Stage — Ypresian).

Age — Lower Eocene.

FAMILY — MYRTACEAE

Genus — *Syzygium* Gaertn.

Syzygium kachchhense sp. nov.

Pl. 1, fig. 5; Pl. 2, figs 6, 7

The species is based on two fairly well-preserved leaf impressions, of which one is split into two counterparts. However, both the specimens are incomplete.

Description — Leaf slightly asymmetrical, ovate-elliptic; lamina length 7.0-9.5 cm, maximum width 5.0-5.5 cm; apex short acuminate; base not preserved; margin entire; texture seemingly chartaceous; petiole not preserved; venation pinnate, brochidodromous; primary vein (1°) single, stout, slightly curved; secondary vein (2°) with angle of divergence varying from right angle (90°) in the basal region to acute (60°) in the apical, moderately thick, uniformly curved, unbranched, forming intramarginal vein; intersecondary veins simple; tertiary veins (3°) fine, abundant, angle of origin AO to RR; pattern random to orthogonal reticulate; quaternary veins (4°) thin, mostly orthogonal, at places randomly oriented; areoles well-developed, oriented, mostly quadrangular, rarely triangular, small, veinlets not seen.

Discussion — The most important characters of the present leaf impressions are: the closely placed secondaries along with intersecondaries and the presence of intramarginal veins. These characters are seen in the leaves of *Calophyllum* Linn. and *Garcinia* Linn. of the family Guttiferae, *Chrysophyllum* Linn. of Sapotaceae, *Ficus* Linn. of Moraceae and *Syzygium* Gaertn. of the family Myrtaceae.

The leaves of *Calophyllum* differ from the fossil in being distinctly coriaceous with much more closely placed secondaries and in having obtuse apex. Among the number of *Garcinia* species compared, the leaves of *G. speciosa* Wall. show apparent similarity with the fossil but they differ in thickness and in the angle of divergence of secondaries. A number of species of *Chrysophyllum* were compared, of which the leaves of *C. oliviforme* Linn. and *C. roxburghii* G. Don. show some resemblance. However, they differ not only in being coriaceous but also in their tertiaries being arranged in ramified pattern as compared to the random-orthogonal reticulate pattern in the present fossil. Out of the large number of *Ficus* species, *F. benjamina* var. *comosa* Kruz, *F. nervosa* Roth., *F. retusa* Linn., *F. stricta* Miq., *F. benjamina* Linn. and *F. elastica* Roxb. show resemblance with the fossil. In the first four of these species, the leaf apex is relatively longer; besides, *F. retusa* and *F. stricta* also differ in the angle of divergence of secondaries. Further, the interval between the two successive secondaries is greater in *F. stricta*. The leaves of *F. benjamina* var. *comosa* and *F. nervosa* are smaller than the fossil. The remaining two, *F. benjamina* and *F. elastica*, show better resemblances. However, the leaves in them are quite thick and coriaceous as compared to the present fossil. Further, the meshes formed by tertiaries in *F. elastica* are much bigger than in the present fossil.

The leaves of *Syzygium* show the closest resemblance with the fossil in shape, size, apex, texture and venation. A large number of *Syzygium* species were examined but none of them appears to be identical with the fossil. Their leaves differ from the present fossil in the origin of secondaries and in the pattern of tertiary veins. The present species perhaps represents an ancestral form of *Syzygium*.

Fossil Records and Comparison — We are aware of only two species of the fossil leaves of *Syzygium*, viz., *S. chaneyi* Huzioka & Takahasi (1970) from the Eocene of Japan and *S. floribundoides* Engelhardt (1911) from the mid-Eocene of West Germany (see Müller, 1934, p. 110). Leaf impressions resembling *Syzygium* have also been reported by Lakhanpal (1970) from the Siwalik beds of India although no specific name has been assigned to them. Besides, there are 22 known fossil species described under the genus *Eugenia* from all over the world. Of these, six species, viz., *E. aizoon* Unger (1850), *E. apollinis* Unger (1850), *E. haeringiana* Unger (1850), *E. heari* Engelhardt (in Müller, 1934), *E. hollae* Heer (in Friedrich, 1883) and *E. protogea* Watelet (1866) belong to the Old World and the rest to the New World. According to the latest interpretation of the distribution of *Syzygium* and *Eugenia* (Schmid, 1972), the above Old World species belong to *Syzygium* instead of *Eugenia* and hence these have been taken into account by us for comparison with the present fossil.

Syzygium chaneyi differs markedly from the fossil in size, shape, apex and angle of divergence of secondaries. The leaves in *S. chaneyi* are 4·0-6·0 cm long, 1·1-2·0 cm broad, oblong with acute apex and secondaries almost at right angle to the midrib, whereas the present fossil leaf is 7·3-9·1 cm long, 5·1-5·4 cm broad, narrow ovate to elliptic in shape with acuminate apex and the angle of divergence of secondaries being 90°-60°. Moreover, the meshes formed by the tertiaries in *S. chaneyi* are usually bigger than in the present fossil. *Eugenia aizoon*, *E. apollinis*, *E. haeringiana* and *E. protogea* differ from the present fossil, in shape, size and in the orientation and arrangement of the secondaries and tertiaries.

Syzygium floribundoides, *Eugenia herri* and *E. hollae* (which are known from West Germany, the first two from Mid-Eocene) could not be compared with the present fossil for want of relevant literature. However, on the basis of the wide gap in distribution, the present fossil in all likelihood would be different from them. Further, during the Eocene the Indian land mass was separated from the European landmass by the Tethys sea and it is almost impossible to assume the presence of the same species in two distantly situated lands separated by a wide sea. Hence, the present fossil, which differs from all the known remains of *Syzygium*, is being given a new specific name, *Syzygium kachchhense* sp. nov. The specific epithet indicates the area from which the fossil has been collected.

Present-day Distribution of Syzygium s.l. — The genus *Syzygium* is palaeotropical in distribution and consists of 500 species (Willis, 1973, p. 1126) of trees, shrubs or rarely climbers. On the basis of floral anatomy, Schmid (1972) provides additional evidence to differentiate *Eugenia s. s.* and *Syzygium s. l.* According to him *Syzygium s. l.* is strictly Old World and *Eugenia s. s.* is distributed mainly in the New World. Brandis (1906) has listed 79 species of *Syzygium* from India, of which at least 76 are indigenous. They are water loving plants which thrive in moist localities along the banks or in the beds of streams. According to Champion and Seth (1968) *Syzygium* occurs in wet evergreen, semi-evergreen, moist deciduous, littoral and swamp, dry evergreen and dry deciduous forests of tropical India.

Holotype — B.S.I.P. Museum no. 35889.

Locality — Lignite mine at Panandhro, district Kachchh, Gujarat.

Horizon — Berwali Series (Kakdi Stage-Ypresian).

Age — Lower Eocene.

FAMILY — LYTHRACEAE

Genus — *Lagerstroemia* Linn.

Lagerstroemia patelii sp. nov.

Pl. 3, fig. 10

This species is based on a single incomplete, well-preserved specimen.

Description — Leaf symmetrical, narrow elliptic; preserved lamina length 16·9 cm, maximum width 5·3 cm; apex broken; base broken (seemingly cuneate); margin entire, slightly wavy; texture chartaceous; petiole unpreserved; venation pinnate, brochidodromous; primary vein (1°) single, stout, slightly curved; secondary veins (2°) with angle of divergence acute (70°-50°), 70° at the basal region and gradually decreasing upwards, relatively fine, curving upward, rarely branched; intersecondary veins present, appearing simple; tertiary veins (3°) and higher order venation not visible.

Discussion — The important features exhibited by the fossil are: (i) seemingly symmetrical shape, (ii) narrow elliptic form, (iii) entire, slightly wavy margin, (iv) seemingly cuneate base, and (v) pinnate, brochidodromous venation.

Leaves of the following genera show some similarities with the fossil, namely, *Terminalia* Linn., *Mangifera* Linn., *Polyalthia* Bl., *Saraca* Linn., and *Lagerstroemia* Linn. The leaves of two species of *Terminalia*, viz., *T. citrina* Roxb. and *T. pyrifolia* Kurz, show apparent resemblance with the fossil. However, they can be easily differentiated as the secondaries in *Terminalia* do not join with the next succeeding secondary; hence no loop formation takes place in *Terminalia* leaves. The leaves of some species of *Mangifera* show similarity with the fossil in shape, size and form but they not only differ in their angle of divergence of secondaries but also in the curvature of the secondaries. The *Polyalthia* leaves differ in having rounded base, closely placed secondaries and very wavy margin. The leaves of *Saraca indica* Linn. show close

resemblance with the fossil but differ in having eucamptodromous venation whereas in the fossil the venation is brochidodromous. Of the genus *Lagerstroemia*, three species come closer to the present fossil, viz., *Lagerstroemia tomentosa* Presl., *L. floribunda* Jack, and *L. speciosa* L. Pers. (Syn. *L. Flos-Reginae* Retz). The leaves of *L. tomentosa* are distinctly smaller in size than the fossil. The leaves of *L. floribunda* show relatively better resemblance. Although some of its leaves reach the same size, they are usually smaller than the fossil. The leaves of *L. speciosa* (Syn. *L. Flos-Reginae*) show the nearest approach (F.R.I. herbarium sheet no. 66458, etc.) to the present fossil.

Fossil Records and Comparison — There are limited records of fossil leaves of *Lagerstroemia*. We are aware of only three, all known from India. Two of them, comparable with *Lagerstroemia indica* Linn., have been described from the Deccan Intertrappean Series by Shukla (1950) and Trivedi (1956). The third, a fossil leaf referred to *Lagerstroemia*, has been described by Lakhanpal and Dayal (1966) from the Lower Siwalik beds of Jawalamukhi, Himachal Pradesh.

The leaf impressions comparable with *Lagerstroemia indica* described by Shukla (1950) and Trivedi (1956) obviously differ from the present fossil which shows close resemblance with *L. speciosa* instead of *L. indica*. The fossil leaf comparable with *Lagerstroemia* described by Lakhanpal and Dayal (1966) differs from the present fossil in its small size, the Siwalik form being about 1/3rd of the present fossil.

Thus, the fossil differs from the known species of *Lagerstroemia* based on leaves. So a new specific name, *Lagerstroemia patelii* sp. nov., is assigned to it. The specific name is after Mr N. C. Patel, the Manager of Panandhro Lignite mine without whose kind help the present material could not have been collected.

Present-day Distribution of Lagerstroemia — The genus *Lagerstroemia* consists of 53 species of trees and shrubs and is distributed in the tropical Asia to North Australia (Willis, 1973, p. 630). Brandis (1906) has listed 12 species of *Lagerstroemia* from the Indian region. *Lagerstroemia speciosa* is found in Assam, Chittagong; Lower Burma, chiefly near river banks; in the foot of Western Ghats ascending to 600 m; Srilanka, moist low country and Malay Peninsula (Brandis, 1906, p. 339, described as *L. Flos-Reginae*).

Holotype — B.S.I.P. Museum no. 35393.

Locality — Lignite mine at Panandhro, district Kachchh, Gujarat.

Horizon — Berwali Series (Kakdi Stage-Ypresian).

Age — Lower Eocene.

FAMILY — LAURACEAE

Genus — *Cinnamomum* Schaeffer

Cinnamomum eokachchhensis sp. nov.

Pl. 1, figs 2-4

This species is based on four fairly well-preserved specimens, one of which is split into two counter parts.

Description — Leaves symmetrical, elliptic to elongate-ovate; lamina length varying from about 5·5-9·5 cm, maximum width 2·8-4·0 cm; apex broken; base symmetrical, obtuse to almost rounded; margin entire; texture seemingly coriaceous; attachment of petiole normal, preserved petiole length 0·2-2·0 cm; Venation basal acrodromous, perfect; primary veins (1°) three, moderate to stout, middle vein straight, two lateral primaries slightly curved, unbranched; secondaries (2°) very fine, visible on careful observation, running more or less horizontally, slightly obliquely, straight to slightly curved, unbranched, those emerging from lateral primaries on fusing forming a fine continuous vein (intramarginal vein) along the margin; tertiaries (3°) still finer, forming numerous very fine meshes; areoles imperfect; veinlets not seen.

Discussion — The important characters exhibited by the present fossil are: (i) symmetrical shape, (ii) elliptic to elongate-ovate form, (iii) symmetrical, obtuse to almost rounded base, (iv) entire smooth margin, (v) somewhat coriaceous texture, (vi) perfect, basal acrodromous venation, (vii) primary veins three, (viii) fine secondaries forming fine intramarginal vein, (ix) secondaries run more or less at right angle or horizontally, and (x) fairly long petiole.

Leaves with an acrodromous pattern of venation are found in a number of modern dicot families, e.g. Aristolochiaceae, Buxaceae, Caprifoliaceae, Compositae, Coriaria-

ceae, Ericaceae, Euphorbiaceae, Lauraceae, Leguminosae, Loganiaceae, Melastomaceae, Menispermaceae, Myrtaceae, Oleaceae, Ranunculaceae, Rhamnaceae, Smilacaceae, Tiliaceae, Ulmaceae, Urticaceae and Verbenaceae. However, leaves showing the above noted characters collectively, are seen in the *Sarcococca* Lindl. of Buxaceae; *Strychnos* Linn. of Loganiaceae; *Smilax* Linn. of Smilacaceae; *Apama* Lam. (*Bragantia* Lour.) of Aristolochiaceae; *Cocculus* DC. of Menispermaceae; *Lindera* Thunb., *Litsea* Lamk., *Neolitsea* (Benth.) Merrill and *Cinnamomum* Schaeffer of Lauraceae.

In the leaves of some of the species of *Strychnos*, which show similarity with our fossil, and also in the *Sarcococca*, prominent pinnate type of secondaries arise in more or less regular sequence from the middle primary and join the two lateral primaries at acute angles whereas in the fossil the secondaries are very fine and more or less arranged horizontally. A few species of *Apama* particularly *Apama siliquosa* Lam. (*Bragantia wallichii* Rob. Br.) show close similarity with the fossil specimens. However, the two can be differentiated on careful examination as the leaves of *Apama* are relatively fine in texture, the secondaries are placed at a greater distance and the secondaries and reticulate veins are very conspicuous. Moreover, the pair of intramarginal veins traverse only about 1/3rd of the basal region of the leaf as against the fossil in which the intramarginal veins run continuously from basal to the upper region. Among the various species of *Cocculus*, only *C. laurifolius* DC. shows similarity with our fossil, but it differs in having weakly wavy margin, lamina usually narrow in width, secondaries forming relatively acute angles and mostly ramifying before joining the adjoining primary; its areoles are bigger in size. Some of the species of *Smilax* show apparent similarity with the fossil, however, they differ in one or more characters from the present fossil. Three species of *Lindera* show resemblance with the above fossil, viz., *L. caudata* Benth., *L. melastomacea* Benth., and *L. pulcherrima* Benth. In *L. caudata* and *L. melastomacea* the leaves are very small in size as compared to the fossil. *L. pulcherrima* shows better resemblance but in this the apex of the leaf is long caudate-acuminate as against seemingly(?) acute apex in the fossils. It may further be ruled out from consideration on the basis of distribution as this species is restricted in the Himalayan region from 1,220-2,744 m. The species of *Litsea* and *Neolitsea* differ from the fossil in having mostly suprabasal acrodromous (very rarely basal) venation as compared to basal acrodromous venation in the fossil. Further, fairly prominent lateral secondaries arise quite frequently at acute angles from the median primary, which are not observed in the fossil. Among the large number of *Cinnamomum* species examined, *C. obtusifolium* Nees, *C. tamala* Nees, and *C. zeylanicum* Breyn were found to be very similar to our fossil specimens. Apparently it is difficult to differentiate the leaves of these three species. However, on closer examination the leaves of *C. obtusifolium* can be differentiated from their usually very big size. In *C. zeylanicum* the leaves are thicker than *C. tamala*. Further, the intramarginal vein in *C. zeylanicum* is formed by the fusion of fine, more or less horizontally running secondaries as compared to *C. tamala* in which usually prominent secondaries arise quite frequently at acute angles from the outer side of the two lateral-primaries and they may or may not form intramarginal veins. Thus, the fossil specimens show closest resemblance with the leaves of *C. zeylanicum*.

Fossil Records and Comparison — The fossil leaves of *Cinnamomum* are assigned to four genera, namely *Cinnamomum* Schaeffer, *Cinnamomiphyllum* Nathorst (1888), *Cinnamomophyllum* Kräusel & Weyland (1950), and *Cinnamomoides* Seward (1925). We are aware of 85 species of *Cinnamomum*, 1 species of *Cinnamomiphyllum*, 9 species of *Cinnamomophyllum* and 5 species of *Cinnamomoides*. These are listed below:

Cinnamomum acrodromum Potbury (listed in LaMotte, 1952)
C. angustum Berry (listed in Knowlton, 1919)
C. aquense Saporta (listed in Schimper, 1870-72)
C. brasiliense Krasser, 1903
C. camphoraefolium Saporta (listed in Schimper, 1870-72)
C. camphoroides Krasser, 1903
C. canadense Dawson (listed in Knowlton, 1919)

C. cinnamomeum (RossMaessler) Hollick (listed in Lamotte, 1952)
C. citridorum Twast (listed in Takhtajan, 1964)
C. corrugatum Perkins (listed in LaMotte, 1952)
C. crassipes Lesquereux (listed in Knowlton, 1919)
C. crassipetiolatum Hollick (listed in Knowlton, 1919)
C. emarginatum Saporta (listed in Schimper, 1870-72)
C. ficoides Hollick (listed in LaMotte, 1952)
C. glanduliferum (Wal.) Meissen (listed in Takhtajan, 1964)
C. grandifolium (Ett.) Schimper (listed in Schimper, 1870-72)
C. haastii Ettingshausen, 1887
C. henrici Saporta (listed in Staub, 1905)
C. hesperium Knowlton (listed in Knowlton, 1919)
C. hobartianum Ettingshausen (listed in Duigan, 1950)
C. intermedium Ettingshausen, 1887
C. lanceolatum (Unger) Heer, 1856
C. laramiense Knowlton (listed in Knowlton, 1919)
C. laurifolium Ettingshausen (listed in Schimper, 1870-72)
C. leichardtii Ettingshausen, 1886
C. lignitum Perkins (listed in Lamotte, 1952)
C. maculatum Ball, 1939
C. marioni Lesquereux, 1892
C. minutulum Saporta (listed in Staub, 1905)
C. miocenum Morita, 1931
C. mississippiensis Lesquereux (listed in Knowlton, 1919)
C. nagatoense Huzioka & Takahasi, 1970
C. naitoanum Huzioka & Takahasi, 1970
C. novae-angliae Lesquereux (listed in Knowlton, 1919)
C. nuytsii Ettingshausen, 1886
C. oblongatum Berry (listed in Knowlton, 1919)
C. obovatus Berry (listed in Knowlton, 1919)
C. oguniense Morita, 1931.
C. ovale Saporta (listed in Schimper, 1870-72)
C. ovoides Perkins (listed in LaMotte, 1952).
C. palaeotamala Lakhanpal & Awasthi, in press.
C. paluxyense Ball, 1937
C. paolucci Principi (listed in Principi, 1915)
C. pendunculatum Presl. (listed in Takhtajan, 1964)
C. personatum Bayer (listed in Berry, 1916)
C. polymorphoides McCoy, 1876
C. postnewberryi Berry (listed in Knowlton, 1919)
C. praevirens Deane, 1923
C. precamphora Ball, 1939
C. primigenium Ettingshausen (listed in Duigan, 1950)
C. rossmässleri Heer, 1856
C. rotundatum Saporta (listed in Staub, 1905)
C. rotundifolium Pruncipi (listed in Principi, 1915)
C. sextianum Saporta (listed in Schimper, 1870-72)
C. *sezannense* Watelet, 1866
C. spectabile Heer, 1856
C. spectandum Saporta (listed in Schimper, 1870-72)
C. spiculatum Pilar (listed in Staub, 1905)
C. (?) *stantoni* Knowlton (listed in Knowlton, 1919)
C. subtilinervium Saporta (listed in Staub, 1905)
C. cf. *tamala* Nees (Pathak, 1969)
C. targonii Rist (listed in Staub, 1905)
C. tatei Chapman, 1937
C. ucrainicum Schmalh. (listed in Staub, 1905)
C. woodwardii Ettingshausen (listed in Duigan, 1950)
C. sp. Berry (listed in LaMotte, 1952)
C. sp. Berry (listed in LaMotte, 1952)
C. sp. Chelidze, 1970
C. (?) sp. Dawson (listed in Knowlton, 1919)
C. sp. Hollick (listed in Knowlton, 1919)
C. sp. Hollick (listed in Knowlton, 1919)
C. sp. Kirchheimer (listed in Kilpper, 1969)
C. sp. Knowlton (listed in Knowlton, 1919)
C. sp. Knowlton (do)
C. sp. Knowlton (do)
C. sp. Knowlton (do)
C. sp. Knowlton (do)
C. sp. Knowlton (do)
C. sp. Knowlton (do)
C. (?) sp. Knowlton (do)
C. sp. Kryshtofovish, 1937
C. sp. Lakowitz (listed in Muller, 1934)
C. sp. Matsuo, 1971
C. sp. Scott (listed in LaMotte, 1952)
C. sp. Tanai & Suzuki, 1965
Cinnamomiphyllum sp. Nathorst, 1888
Cinnamomoides faueri Boureau, 1955

C. heeri (Lesq.) Seward, 1926
C. ievlevii Samylina, 1968
C. newberryi (Berry) Seward, 1925
C. tchadense Boureau, 1955
Cinnamomophyllum bendirei (Knowlton) Wolfe, 1977
C. edwardsi (Band.) Weyland & Kilpper, 1963
C. eocernua (Chaney & Sanborn) Wolfe, 1977
C. kushatakensis Wolfe, 1977
C. latum (MacGinitie) Wolfe, 1977
C. (Cinnamomum) scheuchzeri (Heer) Kräusel & Weyland, 1950
C. sp. Kräusel & Weyland, 1950
C sp. Knobloch, 1964
C. sp. Tanai, 1979

These species have been reported from Africa, Australia, Brazil, England, France, Germany, Greece, Greenland, India, Italy, Japan, Newzealand, Switzerland, U.S.A. and U.S.S.R. Thus, the genus *Cinnamomum* was cosmopolitan in distribution during the geological past. It was quite abundant in the Upper Cretaceous in both the hemispheres. However, it reached its peak in the Early Tertiary in U.S.A. and during the Miocene in Europe. The earliest record of *Cinnamomum* known to the authors is *C. paluxyense* Ball from the Lower Cretaceous (Middle Albian) of Paluxy sands, Texas (Ball, 1937).

Only two species of fossil *Cinnamomum* are known from India. The first, *Cinnamomum* sp. cf. *C. tamala* Nees, is described by Pathak (1969) from the Upper Tertiary (Middle Siwalik), Mahanadi River section, Darjeeling, West Bengal. The other is *Cinnamomum palaeotamala* recently reported by Lakhanpal and Awasthi (in press) from the Siwalik beds of Bihar-Nepal boundary. Middlemiss (1911) had reported *Cinnamomum tamala* from the Lower Karewa (Quaternary) beds of Kashmir. However, Puri (1948) reinvestigated these specimens reported as *C. tamala* by Middlemiss and found them belonging to seven different genera other than *Cinnamomum*. In *Cinnamomum* sp. of Pathak (1969) both the Upper and lower portions of the leaf are broken and secondaries arise at acute angles whereas in the present fossil they arise more or less at right angle. Moreover, intramarginal vein is absent in the former, hence the present species differs from Pathak's species. *Cinnamomum palaeotamala* Lakhanpal & Awasthi (in Press) can be easily differentiated from the present fossil. In the former lateral primaries are suprabasal in origin as compared to basal origin in our specimens. Further, intramarginal vein is present in our specimens whereas the same is invisible in *Cinnamomum palaeotamala*. As the present fossil differs from the known *Cinnamomum* leaves from India, a new name is instituted for this, viz., *Cinnamomum eokachchhensis* sp. nov., the specific epithet *eokachchhensis* indicates that the fossils belong to the Eocene beds of Kachchh.

Present Distribution of Cinnamomum — This genus consists of 250 species (Willis, 1973, p. 255) of evergreen trees and shrubs and is found in the tropical and subtropical regions of East Asia and Indomalaya. *Cinnamomum zeylanicum* is a large tree and is distributed in the Western Ghats and adjoining hill ranges, from the Konkan southwards and also in Tenasserim (Brandis, 1906, p. 533).

Holotype — B.S.I.P. Museum no. 35386.

Locality — Lignite mine at Panandhro, district Kachchh, Gujarat.

Horizon — Berwali Series (Kakdi Stage-Ypresian).

Age — Lower Eocene.

Family — Moraceae

Genus — *Ficus* Linn.

Ficus kachchhensis sp. nov.

Pl. 2, fig. 8

A single well-preserved leaf-impression, split open into two counter-parts, 9·5 cm in length and devoid of any cuticle.

Description — Leaf symmetrical, seemingly wide ovate; preserved lamina length 8·8 cm, maximum width 8·5 cm; apex not preserved; base cordate; margin entire, slightly undulating; texture thick; attachment of petiole normal, preserved length 0·7 cm; venation pinnate, eucamptodromous; primary vein (1°) simple, stout, course more or less straight; secondary veins (2°) angle of divergence acute, moderate (60°-50°), relatively less thick (moderate) than primary vein; uniformly curved, unbranched; intersecondary veins absent; tertiary veins (3°) angle of origin RA to RR, course sinuosus, obliquely arranged in relation to mid-vein, arrangement pre-

dominantly alternate, close to distant; quaternary veins (4°)-size normal, course varying from relatively random to orthogonal; marginal ultimate venation fimbriate; areoles well-developed, shape triangular to pentagonal, size very large, veinlets not seen.

Discussion — The shape of the leaf, its cordate base, and the kind of venation all tend to show that the specimen belongs to the genus *Ficus* Linn. of the family Moraceae. Schimper (1870-72) has grouped the fossil species of *Ficus* into three sections (most probably on the basis of their venation): folia pinnatinervia, folia trinervia and folia palmatinervia. Accordingly, the present leaf-impression belongs to 'folia pinnatinervia', of Schimper, as the venation in this is of pinnate type. This section has the largest number of representatives.

A very large number of *Ficus* species were compared with the fossil. The type of venation and shape of the leaf exhibited by the fossil is found only in a few species of *Ficus*. Taking into consideration all the characters collectively, the *Ficus* spp. that come closer to the present fossil are: *Ficus benghalensis* Linn., *F. roxburghii* Wall., *F. rotundifolia* Roxb., *F. hookeri* Miq., *F. hispida* L. f., *F. laevis* Blume, *F. varigata* Blume, *F. palmata* Forsk., and *F. tomentosa* Roxb.

In the first seven of these species the angle of the lowest prominent pair of secondaries is much sharper than the corresponding angle of the present fossil. In *Ficus palmata* the margin of leaf is serrate, in contrast to the entire and wavy margin of the fossil. The last mentioned species, i.e. *Ficus tomentosa*, shows closest resemblance with the fossil (particularly specimen no. 6484 of the Forest Research Institute, Dehradun, Herbarium).

Fossil Records and Comparison — There are abundant and widespread records of fossil leaves of *Ficus*. Besides some records which have been mentioned under the non-committal name "*Dicotylophyllum*", there are 4 genera under which *Ficus* or *Ficus*-like leaves have been described. These are: *Ficus* Linnaeus, *Ficonium* Ettingshausen, *Ficophyllum* Fontaine emend. Edwards, and *Protoficus* Saporta. Three hundred and ninety eight species of *Ficus*, 2 species of *Ficonium*, 7 species of *Ficophyllum* and 6 species of *Protoficus* have been compiled (Guleria, 1978) from the vast amount of literature available. They are too numerous to be listed here.

The earliest record of *Ficus* or *Ficus*-like leaf is known from the Lower Cretaceous (Potmac group) of Maryland described by Fontaine (1889) under the generic name *Ficophyllum*. Most of them occur in the Upper Cretaceous and Early Tertiary horizons of America and its maximum development in Europe took place in the Late Miocene. Species belonging to *Ficus* have been reported from North America, South America, Africa (Ethiopia), Europe (Belgium, Czechoslovakia, France, Germany, Greenland, Hungary, Italy, Rumania, Yugoslavia, etc.), Asia (Burma, China, Egypt, India, Indonesia, Japan, U.S.S.R.), and Australia (Australia and New Zealand). This cosmopolitanism continued throughout the Tertiary. Thus *Ficus* has continued its existence from Cretaceous onwards till today.

Indian Records and Comparison — In 1947, Puri described fossil leaves of *Ficus cunia* Buch-Ham, besides reporting *F. nemoralis* Wall. (1948, p. 118), from the Karewas of Kashmir. From the Siwalik beds of Himachal Pradesh, Lakhanpal (1968) described *F. precunia* and Gupta and Jiwan (1972) reported *F. cunia*. Lately, one more species, *F. champarense* has been described by Lakhanpal and Awasthi (in Press) from the Siwalik beds of Bihar. Mahajan and Mahabale (1973) described *F. arnottiana* Miq. and *F. glomerata* Roxb. from the Quaternary deposits of Maharashtra. *Ficus precunia* Lakhanpal (1968), *F. champarense* Lakhanpal & Awasthi (in Press) and *F. cunia* described by Puri (1947) differ from the present fossil in having inequilateral or asymmetrical base. *F. cunia* as reported by Gupta and Jiwan (1972) differs in shape and in the type of venation from the present fossil. *F. nemoralis* has an acute base as compared to the cordate base in the present specimen. *F. glomerata* differs from the present fossil in having ovate-narrow-ovate-elliptic leaves. Moreover, the curvature of secondaries is different in *F. glomerata*. *F. arnottiana* shows apparent resemblance with the present fossil in having more or less similar shape and base but differs in the curvature of secondary veins and in having conspicuous submarginal arches formed by the secondaries.

Thus, none of the known Indian fossil species of *Ficus* resembles with our fossil. Therefore, a new name, *Ficus kachchhensis* sp. nov., is assigned to it; the specific name denoting the district from which the fossil was collected.

Present-day Distribution of Ficus — The genus is a very big genus consisting of about 800 species (Willis, 1973, p. 458) widely distributed throughout the tropics of both hemispheres, but most abundant in the islands of Indian Archipelago and the Pacific Ocean. A few species extend beyond the tropics into southern Florida (U.S.A.), Mexico, Argentina, southern Japan and China, the Mediterranean countries, the Canary Islands, and South Africa. Approximately, 80 species are included in the Indian flora (Pearson & Brown, 1932). *Ficus tomentosa*, a large shady tree having thin aerial roots, is found in Bundelkhand, Banda, Bihar, Chota Nagpur, Central Provinces and Western Peninsula (Brandis, 1906, p. 601).

The present fossil leaf is important from the chronological standpoint. It is the first record of *Ficus* from the Eocene of the Indian sub-continent. Roughly speaking, almost 400 species of *Ficus* and *Ficus*-like leaves have been recorded so far. Considering this obviously vast number of fossil species assigned to a genus, it is suggested that a thorough critical examination of all the known records of *Ficus* should be done which, it is hoped, would considerably reduce the number of fossil species as apparent from the revision of Rocky Mountains and Great Plains species by Brown (1962).

Holotype — B.S.I.P. Museum no. 35391.

Locality — Lignite mine at Panandhro, district Kachchh, Gujarat.

Horizon — Berwali Series (Kakdi Stage-Ypresian).

Age — Lower Eocene.

Genus —*Dicotylophyllum* Saporta, 1894

Dicotylophyllum cordatum sp. nov.

Pl. 3, fig. 11

This species is based on two leaf impressions 9·2 cm and 14·7 cm long. The impressions are well-preserved, though broken.

Description — Leaves appear symmetrical, seemingly oblong; preserved lamina length 14·4 cm in one specimen and 9·2 cm in the other, maximum width on one side of the midrib about 4·5 cm; apex broken; base cordate, margin entire, straight to slightly wavy; texture appears to be thick chartaceous; petiole thick (fleshy) about 8 mm wide, about 3·5 cm long; venation pinnate, brochidodromous; primary vein (1°) single, stout, slightly curved; secondary veins (2°) with wide acute (85°-70°) angle of divergence, 85° in the basal region and gradually decreasing upwards, moderately thick, more or less uniformly curved joining superadjacent secondary at right angle to slightly obtuse angle, forming intramarginal veins; intersecondary veins present, simple, reaching almost up to intramarginal vein; tertiary veins (3°) with angle of origin AA, AR or rarely RR, joining intersecondaries, course simple, slightly obliquely arranged in relation to midvein, alternate to opposite in arrangement, distant to close; quaternary veins (4°) thin, course more or less orthogonal; ultimate marginal venation fimbriate; areoles well-developed, oriented, usually quadrangular, small; veinlets not seen.

Discussion — Important features of the present fossil are: (i) fairly big size, (ii) shape appearingly symmetrical, (iii) form seemingly oblong, (iv) base cordate, (v) margin entire, smooth, straight to slightly wavy, (vi) thick (fleshy) petiole, (vii) pinnate brochidodromous venation, (viii) angle of divergence varying from 85°-70°, (ix) intramarginal vein present, and (x) intersecondaries present.

The leaves of *Terminalia* spp., such as *T. crenulata* Heyne ex. Roth, *T. myriocarpa* Heurck & Muell. Arg., *T. coriacea* (Roxb.) W. & A. of Combretaceae; *Garcinia xanthochymus* Hook. f., and *Mammea acuminata* (Kosterm) Kosterm of Guttiferae; *Duabanga grandiflora* (Roxb.) Walp. (= *D. sonneratioides* Buch-Ham) of Sonneratiaceae; *Anisoptera oblonga* Dyer of Dipterocarpaceae; *Plumeria* spp. of Apocynaceae; *Tupidanthus calyptratus* Hook. f. & Thoms. of Araliaceae and *Ficus elastica* Roxb. of Moraceae show varying degree of resemblance with the present fossil.

In the leaves of *Terminalia* spp. secondaries do not form loops as seen in the fossil; instead they move upwards and gradually narrow and finally merge with the margin of the leaf. Intersecondaries

present a regular feature in the fossil whereas they are rarely seen in the *Terminalia* leaves. Moreover, the angle of divergence of secondaries is also different in *Terminalia*. Leaves of *Garcinia xanthochymus* sometimes show apparent similarity but they differ from the present fossil in the angle of divergence (relatively acute) and origin of secondaries. *Mammea acuminata* leaves show close similarity with the fossil except its acute base. Similarly, the leaves of *Plumeria* spp. also differ in having an acute base. *Duabanga* leaves though showing very close similarity in shape, size, form, base and intramarginal veins yet differ in the curvature of secondaries and in having relatively acute angle of divergence of secondaries. Moreover, intersecondaries are rare in *Duabanga* whereas it is a regular feature in the present fossil. The leaves of *Anisoptera* spp. show general similarity but the type of loops formed by the secondaries in the fossil are not seen in the *Anisoptera* leaves. However, in *A. oblonga* similar loops were observed as in the fossil besides fairly long petiole. Still *A. oblonga* differs in the absence of intersecondaries and in having a thinner petiole. The leaflets of *Tupidanthus calyptratus* also show close similarity with the fossil but they differ in having non-cordate base. *Ficus elastica* leaves also show some similarity but they differ in having an acute base. Thus the present fossil does not match with any of the above mentioned modern species.

Fossil Records and Comparison — The present fossil does not resemble any of the earlier known fossil leaves; even those generalized forms described as dicot leaves (Bose, 1952; Singh & Mathew, 1954; Trivedi, 1959); *Dicotylophyllum* (Chaudhri, 1969; Dayal & Chaudhri, 1967; Nambudiri, 1966, 1970; Sahni, 1953; Verma & Mathur, 1968) and *Phyllites* (Chowdhury, Das & Ahmed, 1970; Lakhanpal, 1952; Ramanujam & Rao, 1957; Rode, 1935; Seward, 1912) from India.

Since the present fossil leaf shows the characters of a dicot leaf but its natural affinities have not been ascertained, it is being placed under the form genus *Dicotylophyllum* Saporta. A new name, *Dicotylophyllum cordatum* sp. nov., is assigned to it, the specific epithet signifying the cordate base of the present fossil.

Holotype — B.S.I.P. Museum no. 35394.

Locality — Lignite mine at Panandhro, district Kachchh, Gujarat.

Horizon — Berwali Series (Kakdi Stage-Ypresian).

Age — Lower Eocene.

Dicotylophyllum panandhroensis sp. nov.

Pl. 4, fig. 12

This species is based on a single well-preserved specimen of leaf impression 14·8 cm long. The specimen is split open into two counter-parts.

Description — Leaf slightly asymmetrical, seemingly elliptic; preserved lamina length 13·8 cm, maximum width 11·2 cm; apex broken; base obtuse, inequilateral; margin entire, slightly wavy; texture coriaceous or thickly chartaceous; petiole normal, preserved length 1 cm; venation pinnate, appearing craspedodromous; primary vein (1°) single stout, slightly curved; secondary veins (2°) diverging more or less at right angles, thickness relatively less than that of the primary vein, more or less straight, sometimes slightly curved up near the margin, rarely also bifurcating close to the margin; intersecondary veins present, faint, simple; tertiary veins (3°) very faint, rarely visible, angle of origin almost right angle, distantly arranged; higher order venation not seen.

Discussion — The important features of the present fossil are: (i) large size, (ii) slightly asymmetrical shape, (iii) elliptic form, (iv) inequilateral obtuse base, (v) entire margin, slightly wavy, (vi) petiole normal, (vii) angle of divergence of secondaries almost right angle, and (viii) intersecondaries present.

The leaves of *Plumeria* Linn. of Apocynaceae, *Barringtonia* J. R. & G. Frost. of Barringtoniaceae, *Melanorrhoea* Wall. and *Semecarpus* L. f. of Anacardiaceae show similar type of leaves. The leaves of *Plumeria* spp. resemble in the angle of divergence of secondaries and somewhat in size too. However, the secondaries in *Plumeria* form continuous distinct loops near the margin thereby giving rise to intramarginal veins; this character is not seen in the present fossil. Leaves of some of the *Barringtonia* spp. show apparent resemblance with the fossil but they differ distinctly in shape of the lower half of fossil leaf. Further, in *Barringtonia* the petiole is very small. The leaves of

Semecarpus anacardium L. f. also show some resemblance. However, they differ from the present fossil in their bases and also in the angle of divergence of the secondaries. Of the various species of *Melanorrhoea* compared, the leaves of *M. usitata* Wall. show fairly good resemblance with the present fossil. However, the base in *M. usitata* leaves is cuneate and shows a little prolongation as compared to the present fossil in which the base is obtuse and does not show any prolongation. It may be possible to confirm this similarity with more material, but at present the two do not seem identical.

Comparison with the known fossil leaves — None of the earlier known fossil leaves shows any similarity with the present fossil. Further, the fossil leaves described as dicot leaves, *Dicotylophyllum* and *Phyllites* (see page 358) also do not show any similarity with the present specimen.

The fossil is presently placed under the form genus *Dicotylophyllum* Saporta as it is a dicot leaf. Since it differs from all the known *Dicotylophyllum* spp., a new name, *Dicotylophyllum panandhroensis* sp. nov., is being assigned to it. The specific epithet denotes the locality from where the material was collected.

Holotype — B.S.I.P. Museum no. 35395.

Locality — Lignite mine at Panandhro, district Kachchh, Gujarat.

Horizon — Berwali Series (Kakdi Stage-Ypresian).

Age — Lower Eocene.

Dicotylophyllum quadrinervatum sp. nov.

Pl. 2, fig. 9

The species is based on a single leaf impression representing the lower portion of the leaf, which is preserved in two counter-parts.

Description — Leaf appearing to be symmetrical, ? wide elliptic; preserved lamina length 8·0 cm, maximum preserved width 5·8 cm; apex not preserved; base broad obtuse, slightly cuneate; margin preserved only close to the base, entire; texture chartaceous; petiole normal, curved, preserved length 1·5 cm; venation actinodromous, primary veins radiation basal, development perfect, seemingly marginal; primary veins (1°) four, stout, slightly curved, branched, branches arising at acute angles, moving upwards; secondary veins (2°) distantly placed, arising from primaries and their branches, joining the two adjacent primaries or other secondaries, fine, curved to wavy, two successive secondaries sometimes joining each other in the middle; tertiary veins (3°) fine, percurrent or occasionally joining primaries directly, mostly simple, wavy, approximately at right angle to the primaries; higher order venation not seen.

Discussion — Important characters of the present fossil are: (i) wide elliptic form, (ii) broadly cuneate base, (iii) chartaceous texture, (iv) actinodromous venation, (v) four primaries and their ?divergent arrangement. It has not been possible to compare the present fossil with the leaf of any living plant. At the same time it does not resemble any fossil leaf described so far. As it is beyond doubt a dicot leaf and its further natural affinities are uncertain, it is placed under the form genus *Dicotylophyllum* Saporta. Since our fossil differs from all the known species of *Dicotylophyllum*, a new name, *Dicotylophyllum quadrinervatum* sp. nov., is assigned to it; the specific name *quadrinervatum* refering to the characteristically arranged four primaries of the fossil leaf.

Holotype — B.S.I.P. Museum no. 35392.

Locality — Lignite mine at Panandhro, district Kachchh, Gujarat.

Horizon — Berwali Series (Kakdi Stage-Ypresian).

Age — Lower Eocene.

PALAEOECOLOGICAL INDICATIONS

The floristic composition of the above leaf-impressions in the light of distribution of their modern comparable forms indicates a tropical climate in which these plants had existed. Champion and Seth (1968, p. 45) have divided the tropical vegetation of India into 7 forest types on the basis of moisture conditions. The modern equivalent of Panandhro components are distributed in the following types of tropical forests (Table 1).

From the above analysis it is plausible to conclude that moist evergreen to deciduous vegetation was prevalent around Panandhro. Obviously, the vegetation of Kachchh, during Lower Eocene was much

TABLE 1

Taxa	Tropical Forest Types						
	Wet evergreen forests	Semi-evergreen forests	Moist deciduous forests	Littoral & swamp forests	Dry deciduous forests	Thorn forests	Dry evergreen forests
Cinnamomum zeylanicum	+	+					
Ficus tomentosa	+	+	+		+		
Lagerstroemia speciosa			+	+			
**Pandanus diversus*		+					
**P. furcatus*	+						
**P. tectorius*			+	+			
Syzygium sp.	+	+	+	+	+		+
Terminalia crenulata			+				

**Pandanus* has been described elsewhere. Please see Guleria & Lakhanpal (in Press).

more luxuriant in contrast to the scrubby vegetation of today. Further, the littoral and swampy elements indicate the occurrence of marshes around this locality in which the vegetation got buried and in due course resulted in the formation of lignite.

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EXPLANATION OF PLATES

PLATE 1

1. *Terminalia panandhroensis* sp. nov., leaf: natural size.
2-4. *Cinnamomum eokachchhensis* sp. nov., leaves showing variations in shape and size; natural size.
5. *Syzygium kachchhense*, sp. nov., leaf; natural size.

PLATE 2

Syzygium kachchhense sp. nov.

6. Part of fig. 5 enlarged showing details of venation. × 3.
7. Another specimen of *Syzygium kachchhense*, natural size.
8. *Ficus khariensis* sp. nov., leaf; natural size.
9. *Dicotylophyllum quadrinervatum* sp. nov., leaf; natural size.

PLATE 3

10. *Lagerstroemia patelii* sp. nov., leaf; natural size.
11. *Dicotylophyllum cordatum* sp. nov., leaf; natural size.

PLATE 4

12. *Dicotylophyllum panandhroensis* sp. nov., leaf; natural size.

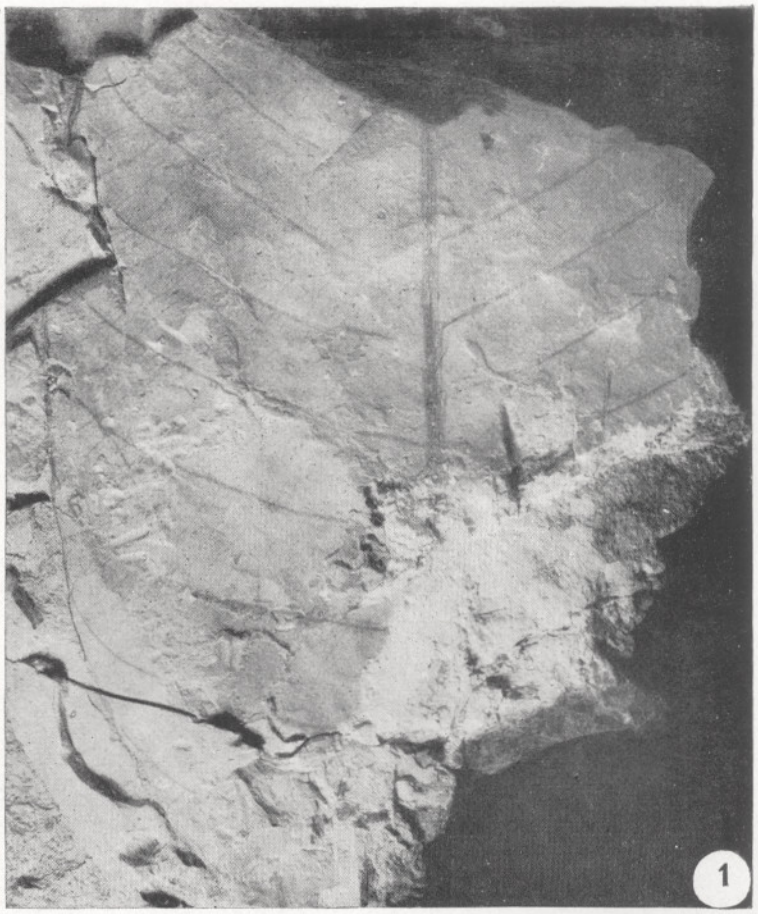

PLATE 1

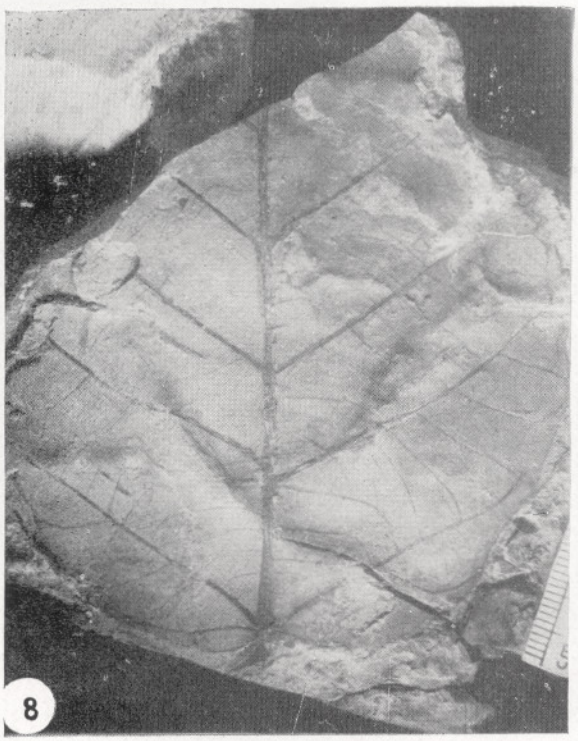

PLATE 2

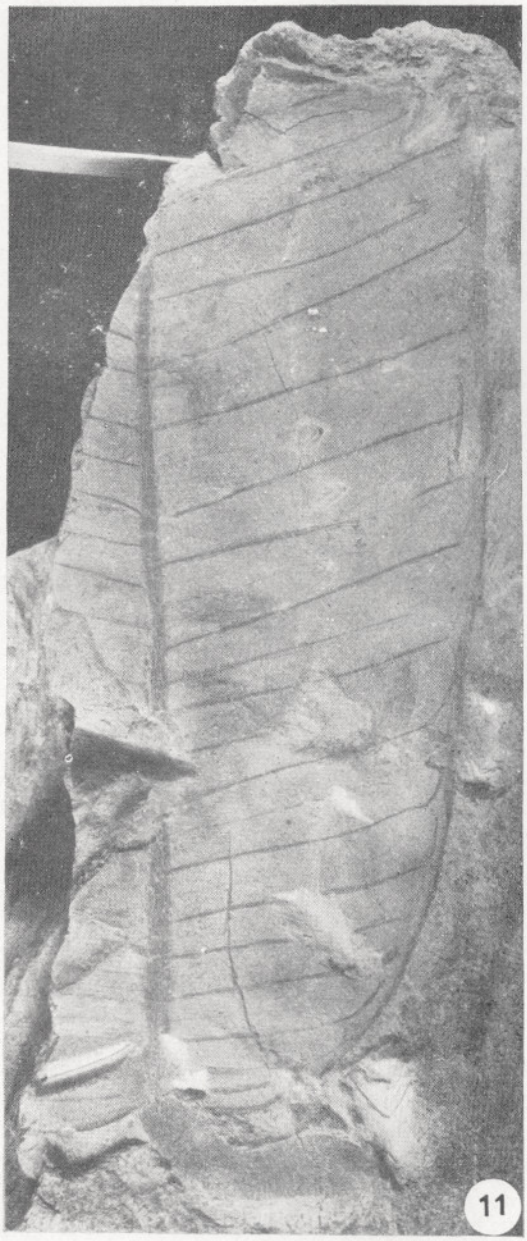

PLATE 3

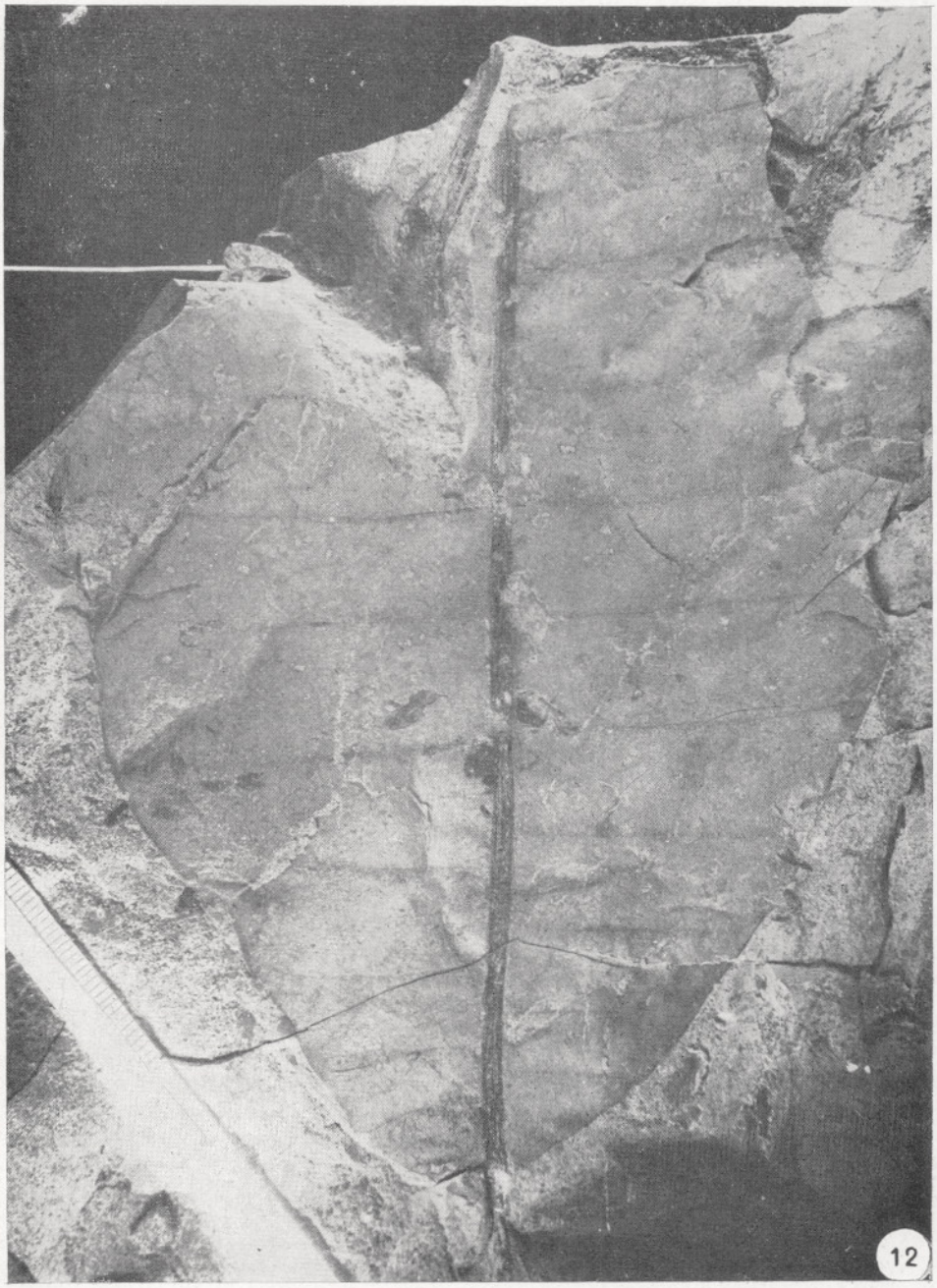

PLATE 4