Contribution to the Siwalik flora from Surai Khola sequence, western Nepal and its palaeoecological and phytogeographical implications

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A systematic study of plant megafossils comprising mostly leaf- impressions and few fruits from a sequence of the Siwalik sediments of Surai Khola area, Rapti Anchal, western Nepal has revealed 33 taxa belonging to 15 dicotyledonous families, viz., Anonaceae, Flacourtiaceae, Clusiaceae, Rutaceae, Meliaceae, Sapindaceae, Anacardiaceae, Fabaceae, Anisophylleaceae, Myrtaceae, Rubiaceae, Apocynaceae, Ebenaceae, Euphorbiaceae and Moraceae. Amongst them, *Goniothalamus, Harpullia, Anisophyllea, Anthocephalus, Diplospora, Chonemorpha* and *Cleistanthus* are new genera to the Indian Tertiary flora. The megafloral assemblage of the Surai Khola sequence, including 21 taxa reported earlier, now comprises 53 taxa of angiosperms. Most of the extant species resembling the fossil taxa are distributed in the tropical evergreen to semi-evergreen forests of Western Ghats, northern India, Andaman Islands, Bangladesh, Myanmar and in Southeast Asia which suggest that warm humid climate with higher precipitation prevailed in the area during Middle Miocene-Pliocene. Looking at the floral assemblages of different formations of the Surai Khola sequence, from base to the top sediments belonging to the Lower, Middle and Upper Siwaliks, one may find a gradual shift in the vegetation pattern. The basal sediments of Bankas and Chor Khola formations have preponderance of a lowland mixed mesophytic broad-leaved evergreen to semi-evergreen elements. An increase in deciduous elements in the floral composition consequent to the disappearance of dipterocarps and other significant evergreen taxa is noticed towards the close of Middle Siwalik and the beginning of Upper Siwalik. This change in the vegetation pattern reflects the changes in climatic conditions which are mainly due to northward movement of the Indian Plate and further uplift of Himalaya.

Key-words—Leaf-impressions, Fruits, Angiosperms, Palaeoclimate, Phytogeography, Siwalik Formation, Surai Khola, (Nepal).

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सारांश

पश्चिमी नेपाल में सुराई खोला अनुक्रम से शिवालिक वनस्पतिजात पर अंशदान तथा इसका पुरापारिस्थितिकीय एवं पुराभौगोलिक महत्व

महेश प्रसाद एवं नीलाम्बर अवस्थी

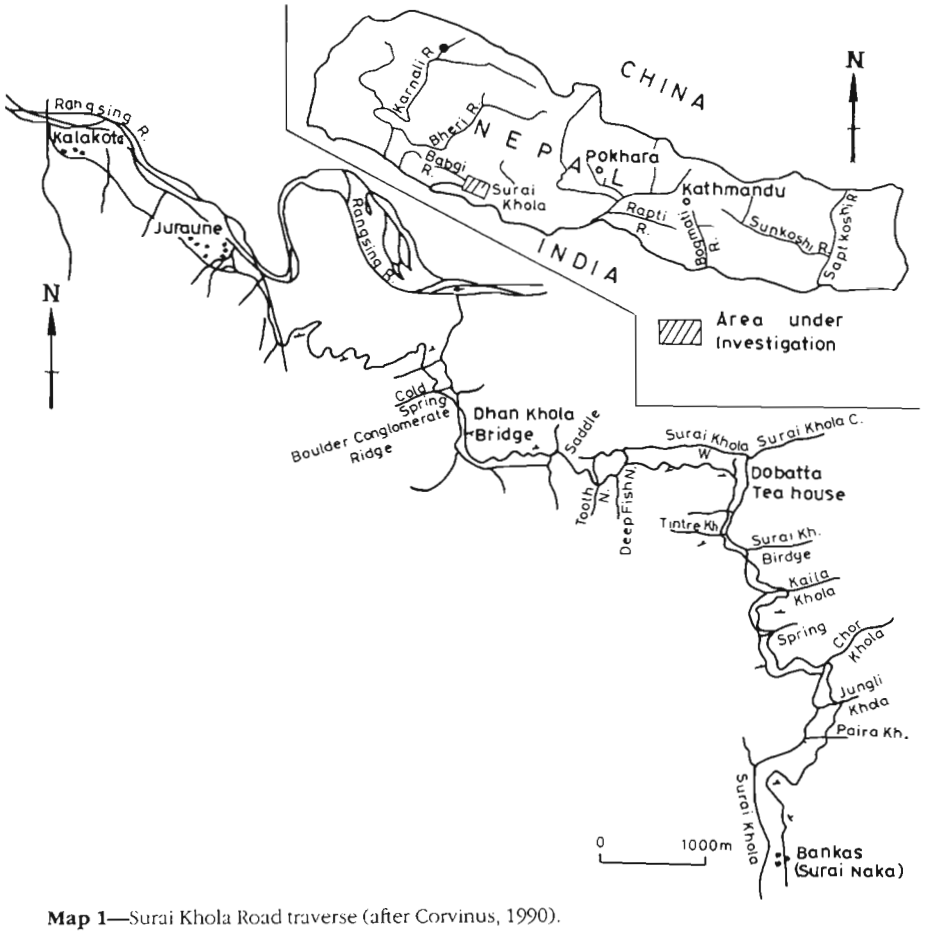
पश्चिमी नेपाल के राप्ती आँचल में सुराई खोला क्षेत्र के शिवालिक अवसादों से प्राप्त पर्ण छापों एवं कुछ बीजों के गुरुपादपाश्मों के अध्ययन से 33 वर्गक प्राप्त हुए हैं जो एनोनेसी, फ्लेकोर्शिएसी, क्लूसिएसी, रूटेसी, मिलिएसी, सेपिन्डेसी, एनाकार्डिएसी, फैबेसी, एनाइसोफिल्लेसी, मिर्टेसी, रूबिएसी, एपोसाइनेसी, एबीनेसी, यूफोर्बिएसी एवं मोरेसी नामक 15 द्विबीजपत्रीय कुलों से सम्बद्ध हैं। इनमें से *गोनिओथैलेमस, हरपुलिया, एनाइसोफिल्लीआ, एन्थोसिफेलस, डिप्लोस्पोरा, कोनिमोर्फा* एवं *क्लिस्टेन्थस* भारतीय तृतीयक वनस्पतिजात के लिए नये हैं।

सुराई खोला अनुक्रम के गुरुपादपाश्म समुच्चय में पूर्व वर्णित 21 वर्गकों सहित अब आवृतबीजीयों के 53 वर्गक सम्मिलित हैं। अश्मित वर्गकों से मिलती-जुलती अधिकतर जातियाँ पश्चिमी घाट, उत्तरी भारत, अंडमान द्वीप, बंगलादेश, मियनमार एवं दक्षिणपूर्व एशिया के उष्णकटिबन्धीय सदाहरित से अर्ध सदाहरित वनों में वितरित हैं जिससे यह प्रस्तावित होता है कि मध्य मध्यनूतन से अतिनूतन कल्प में इस क्षेत्र में अत्याधिक वर्षा के साथ-साथ गर्म आर्द्र जलवायु विद्यमान थी। सुराई खोला अनुक्रम में नीचे से ऊपर तक अधरि, मध्य और उपरि शिवालिक अवसादों से प्राप्त वनस्पतिजातीय समुच्चयों से इस क्षेत्र की वनस्पति में

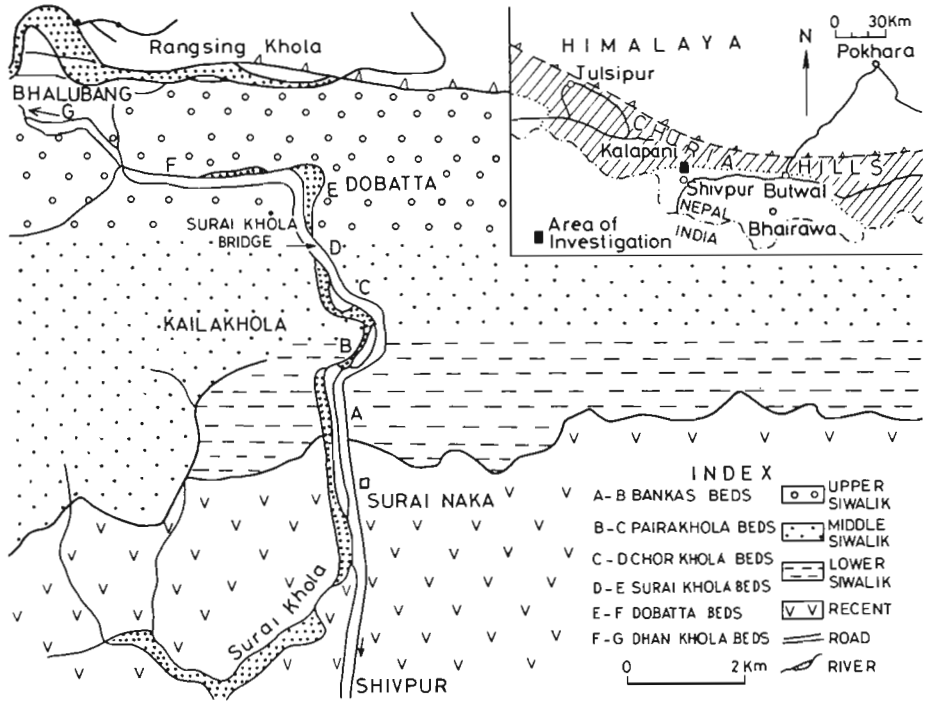
शनैः शनैः परिवर्तन इंगित होता है। बंकस एवं चोर खोला शैल-समूहों के आधारी अवसादों में निम्न भूमि के मिश्रित चौड़ी पत्ती वाले सदाहरित से अर्ध सदाहरित अवयवों की बाहुल्यता है। उपलब्ध वनस्पतिजात में मध्य शिवालिक के अन्त में तथा उपरि शिवालिक के प्रारम्भ में पर्णपाती अवयवों की वृद्धि तथा *डिप्टेरोकार्पस* एवं विशिष्ट सदाहरित वर्गकों की विलुप्ती प्रेक्षित की गई है। वनस्पति के स्वरूप में परिवर्तन जलवायवी परिस्थितियों में हुए परिवर्तन के कारण ही हुआ है जो कि मुख्यतया भारतीय प्लेट के उत्तर की ओर बढ़ने तथा हिमालय के और उत्थान के कारण है।

IN Nepal, the sediments of Siwalik Group are known as Churia Group after the Churia Hills which are the extension of the Himalayan foot-hills (Siwalik Hills) of India. They are distributed along the southern front of the Nepal Himalaya constituting a narrow belt of 800 km bounded by the Main Boundary Thrust (MBT) to the north and Frontal Churia Thrust (FCT) to south.

A complete and uninterrupted sequence of the Siwalik (Churia) Group is exposed along the Mahendra Highway between Surai Naka and Rangsing Khola, in Surai Khola area, about 70 km west of Butwal, district Kapilvastu (Maps 1, 2). The sequence consists of essentially molasse deposits of Lower Siwalik to the Upper Siwalik (Corvinus, 1988a, b, 1990, 1994). This is one of the best sequences of the Siwalik sediments for palaeobotanical studies. There are as many as 51 recognisable fossiliferous beds of mainly shales, siltstone, mudstones and sometimes sandstones. Most of them have yielded a variety of well preserved leaf-impressions and a few fruits and seeds-impressions (Text-figure 1).



Map 1—Surai Khola Road traverse (after Corvinus, 1990).



Map 2—Geological map showing different lithological units in Surai Khola Siwalik sequence (after West, 1984; Corvinus, 1990).

In order to reconstruct the Middle Miocene-Lower Pleistocene plant communities of Siwalik basins of Surai Khola area and to throw light on the climatic changes caused by further uplift of Himalaya, a systematic study of plant fossils was undertaken by the authors.

In an earlier paper, Awasthi and Prasad (1990) described 21 species of leaf-impressions and a seed belonging to 19 genera of 13 families of both dicotyledons and monocotyledons, and discussed broadly the palaeoecological and phytogeographical significance of the flora.

In the present study, 33 leaf-impressions have been identified with the extant taxa belonging to 28 genera of 15 dicotyledonous families. Based on the collective data, different palaeobotanical aspects of the Siwalik flora from the Surai Khola sequence have been precisely discussed.

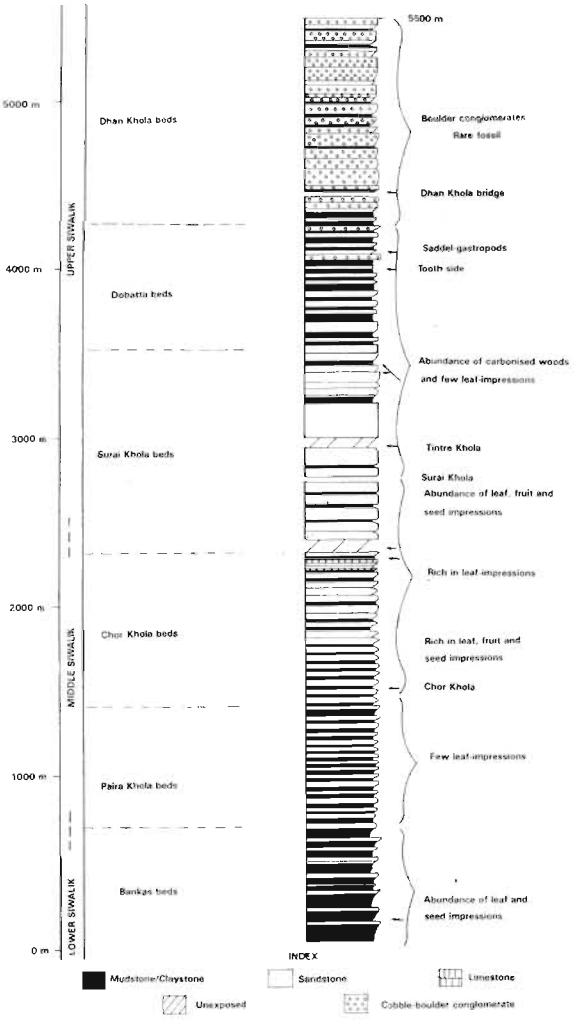
All the specimens have been deposited in the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow.

GEOLOGY

Detailed work on tectonics, lithostratigraphy, magnetostratigraphy, palaeontology and isotopic analysis of the Siwalik (Churia) Group has been carried out by several workers, especially during last decade (Tokuoka *et al.*, 1994; Sah *et al.*, 1994; Appel & Rosler, 1994; Quade *et al.*, 1995). The Surai Khola is one of the most significant areas for such studies. The Siwalik sediments in Surai Khola area are well exposed along the Mahendra Highway Road cutting in between Surai Naka (Bankas) to the south of the Terai Plain and Kalakata to the north in the Rangsing Khola (Map 1). The sequence consists of rocks of all the three sub-groups of Siwalik, i.e., upper part of the Lower Siwalik (the basal part not exposed), Middle Siwalik, and Upper Siwalik. On the basis of lithology, Corvinus (1988a, b, 1990, 1994), measured the whole sequence of sediments of Surai Khola area to 5600 m, and further divided it into five formations, namely-Bankas (corresponding to Chinji), Chor Khola (Mid-

dle Siwalik), Surai Khola (the lower part seems still to belongs to the Middle Siwalik while the upper part belongs to the Upper Siwalik), Dobatta (= Pinjore) and Dhan Khola (= Boulder conglomerate). According to Corvinus (1994), a brief lithology of the Surai Khola sequence is as follows (Map 2; Text-figure 1):

Local Formation	Lithology
Dhan Khola (1500 m)	Consolidated to un-consolidated cobble to boulder conglomerates, subordinate yellow, soft sandstones and siltstones.
Dobatta (550 m)	Alternation of yellow-brown and grey clays + mudstones with soft micaceous medium- to coarse-grained sandstones.
Surai Khola (1150 m)	Massive, grey to beige, micaceous, medium- to coarse-grained sandstone with few intercalations of dark grey clays
Chor Khola Upper member (850 m)	Alternations of calcareous grey-greenish to buff fine- to medium-grained sandstones with mottled siltstones and claystones. Sandstone percentage increasing in younger beds. First appearance of salt and pepper sandstone bed, limestone beds in uppermost part.
Lower member (950 m)	Alternations of grey to greenish, calcareous, fine-grained sandstones with mottled variegated mudstones/claystones.
Bankas (600 m)	Variegated, mottled claystones and mudstones with subordinate grey, calcareous fine-grained sandstones.



Text-figure 1—The Surai Khola Siwalik sequence, western Nepal (after Corvinus, 1990).

The lower part of the sequence representing Bankas, upper and lower parts of Chor Khola and lower part of Surai Khola are rich in plant fossils comprising leaves, fruits and seed-impressions which occur mostly in shales, while carbonised woods in small pockets or as lenses within sandstones. The upper part of Surai Khola and Dobatta formations are poor in plant megafossils. However, ill-preserved grasses and grass-like plant debris occasionally seen in sand and claystones. It is also significant that these sediments contain animal fossils such as molluscs, microvertebrates, fishes, reptiles and mammals, generally occurring in sandstones (Corvinus, 1994).

PLATE 1

(All figures are of natural size unless otherwise mentioned)

1. *Mitrephora siwalica* Antal & Awasthi — Fossil leaf. Specimen no BSIP 37568.
2. *Mitrephora maingayi* Hook & Thoms — Modern leaf.
3. *Mitrephora siwalika* Antal & Awasthi—Another fossil leaf. Specimen no. BSIP 37569.
4. *Goniothalamus chorkholaensis* sp. nov. — Fossil leaf; Specimen no. BSIP 37570.
5. *Flacourtia tertiara* sp. nov —Fossil leaf; Specimen no. BSIP 37571.
6. *Flacourtia inermis* —Modern leaf.
7. *Flacourtia tertiara* — A part of fossil leaf magnified to show details of venation X 2.
8. *Flacourtia inermis* — A part of modern leaf to show similar details of venation X 2.
9. *Hydnocarpus chorkholaensis* sp. nov. — Fossil leaf; Specimen no. BSIP 37572.
10. *Hydnocarpus ovoides*—Modern leaf.

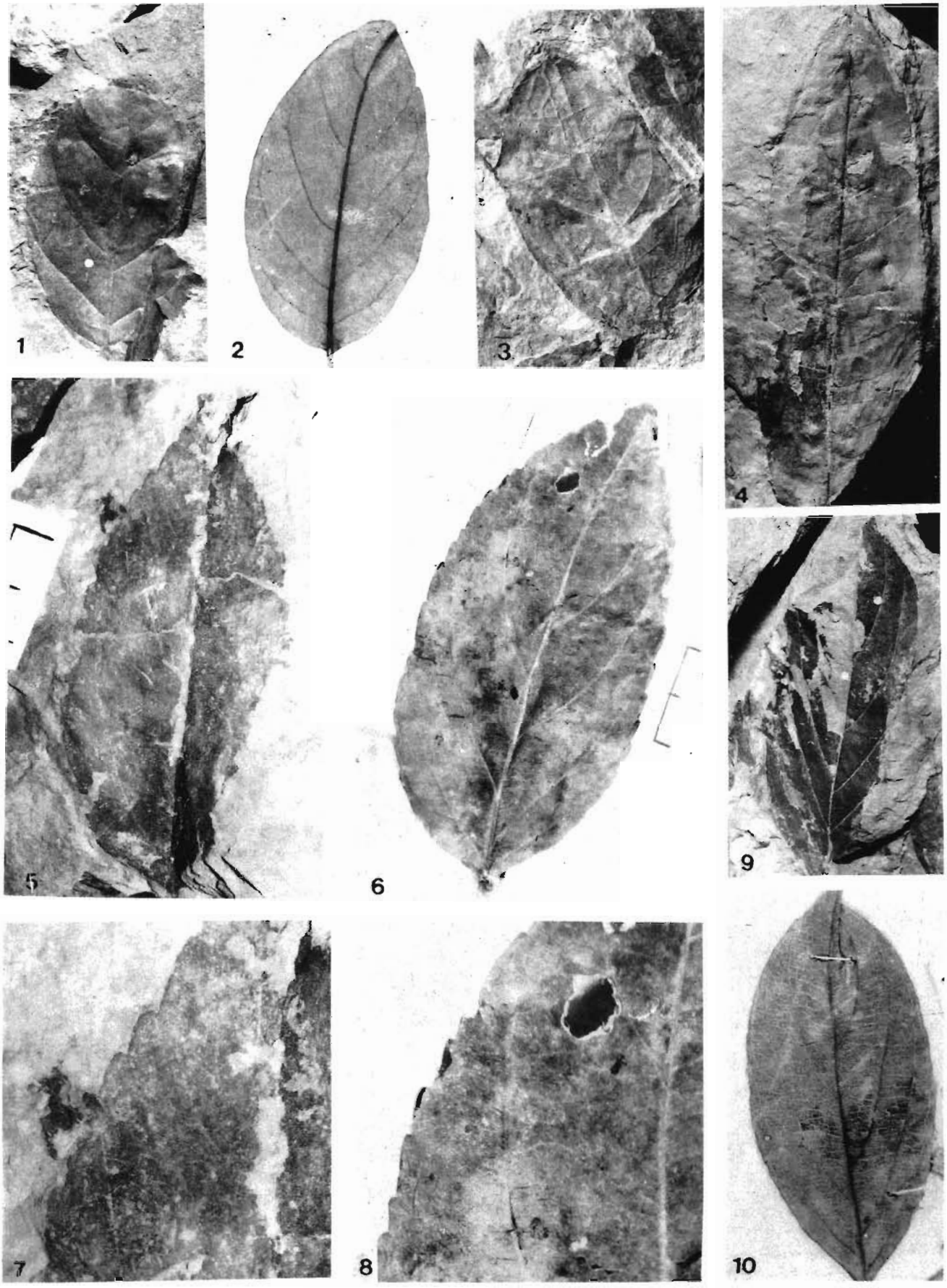


PLATE 1

SYSTEMATIC DESCRIPTION

Family — Anonaceae

Genus—*Mitrephora* (Bl.) Hook.f. & Thoms.

Mitrephora siwalika Antal & Awasthi
Pl. 1, figs 1, 3

Number of specimens—Four.

Description—Leaves simple, symmetrical, elliptic, size 5.5 x 3.0 cm, 5.8 x 3.0 cm, 4.7 x 3.2 cm, 5.0 x 3.0 cm, respectively; apex obtuse; base obtuse; margin entire; texture chartaceous; petiole preserved in one specimen, very small, length 0.2 cm; venation pinnate, eucamptodromous; primary vein prominent, stout, straight to slightly curved towards apex; secondary veins 5-6 pairs, alternate to subopposite, gradually curving up towards margin, unbranched, angle of divergence acute, about 50°-60°; intersecondaries occasionally present, simple; tertiary veins fine, angle of origin RR, percurrent, straight, oblique in relation to midvein.

Holotype—Specimen no. BSIP 37568.

Paratype—Specimen no. BSIP 37569.

Locality—Chor Khola and Wood Seam, Surai Khola area, Nepal.

Horizon & Age—Middle Siwalik; Upper Miocene.

Affinities—The shape, size and venation pattern of the fossil leaves suggest their affinity with the leaves of extant genus *Mitrephora* in general and *M. maingayi* Hook.f. & Thoms of the family Anonaceae in particular (CNH, Howrah, Herbarium sheet no. 13234).

A fossil leaf resembling *Mitrephora maingayi* Hook. f. & Th. is already described as *Mitrephora siwalica* (Antal & Awasthi, 1993) from the Siwalik sediments of West Bengal, India. Except for size variation, our fossil leaves are similar to *Mitrephora siwalica* in their shape and venation pattern. Therefore they are being assigned to the same species.

Mitrephora maingayi Hook. f. & Thoms. is a moderate-sized tree occuring in the evergreen forests of Assam, Chittagong, Myanmar, Malaya, Java and SriLanka (Brandis, 1971; Gamble, 1972).

Genus — *Goniothalamus* Hook.f. & Thoms.

Goniothalamus chorkholaensis sp. nov.
Pl. 1, fig. 4

Number of specimens—Two.

Description—Leaves simple, symmetrical, narrow elliptic, preserved length of one of the specimens 10.0 cm, width 3.3 cm; apex acute; base broken; margin entire; texture chartaceous; petiole missing; venation pinnate, brochidodromous; primary vein prominent, stout, straight; secondary veins 14-16 pairs visible in the preserved part, angle of divergence 60°-80°; secondaries in the basal part arising nearly at right angle, fine, alternate to sub-opposite, running almost straight and then curving up much before reaching the margin and joining superadjacent secondary at an acute angle; intersecondaries present, simple, frequent, mostly 2-3 in between two secondaries; tertiary veins fine, angle of origin AR to RO, random reticulate, branched, oblique in relation to midrib, predominantly alternate; quaternary veins relatively fine randomly oriented.

Holotype—Specimen no. BSIP 37570.

Locality—Chor Khola, Surai Khola area, Nepal.

Horizon & Age—Middle Siwalik; Upper Miocene.

Affinities—The most important character of this fossil leaf is that the venation is brochidodromous having generally 2-3 intersecondary veins in between two secondaries. Considering the shape and size in addition to venation details, the fossil leaf is comparable to those of Myrtaceae, particularly *Syzygium (Eugenia) jambosa, Uvaria lucida* and *Goniothalamus* of Anonaceae. However, the leaves of *Syzygium jambosa* can be differentiated from the fossil in having more acute angle of divergence of secondaries, i.e., about 60° and prominent intramarginal vein. Similarly, the angle of divergence of secondary veins in *Uvaria* is also more acute (65°) and not forming prominent intramarginal loop as observed in the present fossil leaf. There are a number of species of the genus *Goniothalamus* which have leaves very similar to our fossil leaves. Taking into consideration their shape, size and other external features, the fossil leaves resemble those of *Goniothalamus thwaitesii* Hook. f. & Thomas and *G. sesquipedalis* Hook. f. & Thomas. They are placed under a new species,

Goniothalamus chorkholaensis. The specific name is after Chor Khola beds.

Goniothalamus sesquipedalis Hook. f. & Thomas is a small shrub, distributed in the tropical forests of the Sikkim Himalaya, Assam and Myanmar, whereas *G. thwaitesii* Hook. f. & Thomas occurs in the evergreen forests of Travancore and Tirunelveli and in Sri Lanka.

Family—Flacourtiaceae

Genus—*Flacourtia* Comm. ex L' Herit

Flacourtia tertiara sp. nov.
Pl. 1, figs 5, 7

Number of specimen—One.

Description—Leaf simple, symmetrical, elliptic, preserved length and width 9.0 x 3.6 cm; apex seemingly acute; base acute; margin serrate, serration convex from basal as well as apical sides; texture thick chartaceous; petiole not preserved; venation pinnate, simple craspedodromous; primary vein prominent, straight, stout; secondary veins 4 pairs, alternate, curving up towards margin, and the lower secondaries running nearly half distance of leaf before terminating at the margin, angle of divergence acute, about 50°; tertiary veins fine, angle of origin RR, percurrent, branched, almost straight, right angle in relation to midvein, further details not clearly visible.

Holotype—Specimen no. BSIP 37571.

Locality—Chor Khola, Surai Khola area, Nepal.

Horizon & Age—Middle Siwalik; Upper Miocene.

Affinities—In its shape, size and serrate margin the fossil leaf is comparable to those of *Scolopia, Xylosma, Maesa* and *Flacourtia*. However, in the venation pattern, i.e., the number of secondary veins, their course and the angle of divergence the fossil leaf is very similar to *Flacourtia*, especially *F. inermis*. Roxb. of the family Flacourtiaceae (CNH, Howrah, Herbarium Sheet no. 33081).

The genus *Flacourtia* is already known for its fossil leaf, *Flacourtia nepalensis* described by Awasthi and Prasad (1990) from Surai Khola sequence. It differs from the present fossil leaf in its being smaller in size (2.3 x 1.3 cm) and the type of serration. Therefore, it is described as *F. tertiara* sp. nov.

The modern counterpart of the fossil, *Flacourtia inermis* Roxb., an evergreen tree, is native of Malay Archipelago. It is cultivated in India on account of its acid edible fruits (Brandis, 1971).

Genus—*Hydnocarpus* Gaertn.

Hydnocarpus siwalicus sp. nov.
Pl. 2, fig. 3

Number of specimens—Two.

Description—Leaves simple, symmetrical, elliptic, one leaf almost complete, the other without basal portion, size 12.5 x 6.5 cm and 10.0 x 5.0 cm respectively; apex acute; base broken; margin entire; texture coriaceous; petiole missing; venation eucamptodromous; primary vein prominent, stout, almost straight; secondary veins 7 pairs visible, angle of divergence acute, 40°-50°, lower secondaries more acute than the upper, distance between secondaries, 0.5 to 2.4 cm, alternate, lower 2-3 pairs running almost straight and covering almost half of the length of lamina, the remaining upper secondaries uniformly curving upward and terminating at the margin, unbranched; intersecondaries not seen; tertiary veins fine, angle of origin RR, percurrent, generally straight, branched, oblique to right angle in relation to midvein, predominantly alternate and close; higher order of venation not visible.

Holotype—Specimen no. BSIP 37574.

Locality—Wood Seam, Surai Khola area, Nepal.

Horizon & Age—Middle Siwalik; Upper Miocene.

Affinities—The shape, size and venation pattern of fossil leaves clearly show their similarity with that of the extant genus *Hydnocarpus*. The most characteristic feature of the present fossil leaves is that the basal 2-3 pairs of secondary veins run almost straight to the margin. Amongst a number of species of *Hydnocarpus* examined for comparison with the fossil leaves, this feature is observed only in *H. glaucescens* Blume and therefore, it is regarded as the nearest modern counterpart of the fossil leaves (CNH, Howrah, Herbarium Sheet no. 33662). In view of this the leaves are named as *H. palaeoglaucescens* sp. nov.

Fossil leaves resembling *Hydnocarpus kurzii* described as *Hydnocarpus palaeokurzii* are known from the Siwalik sediments of Oodlabari, West Ben-

gal (Antal & Awasthi, 1993) and Kathgodam, Uttar Pradesh (Prasad, 1994). They differ from our fossil leaves in having oblong shape with different nature of secondary veins.

The extant taxon *Hydnocarpus glaucescens* Blume, with which the fossils resemble closely, is distributed in the forest of Sumatra.

Hydnocarpus chorkholaensis sp. nov.
Pl. 1, fig. 9; Pl. 2, fig. 1

Number of specimens—Two.

Description—Leaf simple, seemingly symmetrical, narrow elliptic; size 7.5 x 2.5 cm; apex seemingly acute; base acute; margin entire; texture coriaceous; petiole present, preserved length 0.3 cm; venation pinnate, eucamptodromous; primary vein prominent, stout, straight; secondary veins 6-7 pairs, alternate, angle of divergence about 50°, veins turning upward reaching close to the margin, running parallel to it and covering approximately 3/4 of the lamina; tertiary veins fine, angle of origin RR, percurrent, almost straight to sinuous, right angle in relation to midrib, predominantly alternate, close.

Holotype—Specimen no. BSIP 37572.

Paratype—Specimen no. BSIP 37573.

Locality—Wood Seam, Surai Khola area, Nepal.

Horizon & Age—Middle Siwalik; Upper Miocene.

Affinities—General features of the leaf, such as shape, size and venation pattern suggest its affinities with that of the genus *Hydnocarpus*. Among the various species of this genus, *H. ovoides* Elmer. of Flacourtiaceae (CNH, Howrah, Herbarium Sheet no. 33747) has similar leaves as of the fossils. The leaves of other species can be separated from it in having generally bigger in size and the venation pattern.

Among the fossil leaves, *Hydnocarpus siwalicus* described in preceding pages is bigger in size. Another important difference between the two is that in *H. siwalicus* the basal 2-3 pairs of secondaries run straight towards margin, whereas in *H. chorkholaensis* the basal secondaries curving upward, reaching close to the margin and running parallel to it. Our present fossil leaf is quite different from other known fossil leaves of *Hydnocarpus* in its being smaller in size with distinct venation pattern, the basal secondaries curving up and reaching close to the margin. Therefore, this fossil leaf is placed under a new species, *Hydnocarpus chorkholaensis*, the specific name in after Chor Khola beds.

Hydnocarpus ovoides Elmer. with which fossils show closest resemblance is distributed in the forests of Philippines.

Family—Clusiaceae

Genus—*Garcinia* L.

Garcinia corvinusiana sp. nov.
Pl. 3, figs 3, 5

Number of specimen—One.

Description—Leaf simple, symmetrical, narrow ovate, size 9.0 x 4.0 cm, apex broken; base acute; margin entire; texture thick chartaceous; petiole small, preserved length 1.0 mm; venation pinnate, eucamptodromous; primary vein prominent, stout, straight, slightly curving towards apex and at base just before entering into petiole; secondary veins numerous closely placed, alternate to opposite, about 0.2 cm apart, lower secondary veins more straight than the upper, angle of divergence acute, 55°-60°, basal secondaries straight, upper secondaries slightly curving and running parallel to each other, occasionally branched, intersecondaries present, simple; tertiary veins occasionally seen, angle of origin RR, percurrent, oblique in relation to midvein alternate to opposite and close.

Holotype—Specimen no. BSIP 37575.

PLATE 2

(All figures are of natural size unless otherwise mentioned)

1. *Hydnocarpus chorkholaensis* sp. nov. — Another fossil leaf; Specimen no. BSIP 37573.
2. *Hydnocarpus ovoides* Elmer — Another modern leaf.
3. *Hydnocarpus siwalicus* sp. nov. — Fossil leaf; Specimen no. BSIP 37574.
4. *Hydnocarpus glaucescense* — Modern leaf.
5. *Zanthoxylum siwalicum* sp. nov.— Fossil leaf; Specimen no. BSIP 37577.
6. *Zanthoxylum hamiltonianum* Wall. — Modern leaf.
7. *Murraya khariensis* Lakhanpal & Guleria — Fossil leaf; Specimen no. BSIP 37576.
8. *Murraya paniculata* Linn. (Jacq.) — Modern leaf.

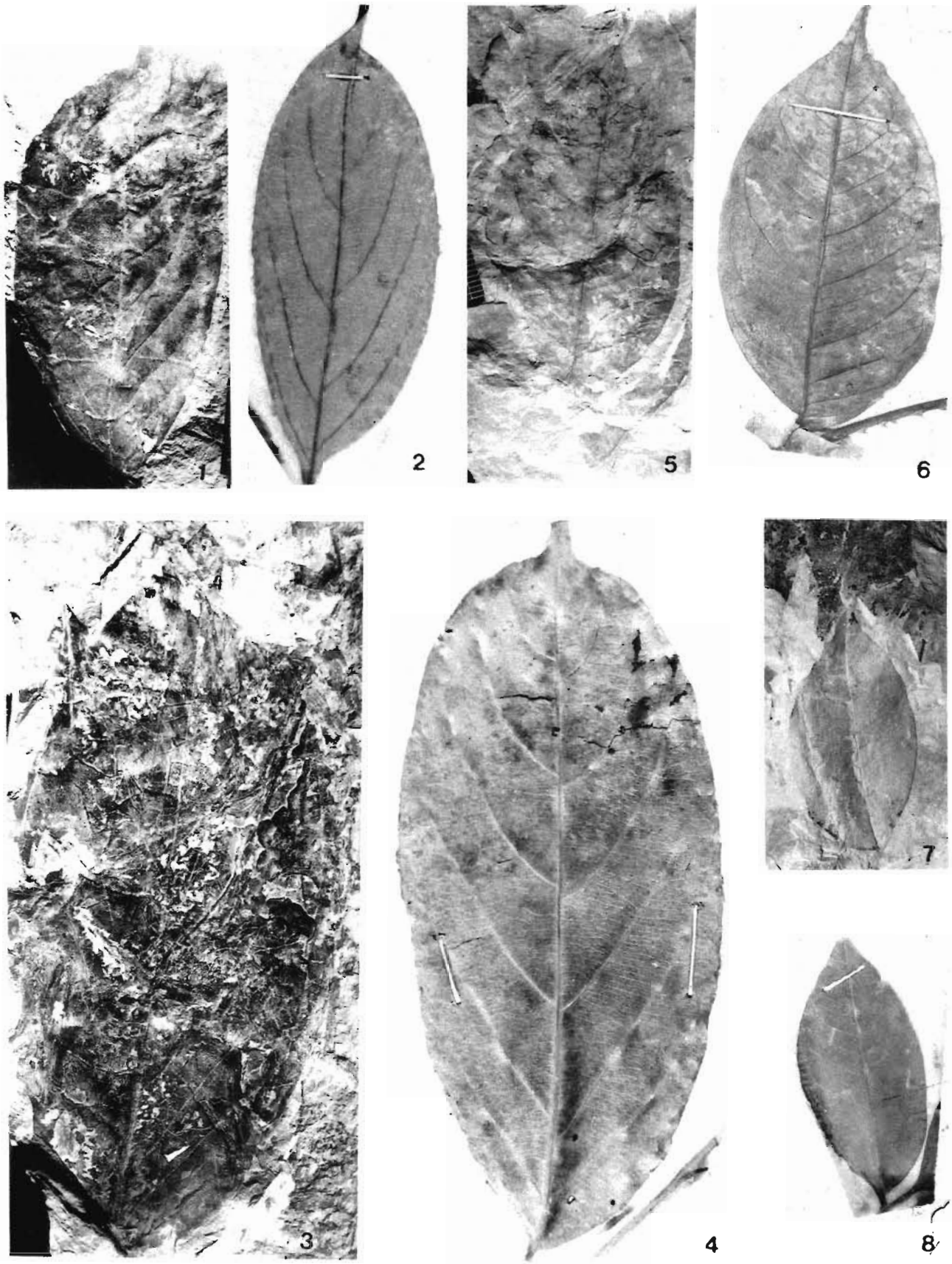


PLATE 2

Locality—River section in front of Chor Khola huts, Surai Khola area, Nepal.

Horizon & Age—Middle Siwalik; Upper Miocene.

Affinities—In its shape and venation pattern the fossil leaf is comparable to that of *Garcinia* of Clusiaceae. Further, considering the size and frequency of secondary veins and their distribution pattern the fossil leaf closely resembles that of *Garcinia speciosa* Wall. of the family Clusiaceae (CNH, Howrah, Herbarium Sheet no. 46210); although it is slightly smaller in size. The fossil leaf is therefore described as a new species, *Garcinia corvinusiana*, the specific name is after Dr G. Corvinus, an Archaeo-Geologist, University of Erlangen, Germany, who, for the first time, discovered plant fossils in the Surai Khola area, Nepal.

There are two species based on leaf fossils assigned to the genus *Garcinia* from the Neogene sediments of India. These are *G. eucambogia* Prasad 1994 from Siwalik sediments of Kathgodam, Uttar Pradesh and *G. kasaulica* Arya & Awasthi 1995 from the Kasauli beds, Himachal Pradesh. Of these, the present fossil differs from *G. eucambogia* in having numerous and closely placed secondary veins. The latter known species which is also comparable to extant *G. speciosa* shows slight difference from the present fossil leaf in the angle of divergence of the secondary veins.

Garcinia speciosa Wall., with which the fossil leaf shows closest similarity, is a tree found in the evergreen forests of Tenasserim and Andman (Brandis, 1971).

Family—Rutaceae

Genus—*Zanthoxylum* L.

Zanthoxylum siwalicum sp. nov.
Pl. 2, fig. 5

Number of specimen—One.

Description—Leaflet simple, slightly asymmetrical, elliptic, size 7.0 x 3.2 cm, apex acute; base nearly obtuse, seemingly inequilateral; margin entire; texture thick chartaceous; petiole broken; venation pinnate, brochidodromous; primary vein prominent, stout, straight; secondary veins 8-9 pairs visible, 0.8-1.3 cm apart, angle of divergence wide acute, 60°-80°, moderately thick, uniformly curving upward, joining superadjacent secondary veins and forming loop, seemingly branched; intersecondaries present, frequent, simple; tertiary veins poorly preserved, seemingly percurrent, angle of origin usually RR, rarely AO, oblique in relation to midvein, predominantly alternate and close.

Holotype—Specimen no. BSIP 37577.

Locality—Chor Khola, Surai Khola area, Nepal.

Horizon & Age—Middle Siwalik; Upper Miocene.

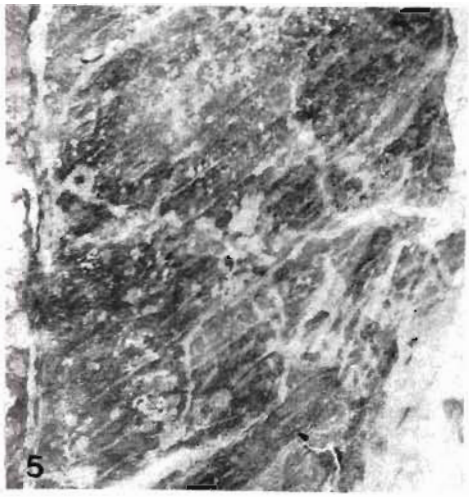
Affinities—In its shape, size and venation pattern the fossil leaf appears very similar to that of *Zanthoxylum hamiltonianum* Wall. of the family Rutaceae (CNH, Howrah, Herbarium sheet no. 74197).

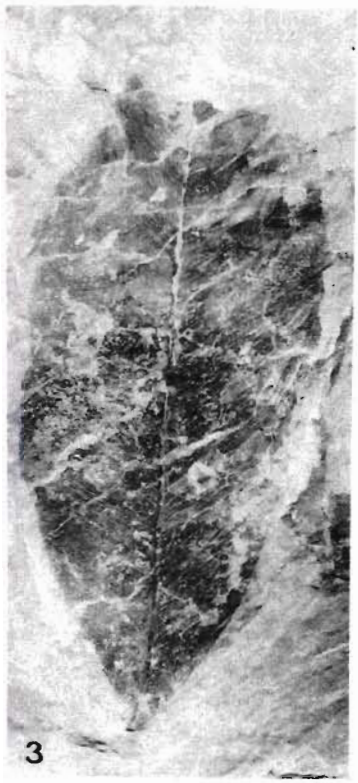
Several fossil leaves resembling the genus *Zanthoxylum* have been recorded from the Tertiary sediments of Europe, Japan, France, West Germany, N. America, USSR and USA (Arenes & Depape, 1956; Depape, 1920; Weyland, 1934; Heer, 1859; Tanai, 1920; Knowlton, 1917; Berry, 1916; LaMotte, 1950;

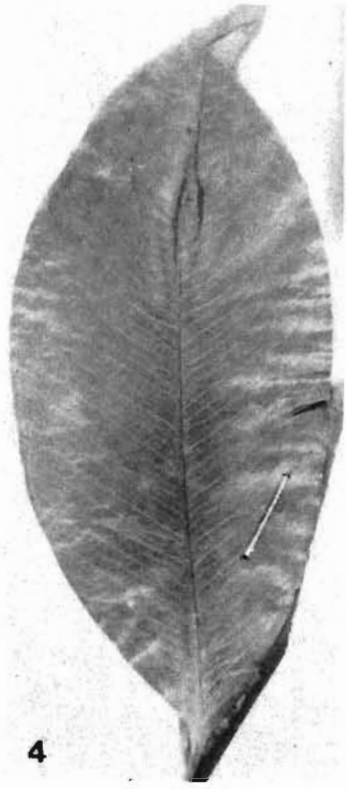
PLATE 3

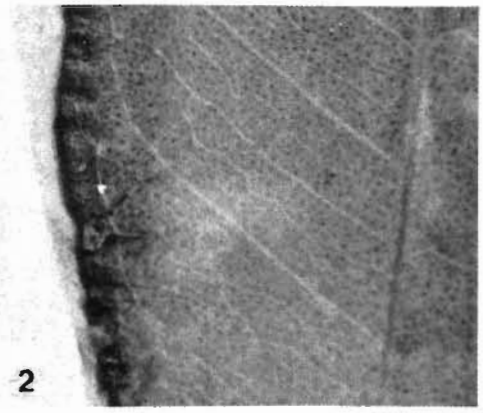
(All figures are of natural size unless otherwise mentioned)

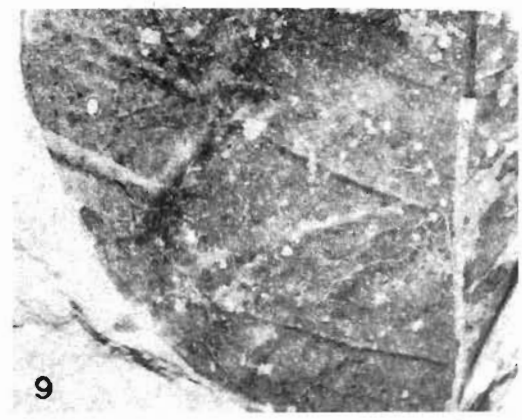
1. *Murraya khariensis* Lakhanpal & Guleria — A part of fossil leaf magnified to show details of venation X 4.
2. *Murraya paniculata* Linn. (Jacq.) — A part of fossil leaf magnified to show details of venation x 4.
3. *Garcinia corvinusiana* sp. nov. — Fossil leaf; Specimen no. BSIP 37575.
4. *Garcinia speciosa* Wall. — Modern leaf.
5. *Garcinia corvinusiana* sp. nov. — A part of fossil leaf magnified to show details of venation X 2.5.
6. *Garcinia speciosa* Wall — A part of fossil leaf magnified to show details of venation X 2.5.
7. *Chukrasia miocenica* Prasad — Fossil leaf; Specimen no. BSIP 37581.
8. *Chukrasia tabularis* Adr. Juss. — Modern leaf.
9. *Chukrasia miocenica* Prasad — A part of fossil leaf magnified to show details of venation X 2.7.
10. *Chukrasia tabularis* Adr. Juss. — A part of modern leaf magnified to show similar details of venation X 2.7.

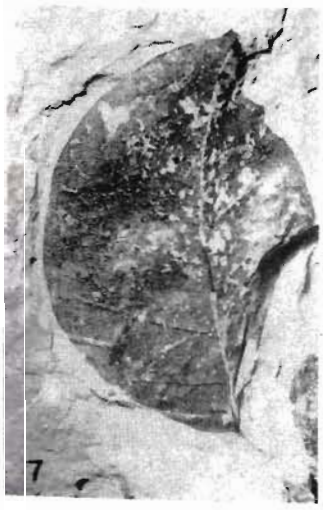












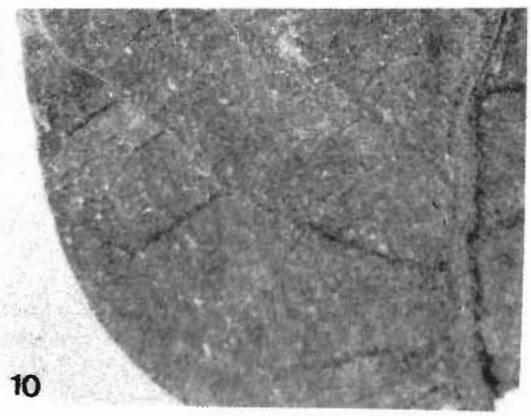


PLATE 3

Salomon- Calvi, 1934). The present fossil leaf has been compared with all the available known fossils and it is found that our fossil leaf is entirely different from them. Hence, it has been assigned to a new species, *Zanthoxylum siwalicum.*

The modern comparable taxon *Z. hamiltonianum* Wall. is a large scrambling shrub distributed in Sikkim, Assam and Upper Myanmar (Brandis, 1971).

Genus—*Murraya* Koen. ex L.

Murraya khariensis Lakhanpal & Guleria
Pl. 2, fig. 7

Number of specimens—Two.

Description—Leaflets asymmetrical, elliptic, size 4.50 x 2.4 cm and 6.00 x 3.00 cm; apex acute; base inequilateral, nearly obtuse; margin entire; texture chartaceous; petiole rudimentary; venation pinnate, eucamptodromous to brochidodromous; primary vein prominent, moderately thick, almost straight; secondary veins 7-8 pairs visible. 0.2-1 cm apart, angle of divergence acute, about 60°, uniformly curving upward and joining superadjacent secondary veins; intersecondary veins simple, frequent; tertiary veins poorly preserved, forming orthogonal to polygonal meshes, oblique in relation to midrib, predominantly alternate and close.

Holotype—Specimen no. BSIP 37576.

Locality—Wood Seam, Surai Khola area, Nepal.

Horizon & Age—Middle Siwalik; Upper Miocene.

Affinities—The fossil leaflets display all the characters of *Murraya paniculata* and are similar to those assigned to *Murraya khariensis* Lakhanpal & Guleria 1982 reported from the Lower Miocene of Kutch, Gujarat, and Siwalik sediments of Koilabas, Nepal (Prasad, 1994b).

Murraya paniculata (Linn.) Jacq. is a large shrub or small evergreen tree occuring from Ravi eastward to Assam in the Lower and Upper Satpura ranges, Hills of peninsula, Andaman, Sri Lanka and Myanmar. It also occurs in China, Australia and Pacific Islands (Brandis, 1971).

Family—Meliaceae

Genus—*Dysoxylum* Blume

Dysoxylum raptiensis sp. nov.
Pl. 4, figs 1, 3; Pl. 5, fig. 1

Number of specimens—Four.

Description—Leaflets simple, symmetrical to asymmetrical due to inequilateral base; narrow elliptic, size 15.4 x 4.5 cm, 14.1 x 4.3 cm, 12.5 x 3.5 cm and 9.7 x 3.4 cm respectively; apex acute; base acute, oblique (inequilateral); margin entire; texture coriaceous; petiole small, 0.3 cm; venation pinnate, eucamptodromous; primary vein prominent, stout, curved; secondary veins 10-11 pairs, 0.8-1.7 cm apart, angle of divergence 55°-75°, decreasing towards apex, alternate, uniformly curving up towards margin, unbranched, intersecondaries present, simple; tertiary veins fine, angle of origin RR, percurrent, straight to sinuous, branched, oblique in relation to midrib, close; quaternary veins thin, forming orthogonal meshes.

Holotype—Specimen no. BSIP 37578.

Paratype—Specimen nos BSIP 37579 and 37580.

Locality—Wood Seam, Surai Khola area, Nepal.

Horizon & Age—Middle Siwalik;Upper Miocene.

Affinities—In their shape, size, angle of divergence of secondary veins and venation pattern the fossil leaflets are closely comparable to that of *Dysoxylum procerum* Hiern of the family Meliaceae (CNH, Howrah, Herbarium Sheet no. 276).

A fossil leaf resembling that of *Dysoxylum* is known from the Siwalik sediments of Kathgodam, Uttar Pradesh as *D. mioklandri* (Prasad, 1994c). This

PLATE 4

(All figures are of natural size unless otherwise mentioned)

1. *Dysoxylum raptiensis* sp. nov. — Fossil leaf; Specimen no. BSIP 37578.
2. *Dysoxylum procerum* Hiern — Modern leaf.
3. *Dysoxylum raptiensis* sp. nov. — Another fossil leaf showing variation in shape and size; Specimen no. BSIP 37579.
4. *Harpullia siwalica* sp. nov. — Fossil leaf; Specimen no. BSIP 37582.
5. *Harpullia cupinoides* Roxb. — Modern leaf.
6. *Harpullia siwalica* sp. nov. — A part of fossil leaf magnified to show details of venation X 4.

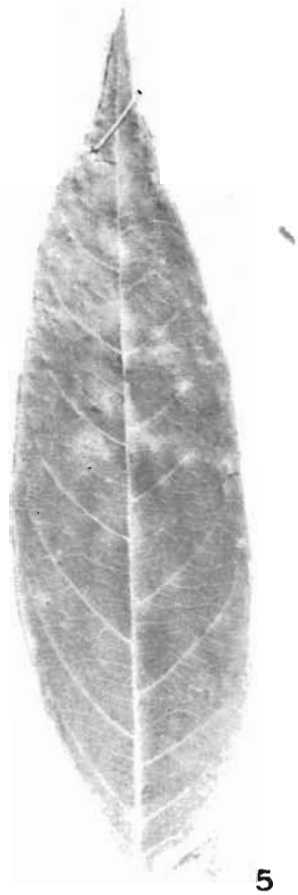


PLATE 4

fossil leaf differs from present fossil in its being smaller in size and wide elliptic shape. Hence, they are placed under a new species *Dysoxylum raptiensis*. The specific name is after Rapti Anchal, Nepal.

Dysoxylum procerum Hiern, the modern counterpart of the fossil, is an evergreen tree occuring in Sikkim, Assam, Khasi Hills and Cachar to Pegu and Tenasserim, Myanmar (Brandis, 1971).

Genus—*Chukrasia* A. Juss.

Chukrasia miocenica Prasad
Pl. 3, figs 7, 9

Number of specimen—One.

Description—Leaflet asymmetrical, wide elliptic, size 5.3 x 3.5 cm; apex seemingly acuminate to acute; base obtuse, inequilateral; margin entire; texture chartaceous; petiole present, about 0.6 cm in length; venation pinnate, eucamptodromous; primary vein prominent, slightly curved, moderate; secondary veins 8-9 pairs visible, 0.4-1.0 cm apart, uniformly curved; angle of divergence wide acute (60^{o}-85^{o}), secondary veins of one side more acute than the other side in the basal part, branched, curving up towards margin; intersecondary veins present, simple; tertiary veins fine, with angle of origin usually RR, rarely AO, percurrent, sinuous, sometimes branched, oblique in relation to midrib, sometimes right angle near the margin, predominantly alternate and close.

Holotype—Specimen no. BSIP 37581.

Locality—Wood Seam, Surai Khola area, Nepal.

Horizon & Age—Middle Siwalik; Upper Miocene.

Affinities—The leaf is characterised by wide elliptic shape, inequilateral base and secondary veins more acute on one side in the basal part of the leaf. In all characters it shows close similarity with the leaflets of *Chukrasia tabularis* A. Juss. of Meliaceae (CNH, Howrah, Herbarium Sheet no. 81853) .

A fossil leaflet showing close affinity with extant *Chukrasia tabularis* has already been described from the Siwalik sediments of Kathgodam, North India as *Chukrasia miocenica* (Prasad, 1994c). In possessing almost similar morphological features the present fossil has been placed under the same species.

Chukrasia tabularis A. Juss. is a large tree growing in the forest of Sikkim Himalaya, Assam, Bengal, Chittagong, Sri Lanka, Myanmar and Andman Islands (Gamble, 1972).

Family—Sapindaceae

Genus—*Harpullia* Roxb.

Harpullia siwalica sp. nov.
Pl. 4, figs 4, 6

Number of specimen—One.

Description—Leaflet simple, symmetrical, narrow elliptic, size 9.3 x 3.0 cm; apex broken; base acute, inequilateral; margin entire; texture thick, chartaceous; petiole not preserved; venation pinnate, eucampto-dromous; primary vein prominent, stout, straight; secondary veins 9 pairs visible, 0.4-1.5 cm apart, alternate, angle of divergence acute, 50^{o}-55^{o}, uniformly curving up and running parallel to the margin to a considerable distance, unbranched; intersecondary veins present, simple; tertiary veins fine, angle of origin AR-RO, percurrent, straight to sinuous, branched, oblique in relation to midvein, predominantly alternate and close.

Holotype—Specimen no. BSIP 37582.

Locality—Chor Khola, Surai Khola area, Nepal.

Horizon & Age—Middle Siwalik; Upper Miocene.

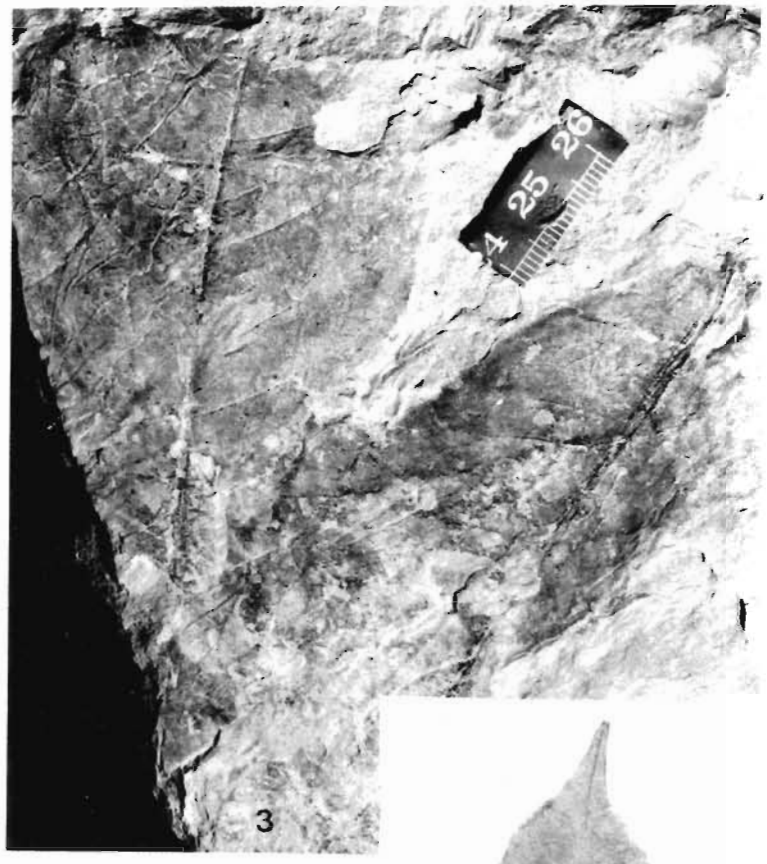
Affinities—A combination of the characters exhibited by the fossil leaf is met with in the leaves of the genus *Harpullia* of Sapindaceae. In its shape, size and details of venation the fossil leaf resembles closely that of *Harpullia cupinoides* Roxb. of the family Sapindaceae (CNH, Howrah, Herbarium sheet no. 1373).

So far there is no record of fossil leaves resembling the genus *Harpullia* from the Tertiary of India

PLATE 5

(All figures are of natural size unless otherwise mentioned)

1. *Dysoxylum raptiensis* sp. nov. — Another fossil leaf showing variation in shape and size; Specimen no. BSIP 37580.
2. *Dysoxylum procerum* Hiern — Another modern leaf showing similarity with fig. 1.
3. *Bouea koilabasensis* Prasad — Fossil leaf; Specimen no. BSIP 37583.
4. *Bouea burmanica* Griff. — Modern leaf.
5. *Bouea koilabasensis* Prasad — A part of fossil leaf magnified to show details of venation X 2.4.



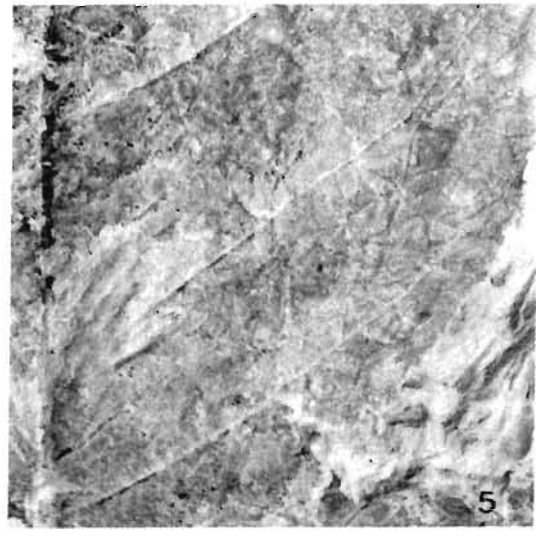


PLATE 5

and abroad. Hence, the present fossil leaf has been assigned to a new species, *Harpullia siwalica.*

Harpullia cupinoides Roxb. is a tall tree, common in the evergreen forests of Western Ghats from Konkan southwards, Chittagong and Andmans (Brandis, 1971).

Family—Anacardiaceae

Genus—*Bouea* Meissn.

Bouea koilabasensis Prasad
Pl. 5, figs 3, 5

Number of specimens—Two.

Description—Leaves simple, symmetrical, apical part missing, narrow elliptic, size of available parts 13.5 x 6.7 cm and 11.5 x 6.7 cm respectively; apex missing; base obtuse; margin entire to undulated; texture chartaceous; primary vein prominent, stout, almost straight; secondary veins about 13 pairs in the available part, 0.8 - 1.8 cm apart, alternate, curving up towards margin, seemingly unbranched, angle of divergence 60^{o}-80^{o}, basal secondary veins wide acute; intersecondaries present, simple; tertiary veins fine, angle of origin usually RR, percurrent, sometimes branched, oblique in relation to midvein, veins while near the margin at right angle, predominantly alternate and close.

Holotype—Specimen no. BSIP 37583.

Locality—Kaila Khola, Surai Khola area, Nepal.

Horizon & Age—Middle Siwalik; Upper Miocene.

Affinities—The leaves possess elliptic shape, eucamptodromous venation and wide acute secondary veins at the basal part which are characteristic of the family Anacardiaceae. Among the genera of this family, the above features of the fossil leaves indicate close resemblance with those of *Bouea burmanica* Griff. of the family Anacardiaceae (CNH, Howrah, Herbarium Sheet no. 99008).

A fossil leaf resembling *Bouea burmanica* is already known from the Siwalik sediments of Koilabas, western Nepal as *Bouea koilabasensis* (Prasad, 1994b). Although, this fossil is smaller in size than the present fossils, the venation pattern in both is so similar that they cannot be separated from one another. Keeping in view the venation pattern, shape and size of the modern leaves of *Bouea burmanica*, the present fossil is placed under the *B. koilabasensis* Prasad. There is another record of fossil leaf resembling the genus *Bouea* from the Siwalik sediments near Oodlabari, West Bengal (Antal & Awasthi, 1994), which, however, differs from present fossil in the nature of secondary veins.

Bouea burmanica Griff. is an evergreen, middle sized tree growing in Sunderban, Andman, Tennasserim, China and Malaya (Brandis, 1971).

Genus—*Swintonia* Griff.

Swintonia palaeoschwenckii sp. nov.
Pl. 6, figs 1, 3

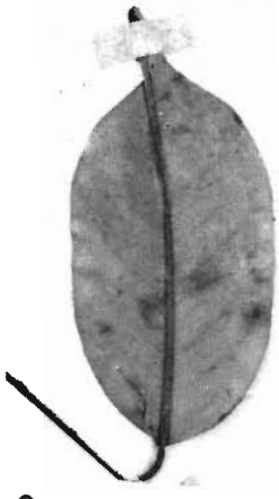
Number of specimen—One.

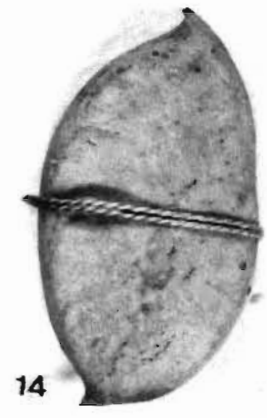
Description—Leaf simple, symmetrical, narrow elliptic; size 7.0 x 3.2 cm; apex broken; base obtuse; margin entire; texture chartaceous; petiole present, 0.5 cm in length; venation pinnate, eucamptodromous, primary vein prominent, stout, straight; secondary veins 10 pairs visible, 0.5-0.8 cm apart, alternate to subopposite, gradually curving up

PLATE 6 ⟶

(All figures are of natural size unless otherwise mentioned)

1. *Swintonia palaeoschwenckii* sp. nov. — Fossil leaf; Specimen no. BSIP 37584.
2. *Swintonia schwenckii* Teysm. & Binnend — Modern leaf.
3. *Swintonia palaoschwenckii* sp. nov. — A part of fossil leaf magnified to show details of venation X 4.
4. *Millettia churiensis* sp. nov. —Fossil leaf; Specimen no. BSIP 37585.
5. *Millettia prainii* Dunn. — Modern leaf.
6. *Pterocarpus dalbergiocarpoides* sp. nov. — Fossil fruit; Specimen no. BSIP 37586.
7. *Pterocarpus dalbergioides* Roxb. — Modern fruit.
8. *Koompassia suraikholaensis* sp. nov. — Fossil leaf; Specimen no. BSIP 37587
9. *Koompassia malaccensis* — Modern leaf.
10. *Koompassia suraikholaensis* sp. nov. — Another fossil leaf; Specimen no. BSIP 37588.
11. *Koompassia suraikholaensis* sp. nov. — A part of fossil leaf magnified to show details of venation X 4.
12. *Koompassia malaccensis* — A part of fossil leaf magnified to show details of venation X 4.
13. *Pongamia kathgodamensis* Prasad — Fossil fruit; specimen no. BSIP 37589.
14. *Pongamia pinnata* Vent. — Modern leaf.





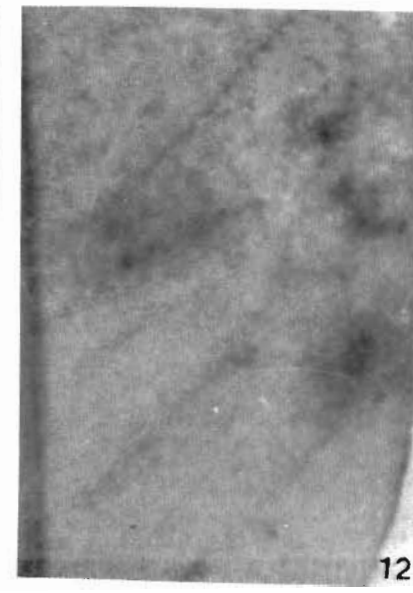


PLATE 6

towards margin, sometimes branched, angle of divergence 50°-75°, basal secondaries with greater angle; intersecondaries present, simple, tertiary veins fine, angle of origin mostly RR, rarely AO, percurrent, branched, oblique in relation to midrib, predominantly alternate, close.

Holotype—Specimen no. BSIP 37584.

Locality—Kaila Khola, Surai Khola area, Nepal.

Horizon & Age—Middle Siwalik; Upper Miocene.

Affinities—In its shape, size and venation pattern the fossil leaf is closely comparable to that of *Swintonia schwenckii* Teysm. & Bennend. of the family Anacardiaceae (CNH, Howrah, Herbarium sheet no. 37034).

The fossil leaves showing close resemblance with that of the genus *Swintonia* are already known under *S. miocenica* Awasthi & Prasad from the Siwalik sediments of Surai Khola, western Nepal and Oodlabari, West Bengal (Awasthi & Prasad, 1990; Antal & Prasad, 1996). The present fossil differs from *Swintonia miocenica* Awasthi & Prasad in possessing obtuse base instead of acute base in the known fossil species. It further differs in the orientation of secondary veins and in having a few intersecondaries. In view of this the present fossil leaf is assigned to a new species—*Swintonia palaeoschwenkii.*

Swintonia schwenkii Teysm. & Binnend. is a tall tree distributed in the tropical forest of Chittagong and Myanmar all along the rivers (Gamble, 1972).

Family—Fabaceae

Genus—*Millettia* Wight & Arn.

Millettia churiensis sp. nov.
Pl. 6, fig. 4

Number of specimen—One.

Description—Leaf simple, symmetrical, lanceolate, size 4.2 x 1.2 cm; apex acuminate; base obtuse; margin entire; texture chartaceous; petiole present, rudimentary; venation pinnate, eucamptodromous; primary vein prominent, stout, straight; secondary veins 8-9 pairs, 0.3-0.9 cm apart, angle of divergence wide acute, about 70°, moderate in thickness, usually opposite, curving abruptly towards margin, unbranched; intersecondaries present, simple; tertiary veins fine; angle of origin RR, percurrent, almost straight, branched, oblique in relation to midrib, alternate to opposite, close.

Holotype—Specimen no. BSIP 37585.

Locality—Bankas, Surai Khola area, Nepal.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinities—In shape, size and venation pattern the present fossil shows close resemblance with the leaves of *Millettia prainii* Dunn. of the family Fabaceae.

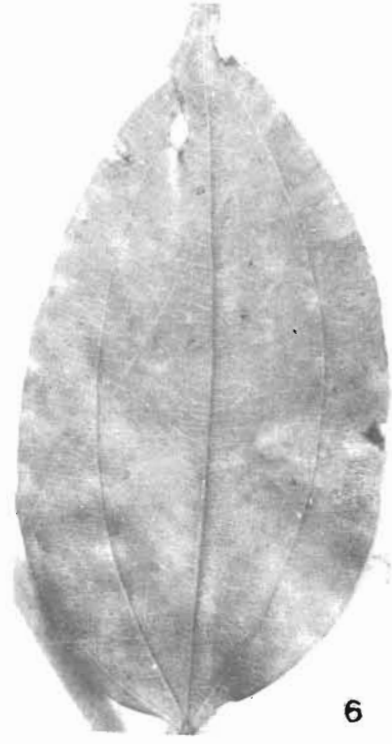
Based on fossil leaflets, eleven species of *Millettia* Wight & Arn. are known so far from all over the world (Prasad, 1994a). Of these, *Millettia koilabasensis* Prasad and *M. siwalica* Prasad are known from the Siwalik sediments of Koilabas, *M. palaeoracemosa* Awasthi & Prasad from Siwalik sediments of Surai Khola, western Nepal (Prasad 1990a, 1990b; Awasthi & Prasad, 1990) and *M. oodlabariensis* Antal & Prasad 1996 from Siwalik sediments of Darjeeling District, West Bengal. A comparison of the present fossil with above already known fossil leaflets reveals that it is quite different from them in size and venation pattern. Hence, it is described as *Millettia churiensis* sp. nov.

Millettia prainii Dunn. occurs in Assam along the right bank of Monos River and Tura Dalu Road in Garo Hills.

PLATE 7 →

(All figures are of natural size unless otherwise mentioned)

1,2. *Albizia microfolia* sp. nov. — Fossil leaves; Specimen nos. BSIP 37590 and 37591.
3. *Albizia siwalica Prasad* — Fossil leaf; Specimen no. BSIP 37592.
4. *Albizia gamblii* — Modern leaf.
5. *Anisophyllea siwalica* sp. nov. — Fossil leaf; Specimen no. BSIP 37593.
6. *Anisophyllea apetala* — Modern leaf.
7. *Anisophyllea siwalica* sp. nov. — A part of fossil leaf magnified to show details of venation X 2.5.
8. *Anisophyllea apetala* — A part of modern leaf magnified to show details of venation X 2.5.
9. *Syzygium palaeocuminii* sp. nov. — Fossil leaf; Specimen no. BSIP 37594.
10. *Syzygium cuminii* — Modern leaf.
11, 12. *Syzygiumpalaeocuminii* sp. nov. — Another fossil leaf; Specimen no. BSIP 37595.



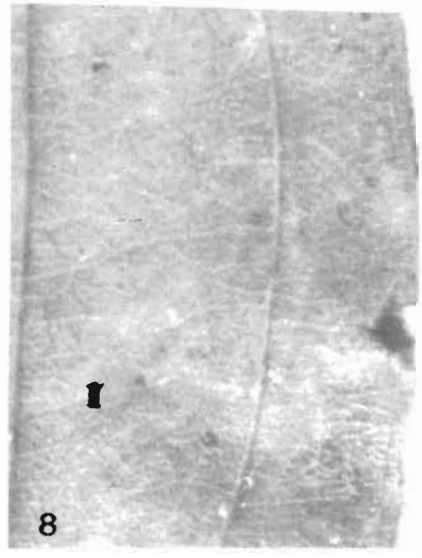


PLATE 7

Genus—*Pterocarpus* Jacq.

Pterocarpus dalbergiocarpoides sp. nov.
Pl. 6, fig. 6

Number of specimen—One.

Description—Fruit single; rounded or orbicular in outline, flat, wall apparently not thickened over the seed, width of entire fruit 2.5 cm, seed locule placed approximately in the centre, 1 or 2 (not definitely ascertainable), seemingly one seeded, radial venation seen in the periphery of fruit body.

Holotype—Specimen no. BSIP 37586.

Locality—Chor Khola, Surai Khola area, Nepal.

Horizon & Age—Middle Siwalik; Upper Miocene.

Affinities—In over all features the present fossil fruit shows close similarity with those of *Pterocarpus dalbergioides* Roxb. of the family Fabaceae (CNH, Howrah, Herbarium Sheet no. 6376).

Fossil fruits resembling *Pterocarpus* are known as *P. tertiarus* Weyland, described from the Tertiary of North Finland, Germany, Rott, at Bonn, N.W. Bohemia and Czechoslovakia (Buzek, 1992). There is a clear distinction between round wing and the pericarp of the fruit body of *P. tertiarus* Weyland. Further, the fruits possess distinct intra-marginal veins formed by the radial venation of pericarp, an important feature which is not seen in our fossil fruit. Because of its close resemblance with the fruits of *Pterocarpus dalbergioides*, the present fossil fruit is named as *P. dalbergiocarpoides* sp. nov.

Pterocarpus dalbergiodes Roxb. is a large tree found in the evergreen forest of Andmans (Brandis, 1971).

Genus—*Koompassia* Maingay

Koompassia suraikholaensis sp. nov.
Pl. 6, figs 8, 10, 11

Number of specimen—Two.

Description—Leaf symmetrical, elliptic, size 4.5 x 2.5 cm; apex broken; base seemingly obtuse; margin entire; texture chartaceous; petiole not preserved; venation 'pinnate, eucamptodromous; primary vein prominent, stout, slightly curved; secondary veins 7-8 pairs visible, 0.4-1.0 cm apart, alternate, angle of divergence acute, about 60°, moderate, uniformly curving up, rarely branched; intersecondary veins present, simple, frequent, atleast 2-3 in between two secondary veins; tertiary veins fine, angle of origin usually AO, almost percurrent, branched, oblique in relation to midrib, predominantly alternate and close.

Holotype—Specimen no. BSIP 37587.

Paratype—Specimen no. BSIP 37588.

Locality—Bankas, Surai Khola area, Nepal.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinities—In its shape, size and venation pattern the fossil leaf appears very similar to that of *Koompassia malaccens* Maing. ex Benth. of the family Fabaceae (CNH, Howrah, Herbarium Sheet no. 136625).

So far there is no record of fossil leaflet resembling the genus *Koompassia* both from India and abroad. Thus it forms the first record from the Siwalik sediments of Surai Khola, Nepal and a new species, *Koompassia suraikholaensis* has been assigned to it. The specific name is after Surai Khola area.

The extant taxon *Koompassia malaccens* Maing. ex Benth. is a large tree found in the forest of Malacca, Sumatra and Malaya (Ridley, 1967).

Genus—*Pongamia* Vent.

Pongamia kathgodamensis Prasad
Pl. 6, fig. 13

Number of specimen—One.

Description—Fruit single, more or less fulcate, one seeded, size 5 x 3.4 cm; ends decurved, striation on the pod not visible.

Figured specimen—Specimen no. BSIP 37589.

Locality—Kaila Khola, Surai Khola area, Nepal.

Horizon & Age—Middle Siwalik; Upper Miocene.

Affinities—In being single seeded, fulcate in shape and decurved ends it appears very similar to the fruits of the extant species *Pongamia pinnata* Vent. of the family Fabaceae.

A fossil fruit resembling *Pongamia pinnata* has already been reported as *Pongamia kathgodamensis* Prasad from the Siwalik beds of Kathgodam (Prasad, 1994c). The present fossil fruit is almost similar to *Pongamia kathgodamensis* except in size which is

comparatively bigger. Hence, it is placed under the same species.

Pongamia pinnata Vent. is a moderate-sized evergreen tree occuring in the tidal and beach forests and along river banks and water course throughout the country. It is also common in Sri Lanka and Myanmar (Gamble, 1972).

Genus—*Albizia* Durraz.

Albizia microfolia sp. nov.
Pl. 7, figs 1, 2

Number of specimen—One with counterpart.

Description—Leaf compound, preserved part consists of eight pairs of leaflets, leaflets small, 2.5 cm in length, each leaflet about 1.0 cm in length and 0.15 cm in width, opposite, narrow oblong, apex obtuse; base obliquely obtuse; margin entire; texture charteaceous; petiolule not discernible; venation pattern not clearly seen.

Holotype—Specimen no. BSIP 37590.

Paratype—Specimen no. BSIP 37591.

Locality—Bankas, Surai Khola area, Nepal.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinities—The leaf is compound with small leaflet arranged oppositely. Such type of compound leaves are produced by a number of taxa, e.g., *Parkia roxburghii, Prosopis spicigera, Cassia pumila, C. mimosoideae, Dalbergia polyphylla, Pterolobium congustum, Delonix regia, Albizia lebbekoides, A. amoora,* and *A. julibrissin* of Fabaceae and an other taxon *Emblica officinalis* of Euphorbiaceae.

However, from a critical examination of the Herbarium sheets of above extant taxa reveals close similarity with the present fossil leaflets and those of *Albizia julibrissin* Durraz. of Fabaceae.

Four fossil leaflets comparable to *Albizia lebbek* Benth. are known from different localities of the Siwalik of India and Nepal (Prasad, 1990a, 1994a, 1994b; Antal & Awasthi, 1994). These fossil leaflets are quite different from our present fossils in their bigger size, therefore, they are being assigned to a new species, *Albizia microfolia.*

The extant taxon *Albizia julibrissin* Durraz. is a large shrub or middle-sized deciduous tree occuring all along outer Himalaya, Hazara to Sikkim, Assam and Manipur (Brandis, 1971).

Albizia siwalica Prasad
Pl. 7, fig. 3

Number of specimen—One.

Description—Leaflet asymmetrical, wide obovate; size 5.0 x 3.5 cm; apex rounded; base obtuse, inequilateral; margin entire, texture charteaceous; petiole missing; venation pinnate, eucamptodromous to brochidodromous; primary vein prominent; moderate, almost straight; secondary veins 6 pairs visible, 0.5 to 1.2 cm apart, alternate, angle of divergence narrow acute, 45°-60°, secondaries on one side of the midrib more acute, uniformly curving upwards, seemingly unbranched; intersecondary veins present, simple; tertiary veins fine, angle of origin RR, percurrent, straight to sinuous, sometimes branched, oblique in relation to midvein, predominantly alternate and close.

Figured specimen—Specimen no. BSIP 37592.

Locality—Wood Seam, Surai Khola area, Nepal.

Horizon & Age—Middle Siwalik; Upper Miocene.

Affinities—In all characters this fossil leaflet is closely comparable to *Albizia gamblii.* Among the known fossil leaves, a similar leaflet is already recorded as *Albizia siwalica* by Prasad (1990b) from the Lower Siwalik sediments of Koilabas, Nepal. Since the present fossil leaflet shows hardly any difference from *Albizia siwalica*, it is placed under the same species.

The comparable taxa *Albizia gamblei* Prain (syn. *A. lebbek* Gamble) is a deciduous tree attaining about 16 meter height and grows in the hills of Myanmar (Brandis, 1971; Gamble, 1972).

Family—Anisophylleaceae

Genus—*Anisophyllea* R. Br.

Anisophyllea siwalica sp. nov.
Pl. 7, figs 5, 7

Number of specimens—Two.

Description—Leaves simple, symmetrical, one specimen almost complete, elliptic, size 11.0 x 5.00 cm, the other 5.3 x 3.5 cm in length and width; apex broken; base wide acute, slightly inequilateral due to curving of margin at the base; margin entire; texture

coriaceous; venation acrodromous, basal, perfect; primary veins three, one midvein and two lateral, one on each side of midveins prominent, stout, unbranched, midvein straight, lateral primary veins slightly curving upward running towards apex, besides two intramarginal veins one on each side arising from the base and running to the whole length of leaf; secondary veins numerous, arising from primary veins, angle of divergence usually right angle, branched; tertiary veins fine, arising at nearly RR, percurrent, branched forming polygonal meshes.

Holotype—Specimen no. BSIP 37593.

Locality—Wood Seam, Surai Khola area, Nepal.

Horizon & Age—Middle Siwalik; Upper Miocene.

Affinities—The leaves are characterised by three primary veins and two marginal veins arising from the base and running throughout the length of leaf. In these features they are closely comparable to the leaves of *Anisophyllea apetala* Scort. of the family Anisophy-lleaceae (CNH, Howrah, Herbarium Sheet no. 162903).

As far as the authors are aware there is no record of fossil leaves of the genus *Anisophyllea* Br. from India and abroad. Hence, the fossil leaves are assigned to a new species, *Anisophyllea siwalica*. The specific name stands after the Siwalik Group.

Anisophyllea apetala Scort. with which the fossil leaf shows closest affinity is an evergreen tree found to grow in the Malayan regions (Ridley, 1967).

Family—Myrtaceae

Genus—*Syzygium* Gaertn.

Syzygium palaeocumini sp. nov.
Pl. 7, figs 9, 11, 12; Pl. 8, fig. 1

Number of specimens—Three.

Description—Leaves simple, symmetrical, narrow elliptic to elliptic; size 7.5 x 3.4, 4.6 x 2.5, 6.7 x 4.6 cm; apex acute; base acute; margin entire; texture chartaceous; petiole 0.7 cm; venation pinnate; eucamptodromous; primary vein prominent, straight, stout, secondary veins seemingly more than 20 pairs, sometimes not easily distinguishable from intersecondary veins, alternate to opposite, branched, angle of divergence widely acute, 60°-80°, basal secondaries arising at nearly right angle; secondary veins joining superadjacent veins forming intra-marginal vein; intersecondary veins numerous, simple to composite, branched; tertiary veins fine, angle of origin AO, exmedially ramified, oblique in relation to midrib, close.

Holotype—Specimen no. BSIP 37594.

Paratype—Specimen nos BSIP 37595 and 37596.

Locality—Chor Khola, Surai Khola area, Nepal.

Horizon & Age—Middle Siwalik; Upper Miocene.

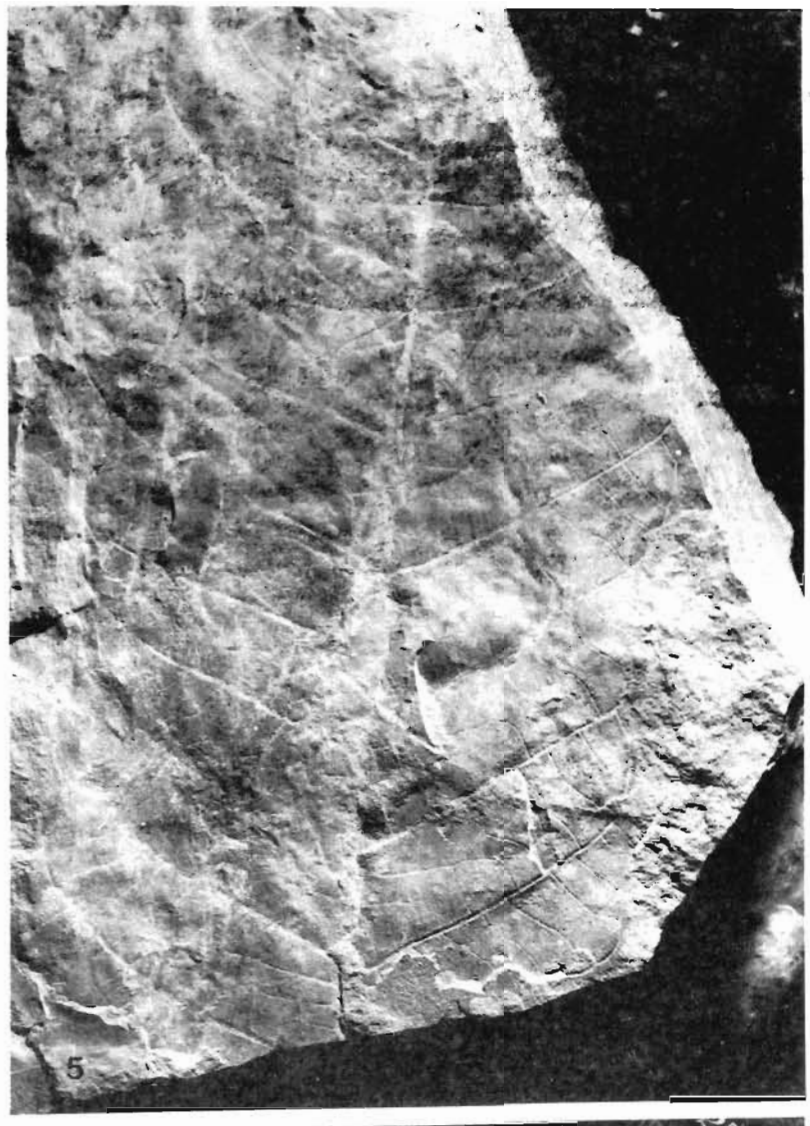
Affinities—In having characteristic venation pattern, such as numerous secondary and intersecondary veins forming intramarginal vein and exmedially ramified tertiary veins the fossil leaves resemble extant *Syzygium cumini* and therefore have been described as *Syzygium palaeocumini* sp. nov. The specific name indicates the antiquity of *Syzygium cumini*.

There are five species of fossil leaves assigned to the genus *Syzygium*. These are *Syzygium floribundoides* Engelhardt (Muller, 1934) from the Middle Miocene of West Germany, *S. chaneyi* Huzioka & Takahashi 1970 from the Eocene of Japan, *S. kachchhense* Lakhanpal & Guleria 1981 from the Eocene of Kachchh, India, *S. miocenicum* Prasad & Prakash 1984 from the Siwalik beds of Koilabas, Nepal and *S. palaeobracteatum* Awasthi & Lakhanpal 1990 from the Siwalik beds of Bhikhnathoree, near Indo-Nepal border, Bihar. Our fossil leaves are different from these species in shape, size and details of venation pattern. Moreover, our leaves are closely comparable to *Syzygium cumini* Roxb. whereas none of other fossil species shows resemblance with this taxon.

PLATE 8

(All figures are of natural size unless otherwise mentioned)

1. *Syzygium palaeocuminii* sp. nov. — A part of fossil leaf magnified to show details of venation X 3.5.
2. *Syzygium cuminii* — A part of modern leaf magnified to show details of venation X 3.5.
3. *Randia palaeofasciculata* sp. nov.— Fossil leaf; Specimen no. BSIP 37598.
4. *Randia fasciculata* D.C. — Modern leaf.
5,6. *Anthocephalus siwalicus* sp. nov. — Fossil leaves; Specimen nos BSIP 37599 and 37600.



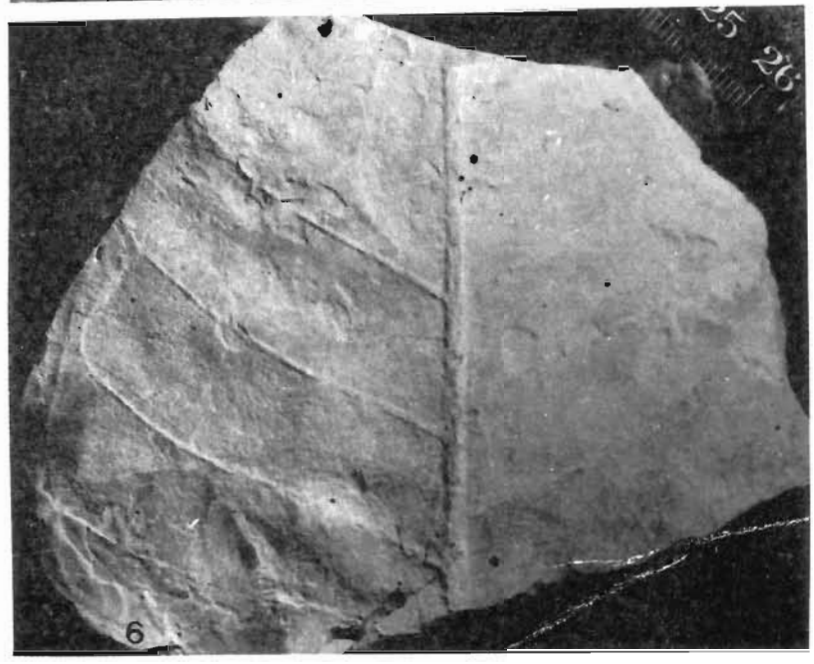


PLATE 8

Syzygium cumini Roxb. is an evergreen tree occuring throughout India, Myanmar and Sri Lanka. It is chiefly found along river banks and in the forests of moister localities (Gamble, 1972).

Family—Rubiaceae

Genus—*Randia* L.

Randia siwalica sp. nov.
Pl. 9, fig. 1

Number of specimen—One.

Description—Leaf simple, symmetrical, narrow elliptic, size 18.5 x 5.8 cm; apex broken; base seemingly wide acute; margin entire; texture thick, chartaceous; petiole not preserved; venation pinnate, eucampto-dromous; primary vein straight, stout, secondary veins 13 pairs visible, each 0.8-1.7 cm apart, alternate, uniformly curving up towards margin, angle of divergence 60°, moderate, unbranched; intersecondary veins present, simple; tertiary veins fine with angle of origin usually RR, sometimes branched, percurrent, oblique in relation to midrib, predominantly alternate and close, further details not discernible.

Holotype—Specimen no. BSIP 37597.

Locality—Chor Khola, Surai Khola area, Nepal.

Horizon & Age—Middle Siwalik; Upper Miocene.

Affinities—Owing to its narrow elliptic shape and large size the fossil leaf is closely comparable to the leaves of *Randia* of the family Rubiaceae. Among the species of *Randia* Linn., *R. macrophylla* Hook. f. is closer to our fossil leaf (CNH, Howrah, Herbarium Sheet no. 20597).

So far five fossil leaves belonging to the genus *Randia* are known from different parts of the world. They are *Randia prodroma* Unger from the Miocene of Germany (Salomon-Calvi, 1938), *R. gossferiana* Kschun from the Tertiary of Kamerum, Germany (Menzel, 1920), *R. mohavensis* Axelrod 1950 from the Miocene of North America and *R. miowallichii* Prasad from the Siwalik sediments of Koilabas, Nepal and Oodlabari, West Bengal, India (Prasad, 1990a; Antal & Awasthi, 1993). However, our fossil leaf differs from these species in having narrow elliptic shape and being large in size with more than 13 pairs of secondary veins.

Randia macrophylla Hook. f. is a shrub or small tree distributed in the Malayan regions (Desch, 1957).

Randia palaeofasciculata sp. nov.
Pl. 8, fig. 3

Number of specimen—One.

Description—Leaf simple, nearly symmetrical, elliptic, size 3.4 x 11.4 cm; apex acute; base acute; margin entire; texture chartaceous, petiole present, less than 0.2 cm; venation eucamptodromous, primary veins prominent, stout, almost straight; secondary veins 6-7 pairs, each 0.2 - 0.7 cm apart, alternate to subopposite, angle of divergence about 50°, moderate in thickness, unbranched, intersecondary veins not discernible; tertiary veins also not clearly seen.

Holotype—Specimen no. BSIP 37598.

Locality—Bankas, Surai Khola area, Nepal.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinities—The shape, size and venation pattern clearly show that the fossil leaf resembles that of *Randia fasciculata* DC. of the family Rubiaceae (CNH, Howrah, Herbarium Sheet no. 205197). Therefore, it is named as *Randia palaeofasciculata* sp. nov. The specific name indicates the antiquity of *Randia fasciculata*.

All the known fossil leaves assigned to the genus *Randia* Linn. are bigger in size than *Randia palaeofasciculata*.

Randia fasciculata DC. is large straggling shrub growing in sub-Himalayan tract and outer valley from Nepal eastward, Assam, Khasi Hills and Tenasserim (Brandis, 1971).

PLATE 9

(All figures are of natural size unless otherwise mentioned)

1. *Randia siwalica* sp. nov. — Fossil leaf showing shape, size and venation pattern; Specimen no. BSIP 37597.
2. *Randia macrophylla* Hook. f. — Modern leaf showing similar shape, size and venation pattern.

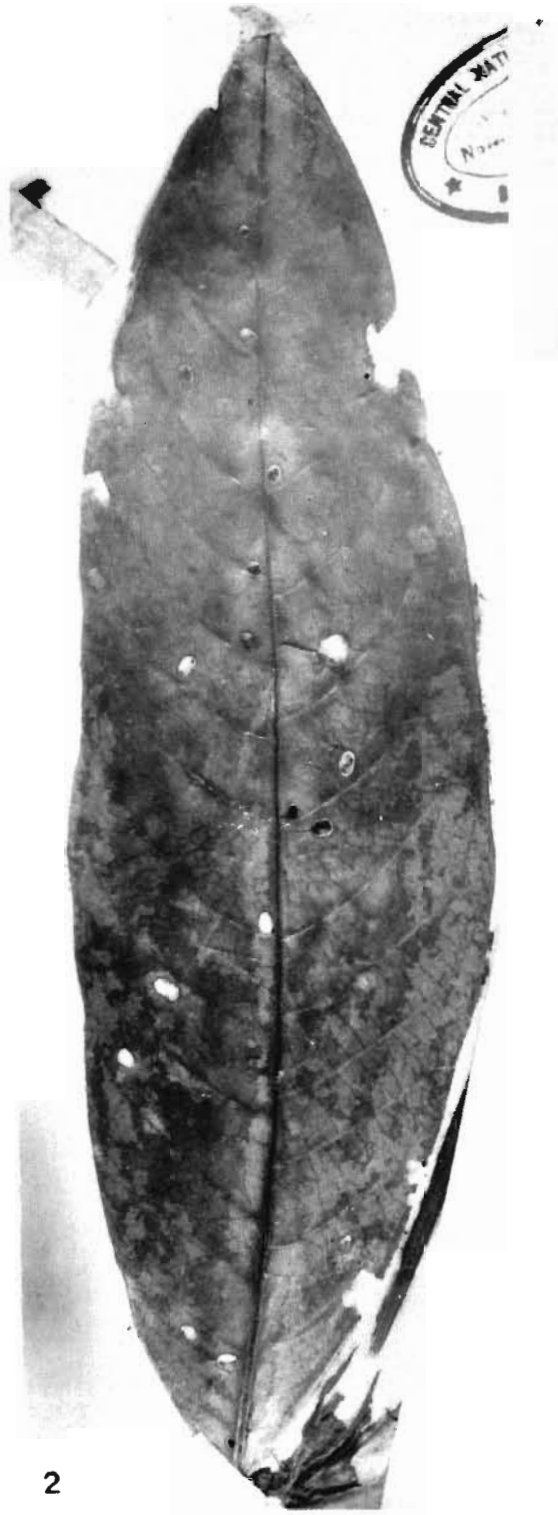


PLATE 9

Genus—*Anthocephalus* A. Rich.

Anthocephalus siwalicus sp. nov.
Pl. 8, figs 5, 6

Number of specimens—Two.

Description—Leaf simple, symmetrical, elliptic, size of better preserved specimen 15.4 x 9 cm; apex and base broken; margin entire; texture thick, chartaceous; venation pinnate, eucamptodromous; primary vein prominent, stout, straight; secondary veins about 10 pairs in the available middle part of lamina, 1.7-2.4 cm apart, alternate to subopposite, angle of divergence 60°-80°, moderate to wide, unbranched, intersecondary veins present, simple to composite; tertiary veins fine, angle of origin RR, percurrent, straight to sinuous, branched, opposite to mostly alternate, close to distantly placed; quaternary veins still fine, arising at right angle forming orthogonal meshes.

Holotype—Specimen no. BSIP 37599.

Paratype—Specimen no. BSIP 37600.

Locality—Bankas, Surai Khola area, Nepal.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinities—Although there are two incomplete specimens, the available part of lamina of one of the specimens shows distinguishing characters to suggest the affinities of the fossil with the leaves of *Anthocephalus*. A survey of Herbarium sheets at CNH, Howrah, however, revealed that the shape, size and venation pattern, as can be seen in the available parts, the fossil leaves are very similar to those of *Anthocephalus macrophyllum* Havil of the family Rubiaceae (CNH, Howrah, Herbarium Sheet no. 19711).

As far as the authors are aware there is no record of fossil leaf of the genus *Anthocephalus* A. Rich. Therefore the present fossil leaf is assigned to a new species, *Anthocephalus siwalicus*.

Anthocephalus macrophylla Havil., with which fossils show closest affinity, now grows in Malaya Archipelago.

Genus—*Diplospora* DC.

Diplospora siwalica sp. nov.
Pl. 10, fig. 2

Number of specimen—One.

Description—Leaf simple, symmetrical, wide elliptic; size 7.5 x 4.2 cm; apex seemingly acuminate; base slightly broken; margin entire; texture chartaceous; petiole broken; venation pinnate; eucamptodromous; primary vein prominent, straight, stout; secondary veins about 11 pairs visible, 0.5-1.0 cm apart, alternate to subopposite, angle of divergence about 60°, deeply curving upward, moderate in thickness, unbranched; intersecondary veins not seen; tertiary veins fine, angle of origin AO, percurrent, straight to sinuous, branched, alternate to opposite, close; further details not discernible.

Holotype—Specimen no. BSIP 37601.

Locality—Bankas, Surai Khola area, Nepal.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinities—The shape, size and venation pattern as seen in the fossil specimen are characteristic of the leaves of *Diplospora* of the family Rubiaceae. Among the genus *Diplospora* the fossil leaf shows close similarity with *D. singularis* Korth. (Pl. 10, fig. 3).

There is no record of the fossil leaf of *Diplospora* both from India and abroad. The present fossil leaf is, therefore, described as *Diplospora siwalica* sp. nov., the specific name is after Siwalik Group.

Diplospora singularis Korth. is a middle-sized evergreen tree occuring in Khasi and Cachar Hills in northeast India, Peguyoma, Tenasserim (Myanmar) and Indian Archipelago (Brandis, 1971).

Family—Apocynaceae

Genus—*Chonemorpha* G. Don.

Chonemorpha miocenica sp. nov.
Pl. 11, figs 1, 3

Number of specimen—Two.

PLATE 10

(All figures are of natural size unless otherwise mentioned)

1. *Anthocephalus macrophyllum* Havil — Modern leaf.
2. *Diplospora siwalica* sp. nov. — Fossil leaf showing shape, size and venation pattern; Specimen no. BSIP 37601.
3. *Diplospora singularis* Korth. — Modern leaf showing similar shape, size and venation pattern.

PLATE 10

Description—Leaf simple, symmetrical, wide elliptic, size 12 x 8.5 cm (length incomplete); apex missing in one of the specimens, seemingly acuminate; base obtuse; margin entire; texture chartaceous; petiole broken; venation eucamptodromous; primary vein prominent, straight, stout; secondary veins 6-7 pairs visible in the available part, 1.3-2.8 cm apart, alternate, unbranched; angle of divergence 50°-60°, apical pairs of secondary veins usually meeting with the superadjacent secondary veins forming distinct loop; intersecondary veins present, simple to composite; tertiary veins fine, angle of origin mostly RR, sometimes AO, percurrent, sometimes branched, straight to sinuous, rarely curved, mostly alternate, close to distantly placed; quaternary veins fine, angle of origin usually RR, branched, forming orthogonal meshes.

Holotype—Specimen no. BSIP 37602.

Paratype—Specimen no. BSIP 37603.

Locality—Wood Seam, Surai Khola area, Nepal.

Horizon & Age—Middle Siwalik; Upper Miocene.

Affinities—In shape, size and venation pattern the fossil leaves show similarity with those of *Chonemorpha macrophylla* G. Don. of Apocynaceae (CNH, Howrah Herbarium sheet nos 52534, 67923; Pl. 11, fig. 2).

As there is no record of fossil leaves resembling *Chonemorpha* G. Don., the present fossil leaves are being assigned to a new species, *Chonemorpha miocenica.*

Chonemorpha macrophylla G. Don. is a large climbing shrub of moist forest in the greater part of India, from Kumaon and Sikkim in the Himalaya to Travancore and Sri Lanka and Andman Islands (Gamble, 1971).

Genus—*Wrightia* R. Br.

Wrightia palaeotinctoria sp. nov.
Pl. 12, fig. 3

Number of specimen—One.

Description—Leaf simple, symmetrical, complete, elliptic, size 10.5 x 5.2 cm; apex broken; base obtuse; margin entire; texture chartaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein straight, stout; secondary veins 7-8 pairs, each 0.6-2.1 cm apart, alternate to opposite, angle of divergence 60°-80°, moderate in thickness, unbranched; intersecondary veins present, frequent, simple; tertiary veins fine, angle of origin RR, percurrent, sometimes branched, straight to sinuous, alternate to opposite, oblique in relation to midrib, close, further details not descernible.

Holotype—Specimen no. BSIP 37604.

Locality—Chor Khola, Surai Khola area, Nepal.

Horizon & Age—Middle Siwalik; Upper Miocene.

Affinities—The characteristic features such as elliptic shape, 60°- 80° angle of divergence of secondary veins and several intersecondary veins displayed by the fossil leaf are seen in *Wrightia tinctoria* R. Br. (Pl. 12, fig. 4).

A fossil leaf resembling the genus *Wrightia* described as *Wrightia siwalica*, is known from the Siwalik sediments of Kathgodam, Nainital District, Uttar Pradesh (Prasad, 1994a). Like our present fossil, this fossil leaf is also comparable to the extant species *Wrightia tinctoria* R. Br. but on comparison with the present fossil leaf it has been found that *Wrightia siwalica* is entirely different in its shape, size as well as venation pattern.

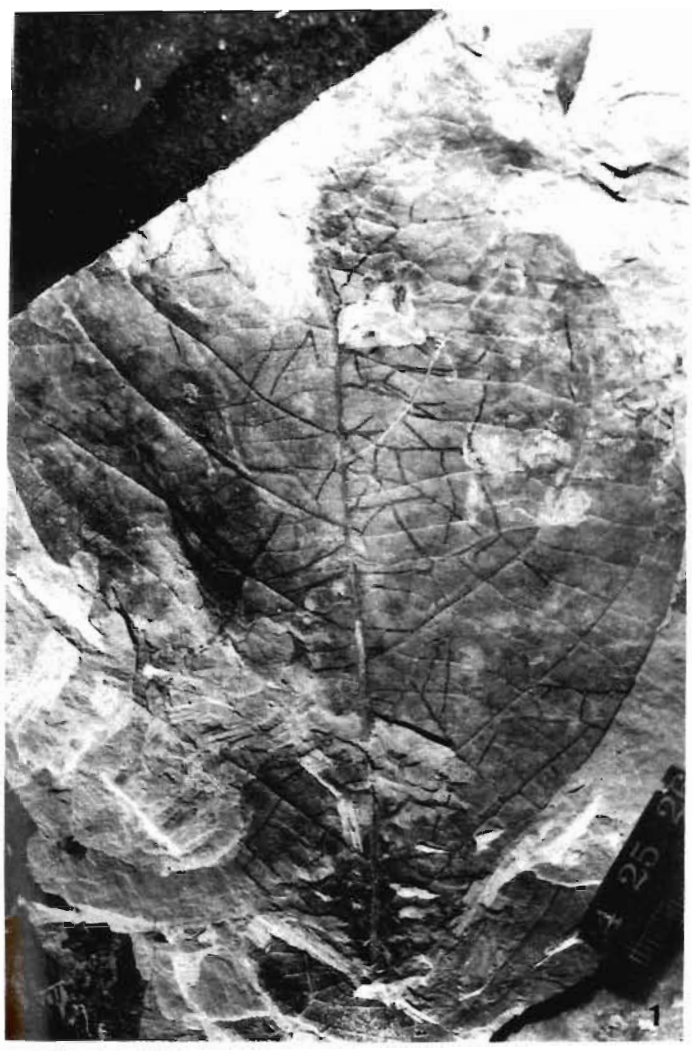
Hence, it is named as *W. palaeotinctoria* sp. nov. The specific name signifies the antiquity of *Wrightia tinctoria.*

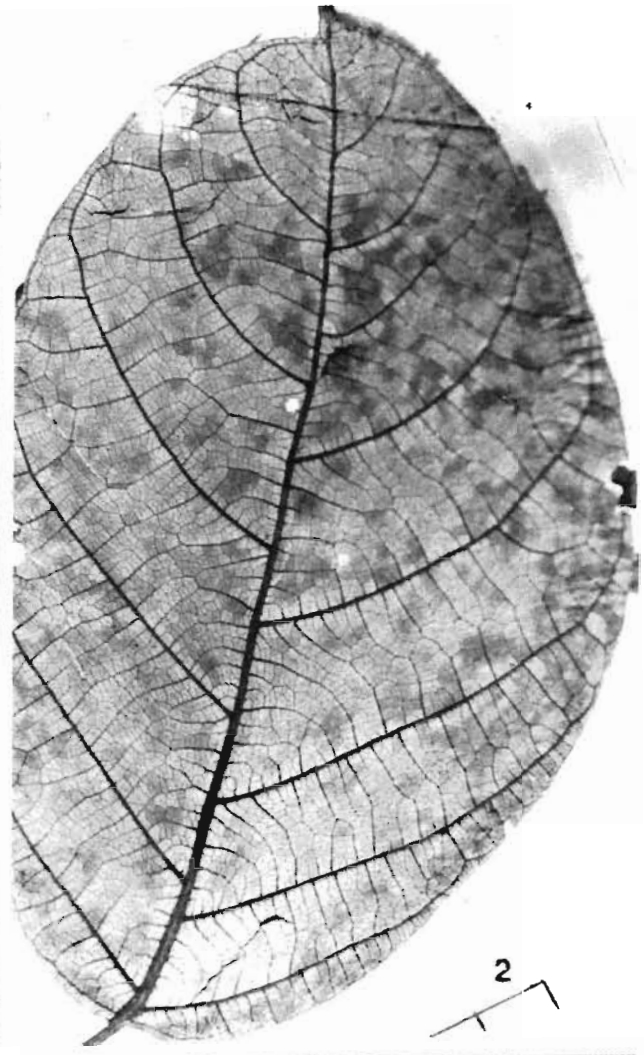
Wrightia tinctoria R. Br. is a small deciduous tree found in the peninsular India. It is common in the Deccan and Carnatic and the Bombay Presidency, extending north to Rajasthan and Vindhyachal, and also in Myanmar (Brandis, 1971).

PLATE 11

(All figures are of natural size unless otherwise mentioned)

1. *Chonemorpha miocenica* sp. nov. — Fossil leaf showing shape, size and venation pattern; Specimen no. BSIP 37602.
2. *Chonemorpha macrophylla* G. Don. — Modern leaf showing similar shape, size and venation pattern.
3. *Chonemorpha miocenica* sp. nov. — Apical part of fossil leaf; Specimen no. BSIP 37603.
4. *Diospyros miocenicus* sp. nov. — Fossil leaf; Specimen no. BSIP 37605.
5. *Diospyros lanceaefolia* Roxb. — Modern leaf.





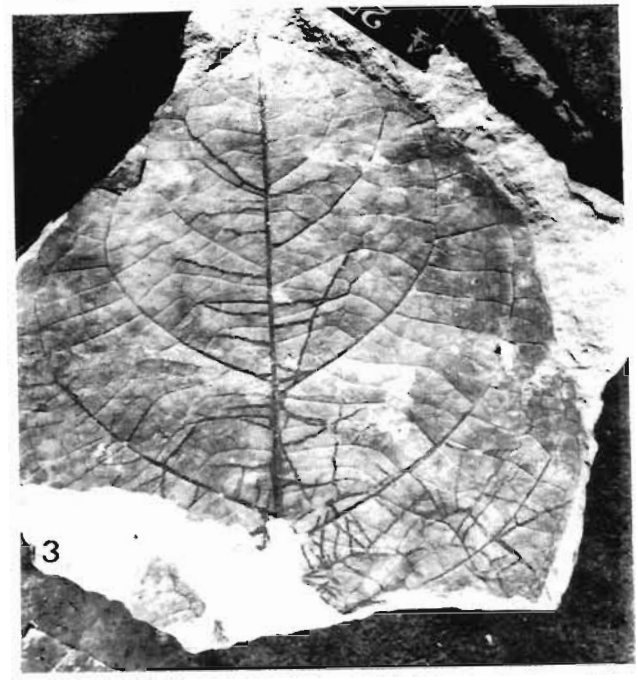


PLATE 11

Family—Ebenaceae

Genus—*Diospyros* L.

Diospyros miocenicus sp. nov.
Pl. 11, fig. 4; Pl. 12, fig. 1

Number of specimen—One.

Description—Leaf simple, symmetrical, narrow oblong, size 7.0 x 2.2 cm; apex acute; base acute; margin entire; texture coriaceous; petiole broken; venation eucamptodromous; primary vein straight, stout; secondary veins 13-14 pairs discernible, 0.3-0.7 cm apart, alternate to subopposite, angle of divergence about 60°, unbranched; intersecondary veins frequently present, simple; tertiary veins fine, angle of origin RR to AO, branched, orthogonal reticulate, oblique in relation to midrib, close.

Holotype—Specimen no. BSIP 37605.

Locality—Wood Seam, Surai Khola area, Nepal.

Horizon & Age—Middle Siwalik; Upper Miocene.

Affinities—The most characteristic feature of the fossil leaf is its narrow oblong shape with 13-14 fine secondary veins. Taking into consideration the size and other features, the fossil specimen shows close resemblance with the leaves of *Diospyros lanceaefolia* Roxb. (=*D. amoena*) of the family Ebenaceae (CNH, Hawrah, Herbarium sheet no. 282434).

The genus *Diospyros* Linn. is one of the most common genera found in the Indian Tertiary rocks. A number of leaf-impressions and carbonised and petrified woods resembling the genus *Diospyros* have been described by several workers. The leaf-impressions described so far from the Indian subcontinent are *Diospyros pretoposia* Prasad 1990a and *D. koilabasensis* Prasad from the Siwalik sediments of Koilabas, Nepal (Prasad, 1990a) and Oodlabari, Darjeeling District, West Bengal (Antal & Awasthi, 1993); *D. miokaki* from the Siwalik sediments of Surai Khola, Nepal (Awasthi & Prasad, 1990); and *D. kathgodamensis* and *D. palaeoebenum* from the Siwalik sediments of Kathgodam in Nainital District of Uttar Pradesh (Prasad, 1994a, c). The present fossil leaf distinctly differs from these species in shape and venation pattern and therefore has been described as *Diospyros miocenicus* sp. nov.

Diospyros lanceaefolia Roxb. (=*D. amoena*) is a middle-sized evergreen tree occuring in Upper Assam, Khasi Hills, Manipur and Upper Tenasserim in Myanmar (Brandis, 1971).

Family—Euphorbiaceae

Genus—*Cleistanthus* Hook.f. ex Planch.

Cleistanthus suraikholaensis sp. nov.
Pl. 12, fig. 8; Pl. 13, fig. 1

Number of specimen—One.

Description—Leaf simple, symmetrical, narrow elliptic, size 9.8 x 4.1 cm; apex broken; base obtuse; margin entire; texture chartaceous; petiole not preserved; venation eucamptodromous; primary vein prominent, straight, stout; secondary veins 12-13 pairs, 0.4-1.2 cm apart, alternate to subopposite, unbranched, angle of divergence 60°-80°, curving gently and running upward parallely up to some distance before joining the superadjacent secondary veins; intersecondary veins present, frequent, simple; tertiary veins fine, angle of origin RR, percurrent, straight to sinuous, sometimes curved, branched, mostly alternate, oblique in relation to midrib, close, quaternary veins visible, arising usually at right angle, branched forming rectangular meshes.

Holotype—Specimen no. BSIP 37606.

PLATE 12

(All figures are of natural size unless otherwise mentioned)

1. *Diospyros miocenicus* sp. nov. — A part of fossil leaf magnified to show details of venation X 4.5.
2. *Diospyros lanceaefolia* Roxb. — A part of modern leaf magnified to show similar details of venation X 4.5.
3. *Wrightia palaeotinctoria* sp. nov. — Fossil leaf; Specimen no. BSIP 37604.
4. *Wrightia tinctoria* R. Br. — Modern leaf.
5. *Phyllanthus palaeoreticulatus* sp. nov. — Fossil leaf; Specimen no. BSIP 37609.
6. *Phyllanthus reticulatus* Poiret — Modern leaf.
7. *Phyllanthus palaeoreticulatus* sp. nov. — A part of fossil leaf magnified to show details of venation X 4.
8. *Cleistanthus suraikholaensis* sp. nov. — A part of fossil leaf magnified to show details of venation X 2.

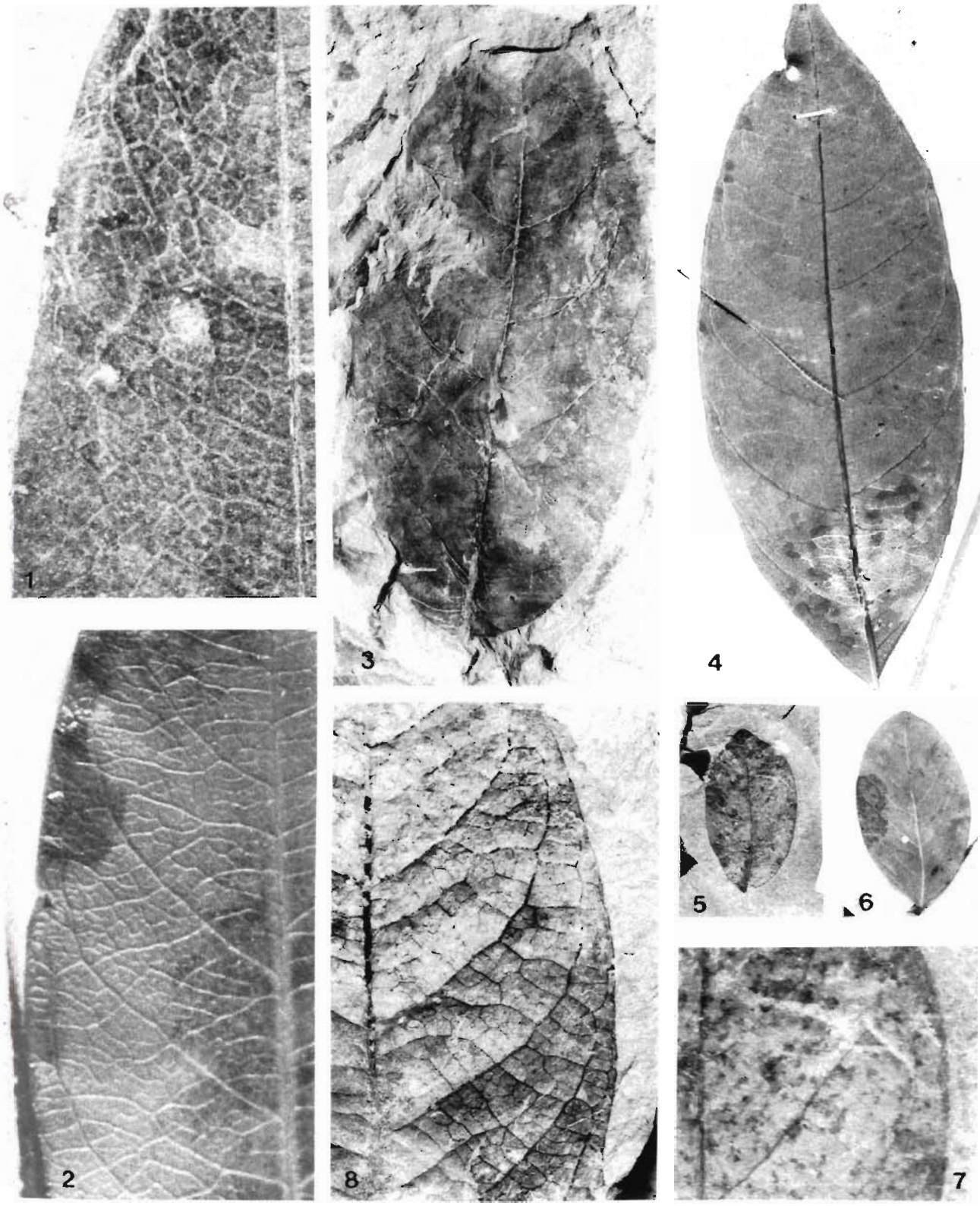


PLATE 12

Locality—Bankas, Surai Khola area, Nepal.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinities—The general shape, size and venation pattern and other features of the fossil leaf match with *Cleistanthus helferi* of the family Euphorbiaceae (CNH, Howrah, Herbarium Sheet no. 400905; Pl. 13, fig. 2).

As far as the authors are aware this is the first record of a fossil leaf of the genus *Cleistanthus* Hook. f. and hence named as *C. suraikholaensis* sp. nov. The extant taxa *Cleistanthus helferi* Hook. f. is a small tree occuring in Malayan region and Myanmar (Hooker, 1887).

Genus—*Mallotus* Lour.

Mallotus venkatachalai Prasad
Pl. 13, fig. 3

Number of specimens—Two.

Description—Leaf simple, symmetrical, ovate, size 4.4 x 3.4 cm, 3.0 x 3.0 cm; apex attenuate; base obtuse; margin entire; texture chartaceous; petiole not well preserved; venation pinnate, basal, acrodromous, imperfect; primary veins three, one mid-primary and two lateral primary veins arising at the base from a single point; secondary veins 5-6 pairs arising from mid-primary vein, lateral primary veins also giving rise to 5-6 secondary veins, running towards margin, primary veins stout, angle of divergence about 60°, each secondary vein 0.4-1.2 cm apart, alternate to subopposite, unbranched; tertiary veins fine, angle of origin usually RR, percurrent, sometimes sinuous, usually unbranched, alternate to opposite, oblique in relation to midrib, close to distantly placed.

Figured specimens—Specimen nos. BSIP 37607 and 37608.

Locality—Bankas, Surai Khola area, Nepal.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinities—In all the morphological features the fossil leaves are similar to already known species, *Mallotus venkatachalai* Prasad 1994a, described from the Lower Siwalik sediments near Kathgodam, Uttar Pradesh. Our present fossil specimens also closely compare with the leaves of *Mallotus repandus* Muell. Arg. of the family Euphorbiaceae (CNH, Howrah, Herbarium Sheet no. 67831) and hence has been described under the same known species.

Mallotus repandus Muell. Arg. is an evergreen shrub distributed in Assam, West Bengal, Bangladesh, Myanmar, Sri Lanka, Malaya, China and New Caledonia (Brandis, 1971).

Genus—*Phyllanthus* L.

Phyllanthus palaeoreticulatus sp. nov.
Pl. 12, figs 5, 7

Number of specimen—One.

Description—Leaflet, symmetrical, elliptic, size 3.0 x 1.6 cm; apex nearly obtuse; base obtuse; margin entire; texture chartaceous; petiole broken; venation pinnate, eucamptodromous; primary vein prominent, slightly curved; stout; secondary veins 8-9 pairs, 0.3-0.6 cm apart, mostly alternate, unbranched, angle of divergence about 50°; intersecondary veins not discernible; tertiary veins poorly preserved, angle of origin RR, seemingly percurrent, oblique in relation to midrib.

Holotype—Specimen no. BSIP 37609.

Locality—Bankas, Surai Khola area, Nepal.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinities—The fossil leaflet is small in size having obtuse base and apex, and about 8-9 pairs of secondary veins arising at about 50°. These features clearly show that the fossil leaflet resembles those of *Phyllanthus reticulatus* Poiret (CNH, Howrah, Herbarium Sheet no. 768).

Two fossil leaves showing resemblance with the genus *Phyllanthus (Glochidion)* are known from the

PLATE 13

(All figures are of natural size unless otherwise mentioned)

1. *Cleistanthus suraikholaensis* sp. nov. — Fossil leaf; Specimen no. BSIP 37606.
2. *Cleistanthus helferi* Hook. — Modern leaf.
3. *Mallotus venkatachalai* Prasad — Fossil leaf; Specimen no. BSIP 37607.
4. *Mallotus repandus* Muell. — Modern leaf.
5, 6. *Ficus raptiensis* sp. nov. — Fossil leaves; Specimen nos. BSIP 37614 and 37615.
7. *Ficus hispida* Linn. — Modern leaf.

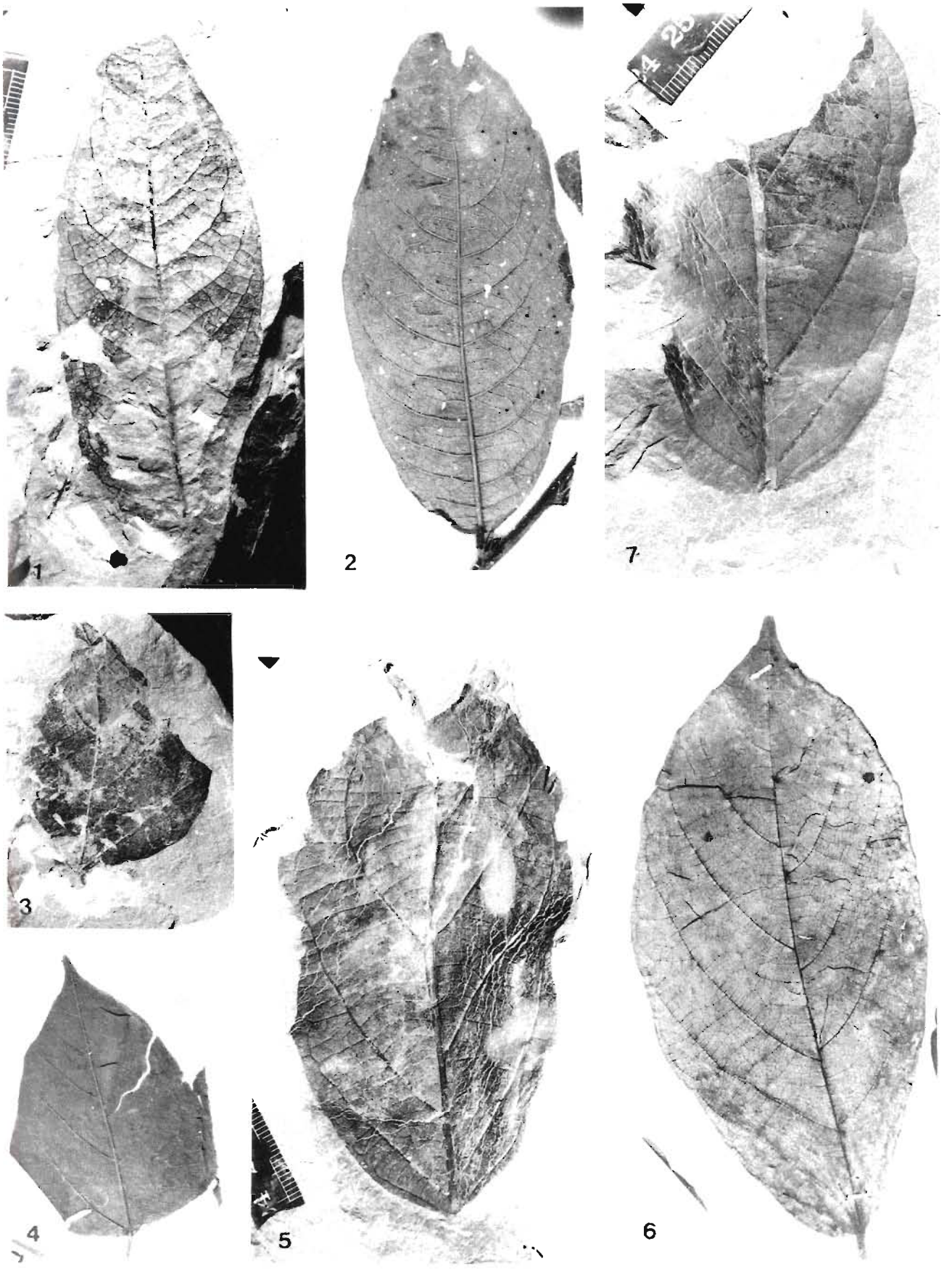


PLATE 13

Siwalik sediments of India. Of them, *Glochidion siwalica* Prasad is from the Siwalik sediments of Kathgodam, Nainital District, Uttar Pradesh (Prasad, 1994a) and other is from Oodlabari area, Darjeeling District, West Bengal (Antal & Prasad, 1996). Both these fossil leaves are much bigger in size with somewhat different type of venation pattern.

Owing to its close similarity with *Phyllanthus reticulatus* Poiret. the fossil leaflet is being described as *Phyllanthus palaeoreticulatus* sp. nov.

Phyllanthus reticulatus Poiret is a large straggling or climbing shrub, common in low moist ground in the drier region of India and Myanmar and also in the forest along Indus, climbing over the largest tree (Brandis, 1971).

Family—Moraceae

Genus—*Artocarpus* J. R. & Forst.

Artocarpus nepalensis sp. nov.
Pl. 14, figs 1, 3, 5, 7, 8, 9

Number of specimens—Three.

Description—Leaves simple, symmetrical, wide obovate, size 8.0 x 4.6, 7.5 x 4.6 and 6.5 x 3.5 cm respectively; apex acuminate to obtuse; base acute; margin entire; texture thick chartaceous; petiole preserved in one specimen, 0.8 cm long; venation eucamptodromous; primary vein prominent, straight, stout; secondary veins 7 pairs, mostly alternate, sometimes subopposite, 0.5- 1.3 cm apart, angle of divergence variable, 60°-85°, secondary veins in the apical part joining to superadjacent secondary veins forming loop; intersecondary veins present, simple; tertiary veins fine, angle of origin mostly RR, occasionally AO, percurrent, sometimes branched, almost sinuous, mostly alternate, oblique in relation to midrib, tertiary veins near the margin right angle in relation to midvein, close; quaternary veins not clearly visible.

Holotype—Specimen no. BSIP 37610.

Paratype—Specimen nos BSIP 37611, 37612 and 37613.

Locality—Wood Seam, Surai Khola area, Nepal.

Horizon & Age—Middle Siwalik; Upper Miocene.

Affinities—The most characteristic feature of the fossil leaves is its obovate shape. In other features also, the leaves resemble those of *Artocarpus* Linn. in general and *A. integrifolius* Linn. f. of Moraceae in particular (CNH, Howrah, Herbarium Sheet no. 430966).

As regard the fossil record of *Artocarpus* there are two species of fossil leaves of *Artocarpus* known from the Tertiary sediments of India. These are *Artocarpus murrecus* from the Murree sediments, Jammu (Sharma & Gupta, 1972) and *A. garoensis* from the Tura Formation (Upper Palaeocene) of Garo Hills, Meghalaya (Bhattacharyya, 1983). Of these, the latter differs from our fossil leaves in being trifoliate, while the former can be differentiated in shape, size and details of venation pattern. In view of this the present specimens are being placed under a new species, *Artocarpus nepalensis.*

Artocarpus integrifolius Linn. f. is a large evergreen tree occuring in dense forests along the Western Ghats up to 1300 m. It is largely cultivated in India, Myanmar and Pakistan (Brandis, 1971).

Genus—*Ficus* L.

Ficus raptiensis sp. nov.
Pl. 13, figs 5, 7

PLATE 14

(All figures are of natural size unless otherwise mentioned)

1. *Artocarpus nepalensis* sp. nov. — Fossil leaf; Specimen no. BSIP 37610.
2. *Artocarpus integrifolius* Linn. f. — Modern leaf.
3, 7, 8. *Artocarpus nepalensis* sp. nov. — Other fossil leaves showing variation in shape, size and venation; Specimen nos BSIP 37611, 37612 and 37613.
4. *Artocarpus integrifolius* Linn.f. — Another Modern leaf showing similarity with fig. 3.
5. *Artocarpus nepalensis* sp. nov. — A part of fossil leaf (fig. 8) magnified to show details of venation X 3.
6. *Artocarpus integrifolius* Linn. f. — A part of modern leaf (fig. 2) magnified to show details of venation X 3.
9. *Artocarpus nepalensis* sp. nov. — A part of fossil leaf (fig. 3) magnified to show details of venation X 3.
10. *Artocarpus integrifolius* Linn. f. — A part of modern leaf (fig. 4) magnified to show similarity with (fig. 9).

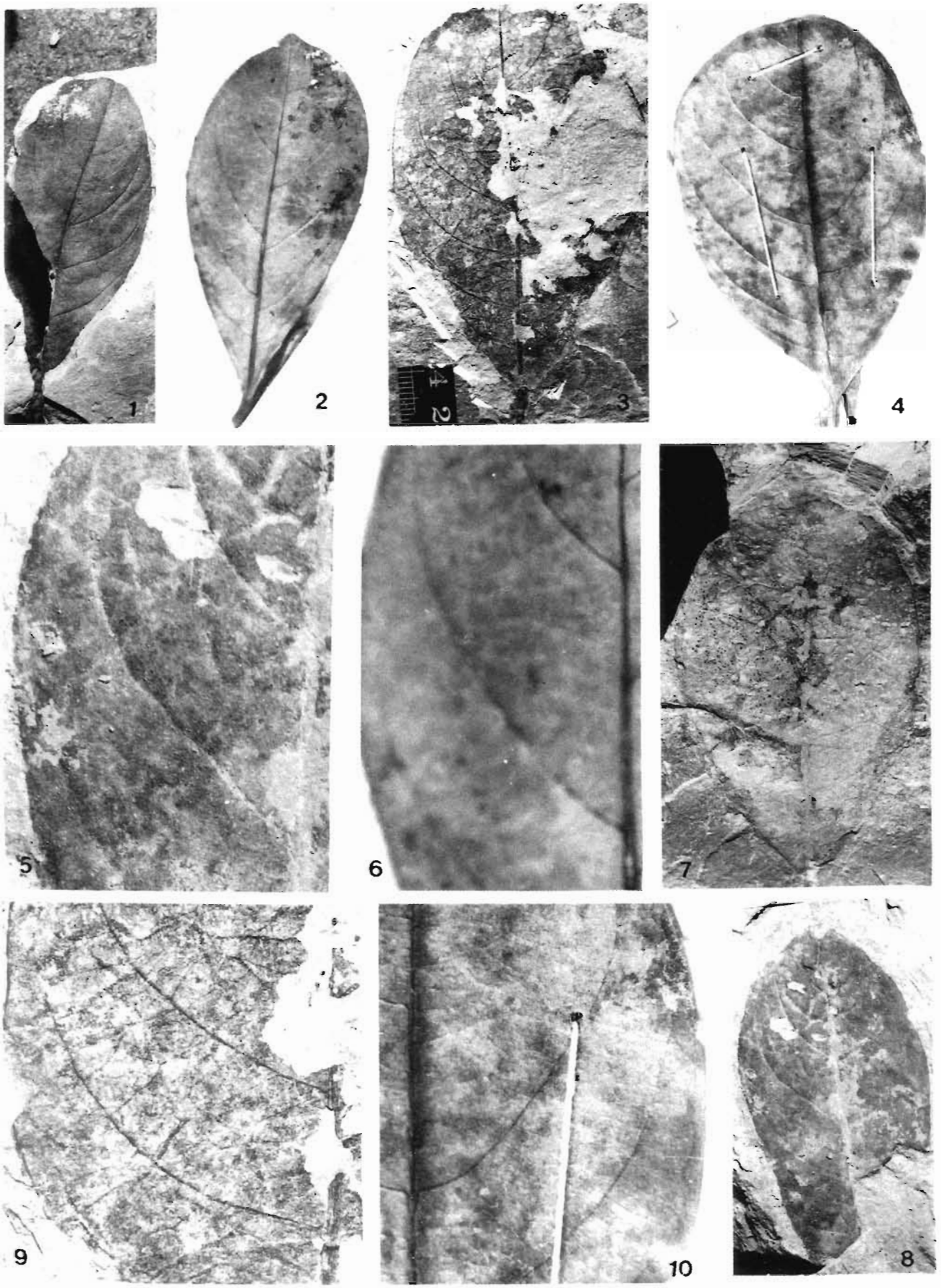


PLATE 14

Table 1—Sequential distribution of Siwalik flora of Sural Khola area, western Nepal

Formations/ beds	Fossil Taxa	Comparable modern taxa	Forest type	Distribution
Dhan Khola	-	-	-	-
Dobatta	-	-	-	-
Surai Khola	• *Clinogyne ovatus*	C. grandis Benth. & Hooker	Moist deciduous	Sub-Himalayan tract
	• *Flacourtia nepalensis*	*F. ramontchii* L. Herit.	Dry deciduous	India, Sri Lanka, Malaya
	• *Millettia palaeocubithii*	*M. cubithii*	Moist deciduous	Malaya
	• *Bauhinia nepalensis*	*B. malabarica* Roxb.	Moist to dry deciduous	Central & S. India, Myanmar
		B. variegata Linn.	-	-
	Pongamia kailakholaensis sp. nov.	*P. pinnata* Vent.	Evergreen	India, Myanmar, Sri Lanka
	• *Diospyros miokaki*	D. kaki Linn. f.	Moist deciduous	NE India, Myanmar, China, Japan
	• *Breynia prerhamnoides*	B. rhamnoides Muell. Arg.	Moist deciduous	India, Myanmar, Malaya
	• *Caryota siwalia*	C. urens Linn.	Evergreen to moist deciduous	Sub-Himalayan tract, Sri Lanka, Myanmar, Malaya, NE India
	Bouea koilabasensis Prasad	*B. burmanica* Griff.	Evergreen	Sunderban, Tennasserim, Malaya
	• *Mangifera someshwarica*	M. indica Linn.	Evergreen to moist deciduous	Sub-Himalayan tract, Myanmar, Thailand, Malaya, Bangladesh
	• *Gluta siwalika*	G. renghas Linn.	Evergreen	Malaya
	• *Swintonia miocenica*	S. floribunda Griff.	Evergreen	Bangladesh, Myanmar, Tenasserim
	S. palaeoschwenckii sp. nov.	*S. schwenkii* Teysm. & Benn.	Evergreen	Bangladesh, Myanmar
	• *Entada palaeoscandens*	E. scandens Benth.	Moist deciduous to semi evergreen	Sub-Himalayan tract, Myanmar, Andaman, Western Ghats, NE India, Nepal
	• *Terminalia palaeochebula*	T. chebula Ritz.	Moist deciduous to semi evergreen	Sub-Himalayan tract, Sri Lanka, India, Nepal
	• *Terminalia panandhroensis*	T. coriacea (Roxb.) W. & A.	Moist deciduous	South & central India, Myanmar
Chor Khola	• *Bambusa siwalica*	Bambusa tulda Roxb.	Moist deciduous	NE India, Bangladesh, Myanmar
	Mitrephora siwalica Antal & Awasthi	M. maingayi Hook. f.	Evergreen	NE India, Myanmar, Malaya, Sri Lanka, Java
	Goniothalamus chorkholaensis sp. nov.	*G. thwaitesii* Hook. f. & Thomas	Evergreen	NE India, Myanmar
		G. sesquipedalis Hook. f. & Thomas	Evergreen	Travancore, Tirunelvelli, Sri Lanka
	• *Calophyllum suraikholaensis*	C. polyanthum Wall.	Evergreen	NE India, Bangladesh, Myanmar, Malaya
	• *Dipterocarpus siwalicus*	D. tuberculatus Roxb.	Evergreen	NE India, Myanmar
		D. turbinatus Gaertn.	Evergreen	NE India, Bangladesh, Myanmar, Malaya
	Flacourtia tertiara sp. nov.	*F. inermis* Roxb.	Evergreen	Malaya
	Hydnocarpus siwalicus sp. nov.	*H. glaucescens* Blume	Evergreen	Sumatra
	H. chorkholaensis sp. nov.	*H. ovoidea* Elmer.	Evergreen	Philippines
	• *Garcinia corvinusiana* sp. nov.	*G. speciosa* Wall.	Evergreen	Tennasserim, Andman
	Zanthoxylum siwalicum sp. nov.	*Z. hamiltonianum* Wall.	Evergreen	NE India, Myanmar

Contd.

Formations/ beds	Fossil Taxa	Comparable modern taxa	Forest type	Distribution
	Murraya khariensis Lakhanpal & Guleria	*M. paniculata* (Linn.) Jacq.	Evergreen	NE India, Myanmar, Sri Lanka, China & Australia
	Dysoxylum raptiensis sp. nov.	*D. procerum* Hiern.	Evergreen	NE India, Myanmar
	Chukrasia miocenica Prasad	*C. tabularis* Adr. Juss.	Evergreen to moist deciduous	NE India, Sri Lanka, Myanmar, Andaman
	Harpullea siwalica sp. nov.	*H. cupinoides* Roxb.	Evergreen	S. India, Bangladesh, Andman
	Pterocarpus dalbergiocarpoides sp. nov.	*P. dalbergiodes* Roxb.	Evergreen	Andmans
	Albizia siwalica Prasad	*A gambeli* Prain.	Moist deciduous	Myanmar
	• *Millettia palaeoracemosa*	M. racemosa Berth.	Evergreen to deciduous	South & Central India, Myanmar, Malaya
	Entada palaeoscandens	E. scandens Benth.	Moist deciduous to semi-evergreen	Sub-Himalayan tract, Nepal, NE India, Andaman, Western Ghats
	Anisophyllea siwalica sp. nov.	*A. apetala* Sart.	Evergreen	Malaya
	Syzygium palaeocuminii sp. nov.	*S. cuminii* Roxb.	Evergreen	Throughout India, Myanmar, Sri Lanka
	Randia siwalica sp. nov.	*R. macrophylla* Hook. f.	Evergreen	Malaya
	Chonemorpha miocenica sp. nov.	*C. macrophylla* G. Don	Moist deciduous	NE India, Travancore, Myanmar, Sri Lanka
	Wrightia palaeotinctoria	W. tinctoria R. Br.	Moist deciduous	India, Myanmar
	• *Myristica palaeoglomerata*	M. palaeoglomerata	Evergreen	Malaya
	Diospyros miocenicus sp. nov.	*D. lanceaefolius* Roxb.	Evergreen	NE India, Tennasserim, Myanmar
	• *Excoecaria palaeocrenulata*	E. crenulata White K.T.	Evergreen	Western Ghat, Andmans
	Artocarpus nepalensis sp. nov.	*A. integrifolia* Linn. f.	Evergreen	Western Ghat, Myanmar
Bankas	• *Dipterocarpus siwalicus*	D. turbinatus Gaertn.	Evergreen	NE India, Bangladesh, Myanmar & Malaya
		D. tuberculatus Roxb.	Evergreen	N.E. India, Myanmar
	• *Polyalthia palaeosimiarum*	P. simiarum Bl.	Evergreen	N.E. India, Bangladesh, Myanmar, Andmans
	• *Cynometra siwalika*	C. polyandra Roxb.	Evergreen	N.E. India, Malaya
	Millettia churiensis sp. nov.	*M. prainii* Dunn.	Evergreen	North East India
	Koompassia suraikholaensis sp. nov.	*K. malaccens* Maing. ex. Benth.	Evergreen	Malaya, Sumatra, Malacca
	Albizia microfolia sp.nov.	*A. julibrisin* Durraz.	Moist deciduous	Outer Himalaya, NE India
	Randia palaeofasciculata sp. nov.	R. fasciculata DC.	Moist deciduous	Sub-Himalayan tract and Nepal, NE India, Tennasserim
	Anthocephalus siwalicus sp. nov.	*A. macrophyllum* Havil.	Evergreen	Malaya
	Diplospora siwalica sp. nov.	*D. singularis* Korth.	Evergreen	NE India, Myanmar, Tennasserim
	Cleistanthus suraikholaensis sp. nov.	*C. helferi* Hook. f.	Evergreen	Malaya, Myanmar
	Mallotus venkatachalai Prasad	*M. repandus* Muell. Arg.	Evergreen	NE India, Sri Lanka, Myanmar, Malaya
	Phyllanthus palaeoreticulata sp. nov.	*P. reticulata* Poiret.	Moist deciduous to evergreen	India, Myanmar
	Ficus raptiensis sp. nov.	*F. hispida* Linn.	Moist deciduous to evergreen	Sub-Himalayan tract, outer hills, India, Myanmar, N. Australia

• Taxa described by Awasthi and Prasad (1990).

Number of specimen—One with counterpart.

Description—Leaf simple, symmetrical, elliptic, size 11.5 x 5.8 cm; apex broken; base obtuse; margin entire to slightly undulated; texture coriaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein very prominent, stout, straight; secondary veins 6 pairs visible in the preserved part, 0.3-3.3 cm apart, alternate, unbranched, angle of divergence about 50°-55°, narrow, turning upward and running parallel to the margin to a greater length; intersecondary veins not seen; tertiary veins very prominent, angle of origin usually RR, percurrent, straight to sinuous, sometimes branched, usually right angle in relation to midrib, mostly alternate, close to distantly placed; quaternary veins arising from tertiary veins at right angle, branched forming orthogonal meshes.

Holotype—Specimen no. BSIP 37614.

Paratype—Specimen no. BSIP 37615.

Locality—Bankas, Surai Khola area, Nepal.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinities—In the above features the fossil leaf is comparable with the leaves of *Ficus* Linn. of the family Moraceae. The genus *Ficus* consists of a large number of species with varied shapes, sizes and venation pattern. However, taking into consideration the shape, size of the leaf and its base, margin and venation pattern, our fossil specimen shows closer resemblance with the leaves of *Ficus hispida* Linn.

The genus *Ficus* is well documented from the Tertiary sediments of India. So far 11 species have been reported from different sedimentary basins of India (see Antal & Awasthi, 1993). From the Siwalik sediments there are five species, viz., *Ficus precunia* from Jawalamukhi, Himachal Pradesh, and Koilabas Nepal (Lakhanpal, 1968; Prasad, 1990a); *F. champarensis* from Bhikhnathoree (Lakhanpal & Awasthi, 1984); *F. retusoides* from Koilabas, Nepal and Oodlabari, West Bengal, India (Prasad, 1990a; Antal & Awasthi, 1993); *F. nepalensis* from Koilabas, Nepal (Prasad, 1990a) and *F. oodlabarensis* from Oodlabari, West Bengal (Antal & Awasthi, 1993). None of these is comparable to *Ficus hispida* Linn. with which our present fossil leaf resembles most and therefore has been described as *Ficus raptiensis* sp. nov.

Ficus hispida Linn. is a small or moderate-sized tree occuring in sub-Himalayan tract and outer hills ascending to 1150 m from Chenab eastward. It is generally found throughout India and Myanmar excepting the arid regions of northwest. It is also found in Hong Kong and North Australia (Brandis, 1971).

DISCUSSION

Floristics and palaeoecology

With the addition of 33 new taxa, described in the present paper, the megafossil assemblage of the Siwalik Group from Surai Khola succession consists of 53 species of angiosperms belonging to 45 genera of 15 families (Table 1). Out of these, the genera *Goniothalamus, Zanthoxylum, Anisophyllea, Anthocephalus, Chonemorpha* and *Cleistanthus* are new to the Indian Tertiary flora. Besides, there are still a number of specimens of mostly fossil leaves and carbonised woods in the collection whose identification with the extant taxa is yet to be confirmed. Therefore this assemblage may be considered a fraction of the total number of arboreal taxa that grew in the Surai Khola area during Middle Miocene-Pliocene. Nevertheless, the floral assemblage is reasonably adequate to draw inferences with regard to palaeoecology, phytogeography and changing pattern of vegetation and climate through the Siwalik succession.

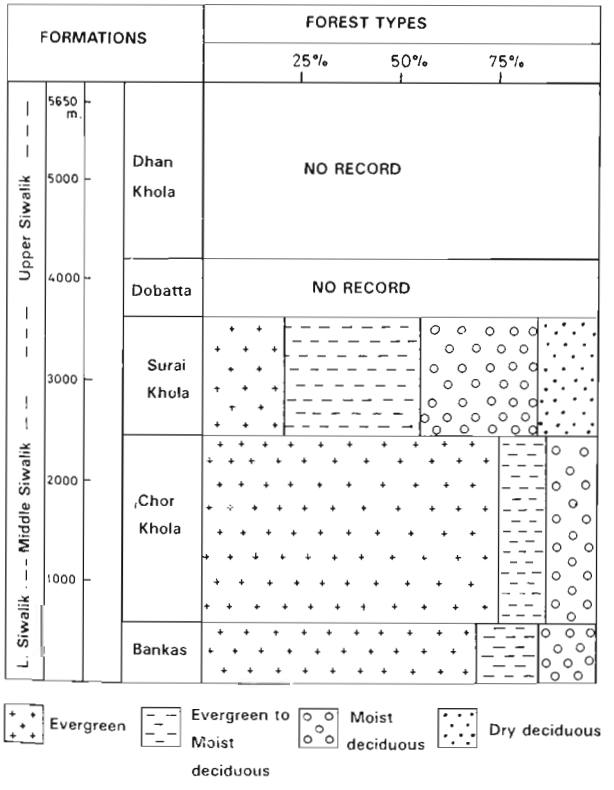
An analysis of the floral assemblage with respect to the forest types (Table 1) revealed that it is dominated by evergreen elements with 60.6 per cent followed by moist deciduous (17.9 %). The percentage of the dry deciduous taxa is as low as 3.9 (Text-figure 3). Excepting a few taxa which still occur in the foot- hills of India and Nepal most of the corresponding modern species of the Surai Khola flora are distributed in the tropical evergreen, semi-evergreen and moist deciduous forests of Western Ghats, northeast India, Andman Islands, Bangladesh, Myanmar and Southeast Asian countries. Thus it is broadly concluded that warm humid climate with high precipitation prevailed in the Surai Khola area during the Siwalik sedimentation. Such conditions seem to have certainly existed not only in the Surai Khola area but in the entire Himalayan foot-hill zone of India and Nepal as evidenced by the close similarity between Surai Khola assemblage and other Siwalik assemblages from Himachal Pradesh, Uttar Pradesh,

West Bengal and Koilabas, Nepal (Awasthi, 1992; Prasad, 1990a, b, 1994a, b, c; Antal & Awasthi, 1993). Amongst the most common and widely distributed genera during Siwalik are : *Polyalthia, Hydnocarpus, Calophyllum, Dipterocarpus, Mangifera, Gluta, Swintonia, Dysoxylum, Millettia, Koompassia, Cynometra, Bauhinia, Albizia, Terminalia, Syzygium, Randia, Diospyros, Mallotus, Ficus* and *Artocarpus*. These are rated as major components of the tropical evergreen forest.

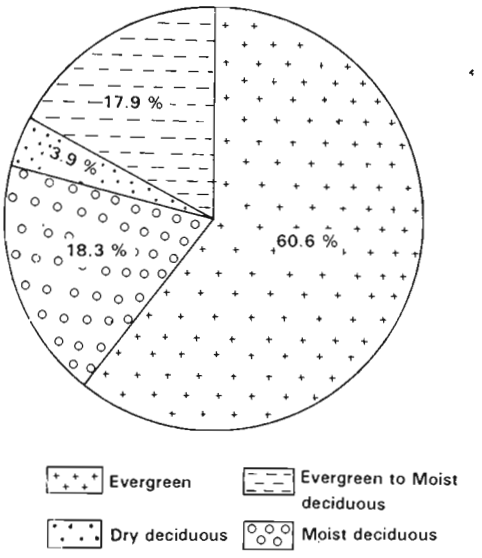
Changing pattern of vegetation and climate

One of the most important aspects of studying fossil plants of Surai Khola sequence is to reconstruct the Siwalik floristics and to throw light on the impact of further uplift of the Himalaya on vegetation and climate of the region during deposition of Siwalik sediments.

Of the five formations of Surai Khola sequence, which are informally distinguished largely on the proportion of mudstones and siltstones to sandstones



Text-figure 2—Diagram showing sequential distribution of taxa recovered from Surai Khola area.



Text-figure 3—Diagramatic representation of four types of elements in the present assemblage of Surai Khola, western Nepal.

and conglomerates, the basal sediments assigned to Bankas Formation have yielded a variety of leaves preserved in shaly horizons. The fossil leaves belong to the genera *Polyalthia, Dipterocarpus, Cynometra, Millettia, Koompassia, Albizia, Anthocephalus, Cleistanthus, Mallotus, Phyllanthus* and *Ficus*. These include broad leaved evergreen trees of top canopy, like *Polyalthia, Dipterocarpus, Cynometra, Koompassia, Anthocephalus* and *Ficus* and the understorey are represented by small trees or shrubs like *Randia, Cleistanthus* and *Phyllanthus*. The corresponding modern species of these genera are distributed in the tropical evergreen to semi-evergreen forests of Indo-Malayan region (Table 1). Thus it is evident that the area was under the domain of luxuriant tropical evergreen lowland vegetation with higher rainfall. Occurrence of algal-remains, such as *Botryococcus, Pediastrum, Zygnema* and *Mougeotia* (Awasthi *et al.*, 1994) suggests that the area must had been occupied by large water bodies, like lakes, swamps and floodplains which created excessive humid conditions for luxuriant growth of evergreen taxa.

The next phase of floral development and diversification in the area during Siwalik can be understood from the assemblage of Chor Khola Formation (Middle Siwalik). It can be conveniently divided into two, the Lower Member and the Upper Member.

From the lower member diverse angiospermous plants belonging to *Mitrephora, Goniothalamus, Flacourtia, Garcinia, Calophyllum, Dipterocarpus, Zanthoxylum, Harpullia, Millettia, Entada, Syzygium, Randia, Wrightia* and *Excoecaria* have been recovered. Besides, other genera which are found in the Bankas beds must have also continued to grow, though they are missing at the site from which the above taxa have been recorded. The floral assemblage of the upper member also consists of tropical elements dominated by evergreen taxa indicating no significant changes in the floristics and climate (Text-figure 2). However, high incidence of aquatic plants like *Typha, Nymphaea, Azolla, Ceratopteris,* etc., depicts increase in precipitation and humidity during the deposition of Chor Khola sediments. It is important to note that the Chor Khola Formation represents the time of maximum diversity of the tropical vegetation in the Himalayan foot-hill zone as well as in the peninsular India. By this time a large number of evergreen to semi-evergreen taxa from tropical Africa and Southeast Asia had already entered the tropical forests of the Indian subcontinent.

The next and the last formation which has yielded a variety of leaf-impressions is Surai Khola Formation. This formation can also be conveniently divided into lower and upper members. The lower member is represented by Kaila Khola beds, which are well exposed along the upstream of Kaila Khola on the road. The beds are rich in leaf-impressions, preserved on thinly laminated dark-grey shales which are generally soft and fragile due to coarsening of the sediments. Since the venation patterns of many leaves is not clearly discernible it could not be possible to identify them with the extant taxa. However, the identified leaves belong to the genera : *Caryota, Bouea, Mangifera, Gluta, Swintonia, Entada, Pongamia, Terminalia* and *Myristica*. The evergreen arboreal taxa still continue to dominate over others. The assemblage, however, shows the absence of *Dipterocarpus*, a member of typical evergreen rain forest of Indo-Malayan region. This clearly indicates the beginning of the major changes in the vegetation pattern and climate (Text-figure 2). The other evergreen taxa of the Kaila Khola assemblage do occur in the moist deciduous forest.

The upper member (part) of the Surai Khola Formation is represented by the beds exposed just before and after Surai Khola Bridge. These beds before the bridge have yielded a large number of leaf-impressions, out of which a few could be identified with the leaves of *Clinogyne grandis* (monocot), *Flacourtia ramnotchii, Millettia cubithii, Bauhinia malabarica, B. variegata, Diospyros kaki* and *Breynia rhamnoides*. These are distributed in the moist deciduous to dry deciduous forest of Indo-Malayan region. A thorough examination of all the remaining fossil specimens collected from the beds of Surai Khola Formation exposed just before and after Surai Khola Bridge did not reveal the presence of any dipterocarps and other elements of tropical evergreen forest.

Regarding the orogenic movement of the Himalaya, the generally accepted view is that the fourth phase of the Himalayan uplift started at the end of Pliocene and ended in Pleistocene, which coincides with disappearance of dipterocarps and associated tropical evergreen plants as indicated by the megafossil assemblage of the Surai Khola Formation. The uplift of the Himalaya brought about significant changes in the physiography and climate. The latter became drier and cool perhaps with distinct summer and winter seasons which caused radical changes in the floristic scenario of the region.

The Dobatta Formation is very poor in plant-remains; although a few grass-like herbaceous plants could be noticed in the sandy clay beds exposed in front of Dobatta tea shop. However, the microfossils recovered from Dobatta beds indicate the existence of upland communities dominated by pinaceous taxa followed by deciduous taxa, like members of Poaceae, Malvaceae, Fabaceae, etc. Among other plant groups, the pteridophytes dominating the assemblage are represented by Cyatheaceae, Parkeriaceae, Schizaeaceae and Polypodiaceae (Sarkar, 1990). The pollen of pinaceous taxa might have blown from the higher reaches in the north suggesting that cool and dry climate had already set during Upper Siwalik.

The Dhan Khola beds also show the absence of plant megafossils. However, the palynofossils recovered from the clays within the conglomerate beds suggest the dominance of the members of Arecaceae, Malvaceae, and variety of herbaceous

plants of which Poaceae and Asteraceae were most dominant (Awasthi *et al.*, 1994).

Shifting of vegetation pattern from tropical evergreen, moist deciduous and dry deciduous forest during Surai Khola Formation to grassland vegetation during Dobatta Formation essentially led to progressive increase mammalean population which is evident from their fossil record (Corvinus, 1994). This is strongly supported by carbon and oxygen isotopic analysis of Siwalik palaeosol from Surai Khola sequence (Quade *et al.*, 1995). According to Quade *et al.* (1995) "the carbon isotopic composition of both soil carbonate and organic matter shifts dramatically starting ca 7.0 Ma, marking the displacement of largely C3 vegetation, i.e., evergreen to moist deciduous forest by C4 grassland". The C4 grass is considered as the chief food for most of the Pliocene-Pleistocene animals.

The lack of carbonised woods and fossil leaves in the sediments of Dobatta Formation and younger beds may perhaps be explained by the dominance of trees only outside the main axis of fluvial deposition (Quade *et al.*, 1995).

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