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Plant fossils from Arung Khola and Binai Khola formations of Churia Group (Siwalik), west central Nepal and their palaeoecological and phytogeographical significance

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ABSTRACT

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Systematic study of plant megafossils comprising dicotyledonous leaves and seeds collected from the Arung Khola and Binai Khola formations of the Churia Group, exposed in Tinau Khola and Mahendra Highway between Barghat and Dumkibas, Nepal, has revealed 15 taxa out of which 14 are new belonging to 14 genera of 12 families. They are named as *Orophea siwalika* sp. nov., *Miliusa brochidodroma* sp. nov. (Annonaceae); *Gynocardia butwalensis* sp. nov. (Flacourtiaceae); *Shorea miocenica* sp. nov., *S. nepalensis* sp. nov., *Hopea siwalika* Antal & Awasthi (Dipterocarpaceae); *Grewia mallotophylla* sp. nov. (Tiliaceae); *Chisocheton ellipticus* sp. nov., *Ventilago ovatus* sp. nov. (Rubiaceae), *Swintonia butwalensis* sp. nov. (Anacardiaceae), *Mitragyna tertiara* sp. nov., *Mussaendopsis suborbiculatus* sp. nov. (Rubiaceae); *Alangium nepalensis* sp. nov. (Alangiaceae); *Homonoia lanceolata* sp. nov. (Euphorbiaceae) and *Ficus miocenicus* sp. nov. (Moraceae). The modern counterparts of these fossils are mostly distributed in the tropical evergreen to semi-evergreen forests of Indo-Malayan region which indicate the existence of similar type of forests in the frontal Himalayan foot-hill zone during Middle Miocene-Pliocene. Absence of tropical evergreen dipterocarps and their associates in the present day flora of this region reflects changes in the annual mean temperature and rainfall caused by further uplift of the Himalaya and northward movement of the Indian Plate.

Key-words—Fossil leaves, Angiosperms, Churia (Siwalik) Group, Middle-Upper Miocene, Nepal.

सारांश

पश्चिम-मध्य नेपाल के चूड़िया समूह (शिवालिक) अवस्थित अरुंगखोला तथा बिनाईखोला शैल समूहों से प्राप्त पादपाश्मों का पुरापर्यावरणीय एवं पादपभूगोलीय महत्व

एम. कोनोमात्सु एवं नीलाम्बर अवस्थी

नेपाल के वड़घाट एवं दुमकीवास नामक स्थानों के वीच स्थित तिनाऊखोला तथा महेन्द्र राजमार्ग से अनावरित चूड़िया समूह के अरुंगखोला एवं विनाईखोला शैल समूहों से संग्रहीत गुरूपादपाश्म पादपों का व्यवस्थित अध्ययन किया गया। इन गुरुपादपाश्म पादपों में द्विवीजपत्री पत्तियाँ तथा वीज पाए गए, जिनमें 15 वर्गक प्रदर्शित हैं, इनमें से 14 अपेक्षाकृत नए हैं, जो 12 कुलों के 14 वंशों से सम्वन्ध रखते हैं। इनके नाम-*ओरोफ़िया शिवालिका* नवप्रजाति,

मिलीयूसा ब्रोकीडोड्रोमा नवप्रजाति, (एनोनेसी), *गाइनोकार्डिया बुटवालेन्सिस* नवप्रजाति (फ्लैकोर्टिएसी), *शोरिया मायोसीनिया* नवप्रजाति, *शोरिया नेपालेन्सिस* नवप्रजाति, *होपियाशिवालिका* अन्तल एवं अवस्थी (डिप्टेरोकार्पेसी), *ग्रीविया मैलोटोफाइला* नवप्रजाति, (टीलिएसी), *चाइसोकिटॉन इलिप्टिकस* नवप्रजाति, (मीलिएसी), *वेन्टिलेगो ओवेटस* नवप्रजाति, (रैमेनेसी), *स्विन्टोनिया बुटवालेन्सिस* नवप्रजाति, (एनाकार्डियेसी), *मित्रेगाइना टर्शियरा* नवप्रजाति, *मुसैन्डॉप्सिस सबआर्बिकुलेटस* नवप्रजाति, (रूबिएसी), *एलैन्जियम नेपालेन्सिस* नवप्रजाति, (एलैन्जिएसी), *होमोनोइया लेन्सियोलेटा* नवप्रजाति, (यूफ़ोर्बिएसी) तथा *फ़ाइकस मायोसीनिकस* नवप्रजाति, (मोरेसी) हैं। इन पादपाश्मों के प्रतिरूप मुख्य रूप से भारत के मलाया क्षेत्र के कटिबन्धीय सदाबहारी से लेकर अर्द्धसदाबहारी वनों में वितरित हैं, जिनसे मध्य मायोसीन-प्लायोसीन युग के दौरान अग्र हिमालयी पाद पहाड़ी क्षेत्र में इसी प्रकार के वनों की विद्यमानता का संकेत मिलता है। इस क्षेत्र के वर्तमान वनस्पतिजात में उष्ण कटिबन्धीय सदाबहारी डिप्टेरोकार्प्स तथा इनके सहयोगियों की अनुपस्थिति से हिमालय के और अधिक उच्चावचन होने तथा भारतीय प्लेट के उत्तरवर्ती दिशा में खिसकने के कारण वार्षिक औसत तापमान एवं वर्षा में परिवर्तन प्रदर्शित हुआ हैं।

INTRODUCTION

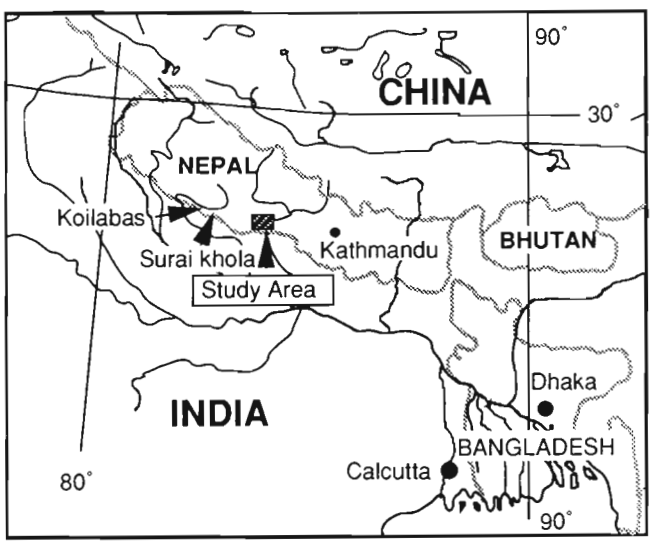
THE Neogene sediments of the Siwalik Group are widely distributed along the southern Frontal Hills of the Himalaya. In Nepal they are generally known as the Churia Group after the Churia Hills (Tokuoka *et al.*, 1986). The Churia Group is very rich in plant-remains, the leaves being most dominant among them. In order to reconstruct the floristic patterns and climatic conditions of the Middle Miocene-Pleistocene time, systematic study of plant fossils of the Churia (Siwalik) Group of Nepal has been undertaken by Awasthi & Prasad (1990), Prasad & Awasthi (1996) and Prasad (1990a, b) from the Surai Khola and Koilabas, West Nepal who identified a large number of fossils in terms of extant genera and species from the Surai Khola and Koilabas, Western Nepal. However, considering wide extent of the Siwalik (Churia) sediments and the amount of plant material preserved therein the number of taxa recognised so far is still small which represents only a small part of the Siwalik flora. Therefore, identification and documentation of more and more taxa from different localities and areas of the known stratigraphic sequence are of utmost importance for precisely reconstructing the floristics and climate through the Siwalik succession.

Another important aspect of extensive study of plant fossils of the Siwalik (Churia) Group is to assess the magnitude of diversification and proliferation of tropical angiosperms in the northern part of peninsular and the extra peninsular regions of the Indian subcontinent with the advent of African and Malaysian elements.

The present authors have initiated the morphotaxonomic study of plant megafossils from the west central Nepal. In their previous study, Konomatsu & Awasthi (1996) have recorded a few significant genera, viz., *Clinogyne, Bambusa, Dipterocarpus, Calophyllum, Ziziphus, Bauhinia* and *Cinnamomum* from the Arung Khola Formation, exposed in Tinau Khola and Jhumsa Khola near Butwal and from the Binai Khola Formation along Mahendra Highway between Barghat and Dumkibas, Nepal (Text-figures 1, 2).

GEOLOGICAL SETTING

The Siwalik (Churia) sediments of Arung Khola and Tinau Khola area west central Nepal lie between the Main Boundary Thrust (MBT) to the north and the Frontal Churia Thrust (FCT) to the south, and are separated by Central Churia Thrust (CCT) (Text-figure 2). It consists of about 6000 m thick fluvial deposits, dominated by mudstones, siltstones, sandstones and conglomerate. The Group exhibits a gradual coarsening upward in the sequence, reflecting the rise of the Himalaya. Detailed work on geological mapping, lithostratigraphy, sedimentology and magnetostratigraphy of the Churia (Siwalik) Group of Arung Khola and Binai Khola area Nepal, has been carried out by Tokuoka *et al.* (1986, 1988, 1990).



Text-figure 1— Index map of the study area.

Lithostratigraphically the Churia Group is divided into Arung Khola Formation, Binai Khola Formation, Chitwan Formation and Deorali Formation in ascending order (Tokuoka *et al.*, 1986, 1988, 1990). The former two are further divided into Arung Khola lower (Al), Arung Khoal middle (Am), Arung Khola upper (Au); Binai Khola lower (Bl), Binai Khola middle (Bm) and Binai Khola upper (Bu). Magnetostratigraphically, the Al and Am members are correlated with the Chinji zone (lower half of Middle Siwalik including Chron 9). The Binai Khola Formation corresponds mostly to the Dhok Pathan zone (upper half of Middle Siwalik) and Tatrot zone (lower half of Upper Siwalik) which ranges from Chron 8 to the Gilbert Reversed Polarity Chron. The Chitwan Formation is correlatable to the Pinjor zone (upper half of Upper Siwalik), and the Deorali Formation to the Boulder Conglomerate (Text-figure 3). Of these, the Arung Khola and Binai Khola formations are highly fossiliferous consisting of mostly leaves and occasionally flowers, fruits/seeds and carbonised woods. They are mostly preserved in the mudstones, claystones and calcareous sandstones as impressions and compressions with poorly preserved fragile cuticles.

MATERIAL AND METHOD

The material for the present study was collected from Tinau Khola and Jhumsa Khola (a tributary of Tinau river near Butwal), Mahendra Highway between Barghat and Dumkibas and from Arung Khola, west central Nepal. The terminology used in describing fossil leaves is after Hickey (1973) and Dilcher (1974). The identification was done by comparing them with the herbarium sheets at the Central National Herbarium, Howrah, India. All the type and duplicate specimens are deposited in the Museum, Birbal Sahni Institute of Palaeobotany, Lucknow.

SYSTEMATICS

Family—ANNONACEAE

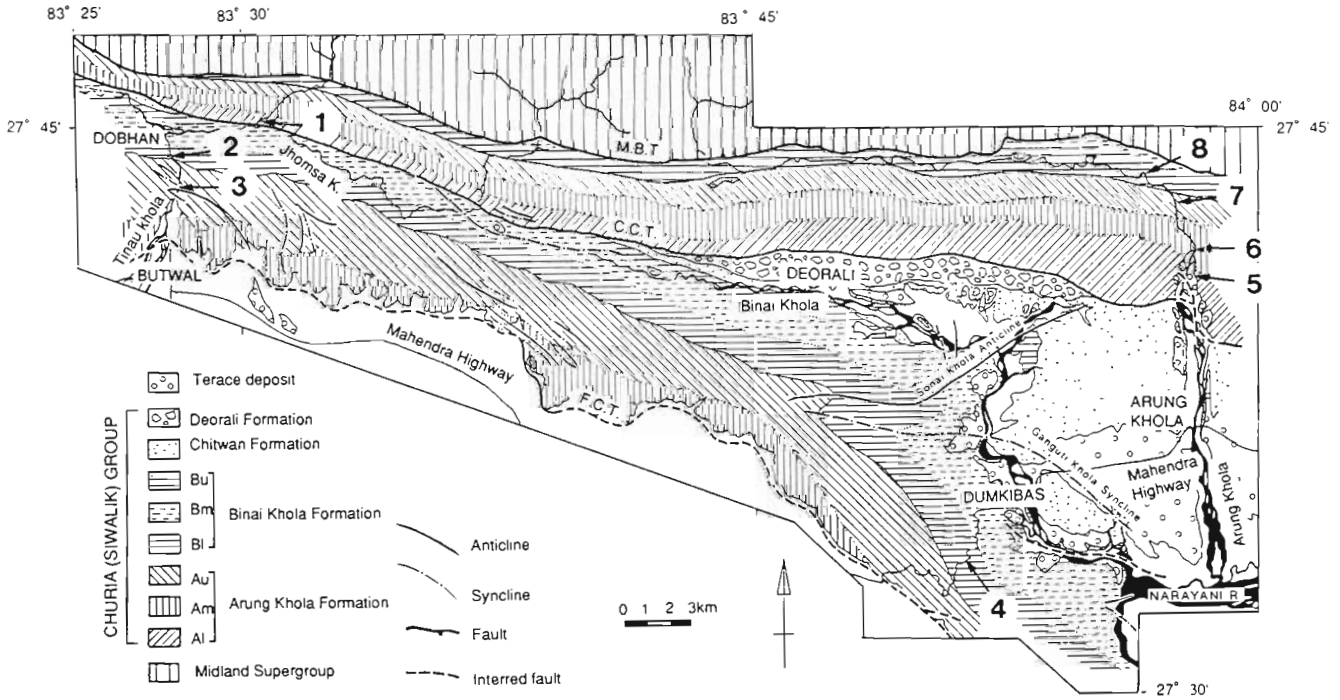
Genus—OROPHEA BL.

OROPHEA SIWALIKA sp. nov.

Pl. 1, figs 5-7

The species is represented by two specimens, of which one is with counterpart.

Description—Leaves simple, symmetrical, narrow elliptic, the bigger and complete one about 9.0 cm in length and 3.5 cm in width; apex acute; base obtuse; margin entire; texture coriaceous; petiole not preserved; venation pinnate, primary vein straight, moderately thick; secondary veins 5 pairs, alternate to subopposite, angle of divergence 45°-50°, prominent, moderately thick, uniformly curving and joining with superadjacent secondaries forming marginal loop; intersecondary veins not seen; tertiary veins present, angle of origin seemingly RR, pattern percurrent, straight, relation with



Text-figure 2—Geological map of the Arung Khola area, west central Nepal (Tokuoka *et al.*, 1990), showing plant fossil localities (1-8).

midvein oblique with constant angle; further details not clearly discernible.

Holotype—Specimen no. BSIP 37676.

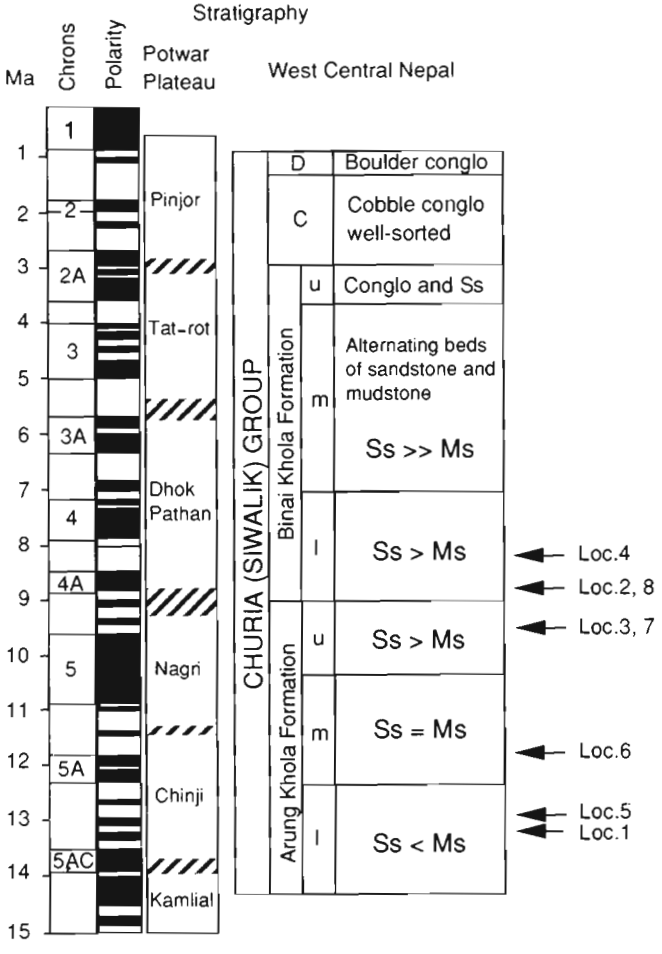
Paratype—Specimen no. BSIP 37677.

Locality—Tinau Khola near Butwal, Nepal (Loc. 1).

Horizon—Al Member.

Age—Middle Miocene.

Discussion—From their shape, size and venation pattern the fossil leaves appear very similar to those of *Orophea* of Annonaceae and *Pterospermum* of Sterculiaceae, but more so with the former. Leaves of *Pterospermum*, though resembling in many features, differ in having basal pairs of secondary veins given off from a single point, i.e. they are opposite, whereas in the fossil as well as in *Orophea* they are alternate to sub-opposite. Among the species of *Orophea*, leaves of *O. uniflora* and *O. polycarpa* A.D. (C.N.H., Sibpur, Howrah Sheet no. 5709) show close similarity with our fossil leaves.



Text-figure 3— Stratigraphic position of fossiliferous horizons with the standard polarity time scale (Cande & Kent, 1992) of Churia Group correlated with the Potwar plateau of Pakistan.

Orophea Bl. is a genus of small tree of shrubs. *O. uniflora* Hook. f. & Thoms, is a middle-sized tree occurring in Western Ghats from Coorg to Travancore. *Orophea polycarpa*, which also resembles the fossil leaves, is found in Andamans, Martaban and Tennasserim (Brandis, 1971).

Genus — MILIUSA Lesch ex A.DC.

MILIUSA BROCHIDODROMA sp. nov.

Pl. 1, fig. 3

There are six well preserved specimens representing the fossil species.

Description—Leaves simple, symmetrical, elliptic, one of the leaves 6.8 x 3.2 cm in length and width; apex acute; base obtuse; margin entire; texture chartaceous to subcoriaceous; petiole very small; venation pinnate; simple, brochidodromous; primary vein prominent, moderately thick, straight; secondary veins 8 pairs, alternate, angle of divergence about 60°, prominent, moderately thick, uniformly curved; intersecondary vein one, seemingly simple; tertiary veins visible at some places, angle of divergence seemingly OR, pattern percurrent, further details not seen.

Holotype—Specimen no. BSIP 37678.

Locality—Arung Khola, Nepal (Loc. 7).

Horizon—Au Member.

Age—Upper Miocene.

Discussion—Brochidodromous venation pattern is the most characteristic feature of the fossil leaves described above. Taking into consideration a combination of other morphographic features as described above the fossil leaves resemble those of *Miliusa* in general and *M. roxburghiana* Hook. f.T. in particular of the family Annonaceae.

Miliusa roburgliana is a tree occurring in the sub-Himalayan tract in Sikkim, ascending to 700 m, Assam, Chittagong Hills and Myanmar.

Owing to their close similarity with the leaves of *Miliusa*, the fossil leaves are assigned to it and named *Miliusa brochidodroma* sp. nov. The specific name indicates brochidodromous venation pattern of the fossil leaves.

Family—FLACOURTIACEAE

Genus—GYNOCARDIA R. Br.

GYNOCARDIA BUTWALENSIS sp. nov.

Pl. 1, fig. 1

The leaf is represented by a single specimen with counterpart.

Description—Leaf simple, symmetrical, elliptic, almost complete, 13.5 x 6.5 cm in length and width; apex acute; base

seemingly acute; margin entire; texture subcoriaceous; petiolar part broken; venation eucamptodromous to brochidodromous; primary vein moderately thick, straight; secondary veins 6-7 pairs, alternate, angle of divergence about 60°-65°, curving upward and joining with superadjacent secondary veins; intersecondary veins present, many; tertiary veins present, arising from secondary veins as well as from primary vein, those arising from primary vein numerous, their angle of divergence almost 90°, running straight and joining with those of other tertiary veins arising from secondaries as well, angle of origin of tertiary veins from secondaries OA, random, reticulate, relation with midveins perpendicular or straight to somewhat oblique; further details not discernible.

Holotype—Specimen no. BSIP 37680.

Locality—Tinau Khola near Butwal Nepal (Loc. 1).

Horizon—Al. Member.

Age—Middle Miocene.

Discussion — In its shape, size, texture and venation pattern the fossil leaf resembles those of *Gynocardia odorata* of the family Flacourtiaceae. Its closeness with this extant taxon can be seen in the venation pattern. In addition to intersecondary veins, the tertiary veins arising from midvein are numerous, extending straight and joining with those of superadjacent secondaries (Pl. 1, fig. 1) which is a characteristic feature of the leaves of *Gynocardia orodata.*

Gynocardia orodata R.Br. is a large evergreen tree occurring in the sub-Himalayan tract, ascending to 1300 m from Sikkim eastward, Khasi Hills, Chittagong, Myanmar (Brandis, 1991).

The fossil leaf is named *Gynocardia butwalensis* sp. nov. the specific name is after Butwal town in Nepal.

Family—DIPTEROCARPACEAE

Genus—SHOREA Roxb. & Gaertn.

SHOREA MIOCENICA sp. nov.

Pl. 2, fig. 3

There are four specimens of leaf-impressions representing this species.

Description—Leaves simple, symmetrical, very narrow to narrow elliptic, biggest one (Pl. 2, fig. 3) about 12 cm in length and 3.5 cm in width, apex not discernible; base seemingly acute; margin entire; texture subcoriaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein prominent, stout, straight; secondary veins about 20 visible in the preserved part, might have been 2 to 4 more in the basal and apical portion, each 6 mm apart, angle of divergence 50°-60°, alternate to sub-opposite, running almost straight and then turning upward before terminating at the margin; intersecondary veins absent; tertiary veins percurrent, angle of origin RR, simple, unbranched to occasionally forked, sometimes curving before joining the superadjacent secondary veins, relationship to midvein oblique, further details not seen.

Holotype—Specimen no. BSIP 37681.

Paratype—Specimen no. BSIP 37682.

Locality—Tinau Khola, near Butwal, Nepal (Loc. 3).

Horizon—Al Member.

Age—Middle Miocene.

Discussion — In shape, size and venation patterns together with other morphological features the fossil leaves clearly show affinities with those of the extant *Shorea* of the family Dipterocarpaceae. Since the leaves of *Dipterocarpus* are mostly large to very large, they need not to be referred to *Dipterocarpus* for comparison.

After going through the herbarium sheets of a large number of species of *Shorea* it was observed that the leaves of *Shorea* do show considerable variation in shape and size and in number of secondary veins. However, considering further the above morphological details, the fossil leaves show close resemblance with *Shorea sericea* (C.N.H. sheet no. 21784) and also to some extant with *S. macroptera* and *S. rigida.*

Two fossil leaves assigned to the genus *Shorea* are so far known from Cenozoic rocks of the Indian subcontinent. They are *Shorea siwalika* Antal & Awasthi (1993) from the Siwalik sediments of north Bengal and *Shorea robusta* Roxb. Bande & Srivastava (1990) from the late Tertiary (probably Pleistocene-Holocene) sediments of Mahuadanr, Palamu District, Bihar. These are comparable to the leaves of *Shorea assamica* and *Shorea robusta* respectively. In shape, size and in the number of secondary veins our fossil leaves are quite different from the known species and therefore they are being placed under a new species, *Shorea miocenica.*

Shorea sericea Dyer occurs in the evergreen forest of Malaya, Borneo and Malacca.

SHOREA NEPALENSIS sp. nov.

Pl. 2, figs 4, 5

This species is represented by three specimens.

Description — Leaves simple, symmetrical, elliptic, two of them 5.5 x 2.3 cm-5.0 x 2.4 cm in length and width; apex acute; margin entire; texture subcoriaceous; petiole present in one specimen, about 2.0 mm in length; venation pinnate; eucamptodromous; primary vein prominent, straight, secondary veins about 14-15 pairs, angle of divergence moderate, 50°-60°, moderately thick, uniformly curving upward, unbranched; tertiary veins fine angle of origin RR, seemingly percurrent, further details not discernible.

Holotype—Specimen no. BSIP 37683.

Paratype—Specimen no. BSIP 37684.

Locality—Mahendra Highway between Barghat and Dumkibas, Nepal (Loc.4).

Horizon—Bl Member.

Age—Upper Miocene.

Discussion—The general features of fossil leaves suggest their affinities with those of the family Dipterocarpaceae. On critical examination the most favourable comparison is noticeable with the leaves of *Shorea lamellosa* and *S. leprosula*, especially in shape, size, texture and venation pattern, although the leaves of the former are slightly bigger. In shape, size and number of secondary veins they are also comparable to the leaves of *Anisoptera curtisii*, but markedly differ in the absence of marginal loop.

Since these fossil leaves are different from the known species, they are being assigned to a new species, *Shorea nepalensis*. The specific name is after Nepal from where the fossil material was collected.

Shorea leprosula Miq. is a tall tree of 50-60 m. high, about 1 m with buttresses. It is distributed in Sumatra and Borneo (Ridley, 1922).

Genus—HOPEA Roxb.

HOPEA SIWALIKA Antal & Awasthi

Pl. 2, fig. 1

There is one specimen representing the species from Nepal.

Description—Leaf simple, slightly symmetrical, narrow elliptic to oblong, length 14.2 cm and maximum width 3.8 cm, one side of the midrib slightly more in width than the other; apex acute; base acute to obtuse; margin entire; texture subcoriaceous; petiole small, preserved length about 5 mm; venation pinnate, simple, eucamptodromous; primary vein prominent, thick in the lower half and gradually thinning toward apex, moderately stout, markedly curved; secondary veins 9 pairs visible, alternate, fine in thickness, angle of divergence 50°-60°, basal two pairs narrow, acute, uniformly curving upward and seemingly forming marginal loop with superadjacent secondary veins through cross veins; intersecondary veins present, faint and not easily recognisable; tertiary veins faint, angle of origin seemingly right angle (RR), percurrent to orthogonal reticulate, relationship with midvein oblique, further details not discernible.

Paratype—Specimen no. BSIP 37685.

Locality—Mahendra Highway between Barghat and Dumkibas (Loc. 4).

Horizon—Bl Member.

Age—Upper Miocene.

Discussion—The fossil leaf is characterised by narrow elliptic to oblong shape with midvein markedly curved and the lamina of one side of the midvein slightly wider than the other. Although the tertiary and quaternary veins are not so well preserved, and venation pattern the fossil leaf appears very similar to that of *Hopea wightiana* Wall. It has been found that the leaves of this species show wide range of variation in size and shape but their venation pattern and curvaturing of midvein remain unchanged. The curvaturing of midvein is one of the most important features of *H. wightiana*.

There is a single record of fossil leaf of *Hopea*, i.e. *H. siwalika*, by Antal & Awasthi (1993) from the Siwalik sediments of Darjeeling foot-hills, India. Although this leaf is much smaller in size, but in shape, venation pattern and coarse of midrib it is more or less similar to our fossil leaf. Moreover, both the fossil leaves are comparable to different specimens of the same extant species, *Hopea wightiana*. Therefore it is being assigned to *Hopea siwalika* Antal & Awasthi.

Hopea wightiana is a tree occurring in the evergreen forests at the foot of Western Ghats from North Kanara southward, often gregarious, covering large tracts in the low country of South Kanara (Brandis, 1971).

Family—TILIACEAE

Genus—GREWIA L.

GREWIA MALLOTOPHYLLA sp. nov.

Pl. 3, fig. 7

This species is based on a single specimen.

Description—Leaf simple, incomplete, apical and marginal parts broken, symmetrical, seemingly ovate to elliptic, preserved length and width 9.0 x 6.0 cm; apex not preserved; base probably obtuse margin not clearly discernible; texture chartaceous; petiole not preserved; venation pinnate, acrodromous, two strongly developed secondary veins arising from a single point at the base, secondary veins arising from midrib at acute angle, about 45°-50°, only two pairs

PLATE 1 →

(All photographs are of natural size unless otherwise mentioned)

1. *Gynocardia butwalensis* sp. nov., Specimen no. BSIP 37680.
2. *Gynocardia odorata*, showing similarity with fossil leaf (C.N.H., Howrah Specimen no. 512).
3. *Miliusa brochidodroma* sp. nov., Specimen no. BSIP 37678.
4. *Miliusa roxburghiana*, showing similarity with fossil leaf.
5, 6, 7. *Orophea siwalika* sp. nov., Specimen nos. BSIP 37676-37677a b.

PLATE 1

present in the available part; tertiary veins arising almost at right angles from midvein as well as from secondary veins, convex, percurrent, forked, relation to midvein perpendicular; quaternary veins thin, orthogonal.

Holotype—Specimen no. BSIP 37686.

Locality—Arung Khola (Loc. 7).

Horizon—Au Member.

Age—Upper Miocene.

Discussion—The above features of the fossil leaf are met with in the leaves of *Grewia* of Tiliaceae. Among *Grewia* it shows resemblance with a number of species, namely *Grewia laevigata, G. tiliaefolia, G. microcos* and *G. umbellata* (C.N.H., sheet no. 161767). In the venation pattern it is also comparable to some extent with *Mallotus philippense* of Euphorbiaceae. Since the fossil leaf is slightly incomplete and further morphological details of the apical part are not available to arrive at definite conclusion as to which of the species of *Grewia* it resembles most. Since it also shows some resemblance with the leaves of *Mallotus philippense,* we prefer to name it as *Grewia mallotophylla* sp. nov..

The above species of *Grewia* with which the fossil leaf resembles are generally small trees, distributed in India and Southeast Asia in the evergreen forests. *Mallotus philippense* Muell. is widely distributed in tropical to subtropical regions of India, Southeast Asia, Australia and China, mostly in evergreen and moist deciduous forests (Brandis, 1971).

Family—MELIACEAE

Genus—CHISOCHETON Bl.

CHISOCHETON ELLIPTICUS sp. nov.

Pl. 3, figs 1-4s

This species is represented by 4 specimens.

Description—Leaves simple, symmetrical, narrow elliptic to very narrow elliptic, preserved length of bigger leaf 11.2 cm and width 3.0 cm; apex broken; base acute to slightly inequilateral; margin entire; texture subcoriaceous; petiole not preserved; venation pinnate, eucamptodromous, primary vein prominent, stout, straight; secondary veins 12 pairs visible, angles of divergence about 70°-80°, almost uniform, alternate to sub-opposite, moderate in thickness, unbranched, uniformly curving upward and joining with superadjacent secondaries forming marginal loop; intersecondary veins many, arising at right angle, straight, simple; tertiary veins present, angle of origin RO, percurrent to random reticulate, relation with midvein oblique.

Holotype—Specimen no. BSIP 37687.

Paratype—Specimen no. BSIP 37688.

Locality—Tinau Khola near Butwal (Loc. 3).

Horizon—Au Member.

Age—Upper Miocene.

Discussion—The fossil leaves are characterised by narrow elliptic shape with 11-12 secondary veins arising at an angle of about 80°-85° and numerous intersecondary veins arising at right angles, running straight and joining with the tertiary veins. In these features the fossil specimens closely resemble the leaves of *Chisocheton*, particularly *C. patens* Bl. and to some extent *C. divergence* BC. of the family Meliaceae (C.N.H., sheet no. 79990).

Among the known fossil leaves of Meliaceae, no such leaf has been described so far. Therefore these fossil leaves are being assigned to a new species, *Chisocheton ellipticus*. The specific name indicates the narrow elliptic shape of leaves.

FAMILY—RHAMNACEAE

GENUS—VENTILAGO Gaerthn.

VENTILAGO OVATUS sp. nov.

Pl. 4, fig. 1

There is a single specimen representing the species.

Description—Leaf simple, symmetrical, narrow ovate, preserved length and width 9.5 x 4.2 cm; apex acute; base seemingly obtuse; margin entire or serrate, serration not discernible; texture subcoriaceous; petiole missing; venation pinnate, eucamptodromous, primary vein moderately thick, straight; secondary veins 6 pairs, alternate, angle of divergence 45°-60°, upper secondaries more acute; intersecondaries not visible; tertiary veins not clearly seen.

Holotype—Specimen no. BSIP 37689.

Locality—Mahendra Highway between Barghat and Dumkibas.

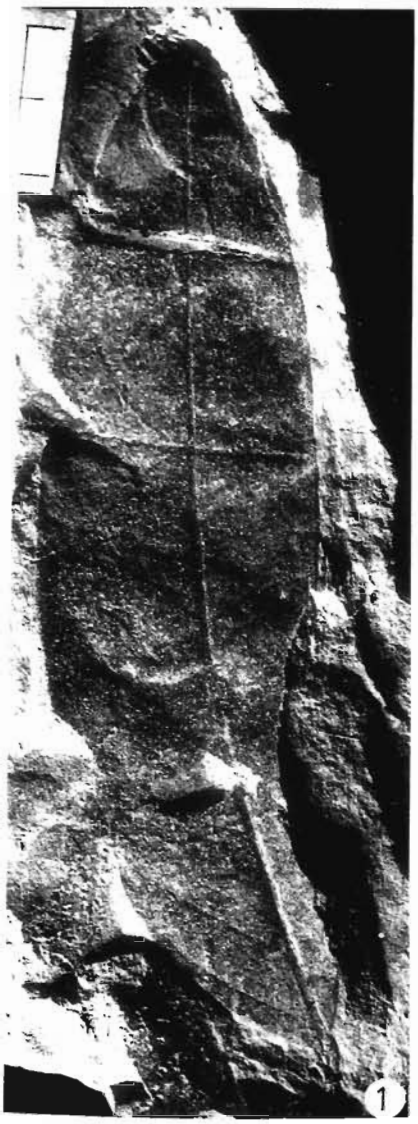
Horizon—Bl Member.

Age—Upper Miocene.

PLATE 2 ⟶

(All photographs are of natural size unless otherwise mentioned)

1 *Hopea siwalika* Antal & Awasthi, Specimen no. BSIP 37685.
2. *Hopea wightiana,* showing similarity in shape and venation pattern with fossil leaf.
3. *Shorea miocenica* sp. nov. Specimen no. BSIP 37686.
4, 5. *Shorea nepalensis* sp. nov. Specimen no. BSIP 37683, 37684.
6, 7. *Shorea lamellosa* and *Shorea leprosula,* showing similarity with fossil leaves.



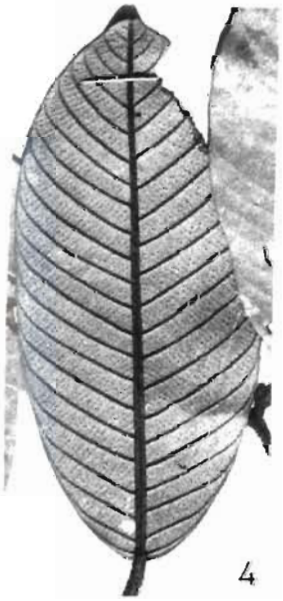


PLATE 2

Discussion—Although the tertiary veins and further details of venation pattern are not clearly visible due to bad preservation, in its shape, size and number of secondary veins and their angle of divergence, the fossil leaf appears very similar to the leaves produced by *Ventilago calyculata* of the family Rhamnaceae.

There is no record of fossil leaves comparable to *Ventilago*, therefore, present fossil specimen is named *Ventilago ovatus* sp. nov., the specific name signifies ovate shape of the leaf.

Ventilago calyculata Tul. is found in the sub-Himalayan tract from Jamuna eastward, Nepal, Bihar, Central Assam and Myanmar in evergreen to moist deciduous forests.

Family—ANACARDIACEAE

Genus—SWINTONIA Griff.

SWINTONIA BUTWALENSIS sp. nov.

Pl. 4, figs 3, 6

The species is based on a leaf impression and a seed collected from the same locality.

Description—Leaf simple, symmetrical, narrow elliptic, 11.5 cm in length and 4.3 cm in width; apex broken; base normal, acute; margin entire; texture coriaceous; petiole not preserved; venation pinnate, simple, eucamptodromous; primary vein prominent, stout, markedly curved, secondary veins 12 pairs, alternate to opposite and sub-opposite, angle of divergence 60°-80°, upper secondaries more acute than the lower, moderately thick, course curved, uniformly forming marginal loop with superadjacent secondary veins through cross veins, intersecondary veins present, 1-2, simple; tertiary veins present, angle of origin AO, percurrent to random reticulate, further details not seen.

Fruit—(Pl. 4, fig. 6) represented by a prominent wing, seemingly drupe, subtended by enlarged petal, about 2.0 cm, with longitudinally fine nerves, irregularly intersected by prominent cross lines.

Holotype—Specimen no. BSIP 37690a, b.

Locality—Tinau Khola, near Butwal, Nepal.

Horizon—Arung Khola Formation.

Age—Middle Miocene.

Discussion - In its shape, size, venation pattern and texture, the fossil leaf is comparable to those of *Swintonia* and *Mangifera* of the family Anacardiaceae. Critical examination of the venation pattern and other morphological details revealed that the fossil leaf is closer to *Swintonia* compare to *Mangifera*. The secondary veins in fossil leaf are mostly opposite to sub-opposite which may be considered as a characteristic feature of the leaves of *Swintonia schenckii* as well of *S. floribunda*. However, in the nature and course of tertiary veins it is more closer to *S. schenckii* (Pl. 4 fig. 4). Thus it combines the characters of leaves of both the extant species of *Swintonia*. The fruit is also closely comparable to those of *S. floribunda* and *S. schenckii*.

As far as the authors are aware there is only a single record of fossil leaf of *Swintonia, Swintonia miocenica*, described by Awasthi & Prasad (1990) from the Siwalik sediments of Surai Khola area, Nepal. Although this fossil leaf is shown to resemble that of *S. floribunda*, the same species with which the present fossil leaf is also comparable, the latter is somewhat different in the nature and course of the tertiary veins and in other minor characters. Therefore, the present fossil leaf is assigned to a new species, *Swintonia butwalensis*.

Swintonia schenckii T. et B. frequently occurs in the tropical forest of Martaban down to Tenasserim in Myanmar. *S. floribunda* is found in Chittagong and also in Myanmar. It is common in Tenasserim.

Family—RUBIACEAE

Genus—MITRAGYNA Korth.

MITRAGYNA TERTIARA sp. nov.

Pl. 6, fig. 5

This species is based on a single specimen.

Description—Leaf simple, symmetrical, narrow obovate, 9.0 cm in length and 4.5 cm in width, apex broken, seemingly obtuse; base obtuse; margin entire; texture chartaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein prominent, moderate in thickness, straight; secondary veins 9 pairs visible, might have been 1 or 2 more in the apical portion, angle of divergence acute 30°-40°, alternate to sub-opposite, running almost straight or slightly recurved been moderate in thickness; intersecondary veins not visible; tertiary veins thin, angle of origin seemingly AA to RR.

Holotype—Specimen no. BSIP 37691.

Locality—Tinau Khola, near Butwal, Nepal (Loc. 3).

Horizon—Au Member.

Age—Upper Miocene.

PLATE 3 →

(All photographs are of natural size unless otherwise mentioned)

1-4. *Chisocheton ellipticus* sp. nov. Specimen no. BSIP 37687, 37688a, b, c.
5, 6. *Chisocheton patens* Bl., showing similarity with fossil leaves.
7. *Grewia mallotophylla* sp. nov. Specimen no. BSIP 37686.
8. *Grewia umbellata* (C.N.H. Sheet no. 161767) showing resemblance with fossil leaf.

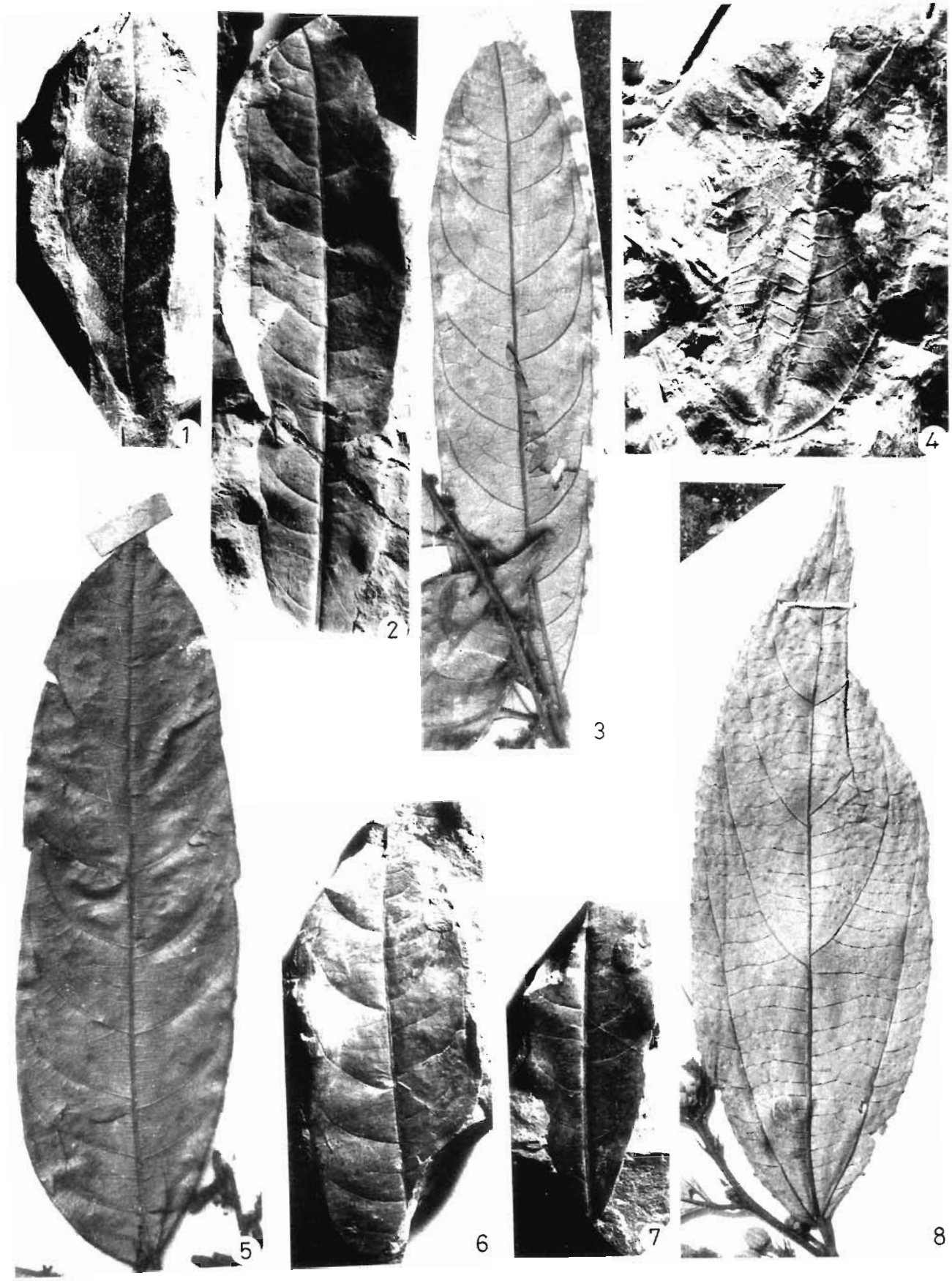


PLATE 3

Discussion—In shape, size, number and angle of divergence of secondary veins and their course, the fossil leaf appears very similar to the medium-sized leaves of *Mitragyna parvifolia* belonging to the family Rubiaceae. In this context it may be mentioned that the leaves of this species vary in size from small to large, i.e., they are about 2.0-18.0 cm in length and 2.0-10.0 cm in width, without much noticeable difference in the venation pattern.

As far as the authors are aware there is no record of fossil leaves of *Mitragyna*. The fossil leaf is therefore placed under a new species, *Mitragyna tertiara*.

The genus *Mitragyna* Korth. consists of 12 species, distributed in tropical Africa and Asia (Willis, 1977), *Mitragyna parvifolia* Korth. with which the fossil leaf resembles is a large deciduous tree, often irregularly shaped and butteressed. It is found in the foot-hills of North-West Himalaya from the Beas eastwards, ascending to 1,300 m, Bihar, central India and Myanmar, common in both peninsulas, often gregarious, particularly in moist places (Brandis, 1971).

Genus — MUSSAENDOPSIS Baill.

MUSSAENDOPSIS SUBORBICULATUS sp. nov.

Pl. 5, figs 1, 2

This species is represented by two specimens.

Description—Leaves simple, symmetrical, seemingly wide elliptic to suborbicular, about 14 cm in length and 10 cm in width; apex obtuse or mucronate; base broken; margin entire; texture coriaceous, petiole broken; venation pinnate, eucamptodromous; primary vein thicker, straight; secondary veins 6-7 pairs visible, alternate, angle of divergence of lower secondaries 60° and upper pairs 45°-50°, moderately thick, uniformly curving up towards margin, unbranched; 1 to 3, intersecondary veins visible in the apical parts angle of origin of tertiary veins AA to AO, seemingly percurrent, simple, unbranched, relation with midvein oblique, higher order of venation not discernible.

Holotype—Specimen no. BSIP 37692.

Paratype—Specimen no. BSIP 37693.

Locality—Mahendra Highway between Barghat and Dumkibas, Nepal (Loc. 4).

Horizon—BI Member.

Age—Upper Miocene.

Discussion—Wide elliptic to suborbiculate shape with coriaceous texture and 6-7 secondary eucamptodromous veins are the characteristic features of the fossil leaves, which suggest their affinity with those of *Mussaendopsis* of the family Rubiaceae. *Mussaendopsis baccariana* Baill., the only species available for comparative study, shows close resemblance with our fossil leaves. The only difference between the two is that the fossil leaves are slightly smaller and less orbicular. This could be due to variation which is commonly observed among the leaves of the same species.

Because of their resemblance with the leaves of *Mussaendopsis*, the fossil leaves are assigned to it and named *Mussaendopsis suborbiculatus* sp. nov. The specific name denotes the sub-orbiculate shape of the leaves.

The genus *Mussaendopsis* Baill. consists of only two species, distributed in west Malaysia (Willis, 1976). *M. baccariana* Baill. is a big glabrous tree occurring in the evergreen forest in Malaysia, Borneo and Sumatra (Rindley, 1923).

Family — ALANGIACEAE

Genus — ALANGIUM Lam.

ALANGIUM NEPALENSIS sp. nov.

Pl. 6, fig. 1

There are two specimens representing this species, the one is more or less complete except the apical portion.

Description—Leaf simple, pinnate asymmetrical, seemingly narrow elliptic, preserved length about 10.0 cm in length and 4.0 cm in width; apex broken; base inequilateral, one side slightly bigger; margin entire; texture chartaceous to subcoriaceous; petiole small; venation pinnate, seemingly brochidodromous, primary vein prominent, moderate in thickness, straight; secondary veins 5 pairs visible, basal pair arising alternately just above the petiolar point and each running upward up to 2/3 of lamina leaving a distance of 5 mm from the margin, angle of divergence 45°-60°, moderately thick, curving upward and joining superadjacent secondary veins forming marginal loop; intersecondary veins well developed, many, simple, arising at right angles from midvein, running straight or slightly zig-zag towards right and joining tertiary veins arising from the secondaries, angle of origin of tertiary veins and intersecondary veins AO to RO, percurrent, straight to forked, relation to midvein oblique, unbranched; quaternary veins thin, randomly oriented to orthogonal; marginal ultimate veins looped.

PLATE 4 →

(All photographs are of natural size unless otherwise mentioned)

1. *Ventilago ovatus* sp. nov. Specimen no. BSIP 37689.
2. *Ventilago calyculata* Tulasue, showing similarity with fossil leaf.
3. *Swintonia butwalensis* sp. nov. Specimen no. BSIP 37690a.
4. *Swintonia schenckii* to show general similarity with fossil leaf.
5. *Swintonia floribunda* to show general similarity with fossil leaf.
6. A part of fossil fruit resembling that of *Schenckii* x 4, sp. nov. Specimen no. BSIP 37690b.

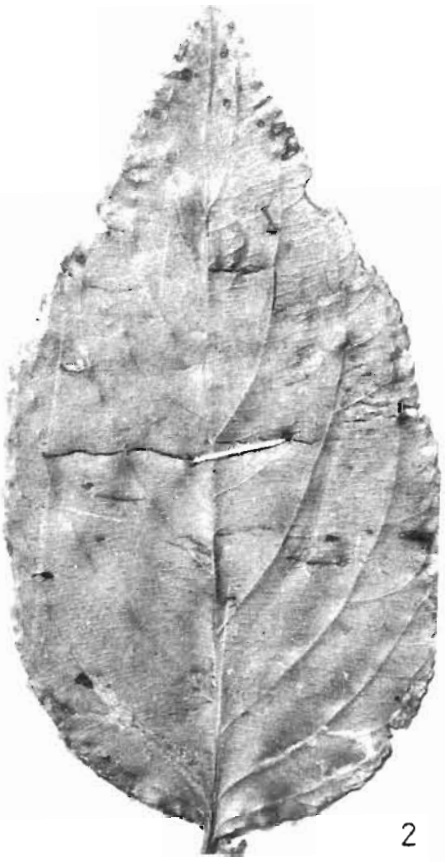


PLATE 4

Holotype—Specimen no. BSIP 37694.

Locality—Tinau Khola, near Butwal, Nepal (Loc. 2).

Horizon—Bl Member.

Age—Upper Miocene.

Discussion—The most important character of the fossil leaves is that the venation is brochidodromous, two pairs of secondary veins arising at the base alternately and running upward up to 2/3 lamina, leaving a distance of about 5 mm from margin and joining with those of tertiary veins given off by upper pairs of secondary veins and forming prominent loop. Besides, marginal loop is also formed by the tertiary veins given off by the two secondary veins in the 2/3 basal part. There are many intersecondary veins arising from the primary veins at right angle. Taking all these features into consideration, the fossil leaves show close similarity with those produced by *Alangium* in general and *A. salvifolium* var. *hexapetalum* (Pascal & Ramesh, 1987; p. 71, p. 1, fig. 1) in particular.

Since our fossil leaves are different from the known species, they are being placed under a new species, *Alangium nepalensis*. The specific name indicates its occurrence in Nepal.

Alangium salvifolium is a small tree found in the sub-Himalayan tract of Uttar Pradesh and Gangetic plains, central India and western peninsula (Brandis, 1971).

Family — EUPHORBIACEAE

Genus — HOMONOIA Lour.

HOMONOIA LANCEOLATA sp. nov.

Pl. 6, figs 2, 3

Homonoia cf. *H. riparia* auct. non Lour., Prasad 1994.

There are five specimens representing the species.

Description—Leaves simple, symmetrical, linear to lanceolate, the complete one smaller, measuring 7.0 x 0.8 cm in length and width; the incomplete one bigger, about 9.2 x 1.5 cm; apex acute; base acute; margin entire, slightly upturned; texture sub-coriaceous; petiole seemingly short; venation pinnate, eucamptodromous; primary vein prominent, massive in thickness, gently decreasing towards apex, straight; secondary veins numerous, alternate to sub-opposite, angle of divergence about 45°-60° fine, uniformly curving upward forming marginal loop with superadjacent secondary veins through cross veins; intersecondary veins present, 1-2; tertiary veins present, angle of origin seemingly AO, reticulate pattern, further details not seen.

Holotype—Specimen no. BSIP 37695.

Paratype—BSIP Museum no. 37696.

Locality—Tinau Khola, near Butwal, Nepal (Loc. 3).

Horizon—Au Member.

Age—Upper Miocene.

Discussion—The most important character of fossil leaves is that they are linear to lanceolate in shape and eucamptodromous in venation pattern with numerous secondary veins. Leaves having such characters are met with in the genus *Homonoia* of Euphorbiaceae. From a careful examination of the leaves of *Homonoia* it was found that there is close similarity between fossil leaves and those of *H. riparia* Lour. Hence the fossil leaves are placed under the genus *Homonoia* and named *H. lanceolata* sp. nov. Regarding fossil record of *Homonoia* (Prasad, 1994) reported a leaf as *Homonoia* cf. *H. riparia* Lour. from Middle Siwalik sediments near Hardwar, India. This fossil leaf is not different from ours. Therefore it is also being placed under *H. lanceolata*.

Homonoia riparia Lour. is an evergreen gregarious shrub in the rocky and stony river beds and is distributed in the foothills of Sikkim, Assam, Khasi Hills, Upper and Lower Myanmar, Bihar, central India, western peninsular India, Sri Lanka, Malay Peninsula and Archipelago and China (Brandis, 1971).

Family — MORACEAE

Genus — FICUS Linn.

FICUS MIOCENICUS sp. nov.

Pl. 6, fig. 7

This species is based on one specimen.

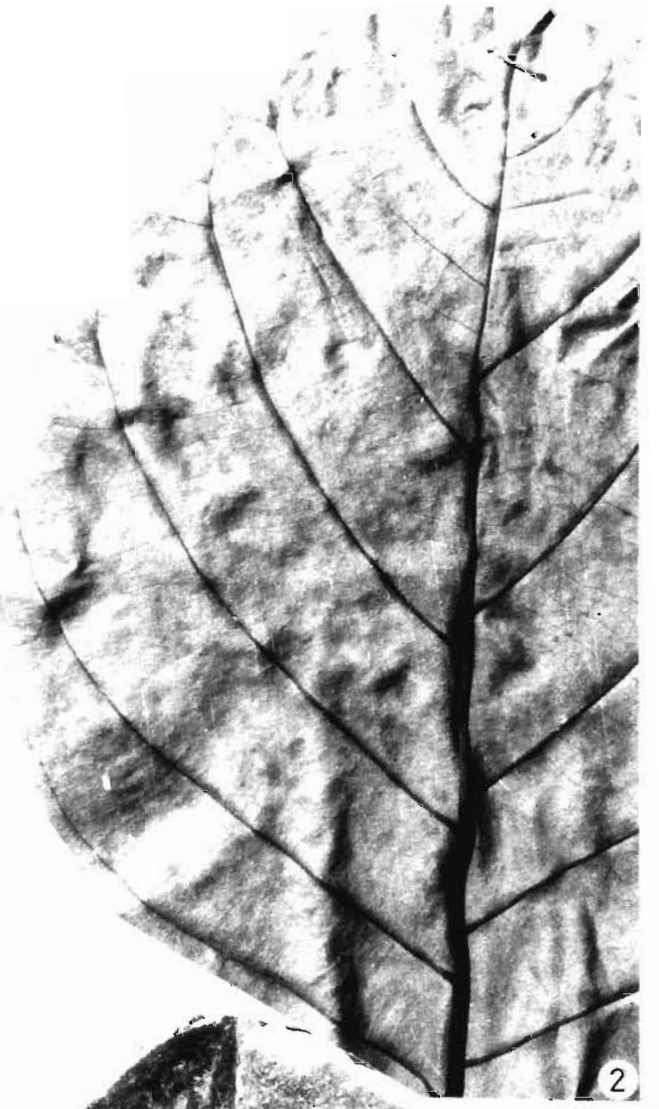
Description—Leaf simple, symmetrical, elliptic, 14.5 x 7.7 cm in length and width; apex obtuse; base obtuse, margin entire; texture coriaceous; petiolar portion missing; venation pinnate, eucamptodromus; primary vein prominent, massive at the base and gradually turning to moderate towards apex, straight; secondary veins 7-8 pairs, alternate, angle of divergence about 45° a pair of basal secondaries arising from a single point (opposite) and running straight and forming marginal loop with superadjacent secondary veins through cross veins; tertiary veins occasionally visible, angle of origin seemingly OA, weakly percurrent, further details not visible.

PLATE 5 →

(All photographs are of natural size unless otherwise mentioned)

1, 2. *Mussaendopsis sub-orbiculatus* sp. nov. Specimen no. BSIP 37692-93.

3, 4. *Mussaendopsis baccariana* Baill. (CNH Sheet no. 198620) showing general similarity with the fossil leaf.



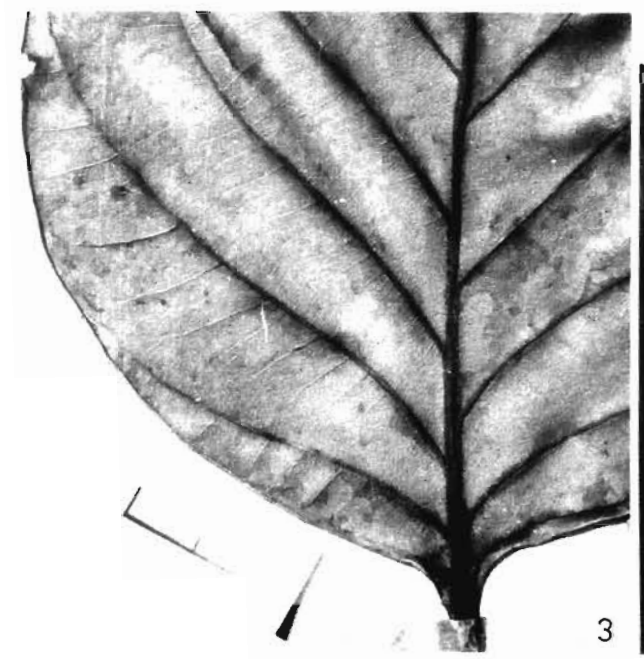


PLATE 5

Holotype—Specimen no. BSIP 37697.

Locality—Mahendra Highway between Barghat and Dumkibas, Nepal (Loc. 4).

Horizon—Bl Member.

Age—Upper Miocene.

Discussion—In its shape, size, texture and secondary venation pattern, the fossil leaf shows resemblance with those of *Ficus bengalensis* Linn., *F. tomentosa* Roxb. and *F. callosa* Willd. Since the tertiary and quaternary venation pattern is not clearly discernible, it is rather difficult from a solitary specimen to suggest which of these species could be the nearest modern equivalent of the fossil. However, from its shape, size and venation pattern the possibility of its being closer to *Ficus bengalensis* cannot be ruled out.

Although there are a number of fossil leaves assigned to the genus *Ficus* from the Indian Tertiary sediments (see Antal & Awasthi, 1993), the present fossil leaf being typically a *Ficus* - like, differs from all the known species in their shape, size and venation pattern. Therefore, it is described as a new species of *Ficus, Ficus miocenica*, the specific name indicates Miocene age of the fossil leaf.

Ficus bengalensis Linn. is a large tree, indigenous in the sub-Himalayan Tract and western peninsula, commonly planted in the forest of the Western Coast and Ghats from Konkan southward. In Travancore, it is common up to 1,000 m, and also occurs in Andamans, Myanmar, Sri Lanka, central India, western peninsula, Bihar and Chota Nagpur (Brandis, 1971).

GENERAL DISCUSSION

Floristic Composition, Palaeoecology and Phytogeography—

Out of a large number of fossil leaves studied from Arung Khola and Binai Khola formations of the Siwalik (Churia) Group, west central Nepal, 22 species of angiosperms belonging to 21 genera of 16 families have been identified (Table 1). Of these the genera *Orophea, Gynocardia, Ventilago, Mussaendopsis, Miliusa, Chisocheton* and *Mitragyna* are new to the Siwalik (Churia) flora. The floral assemblage shows overall dominance of Dipterocarpaceae with three genera, viz., *Dipterocarpus, Shorea* and *Hopea,* already identified from this area. The other genera of the assemblage which are also known from other localities of Siwalik (Churia) of India and Nepal include *Calophyllum, Grewia, Ziziphus, Swintonia, Bauhinia, Cinnamomum, Homonoia, Bambusa, Clinogyne* (Awasthi, 1992; Awasthi & Prasad, 1990; Prasad & Awasthi, 1996; Antal & Awasthi, 1993; Konomatsu & Awasthi, 1996). The extant species comparable to the Churia fossils are mostly distributed in the tropical evergreen to semi-evergreen forests of Western Ghats, northeast India, Andaman and Nicobar Islands, Myanmar and Malayan region, and a few of them still continue to occur in the sub-Himalayan tract, mostly in the valleys and along the river banks (Table 1). From the distribution pattern of its components, it is evident that the flora of Arung Khola and Binai Khola formations flourished under tropical climate with very warm and humid conditions during the Miocene.

In its composition and the type of forest indicated, the floral assemblage is not much different from those of other localities of the Siwalik (Awasthi; 1992; Antal & Awasthi, 1993) although it includes some new tropical evergreen and moist deciduous taxa, viz., *Gynocardia, Orophea, Miliusa, Chisocheton, Ventilago, Mitragyna* and *Mussaendopsis*. These genera further strengthen the above palaeoclimatic interpretation of the flora.

From the distribution of modern equivalent species of fossils in the Indo-Malayan region and the climate they indicate (Table 1) it may be inferred that the physical conditions controlling the distribution pattern of plant remained nearly equable throughout the Himalayan frontal zone during laying down of the Arung Khola and Binai Khola sediments. Owing to several water bodies, such as lakes, swamps and rivers occupying vast area in the region, excessive humid condition seems to have prevailed all along favouring maximum development and proliferation of evergreen mesophytic lowland and tropical vegetation. Further, the climatic conditions became so conducive that the tropical evergreen families, migrated to the Indian subcontinent (Awasthi, 1992; Guleria, 1992). The genus *Mussaendopsis* of Rubiaceae, *Orophea, Chisocheton patens* and *Swintonia* which have been recovered from Arung Khola and Binai Khola sediments are among other probable migrants of Southeast Asian origin.

The periodic orogeny of the Himalayan ranges continued to change the climatic, geomorphologic and ecological conditions, thus adversely affecting the vegetational dynamics especially of the extra-peninsular region. Consequently, the tropical conditions started disappearing from all over during the upper part of the Middle Siwalik, i.e., Middle Binai Khola Formation. Evidence to this effect is provided by the

PLATE 6 →

(All photographs are of natural size unless otherwise mentioned)

1. *Alangium nepalensis* sp. nov. Specimen no. BSIP 37694.
2, 3. *Homonoia lanceolata* sp. nov. Specimen no. BSIP 37695-96.
4. *Homonoia riparia* Lour. showing similarity with fossil leaves.
5. *Mitragyna tertiara* sp. nov. Specimen no. BSIP 37691.
6. *Mitragyna parvifolia* showing similarity with fossil leaves.
7. *Ficus miocenicus* sp. nov. Specimen no. BSIP 37697.

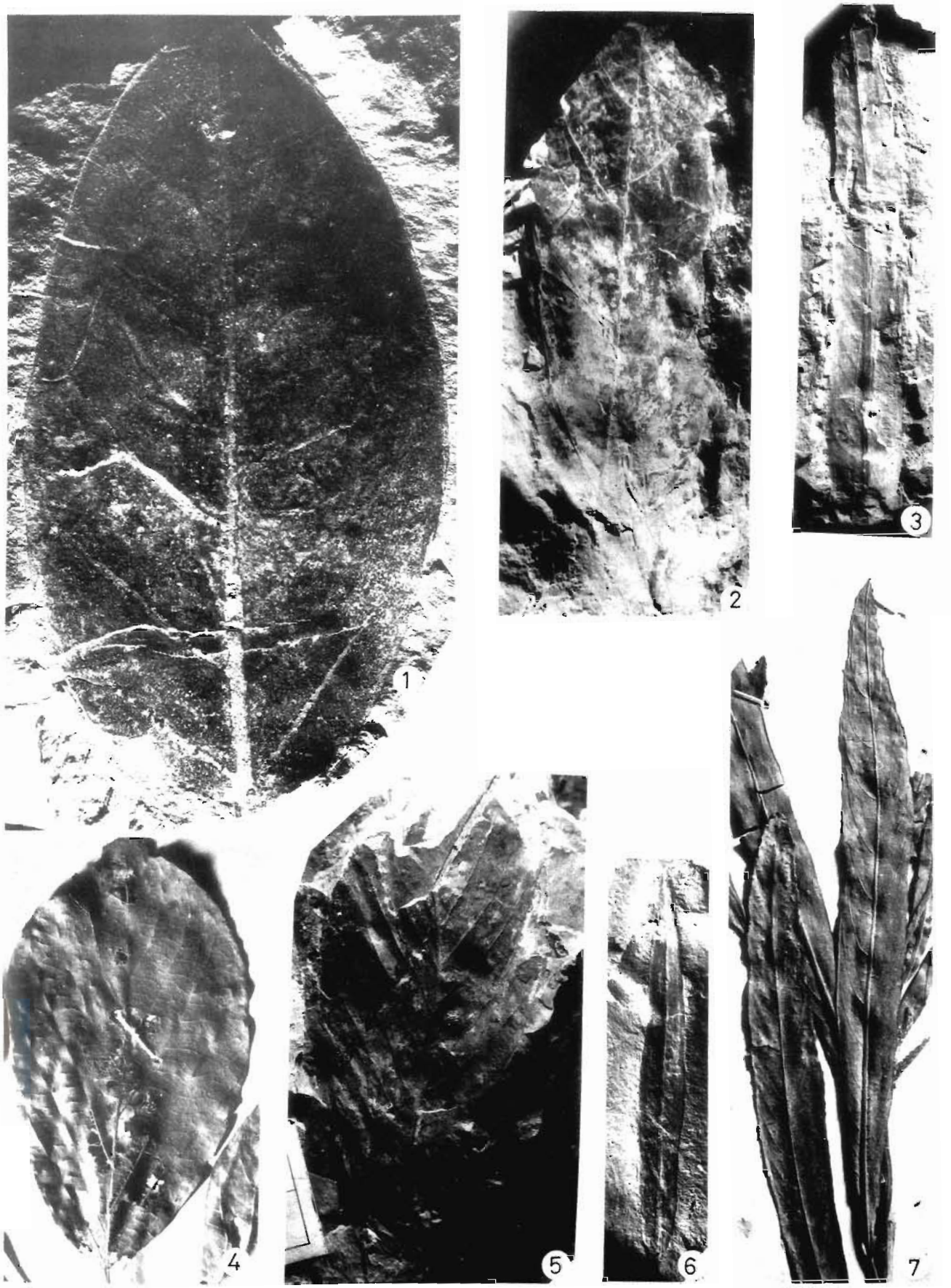


PLATE 6

Table 1—Churia (Siwalik) plant fossils from Tinau-Khola, Binai Khola and Arung Khola, west central Nepal

NAME OF FORMATION		Name of fossil	Family	Comparable extant species	Distribution of extant species	Type of forest
DEORALI		—	—	—	—	—
CHITWAN		—	—	—	—	—
CHURIA (SIWALIK) GROUP — BINAI KHOLA FORMATION	UPPER	—	—	—	—	—
	MIDDLE	—	—	—	—	—
	LOWER	*Shorea nepalensis* sp. nov.	Dipterocarpaceae	*Shorea lamellosa, S. leprosula*	Malayan region	Tropical evergreen
		Hopea siwalika Antal & Awasthi	-do-	*Hopea wightiana*	Western Ghats	Tropical evergreen
		Ventilago ovatus sp. nov.	Rhamnaceae	*Ventilago calyculata*	Sub-Himalayan tract and Myanmar	Evergreen to moist deciduous
		**Ziziphus siwalicus* Lakhanpal	-do-	*Ziziphus xylopyrus, Z. incurva*	India and Myanmar	Tropical semi-evergreen to moist deciduous
		**Bauhinia siwalika* Lakhanpal & Awasthi	Fabaceae	*Bauhinia* spp.	Sub-Himalayan tract and Western Ghats	Tropical evergreen
		**Cinnamomum palaeotamala* Lakhanpal & Awasthi	Lauraceae	*Cinnamomum tamala*	Indo-Malayan region	Tropical evergreen
		Mussaendopsis sub-orbiculatus sp. nov.	Rubiaceae	*Mussaendopsis baccariana*	Malayan region	Tropical evergreen to moist deciduous
		Alangium nepalensis sp. nov.	Alangiaceae	*Algangium salvifolium*	Sub-Himalayan tract	Tropical evergreen to deciduous
		Ficus miocenicus sp. nov.	Moraceae	*Ficus bengalensis, F. tomentosa,*	Sub-Himalayan tract	Tropical evergreen to deciduous
				F. callosa	Indo-Malayan region	Tropical evergreen
		Miliusa brochidodroma sp. nov.	Annonaceae	*Miliusa roxburghiana*	sub-Himalayan region	Tropical evergreen
		**Dipterocarpus siwalicus* Lakhanpal & Guleria	Dipterocarpaceae	*D. tuberculatus, D. turbinatus*	Northeast India Myanmar, Thailand.	Tropical evergreen
		**Calophyllum* sp.	Clusiaceae	*Calophyllum* spp.	Indo-Malayan region	Tropical evergreen
		Grewia mallotophylla sp. nov.	Tiliaceae	*Grewia umbellata, G. tiliaefolia G. microcos*	Indo-Malayan region	Tropical evergreen
		Chisocheton ellipticus sp. nov.	Meliaceae	*Chisocheton patens*	Malayan region	Tropical evergreen
		Swintonia butwalensis sp. nov.	Anacardiaceae	*Swintonia schenckii S. burmanica*	Myanmar	Tropical evergreen
		**Bauhinia siwalica* Lakhanpal & Awasthi	Fabaceae	*Bauhinia* spp.	Indo-Malayan region	Evergreen to moist deciduous
		Mitragyna tertiara sp. nov.	Rubiaceae	*Mitragyna parvifolia*	Sub-Himalayan region	Tropical moist deciduous
		Homonoia lanceolata sp. nov.	Euphorbiaceae	*Homonoia riparia*	Sub-Himalayan region	Tropical evegreen
		**Clinogyne ovatus* Awasthi & Prasad	Marantaceae	*Clinogyne grandis*	Sub-Himalayan region	Tropical moist deciduous
ARUNG KHOLA FORMATION	MIDDLE	*Swintonia butwalensis* sp. nov.	Anacardiaceae	*Swintonia schenckii*	Myanmar	Tropical evergreen
	LOWER	*Orophea siwalika* sp. nov.	Annonaceae,	*Orophea uniflora*	Western Ghats, Andamans, Myanmar	Tropical evergreen
		Gynocardia butwalensis sp. nov.	Flacourtiaceae	*Gynocardia odorata*	sub-Himalayan tract, Khasi Hills, Myanmar	Tropical evergreen
		Shorea miocenica sp. nov.	Dipterocarpaceae	*Shorea sericea*	Malayan region	Tropical evergreen
		**Ziziphus siwalicus* Lakhanpal	Rhamnaceae	*Ziziphus xylopyrus, Z. incurva*	India and Myanmar	Semi-evergreen to moist deciduous
		**Bambusa* sp.	Bambusaceae	*Bambusa* spp.	Indo-Malayan region	Evergreen to moist deciduous

Species marked with (*) reported earlier by Konomatsu & Awasthi (1996)

flora of Surai Khola succession in west Nepal. In this context, it may be mentioned here that in Surai Khola area a complete and uninterrupted sequence of the Siwalik Group, measuring about 5500 m in thickness, is exposed along Mahendra Highway between Bankas and Dhan Khola. On the basis of lithology Corvinus (1990) informally divided the whole sequence into five formations, viz., Bankas, Chor Khola, Surai Khola, Dobatta and Dhan Khola. Of these the first three formations corresponding to Arung Khola Formation and Lower Binai Khola Formation of west central Nepal (Tokuoka *et al.*, 1986) consist of deposits containing rich plant megafossils. The upper part of Surai Khola Formation which corresponds to Middle Binai Khola Formation exhibits significance change in the floristic composition. The evergreen dipterocarps and their associates which had been growing luxuriantly during the Lower and Middle Siwalik (Awasthi & Prasad, 1990; Awasthi, 1992, Awasthi *et al.*, 1994) seem to have disappeared during the middle part of the Middle Siwalik as none of them has been found in the beds of the Surai Khola Formation exposed just before and after Surai Khola bridge. The shift in the floral composition from wet evergreen and semi-evergreen to moist and dry deciduous habitats cannot be regarded a local phenomenon but seemingly occurred throughout the Himalayan foot-hills. Obviously it was due to changes in the geomorphology, temperature and climate caused by further uplift of the Himalaya and northward movement of the Indian Plate.

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