Plant megafossils from the Siwalik sediments of Koilabas, central Himalaya, Nepal and their impact on palaeoenvironment

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A systematic study on plant megafossils comprising mainly leaf-impressions from the Himalayan foot-hills near Koilabas, Nepal has been carried out. The comparative study of plant fossils with the extant taxa reveals the occurrence of 26 new species belonging to 14 dicotyledonous families. The floral assemblage suggests that tropical evergreen to moist deciduous vegetation flourished around Koilabas area during the Siwalik time. The habit and habitat of the comparable extant taxa indicate a warm humid climate all along the foot-hills during the Mio-Pliocene. The presence of a sizeable number of Indo-Malayan taxa in the present assemblage shows fair exchange of floral elements between two subcontinents and further extension towards Nepal territory. The significance of physiognomic characters of the leaf-impressions in relation to environment has also been discussed.

Key-words—Plant megafossils, Angiosperms, Morphotaxonomy, Palaeoenvironment, Siwalik, Mio-Pliocene (Nepal).

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सारांश

नेपाल में केन्द्रीय हिमालय में कोयलाबास के शिवालिक अवसादों से प्राप्त गुरुपादपाश्म तथा पुरावातावरण पर इनका प्रभाव

महेश प्रसाद

नेपाल में कोयलाबास के समीप हिमालयी गिरि-पादों से उपलब्ध गुरुपादपाश्मों मुख्यतया पर्ण-छापों का वर्गीकृत अध्ययन किया गया है। उपलब्ध अश्मित पादपों की वर्तमान वर्गकों से तुलना के आधार पर 14 द्विबीजपत्रीय कुलों से सम्बद्ध 26 नई जातियाँ प्राप्त हुई हैं जिससे यह इंगित होता है कि शिवालिक अवसादन के समय कोयलाबास के आस-पास उष्णकटिबन्धीय सदाहरित से नम पर्णपाती वनस्पति विद्यमान थी। तुलनीय वर्तमान वर्गकों के साहचर्य से भी प्रस्तावित होता है कि मध्य-अतिनूतन कल्प में गिरि-पादों में दूर-दूर तक उष्ण नम जलवायु विद्यमान थी। इस समुच्चय में भारतीय-मलाया के वर्गकों की अधिक संख्या से इन दो उपमहाद्वीपों के मध्य वनस्पतिजातीय अवयवों का विनिमय भी प्रदर्शित होता है जो कि नेपाल के क्षेत्र तक विस्तृत था। इस शोध-पत्र में वातावरण से सम्बन्धित पर्ण-छापों के लक्षणों की भी विवेचना की गई है।

THE Siwalik Formation is composed of fluviatile sediments derived from the rising Himalaya and laid down in a narrow depression formed by the mountain building processes during Middle Miocene onwards. It extends continuously all along the foot-hills of the Himalaya from western Pakistan in the west to Assam in the east covering a distance of about 2,400 km in length and 20-25 km in width. The Siwalik Formation is made up of sandstone, grits, conglomerates, pseudoconglomerates, clays and silts (Krishnan, 1982).

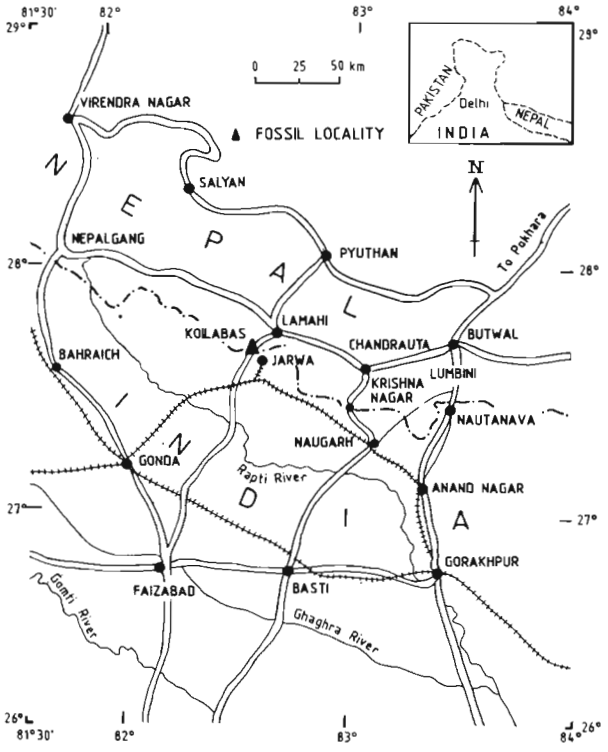
The Siwalik Formation in Nepal Himalaya often called as Churia Group (Sharma, 1977) has been studied by several geologists from time to time. Detailed lithology and stratigraphy of the Siwalik sediments of Nepal have been given by Auden (1935), Lehner (1943), Hagen (1959), Bordet (1961), Gleinnie and Ziegler (1964), Ohta and Akiba (1973), Sharma (1977, 1980), Kumar and Gupta (1981), Chaudhuri (1983), West (1984), Tokuoka *et al.* (1986, 1988) and Corvinus (1990).

The Churia Group has often been classified into two formations : (i) Lower Churia Formation (Sandstone facies), and (ii) Upper Churia Formation (Conglomerate facies; Hagen, 1959; Bordet, 1961; Gleinnie & Ziegler, 1964). However, a three fold lithostratigraphical classification of the formation in the western Nepal Himalaya has been suggested by Chaudhuri (1983). The Lower Churia Formation with an average thickness of about 1,800 m is characterized by alternate sequence of sandstones and clays. The Middle Churia Formation consists of about 2,000 m thick succession of dominantly arenaceous rocks with intercalation of clay beds. The Upper Churia Formation reaches up to 2.5 km in

thickness and is represented by fine-grained poorly indurated sandy clays in the lower part and boulder conglomerates in the upper part of the sequence. Recently, Corvinus (1990) studied the lithology of Surai Khola area in the Churia hills of western Nepal and also proposed a three-fold division representing the Lower, Middle and Upper Siwaliks.

The present fossil locality, Koilabas (27°42′ : 82°20′) is situated in the north of Terai plain in Churia hills just near Indo-Nepal border (Text-figure 1). This is one of the richest fossiliferous localities in the Himalayan foot-hills of Nepal). In this area the Lower Churia Formation is exposed in river cuttings from Koilabas Village to Darwaja and consists of fine-grained sandstones, calcareous thin limestones and variegated clays. Beyond Darwaja up to Chorkholi and onwards the rocks are supposed to be belonging to Middle Churia Formation which is predominantly arenaceous in nature (Sharma, 1977).

The Siwalik sediments are rich in petrified woods, leaf-impressions, fruits, seeds and some charophytic remains (Prakash & Tripathi, 1992; Prasad, 1993a, b, 1994b). Realizing the extent and thickness of Siwalik sediments in Nepal the plant fossil data available so far are still meagre. Nevertheless, some fossil plants, especially leaf impressions, have been studied and published (Tripathi & Tiwari, 1983; Prasad & Prakash, 1984; Prasad, 1990a, b; Awasthi & Prasad, 1990). Keeping in view the meagre work on plant fossils of Koilabas area a further survey was taken and a lot of well-preserved leaf-impressions were collected from different exposures. The detailed study on almost complete and well-preserved leaf-impressions and their comparison with extant taxa reveal that they belong to 26 species of 14 dicotyledonous families, which have been presented in this paper (Table 1).



Text-figure 1—Map showing the location of fossil locality.

MATERIAL AND METHODS

Forty six specimens of well-preserved leaf-impressions and a seed, described in this paper, were collected from Siwalik sediments of Koilabas area near Darwaja (Middle Miocene age) and Chorkholi (Mio-Pliocene age) in the Himalayan foot-hills of western Nepal. The leaf-impressions are devoid of cuticle and found to be preserved mostly in shales and a few of them on fine grained sandstones. The leaf-impressions were studied morphologically with the help of either handlens or low power microscope under reflected light. In order to identify the leaf-impressions, a number of herbarium sheets of extant taxa were examined at the herbaria of National Botanical Research Institute, Lucknow, Forest Research Institute, Dehradun and Central National Herbarium, Sibpur, Howrah. For description of leaf-impressions the terminology given by Hickey (1973) and Dilcher (1974) has been followed. The photographs of the leaves of extant species have also been provided to show similarity with fossil leaves. The specimens and their photo negatives are preserved in the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow, India under Museum Repository number 827.

SYSTEMATIC DESCRIPTION

Family—Clusiaceae

Genus—*Kayea* Wall.

Kayea kalagarhensis Prasad 1993a

Pl. 1, figs 1, 2

1993a *Kayea kalagarhensis* Prasad, p. 109, pl. 1, figs 1-4; text-fig. 2a, b, c.

Number of specimens—Four.

Description—Leaves symmetrical, very narrow elliptic, preserved size 13.0 × 3.1 cm and 10.5 × 3.2 cm; apex broken; base acute, normal; margin entire; texture coriaceous; petiole 0.3 cm long, normal; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, massive, almost straight; secondary veins (2°) about 35 pairs, with nearly right angle of divergence, angles gradually decreasing towards apex, uniformly curved up, closely spaced, opposite to alternate, rarely branched;

Table 1—A list of fossil plants from the Himalayan foot-hills of Koilabas, western Nepal

Fossil Taxa	Modern Equivalents	References
Dilleniaceae		
Dillenia palaeoindica Prasad & Prakash	*D. indica* Lnn.	Prasad & Prakash, 1984
Flacourtiaceae		
Ryparosa prekunstelri Prasad	*R. kunstelri* King	Prasad, 1990b
Clusiaceae		
Mesua tertiara Lakhanpal	*M. ferrea* Linn	Prasad, 1990b
Kayea kalagarhensis Prasad	*K. floribunda* Wall.	—
Dipterocarpaceae		
Dipterocarpus siwalicus Lakhanpal & Guleria	*D. tuberculatus* Roxb.	Prasad, 1990a
Hopea mioglabra sp. nov.	*H. glabra* W. & A.	—
Rutaceae		
Evodia koilabasensis sp. nov.	*E. fraxinifolia* Hook. f.	—
Murraya khariense Lakhanpal & Guleria	*M. paniculata* (Linn.) Jacq.	—
Atlantia miocenica sp. nov.	*A. monophylla* Corr.	—
Meliaceae		
Chloroxylon palaeoswietenia Prasad	*C. swietenia* DC.	Prasad, 1990b
Rhamnaceae		
Zizyphus miocenica Prasad	*Z. jujuba* Lam.	—
Sapindaceae		
Filicium koilabasensis sp. nov.	*F. decipiens* Thw.	—
Euphoria nepalensis sp. nov.	*E. longan* Lamk.	—
Otophora miocenica sp. nov.	*O. fruticosa* Blume	—
Sabiaceae		
Sabia eopaniculata sp. nov.	*S. paniculata* Seem.	—
Anacardiaceae		
Bouea koilabasenisis sp. nov.	*B. burmanica* Griff.	—
Tapiria chorkholiense sp. nov.	*T. hirsuta* Hook. f.	—
Mangifera someshwarica Lakhanpal & Awasthi	*M. indica* Linn.	
Fabaceae		
Albizia siwalica Prasad	*A. lebbek* Gamble	Prasad, 1990a
Cassia nepalensis Prasad	*C. hirsuta* Linn	Prasad, 1990b
C. miosiamea sp. nov.	*C. siamea* Lam.	—
C. neosophora sp. nov.	*C. sophora* Wall.	—
Dalbergia miosericea Prasad	*D. sericea* Boj.	Prasad, 1990b
D. siwalika sp. nov.	*D. sissoo* Roxb.	—
Millettia siwalica Prasad	*M. ovalifolia* Kurz.	Prasad, 1990b
M. koilabasensis Prasad	*M. macrostachya* Coll. & Hemsl.	Prasad, 1990a
M. miobrandisiana sp. nov.	*M. brandisiana* Kurz.	—
Ormosia robustoides Prasad	*O. robustoides* Jacq.	Prasad, 1990a
Samanea siwalica Prasad	*O. saman* Merr	—
Entada palaeoscandens Awasthi & Prasad	*E. scandens* Benth.	—
Combretaceae		
Anogeissus eosericea Prasad & Prakash	*A. sericea* Brandis	Prasad & Prakash, 1984
Clycopteris floribundaoides Prasad	*C. floribunda* Lam.	Prasad, 1990b
Terminalia koilabasensis Prasad	*T. angustifolia* Jacq.	Prasad, 1990b
T. siwalica Prasad	*T. pyrifolia* Kurz.	Prasad, 1990b
T. panandhroensis Lakhanpal & Guleria	*T. tomentosa* W.A.	—
Combretum sahnii Antal & Awasthi	*C. decandrum* Roxb.	—
Lythraceae		
Lagerstroemia siwalika sp. nov.	*L. lanceolata* Wall.	—
Woodfordia neofruticosa sp. nov.	*W. fruticosa* Kurz.	—
Myrtaceae		
Syzygium miocenica Prasad & Prakash	*S. claviflorum* Roxb.	Prasad & Prakash, 1984
Caprifoliaceae		
Lonicera mioquinquelocularis Prasad	*L. quinquelcularis* Hardw.	Prasad, 1990b
Rubiaceae		
Randia miowallichii Prasad	*R. wallichii* Hook. f.	Prasad, 1990b
Morinda siwalika sp. nov.	*M. umbellata* Linn.	—
Ebenaceae		
Diospyros koilabasensis Prasad	*D. montana* Roxb.	Prasad, 1990b
D. pretoposia Prasad	*D. toposia* Ham.	Prasad, 1990b

Apocynaceae		
Tabernaemontana precoronaria Prasad	*T. coronaria* Willd.	Prasad, 1990b
Carissa koilabasensis sp. nov.	*C. paucinervia* A. Dc.	—
Loganiaceae		
Gaertnera siwalica Prasad	*G. bieleri* D. Willd. E. Petit	Prasad, 1990b
Solanaceae		
Datura miocenica Prasad	*D. fastuosa* Linn.	Prasad, 1990b
Oleaceae		
Anacolosa mioluzoniensis sp. nov.	*A. luzoniensis* Merr	—
Verbenaceae		
Vitex prenegundo Prasad	*V. negundo* Linn.	Prasad, 1990b
V. siwalica Prasad	*V. pubescens* Vahl.	Prasad, 1990b
Lauraceae		
Cinnamomum mioinuctum Prasad	*C. inuctum* Meissn.	Prasad, 1990b
Moraceae		
Ficus precunia Lakhanpal	*F. cunia* Ham.	Prasad, 1990b
F. retusoides Prasad	*F. retusa* Linn.	Prasad, 1990b
F. nepalensis Prasad	*F. glaberrima* Blume	Prasad, 1990b

intersecondary veins present, simple, frequent; tertiary vein (3°) fine, angle of origin nearly RR, almost percurrent, rarely branched, oblique in relation to midvein, predominantly alternate and close.

Figured specimens—BSIP Specimen nos. 36876 and 36877; Darwaja, Koilabas, western Nepal.

Horizon and Age—Lower Siwalik, Middle Miocene.

Affinities—The important characters of the fossil leaves such as narrow elliptic shape, coriaceous texture, eucamptodromous venation and closely spaced secondaries with nearly right angle of divergence indicate their close affinity with the modern leaves of *Kayea floribunda* Wall. of Clusiaceae (Forest Research Institute, Dehradun Herbarium Sheet no. 73232; Pl. 1, fig. 3).

The present leaf-impressions are identical to *Kayea kalagarhensis* Prasad 1993a described from the Siwalik sediments of Kalagarh, Pauri Garhwal, Uttar Pradesh, India.

The modern taxon *Kayea floribunda* Wall. with which the fossils show close affinity, is a medium-sized tree growing in the forests of Sikkim, Khasi Hills, rarely in the tropical forests of Martaban Hills (Myanmar) and east of Tounghoo (Chowdhury & Ghosh, 1958).

Family—Dipterocarpaceae

Genus—*Hopea* Roxb.

Hopea mioglabra sp. nov.

Pl. 1, figs 4, 6, 7

Number of specimens—Five.

Description—Leaves symmetrical, narrow elliptic, preserved size 9.5 × 3.6 cm and 7.9 × 3.6 cm; apex and base slightly broken, seemingly acute; margin entire; texture coriaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) 8 pairs visible, angle of divergence about 60°, 0.3 to 2.5 cm apart from each other, uniformly curved up, usually alternate, unbranched; intersecondary veins sometimes present, simple; tertiary veins (3°) fine with angle of origin RR, percurrent, almost straight, rarely branched, oblique to right angle in relation to midvein, predominantly alternate, closely spaced; quaternary veins (4°) still fine, forming orthogonal to polygonal meshes.

Holotype—BSIP Specimen no. 36878, Chorkholi, Koilabas, western Nepal.

Paratype—BSIP no. 36879.

Horizon and Age—Middle Siwalik, Mio-Pliocene.

Name derivation—The specific epithet has been derived after the extant species *Hopea glabra* by adding a prefix "mio" to species name.

Affinities—The fossil leaves are characterised by its elliptic shape, acute base, coriaceous texture, predominantly alternate secondaries with about 60° angle of divergence and comparatively very fine tertiary veins with right angle of origin. These features are found in the modern leaves of *Hopea* Roxb. of the family Dipterocarpaceae. A critical examination of modern leaves of a number of species of *Hopea* indicates that the leaves of *Hopea glabra* W. & A. (Forest Research Institute, Dehradun, Herbarium Sheet no. 3606; Pl. 1, fig. 5) show closest resemblance with the fossils.

So far there is only one record of a fossil leaf—*Hopea siwalika* Antal & Awasthi 1994, resembling extant *Hopea wightiana* Wall. from the Siwalik sediments of West Bengal, India. Five fossil woods of different species of *Hopea* have also been described from the Tertiary of India. Out of them, two have been reported from the Siwalik sediments of Kalagarh, Uttar Pradesh (Prasad, 1993b). Thus the present fossil leaves have been described as a new species—*Hopea mioglabra*.

Hopea glabra W & A. is a large tree occurring all along the river banks in the Ghats of Tinnelveli and Travancore (Brandis, 1971; Gamble, 1972).

Family—Rutaceae

Genus—*Evodia* Forst.

Evodia koilabasensis sp. nov

Pl. 2, fig. 1

Number of specimen—One.

Description—Leaflet slightly asymmetrical, elliptic, preserved size 6.3 × 3.0 cm, apex broken; base nearly obtuse, slightly oblique; margin entire; texture chartaceous; petiole not preserved; venation pinnate, simple, craspedodromous; primary vein (1°) single, prominent, stout, straight; secondary veins (2°) about 11 pairs visible with acute angle of divergence (about 60°), basal pairs of secondary veins arise nearly at right angle, less than 0.2 to 1 cm apart, uniformly curved up, usually alternate, sometimes branched, intersecondary veins present, simple; tertiary veins (3°) fine, with angle of origin usually RR, percurrent, rarely branched, straight, oblique in relation to midvein, predominantly alternate, closely to distantly spaced. Further details could not be seen.

Holotype—BSIP Specimen no. 36880, Chorkholi, Koilabas, western Nepal.

Horizon and Age—Middle Siwalik, Mio-Pliocene.

Name derivation—The specific epithet is after the fossil locality Koilabas from where the specimen was collected.

Affinities—The important features of the present leaves are elliptic shape, obliquely obtuse base, craspedodromous venation and closely placed basal secondaries arising at right angle. These features are found common in the modern leaves/leaflets of *Sageraea listeri* King of the family Anonaceae. *Evodia roxburghiana*, *E. fraxinifolia* Hook. f. and *E. hypenensis* of the family Rutaceae. Of these, the leaves of *S. listeri* King differ from fossil in the nature of comparatively distantly placed basal secondaries. Among the above three species of *Evodia* the present fossil shows closest affinity with the leaflets of *E. fraxinifolia* Hook. f. (Forest Research Institute, Dehradun Herbarium Sheet no. 17346/105288; Pl. 2, fig. 2). The other two species are different from the fossil specimens in possessing a somewhat serrate margin and less angle of divergence of secondary veins.

The fossil woods of the genus *Evodia* are known from the Deccan Intertrappean beds of Nawargaon, Maharashtra, India (Bande & Prakash, 1984) and also from other parts of the world (Chiarugi, 1933; Kräusel, 1939; Madel-Angeliewa & Muller-Stoll, 1973). Thus, the present fossil leaf of *Evodia* from Siwalik sediments of Koilabas, Nepal has been reported for the first time and described as *E. koilabasensis* sp. nov.

Evodia fraxinifolia Hook. f., with which the fossil leaf shows close affinity, is a medium-sized tree distributed in the tropical forests of Khasi Hills, Meghalaya, Nepal and Malaya Peninsula (Gamble, 1972).

Genus—*Murraya* Koen ex. Linn.

Murraya khariense Lakhanpal & Guleria 1982

Pl. 1, fig. 8

1982 *Murraya khariense* Lakhanpal & Guleria, p. 280, pl. 1, figs 1, 2; text-fig., 1A, B.

Number of specimen—One.

Description—Leaflet asymmetrical , elliptic; lamina size 4.3 × 1.7 cm; apex bluntly acute; base acute, oblique; margin entire; texture seemingly coriaceous; petiole hardly visible; venation pinnate, eucamptodromous; primary vein (1°) single, stout, slightly curved; secondary veins (2°) 5-6 pairs visible with acute angle of divergence (50°-60°), moderate, alternate, uniformly curved up; further details not seen.

Figured specimen—BSIP Specimen no. 36881, Darwaja, Koilabas, western Nepal.

Horizon and Age—Lower Siwalik, Middle Miocene.

Affinities—Asymmetrical elliptic shape with oblique base, bluntly acute apex and eucamptodromous type of venation of the present fossil leaf show its resemblance with the modern leaflets of *Murraya paniculata* (Linn.) Jacq. (Forest Research Institute, Dehradun Herbarium Sheet no. 360; Pl. 1, fig. 9) of the family Rutaceae.

PLATE 1 →

(All figures are of natural size unless otherwise mentioned)

1,2. *Kayea kalagarhensis* Prasad—Fossil leaves showing shape, size and venation pattern.

3. *Kayea floribunda*—Modern leaf resembling in similar shape, size and venation pattern.

4,7 *Hopea mioglabra* sp. nov.—Fossil leaves showing shape, size and venation pattern.

5. *Hopea glabra*—A modern leaf resembling the fossil leaves in all features.

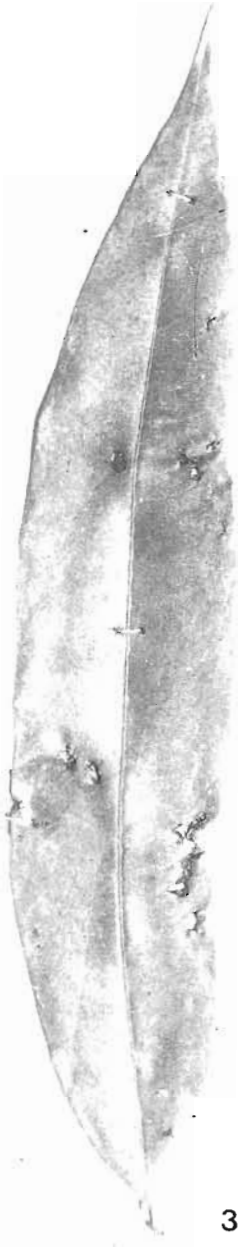
6. *Hopea mioglabra* sp. nov.—Fossil leaf magnified to show details of venation. × 2.

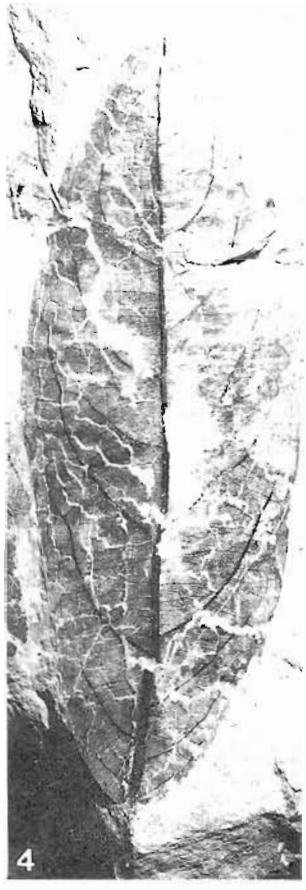
8. *Murraya paniculata* Lakhanpal & Guleria—Fossil leaflet showing similar shape, size and venation.

9. *Murraya khariense*—A modern leaflet showing similar shape, size and venation.

10. *Samanea siwalica* Prasad 1994b—Fossil leaflet showing shape, size and venation pattern.

11 *Samanea saman*—A modern leaflet showing similar shape, size and venation pattern.





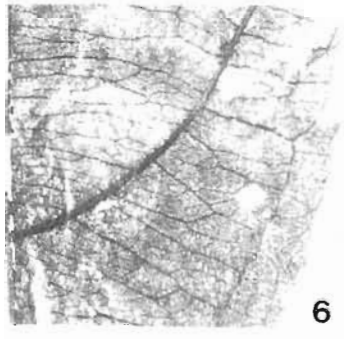


PLATE 1

A fossil leaflet of *Murraya khariense* which has already been described from the Miocene of Kutch, western India (Lakhanpal & Guleria, 1982) shows close similarity with the present fossil leaflet. Therefore. this fossil has been kept under the same species.

The extant *Murraya paniculata* (Linn.) Jacq. with which fossil shows closest affinity is a large shrub or small evergreen tree occurring from Ravi eastwards to Assam, in the lower and upper Satpura ranges, hills of peninsula, Andamans, Sri Lanka and Myanmar. It also occurs in China, Australia and the Pacific Islands (Brandis, 1971).

Genus—*Atlantia* Correa.

Atlantia miocenica sp. nov.

Pl. 7, fig. 1

Number of specimen—One.

Description—Leaflet symmetrical, elliptic, size 2.9 × 1.8 cm; apex broken; base seemingly acute; margin entire; texture chartaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein (1°) single prominent, moderate, straight; secondary veins (2°) about 16 pairs visible, less than 0.2 cm apart, closely placed, angle of divergence wide acute (about 70°), opposite to alternate, rarely branched; intersecondary veins present, simple; tertiary veins (3°) fine, with angle of origin usually RR, percurrent, sometimes forked, oblique in relation to midvein, alternate to opposite and close.

Holotype—BSIP Specimen no. 36882, Darwaja, Koilabas, western Nepal.

Horizon and Age—Lower Siwalik, Middle Miocene.

Name derivation—The specific epithet is derived from the age (Miocene) of the fossil locality.

Affinities—The important features of the present fossil are small size with elliptic shape, acute base, coriaceous texture and very closely spaced secondaries with wide acute angle of divergence. A critical examination of a number of herbarium sheets indicates that the above features are found common in the modern leaflets of *Caesalpinia nuga* Alt. of Fabaceae and *Atlantia monophylla* Correa. of Rutaceae. Of these, the former differs from the fossil in being slightly asymmetrical in shape, whereas the leaflets of the extant *Atlantia monophylla* Correa. (Central National Herbarium, Howrah Herbarium Sheet no. 21320; Pl. 7, fig. 3) show closest resemblance with the present fossil.

Fossil leaflet resembling the extant genus *Atlantia* Correa. has not been reported so far from the Tertiary of India and other places. Although, a fossil wood *Atlantioxylon indicum* is known from the Deccan Intertrappean beds of Mohgaonkalan, Mandla District, Madhya Pradesh, India. This fossil shows close similarity with the extant genera *Atlantia* and *Limonia* of the family Rutaceae (Lakhanpal *et al.*, 1978).

The extant *Atlantia monophylla* Correa. is an evergreen shrub or tree growing in Kanara, western Mysore, Nilgiris, hills of the northern Circars, the Ceded districts and the Karnataka, Sriharikota, Khasi Hills, Andamans and Myanmar (Brandis, 1971).

Family—Rhamnaceae

Genus—*Zizyphus* Juss.

Zizyphus miocenica Prasad 1994b

Pl. 3, fig. 1

1994b *Zizyphus miocenica* Prasad, pl. 5, figs 6, 7.

Number of specimens—Two.

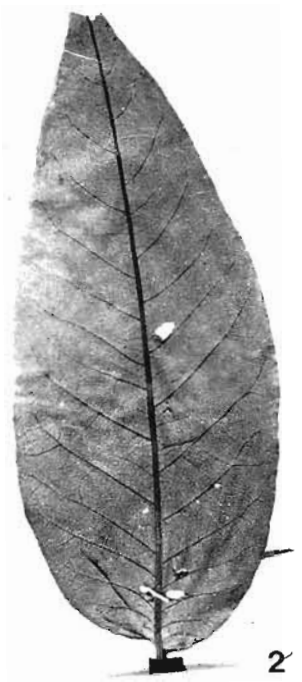
Description—Leaf symmetrical, elliptic, preserved size 2.8 × 2.0 cm and 1.5 × 1.5 cm; apex broken; base seemingly obtuse; margin entire; texture thick, chartaceous; petiole not preserved; venation pinnate, acrodromous, perfect; primary veins (1°) three, arising from the base, two lateral primaries curved up and joined to the margin; secondary veins (2°) originate from both mid primary and lateral primaries at acute (50°-60°) angle of divergence; tertiary veins (3°) fine with angle of origin nearly RR to AO, percurrent, almost straight, rarely branched, oblique to right angle (in relation) to midvein, predominantly alternate and close.

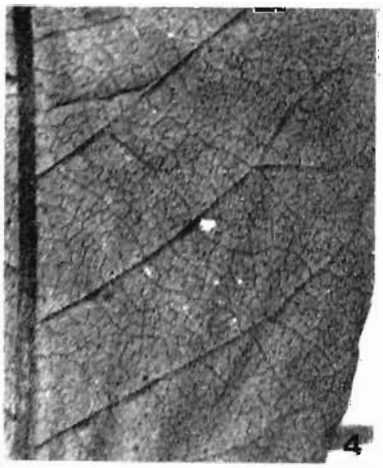
Figured specimen—BSIP no. 36883, near Koilabas Village, western Nepal.

PLATE 2 →

(All figures are of natural size unless otherwise mentioned)

1. *Evodia koilabasensis* sp. nov.—Fossil leaflet showing shape, size and venation pattern.
2. *Evodia fraxinifolia*—A modern leaflet showing similar shape, size and venation pattern.
3. *Evodia koilabasensis* sp. nov.—Fossil leaflet magnified to show details of venation, × 2.5.
4. *Evodia fraxinifolia*—A modern leaflet magnified to show similar details of venation, × 2.5.
5. *Filicium koilabasensis* sp. nov.—Fossil leaflet showing shape, size and venation.
6. *Filicium decipiens*—A modern leaflet showing similar shape, size and venation pattern.
7. *Filicium koilabasensis* sp. nov.—Fossil leaflet magnified to show details of venation, × 3.
8. *Filicium decipiens*—A modern leaflet magnified to show details of venation, × 3.
9. *Filicium koilabasensis* sp. nov.—Another fossil leaflet showing variation in shape and size.
10. *Filicium decipiens*—Another modern leaflet showing similarity with fig. 9.





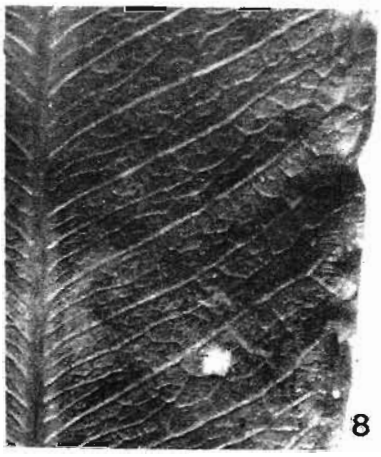


PLATE 2

Horizon and Age—Lower Siwalik, Middle Miocene.

Affinities—The characteristic features of the present fossils such as elliptic shape, obtuse base, chartaceous texture and perfect acrodromous venation indicate their resemblance with the modern leaves of *Zizyphus* Juss. of Rhamnaceae. A careful examination of the leaves of about 20 species of *Zizyphus* indicates that *Z. jujuba* Lam. (Central National Herbarium, Howrah Herbarium Sheet nos. 115347, 9703; Pl. 3, fig. 2) shows closest similarity with the present fossils.

So far, 16 fossil species of *Zizyphus* are known from different parts of the world (Singh & Prakash, 1980). The species known from the Siwalik sediments of India are—*Z. siwalicus* Lakhanpal 1965, 1966 from Jwalamukhi, Himachal Pradesh, *Z. indicus* Singh & Prakash 1980 from Arunachal Pradesh, *Z. champarensis* Lakhanpal & Awasthi 1984 from Bhikhnathoree, Bihar, *Zizyphus* cf. *Z. rugosa* Prasad 1994a from Hardwar, Uttar Pradesh and *Z. miocenica* Prasad 1994b from Kathgodam area in Uttar Pradesh. A detailed comparison of the present fossil leaves with the above known *Zizyphus* spp. indicates that the fossils show closest similarity with *Z. miocenica* Prasad 1994b. Hence, it is described under the same species.

The extant *Zizyphus jujuba* Lam. is a middle-sized tree, indigenous and naturalised throughout India and Myanmar, ascending in the outer Himalaya up to 4,500 ft. It is also cultivated for its fruits (Brandis, 1971; Gamble, 1972).

Family—Sapindaceae

Genus—*Filicium* Thw.

Filicium koilabasensis sp. nov.

Pl. 2, figs 5, 7, 9

Number of specimens—Four.

Description—Leaflets almost symmetrical, oblanceolate to narrow elliptic, preserved size 7.0 × 2.5 cm, 7.5 × 2.2 cm, 1.5 × 2.1 cm and 8.0 × 2.1 cm; apex acute to attenuate; base acute, normal, sometimes slightly oblique; margin entire; texture chartaceous; petiole 0.5 to 0.7 cm long, normal; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, straight to somewhat curved; secondary veins (2°) 24 pairs visible, 0.2 to 0.5 cm apart, closely placed, angle of divergence acute (about 60°), opposite, rarely branched; 1-2 intersecondaries arise in between two secondaries; tertiary veins (3°) fine, with angle of origin AR-AO, percurrent, almost straight, branched, oblique (in relation) to midvein, predominantly alternate, close to distinct.

Holotype—BSIP no. 36884, Darwaja, Koilabas, western Nepal.

Paratype—BSIP no. 36885.

Horizon and Age—Lower Siwalik, Middle Miocene.

Name derivation—The specific name has been given after the fossil locality Koilabas from where specimens were collected.

Affinities—The distinguishing features of the present fossil leaves are oblanceolate to narrow elliptic shape, chartaceous texture, closely spaced secondaries and presence of abundant intersecondaries. Such features are found common in the modern leaves/leaflets of *Toddalia lanceolata* of the family Rutaceae and *Filicium decipiens* Thw. of Sapindaceae. Of these, *Toddalia lanceolata* slightly differs from present fossil in the nature of secondary veins which do not join each other near the margin as found in the fossil. Thus *Filicium decipiens* Thw. (Forest Research Institute, Dehradun Herbarium Sheet nos. 78481, 23155; Pl. 2, figs 6, 8, 10) shows closest affinity with the fossils in all morphological features.

So far, there is no fossil record of the genus *Filicium* Thw. from India and other places. Nevertheless, a number of fossil woods resembling other genera, viz., *Schleichera, Euphoria* and *Pometia* of the same family are known from the Tertiary of different parts of the world (Dayal, 1965; Prakash & Tripathi, 1970; Prasad, 1993b).

PLATE 3 →

(All figures are of natural size unless otherwise mentioned)

1. *Zizyphus miocenica* Prasad—Fossil leaf showing shape, size and venation pattern.
2. *Zizyphus jujuba*—A modern leaf resembling in shape, size and venation pattern.
3. *Sabia sopaniculata* sp. nov.—Fossil leaf showing shape, size and venation pattern.
4. *Sabia paniculata*—A modern leaf resembling in shape, size and venation pattern.
5. *Mangifera someshwarica* Lakhanpal & Awasthi—Fossil leaf showing shape, size and venation pattern.
6. *Mangifera indica*—A modern leaf resembling in similar shape, size and venation pattern.
7. *Mangifera someshwarica* Lakhanpal & Awasthi—Fossil leaf magnified to show details of venation, × 3.5.
8. *Mangifera indica*—A modern leaf magnified to show details of venation, × 3.5.
9. *Millettia miobrandisiana*—Fossil leaflet showing shape, size and venation pattern.
10. *Millettia brandisiana*—A modern leaflet showing shape, size and venation pattern.
11. *Dalbergia siwalika* sp. nov.—Fossil leaflet showing shape, size and venation pattern.
12. *Dalbergia sissoo*—A modern leaflet resembling in shape, size and venation pattern.

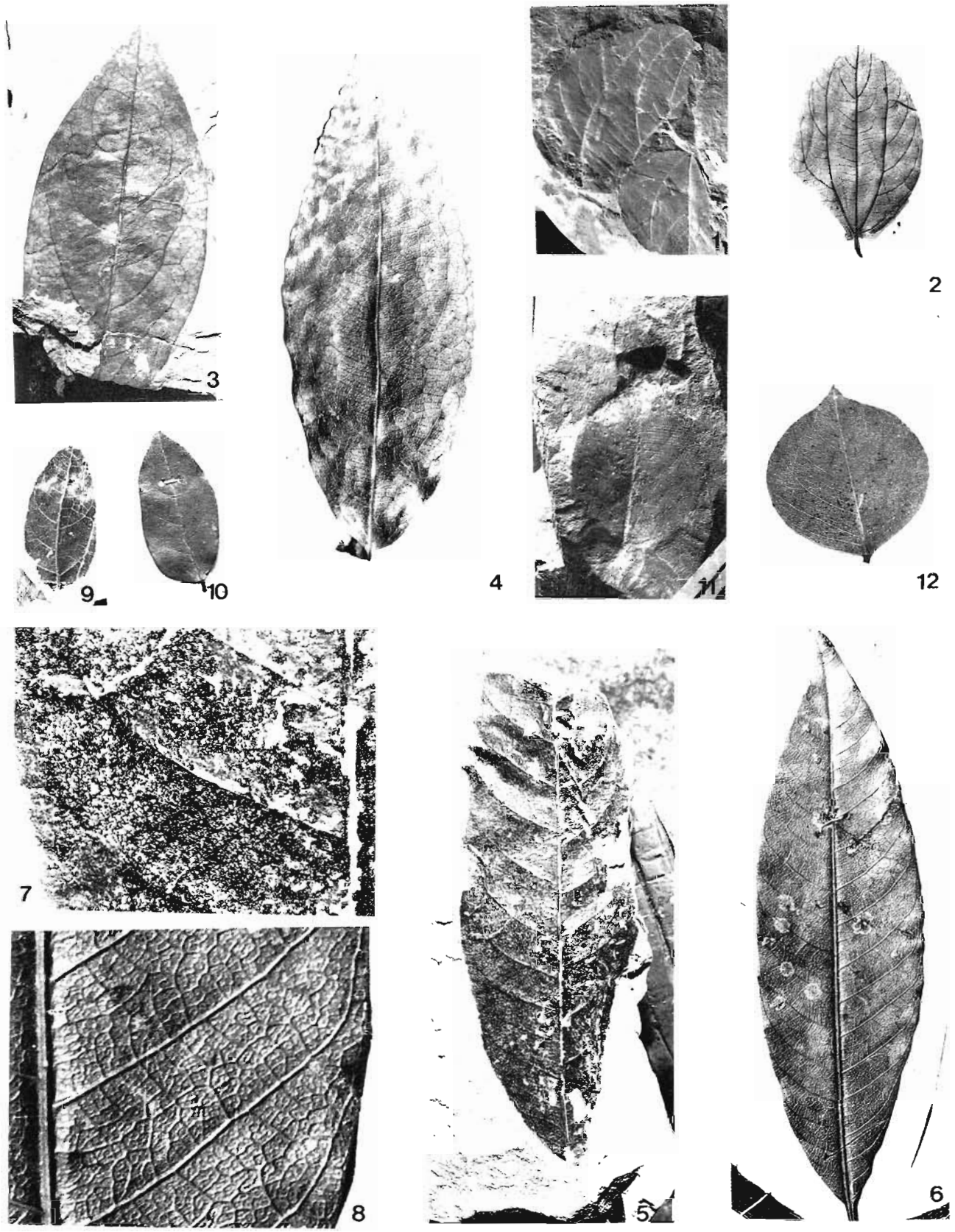


PLATE 3

The comparable extant species *Filicium decipiens* is a middle-sized tree occurring in Western Ghats from Malabar southwards, Sri Lanka and tropical Africa (Brandis, 1971).

Genus—*Euphoria* Comm. ex. Juss.

Euphoria nepaiensis sp. nov.

Pl. 4, figs 1, 3

Number of specimens—Three.

Description—Leaflet asymmetrical, lanceolate, size 9.3 × 2.0 cm; apex attenuate; base slightly broken, seemingly acute, inequilateral; margin entire; texture coriaceous; petiole not preserved, venation pinnate, craspedodromous to eucamptodromous; primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) about 17 pairs visible, with acute angle of divergence (50°-60°), moderate, angle decreasing towards the apex, uniformly curved up, usually alternate, unbranched; intersecondary veins present, simple; tertiary veins (3°) fine, angle of origin usually RR, percurrent, sometimes branched, oblique (in relation) to midvein, predominantly alternate and close.

Holotype—BSIP no. 36886, Darwaja, Koilabas, western Nepal.

Paratype—BSIP no. 36887.

Horizon and Age—Lower Siwalik, Middle Miocene.

Name derivation—The specific epithet is derived from Nepal, a country to which the fossil locality belongs.

Affinities—The characteristic features of the present fossil leaflets are lanceolate shape, inequilateral acute base, presence of intersecondary veins and RR angle of origin of tertiary veins which indicate their closest resemblance with the modern leaves of *Euphoria longan* (Lour.) Steud (Central National Herbarium, Howrah Herbarium Sheet no. 95550; Pl. 4, fig. 2) of Sapindaceae.

A fossil leaflet *Euphoria siwalica*, described from the Siwalik sediments of Kathgodam, Nainital District, Uttar Pradesh, India (Prasad, 1993C), differs from the present specimen in being elliptic in shape and moreover less number of secondaries which are comparatively distantly arranged. Hence, a new name *Euphoria nepalensis* has been proposed for it. A fossil seed, *Euphoria longanoides* Antal & Awasthi 1994 resembling modern *E. longan* has also been reported from the Himalayan foot-hills of Darjeeling District, West Bengal.

The modern comparable taxa *Euphoria longan* (Lour.) Steud is a middle-sized tree occurring in the west side of the peninsula. It is also found in evergreen forests from Konkan southwards, Khasi Hills, Myanmar, Sri Lanka, Malaya Peninsula and South China (Brandis, 1971).

Genus—*Otophora* Blume

Otophora miocenica sp. nov.

Pl. 4, fig. 4

Number of specimen—One.

Description—Leaflet almost symmetrical, narrow oblong, preserved size 7.1 × 2.0 cm; apex bluntly acute; base broken; margin entire; texture coriaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, slightly curved; secondary veins (2°) 11 pairs visible, angle of divergence acute (about 60°), moderate, 0.4-1.2 cm apart, uniformly curved up, usually alternate, seemingly unbranched; intersecondary veins present, frequent, simple; tertiary veins (3°) fine, angle of origin usually AO percurrent branched, oblique in relation to midvein, predominantly alternate and close.

Holotype—BSIP no. 36888, Darwaja, Koilabas, western Nepal.

Horizon and Age—Lower Siwalik, Middle Miocene.

Name derivation—The specific name has been derived after the Miocene Epoch.

Affinities—Narrow oblong shape, bluntly acute apex, presence of abundant intersecondary veins undoubtedly suggest its affinity with the modern leaves of *Otophora fruticosa* Blume (Central National Herbarium, Howrah Herbarium Sheet no. 95319; Pl. 4, fig. 4) of the family Sapindaceae.

PLATE 4 →

(All figures are of natural size unless otherwise mentioned)

1. *Cassia miosiamea* sp. nov.—Fossil leaflet showing shape, size and venation pattern.
2. *Cassia siamea*—A modern leaflet resembling in shape, size and venation pattern.
3. *Cassia neosophora* sp. nov.—Fossil leaflet showing shape, size and venation pattern.
4. *Cassia sophora*—A modern leaflet showing similar shape, size and venation pattern.
5. *Albizia siwalica* Prasad—Fossil leaflet showing shape, size and venation pattern.
6. *Albizia lebbek*—A modern leaflet showing similar shape, size and venation pattern.
7. *Combretum sahnii* Antal & Awasthi—Fossil leaf showing similar shape, size and venation pattern.
8. *Combretum decandrum*—A modern leaf showing similar shape, size and venation pattern.
9. *Combretum sahnii* Antal & Awasthi—Fossil leaf magnified to show details of venation, × 3.3.
10. *Morinda siwalika* sp. nov.—Fossil leaf showing shape, size and venation pattern.
11. *Morinda umbellata*—A modern leaf showing similar shape, size and venation pattern.

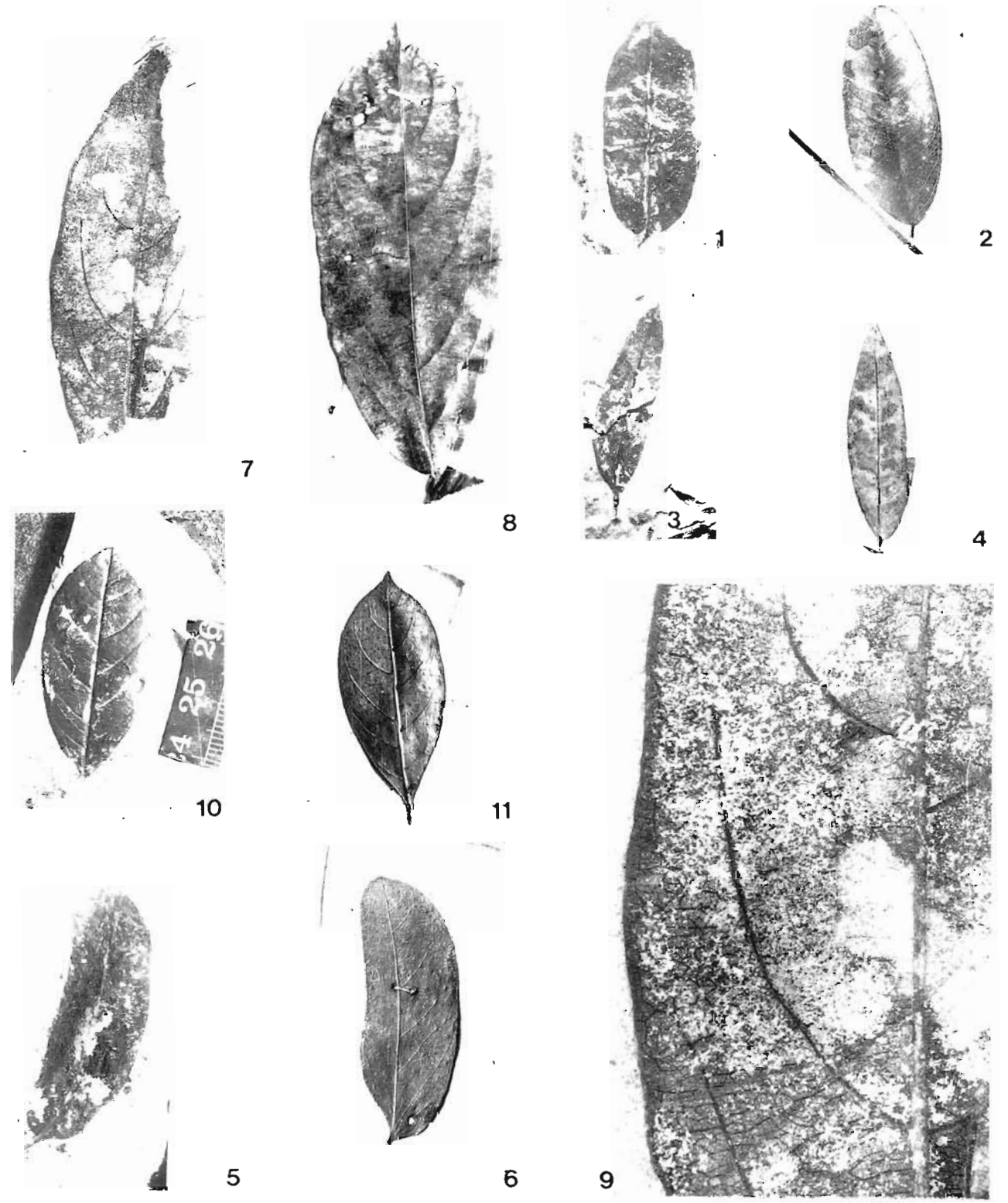


PLATE 4

As far as the author is aware, there is no record of fossil leaflets of the genus *Otophora* Blume from the Tertiary sediments of India and other places. Therefore, it forms the first record from the Siwalik sediments of

Nepal and has been described as a new species *Otophora miocenica*.

The extant genus *Otophora* Blume includes only eight species confined to the Malaya Peninsula and Archipelago (Hooker, 1872).

Family—Sabiaceae

Genus—*Sabia* Colebr.

Sabia eopaniculata sp. nov.

Pl. 3, fig. 3

Number of specimens—Two.

Description—Leaf symmetrical, elliptic, preserved size 6.0 × 2.0 cm; apex acute; base broken; margin entire; texture thin, chartaceous; petiole not preserved; venation pinnate, eucamptodromous to brochidodromous; primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) 5 pairs visible, 0.9 to 1.6 cm apart, angle of divergence wide (70°-80°), uniformly curved up and running parallel to the margin up to a short distance and joined to the superadjacent secondaries, alternate, sometimes branched; intersecondary veins present, simple, arising from midrib and joined to the secondaries; tertiary veins (3°) fine, with angle of origin usually RR, percurrent, straight to sinuous, rarely branched, oblique to nearly right angle in relation to midvein, predominantly alternate and close.

Holotype—BSIP no. 36889, Chorkholi, Koilabas, western Nepal.

Horizon and Age—Middle Siwalik, Mio-Pliocene.

Name derivation—The specific name is derived by adding a prefix 'eo' to the extant taxa *Sabia paniculata*.

Affinities—Characteristic features of the present fossil leaves such as elliptic shape, thin chartaceous texture, wide acute angle of divergence of secondary veins and percurrent tertiaries with nearly right angle in relation to midvein clearly indicate that they show close affinity with the modern leaves of *Sabia paniculata* Seem. (Forest Research Institute, Dehradun Herbarium Sheet no. 4289; Pl. 4, fig. 4) of Sabiaceae.

So far there is no fossil record of the genus *Sabia* Colebr. from India and other places. Thus it is recorded for the first time from Nepal Siwaliks and described here as *Sabia eopaniculata* sp. nov.

The modern comparable taxa *Sabia paniculata* Seem. is a large shrub distributed throughout sub-Himalayan tract and outer valleys from Jammu southwards, Upper Myanmar and Malayan region (Brandis, 1971).

Family—Anacardiaceae

Genus—*Bouea* Meissn.

Bouea koilabasensis sp. nov.

Pl. 7, fig. 4

Number of specimens—Two.

Description—Leaf simple, symmetrical, narrow elliptic, size 5.00 × 1.8 cm; apex slightly broken; base acute; margin entire; texture coriaceous; petiole 0.4 cm long, normal, venation pinnate, mixed craspedodromous; primary vein (1°) single, prominent, stout, slightly curved; secondary veins (2°) 13 pairs visible, 0.2-0.5 cm apart, angle of divergence wide acute (70°-80°), uniformly curved up; intersecondary veins rare; tertiary veins (3°) not clearly seen.

Holotype—BSIP no. 36890, Darwaja, Koilabas, western Nepal.

Horizon and Age—Lower Siwalik, Middle Miocene.

Name derivation—The specific epithet is after the fossil locality—Koilabas.

Affinities—The diagnostic features of the present fossil leaves are narrow elliptic shape, mixed craspedodromous venation, wide acute angle of divergence of secondary veins and presence of intersecondary veins. These features are found common in the modern leaves of the extant genus *Bouea* Meissn. of the family Anacardiaceae. A critical examination of the leaves of a number of *Bouea* species was done and found that the leaves of *B. burmanica* Griff. are similar to the present fossil (Central National Herbarium, Howrah, Herbarium Sheet no. 98983; Pl. 7, fig. 5) and therefore has been described as a new species—*Bouea koilabasensis*. So far, there is only one record of a fossil leaf—*Bouea premacrophylla* Antal & Awasthi 1994 from Darjeeling District, West Bengal and a fossil wood from the Neyveli Lignite, south India (Agarwal, 1988).

Bouea burmanica Griff., with which the fossil shows closest affinity, is an evergreen, middle-sized tree growing in Sunderban, Andaman, Tennasserim, Cochin China, Malaya Peninsula and Archipelago (Brandis, 1971).

Genus—*Tapiria* Hook. f.

Tapiria chorkholiense sp. nov.

Pl. 7, figs 6, 7

Number of specimens—Two.

Description—Leaflets slightly asymmetrical, narrow ovate, size 4.5 × 2.5 cm and 3.6 × 2.0 cm; apex broken; base obtuse; margin entire; texture coriaceous; petiole small, less than 0.2 cm long, normal, venation pinnate,

mixed craspedodromous; primary vein (1°) single, prominent, stout, slightly curved; secondary veins (2°) 6 pairs visible, less than 0.2-1.3 cm apart, angle of divergence wide acute (50°-70°), lowest pair of secondary arising nearly at right angle and also very closely spaced, uniformly curved up, usually alternate, unbranched; intersecondary veins present, rare; tertiary veins (3°) fine with angle of origin usually RR, percurrent, seemingly unbranched, oblique in relation to midvein, alternate to opposite and close.

Holotype—BSIP Specimen no. 36891, Chorkholi, Koilabas, western Nepal.

Paratype—BSIP no. 36892.

Horizon and Age—Middle Siwalik, Mio-Pliocene.

Name derivation—The specific epithet is derived after the locality Chorkholi, from where the fossils were collected.

Affinities—Narrow ovate shape, obtuse base, coriaceous texture, small petiole, wide acute angle of divergence of secondary veins of which the lowest pair arises nearly at right angle indicate that the fossil leaflets closely resemble the modern leaflets of *Tapiria hirsuta* Blume (Central National Herbarium, Howrah Herbarium Sheet no. 12915, 99553; Pl. 7, fig. 8) of Anacardiaceae.

So far, no fossil record of the genus *Tapiria* Hook. f. is known and hence the present fossil leaflet forms the first record from the Siwalik sediments of Nepal and described as *Tapiria chorkholiense* sp. nov.

The extant *Tapiria hirsuta* Blume is a large climbing shrub distributed in Nepal, Sikkim, Assam, Bhutan, Khasi Hills and Manipur (Brandis, 1971).

Genus—*Mangifera* Linn.

Mangifera someshwarica Lakhanpal & Awasthi 1984

Pl. 3, figs 5, 7

1984 *Mangifera someshwarica* Lakhanpal & Awasthi, p. 589, pl. 1, fig. 4.

1990 *Mangifera someshwarica* (Lakhanpal & Awasthi) Awasthi & Prasad, p. 304, pl. 3, figs 1, 3, 5.

Number of specimens—Two.

Description—Leaf symmetrical, narrow elliptic, preserved size 8.8 × 3.0 cm; apex broken; base wide acute; margin entire; texture thick chartaceous, petiole not preserved; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) 13 pairs visible, 0.3 to 1.0 cm apart, alternate to subopposite, uniformly curved up, unbranched, angle of divergence 60°-80°; intersecondary veins present, simple; tertiary veins (3°) fine, with angle of origin usually RR rarely RO, percurrent, almost straight, branched, oblique in relation to midvein, predominantly, alternate, close.

Figured specimen—BSIP no. 36893, Chorkholi, Koilabas, western Nepal.

Horizon and Age—Middle Siwalik, Mio-Pliocene.

Affinities—The important features of the fossils like narrow elliptic shape, thick chartaceous texture, wide acute to nearly right angle of divergence of secondary veins and percurrent with RR angle of origin of tertiary vein indubitably suggest their affinity with the modern leaves of *Mangifera indica* Linn. (Forest Research Institute, Dehradun Herbarium Sheet no. 65938; Pl. 3, figs 6, 8) of Anacardiaceae.

Two fossil leaves resembling extant *Mangifera indica* Linn. have already been described under the form species *Mangifera someshwarica* from the Siwalik sediments. Of them, one is from the Siwalik sediments of Bhikhnathoree, Bihar, India (Lakhanpal & Awasthi, 1984) and the other is from Surai Khola, Dang Valley, Nepal (Awasthi & Prasad, 1990). Another fossil leaf *Mangifera takashimensis* Matsuo has been recorded from the Palaeogene of Kyushu and from the Eocene of southwest Honshu, Japan (Matsuo, 1967). Among the above known fossils, *Mangifera someshwarica* described from the Siwalik sediments in Nepal, bears features similar to the present fossil and therefore, has been kept under the same.

The modern camparable taxon *Mangifera indica* Linn. is a medium to large evergreen tree distributed in a sub-Himalayan tract, outer hills of Kumaon and Garhwal. It also grows in Sikkim, the Nambar forest of Assam, Khasi Hills, Western Ghats, Chittagong, Vietnam and Malaya Peninsula (Brandis, 1971; Gamble, 1972).

Family—Fabaceae

Genus—*Albizia* Duraz.

Albizia siwalica Prasad 1990a

Pl. 4, fig. 5

1990a *Albizia siwalica* Prasad, p. 300, pl. 1, figs 5, 7.

1994a *Albizia* sp. cf. *A. lebbek*, p. 89, pl. 1, figs 5, 7.

1994b *Albizia siwalica* Prasad, pl. 7, fig. 7.

1994 *Albizia palaeolebbek* Antal & Awasthi, p. 34, pl. 9, figs 5, 6.

Number of specimen—One.

Description—Leaflet asymmetrical, narrow elliptic, size 4.7 × 1.5 cm; apex obtuse; base wide acute, oblique; margin entire; texture coriaceous; petiole 0.2 cm long curved; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, gradually curved; secondary veins (2°) 6-7 pairs, up to 0.8 cm apart, angle of divergence acute (45°-55°), moderate, uniformly curved up, usually alternate; intersecondary veins present, simple; tertiary veins not clearly seen.

Figured specimen—BSIP no. 36894, Darwaja, Koilabas, western Nepal.

Horizon and Age—Lower Siwalik, Middle Miocene.

Affinities—The characters like small asymmetric shape, oblique base, small petiole and presence of intersecondary veins indicate that the present fossil leaflet shows its nearest similarity with modern leaflets of *Albizia lebbek* Benth. (Pl. 4, fig. 6) of the family Fabaceae.

Four fossil leaflets comparable to *Albizia lebbek* Benth. have been described from the Siwalik sediments of different places in the Himalayan foot-hills. Prasad (1990b) described *Albizia siwalica* from Koilabas, western Nepal and Kathgodam area in Nainital District and *Albizia* sp. cf. *A. lebbek* from Hardwar in Saharanpur District, Uttar Pradesh, India (Prasad, 1994a, 1994b) and *A palaeolebbek* from Darjeeling District, West Bengal. The comparative study of the present fossil with those of already known fossils shows that the fossil leaflet from Kathgodam possesses similar morphological features to that of present Koilabas fossil leaflet.

In a critical survey of a variety of herbarium sheets of the extant taxon *Albizia lebbek* growing in different ecological conditions indicates that its leaflets vary in shape from wide obovate to narrow elliptic. The size also varies from small to medium. Obviously, the similar features are also found here in the fossil leaflets recorded from Koilabas, western Nepal. The former fossil leaflet *Albizia siwalica* described from Koilabas (Prasad, 1990a) has a obovate shape, while the present fossil leaflet possesses a narrow elliptic shape.

Genus—*Cassia* Linn.

Cassia miosiamea sp. nov.

Pl. 4, fig. 1

Number of specimen—One.

Description—Leaflet symmetrical, narrow elliptic, size 3.5 × 1.5 cm; apex slightly broken; base obtuse, normal; margin entire; texture thick, chartaceous; petiole 0.2 cm long, curved; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, moderate, straight; secondary veins (2°) 8-9 pairs visible, less than 0.5 cm apart, angle of divergence acute (about 60°), moderate, uniformly curved up, alternate to opposite, seemingly unbranched; intersecondary veins present, simple, frequent, sometimes 2-3 intersecondary found in between two secondaries. Further details could not be seen.

Holotype—BSIP no. 36895, Chorkholi, Koilabas, western Nepal.

Horizon and Age—Middle Siwalik, Mio-Pliocene.

Affinities—The important characters exhibited by the fossil leaflet collectively indicate that the fossil leaflet belongs to genus *Cassia* Linn. of the family Fabaceae. Among the species of *Cassia* the fossil shows close similarity with that of *Cassia siamea* Lam. (Central National Herbarium, Howrah, Herbarium Sheet no. 1546; Pl. 4, fig. 2).

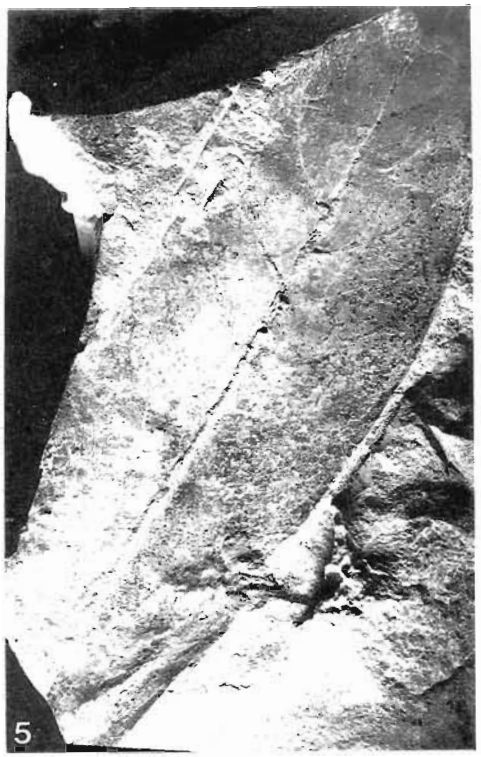
The fossil leaflets showing close resemblance with leaflets of *Cassia* Linn. have been assigned to genera *Cassia* Linn. and *Cassiophyllum* Geyler. The latter consists of only two species *Cassiophyllum* sp. Geyler 1887 and *Cassiophyllum berinices* (Ung.) Krausel (Givulescu, 1968). However, *Cassia* Linn. comprises more than hundred species recorded from different parts of the world (Prasad, 1987, 1990b). From the Indian subcontinent only two species are known, viz., *Cassia miokachchhensis* from the Miocene of Kutch (Lakhanpal & Guleria, 1982) and *Cassia nepalensis* from the Siwalik sediments of Koilabas, Nepal (Prasad, 1990b). The former differs from present fossil leaflet in being wide ovate in shape as compared to narrow elliptic shape of present fossil leaflet, while the latter species described from Koilabas locality may be distinguished from *Cassia miosiamea* in possessing a narrow ovate shape with acuminate apex. Moreover, the other records available to the author have been compared with the present fossil and none of them shows similarity with it. Hence, a new name—*C. miosiamea* has been proposed.

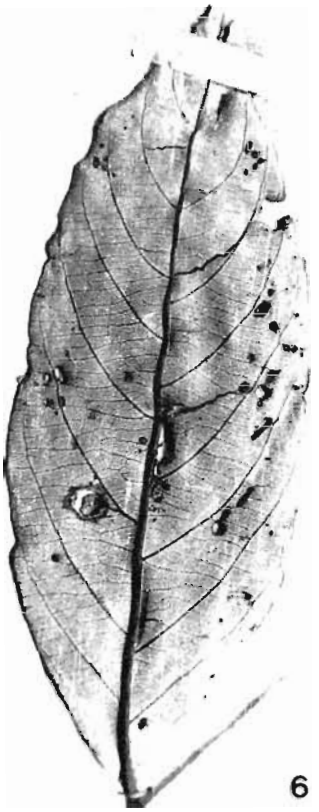
The modern comparable taxon *Cassia siamea* Lam. is a middle to large size tree distributed in southernmost parts of Western Ghats, Myanmar, Malaya Peninsula and Archipelago. It is also cultivated throughout India and Myanmar (Brandis, 1971).

PLATE 5 →

(All figures are of natural size unless otherwise mentioned)

1. *Carissa koilabasensis* sp. nov.—Fossil leaf showing shape, size and venation pattern.
2. *Carissa paucinervia*—A modern leaf resembling in shape, size and venation pattern.
3. *Woodfordia neofruticosa* sp. nov.—Fossil leaf showing shape, size and venation pattern.
4. *Woodfordia fruticosa*—A modern leaf with similar shape, size and venation pattern.
5. 7. *Lagerstroemia siwalika* sp. nov.—Fossil leaves showing shape, size and venation pattern.
6. *Lagerstroemia lanceolata*—A modern leaf with similar shape, size and venation pattern.
8. *Combretum decandrum*—A part of modern leaf magnified to show the venation pattern, × 3.3.





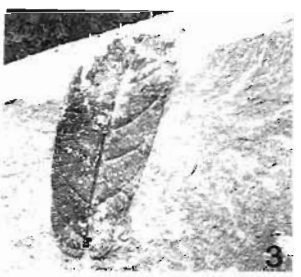


PLATE 5

Cassia neosophora sp. nov.

Pl. 4, fig. 3

Number of specimen—One.

Description—Leaflet slightly asymmetrical, lanceolate, size 3.8 × 1.0 cm; apex acute; base nearly obtuse, oblique; margin entire; texture chartaceous; petiole 0.3 cm long, normal; venation pinnate, seemingly craspedodromous; primary vein (1°), single, prominent, stout, slightly curved; secondary veins (2°) 9-10 pairs, 0.2-0.4 cm apart, angle of divergence acute (55°-70°), moderate, uniformly curved up, usually alternate, intersecondary veins present, simple. Further details are not visible.

Holotype—BSIP no. 36896, Darwaja, Koilabas, western Nepal.

Horizon and Age—Lower Siwalik, Middle Miocene.

Name derivation—The name of species is derived by adding a prefix 'neo' to the extant species *C. sophora* Wall.

Affinities—The important diagnostic characters of the fossil leaflet such as asymmetric lanceolate shape, obtuse base, short petiole and craspedodromous venation indicate its affinity with the leaves of extant *Cassia* Linn. of Fabaceae, in which it shows its closest resemblance with the leaves of *Cassia sophora* Wall. (Central National Herbarium, Howrah, Herbarium Sheet no. 592; Pl. 4, fig. 4).

The present fossil leaflet has been compared with all the known fossil species (Prasad, 1987, 1990b) and found it different from them in either shape, size or venation pattern. It can also be distinguished from the earlier described species *Cassia miosiamea* in possessing large size with elliptic shape in comparison to small lanceolate shape of the present fossil. Moreover, the secondaries in the present fossil are with greater angle of divergence and characterised by craspedodromous venation instead of eucamptodromous venation in *Cassia miosiamea*. Thus, the present specimen has been described as *Cassia neosophora* sp. nov.

The extant *Cassia sophora* Wall. is a small shrub distributed in tropics. It is native of Asia and found common in Sri Lanka and Penang all along the river banks (Hooker, 1879).

Genus—*Dalbergia* Linn.

Dalbergia siwalika sp. nov.

Pl. 3, fig. 11

1984 *Dalbergia* sp. Lakhanpal & Awasthi, p. 590, pl. 1, fig. 7.

1994a *Dalbergia* cf. *D. sissoo* Prasad, p. 89, pl. 2, fig. 5.

Number of specimen—One.

Description—Leaflet symmetrical, wide elliptic, size 3.0 × 2.4 cm; apex slightly broken, seemingly acute; base nearly obtuse, normal; margin entire; texture chartaceous; petiolule not preserved; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, moderate, straight; secondary veins (2°) 6 pairs visible, 0.2 to 0.5 cm apart, angle of divergence acute (about 60°), moderate, uniformly curved up, alternate to subopposite; intersecondary veins present, simple; tertiary veins (3°) poorly preserved.

Holotype—BSIP no. 36897, Darwaja, Koilabas, western Nepal.

Horizon and Age—Lower Siwalik, Middle Miocene.

Name derivation—The specific epithet has been derived after the name 'Siwalik' Formation.

Affinities—Wide elliptic shape, acute apex, entire margin and eucamptodromous venation indicate its close resemblance with the modern leaflets of *Dalbergia sissoo* Roxb. (Forest Research Institute, Dehradun, Herbarium Sheet no. 8879; Pl. 3, fig. 12) of Fabaceae.

About 48 fossil leaflets showing close resemblance with extant *Dalbergia* have been recorded from the Tertiary sediments of all over the world (Prasad, 1987, 1990b). Of these, *Dalbergia* sp. Lakhanpal & Awasthi, *Dalbergia miosericea* Prasad and *Dalbergia* cf. *D. sissoo* are known from the Siwalik (Mio-Pliocene) sediments of Indian sub-continent. *D. miosericea* Prasad 1990b described from Koilabas, Nepal differs from the present fossil in being narrow elliptic in shape with emarginate apex in comparison to wide elliptic shape with acute apex. The remaining *Dalbergia* cf. *D. sissoo* described from Siwalik sediments of Hardwar, Uttar Pradesh and *Dalbergia* sp. from the Siwaliks of Bhikhnathoree, Bihar, India also show their close resemblance with the modern leaflets of *Dalbergia sissoo* Roxb. Thus they may be conspecific and should be kept under *Dalbergia siwalika*.

Dalbergia sissoo Roxb., with which fossil shows closest similarity, is a large sized deciduous tree growing in sub-Himalayan tract and in the outer valley from Indus to Assam, Baluchistan, and very commonly occurs all along the river banks (Brandis, 1971; Gamble, 1972).

Genus—*Millettia* Wt.

Millettia miobrandisiana sp. nov.

Pl. 3, fig. 9

Number of specimen—One.

Description—Leaflet slightly asymmetrical, wide ovate, size 2.3 × 1.1 cm; apex slightly broken, seemingly acute; base obtuse, oblique; margin entire; texture thin chartaceous; petiolule not preserved; venation pinnate, brochidodromous; primary vein (1°) single, prominent,

moderate, slightly curved; secondary veins (2°) 7 pairs, less than 0.2 to 0.8 cm apart, uniformly curved up and joined to the superadjacent secondary by forming loops, angle of divergence (50°-85°), acute to right angle, upper secondaries less acute than basal ones, alternate to sub-opposite, unbranched; intersecondary veins present, simple; tertiary veins (3°) fine, with angle of origin RR, percurrent, usually straight, branched, oblique in relation to midvein, predominantly alternate, close to distant.

Holotype—BSIP Specimen no. 36898, Chorkholi, Koilabas, western Nepal.

Horizon and Age—Middle Siwalik, Mio-Pliocene.

Name derivation—The specific name is derived by adding a prefix 'mio' to the extant species *Millettia brandisiana*.

Affinities—Asymmetric ovate shape, oblique and obtuse base, chartaceous texture and prominent loops formed by the secondary veins of the fossil leaflet are comparable with those of *Millettia brandisiana* Kurz. (Forest Research Institute, Dehradun, Hebarium Sheet no. 37798; Pl. 3, fig. 10) of Fabaceae.

About 10 fossil leaflets comparable to those of *Millettia* Wt. have so far been known from all over the world (Prasad, 1994b). Of these, *Millettia koilabasensis* Prasad 1990a and *M. siwalica* Prasad 1990b are recorded from the Siwalik sediments of Koilabas, and *M. palaeoracemosa* Awasthi & Prasad 1990 from the Siwalik sediments of Surai Khola, western Nepal and Kathgodam, Nainital District, India (Prasad, 1994b). From a comparative study of the present fossil leaflet with above already known fossils from the Siwalik sediments it has been concluded that it is quite different from them. Hence, it is described as *Millettia miobrandisiana* sp. nov.

Millettia brandisiana Kurz. showing closest affinity with the fossil specimen is a large tree distributed in the upper mixed forest of Peguyomah and Myanmar (Brandis, 1971).

Genus—*Samanea* (Benth.) Merr.

Samanea siwalica Prasad 1994b

Pl. 1, fig. 10

1994b *Samanea siwalica* Prasad, pl. 7, fig. 11.

Number of specimen—One.

Description—Leaflet asymmetrical, elliptic, preserved size 1.9 × 1.0 cm; apex broken; base nearly obtuse, oblique; margin entire; texture chartaceous; petiolule less than 0.2 cm long, slightly curved; venation pinnate, eucamptodromous; primary vein (1°) single, almost straight, stout; secondary veins (2°) 5 pairs visible, less than 0.5 cm apart, angle of divergence acute (50°-60°), moderate, uniformly curved up, alternate, unbranched. Further details not seen.

Figured specimen—BSIP no. 36899, Darwaja, Koilabas, western Nepal.

Horizon and Age—Lower Siwalik, Middle Miocene.

Affinities—In over all morphological structures the fossil leaflet shows resemblance with fabaceous (Legume) leaves. Further examination of a number of Herbarium sheets reveals that the fossil leaflet resembles that of *Samanea saman* Merr. (Pl. 1, fig. 11).

A fossil leaflet resembling *Samanea saman* Merr. has already been described under *Samanea siwalica* Prasad from the Siwalik sediments of Kathgodam area in Nainital District, Uttar Pradesh, India (Prasad, 1994b). In possessing similar features the present fossil leaflet has been described under the same species.

Samanea saman Merr. is a large evergreen tree distributed in tropical America.

Genus—*Entada* Adans.

Entada palaeoscandens Awasthi & Prasad 1990

Pl. 7, fig. 9

1990 *Entada palaeoscandens* Awasthi & Prasad, p. 309, pl. 5, fig. 4.

1994 *Entada palaeoscandens* (Awasthi & Prasad) Antal & Awasthi, p. 53, pl. 19, fig. 7.

Number of specimen—One.

Description—Seed large, 3.2 cm in diameter, flattened, almost circular, slightly broken towards the hilum.

Figured specimen—BSIP no. 36900, Chorkholi, Koilabas, western Nepal.

Horizon and Age—Middle Siwalik, Mio-Pliocene.

Affinities—The features exhibited by the fossil seed are very similar to the extant *Entada phaseoloides* Benth. (syn. *E. scandens*) of the family Fabaceae (Pl. 7, fig. 10).

The fossil records (leaflets and seeds) of extant genus *Entada* Adans. are known from the Tertiary sediments of Austria, Japan, U.S.A., Venezuela, South America and India (Tanai, 1955; Ishida, 1970; Huzioka, 1972; Takahasi, 1954; Berry, 1921; Awasthi & Prasad, 1990; Antal & Awasthi, 1994). Since the fossil seeds described under *Entada palaeoscandens* Awasthi & Prasad 1990 from the Siwalik sediments of Surai Khola, western Nepal are very similar to the present fossil seed, it has been placed under it.

The extant *Entada phaseoloides* Benth. with which fossil seed shows resemblance, is a large woody climber distributed in sub-Himalayan tract from Nepal eastwards. It is very common in Sylhet, Manipur, Western Ghats, Andaman-Nicobar Islands and Myanmar (Brandis, 1971).

Family—Combretaceae

Genus—*Terminalia* Linn.

Terminalia panandhroensis Lakhanpal & Guleria 1981

Pl. 6, figs 6, 7

1981 *Terminalia panandhroensis* Lakhanpal & Guleria, pp. 354-355, pl. 1, fig. 1.

1990 *Terminalia panandhroensis* (Lakhanpal & Guleria) Awasthi & Prasad, p. 310, pl. 6, fig. 3.

Number of specimens—Two.

Description—Leaf symmetrical, narrow elliptic, size 13.2 × 5.0 cm; apex broken; base seemingly obtuse; margin entire; texture coriaceous; petiole 0.5 cm long, normal; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) 13 pairs visible, less than 0.5 to 1.5 cm apart, uniformly curved up and joined to the superadjacent secondaries at acute angle, angle of divergence 75°-90°, wide acute to right angle, lower pairs arising at right angle and closely spaced than above secondaries, usually alternate, seemingly unbranched; intersecondary veins present, simple; tertiary veins (3°) fine, with angle of origin usually AO, percurrent, straight, sometimes branched, oblique in relation to midvein, predominantly alternate and close to nearly distant.

Figured specimen—BSIP no. 36901, Chorkholi, Koilabas, western Nepal.

Horizon and Age—Middle Siwalik, Mio-Pliocene.

Affinities—The important characters exhibited by the present fossil leaf such as narrow elliptic shape, obtuse base, entire margin, coriaceous texture, eucamptodromous venation and right angle of divergence of basal, secondary veins strongly indicate its close resemblance with the modern leaves of *Terminalia tomentosa* W. & A. (= *T. coriacea* W. & A.) of the family Combretaceae (Central National Herbarium, Howrah, Herbarium Sheet no. 163768; Pl. 6, fig. 8).

About 30 fossil leaves resembling those of extant genus *Terminalia* Linn. have been described under three generic names, viz., *Terminalia* Linn., *Terminaliphyllum* Velenovsky and *Terminaliophyllum* Geyler from all over the world (Prasad, 1990b, 1994b). Out of these, three fossil leaves have been reported from Siwalik sediments of Nepal and one from India. *Terminalia koilabasensis* and *Terminalia siwalica* are known from the Lower Siwalik sediments of Koilabas, Nepal (Prasad, 1990b), while *T. panandhroensis* Lakhanpal & Guleria is known from Surai Khola, western Nepal (Awasthi & Prasad, 1990) and *T. miobelerica* from Kathgodam area in Nainital District of Uttar Pradesh, India (Prasad, 1994b).

A detailed comparison of the present fossil leaf with those of already known fossil species led to the conclusion that it shows close similarity with *Terminalia panandhroensis* Lakhanpal & Guleria described from Siwalik sediments of Surai Khola (about 40 km north-east of Koilabas), western Nepal. Hence, this has been kept under the same species.

Terminalia tomentosa W. & A. (syn. *T. coriacea* W. & A.) with which fossil leaves show closest affinity is a tall tree distributed in sub-Himalayan tract from Ravi eastwards. It is common throughout India except in the arid regions and Myanmar (Brandis, 1971).

Genus—*Combretum* Linn.

Combretum sahnii Antal & Awasthi 1994

Pl. 4, figs 7, 9

1994 *Combretum sahnii* Antal & Awasthi, p. 36, pl. 10, figs 3, 5.

Number of specimen—One.

Description—Leaf symmetrical, narrow elliptic, preserved size 6.3 × 2.5 cm; apex slightly broken, seemingly acute; base broken; margin entire; texture thick chartaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, straight; secondary veins (2°) five pairs visible, 0.8 to 1.3 cm apart, angle of divergence acute (50°-70°), moderate, uniformly curved up and running parallel to the margin for a short distance and join the superadjacent secondaries, alternate to opposite, unbranched; tertiary veins (3°) fine, with angle of origin RR, percurrent, almost straight, branched, usually right angle in relation to midvein, predominantly alternate and close.

PLATE 6 →

(All figures are of natural size unless otherwise mentioned)

1,3. *Euphoria nepalensis* sp. nov.—Fossil leaflet showing shape, size and venation pattern.

2. *Euphoria longan*—A modern leaflet resembling in shape, size and venation pattern.

4. *Otophora miocenica* sp. nov.—Fossil leaflet showing shape, size and venation pattern.

5. *Otophora fruticosa*—A modern leaflet with similar shape, size and venation pattern.

6,7 *Terminalia panandhroensis* Lakhanpal & Guleria—Fossil leaves showing shape, size and venation pattern.

8. *Terminalia tomentosa*—A modern leaf resembling in shape, size and venation pattern.

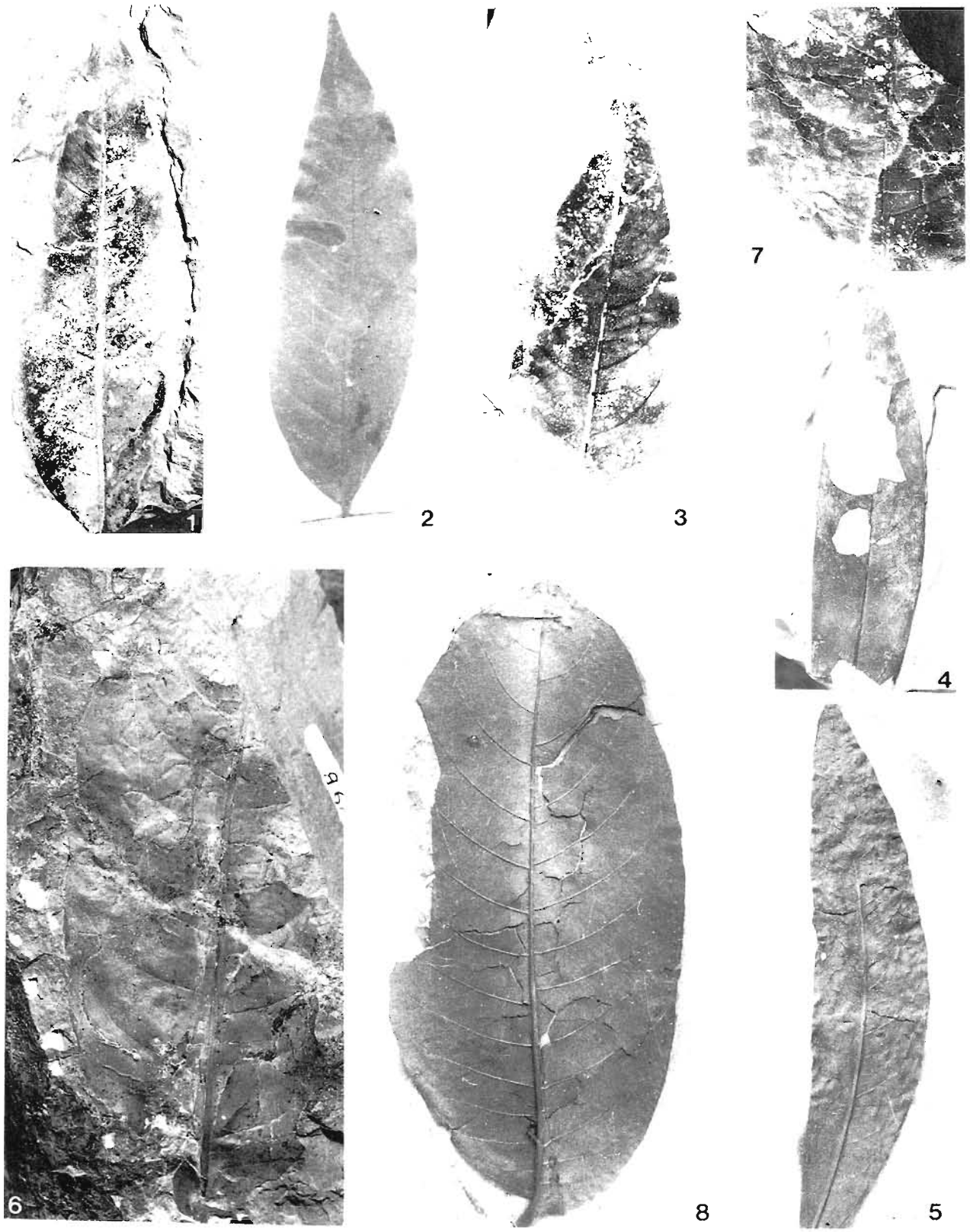


PLATE 6

Holotype—BSIP no. 36902, Darwaja, Koilabas, western Nepal.

Horizon and Age—Lower Siwalik, Middle Miocene.

Affinities—Narrow elliptic shape, eucamptodromous

venation, the orientation of the secondary veins and percurrent tertiary which is right angle in relation to midvein indicate that this fossil shows close affinity with the modern leaves of *Combretum* Linn. of the family Combretaceae. Further examination of herbarium sheets of a number of *Combretum* species showed that it has closest similarity with those of *Combretum decandrum* Roxb. (Forest Research Institute, Dehradun Herbarium Sheet no. 536; Pl. 4, fig. 8; Pl. 5, fig. 8).

So far only three fossil leaves resembling the genus *Combretum* Linn. are known from the Tertiary sediments of India and overseas. *Combretum europeum* (Web.) Principi 1926a has been described from Oligocene of Chivon e Salcedo and *C. sarothrosatachyoides* (Mass.) from the Pliocene of Sarmaziana (Principi, 1926b). Of these, the former is entirely different from the present fossil in possessing a spathulate shape with only 2-3 pairs of secondaries. Similarly, the latter species—*C. sarothrostachyoides*, differs in having brochidodromous venation as compared to eucamptodromous type of venation in the present fossil. Moreover, the secondaries in Sarmaziana fossil are more in number and ramified. The fossil leaves—*C. sahnii* Antal & Awasthi, described from the Siwalik sediments of Darjeeling District, West Bengal shows close similarity with the present fossil leaf and hence, it has been kept under the same.

The modern comparable taxon *Combretum decandrum* Roxb. is a large climbing woody shrub distributed in sub-Himalayan tract from Jammu eastwards, Sikkim to 2,000 ft., Assam, Chittagong, Bihar, Central Provinces, Northern Circars and the northern Deccan (Brandis, 1971).

Family—Lythraceae

Genus—*Lagerstroemia* Linn.

Lagerstroemia siwalika sp. nov.

Pl. 5, figs 5, 7

1983 *Terminalia* sp. Tripathi & Tiwari, p. 167, fig. 1.

Number of specimens—Two.

Description—Leaf symmetrical, narrow elliptic, preserved size 0.5 × 3.5 cm; apex and base slightly broken; margin entire; texture thick chartaceous; petiole not preserved, venation craspedodromous to eucamptodromous; primary vein (1°) single, prominent, stout, secondary veins (2°) about 10 pairs, 0.7 to 1.7 cm apart, alternate, angle of divergence acute (about 60°), moderate, uniformly curved up, unbranched; intersecondary veins rarely present, simple; tertiary veins (3°) fine, with angle of origin nearly RR, percurrent, straight to sinuous, sometimes branched, oblique in relation to midvein, predominantly alternate, close.

Holotype—BSIP Specimen no. 36903, Darwaja, Koilabas, western Nepal.

Paratype—BSIP Specimen no. 36904.

Horizon and Age—Lower Siwalik, Middle Miocene.

Name derivation—The specific epithet is after Siwalik horizon, from where the specimens were collected.

Affinities—The diagnostic features of the present fossils such as narrow elliptic shape, entire margin, thick chartaceous texture, craspedodromous to eucamptodromous venation, rare occurrence of intersecondary veins, percurrent tertiary with RR angle of origin show that the fossils are comparable to extant taxon *Lagerstroemia lanceolata* Wall. (Forest Research Institute, Dehradun, Herbarium Sheet no. 14729; Pl. 5, fig. 6) of the family Lythraceae.

Shukla (1950) and Trivedi (1956) described the fossil leaves resembling extant *Lagerstroemia indica* from the Deccan Intertrappean beds of Madhya Pradesh, India and later Lakhanpal and Dayal (1966) also reported a fossil leaf similar to *Lagerstroemia* from the Lower Siwalik sediments of Jawalamukhi, Himachal Pradesh, India. A critical study of the above mentioned fossil leaves shows that they do not bear the features of the leaves of *Lagerstroemia* species (Prasad, 1994b). The other species, viz., *Lagerstroemia patelii* Lakhanpal & Guleria from the Eocene of Kutch, western India (Lakhanpal & Guleria, 1981), Siwalik sediments of Darjeeling District, West Bengal (Antal & Awasthi, 1994) and Kathgodam area in Nainital District of Uttar Pradesh, India (Prasad, 1994b) differs from the present fossil in shape, size and

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PLATE 7 →

(All figures are of natural size unless otherwise mentioned)

1 *Atlantia miocenica* sp. nov.—Fossil leaflet showing shape, size and venation pattern.

2. *Atlantia miocenica* sp. nov.—A part of fossil leaflet magnified to show details of venation pattern, × 6.

3. *Atlantia monophylla*—A modern leaflet resembling in shape, size and venation pattern.

4. *Bouea koilabasensis* sp. nov.—Fossil leaf showing shape, size and venation pattern.

5. *Bouea burmanica*—A modern leaf showing similar shape, size and venation pattern.

6,7. *Tapiria chorkholiense* sp. nov.—Fossil leaflet showing shape, size and venation pattern.

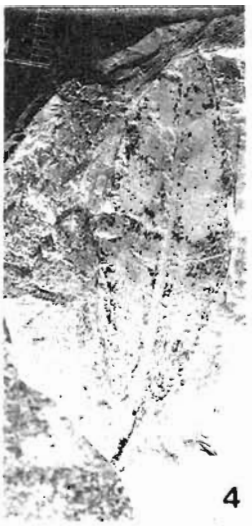
8. *Tapiria birsuta*—A modern leaflet with similar shape, size and venation pattern.

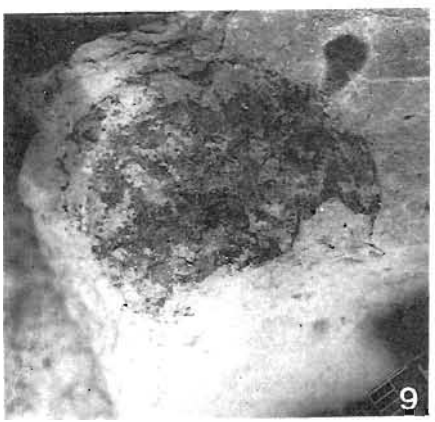
9. *Entada palaeoscandens*—Awasthi & Prasad—Fossil seed.

10. *Entada scandens*—A modern seed.

11. *Anacolosa mioluzoniensis* sp. nov.—Fossil leaf showing shape, size and venation pattern.

12. *Anacolosa luzoniensis*—A modern leaf showing similar shape, size and venation pattern.





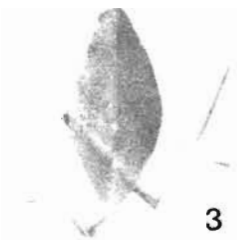


PLATE 7

orientation of secondary veins. Tripathi and Tiwari (1983) also described a fossil leaf from the same locality indicating its resemblance with *Terminalia arjuna* of the family Combretaceae. The examination of this fossil specimen suggests that it is conspecific to the present fossil and hence has been kept under the same.

The extant *Lagerstroemia lanceolata*, with which the present specimens show close affinity, is a large tree growing in the west side of the peninsula extending east as far as Bellary (Brandis, 1971).

Genus—*Woodfordia* Salisb.

Woodfordia neofruticosa sp. nov.

Pl. 5, fig. 3

Number of specimen—One.

Description—Leaflet symmetrical, narrow elliptic, preserved size 3.0 × 1.0 cm; apex broken, base nearly cordate; margin entire; texture coriaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, slightly curved; secondary veins (2°) 7 pairs visible, less than 0.2 to 0.5 cm apart, basal secondary arising more closely, angle of divergence acute (50°-80°), basal secondaries with greater angle, uniformly curved up, alternate to subopposite, unbranched; tertiary veins (3°) fine, with angle of origin usually RR, percurrent, almost straight, branched, oblique in relation to midvein, predominantly alternate and close.

Holotype—BSIP Specimen no. 36905, Darwaja, Koilabas, western Nepal.

Horizon and Age—Lower Siwalik, Middle Miocene.

Name derivation—The specific name has been derived after the name of modern comparable taxon *W. fruticosa* by adding a prefix 'neo'.

Affinities—The narrow elliptic shape, cordate base, entire margin, coriaceous texture, eucamptodromous venation and closely spaced basal secondaries which arise nearly at right angle strongly indicate its resemblance with the modern leaves of *Woodfordia fruticosa* Kurz. (Forest Research Institute, Dehradun, Herbarium Sheet no. 7337; National Botanical Research Institute, Lucknow, Herbarium Sheet no. 15702; Pl. 5, fig. 40) of the family Lythraceae. So far, there is no record of fossil leaves of *Woodfordia* Salisb. from the Siwalik sediments of India. *Woodfordia fruticosa* Kurz. (= *W. floribunda* Salisb.) shows closest affinity with the present specimen and is an ornamental shrub widely spread from tropical Africa, Arabia to India ascending to 5,000 ft. in Himalaya, China and Myanmar (Brandis, 1971).

Family—Rubiaceae

Genus—*Morinda* Linn.

Morinda siwalika sp. nov.

Pl. 4, fig. 10

Number of specimen—One.

Description—Leaf symmetrical, elliptic, size 4.2 × 1.8 cm; apex seemingly acuminate; base acute, normal; margin entire; texture coriaceous; petiole about 0.2 cm long, normal; venation pinnate, craspedodromous to eucamptodromous; primary vein (1°) single, prominent, moderate, straight; secondary veins (2°) 7-8 pairs, 0.3 to 0.8 cm apart, angle of divergence acute (50°-60°), moderate, uniformly curved up, usually alternate, unbranched, intersecondary veins present, simple, rare; tertiary veins (3°) fine, with angle of origin usually RR, percurrent, straight to sinuous, rarely branched, oblique to nearly right angle in relation to midvein, predominantly alternate and close to distant.

Holotype—BSIP Specimen no. 36906, Chorkholi, Koilabas, western Nepal.

Horizon and Age—Middle Siwalik, Mio-Pliocene.

Name derivation—The species stands after the Siwalik Horizon.

Affinities—The diagnostic features of the present fossil such as small size, elliptic shape, acute base, small petiole, craspedodromous to eucamptodromous venation, rare occurrence of intersecondary veins and tertiary with nearly right angle in relation to midvein favourably indicate that the modern leaves of extant *Morinda umbellata* Linn. (Forest Research Institute, Dehradun, Herbarium Sheet no. 49305; Pl. 4, fig. 11) of the family Rubiaceae have closest affinity with the present fossil.

Recently, a fossil leaf showing close resemblance with *Morinda tinctoria* has been described under form species *Morinda palaeotinctoria* Prasad 1994b from the Siwalik sediments of Kathgodam area in Nainital District of Uttar Pradesh, India.. As this fossil has a comparatively large size (14.0 × 7.3 cm) with an unmatched venation pattern, it can be distinguished from the present fossil which is described as *Morinda siwalika* sp. nov.

Morinda umbellata Linn. is a large shrub distributed in the west side of the peninsula in evergreen forests from Coorg southwards, Khasi Hills, Tennasserim, Sri Lanka, Malaya Peninsula and China (Brandis, 1971).

Family—Apocynaceae

Genus—*Carissa* Linn.

Carissa koilabasensis sp. nov.

Pl. 5, fig. 1

Number of specimen—One.

Description—Leaf almost symmetrical, elliptic, size 3.5 × 1.6 cm; apex bluntly acute; base slightly indistinct, seemingly wide acute; margin entire, texture thick chartaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein (1°) single, stout, almost straight; secondary veins (2°) 4 pairs, 0.3 to 1.2 cm apart, angle of divergence acute (about 50°), moderate, uniformly curved up and run for a short distance towards the apex, joining superadjacent secondary by a cross vein, alternate, unbranched; tertiary veins (3°) fine, poorly preserved with angle of origin usually RR, percurrent, straight, oblique to right angle in relation to midvein, predominantly alternate and close.

Holotype—BSIP Specimen no. 36907, Chorkholi, Koilabas, western Nepal.

Horizon and Age—Middle Siwalik, Mio-Pliocene.

Name derivation—The specific epithet is after the fossil locality.

Affinities—The most important features of the present fossil namely small elliptic shape, bluntly acute apex, eucamptodromous venation and typical orientation of secondary veins suggest that the fossil leaf belongs to the genus *Carissa* Linn. of the family Apocynaceae. Amongst 18 extant species of *Carissa*, *C. paucinervia* A. Dc. (Forest Research Institute, Dehradun, Herbarium Sheet no. 83865) shows closest affinity with the present fossil (Pl. 5, fig. 2).

The fossil record of the genus *Carissa* Linn. is not yet known. Therefore, this is the first report from the Siwalik sediments of Nepal.

Carissa paucinervia A. Dc. is a small shrub found in the forests of Lower Bengal, Manipur, Sri Lanka and Myanmar (Hooker, 1882).

Family—Olacaceae

Genus—*Anacolosa* Blume

Anacolosa mioluzoniensis sp. nov.

Pl. 7, fig. 1

Number of specimen—One.

Description—Leaf symmetrical, elliptic, size 7.0 × 4.5 cm; apex wide acute; base acute, slightly oblique; margin entire; texture coriaceous; petiole not preserved; venation pinnate, brochidodromous; primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) 6 pairs visible, 0.5-1.5 cm apart, angle of divergence acute to right angle (50°-90°), apical and basal pairs of secondary veins are with less angle than middle ones, joined superadjacent secondary much before the margin at about right angle, alternate branched; tertiary veins (3°) fine, with angle of origin AO-RR, percurrent, straight, sometimes branched, oblique to right angle in relation to midvein and close.

Holotype—BSIP Specimen no. 36908, Chorkholi, Koilabas, western Nepal.

Horizon and Age—Middle Siwalik, Mio-Pliocene.

Name derivation—The specific name has been derived after the extant species *A. luzoniensis* by adding a prefix 'mio'.

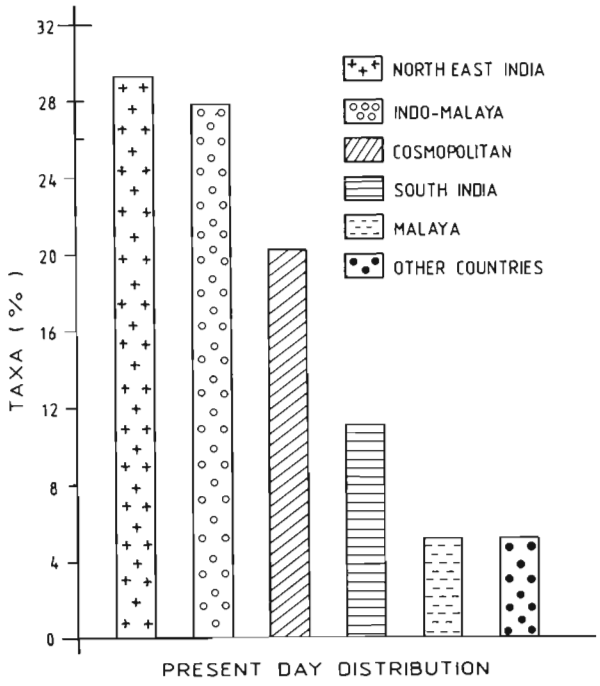
Affinities—The characteristic features of the fossil leaf such as elliptic shape, wide acute apex, and the nature of secondary veins which arise at acute to right angle and join superadjacent secondary much before the margin suggest that the present fossil leaf has closest affinity with the modern leaves of *Anacolosa luzoniensis* Merr. (Central National Herbarium, Howrah Herbarium Sheet no. 82996; Pl. 7, fig. 12) of the family Olacaceae.

So far, there is no record of any fossil leaf of the genus *Anacolosa* Blume from India and other countries. The occurrence of this fossil forms the first record and hence described as *Anacolosa mioluzoniensis* sp. nov.

The extant taxon *Anacolosa luzoniensis* Merr., with which the present fossil leaf resembles, now grows in the evergreen forests of Philippines.

FLORISTIC COMPOSITION

The present assemblage comprising a variety of taxa recovered from Koilabas area in the foot-hills of Nepal consists of 55 species and 44 genera belonging to 24 families of dicotyledons. They are mainly based on leaf-impressions and a seed which shows close resemblance with the extant *Entada scandens* of the family Fabaceae (Table 1). This assemblage is represented by mostly large trees (40 species), shrubs (12 species) and a few climbers (3 species). Herbs are totally absent. The legumes are found in good percentage representing 12 taxa. The fossil record also supports their abundant occurrence in other localities in the foot-hills during Siwalik (Prasad, 1987, 1993b; Prakash & Tripathi, 1992), whereas the legumes are not authentically represented from Palaeogene sub-Period in the Indian subcontinent. This suggests that they may have entered the Indian subcontinent later but before Middle Miocene after the establishment of land connection where they were flourishing. Combretaceae is the next family which



Text-figure 2—Showing present day distribution of comparable extant taxa with fossils from Koilabas area in different geographical regions.

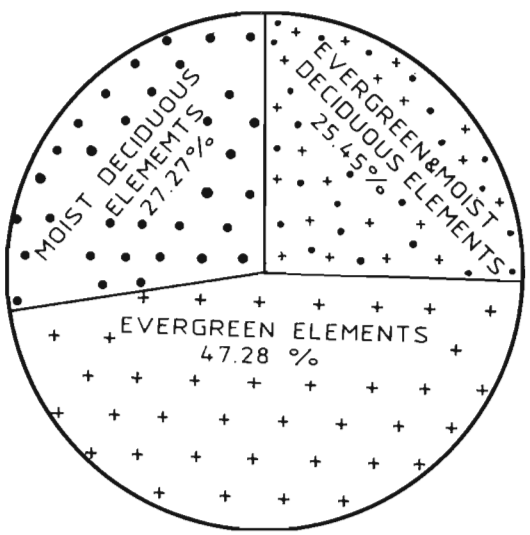
includes 5 taxa distributed in the tropics of India, Nepal and other places. Few genera, viz., *Sabia, Carissa, Otophora, Anacolosa, Tapiria* described in this paper are completely unrepresented in the Tertiary flora. Their modern comparable taxa are presently known to grow in different geographical regions all over India and other places (Text-figure 2). In India, they are distributed mostly in northeast and southern regions, wherever favourable climatic conditions are found. In this assemblage there are about 15 taxa which are found to grow both in India and Malaya Peninsula. They are *Dillenia indica, Mesua ferrea, Dipterocarpus tuberculatus, Evodia fraxinifolia, Euphoria longan. Sabia paniculata, Bouea burmanica, Mangifera indica, Albizia lebbek, Cassia siamea, Dalbergia sericea, Morinda umbellata, Cinnamomum inuctum, Ficus retusa* and *F. glaberima* which indicate that there has been a fair exchange of floral elements between the two subcontinents. However, the taxa like *Ryparosa kunstelri* and *Otophora fruticosa* grow in the Malayan regions indicating that the migration of these plants from India to Malaya has taken place during Miocene (Prasad & Prakash, 1987). They flourished around Koilabas in the foot-hills of Nepal during the deposition of Siwalik sediments and later became extinct due to unfavourable climatic conditions.

The genus *Samanea* consists of about 20 species (Willis, 1973) distributed in tropical Africa and South America. The occurrence of this genus in the Koilabas area during Siwalik is phytogeographically important as either it originated there during that time or migrated from the above mentioned land masses to India (Guleria, 1992: Prasad, 1994b).

Similarly, 16 taxa in the present floral assemblage, viz., *Kayea floribunda, Tapiria hirsuta, Millettia ovalifolia, M. macrostachya, M. brandissiana, Ormosia robusta, Calycopteris floribunda, Terminalia pyrifolia, T. tomentosa, Sygygium claviflorum, Randia wallichii, Diospyros montana, D. toposia, Tabernaenontana coronaria, Carissa paucinervia* and *Ficus cunia* are still growing in north-east India, Bangladesh and Myanmar. This suggests that these taxa, present during Mio-Pliocene in the foot-hills near Koilabas area, do not grow now-a-days and have migrated towards east in Assam, Bengal, Sikkim, Meghalaya, Bangladesh and Myanmar because of favourable conditions.

Some of the taxa found to grow still at different altitudes in the foot-hills near Koilabas are *Murraya paniculata, Zizyphus jujuba, Mangifera indica, Dalbergia sissoo, Terminalia tomentosa, Combretum decandrum, Woodfordia fruticosa, Diospyros montana, Datura fastuosa, Vitex negundo* and *Ficus cunia* which suggest that they have the susceptibility to adapt in the new climatic conditions prevailing there after Middle Miocene, mostly due to further rise of Himalaya.

In the present floral assemblage three types of elements have been identified, viz., (i) evergreen, (ii) evergreen and moist deciduous, and (iii) moist deciduous elements (Text-figure 3). The evergreen elements constituting about 47 per cent of the total assemblage are in abundance as compared to others. Thus, it may be inferred that the tropical evergreen forest was growing around Koilabas during Mio-Pliocene against the present mixed deciduous forests in the region.



Text-figure 3—Diagramatic representation of three types of elements in the present assemblage from Siwalik sediments near Koilabas, western Nepal.

PALAEOENVIRONMENT

The Tertiary plant fossils are supposed to be good indicators to understand past environmental conditions. The interpretations based on them become more reliable as they are compared with extant floral elements. The other parameters for deducing palaeoenvironment are the physiognomic characters of plant fossils. In the presence of exclusively leaf-impressions in any floral assemblage this parameter plays an important role in interpreting the palaeoenvironment. Further, this is an independent systematic relationship of the species and therefore it is likely that the errors in interpretation are minimum. The inferences regarding palaeoenvironment can be drawn by two methods (i) nearest living relativeness, and (ii) foliar physiognomy.

Nearest living relativeness—This extrapolates known climatic requirement of modern taxa with the comparable and related taxa in the past. The plant fossils recovered from Koilabas localities have been compared with their modern equivalents and it has been observed that a number of them still exist there. Therefore it will be easier to infer the palaeoclimate of the region during sedimentation.

The plant fossils recovered from Koilabas, Nepal and their present habit and habitat show that mostly they are the native of tropical evergreen and moist deciduous forests of north-east India (Assam, Sikkim, Meghalaya), Bangladesh, Myanmar and Malaya Peninsula (Table 2). Thus it may be concluded that a warm and humid climate was prevalent around Koilabas during Middle Miocene-Pliocene Epoch in contrast to the relatively present dry climate in the area. The occurrence of a sizeable number of evergreen elements (about 47%) itself indicates the presence of tropical climate with plenty of rainfall.

Present day distribution of the modern equivalents of all taxa obtained from the Koilabas area shows that out of them only 11 taxa now grow along the foothills. While the other taxa have migrated to some other suitable regions like north-east India, south India, Bangladesh, Myanmar and Malaya Peninsula where they receive higher rainfall (Brandis, 1971; Hooker, 1872, 1879, 1882; Champion & Seth, 1968; Kanji Lal, 1928; Desch, 1957). This indicates that changes in climate may have taken place after Mio-Pliocene times due to rise of Himalaya.

Foliar physiognomy—The study of physiognomic characters of angiospermous leaves recovered from the Siwalik sediments of Koilabas area, Nepal throws some light on the climatic conditions prevailing during sedimentation. The present vegetation in the area consists of mostly large trees and woody climbers. The leaf-impressions recovered from the area seem to have belonged to arborescent or large woody species. Amongst woody plants, leaves/leaflets with entire margins are overwhelmingly predominant in a tropical and subtropical environment.

The non-entire margins occur commonly in thin and soft leaves with prominent veins. The entire margins, on the other hand, usually occur in thicker, stiffer and more leathery leaves having structures responsible in retarding evaporation and transpiration. Furthermore, in the distribution of woody representatives of dicotyledonous families there is a correlation between leaf form and environment. For example, typical entire margined leaves of woody families like Anonaceae, Lauraceae, Ebenaceae, Clusiaceae, Sapotaceae and Apocynaceae, etc. are practically absent from mesophytic cold temperate regions. On the contrary, non-entire leaved families as Betulaceae, Aceraceae, Platanaceae, etc. are absent from low land tropical areas. However, the families like Malvaceae, Rosaceae, Ulmaceae, Fagaceae, Tiliaceae, Flacourtiaceae, Anacardiaceae and Fabaceae possess both types of leaf margins. The non-entire leaf types usually reach their optimum development on mesophytic temperate cool land or in equable environment, while the entire leaf types attain their optimum development in lowland tropical or physiologically dry habitat. Bailey and Sinnot (1916) pointed out that woody plants of tropical lowland possess entire margined leaves, while in temperate region they possess non-entire margined leaves. Wolfe (1969) also concluded that the tropical rain forests have the highest percentage of entire margined species. In the present fossil plant assemblage only two elements—*Dillenia palaeoindica* and *Datura miocenica* have non-entire margins, while the others bear entire margins indicating the prevalence of warm and humid climate during the deposition of Siwalik sediments.

The extended leaf tip known as 'drip tip' is also an important physiognomic character of angiospermous leaves and is generally seen in wet tropical forest elements. The function of the drip tip is to hasten the run off of water from the leaf. According to Richards (1952) the drip tips of leaves are the characteristics of plants of wet regions, especially of tropical rain forests and facilitates them to retard the growth of epiphytes. Deciduous leaves generally lack drip tips perhaps because of their short life span. However, in the present assemblage a good number of taxa possess drip tips (Table 3); in several specimens the tips either got broken or indistinct due to the preservation factor. It is significant to mention here that out of 55 species in the assemblage, only 45 species possess drip tip. Thus, this further indicates the presence of a warm humid climate in the area during Siwalik sedimentation.

Leaf size is another physiognomic character for inferring past climate (Raunkiaer, 1934; Givnish, 1979). It is bigger in understory elements of humid evergreen

Table 2—Distribution of comparable extant taxa of fossils from Koilabas in various tropical forest types

TAXA	TROPICAL FOREST TYPES						
	Wet evergreen forest	Semi evergreen forest	Moist deciduous forest	Littoral and Swamp forest	Dry deciduous forest	Thorn forest	Dry evergreen forest
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dillenia indica	+	+	+				
Ryparosa kunstelri	+						
Mesua ferrea	+	+					
Kayea floribunda	+						
Dipterocarpus tuberculatus	+		+				
Hopea glabra	+						
Evodia fraxinifolia	+		+		+		
Hopea glabra	+						
Evodia fraxinifolia	+		+				
Murraya paniculata			+		+		
Atlantia monophylla	+						
Chloroxylon swietenia			+		+		
Zizyphus jujuba			+		+		
Filicium decipiens	+						
Euphoria longan	+		+				
Otophora fruticosa	+						
Sabia paniculata	+		+				
Bouea burmanica	+						
Tapiria hirsuta			+				
Mangifera indica	+		+				
Albizia lebbek	+	+	+				
Cassia hirsuta			+		+		
C. laevigata			+				
C. siamea			+				
C. sophora		+	+				
Dalbergia sericea			+				
D. sissoo			+				
Millettia ovalifolia	+						
M. macrostachya	+	+					
M. brandisiana			+				
Ormosia robusta	+	+					
Samanea saman	+						
Entada scandens		+	+				
Anogeissus sericea			+				
Calycopteris floribunda			+		+		
Terminalia angustifolia	+	+					
T. pyrifolia	+	+	+				
T. tomentosa			+				
Combretum decandrum	+	+	+				
Lagerstroemia lanceolata		+	+				
Woodfordia fruticosa			+		+		
Syzygium claviflorum	+	+	+	+			
Lonicera quinqueloculoris			+				
Randia wallichii	+		+				
Morinda umbellata	+						
Diospyros montana			+		+		
D. toposia	+						
Tabernaemontana coronaria	+		+				
Carissa paucinervia	+	+					
Gaertnera heleri	+	+	+				
Datura fastuosa	+		+				
Anacolosa luzoniensis	+						
Vitex negundo			+		+		
V. pubescens	+						
Cinnamomum inuctum	+	+					
Ficus cunia			+		+		
F. retusa	+						
F. glaberrima	+	+					

Table 3—Physiognomic characters of the fossil flora recovered from Koilabas area, western Nepal

	PHYSIOGNOMIC CHARACTERS							
	Average leaf size sq cm	Leaf margin Entire (E) Nonentire (N) Indistinct (–)	Drip tips Presence (P) Absence (A) Indistinct (–)	Nature of petiole Swollen (S) Normal (N)	Leaf texture Chartaceous (CH) Coriaceous (CO)	Leaf base shape Acute (A) Obtuse (O) Cuneate (C) Cordate (CR) Attenuate (AT) Indistinct (–)	Leaf Organization Simple (S) Compound (C)	Venation pattern Close (C) Distant (D)
Dillenia palaeoindica	52.50	N	—	—	CH	—	S	C
Ryparosa prekunstelri	61.92	E	—	N	CO	A	S	D
Mesua tertiara	10.00	E	P	N	CH	A	S	C
Kayea kalagarhensis	41.60	E	—	N	CO	A	S	C
Dipterocarpus siwalicus	66.00	E	P	N	CH	O,CR	S	D
	190.00	E	—	N	CH	O	S	D
Hopea mioglabra	28.44	E	—	—	CO	A	S	D
Evodia koilabasensis	20.90	E	—	—	CH	O	C	C
Murraya khariense	07.30	E	A	—	CO	A	C	D
Atlantia miocenica	05.22	E	—	—	CH	A	C	C
Chloroxylon palaeosuietenia	05.60	E	—	—	CH	A	C	C
Zizyphus miocenica	05.60	E	—	—	CH	O	S	D
Filicium koilabasensis	26.25	E	P	N	CH	A	S	C
Euphoria nepalensis	27.00	E	P	—	CO	A	S	C
Otophora miocenica	14.25	E	A	S	CO	—	S	D
Sabia eopaniculata	21.98	E	P	—	CH	—	S	C
Bouea koilabasensis	12.00	E	P	N	CO	A	S	D
Tapiria chorkholiense	11.25	E	—	—	CO	O	S	D
Mangifera someshwarica	26.40	E	P	N	CH	A	S	D
Albizia siwalica	07.50	E	A	N	CO	A	C	D
C. nepalensis	10.08	E	P	—	CO	A	C	D
C. miosiamea	05.25	E	A	N	CH	O	C	C
C. neosophora	03.80	E	A	N	CH	O	C	C
Dalbergia miosericea	14.40	E	A	N	CH	A	C	D
D. siwalika	07.20	E	—	—	CH	O	C	C
Millettia siwalica	06.20	E	A	N	CH	O,A	C	D
M. koilabasensis	28.40	E	P	—	CH	A	C	D
M. miobrandisiana	02.53	E	—	—	CH	O	C	D
Ormosia robustoides	35.00	E	P	—	CH	O	C	C

Samanea siwalica	02.00	E	—	—	CH	O	C	D
Anogeissus eosericea	10.75	E	—	N	CH	O	S	D
Calycopteris floribundoides	12.48	E	P	—	CO	O	S	D
Terminalia koilabasensis	11.20	E	P	—	CH	A	S	D
T. siwalica	35.60	E	P	N	CO	A	S	D
T. panandhroensis	57.60	E	—	N	CO	O	S	D
Combretum sahnii	15.75	E	P	—	CH	—	S	D
Largerstroemia siwalika	42.00	E	—	—	CH	—	S	D
Woodfordia neofruticosa	03.00	E	—	—	CO	CR	C	D
Syzygium miocenicum	24.44	E	—	N	CH	C	S	C
Lonicera mioquinquelocularis	08.75	E	—	—	CH	O	C	D
Randia miowallichii	13.80	E	—	N	CH	C	S	D
Morinda siwalika	07.56	E	P	—	CH	—	S	C
Diospyros koilabasensis	09.00	E	—	—	CH	CR	S	D
D. pretoposia	108.00	E	—	N	CO	O	S	D
Tabernaemontana precoronaria	13.86	E	P	N	CH	C	S	D
Carissa koilabasensis	05.60	E	A	—	CH	A	S	D
Gaertnera siwalica	12.00	E	—	—	CH	A	S	D
Datura miocenica	59.20	N	P	N	CH	A	S	C
Anacolosa mioluzoniensis	23.12	E	A	N	CO	A	S	D
Vitex prenegundo	20.90	E	P	N	CH	A	S	C
V. siwalica	31.50	E	—	—	CH	—	S	C
Cinnamomum mioinuctum	06.48	E	A	N	CH	C	S	D
Ficus precunia	20.25	E	—	—	CO	CR	S	D
F. retusoides	31.32	E	P	N	CH	A	S	C
F. nepalensis	28.00	E	—	—	CO	O	S	D

forests and decreases with temperature or precipitation. According to Raunkiaer (1934) and later modified by Webb (1955) the leaf size may be measured typically by 5 size classes, viz., leptophyll (0.25 sq cm), nanophyll (0.25-2.25 sq cm), microphyll (2.25-20 sq cm), mesophyll (20.00-182 sq cm) and macrophyll (182-1640 sq cm). According to this classification the floral elements recovered from Koilabas area though includes the species from microphyll to macrophyll, the majority of species are of microphyll-mesophyll size classes as given below:

Leaf size	*No. of taxa*	*Percentage*
Leptophyll	—	—
Nanophyll	—	—
Microphyll	30	55.5
Mesophyll	23	42.6
Macrophyll	1	1.9

The absence of leptophyll and nanophyll leaves suggests the prevalence of tropical climate in the foot-hill region during sedimentation.

Other physiognomic features of angiospermous leaves which have been used as a tool in interpreting past climate are (i) leaf organization, compound versus simple (Bailey & Sinnot, 1916; Dolph & Dilcher, 1979), (ii) major venation pattern (Bailey & Sinnot, 1916), (iii) venation density (Wolfe, 1969), and (iv) leaf shape (Richards, 1952; Givnish, 1979).

The organization of leaves (compound or simple) solely depends upon the availability of moisture/ precipitation. Givnish (1979) postulated that the compound foliage are commonly associated with deciduousness. Dolph and Dilcher (1979) opined that the percentage of simple leaves increased from piedmont to both mountain and coastal regions where precipitation is high. Interestingly, majority of taxa in the plant assemblage of Koilabas in the foot-hills of Nepal possesses simple leaves. Therefore, this further supports the prevalence of somewhat higher precipitation in the region during the deposition of Siwaliks.

Regarding the venation pattern and venation density, the Siwalik flora of Koilabas area does not allow for any marked conclusion because the elements possess different types of venation pattern and the venation density has not been found constant (Table 3). The shape of the leaves in this flora is mostly stenophyllous (narrow leaves) type which tends to occur on stream side plants (Richards, 1952) where the environment is rich with moisture. In fossil leaves, particularly in leaf-impressions, it becomes rather difficult to determine the chartaceous or coriaceous nature of leaves. Although the leaves with swollen base are indicators of humid climate.

Thus from the foregoing discussion it may be concluded that the Himalayan foot-hills near Koilabas in western Nepal enjoyed a tropical climate with plenty of rainfall during the Siwalik sedimentation. This is, however, contrary to the present day climate of the area with reduced precipitation.

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REFERENCES

Agarwal A 1989. Occurrence of *Bouea* in the Neyveli lignite deposits, India. *Geophytology* **18** : 166-168.

Antal JS & Awasthi N 1993. Fossil flora from the Himalayan foot-hills of Darjeeling District, West Bengal and its palaeoecological and phytogeographical significance. *Palaeobotanist* **42**(1) : 14-60.

Auden JB 1935. Traverses in the Himalaya. *Rec. geol. Surv. India* **69**(2) : 123-167

Awasthi N & Prasad M 1990. Siwalik plant fossils from Surai Khola area, western Nepal. *Palaeobotanist* **38** : 298-318.

Bailey IW & Sinnot EW 1916. The climate distribution of certain type of angiosperm leaves. *Amer. J. Bot.* **3** : 24-39.

Berry EW 1921. Tertiary fossil plants from Venezuela. *Proc U.S. natn. Mus.* **59** : 553-579.

Bordet P 1961. Recherches Geologiques Dans L' Himalaya Du Nepal region du Makalu. *Cont. Nat. Del la Res. S. Sci. Paris*, 275 p.

Brandis D 1971 *Indian Trees*. Bishen Singh Mahendra Pal Singh, Dehradun.

Cautley PT 1832. Letter noticing the discovery of further fossils in vast quantity in the Siwalik range. *J. Asiatic Soc. Bengal* **4** : 585-587.

Champion HG & Seth SK 1968. *The forest types of India*. Manager of Publications, Delhi.

Chaudhuri RS 1983. Provenance of the Siwalik sediments of Nepal Himalaya. *Contemporary Geosci. Res. in Himalaya* **2** : 85-90.

Chiarugi A 1933. Legnifossili della Somalia Italiana. *Palaeontogr. ital.* **32**(Suppl. 1) : 97-167.

Chowdhury KA & Ghosh SS 1958. *Indian Woods*. Manager of Publications, Delhi.

Corvinus G 1990. Litho- and biostratigraphy of the Siwalik succession in Surai Khola area, Nepal. *Palaeobotanist* **38** : 293-297

Dayal R 1965. *Sapindoxylon schleicheroides* sp. nov. : a fossil dicotyledonous wood from the Deccan Intertrappean beds of Madhya Pradesh. *Palaeobotanist* **13**(2) : 163-197.

Desch HF 1957. Manual of Malayan timbers 1. *Malayan Forest Rec.* **15** : 1-328.

Dilcher DL 1979. Approaches to identification of angiosperm leaf remains. *Bot. Rev.* **40**(1) : 1-157

Dolph GE & Dilcher DL 1979. Foliar physiognomy as aid in determining palaeoclimate. *Palaeontographica* **170**(4-6) : 151-172.

Falconer H 1968. Introductory observations on the geography, geological structure and fossil remains in the Siwalik hills. *Palaeontol. Mem.* **1** : 1-29.

Gamble JS 1972. *A manual of Indian timbers*. Bishen Singh Mahendra Pal Singh, Dehradun.

Geyler HT 1887. Uber fossil Pflanzen von Labuan. *Vega-Exped. Vetensk Arbeten* **4** : 475-507.

Givnish T 1979. On the adaptive significance of leaf form. *In* : Solbrig OT, Jain S, Johnson GB & Raven P (Editors)—*Topic on plant population biology* : 375-407. New York, Columbia Univ. Press.

Givulescu R 1968. Ein neuer Beitrag zur Kenntnis der fossilen Flora von Cerus Beiduy (Rumanien). *Geologie* **17**(5) : 572-605.

Gleinnie KW & Zeigler MA 1964. The Siwalik Formation in Nepal. *22nd Int. geol. Congr.* **15** : 82-95.

Guleria JS 1992. African elements in the Upper Tertiary flora of Rajasthan, western India. *I.A.W.A. Bull* (Abstract).

Hagen T 1959. Uber den geologischen Bau des Nepal Himalaya. *J. St. Gall. Natur Ges* **76** : 3-48.

Hickey LJ 1973. Classification of architecture of dicotyledonous leaves. *Am. J. Bot.* **60** : 17-33.

Huzioka K 1972. The Tertiary flora of Korea. *J. Min. Coll. Akita Univ.* ser. A **5**(1) : 1-83.

Ishida S 1970. The Noroshi flora of Noto Peninsula, central Japan. *Mem. Fac. Sci. Kyoto Univ.* ser. *Geol. Min.* **37**(1) : 1-112.

Kanji Lal UN 1928. *The forest flora of the Siwalik and Jaunsar forest division, U.P.* Manager of Publications, Delhi.

Krausel R 1939. Ergebnisse der Forschungsreisen Prof. E. Stromers in den Wusten Agyptens IV Die fossilen Floren. Agyptens. Teil 3, E-I: *Abh. bayer. Akad. Wiss. Math-nat. Abt.*, NF. **47** : 1-140.

Krishnan MS 1968. *Geology of India and Burma.* Higgin-bothams Ltd., Madras.

Kumar R & Gupta VJ 1981. Stratigraphy of Nepal Himalaya. *Contemp. Geosci. Res. in Himalaya, Dehradun* : 161-176.

Lakhanpal RN 1956. Occurrence of *Zizyphus* in the Lower Siwalik beds near Jawalamukhi. *Curr. Sci.* **34**(23) : 666-667.

Lakhanpal RN 1966. Fossil Rhamnaceae from the Lower Siwalik beds near Jawalamukhi (Himachal Pradesh). *Publ. Centre Adv. Study Geol. Panjab Univ.* **3** : 23-26.

Lakhanpal RN & Awasthi N 1984. A Late Tertiary florule from near Bhikhnathoree in West Champaran District, Bihar. *Proc. Symp. Evol. Bot. biostratigr. (A.K. Ghosh Commem. Vol.)* : 587-596. Bot. Soc. Bengal, Calcutta.

Lakhanpal RN & Dayal R 1966. Lower Siwalik plants from near Jawalamukhi, Punjab. *Curr. Sci.* **35**(8) : 209-211.

Lakhanpal RN & Guleria JS 1982. Plant remains from the Miocene of Kachchh, western India. *Palaeobotanist* **30**(3) : 270-296.

Lakhanpal RN, Prakash U & Bande MB 1978. Fossil dicotyledonous woods from the Deccan Intertrappean beds of Mandla District, Madhya Pradesh. *Palaeobotanist* **25** : 190-204.

Madel-Angeliewa E & Muller-Stoll WR 1973. Kritische studien uber fossile Combretaceen Holzer. Uber Holzer von typus. *Terminalioxylon* G. Schonfeld mit einer Revision der bisher zu *Evodioxylon* Chiarugi gestellten arten. *Palaeontographica* **142B**(4-6) : 117-136.

Matsuo H 1967. Palaeogene floras of northwestern Kyushu—Part 1. The Takahisma flora. *Ann. Sci., Kanazawa Univ.* **4** : 15-90.

Ohta Y & Akiba C 1973. *Geology of Nepal Himalayas.* Him. Comm. Hokkado Univ., Japan.

Pilgrim GE 1913. Correlation of the Siwalik with the Mammal horizon of Europe. *Rec. geol. Surv. India* **43** : 262-326.

Prakash U & Tripathi PP 1970. Fossil woods from the Tipam Sandstones near Hailakandi, Assam. *Palaeobotanist* **18**(2) : 183-191.

Prakash U & Tripathi PP 1992. Floral evolution and climatic changes during the Siwalik period. *Biol. Mem.* **18**(1, 2) : 57-68.

Prasad M 1990a. Some more leaf-impressions from the Lower Siwalik beds of Koilabas, Nepal. *Palaeobotanist* **37**(3) : 299-305.

Prasad M 1990b. Fossil flora from the Siwalik sediments of Koilabas, Nepal. *Geophytology* **19**(1) : 79-105.

Prasad M 1993a. Leaf-impressions of *Kayea* from the Siwalik sediments (Miocene-Pliocene) of Kalagarh, Uttar Pradesh, India. *Tertiary Res.* **14**(3) : 107-110.

Prasad M 1993b. Siwalik (Middle Miocene) woods from Kalagarh area in the Himalayan foot-hills and their bearing on palaeoclimate and phytogeography. *Rev. Palaeobot. Palynol* **76** : 49-82.

Prasad M 1994a. Angiospermous leaf remains from the Siwalik sediments of Hardwar, Uttar Pradesh and their bearing on palaeoclimate and phytogeography. *Him. Geol.* **14** : 83-94.

Prasad M 1994b. Investigations on the Siwalik (Middle Miocene) leaf impressions from the foot-hills of the Himalaya, India. *Tertiary Res.* (in press).

Prasad M & Prakash U 1984. Leaf-impressions from the Lower Siwalik beds of Koilabas, Nepal. *Proc. V Indian geophytol. Conf., Lucknow Stl. Publ.* : 246-256.

Prasad M & Prakash U 1987. Occurrence of Malayan dipterocarps in the Siwalik sediments of Uttar Pradesh. *Geophytology* **17**(2) : 245-255.

Principi P 1926a. La flora oligocenica di chiavon e Salcedo. *Mem. del R. uff. geol. d' Italia* **X** : 1-130.

Principi P 1926b. Nuovo contributo alle Studio della flora Sarmaziana di Polenta. *Acta Soc. ligustica Sci. Letter* **V**(III) : 1-72.

Raunkiaer C 1934. *Life forms of plants and statistical plant geography.* Oxford Univ. Press.

Richards PW 1952. *The tropical rain forest : an ecological study.* Cambridge Univ. Press, Cambridge.

Sharma CK 1977. *Geology of Nepal.* Kathmandu, Nepal.

Sharma CK 1980. Geological study of the Nepal Himalaya. *Structural Geology of Himalaya* : 221-225.

Shukla VB 1950. *Sahnipushpum* gen. nov. and other plant remains from the Deccan Intertrappean. *J. Indian bot. Soc.* **29**(1) : 29.

Singh T & Prakash U 1980. Leaf-impressions from the Siwalik sediments of Arunachal Pradesh, India. *Geophytology* **10**(1) : 104-107.

Takahashi K 1954. Zurfosslen flora aus der oya Formation von Kiushiu, Japan. *Mem. Fac. Sci. Kyushu Univ.* ser. D **5**(1) : 47-67.

Tanai T 1955. Illustrated catalogue of Tertiary plants in Japanese coalfield I. Early and Middle Miocene floras. *Geol. Surv. Jap. Rep.* **163** : 1-16.

Tokuoka T, Takayasu K, Yoshida M & Hisatomi K 1986. The Churia (Siwalik) Group of the Arung Khola area, west central Nepal. *Mem. Fac. Sci., Shimane Univ.* **20** : 135-210.

Tokuoka T, Takeda S, Yoshida M & Upreti BN 1988. The Churia (Siwalik) Group in the western part of the Arung Khola area, west central Nepal. *Mem. Fac. Sci., Shimane Univ.* **22** : 131-140.

Tripathi PP & Tiwari VD 1983. Occurrence of *Terminalia* in the Lower Siwalik beds near Koilabas, Nepal. *Curr. Sci.* **52**(4) : 167.

Trivedi TK 1950. Preliminary report on the leaf-impressions from the Mewar State. *Curr. Sci.* **28**(6) : 253-254.

Webb LJ 1959. A physiognomic classification of Australian rain forests. *J. Ecol.* **47** : 55-70.

West MR 1984. Siwalik fauna from Nepal : palaeoecologic and palaeoclimate implications. *In* : White RO (Editor)—*The evolution of the East Asian environment* **II** : 724-744. Centre of Asian Studies, University of Hongkong.

Willis JC 1973. *A dictionary of the flowering plants and ferns.* Cambridge.

Wolfe JA 1969. Palaeogene flora from the Gulf of Alaska region. *U.S. Geol. Surv. open file rept.*