

Siwalik (Middle Miocene) leaf impressions from Tanakpur area, Uttaranchal and their bearings on climate

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Shashi, Pandey SM & Prasad M. 2008. Siwalik (Middle Miocene) leaf impressions from Tanakpur area, Uttaranchal and their bearings on climate. *Geophytology* 37 : 99-108.

The present paper gives a detailed account on morphotaxonomy of eight leaf impressions from the Siwalik sediments of Tanakpur area in Champawat District of Uttaranchal, India. These leaf impressions have been identified with the extant taxa, *Ellipeia cuneifolia* H. & Th. (Anonaceae), *Commiphora caudata* Engl. (Burseraceae), *Caesalpinia microphylla* G. Don. and *Millettia atropurpurea* Benth. (Fabaceae), *Cinnamomum caudatum* Nees and *C. tavoyanum* Meiss. (Lauraceae), *Diospyros ebenum* Koenig and *D. variegata* Kurz (Ebenaceae). Occurrence of these taxa in the Lower Siwalik sediments (Middle Miocene) suggests that a tropical evergreen forest was flourishing under warm humid climate in the vicinity of Tanakpur area in contrast to the present day mixed deciduous forest.

Key-words – Leaf impressions, Angiosperm, Climate, Lower Siwalik (Middle Miocene), Tanakpur area, Uttaranchal.

INTRODUCTION

THE sediments of the Siwalik Group were deposited continuously by various rivulets in the Himalayan foreland for last 20 Myr (DeCelles *et al.*, 2001). These sediments provide an excellent opportunity to study the plant megafossils comprising woods (petrified and carbonized), leaf, fruit and seed impressions entombed in the alluvial sediments. The Siwalik sediment in India, Nepal and Bhutan are exposed in the southern frontal area of the Himalaya in a WNW to ESE trending belt and is bounded by the Main Boundary Thrust (MBT) to the north and the Himalayan Frontal Thrust (HFT) to the south. The fossil locality, Tanakpur (29° 04' : 80° 07') is situated in the foothills of Champawat District, Uttaranchal (Fig. 1) and very rich in plant fossils comprising petrified and carbonized woods, leaf, fruit, and seed impressions.

The Siwalik beds in the Tanakpur area are found running in the north-east direction and are well exposed at the bank of Sarda river near Thuligad, and on Thuligad-Purniyagiri road, about 15 km from Tanakpur and Tanakpur-Pithoragarh road. Recently, a lot of plant megafossils including leaf and fruit impressions were collected from a road cutting section from Thuligad to Purniyagiri temple. The morphotaxonomical study of well preserved leaf impressions has been done which reveals the occurrence of eight angiospermous fossil taxa, viz., *Ellipeia miocenica* sp. nov., *Commiphora precaudata* sp. nov., *Caesalpinia purniyagiriensis* sp. nov., *Millettia prakashii* sp. nov., *Cinnamomum miotavoyanum* sp. nov., *Cinnamomum nepalensis* Prasad & Pandey, *Diospyros purniyagiriensis* sp. nov., and *D. palaeoebenum* Prasad.

MATERIAL AND METHOD

More than 40 specimens of well preserved leaf

impressions were collected from the Lower Siwalik fossiliferous beds exposed in a road cutting section near Purniyagiri about 18 km north of Tanakpur (29° 04' : 80° 7') in Champawat District of Uttaranchal (Figs 1-2). The leaf impressions are devoid of cuticle and preserved on grey and purple shales and few of them on fine grained sandstone. The leaf impressions have been studied morphologically with the help of either hand lens or low power microscope under reflected light.

The herbarium sheets of several extant families and genera were examined at the Central National herbarium, Sibpur, Howrah, West Bengal in order to identify these leaf impressions. For description of leaf impressions, the terminology given by Hickey (1973) and Dilcher (1974) has been followed. The photographs of the leaves of the modern comparable taxa have been provided to show similarity with the fossil leaves. All the figured specimens have been deposited at Department of Botany, M.L.K. Post Graduate College, Balrampur, U.P.

SYSTEMATICS OF FOSSIL LEAVES

Angiosperm

Dicotyledons

Family – Annonaceae

Genus – *Ellipeia* Hook. F. Th.

Ellipeia miocenica sp. nov.

(Pl. 1, Fig. 1)

Material—This species is based on two, well preserved leaf impressions.

Description—Leaf simple, symmetrical; elliptic; preserved size 8.8 x 5.4 cm; apex and base broken; texture coriaceous; margin entire; venation pinnate,

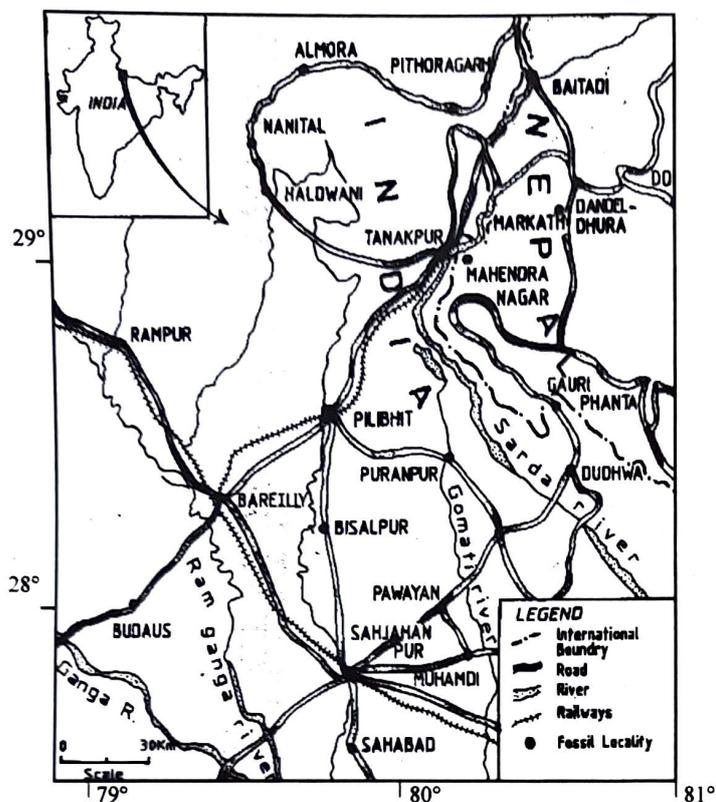


Fig. 1. Map of Tanakpur area showing fossil locality.

eucamptodromous; primary vein (1°) single, slightly curved, stout; secondary veins (2°) 7-8 pairs visible, 1.3-1.6 cm apart, alternate to opposite, angle of divergence 50° - 60° , curvature distinct, moderate, uniformly curved up, unbranched; intersecondary veins present; tertiary veins (3°) fine, poorly preserved, angle of origin RR, percurrent, straight to sinuous, oblique in relation to midvein; alternate to opposite and close.

Affinities—Symmetrical shape, entire margin, eucamptodromous venation, distinct curvature of secondary veins which arise at moderately acute angle, presence of intersecondary veins and RR, percurrent, straight to sinuous tertiaries undoubtedly suggest its affinity with the leaves of extant *Ellipeia cuneifolia* H. f. & Th. of the family Annonaceae (C.N.H. herbarium sheet no. 11009). During its identification it has been observed that the leaves of *Shorea stellata* Dyer. show superficial resemblance with the fossil leaves but they differ in nature of secondary veins which are not so markedly curved as in the fossil leaves.

As far as authors are aware it is the first record of fossil

leaf showing resemblance with the leaves of the genus *Ellipeia* H.f. & Th. from Tertiary sediments of India and abroad hence these are described here as a new species, *Ellipeia miocenica*.

The genus, *Ellipeia* H. f. & Th. consists of five species distributed in Western Malaysia (Willis, 1966; Mabberley, 1997, p.253). The comparable species *E. cuneifolia* Hook. f. & Th. is a climber growing in the dense forests of Malacca, Tobang and Malaya (Ridley, 1967).

Holotype – Specimen no. Tnk 32.

Paratype - Specimen no. Tnk 33.

Locality - Purniyagiri road section, Tanakpur area, Champawat District, Uttaranchal.

Horizon & Age – Lower Siwalik, Middle Miocene.

Etymology – After the Miocene age of the sediments from which fossils were collected.

Family – Burseraceae

Genus – *Commiphora* Jacq.

Commiphora precaudata sp. nov.

(Pl.1, Fig. 3)

Material—This species is based on a single, fairly preserved leaf impression.

Description—Leaf, symmetrical; preserved lamina size 3.5x2.2 cm; wide elliptic; apex acuminate; base obtuse; margin entire; texture coriaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein (1°) single, stout, straight, thicker at the basal portion; secondary veins (2°) 5-6 pairs visible, .04-.09 cm apart, angle of divergence 50° , moderately acute, opposite to alternate, joined adjacent secondary at acute angle; intersecondary veins poorly preserved, simple; tertiary veins (3°) fine and very poorly preserved, angle of origin AO-RR, percurrent, straight to sinuous, oblique in relation to midvein, predominantly alternate and close.

Affinities—The diagnostic features of the present fossil leaf are small, elliptic shape, acuminate apex, obtuse base, eucamptodromous venation, presence of intersecondary veins and AO-RR, percurrent tertiary veins. These features are found common in the extant leaves of *Commiphora caudata* Engl. of the family Burseraceae and *Xanthophyllum pulcherum* R. of the family Xanthophyllaceae. On critical examination of the herbarium sheets of both the taxa it has been observed that

PLATE-1

(All figures in natural size)

1. *Ellipeia miocenica* sp. nov. – Fossil leaf showing shape, size and venation pattern.
2. *E. cuneifolia* Hook. f. & Th. - Modern leaf showing shape, size and venation pattern similar to the fossil.
3. *Commiphora precaudata* sp. nov. Fossil leaf showing shape, size and venation pattern.
4. *C. caudata* Engl. - Modern leaf showing shape, size and venation pattern similar to the fossil.
5. *Cinnamomum nepalensis* Prasad & Pandey- Fossil leaf showing shape, size and venation pattern.
6. *C. caudatum* Nees. – Modern leaf showing shape, size and venation pattern similar to the fossil.
7. *Diopyros palaeoebenum* Prasad - Fossil leaf showing shape, size and venation pattern.
8. *D. ebum* Koinig - Modern leaf showing shape, size and venation pattern similar to the fossil.



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PLATE-1

the leaves of *Xanthophyllum pulcherum* differ from fossil leaf in possessing narrow ovate shape against wide ovate shape in the fossil. Thus the leaves of *Commiphora caudata* Engl. show closest affinity with the present fossil (C.N.H. herbarium sheet no. 13285; Pl.1, Fig.4).

So far, there is no record of fossil leaf resembling the genus *Commiphora* Jack. from the Tertiary sediments of India therefore it is described as *Commiphora precaudata* sp. nov.

The genus, *Commiphora* Jacq. consists of about 190 species of shrub or small tree distributed in the tropical region of Africa, Madagascar and Arabia to Western India, Sri Lanka and South America (Mabberley, 1997, p. 174). The extant taxa, *C. caudata* Engl. with which fossil shows closest affinity is a small tree growing in the mixed deciduous forest of western peninsula.

Holotype – Specimen no. Tnk 34.

Locality - Purniyagiri road section, Tanakpur area, Champawat District, Uttaranchal.

Horizon & Age – Lower Siwalik, Middle Miocene.

Etymology – By adding a prefix 'pre' to the modern comparable species, *C. caudata*.

Family – Fabaceae

Genus – *Caesalpinia* Linn.

Caesalpinia purniyagiriensis sp. nov.

(Pl.2, Figs 1, 2; Pl.3, Fig.1)

Material—There are three fairly preserved specimens and the leaflets are arranged on the rachis.

Description—Leaf compound, the preserved part consist of up to 10 pairs of small leaflets, 1.5cm in length and 0.3 cm width; asymmetrical, opposite; narrow oblong; apex and base both obtuse; margin entire; texture chartaceous; petiole attached with rachis; venation pattern not clearly seen; primary vein (1°) single, prominent, almost straight running not in the mid of the lamina; secondary veins (2°) poorly preserved, seemingly arise closely at acute angle.

Affinities—The characteristic features of the fossil leaflets such as small, asymmetrical, narrow oblong shape, obtuse apex and base and the nature of primary and secondary veins indicate that the fossil specimens belong to the family Fabaceae. After a critical examination of the herbarium sheets of the genera containing such small compound leaf of this family it

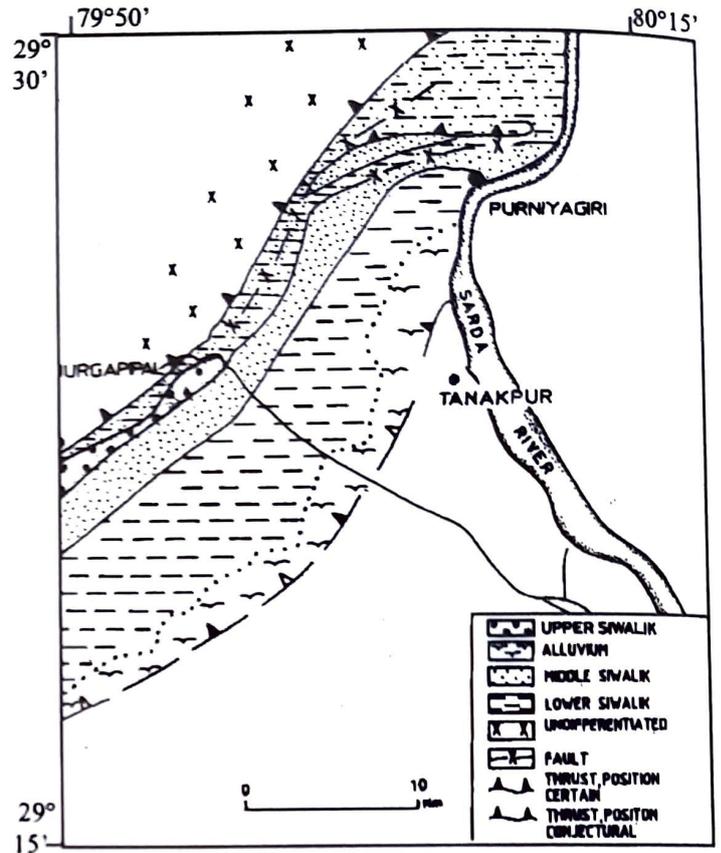


Fig. 2. Map showing Siwalik outcrops in the study area.

has been concluded that these fossil leaflets show closest resemblance with the leaflets of the extant genus *Caesalpinia* Linn. particularly *C. microphylla* Ham. (C.N.H. Herbarium sheet no. 134429; Pl.2, Fig.3, Pl.3, Fig.2).

As far as authors are aware there is no record of fossil leaflet resembling genus *Caesalpinia* from the Tertiary sediments of India and they are described here as *Caesalpinia purniyagiriensis* sp. nov.

The genus *Caesalpinia* Linn. consists of more than 150 species (Mabberley, 1997, p.113) of trees shrubs and climbers and distributed throughout tropical and subtropical regions. *C. microphylla* Ham. with which fossil leaflets resemble closely, is a tree which grows in the forest of Sikkim, western Bhutan, Assam and Sylhet (Brandis, 1971).

Holotype—Specimen no. Tnk 36.

Paratype—Specimen no. Tnk 35, 37.

PLATE -2

(All figures in natural size)

- 1,2. *Caesalpinia purniyagiriensis* sp. nov. – Fossil leaf showing shape, size and venation pattern.
3. *C. microphylla* G. Don.- Modern leaf showing shape, size and venation pattern similar to the fossil.
4. *Cinnamomum miotavoyanum* sp. nov. - Fossil leaf showing venation pattern.
5. *Diospyros purniyagiriensis* sp. nov. - Fossil leaf showing shape, size and venation pattern.
6. *D. variegata* Kurz – Modern leaf showing shape, size and venation pattern similar to the fossil.



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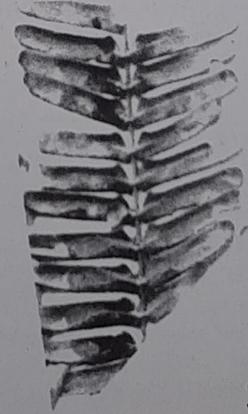
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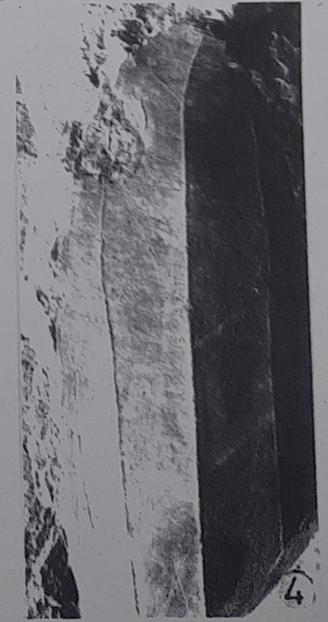
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PLATE-2

Locality—Purniyagiri road section, Tanakpur area, Champawat District, Uttaranchal.

Horizon & Age—Lower Siwalik, Middle Miocene.

Etymology—The specific name is after the name of fossil locality, Purniyagiri.

Genus – *Millettia* W. & A.

Millettia prakashii sp. nov.

(Pl.3, Fig. 3)

Material—A single, well preserved leaf impression.

Description—Leaf simple, symmetrical; nearly narrow elliptic; preserved size 10.0x3.8 cm; apex broken; base slightly broken, seemingly acute; margin entire; texture coriaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein (1°) single, straight, prominent, stout; secondary veins (2°) 7-8 pairs visible, 1.2 to 2.4 cm apart, angle of divergence 45°-55°, moderate, uniformly curved up, lower pair more acute than above, joined superadjacent secondary at acute angle, unbranched; inter secondary veins present, simple; tertiary veins (3°) fine, angle of origin, usually AR, percurrent, retroflexed, oblique in relation to midvein, predominantly opposite and close.

Affinities—The most important features of the present fossil leaflet are narrow elliptic shape, entire margin, coriaceous texture, eucamptodromous venation, moderately acute angle of secondaries, orientation of lower pairs of secondaries, RR, percurrent, retroflexed and close tertiary veins. A critical study of the herbarium sheets of different extant taxa it has been concluded that the leaflets of *Millettia atropurpurea* Dunn. (C.N.H. herbarium sheet no. 112825; Pl.3, Fig.4) of the family Fabaceae show closest resemblance with the fossil leaflets in shape, size and venation pattern.

A number of fossil leaflets showing similarity with *Millettia* W. & A. leaflets are known from Tertiary sediments of India and abroad (Prasad *et al.*, 1999). Seven species are known from Siwalik sediments of India, Bhutan and Nepal. These are *Millettia koilabasensis* Prasad, 1990b; *M. siwalica* Prasad 1990a. *M. miobrandissiana* Prasad 1994a and *M. imlibasensis* Prasad *et al.*, 1999 from the Siwalik sediments of Koilabas, western Nepal, *M. palaeoracemosa* Awasthi & Prasad, 1990 and *M. churiensis* Prasad & Awasthi, 1996 and *M. koilabasensis* (Prasad) Prasad & Pandey, 2008 from Surai Khola, western Nepal; *M. oodlabariensis* Antal & Prasad, 1996a from the Lower Siwalik sediments of Darjeeling District,

West Bengal, India. *M. palaeoracemosa* Awasthi & Prasad (Prasad, 1994c) and *M. kathgodamensis* Prasad *et al.*, 2004 from Siwalik sediments of Kathgodam, India and *M. koilabasensis* Prasad from Siwalik sediments of Laxmi River beds, Bhutan (Prasad and Tripathi, 2000). The present fossil leaflet has been compared with all the above known species but they differ mostly in nature and course of secondary veins. More over, most of them are either wider or smaller in size than the present fossil. In view of this the present fossil has been described under a new specific name, *Millettia prakashii*.

The genus *Millettia* W. & A., comprises about 90 species (Mabberley, 1997, p.457) of tree, shrub and climber distributed in the tropical regions of Africa, Asia and Australia. About 30 species distributed in the Indian region. *Millettia atropurpurea* Benth., with which the fossil resembles is a large tree which occurs in the evergreen forests of south eastern part of the Pegu Hills between the Thaungyin and Hlaingbwe rivers and elsewhere in Martaban and Tennasserim and Myanmar (Brandis 1971, Gamble, 1972).

Holotype—Specimen no. Tnk 38.

Locality—Purniyagiri road section, Tanakpur area, Champawat District, Uttaranchal.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—In honour of late Dr. Uttam Prakash, an eminent Palaeobotanist, Birbal Sahni Institute of Palaeobotany, Lucknow.

Family – Lauraceae

Genus - *Cinnamomum* Schaeffer

Cinnamomum miotavoyanum sp. nov.

(Pl. 2, Fig. 4; Pl.3, Fig.5)

Material—This species is based on a single, well preserved and almost complete leaf impression.

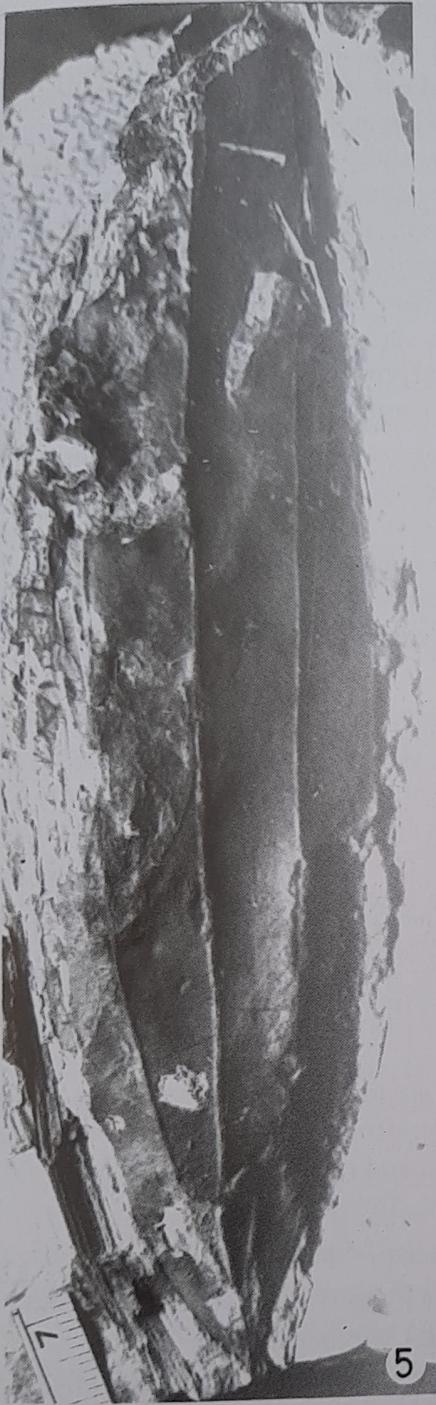
Description—Leaf simple, symmetrical; lorate; preserved size 15.2x3.2 cm; apex broken; base acute to cuneate; margin entire; petiole preserved, very short, 0.2 cm visible; texture coriaceous; venation acrodromous, imperfect, lateral veins arising slightly above the base; primary vein (1°) three stout; secondary veins (2°) arising from primaries nearly at right angle, numerous, almost right angle in relation to midveins.

Affinities—The diagnostic features of the present fossil leaf such as lorate shape, acute to cuneate base, entire margin, small petiole, acrodromous, imperfect venation and nearly right

PLATE -3

(All figures in natural size)

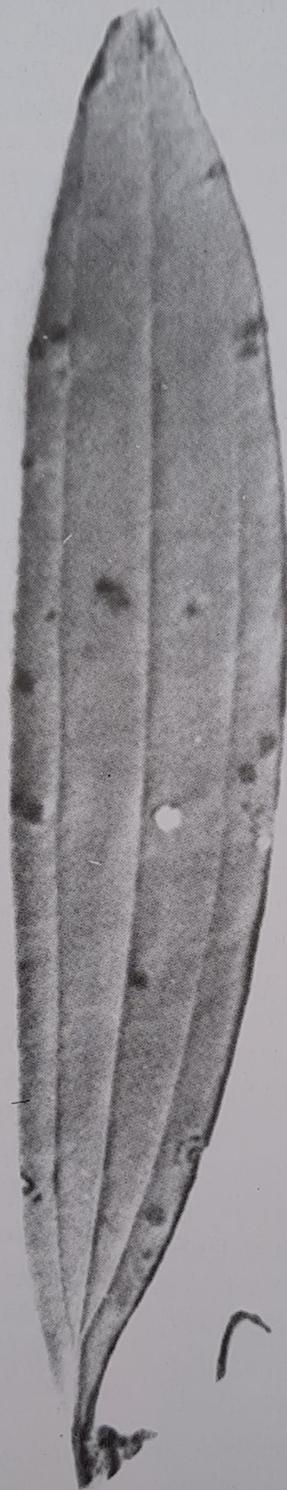
1. *Caesalpinia purniyagiriensis* - Fossil leaflets showing shape, size, venation pattern and their arrangement.
2. *C. microphylla* G. Don - Modern leaf showing shape, size, venation pattern and their arrangement similar to the fossil.
3. *Millettia prakashii* sp. nov. - Fossil leaf showing shape, size and venation pattern.
4. *M. atropurpurea* Benth. - Modern leaf showing shape, size and venation pattern.
5. *Cinnamomum miotavoyanum* sp. nov. - Fossil leaf showing shape, size and venation pattern.
6. *C. tavoyanum* Miess.- Modern leaf showing shape, size and venation pattern.



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PLATE-3

angle of divergence of secondary veins undoubtedly indicate that the fossil leaf shows affinity among the leaves of the family Lauraceae. On critical study of the herbarium sheets of different genera and species belonging to this family it has been observed that the leaves of the extant taxon, *Cinnamomum tavoyanum* Miess. (Syn. *C. sulphuratum* Kurz) show closest affinity with the present fossil in almost all the morphological features (C.N.H. Herbarium sheets no. 265, 285; Pl.3, Fig.6).

There are six fossil records of *Cinnamomum* from India and Nepal. These are *Cinnamomum* sp. Pathak (1969) from the Middle Siwalik sediments in Mahanadi River Section, near Darjeeling, West Bengal, *C. eokachchhensis* Lakhanpal and Guleria (1981) from the Eocene of Kachchh, western India; *C. palaeotamala* Lakhanpal and Awasthi (1984) from the Siwalik sediments of Bhikhnathoree, West Champaran District, Bihar, *C. mioinuctum* Prasad (1990a) from the Siwalik sediments exposed near Koilabas, Nepal, *Cinnamomum* sp. Antal and Awasthi (1993) from Siwalik sediments of Darjeeling District, West Bengal and *C. nepalensis* Prasad and Pandey, (2008) from Siwalik sediments, Surai Khola, Nepal.

After comparison of present fossil leaf with all the above known species it has been found that *C. mioinuctum* Prasad differs from present fossil in being obovate shape with eucamptodromous type of venation as compared to elliptic shape with acrodromous venation. The other species having acrodromous venation differ in being possessing either narrow oblong or narrow elliptic shape against lorate shape in the present fossil. Besides in the present fossil leaf the lateral primaries arise from above the base of mid primary (imperfect acrodromous type of venation). Thus being different from all the already described species, the present fossil leaf has been assigned to a new specific name, *Cinnamomum miotavoyanum*.

The genus, *Cinnamomum* Schaeffer comprises 350 species (Mabberley, 1997, p.158) of evergreen trees and shrubs occurring in tropical and subtropical regions of East Asia and south east to Australia and Tropical America. Gamble (1972) enumerated 24 species of this genus from India. *Cinnamomum tavoyanum* Meiss., with which fossil leaf shows closest affinity is an evergreen tree distributed in the forests of Myanmar and Tenasserim as well as in the Sola forests of Nilgiris. (Brandis, 1971, Gamble, 1972).

Holotype—Specimen no. Tnk 39.

Locality—Purniyagiri road section, Tanakpur area, Champawat District, Uttaranchal.

Horizon & Age—Lower Siwalik; Middle Miocene

Etymology—By adding prefix 'Mio' (after Miocene age of the rocks) to the extant comparable species, *C. tavoyanum*.

Cinnamomum nepalensis Prasad and Pandey, 2008

(Pl.1, Fig.5)

Material—This species consists of a single, well

preserved leaf impression which is slightly broken toward basal region.

Description—Leaf simple, symmetrical; wide elliptic; preserved size 4.5x3.5cm; apex acute; base broken; margin entire; texture coriaceous; venation acrodromous, two veins arising at the base running parallel and reaching the apex; primary vein (1°) stout, prominent, slightly curved; secondary veins (2°) arising from primaries nearly at right angle, moderate in thickness; sometimes branched, arising from mid primary and join to laterals, secondaries also arising from the outer side of the two lateral primaries and running upward and some joined to form intramarginal vein.

Affinities: The most important features of the fossil leaf such as wide elliptic, acute apex, entire margin, acrodromous venation with two lateral primaries and formation of intramarginal veins suggests that the fossil leaf shows closest affinity with the extant leaves of *Cinnamomum caudatum* Nees of the family Lauraceae (C.N.H. Herbarium sheets no. 383936; Pl.1, Fig.6).

Seven fossil leaves of *Cinnamomum* Shaeffer are known from the Tertiary sediments of India and Nepal (listed earlier in this text). The present fossil leaf has been compared with the already known species of *Cinnamomum* Shaeffer and it has been concluded that *C. nepalensis* Prasad and Pandey (2008) described from the Siwalik sediments of Surai Khola area, western Nepal is showing similarity with the present fossil leaf in almost all the morphological features and hence this fossil is assigned to the same species *C. nepalensis* Prasad and Pandey.

The extant, *Cinnamomum caudatum* Nees with which fossil shows closest affinity is a tree and distributed in the sub-Himalayan tract and outer ranges from Nepal eastwards and Upper Myanmar. (Brandis, 1971).

Figured specimen—Specimen no Tnk 40.

Locality—Purniyagiri road section, Tanakpur area, Champawat District, Uttaranchal.

Horizon & Age—Lower Siwalik; Middle Miocene.

Family – Ebenaceae

Genus – *Diospyros* Linn.

Diospyros purniyagiriensis sp. nov.

(Pl.2, Fig.5)

Material—This species is based on a well preserved leaf impression which is slightly broken towards apex.

Description—Leaf simple, symmetrical; narrow elliptic to oblong; preserved size 16.0x7.0cm; apex broken; base seemingly wide acute; margin entire; texture coriaceous; petiole not preserved; venation pinnate, simple craspedodromous to eucamptodromous; primary vein (1°) single, straight, prominent, stout; secondary veins (2°) 7-8 pairs visible, 1.6 to 2.8cm apart, angle of divergence about 50°, moderate, uniformly curved up, lower pair more acute than

above, joined super adjacent secondary at acute angle, thick moderate; intersecondary veins present, frequent, 3-4 veins in between two secondaries; tertiary veins (3°) fine, angle of origin RR, percurrent, straight to sinuous, oblique in relation to midvein, predominantly alternate and close.

Affinities—After critical examination of the herbarium sheets of different genera and species of dicotyledonous families it has been concluded that the morphology of present species resembles with those of the extant species *Diospyros variegata* Kurz of the family Ebenaceae (C.N.H. Herbarium sheet no. 282208; Pl.2, Fig.6). The present fossil leaf resembles to it in shape, size, venation and other morphological features.

Fossil leaves resembling the genus *Diospyros* have been described under two generic names i.e. *Diospyros* Linn. and *Diospyrophyllum* Velenovsky. The later consists of only one species, *Diospyrophyllum provectum* Velenovsky, 1889 from the Upper Cretaceous of Bohemia. However, *Diospyros* Linn. contains about 70 species reported from different parts of the world.

Eleven species have been reported from the Tertiary sediments of Indian sub-continent. These are *Diospyros embryopterisites* Varma, 1968 from the Middle Siwalik of Haridwar, Uttar Pradesh, India (now in Uttaranchal), *D. miocenicus* Prasad & Awasthi, 1996, *D. miokaki* Awasthi & Prasad, 1990 from the Lower Siwalik sediments of Surai Khola, western Nepal; *D. kathgodamensis* Prasad, 1994b and *D. palaeoebenum* Prasad, 1994c from the Lower Siwalik sediments of Kathgodam. The later species has also been reported from the Lower-Middle Siwalik of Darjeeling District, West Bengal. *D. tulsipurensis* Prasad *et al.*, 1997 from the Lower Siwaliks of Seria Naka, at Indo-Nepal Border in Gonda District of Uttar Pradesh, *D. koilabasensis* Prasad, 1999a and *D. pretoposia* Prasad 1990a, *D. darwajaensis* Prasad *et al.*, 1999 from the Siwalik sediments of Koilabas, W. Nepal and *D. miocenicus* Prasad & Awasthi, and *D. pretoposia* Prasad from Miocene Neyveli lignite deposit of Tamil Nadu (Agarwal, 2002), *D. nainitalensis* and *D. palaeoeriantha* Prasad *et al.*, 2004 from Siwalik sediments of Gola River near Jamrani, Kathgodam, Uttaranchal.

The present fossil leaf has been compared with all the above known fossils and found that none of them show similarity with it. The fossil leaf *D. pretoposia* Prasad, 1990a only show some superficial resemblance in shape and size but differ in venation pattern. Thus, in being different the present fossil has been assigned to a new species, *Diospyros purniyagiriensis*. The modern comparable taxon, *Diospyros variegata* Kurz is a large tree growing now a days in the forests of Assam, Pegu and Martaban (Brandis, 1971).

Holotype—Specimen no. Tnk 41.

Locality—Purniyagiri road section, Tanakpur area, Champawat District, Uttaranchal.

Horizon & Age—Lower Siwalik; Middle Miocene.

Table 1—Present day distribution and forest types of the modern comparable taxa of the fossils recovered from Tanakpur area

| Modern comparable taxa | Forest type | Distribution |
|---------------------------------------|------------------------------|--|
| <i>Ellipeia cuneifolia</i> H.f. & Th. | Evergreen | Malaya Peninsula and Archipelago |
| <i>Commiphora caudata</i> Engl. | Mixed deciduous | Western Peninsula |
| <i>Caesalpinia microphylla</i> G. Don | Evergreen | Assam, Sylhet, and Java |
| <i>Milletia atropurpurea</i> Benth. | Evergreen | Peguyama, Martaban and Tenasserim |
| <i>Cinnamomum caudatum</i> Nees | Evergreen to Moist deciduous | N.E. India and Myanmar |
| <i>C. tavoyanum</i> Meiss. | Evergreen | Tenasserim, Nilgiris, Myanmar |
| <i>Diospyros ebenum</i> Kurz | Moist deciduous to evergreen | Deccan Cuddapah, Kurnool and Sri Lanka |
| <i>D. variegata</i> Kurz | Evergreen | Assam, Pegu and Martaban |

Etymology—Specific name is after the name of fossil locality, Purniyagiri.

***Diospyros palaeoebenum* Prasad 1994c**

(Pl.1, Fig.7)

Material—A single, fairly preserved and complete leaf impression.

Description—Leaf simple, symmetrical; narrow elliptic; preserved size 13.0x3.2cm; apex acute; base acute; petiole preserved, 3 cm long, normal; margin entire; texture coriaceous; venation pinnate, eucamptodromous; primary vein (1°) single, stout, markedly curved; secondary veins (2°) 5-6 pair visible, 0.9-1.3 cm apart, alternate, angle of divergence 45°-50°, moderate, uniformly curved up and joined their superadjacent secondary at acute angle; some times branched, intersecondary veins present; tertiary vein (3°) poorly preserved, angle of origin usually RR, usually percurrent, predominantly alternate and close.

Affinities—The diagnostic features of the present fossil leaf are - narrow elliptic shape, acute apex and base, entire margin, eucamptodromous venation, presence of intersecondary veins; and RR, percurrent tertiaries undoubtedly indicate that the present fossil leaf resembles closely with the extant leaves of *Diospyros ebenum* Kurz of the family Ebenaceae (C.N.H. Herbarium sheet no. 282226; Pl.1, Fig.8).

A number of fossil leaves showing affinity with the genus *Diospyros* Linn. have been reported from different parts of India and abroad. Of these eleven species have been known from Tertiary sediments of India (mentioned in this text). The fossil leaf described as *Diospyros palaeoebenum* (Prasad, 1994c) from Siwalik sediments of Kathgodam area of Nainital District shows resemblance with the same extant species, *D. ebenum* Kurz as the present fossil. On comparative study of present fossil as well as *Diospyros palaeoebenum* Prasad it

has been observed that both are not exactly similar to each other. The present fossil slightly differs in being narrow elliptic shape as compared to narrow ovate shape in *D. palaeoebenum* Prasad. As the present fossil is identified with extant species *D. ebenum* as *D. palaeoebenum* Prasad therefore, it has been assigned to the same.

The extant taxon, *Diospyros ebenum* Kurz with which fossil shows affinity is a large gregarious tree found to grow in the hills of Deccan and Sri Lanka. It is common in the dry evergreen forests of Cuddapah District especially Kurnool and Cuddapah (Brandis, 1971).

DISCUSSION

Present investigation on the plant fossils from the Siwalik sediments of Tanakpur, reveals the occurrence of 8 new fossil leaves showing affinity with the extant taxa *Ellipeia cuneifolia*, *Commiphora caudata*, *Caesalpinia microphylla*, *Millettia atropurpurea*, *Cinnamomum caudatum*, *C. tavoyanum*, *Diospyros ebenum* and *D. variegata*. The habit, habitat and distribution of modern equivalent taxa indicate that evergreen to moist deciduous elements (Table-1) were flourishing under warm humid climate in the region during the Lower Siwalik period in contrast to mixed deciduous elements of present day. It further indicates that none of the taxa now found to grow in the Himalayan foot-hills of Uttaranchal. All are extinct from the region and flourish today wherever suitable climatic conditions are found. This suggests that the climatic changes must have taken after deposition of Siwalik sediments.

ACKNOWLEDGEMENTS

The authors are thankful to authorities of Birbal Sahni Institute of Palaeobotany, Lucknow for providing necessary facilities. They are also thankful to the authorities of Central National Herbarium, Sibpur, Howrah, West Bengal for permission to consult the Herbarium.

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