Fossil leaf impressions from Siwalik sediments of Himalayan foot hills of Uttarakhand, India and their significance

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ABSTRACT


Morphotaxonomical study of well preserved angiospermous leaf impressions collected from Siwalik sediments of Purniyagiri near Tanakpur, Uttarakhand records five species viz., Mitrephora siwalika Antal & Awasthi, Sterculia tertiara sp. nov., Millettia purniyagiriensis sp. nov., Cynometra siwalika Awasthi & Prasad and Chonemorpha miocenica Prasad & Awasthi. These species compare with the extant taxa Mitrephora maingayi (Anonaceae), Sterculia ensifolia (Sterculiaceae), Millettia auriculata, Cynometra polyandra (Fabaceae) and Chonemorpha macrophylla (Apocynaceae) respectively. The habit, habitat and the present day distribution of the comparable extant taxa indicate that tropical evergreen forest was flourishing under warm humid climate in the area during the Siwalik times as compared to mixed deciduous forest there at present.

Key-words—Angiospermous leaf impression, Morphotaxonomy, Palaeoclimate, Siwalik (Middle Miocene), Uttarakhand.
INTRODUCTION

The Siwalik sediments of the Himalayan foothills were deposited continuously by various rivers in the Himalayan foreland for the last 20 Ma which provide an excellent opportunity to study the flora and fauna entombed in these fluvial sediments. The Lower Siwalik sediments consist of alternation of sandstone and mudstone beds while the Upper Siwalik sediments are mostly characterised by alternation of conglomerate and mudstone with local lenses of sandstone. Middle Miocene age was assigned to the Lower Siwalik sediments on the basis of lithology and vertebrate faunal evidences (Ranga Rao et al., 1979).

Palaeobotanical work has been carried out from Tanakpur area and only a lauraceous leaf impression resembling the genus Persea has been reported (Lakhanpal & Guleria, 1978). In view of this, an extensive field survey has been made around Tanakpur and a lot of plant megafossils especially leaf impression have been collected. In the present communication five fossil angiospermous leaf taxa viz., Mitrephora siwalika Antal & Awasthi, Sterculia tertiara sp. nov., Milletia purniyagiriensis sp. nov., Cynometra siwalika Awasthi & Prasad and Chonemorpha miocenica Prasad & Awasthi have been described and discussed.

Fig. 1—Map of Tanakpur area showing fossil locality.
MATERIAL AND METHOD

Thirty specimens of well preserved leaf impressions have been collected from Lower and Middle Siwalik sediments exposed in a road cutting section from Thuligad to Purniyagiri Temple in Champawat District of Uttaranchal (Fig. 1). Geological map of the area is shown in Fig. 2. Specimens are devoid of cuticle and are preserved mostly in grey and purple shales and few in fine grained sandstone. These leaf impressions were cleared with the fine chisels and studied with the help of hand lens and low power microscope under reflected light. The photographs were taken on 35 mm B/W film by Yashica SLR Camera with zooming facility.

Herbarium sheets of several extant families and genera were examined at the Central National Herbarium (C.N.H.), Sibpur, Howrah, West Bengal in order to identify the fossil specimens. For description of leaf impressions, the terminology given by Hickey (1973) and Dilcher (1974) has been followed. All the figured specimens have been deposited at the Post Graduate Department of Botany, M.L.K. College, Balrampur, Uttar Pradesh.

SYSTEMATICS

DICOTYLEDONS

Family—ANONACEAE

Genus—MITREPHORA (Blume) Hooker f. & Thomas

*Mitrephora siwalika* Antal & Awasthi, 1993

(Pl. 1.1, 2, 4)

*Material*—This species consists of two leaf impressions which are almost complete with satisfactory preservation.

*Description*—Leaf simple, symmetrical; preserved lamina 8.0 x 4.0 cm and 5.3 x 4.0 cm, wide elliptic, apex acute, base obtuse, texture chartaceous, margin entire, petiole broken, venation pinnate, eucamptodromous, primary vein (1°) stout, straight but curved in the middle; secondary veins (2°) about 8-9 pairs visible, 0.5-2 cm apart, angle of divergence 50-60°, moderate, nearly uniform, lower pair more acute than the upper pairs, uniformly curved and joined super-adjacent secondary at acute angle, moderate; intersecondary veins present, simple; tertiary veins (3°) fine, angle of origin AR-RR, percurrent, oblique in relation to mid vein, sinuous, opposite to alternate and close.

*Specimen no.*—Tnk. 28A.

*Locality*—Purniyagiri, Tanakpur, Champawat District, Uttaranchal.

*Horizon & Age*—Lower Siwalik; Middle Miocene.

*Affinities*—The most important features of the present specimens such as wide elliptic shape, acute apex, obtuse base, entire margin, eucamptodromous venation, moderate angle of divergence of secondary veins, presence of inter secondary veins, AR-RR, percurrent, straight to sinuous tertiary veins collectively indicate its resemblance with the extant leaves of the genus *Mitrephora* (Blume) Hooker f. & Thomas of
the family Anonaceae. A critical study of all the available species (about 18 species; listed in Antal & Awasthi, 1993, p.18) of this genus shows that the leaves of *Mitrephora maingayi* Hooker f. Thomas (C.N.H. Herbarium Sheet no. 13273; Pl. 1.3) have closest affinity with the present fossils in their shape, size and venation pattern.

**Fossil records and comparison**—So far, two species showing resemblance with the extant genus *Mitrephora* have been described from Siwalik sediments of India and Nepal. These are *Mitrephora siwalika* Antal & Awasthi (1993) described from Oodlabari area in West Bengal, and Surai Khola area, Western Nepal (Prasad & Awasthi, 1996) and *M. miocenica* (Prasad et al., 1997) from Seria Naka, north- west of Tulsipur, Uttar Pradesh. These species have been compared with our fossils and found that *M. miocenica* differs in being large size (10.5 x 4.2 cm) with narrow obovate shape. *M. siwalika* shows close affinity with the present fossils in shape, size and venation pattern. In view of this, the present fossils are described under *M. siwalika*.

The extant genus *Mitrephora* comprises about 40 species (Mabberley, 1997, p. 460) of trees and are distributed in Myanmar, Java, Malaya, Sri Lanka and North East India. The extant taxon, *M. maingayi* with which fossils resemble closely now a day grows in the evergreen forests of Assam, Chittagong, Malabar hills, Sri Lanka, Java and Malaya peninsula (Brandis, 1971; Gamble, 1972).

**Family**—STERCULIACEAE

**Genus**—STERCULIA Linnaeus

**Sterculia tertiara** sp. nov.

(Pl. 1.5; Pl. 2.5, 6, 7)

**Materials**—The study is based on three well preserved leaf impressions and one of them is almost complete specimen.

**Description**—Leaves simple, symmetrical; preserved lamina 9.1 x 2.6, 7.5 x 2.7 and 9.5 x 2.6 cm, very narrow elliptic, apex broken, base acute, texture chartaceous, margin entire; venation pinnate eucamptodromous; primary vein (1°) massive, thicker at basal portion than the middle and upper portion, markedly curved; secondary veins (2°) about 13-14 pairs visible, 0.4-1.2 cm apart, usually alternate, rarely sub-opposite, angle of divergence 50-60°, acute, narrow to moderate, unbranched; intersecondary veins present, simple; tertiary veins (3°) fine, angle of origin RR, percurrent, oblique in relation to midvein, alternate to opposite and close. Further details could not be seen.

**Holotype**—Specimen no. Tnk. 22.

**Locality**—Purniyagiri, Tanakpur, Champawat District, Uttaranchal.

**Horizon & Age**—Lower Siwalik; Middle Miocene.

**Etymology**—After the name of geological period ‘Tertiary’.

**Affinities**—The characteristic features of the present fossil leaves are symmetrical, very narrow elliptic shape, acute base, eucamptodromous venation, markedly curved secondaries with narrow acute angle which usually alternate to rarely sub-opposite, presence of inter secondary veins, RR, percurrent, alternate to opposite and close tertiary veins. A critical examination
PLATE 1
of herbarium sheets of angiospermous taxa suggests that these features are commonly found in the modern leaves of *Sterculia ensifolia* Masters of the family Sterculiaceae (C.N.H. Herbarium Sheet No. 57923, Pl. 1.6).

**Fossil records and comparison**—So far, there is only one fossil record of the genus *Sterculia* Linnaeus as *Sterculia kathgodamensis* reported by Prasad (1994b) from Siwalik sediments of Kathgodam area in Nainital District of Uttaranchal. The present fossil leaves have been compared with *S. kathgodamensis* and found that the present species differs in being very narrow elliptic shape with different course of secondary veins. Therefore, these fossil leaves have been described under a new specific name *Sterculia tertiara*.

The genus *Sterculia* consists of about 150 species (Mabberley, 1997, p. 683) and are distributed in the tropics of both hemisphere. The extant taxon, *S. ensifolia* with which fossils show closest affinity is a tree which grows in the evergreen forests of Penang, Philippines, Mergui and Griffith (Hooker, 1872).

**Family—FABACEAE**

**Genus—MILLETTIA** Wight & Arnott

*Milletia purniyagiriensis* sp. nov.

(Pl. 2.1, 3)

**Material**—This species is based on a single well preserved leaf impression.

**Description**—Leaflet slightly symmetrical near base, preserved lamina 8.5 x 5.5 cm, elliptic, apex broken, base broken, seemingly obtuse, texture thick chartaceous; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) about 7-8 pairs visible, 1.2-1.4 cm apart, straight to slightly curved, angle of divergence 50-60°, acute, narrow, angle of secondary veins in one side of lamina greater than the secondaries of other side, alternate to opposite, unbranched; intersecondary veins present, simple; tertiary veins (3°) fine, angle of origin AR-RR, percurrent, straight to sinuous, oblique in relation to midvein, alternate to sub-opposite and close. Further details could not be seen.

**Holotype**—Specimen no. Tnle 2.

**Locality**—Purniyagiri, Tanakpur, Champawat District, Uttaranchal.

**Horizon & Age**—Lower Siwalik; Middle Miocene.

**Etymology**—After the name of famous Purniyagiri Mata Temple situated near the fossil locality.

**Affinities**—The diagnostic features of the present fossil viz., elliptic shape, eucamptodromous venation, acute angle of divergence of secondary veins with variation of angle of secondaries in both side of lamina, presence of inter secondary veins, AR-RR, percurrent, straight to sinuous tertiary veins suggest closest similarity of the present fossil leaf with the extant leaves of *Milletta auriculata* Backer of the family Fabaceae (C.N.H. Herbarium Sheet nos. 112486, 377591; Pl. 2.2, 4).

**Fossil records and comparison**—About 16 fossil species comparable to extant genus *Milletia* Wight & Arnott have been recorded from the Tertiary sediments of India and abroad (Prasad et al., 1999). Of these eight species are known from the Siwalik sediments of India, Bhutan and Nepal. These are *Milletta koilabasensis* Prasad (1990b), *M. siwalia* Prasad (1990a), *M. miobrandissiana* Prasad (1994a) and *M. terciara* sp. nov., a part of fossil leaf magnified to show details of venation and shape. (All figures are of natural size unless otherwise mentioned)
imlibasensis Prasad et al. (1999) recorded from Koilabas, western Nepal; *M. palaeoracemosa* Awasthi & Prasad (1990), *M. churiensis* Prasad & Awasthi (1996) and *M. koilabasensis* Prasad from Surai Khola, western Nepal; *M. koilabasensis* from Laxmi River beds, Bhutan by Prasad and Tripathi (2002); *M. oodlabariciensis* Antal & Prasad (1996) from Darjeeling District, West Bengal; *M. palaeoracemosa* Awasthi & Prasad and *M. kathgodamensis* Prasad et al. (2004) from Siwalik sediments of Kathgodam, India. The present fossil leaflet has been compared with all the above species and it is observed that none of them show similarity with the present fossil. They differ in nature and course of secondary veins. Moreover, most of them are either narrow or smaller in size than the present fossil. In view of this, the present fossil has been described under a new specific name *Millettiapurniyagiriensis*.

The genus *Millettia* Wight & Arnott comprises about 90 species (Mabberley, 1997, p. 457) of trees, shrubs and climbers which are distributed in the tropical regions of Africa, Asia and Australia (Willis, 1973). About 30 species are distributed in the Indian region. *Millettia auriculata* (= *M. macrophylla* Kurz) with which the present fossil resembles is growing in the Himalayan foothills commonly in the sal forest from Sutlej eastward, Bihar, Central India and south of the Godavory (Brandis, 1971).

**Genus—CYNOMETRA Linnaeus**

*Cynometra siwalika* Awasthi & Prasad, 1990

(Pl. 1.7, 8, 9)

**Material**—The study is based on two well preserved leaf impressions. One specimen is represented by apical part and the other is basal part.

**Description**—Leaflet asymmetrical, preserved lamina 4.7 x 2.4 cm and 3.5 x 2.0 cm; narrow elliptic, apex acute, base acute, texture coriaceous; venation pinnate, brochidodromous; primary vein (1°) single prominent, moderate, almost straight; secondary veins (2°) about 13-14 pairs visible, alternate to sub-opposite, angle of divergence 50-70°, less acute towards apex, uniformly curved, branched, forming loop with superadjacent secondaries before reaching the margin; intersecondary veins present, simple; tertiary veins (3°) fine, angle of origin RR, pattern orthogonal reticulate, forked, oblique in relation to midvein, predominantly alternate and close.

**Specimen**—Specimen no. Trk. 8.

**Locality**—Purniya, Tanakpur, Champawat District, Uttarakhand.

**Horizon & Age**—Lower Siwalik; Middle Miocene.

**Affinities**—The most important features of the present fossil leaflets viz., asymmetrical, narrow elliptic shape, acute apex and base, brochidodromous venation, closely placed, alternate to sub-opposite secondary veins forming loop with superadjacent secondaries before reaching the margin, presence of inter secondary veins and RR, percurrent and branched tertiary veins collectively suggest its affinity with the extant leaves of *Cynometra polyandra* Roxburgh of the family Fabaceae (C.N.H. Herbarium Sheet No. 138768).

**Fossil records and comparison**—So far, three fossil species resembling the genus *Cynometra* Linnaeus have been reported from the Siwalik sediments of India and Nepal. They are *Cynometra siwalika* Awasthi & Prasad (1990) from Surai Khola, western Nepal, *C. tertiara* Antal & Awasthi (1993) from Oodlabari, West Bengal, *C. palaeoripa* from Koilabas...
area (Prasad et al., 1999) and Surai Khola, western Nepal (Prasad & Pandey, 2006). The present fossil leaflets have been compared with the above known species and observed that C. siwalika shows closest similarity in shape, size and venation pattern. Thus the specimens are described as C. siwalika.

The genus Cynometra Linnaeus consists of about 70 species (Mabberley, 1997, p. 207) which are distributed in the tropical regions of the world and about five species grow in Indian region. The modern comparable taxon, C. polyandra Roxburgh is a member of evergreen forests of Khasi and Cachar Hills and Malaya peninsula (Brandis, 1971).

**Family—APOCYNACEAE**

**Genus—CHONEMORPHA George Don**

*Chonemorpha miocenica* Prasad & Awasthi, 1996

(Pl. 3.1, 3, 4)

**Material**—This study is based on two well preserved and almost complete leaf impressions.

**Description**—Leaf simple, slightly asymmetrical; lamina 12.0 x 8.0 cm and 9.0 x 5.0 cm, wide elliptic, apex acute, base obtuse, texture coriaceous, margin entire, petiole not preserved; venation pinnate, eucamptodromous; primary vein (1°) single, stout, markedly curved, thicker at basal portion; secondary veins (2°) about 11 pairs visible, angle of divergence 50-70°, opposite to alternate, upper secondary veins more acute than the lower, join superadjacent secondary forming acute angle, moderate; intersecondary veins present, simple; tertiary veins (3°) fine, angle of origin AO-RR, percurrent, sinuous to straight, oblique in relation to mid vein, predominantly alternate and close.

**Specimen no.**—Tnk. 28B.

**Locality**—Purniyagiri, Tanakpur, Champawat District, Uttarakhand.

**Horizon & Age**—Lower Siwalik; Middle Miocene.

**Affinities**—The most characteristic features of the present fossil leaves are slightly asymmetrical lamina, wide elliptic shape, acute apex, obtuse base, entire margin, eucamptodromous venation, markedly curved primary vein, acute angle of divergence of secondary veins varying from 50°-70°, presence of intersecondary veins, AO-RR, percurrent, sinuous to straight tertiary veins which undoubtedly suggest close resemblance with the leaves of extant taxon *Chonemorpha macrophylla* George Don of the family Apocynaceae (C.N.H. Herbarium Sheet nos. 292240, 292229; Pl. 3.2).

**Fossil records and comparison**—There is a single fossil record of *Chonemorpha* as *C. miocenica* Prasad and Awasthi (1996) from the Middle Siwalik sediments of Surai Khola, western Nepal. This fossil species shows its affinity with the leaves of extant *Chonemorpha macrophylla*. However, *C. miocenica* differs in being bigger size (12 x 8.5 cm) with the present fossils. During examination of herbarium sheets of extant species of *C. macrophylla* George Don it has been observed that such variation of shape and size is common feature. In view of this, the present fossils have been described as *C. miocenica*.

The genus *Chonemorpha* George Don consists of 13 species (Mabberley, 1997; p. 154) and are distributed in the Indo- Malayan region. Modern comparable taxon, *C. macrophylla* is a large climbing shrub distributed in the moist forest of Travancore, Malaya, Sri Lanka and Andaman Island (Gamble, 1972).

**CONCLUSION**

Five angiospermous fossil taxa viz., *Mitrephora siwalika*, *Sterculia tertiara*, *Millettia purniyagiriensis*, *Cynometra siwalika* and *Chonemorpha miocenica* have been studied which show their close affinities with the extant species *Mitrephora maingayi* (Anonaceae), *Sterculia ensifolia* (Sterculiaceae), *Millettia auriculata*, *Cynometra polyandra* (Fabaceae) and *Chonemorpha macrophylla* (Apocynaceae) respectively. Of these taxa, two species *Sterculia tertiara* and *Millettia purniyagiriensis* are new to the Tertiary flora of Indian subcontinent. The remaining three taxa *Mitrephora siwalika*, *Cynometra siwalika* and *Chonemorpha miocenica* have been described earlier from other localities of India and Nepal and indicate their wider
distribution during the Middle Miocene time. The present habit and habitat of the comparable extant taxa show that none of them is growing presently in the Himalayan foot hills of Uttaranchal but they occur in the tropical evergreen forests of North East India, Bangladesh, Myanmar and Malaya peninsula which receive high rainfall. Thus, it may be concluded that a warm and humid climate prevailed in Tanakpur area at the time of deposition in contrast to present day relatively dry climate.

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