The Palaeobotanist 55(2006): 77-87
0031-0174/2006 $2.00

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

SHASHI, S.M. PANDEY AND P.P. TRIPATHI

Department of Botany, M.L.K. Post Graduate College, Balrampur, Uttar Pradesh, India.

(Received 13 March, 2006; revised version accepted 13 September, 2006)

ABSTRACT

Shashi, Pandey SM & Tripathi PP 2006. Fossil leaf impressions from Siwalik sediments of Himalayan foot hills of Uttaranchal, India and their significance. The Palaeobotanist 55(1-3): 77-87.

Morphotaxonomical study of well preserved angiospermous leaf impressions collected from Siwalik sediments of Purniyagiri near Tanakpur, Uttaranchal 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), Uttaranchal.

भारत में उत्तराँचल के हिमालयी गिरिपादों के शिवालिक अवसादों से प्राप्त अश्मीभूत पर्ण मुद्राश्में व उनका महत्व

शशि, एस.एम. पाण्डेय एवं पी.पी. त्रिपाठी

सारांश

उत्तराँचल में टनकपुर के निकट पूर्णागिरि के शिवालिक अवसादों से एकत्रित सुपरिरक्षित आवृतबीजी पर्ण मुद्राश्मों के आकारवर्गिकीय अध्ययन से पाँच प्रजातियों अर्थात् - *मिट्रेफोरा शिवालिका* अंतल व अवस्थी, *स्टरकुलिया टर्शिरा* नवप्रजाति, *मिलेशिया पूर्णियागिरिएन्सिस* नवप्रजाति, *सायनोमिट्रा शिवालिका* अवस्थी व प्रसाद तथा *कोनेमॉर्फा मायोसिनिका* प्रसाद व अवस्थी अंकित की गई हैं। इन प्रजातियों को विद्यमान वर्गकों *मिट्रेफोरा मेनगयी* (एनोनेसी), *स्टरकुलिया एन्सीफोलिया* (स्टरकुलिएसी), *मिलेशिया औरीकुलेटा, सायनोमिट्रा पॉलीएन्ड्रा* (फैबेसी) एवं *कोनेमॉर्फा* मेक्रोफिल्ला (एपोसीनेसी) से क्रमशः तुलना करते हैं। तुलनात्मक विद्यमान वर्गकों का स्वभाव, आवास व वर्तमान वितरण इंगित करता है कि उँणकटिबंधीय सदाहरित वन वर्तमान में मिश्रित पतझड़ी वन की तुलना में शिवालिक काल के दौरान इस क्षेत्र में उष्ण-आर्द्र जलवायु के अन्तर्गत समृद्ध थे।

संकेत-शब्द—आवृतबीजीय पर्ण मुद्राश्म, आकारवर्गिकी, पुराजलवायु, शिवालिक (मध्य मध्यनूतन), उत्तराँचल।

© Birbal Sahni Institute of Palaeobotany, India

INTRODUCTION

THE Siwalik sediments of the Himalayan foot hills 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., *Millettia purniyagiriensis* sp. nov., *Cynometra siwalika* Awasthi & Prasad and *Chonemorpha miocenica* Prasad & Awasthi have been described and discussed.

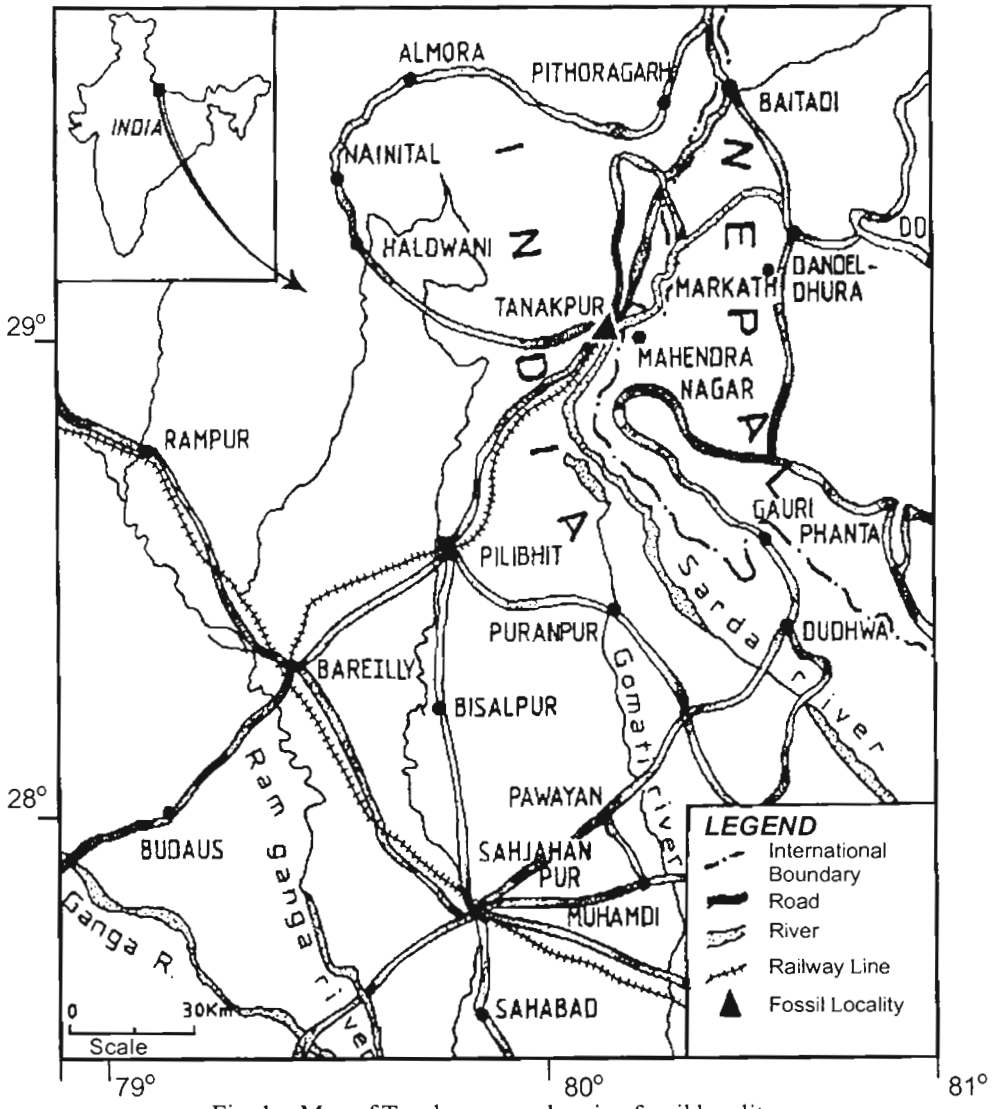


Fig. 1—Map of Tanakpur area showing fossil locality.

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.

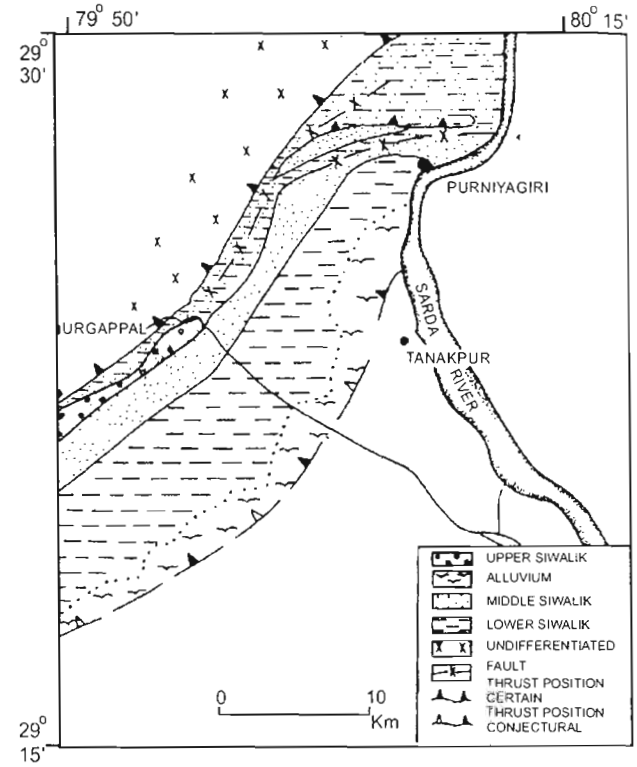


Fig. 2—Geological map of the area showing Siwalik outcrops (After Ranga Rao *et al.*, 1979).

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 ⟶

(All figures are of natural size unless otherwise mentioned)

1, 2. *Mitrephora siwalika* Antal & Awasthi, fossil leaves showing shape, size and venation pattern.

3. *Mitrephora maingayi* Hooker f. & Thomas, modern leaf showing shape, size and venation pattern similar to fossil leaf.

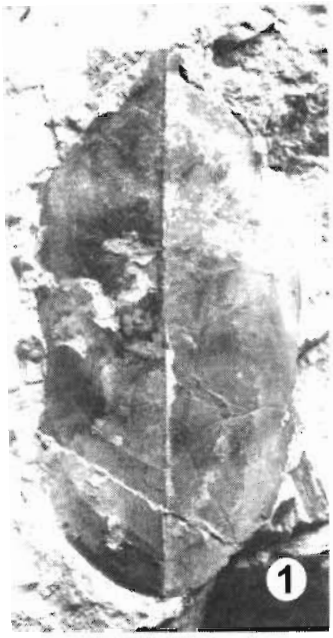
4. *M. siwalika* Antal and Awasthi, a part of fossil leaf (Pl. 1.2) magnified to show the details of venation. x 3.

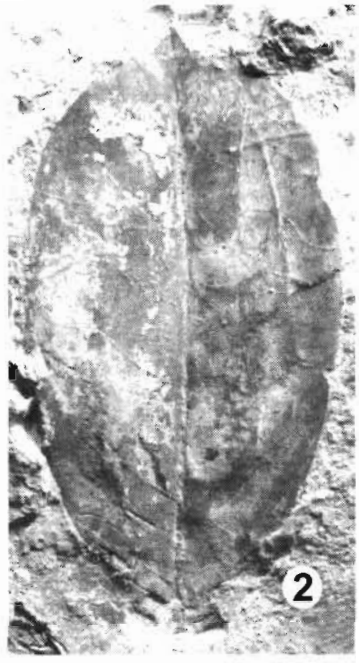
5. *Sterculia tertiara* sp. nov., fossil leaf showing shape, size and venation pattern.

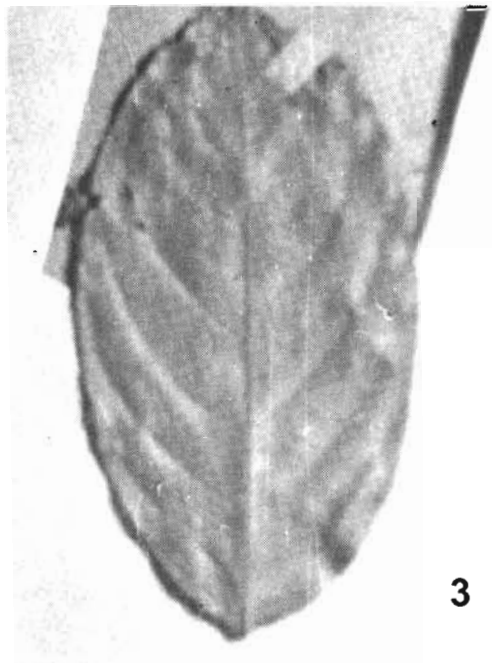
6. *Sterculia ensifolia* Masters, modern leaf showing similar shape, size and venation pattern with fossil one.

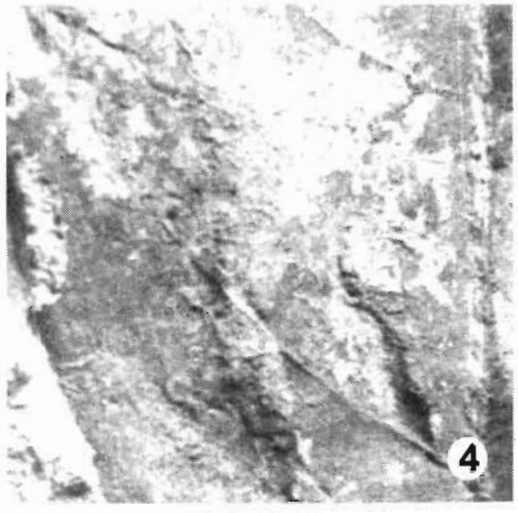
7, 8. *Cynometra siwalika* Awasthi & Prasad, fossil leaves showing shape, size, apex, base and venation pattern.

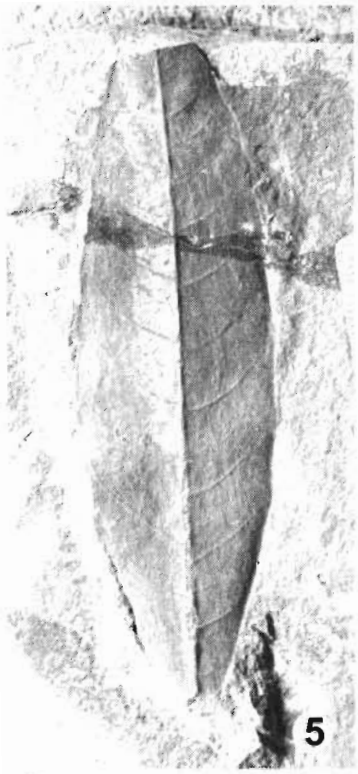
9. A part of fossil (Pl. 1.8) magnified to show details of venation. x 4.5.

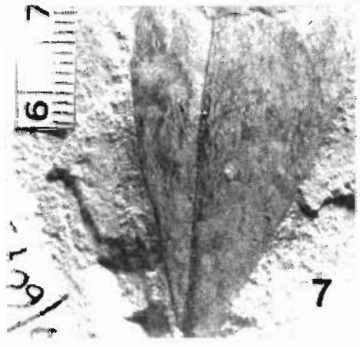


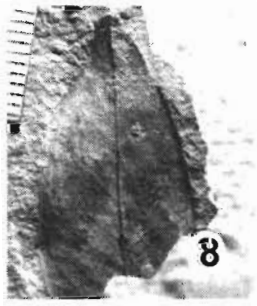












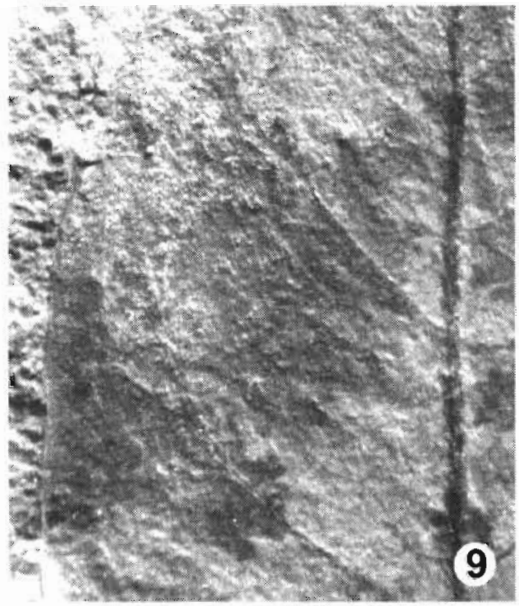


PLATE 1

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

Millettia 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. Tnk. 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 *Millettia 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 *Millettia* 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 *Millettia koilabasensis* Prasad (1990b), *M. siwalica* Prasad (1990a), *M. miobrandissiana* Prasad (1994a) and *M.*

PLATE 2 →

(All figures are of natural size unless otherwise mentioned)

1. *Millettia purniyagiriensis* sp. nov., fossil leaf showing shape, size and venation pattern.
2. *Milletia auriculata* Backer, modern leaf showing similar shape, size and venation pattern.
3. *M. purniyagiriensis* sp. nov., a part of fossil leaf magnified to show details of venation. x 2.
4. *M. auriculata* Backer, a part of modern leaf magnified to show details of venation similar to fossil. x 2.
5, 6. *Sterculia tertiara* sp. nov., fossil leaves showing slight variation in shape and size.
7. *S. tertiara* sp. nov., a part of fossil leaf magnified to show details of venation. x 2.

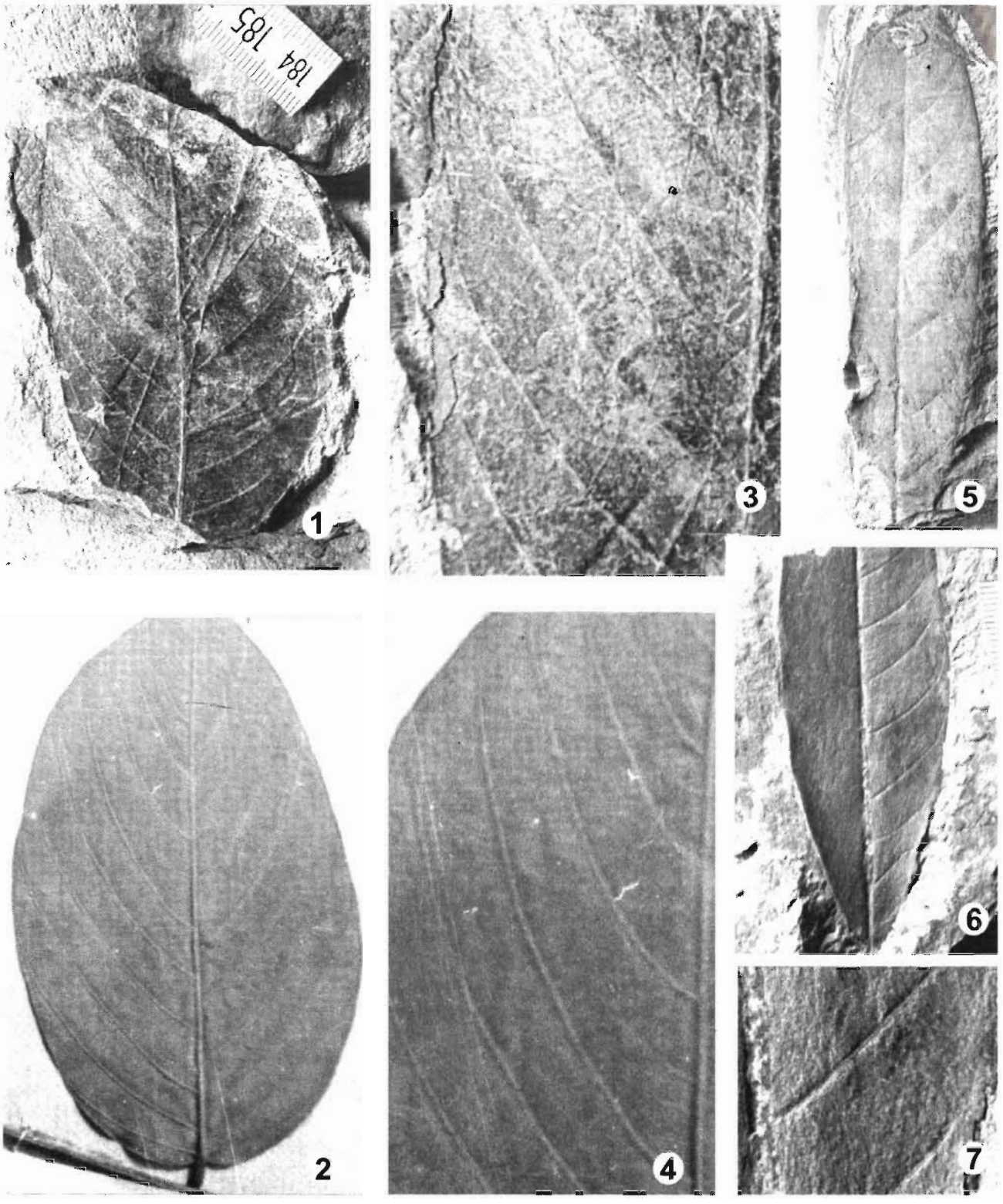


PLATE 2

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. oodlabariensis* 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 *Millettia purniyagiriensis.*

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 foothill 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. Tnk. 8.

Locality—Purniyagiri, Tanakpur, Champawat District, Uttaranchal.

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. palaeoeripa* from Koilabas

PLATE 3 →

(All figures are of natural size unless otherwise mentioned)

1, 3. *Chonemorpha miocenica* Prasad & Awasthi, fossil leaves showing shape, size and venation pattern.

2. *Chonemorpha macrophylla* George Don, modern leaf showing shape, size and venation pattern similar to fossil species.

4. *C. miocenica* Prasad & Awasthi, a part of fossil leaf (Pl. 3.3) magnified to show the details of venation similar to extant species. x 2.

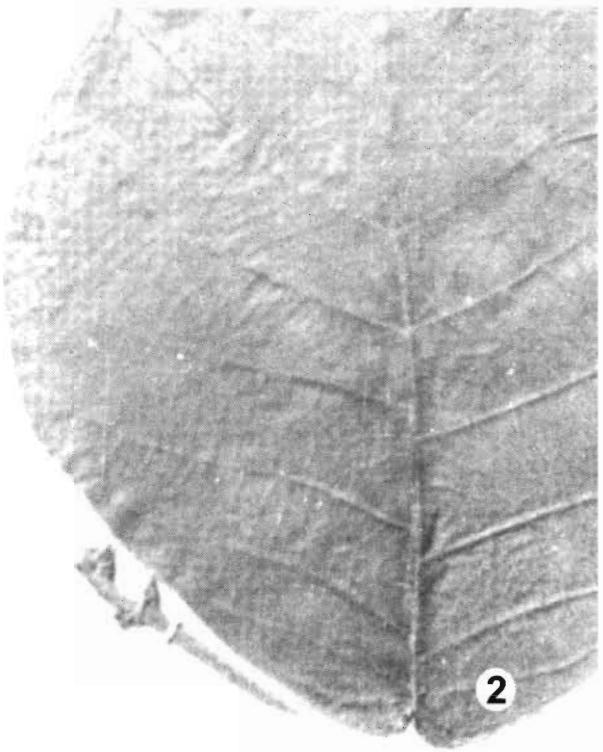


PLATE 3

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 comprable 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, Uttaranchal.

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.

Acknowledgements—*Authors are thankful to authorities of Birbal Sahni Institute of Palaeobotany, Lucknow for providing various facilities. We are also thankful to the authorities of Central National Herbarium, Sibpur, Howrah, West Bengal for the permission to consult the Herbarium for identification of the leaf impressions.*

REFERENCES

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 : 14-60.

Antal JS & Prasad M 1996. Some more leaf-impressions from the Himalayan foot-hills of Darjeeling District, West Bengal, India. Palaeobotanist 43 : 1-9.

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

Brandis D 1971. Indian Tree. Bishen Singh Mahendra Pal Singh, Dehradun.

Dilcher DL 1974. Approaches to identification of angiospermous leaf remains. Botanical Review 40 : 1-157.

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

Hooker JD 1872. The flora of British India. I Kent.

Hickey LJ 1973. Classification of architecture of dicotyledonous leaves. American Journal of Botany 60 : 17-33.

Lakhanpal RN & Guleria JS 1978. A lauraceous leaf-impression from the Siwalik beds near Tanakpur, Uttar Pradesh. Geophytology 8 : 19-21.

Mabberley DJ 1997. The plant-book. Cambridge University Press, Cambridge.

Prasad M 1990a. Fossil flora from the Siwalik sediments of Koilabas, Nepal. Geophytology 19 : 79-105.

Prasad M 1990b. Some more leaf impressions from the Lower Siwalik beds of Koilabas, Nepal. Palaeobotanist 37 : 299-315.

Prasad M 1994a. Plant megafossils from the Siwalik sediments of Koilabas, central Himalaya, Nepal and their impact on palaeoenvironment. Palaeobotanist 42: 126-156.

Prasad M 1994b. Siwalik (Middle Miocene) leaf impressions from the foot hills of the Himalaya, India. Tertiary Research 15: 53-90.

Prasad M & Awasthi N 1996. Contribution to the Siwalik flora from Surai Khola sequence, western Nepal and its palaeoecological and phytogeographical implications. Palaeobotanist 43: 1-42.

Prasad M & Pandey SM 2006. Plant diversity and climate during Siwalik (Miocene-Pliocene) in the Himalayan foot hills of western Nepal. Palaeontographica (in press).

Prasad M & Tripathi PP 2002. Plant megafossils from the Siwalik sediments of Bhutan and their climatic significance. Biological Memoirs 26 : 6-19.

Prasad M, Antal JS & Tiwari VD 1997. Investigation on plant fossils from Seria Naka in Himalayan foot hills of Uttar Pradesh, India. Palaeobotanist 46 : 44-95.

Prasad M, Ghosh R & Tripathi PP 2004. Floristics and climate during Siwalik (Middle Miocene) near Kathgodam in the himalayan foot hills of Uttaranchal, India. Journal of the Palaeontological Society of India 49 : 35-93.

Prasad M, Antal JS, Tripathi PP & Pandey VK 1999. Further contribution to the Siwalik flora from Koilabas area, western Nepal. Palaeobotanist 48: 49-95.

Ranga Rao A, Khan KN, Venkatachala VS & Sastri VV 1979. Neogene/Quaternary boundary *In*: Sastri VV *et al.* (Editors)—Proceeding of Neogene/Quaternary boundary, Field conference, Geological Survey of India: 31-142.

Willis JC 1973. A dictionary of the flowering plants and ferns (8th Edition). Cambridge University Press, Cambridge.