Investigation on plant fossils from Seria Naka in the Himalayan foot-hills of Uttar Pradesh, India

M. Prasad, J.S. Antal & V.D. Tiwari*

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A floral assemblage consisting of leaf-impressions recovered from the Lower Siwalik sediments of Seria Naka, about 30 km north-west of Tulsipur town in Gonda District of Uttar Pradesh, India has been described and discussed in the present paper. The assemblage comprises 10 taxa belonging to seven dicotyledonous families — Anonaceae, Flacourtiaceae, Polygalaceae, Sapindaceae, Anacardiaceae, Fabaceae and Ebenaceae. An analysis of the floral assemblage with respect to the distribution pattern of modern equivalent taxa reveals the prevalence of warm and humid climate in the region during the deposition of these sediments. The fossil flora also indicates that tropical evergreen forests with few moist deciduous plants were flourishing around Seria Naka in the Himalayan foot-hills during Middle Miocene in contrast to the mixed deciduous type of present day forests. Further, the presence of some Malayan elements like *Goniothalamus meboldii, Mitrephora macrophylla* and *Nephelium glabrum* is phytogeographically important supporting the view of migration of some taxa from South-east Asia to Indian subcontinent during Neogene.

Key-words—Megafossils, Leaf-impressions, Angiosperms, Palaeoclimate, Phytogeography, Lower Siwalik, Middle Miocene, India.

M. Prasad & J.S. Antal, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

**V.D. Tiwari, M.L.K. Postgraduate College, Balrampur, Gonda, Uttar Pradesh, India.*

सारांश

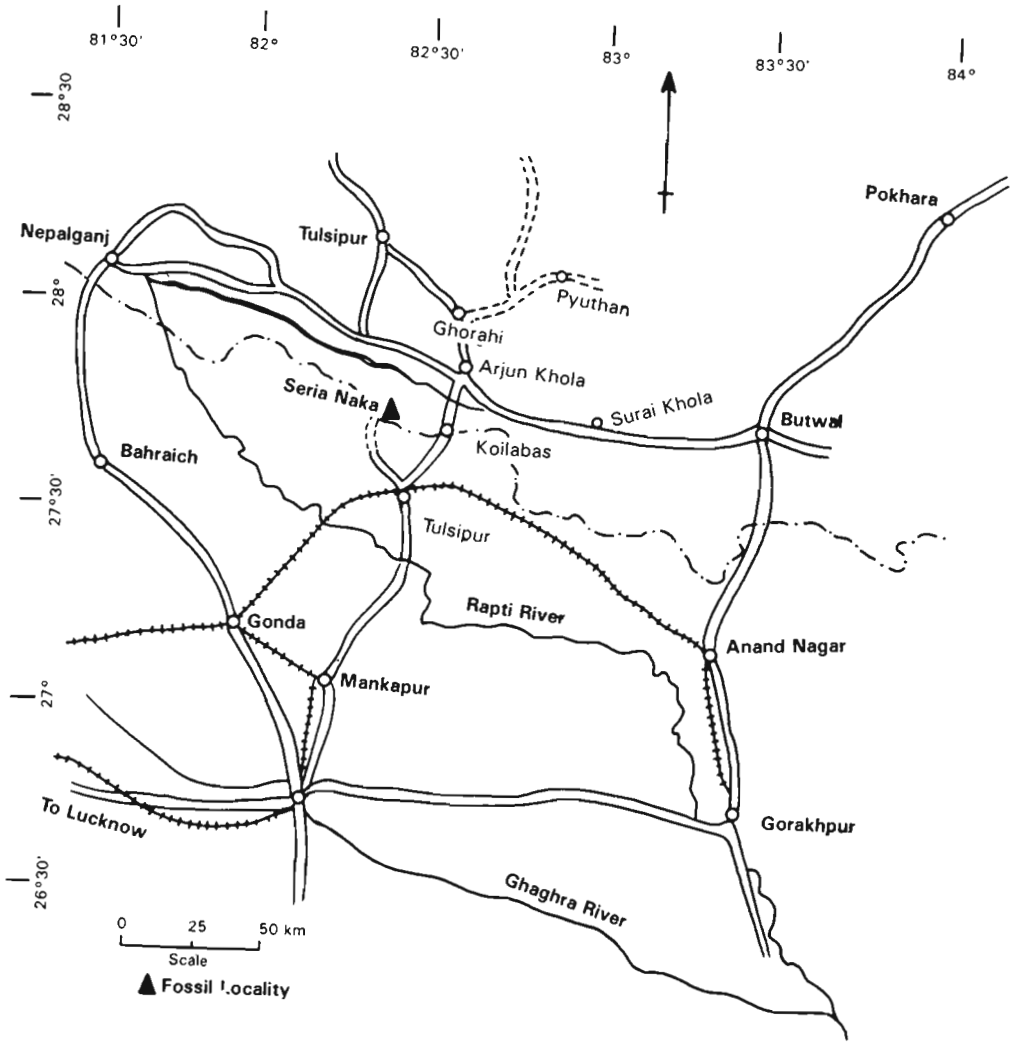
उत्तर प्रदेश (भारत) के हिमालय गिरि-पादों में सीरिया नाका से प्राप्त अश्मित पौधों का अध्ययन

महेश प्रसाद, जसवन्त सिंह अन्तल एवं वी. डी. तिवारी

उत्तर प्रदेश के गोंडा जनपद में तुलसीपुर कस्बे के लगभग 30 किलोमीटर उत्तर पश्चिम में सीरिया नाका के शिवालिक अवसादों से उपलब्ध पर्ण-छापों का इस शोध-पत्र में वर्णन किया गया है। इस समुच्चय में एनोनेसी, फ्लेकोर्शिएसी, पोलीगैलेसी, सेपिन्डेसी, एनाकार्डिएसी, फैबेसी एवं एबीनेसी नामक सात द्विबीजपत्री कुलों के 10 वर्गक सम्मिलित हैं। वर्तमान समतुल्य वर्गकों के वितरण के आधार पर किये गये विश्लेषण से इन अवसादों के निक्षेपण के समय उष्ण और नम जलवायु का होना इंगित होता है। उपलब्ध वनस्पतिजात से यह भी प्रदर्शित होता है कि मध्य मायोसीन काल में हिमालय गिरि-पादों में स्थित सेरिया नाका के आस-पास कुछ पर्णपाती अवयवों से युक्त उष्णकटिबन्धीय सदाहरित वन विद्यमान थे जबकि आजकल वहाँ मिश्रित पर्णपाती प्रकार के वन विद्यमान हैं। इसके अलावा *गोनिओथैलेमस मीबोल्डाई, मिट्रेफ़ोरा मैक्रोफ़िल्ला* एवं *निफ़ेलिश्म ग्लेब्रम* नामक कुछ मलाया के तत्वों की उपस्थिति पादप भौगोलिक दृष्टि से महत्वपूर्ण है जिससे निओजीन काल में दक्षिण पूर्व एशिया से भारतीय उपमहाद्वीप में कुछ वर्गकों के आगमन की पुष्टी होती है।

THE Himalayan foot-hills have resulted from the tectonic processes that have been taking place in the Himalayan orogeny since the Cenozoic era. The Siwalik Basin, a part of the Himalayan foot-hills, was formed as a foredeep in front of the newly risen Himalaya during Middle Miocene orogeny and was the site of deposition of the Siwalik sediments (Saxena & Verma, 1976). The Siwalik System is 5-6 km thick (Wadia, 1975; Saxena, 1976; Krishnan, 1982; Mukherjee, 1984) and is composed mainly of sandstones, grits and conglomerates. On the basis of litho-biostratigraphical/palaeontological studies the Siwalik System has been divided into three groups — the Lower, Middle and Upper Siwaliks ranging in age from Middle Miocene to Lower Pleistocene.

The fossil locality Seria Naka is situated about 30 km north-west of Tulsipur town at Indo-Nepal



Text-figure 1 — Map showing the fossil locality.

PLATE 1

(All figures are of natural size unless otherwise mentioned)

1. *Mitrephora miocenica* sp. nov.; Fossil leaf, Specimen no. BSIP 37776.
2. *Mitrephora macrophylla* Oliver.; Modern leaf.
3. *Mitrephora miocenica* sp. nov.; A part of fossil leaf magnified to show the details of venation. x 2.
4. *Mitrephora macrophylla* Oliver.; A part of modern leaf magnified to show similar details of venation. x 2.
5. *Goniothalamus siwalicus* sp. nov.; Fossil leaf showing its shape, size and venation pattern; Specimen no. BSIP 37778.
6. *Goniothalamus meboldii*; Modern leaf showing similar shape, size and venation pattern.

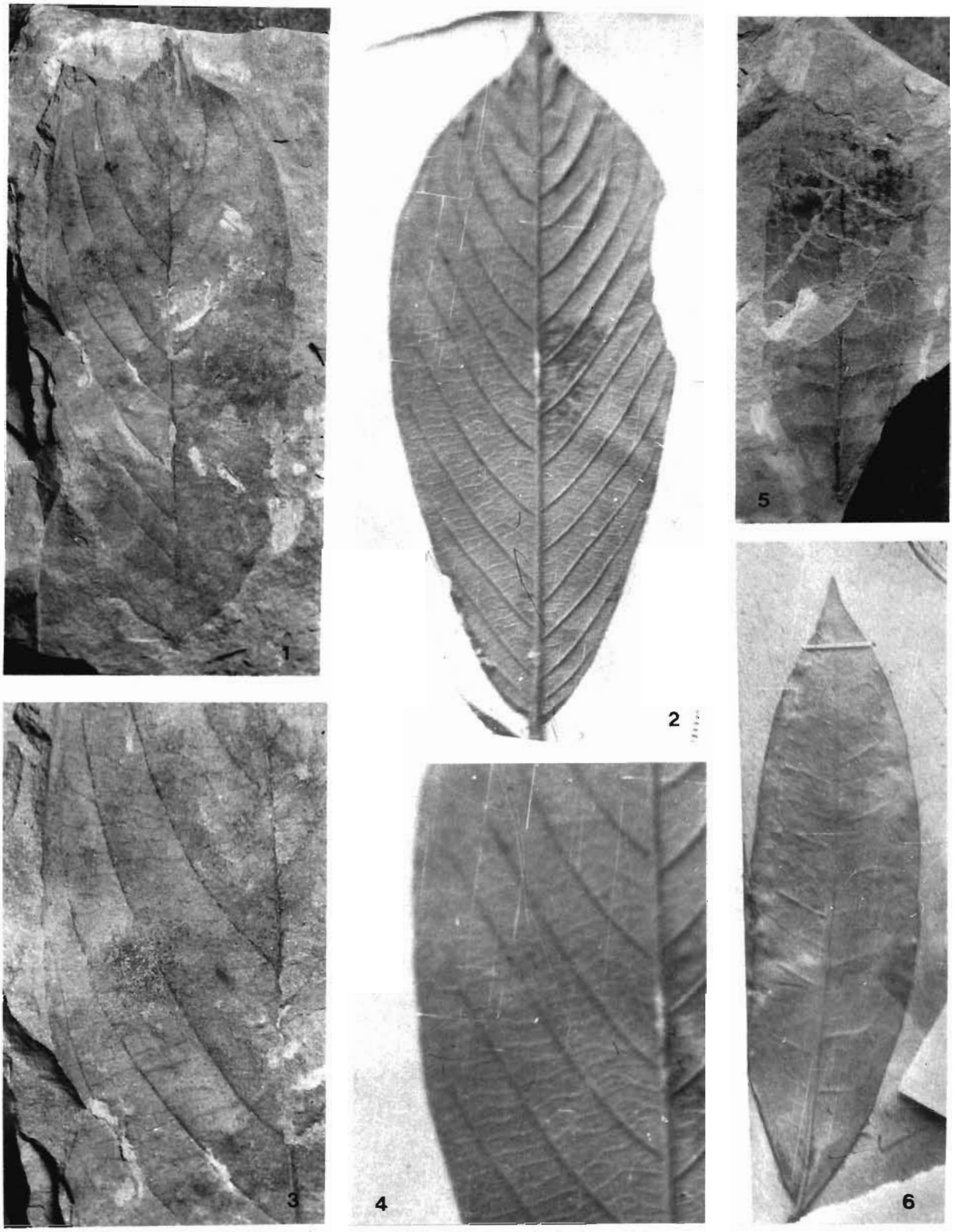
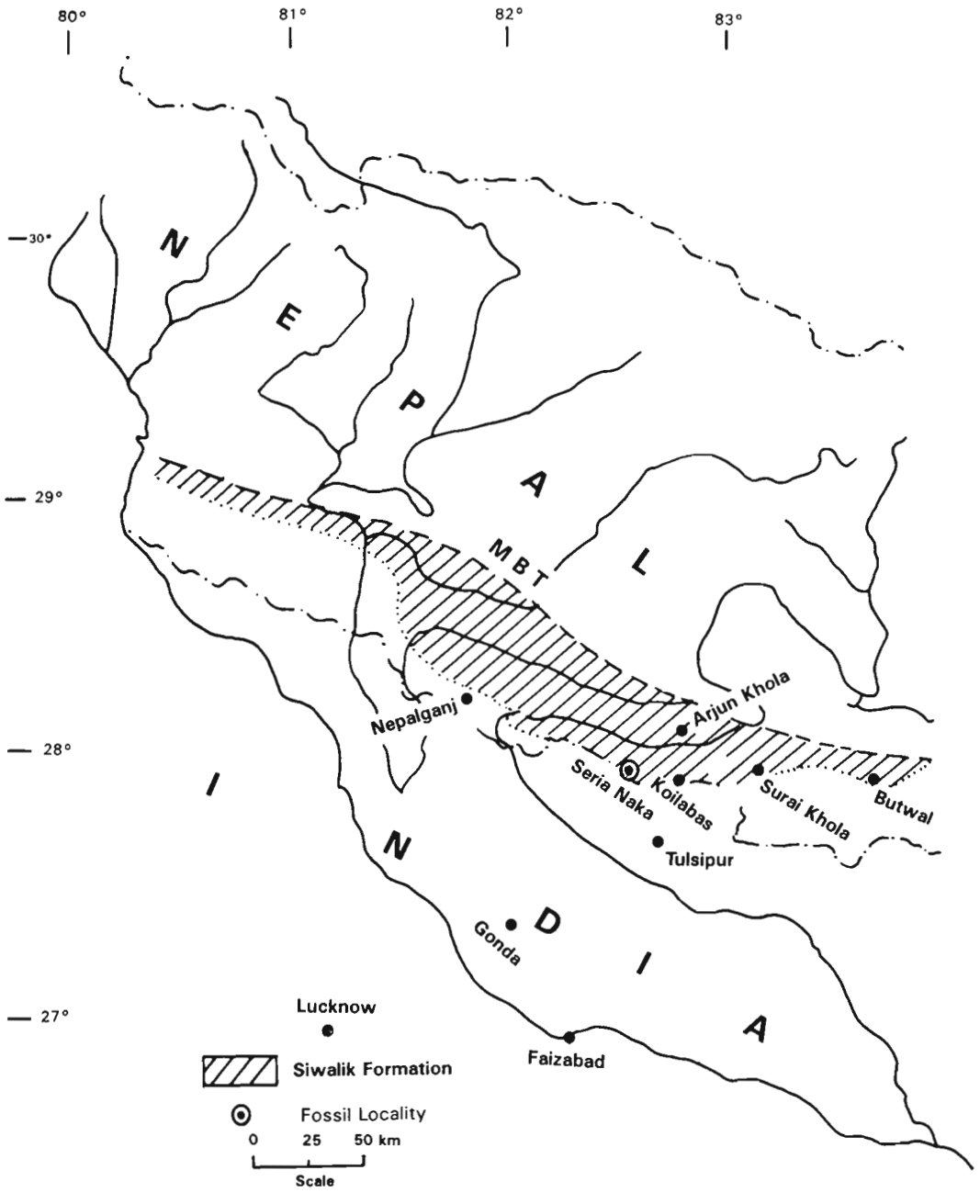


PLATE 1



Text-figure 2—Geological map showing Siwalik Formation around Seria Naka area (after Glennie & Zeigler, 1964).

border in the Gonda District of Uttar Pradesh. The Siwaliks occur here as foot-hills running in north east direction (Text-figures 1, 2). The geological/ palaeontological studies of this particular area have not been carried out so far. Nevertheless, on the basis of lithology of exposed sections these sediments are considered as Lower Siwaliks of Middle Miocene age.

A large number of plant fossils including woods, leaves, fruits, seeds and flowers have been reported from the Siwalik sediments at different places, viz., Mohand, Hardwar, Kalagarh, Kathgodam, Tanakpur and Koilabas (at Indo-Nepal border) in Uttar Pradesh (Awasthi, 1992; Prasad, 1994a, 1994b, 1994c, 1994d). Unfortunately, the fossiliferous area Seria Naka remained untouched and there is no report of plant fossils from this area, although this area is very rich in plant fossils especially leaf-impressions and fruit and seed-impressions. Recently in January 1997, a number of well-preserved leaf-impressions were collected from the locality and investigation on these leaf-impressions has been undertaken to work out in detail the fossil assemblage of this area to reconstruct the history of past vegetation, palaeoclimate and phytogeography of the region during Siwalik period.

MATERIAL AND METHOD

Out of a number of specimens, 21 well-preserved leaf-impressions were collected from two well exposed sections situated about 0.5 km upstream from Seria Naka Village in a small rivulet "Seria". The leaf-impressions are devoid of cuticle and preserved mostly in shales and fine-grained sandstones. The leaf-impressions have been studied morphologically with the help of either hand lens or low power microscope under reflected light. A lot of herbarium sheets of several extant families and genera were examined at the Herbarium of Central National Herbarium, Sibpur, Howrah in order to identify them. For description the terminology given by Hickey (1973) and Dilcher (1974) has been followed. Photographs of the leaves of modern comparable species have been provided to show similarity with the fossil leaves. The specimens and their photonegatives are preserved in the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow, India.

SYSTEMATIC DESCRIPTION

Family — Anonaceae

Genus — *Mitrephora* (Bl.) Hook.f. & Thoms.

Mitrephora miocenica sp. nov.
Pl. 1, figs 1, 3

This species is based on single specimen with counter part.

Description — Leaf simple, symmetrical, narrow obovate, preserved length 10.5 cm, width 4.2 cm; apex seemingly acuminate; base nearly obtuse, equilateral; margin entire; texture chartaceous; petiole 0.3 cm visible, normal; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) about 11 pairs visible, less than 0.2 to 1.7 cm apart; uniformly curved up to somewhat greater height seemingly unbranched; alternate to sub-opposite, angle of divergence acute 50°-55°, moderate, basal secondaries arise closely with comparatively more angle; intersecondary veins present, rare, simple; tertiary veins (3°) fine with angle of origin usually RR rarely AO, percurrent, branched, oblique to right angle in relation to midvein, alternate to opposite and close; quaternary veins (4°) still fine, with angle of origin usually RR forming orthogonal to sometime polygonal meshes.

Holotype — Specimen no. BSIP 37776.

Locality — Seria Naka Village about 30 km northwest of Tulsipur town, Gonda District, Uttar Pradesh.

Horizon & Age — Lower Siwalik, Middle Miocene.

Affinities—The most characteristic features of the fossil leaves such as narrow obovate shape, acuminate apex, obtuse base, eucamptodromous venation, curving up of secondary veins to somewhat greater height and percurrent, branched tertiary veins indicate its close resemblance with the modern leaflets of the genus *Mitrephora* of the family Anonaceae. A large number of herbarium

specimens of this genus have been studied and it was found that the present fossils show close similarity with the leaves of *M. macrophylla* Oliver (CN Herbarium Sheet nos. 13318 & 13303; Pl. 1, figs 2, 4) of the family Anonaceae.

So far, two fossil leaves resembling the genus *Mitrephora* (Bl.) Hook.f. & Thoms. have been described under *Mitrephora siwalica* Antal & Awasthi 1993. Of them, one is from the Lower-Middle Siwalik sediments of Oodlabari, Darjeeling District, West Bengal (Antal & Awasthi, 1993) and other from Middle Siwalik of Surai Khola, western Nepal (Prasad & Awasthi, 1996). These two known fossil leaves differ from the present fossil leaves in being small size with fewer secondaries (5-6 pairs). As the present fossil leaf is entirely different from already known species, they have been described under a new specific name *Mitrephora miocenica.*

Mitrephora macrophylla Oliver, with which the fossil shows close resemblance, is a large tree occurring in the evergreen forest of Malaya.

Genus — *Melodorum* (= *Fissistigma*) Dunal.

Fissistigma senti Lakhanpal 1969
Pl. 3, fig. 1

There is only one specimen in the collection.

Description — Leaf simple, symmetrical, elliptic, preserved length 6.5 cm, width 2.7 cm; apex acute; base acute, normal, equilateral; margin entire; texture chartaceous; petiole invisible; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, curved; secondary veins (2°) about 9 pairs visible, less than 0.3 to 1.2 cm apart, uniformly curved up, unbranched, usually alternate, angle of divergence about 45°, acute, moderate; tertiary veins (3°) fine, angle of origin usually RR, percurrent, branched, oblique to nearly right angle in relation to midvein, predominantly alternate and close to nearly distant; quaternary veins (4°) not fairly preserved.

Holotype — Specimen no. BSIP 37777.

Locality — Seria Naka Village about 30 km northwest of Tulsipur town, Gonda District, Uttar Pradesh.

Horizon & Age—Lower Siwalik, Middle Miocene.

Affinities — The distinguishing features of the fossil leaf like elliptic shape, acute base and apex, entire margin, eucamptodromous venation and percurrent tertiaries arising at right angle indicate that the fossil leaf shows similarity with the modern leaves of *Melodorum (= Fissistigma) wallichii* H.f. & T. of the family Anonaceae (CN Herbarium Sheet no. 383; Pl. 3, fig. 2). So far, only two fossil leaves showing similarity with the genus *Fissistigma* are known. Lakhanpal and Awasthi (1992) reported a fossil leaf under *Fissistigma siwalika* from the Siwalik sediments near Jawalamukhi, Himachal Pradesh. This fossil is large in size (14.5 x 5.3 cm) having oblanceolate shape with rounded apex. So, it is entirely different from the present fossil. Earlier, Lakhanpal (1969) described a fossil leaf as *Fissistigma senti* from the same locality in Himachal Pradesh showing close resemblance with *Fissistigma wallichii.* As the present fossil leaf from Seria Naka shows closest similarity with *F. wallichii* and also almost similar to *F. senti* Lakhanpal 1969 in shape, size and venation pattern, it has therefore been placed under the same species.

PLATE 2

(All figures are of natural size unless otherwise mentioned)

1. *Flacourtia seriaensis* sp. nov.; Fossil leaf showing its shape, size, serrate margin and venation pattern; Specimen no. BSIP 37779.
2. *Flacourtia catafracta* Roxb.; Modern leaf showing similar shape, size and venation pattern.
3. *Securidaca miocenica* sp. nov.; Fossil leaf showing its shape, size and venation pattern; Specimen no. BSIP 37780.
4. *Securidaca inappendiculata* Hask.; Modern leaf showing similar shape, size and venation pattern.
5. *Securidaca miocenica*; A part of fossil leaf magnified to show details of venation. x 2.5.
6. *Nephelium palaeoglabrum* sp. nov.; Fossil leaf showing its shape, size and venation pattern; Specimen no. BSIP 37781.
7. *Nephelium glabrum* Moronh.; Modern leaf showing similar shape, size and venation pattern.
8. *Nephelium palaeoglabrum* sp. nov.; Another fossil leaf showing variation in shape and size; Specimen no. BSIP 37782.

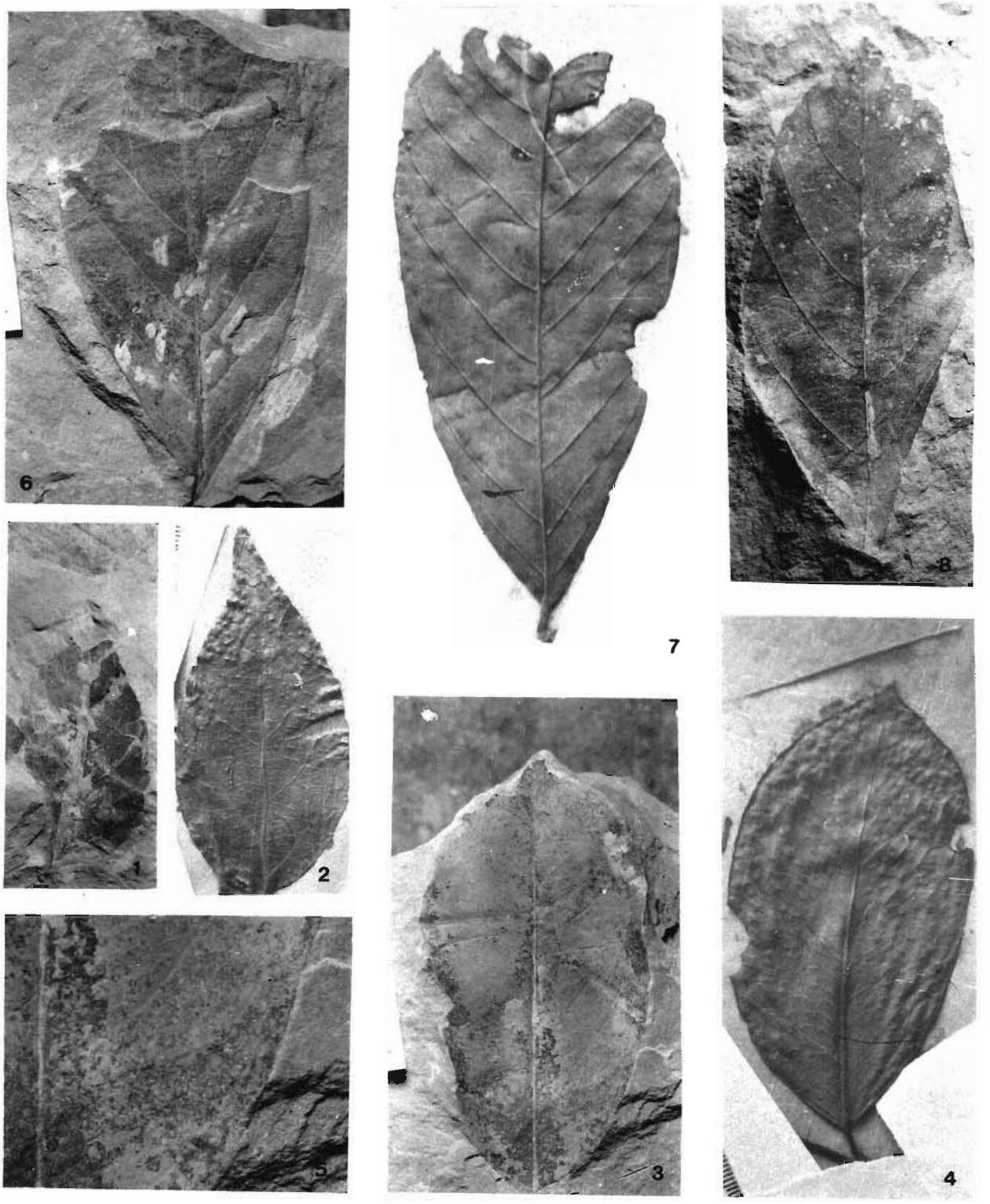


PLATE 2

Fissistigma wallichii (H.f. & T.) Merril, with which the fossil shows similarity, is a large woody climber found in eastern Bengal, Assam and Sylhet (Hooker, 1872).

Genus — *Gontothalamus* Hook.f. & Thoms.

Gontothalamus siwalicus sp. nov.
Pl. 1, fig. 5

There is only one specimen in the collection.

Description— Leaf simple, symmetrical, narrow elliptic, preserved length 7.4 cm, width 2.4 cm; apex broken, seemingly acute; base acute, equilateral; margin entire; texture chartaceous; petiole not preserved; venation pinnate, brochidodromous; primary vein (1°) single, prominent, almost straight; secondary veins (2°) about 9 pairs visible, less than 0.4 to 1.3 cm apart, curved up near the margin and joined to their superadjacent secondary at wide-acute angle, unbranched, almost alternate, angle of divergence about 60°-90°, acute to right angle, basal secondaries arise nearly right angle while upper secondaries arise at acute angle, intersecondary veins present, simple; tertiary veins (3°) not clearly seen.

Holotype — Specimen no. BSIP 37778.

Locality — Seria Naka Village about 30 km northwest of Tulsipur town, Gonda District, Uttar Pradesh.

Horizon & Age — Lower Siwalik, Middle Miocene.

Affinities — The diagnostic features of the present fossil leaf such as narrow elliptic shape, acute base, entire margin, brochidodromous venation, right angle divergence of secondary veins and presence of intersecondary veins strongly suggest its resemblance with the modern leaves of *Uvaria* and *Gontothalamus* of the family Anonaceae. After critical examination of the Herbarium sheets of different species of these genera it has been found that the present fossil leaf comes closest with the extant *Gontothalamus meboldii* Bl. (CN Herbarium Sheet no. 13141, Pl. 1, fig. 6).

A fossil leaf resembling the genus *Gontothalamus* has already been described as *Gontothalamus chorkholaensis* Prasad & Awasthi 1996 from the Siwalik sediments of Surai Khola, Nepal. On comparison with already known species it was found that the present fossil is different in the nature of secondary veins arising more straightly in *G. chorkholaensis* and also the intersecondary veins are more in number. Thus, in being different from the known species a new specific name *G. siwalicus* is given to the present fossil leaf.

The extant species *G. meboldii* Bl., with which the present fossil shows closest similarity, now grows in the Malayan region.

Family—Flacourtiaceae

Genus—*Flacourtia* Commers.

Flacourtia sertaensis sp. nov.
Pl. 2, fig. 1

This species is represented by only one specimen.

Description— Leaf simple, symmetrical, narrow ovate, preserved length 3.8 cm, width 2 cm; apex seemingly acute; base broken; margin serrate; texture chartaceous; petiole not preserved; venation

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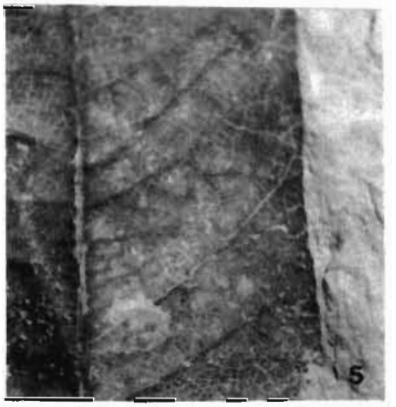
PLATE 3 ⟶

(All figures are of natural size unless otherwise mentioned)

1. *Fissistigma senii* Lakhanpal; Fossil leaf showing shape, size and venation pattern; Specimen no. BSIP 37777.
2. *Fissistigma wallichii* H.f. & T.; Modern leaf showing similar shape, size and venation pattern.
3. *Mangifera someshwarica* Lakhanpal & Awasthi; Fossil leaf — Specimen no. BSIP 37783.
4. *Mangifera indica* Linn.; Modern leaf showing similar shape, size and venation pattern.
5. *Mangifera someshwarica* Lakhanpal & Awasthi; A part of fossil leaf magnified to show details of venation. x 1.5.
6. *Mangifera indica* Linn.; A part of modern leaf magnified to show similar details of venation. x 1.5.



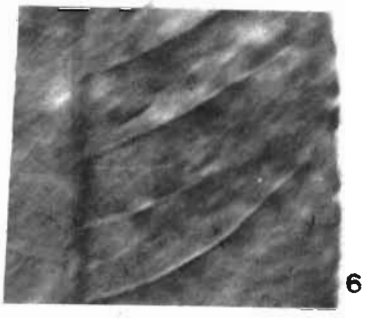


PLATE 3

pinnate, craspedodromous to eucamptodromous; primary vein (1°) single, stout, not very prominent, almost straight; secondary veins (2°) about 6 pairs visible, less than 0.5 to 1.2 cm apart, uniformly curved up, sometimes branched near the margin, alternate, angle of divergence about 55°, acute, moderate, intersecondary veins present, simple; tertiary veins (3°) fine, poorly preserved with angle of origin AO to RR, percurrent, branched, oblique in relation to midvein, alternate to opposite and close.

Holotype — Specimen no. BSIP 37779.

Locality — Seria Naka Village about 30 km northwest of Tulsipur town, Gonda District, Uttar Pradesh.

Horizon & Age — Lower Siwalik, Middle Miocene.

Affinities — The most characteristic features of the present fossil leaf are narrow ovate shape, acute apex, serrate margin, craspedodromous to eucamptodromous venation, moderate angle of divergence, presence of intersecondary veins and percurrent tertiaries. These features collectively indicate its affinity with the family Flacourtiaceae specially the genus *Flacourtia* Comm. ex. L' Herit. A large number of herbarium sheets (about 15 species) of this genus were studied in order to find out its specific affinity. Ultimately, it has been concluded that the present fossil shows closest resemblance with the extant species *Flacourtia catafracta* Roxb. in shape, size and venation pattern (CN Herbarium Sheet nos. 259, 32999, 33000; Pl. 2, fig. 2).

Two fossil leaves, viz., *F. nepalensis* Awasthi & Prasad and *F. terttara* Prasad & Awasthi showing affinity with the genus *Flacourtia* Commers. are already known from the Siwalik sediments of Surai Khola, Nepal (Awasthi & Prasad, 1990; Prasad & Awasthi, 1996). Of these, former is entirely different from the present fossil in being small size (2.3 x 1.3 cm) with obovate apex. While the later is larger in size (9.0 x 3.6 cm) and possesses different nature of secondary veins which run nearly half the distance of lamina before terminating at the margin. Thus, in being different from already known species it is described as a new species *Flacourtia seriaensis*. The specific epithet is after a small Seria River in the area.

The extant taxon *F. catafracta* Roxb., with which fossil resembles closely, is a small tree growing in damp forest in Dehradun (Uttar Pradesh), Bengal, Assam, Chittagong, south India, Myanmar, Phillippine and Malaya regions (Gamble, 1972; Hooker, 1872; Ridley, 1967).

Family—Polygalaceae

Genus—*Securidaca* Linn.

Securidaca miocenica sp. nov.
Pl. 2, figs 3, 5

This species is represented by three specimens in the collection.

Description— Leaf simple, symmetrical, elliptic, preserved size 6.5 x 3.4 cm, 7.0 x 3.5 cm, 6.0 x 3.0 cm; apex seemingly acuminate; base acute to obtuse, almost equilateral; margin entire; texture

PLATE 4 →

(All figures are of natural size unless otherwise mentioned)

1. *Mangifera someshwarica* Lakhanpal & Awasthi; Another fossil leaf showing variation in shape and size; Specimen no. BSIP 37784.
2. *Mangifera indica* Linn.; Another modern leaf showing similar variation in shape and size.
3. *Dracontomelon seriaense* sp. nov.; Fossil leaf showing its shape, size and venation pattern; Specimen no. BSIP 37785.
4. *Dracontomelon sylvestre* Blume.; Modern leaf showing similar shape, size and venation pattern.
5. *Dalbergia miovolubilis* sp. nov.; Fossil leaf — Specimen no. BSIP 37786.
6. *Dalbergia volubilis* Roxb.; Modern leaf.
7. *Dalbergia miovolubilis* sp. nov.; A part of fossil leaf magnified to show details of venation. x 2.
8. *Dalbergia volubilis* Roxb.; A part of modern leaf magnified to show similar details of venation. x 2.
9. *Diospyros tulsipurensis* sp. nov.; Fossil leaf showing its shape, size and venation pattern — Specimen no. BSIP 37787.
10. *Diospyros pruriens* Dalz.; Modern leaf showing similar shape, size and venation pattern.

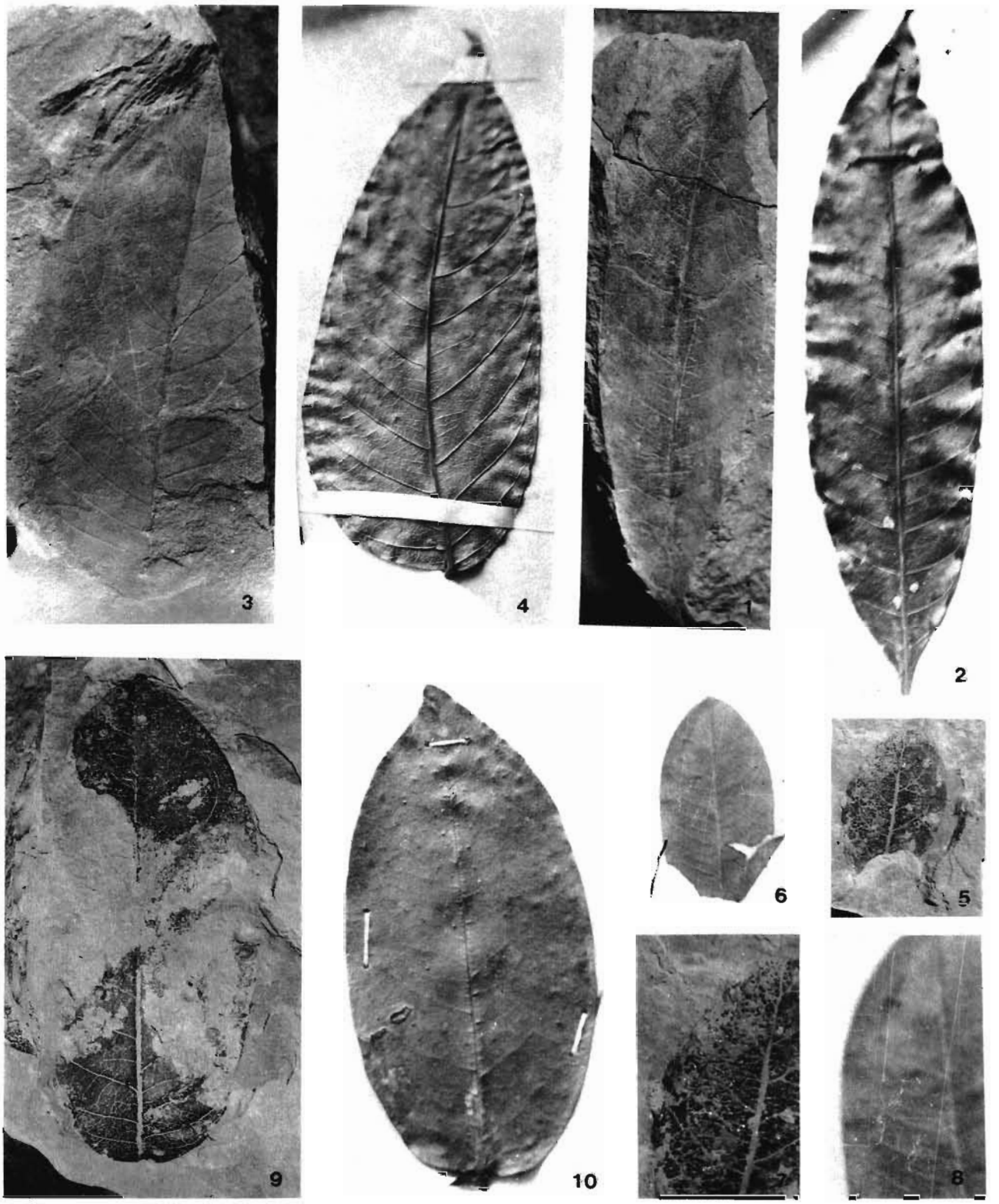


PLATE 4

chartaceous; petiole broken; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) 8 pairs visible, less than 0.3 to 1.4 cm apart, uniformly curved up, seemingly unbranched, alternate to subopposite, angle of divergence about 55°, moderate, acute, intersecondary veins frequent, simple; tertiary veins (3°) not clearly seen.

Holotype — Specimen no. BSIP 37780.

Locality — Seria Naka Village about 30 km northwest of Tulsipur town, Gonda District, Uttar Pradesh.

Horizon & Age — Lower Siwalik, Middle Miocene.

Affinities — The elliptic shape, acuminate apex, acute to obtuse base, entire margin, eucamptodromous venation, moderate angle of divergence of secondary veins and abundant intersecondary veins of the present fossil strongly suggest its affinity with the modern leaves of *Securidaca inappendiculata* Hask. (*S. tavoyana* Wall.) of the family Polygalaceae (CN Herbarium Sheet no. 36383; Pl. 2, fig. 4).

As far as the authors are aware there is no record of fossil leaf of the genus *Securidaca* from Indian Tertiary sediments. Therefore, the present fossil leaf has been described under a new species *Securidaca miocenica.*

The taxon *Securidaca inappendiculata* Hask., with which the fossil shows affinity, is a large woody climber growing in eastern Bengal, Aracan and Tenasserim. It is also found in the Kachar Hills near Myitkyina and Java (Gamble, 1972; Hooker, 1872).

Family — Sapindaceae

Genus — *Nephelium* Linn.

Nephelium palaeoglabrum sp. nov.
Pl. 2, figs 6, 8

This species is represented by five specimens in the collection.

Description — Leaf simple, symmetrical, narrow obovate to elliptic; preserved size 7.3 x 3.5 cm, 7.5 x 3.0 cm, 10.2 x 5.0 cm, 7.4 x 3.6 cm and 8.5 x 3.4 cm; apex acute; base acute; equilateral; margin entire; texture chartaceous; petiole 0.5 cm visible, normal; venation pinnate, craspedodromous to eucamptodromous; primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) 6 to 7 pairs visible, less than 0.8 to 1.5 cm apart, uniformly curved up and become finer before joining the superadjacent vein, unbranched, usually alternate, rarely subopposite; intersecondary veins absent; tertiary veins (3°) fine with angle of origin usually RR, branched, percurrent, oblique to nearly right angle in relation to midvein, predominantly alternate, close; quaternary veins (4°) poorly preserved, angle of origin RR, branched forming orthogonal to polygonal meshes.

Holotype — Specimen no. BSIP 37781.

Paratype — Specimen no. BSIP 37782.

Locality — Seria Naka Village about 30 km northwest of Tulsipur town, Gonda District, Uttar Pradesh.

Horizon & Age — Lower Siwalik, Middle Miocene.

Affinities — Narrow obovate to elliptic shape, acute apex and base, entire margin, craspedodromous to eucamptodromous venation and percurrent tertiaries which are oblique to nearly right angle in relation to midvein are the diagnostic features of the present fossil leaves. Besides, the fossil leaf is also characterised by uniformly curved up secondaries which become finer before joining the superadjacent veins. These features collectively indicate that the present fossil leaves show closest resemblance with the modern leaves of *Nephelium glabrum* Noronh. of the family Sapindaceae (CNH Herbarium Sheet no. 95476; Pl. 2, fig. 7).

So far, three fossil leaves resembling the genus *Nephelium* have been described from the Tertiary sediments of India and abroad. They are *Nephelium jovis* Unger 1867 from the Tertiary of Europe, *N. verbeerkianum* Geyler 1875 from Tertiary of Borneo and *N. oligocenicum* Awasthi & Mehrotra 1995 from the Oligocene of Makum Coalfield, Assam, India.

On comparison of these known fossil leaves with that of the present fossil leaf it has been found that the present fossil leaf is different from already known fossils either in shape, size or in venation pattern. In being different from known species this fossil leaf is described as *Nepheltum palaeoglabrum* sp. nov. The name of species is after modern comparable species *N. glabrum.*

Nepheltum glabrum Noronh., with which fossil shows closest affinity, is an evergreen tree found to grow in Malayan archipelago (Hooker, 1872).

Family — Anacardiaceae

Genus — *Mangifera* Linn.

Mangifera someshwarica Lakhanpal & Awasthi 1984
Pl. 3, figs 3, 5; Pl. 4, fig. 1

There are three specimens in the collection.

Description — Leaves simple, symmetrical, very narrow, elliptic, preserved size 14.2 x 4 cm, 9.5 x 2.7 cm, 9.9 x 2.7 cm; apex acute; base acute, equilateral; margin almost entire; texture thick chartaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout; secondary veins (2°) more than 22 pairs visible, less than 0.4 to 1.6 cm apart, uniformly curved up, towards margin become more fine before joining the superadjacent vein, unbranched, alternate to opposite, angle of divergence 70° to 90°, acute to right angle, basal secondaries arise at right angle, intersecondary veins present, frequent, simple to composite; tertiary veins (3°) still fine, with angle of origin RR to AO, percurrent, branched, oblique in relation to midvein, alternate to opposite, close; quaternary veins (4°) very fine, usually arise at right angle forming rectangular to polygonal meshes.

Specimen — Nos. BSIP 37783 and 37784.

Locality — Seria Naka Village about 30 km northwest of Tulsipur town, Gonda District, Uttar Pradesh.

Horizon & Age — Lower Siwalik, Middle Miocene.

Affinities — The important features of the fossil leaves are very narrow elliptic shape, acute apex and base, entire margin, eucamptodromous venation, right angle divergence of secondary veins, presence of frequent intersecondary veins and percurrent, branched tertiaries. These features collectively indicate that these fossil leaves belong to the family Anacardiaceae. Among this family the genus *Mangifera* Linn. shows resemblance with the fossil specimens. A large number of herbarium sheets of different species of *Mangifera* were examined in which *Mangifera indica* Linn. shows closest affinity with the fossil leaves (C N Herbarium Sheet no. 8493; Pl. 3, figs 4, 6).

So far, six fossil leaves resembling *Mangifera indica* Linn. have been described from the Tertiary sediments of India and abroad. Of them, two are described under *Mangifera takashimensis* Matsuo 1967 in which one is from the Palaeogene of Kyushu and the other from the Eocene of Southwest Honshu, Japan. The remaining three leaves have been described under *Mangifera someshwarica* Lakhanpal & Awasthi 1984. They are from the Siwalik sediments of Bhikhnathoree, Bihar (Lakhanpal & Awasthi, 1984), Surai Khola, Nepal (Awasthi & Prasad, 1990), Koilabas, Nepal (Prasad, 1994b) and from Oligocene sediments of Makum Coalfield, Assam, India (Awasthi & Mehrotra, 1995). Out of these, the identification of leaves described under *M. takashimensis* appears to be doubtful (Awasthi & Prasad, 1990). As the present fossil leaves resemble modern taxon *M. indica* Linn. and very near to the fossil leaves already known from Siwaliks of Surai Khola, Nepal and Oligocene of Makum Coalfield, Assam, India, they have been described under *Mangifera someshwarica* Lakhanpal & Awasthi 1984.

The modern comparable taxon *Mangifera indica* Linn. is a large evergreen tree growing in sub-Himalayan tract and in the outer hills of Kumaon and Garhwal. It also grows in Chittagong Hills tract in Bangladesh, Myanmar, Thailand, Vietnam and Malaya Peninsula (Gamble, 1972).

Genus — *Dracontomelon* Blume

***Dracontomelon seriaense* sp. nov.**
Pl. 4, fig. 3

This species is represented by a single specimen.

Description — Leaf simple, somewhat asymmetrical, narrow ovate, preserved length 8.5 cm, width 3.9 cm; apex acute; base obtuse, slightly inequilateral; margin entire; texture thick, chartaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein (1°) prominent, stout slightly curved; secondary veins (2°) 14 pairs visible, less than 0.4 to 1.2 cm apart, uniformly curved up, unbranched, alternate to subopposite, angle of divergence 50°-80°, wide-acute, basal secondaries arise less acutely; intersecondaries frequently present, simple; tertiary veins (3°) fine with angle of origin RR, percurrent, branched, sometimes straight to sinuous, oblique in relation to midvein, predominantly alternate and close; quaternary veins (4°) still fine with angle of origin acute to right angle, branched, forming orthogonal to polygonal meshes.

Holotype — Specimen no. BSIP 37785.

Locality — Seria Naka Village about 30 km northwest of Tulsipur town, Gonda District, Uttar Pradesh.

Horizon & Age — Lower Siwalik, Middle Miocene.

Affinities — Slightly asymmetrical narrow ovate shape, acute apex, obtuse and inequilateral base, entire margin, eucamptodromous venation, wide acute angle of divergence of secondary veins, presence of intersecondary veins and percurrent straight to sinuous tertiary veins suggest that the present fossil leaf shows close resemblance with the modern leaves of *Dracontomelon sylvestre* Blume of the family Anacardiaceae (CN Herbarium Sheet no. 10096; Pl. 4, fig. 4).

As far as the authors are aware, there is no record of fossil leaf resembling the genus *Dracontomelon* from the Tertiary sediments of India and other places. Therefore, it forms the first record from the Siwalik sediments of Seria Naka and has been described as *Dracontomelon sertaense* sp. nov., the specific name is after a local small river Seria.

Dracontomelon sylvestre Blume, with which fossil shows closest affinity, is a large tree found to grow in Borneo.

Family—Fabaceae

Genus—*Dalbergia* Linn.f.

Dalbergia mtovolubilis sp. nov.
Pl. 4, figs 5, 7

This species is represented by three specimens.

Description — Leaflet simple, symmetrical, wide-elliptic, preserved size 2.3 x 1.5 cm, 3.3 x 2.2 cm, 2.9 x 2.0 cm; apex nearly obtuse; base broken; margin entire; texture chartaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, moderate, almost straight; secondary veins (2°) about 7 pairs visible, less than 0.5 cm apart, uniformly curved up, unbranched but sometimes branched, alternate, angle of divergence about 50°, intersecondary veins frequent, simple; tertiary veins (3°) fine with angle of origin RR-AO, percurrent, branched, oblique in relation to midvein, alternate to opposite, close; quaternary veins (4°) not preserved.

Holotype — Specimen no. BSIP 37786.

Locality—Seria Naka Village about 30 km northwest of Tulsipur town, Gonda District, Uttar Pradesh.

Horizon & Age — Lower Siwalik, Middle Miocene.

Affinities — The characteristic features of the present fossil leaflets such as small size, wide elliptic shape, nearly obtuse apex, entire margin, eucamptodromous venation, acute angle of divergence of secondary veins, presence of intersecondaries and percurrent tertiaries collectively indicate its affinity with the modern leaflets of the genus *Dalbergia* Linn.f. of the family Fabaceae. The herbarium sheets of more than 20 species of the genus were studied critically in order to find out the specific affinity of these fossil leaflets. Out of these, the modern leaflets of *Dalbergia volubilis* Roxb. (CN Herbarium Sheet no. 28172; Pl. 4, fig. 6) show closest resemblance with the fossil leaflets in shape, size and venation pattern.

Fossil leaflets resembling the genus *Dalbergia* Linn.f. have been described under the genera *Dalbergia* Linn.f. and *Dalbergites* Berry. So far, 40 species of *Dalbergia* Linn.f. and 3 species of *Dalbergites* Berry have been recorded from different parts of the world (Prasad, 1990, 1994a, 1994b). Firstly, the occurrence of *Dalbergia* in the Siwalik sediments in India is known by a fruit resembling *D. sissoo* (Lakhanpal & Dayal, 1966). Later on four fossil leaflets, viz., *Dalbergia* sp. (Lakhanpal & Awasthi, 1984) from Siwalik sediments of Bhikhnathoree, *Dalbergia miosericea* Prasad 1990 and *D. siwalika* Prasad 1994a from the Siwalik sediments of Koilabas, Nepal and *Dalbergia* cf. *D. sissoo* from Siwalik sediments of Hardwar, Uttar Pradesh, India (Prasad, 1994b) were described from the Siwalik sediments of India and Nepal. Of these, three fossil leaflets, *Dalbergia* sp. (Lakhanpal & Awasthi,1984). *Dalbergia* cf. *D. sissoo* Prasad and *D. siwalika* Prasad have been compared with a single modern taxon *Dalbergia sissoo* and are entirely different from the present fossil leaflets in shape, size and venation pattern. The other species *D. miosericea* Prasad described from the Siwalik sediments also differs in being possessing emarginate apex. The present fossil leaflets have also been compared with other available known species described from outside the Indian subcontinent and found that none of them comes close to the present fossil leaflets. Thus, these fossil leaflets have been described under a new species — *Dalbergia miovolubilis*. The specific name indicates that the fossils show resemblance with modern species *D. volubilis*.

The modern comparable taxon *D. volubilis* Roxb. is a large climbing shrub growing in central and eastern Himalaya from Kumaon to Sikkim, Bihar, Central Provinces, Chhota Nagpur, south and west India (Gamble, 1972).

Family — Ebenaceae

Genus — *Diospyros* Linn.

Diospyros tulsipurensis sp. nov.
Pl. 4, fig. 9

This species is represented by a single specimen.

Description — Leaf simple, symmetrical, wide elliptic, preserved length 8.4 cm, width 3.8 cm; apex wide acute; base obtuse; margin entire; texture chartaceous; petiole broken; venation pinnate, eucamptodromous to brochidodromous; primary vein (1°) single, prominent, stout, straight, thicker in the basal part; secondary veins (2°) about 9 pairs visible, less than 0.3 to 1.5 cm apart, uniformly curved up, alternate to opposite, seemingly unbranched, angle of divergence about 60°-90°, acute to right angle, few basal secondaries arise nearly at right angle; intersecondaries present, simple; tertiary veins (3°) fine with angle of origin usually RR, percurrent, branched, usually oblique in relation to midvein, in the apical part towards margin the tertiaries are nearly right angle in relation to midvein, opposite to alternate and close; quaternary veins (4°), very fine, arising usually at right angle from tertiary veins, branched forming meshes.

Holotype — Specimen no. BSIP 37787.

Locality — Seria Naka Village about 30 km northwest of Tulsipur town, Gonda District, Uttar Pradesh.

Horizon & Age — Lower Siwalik, Middle Miocene.

Affinities — The most important features of the present fossil leaf are wide elliptic shape, wide acute apex, obtuse base, entire margin, eucamptodromous to brochidodromous venation, acute to right angle of divergence of secondary veins, presence of intersecondary veins and percurrent tertiaries with right angle in relation to midvein near the margin. These features suggest that the present fossil leaf belongs to the genus *Diospyros* of Ebenaceae. In view of specific identification, the herbarium sheets of all the available species were examined and found that the modern leaves of *Diospyros prurtens* Dalz. show closest affinity with the fossil leaf (CN Herbarium Sheet nos. 58781, 62672; Pl. 4, fig. 10).

Fossil leaves resembling the genus *Diospyros* Linn. have been described under the genera *Diospyros* Linn. and *Diospyrophyllum* Velenovsky. The former includes about 70 species described from all over

Table 1–Present day distribution of modern equivalents of fossil taxa from the Lower Siwalik sediments of Seria Naka

Fossil taxa	Modern equivalents taxa	Present day distribution
Anonaceae		
Mitrephora miocenica sp. nov.	*Mitrephora macrophylla* Oliver.	Malaya
Fissistigma senii Lakhanpal	*Fissistigma wallichii* H.f. & T.	North east region
Goniothalamus siwalicus sp. nov.	*Goniothalamus meboldii* Bl.	Malaya
Flacourtiaceae		
Flacourtia seriaensis sp. nov.	*Flacourtia catafracta* Roxb.	North India, S. India, Philippines, Malaya, *Myanmar and Bangladesh*
Polygalaceae		
Securidaca miocenica sp. nov.	*Securidaca inappendiculata* Hask.	North-east India, South India & Java
Sapindaceae		
Nephelium palaeoglabrum sp. nov.	*Nephelium glabrum* Noronh.	Malaya
Anacardiaceae		
Mangifera someshwarica Lakhanpal & Awasthi	*Mangifera indica* Linn.	India, Bangladesh, Myanmar, Thailand, Vietnam and Malaya
Dracontomelon seriaensis sp. nov.	*Dracontomelon sylvestre* Blume	Borneo
Fabaceae		
Dalbergia miovolubilis sp. nov.	*Dalbergia volubilis* Roxb.	Central and eastern Himalaya, *Central, South and West India*
Ebenaceae		
Diospyros tulsipurensis sp. nov.	*Diospyros pruriens* Dalz.	Western Ghat, Wynaad and Andamans

the world (Prasad, 1987, 1990, 1994c, 1994d; Antal & Awasth, 1993; Prasad & Awasthi, 1996). However, *Diospyrophyllum* Velenovsky consists of single species *Diospyrophyllum provectum* which goes back to the Upper Cretaceous of Bohemia (Velenovsky, 1884). So far, six species have been reported from the Siwalik sediments of both India and Nepal. They are *Diospyros kotlabasensis* Prasad 1990 (also from West Bengal; Antal & Awasthi, 1993) and *D. pretoposia* Prasad 1990 from the Siwalik sediments of Koilabas, western Nepal; *D. miokaki* Hu & Chaney and *D. miocenicus* Prasad from the Siwalik sediments of Surai Khola, western Nepal (Awasthi & Prasad, 1996; Prasad & Awasthi, 1996); and *D. palaeoebenum*

Table 2 — Distribution of modern equivalents of fossil flora of Seria Naka in different tropical forest types

Taxa	1	2	3	4	5	6
Mitrephora macrophylla	+	+				
Fissistigma wallichii	+	+	+			
Goniothalamus meboldii	+	+				
Flacourtia catafracta		+	+			
Securidaca inappendiculata	+	+	+			
Nephelium palaeoglabrum	+					
Mangifera indica	+	+	+		+	
Dracontomelon sylvestre	+	+				
Dalbergia volubilis			+		+	
Diospyros pruriens	+		+	+		

1. Evergreen, **2.** Semi-evergreen, **3.** Moist deciduous, **4.** Littoral and swamp forest, **5.** Dry deciduous, and **6.** Thorn forest.

Prasad 1994c and *D. kathgodamense* Prasad 1994d from Siwaliks of Kathgodam, Uttar Pradesh. The present fossil leaf has been compared with above known species and found that it is entirely different from them in possessing secondaries in the basal part which arise from midvein almost at right angle. This feature is not found in any of above known species of *Diospyros*. Therefore, the present fossil leaf has been described under a new species *Diospyros tulsipurensis*; the specific name indicates the nearest Tulsipur town from the fossil locality.

The modern taxon *D. prurtens* Dalz., with which the fossil shows closest affinity, is a common tree of the forest of Western Ghat from North Kanara, southwards ascending to about 1,000 m in the Wynaad and Andamans (Gamble, 1972).

DISCUSSION

Floral analysis, palaeoclimate and phytogeography

The present fossil assemblage recovered from the Lower Siwalik sediments of Seria Naka in the Himalayan foot-hills of Gonda District, Uttar Pradesh, India is represented by angiospermous leaf-impressions consisting of 10 species. They belong to 10 genera of seven dicotyledonous families. Out of them, the genus *Securidaca* of family Polygalaceae is new to the fossil record of the Tertiary sediments of India. The assemblage is represented by medium to large trees (7 species) and climbers (3 species). Herbs are totally absent. The Seria Naka fossil flora mostly consists of evergreen taxa (Table 2) which indicate that a tropical evergreen forest was flourishing in and around the area during deposition. On the contrary, mixed deciduous forest grows these days in the area. The present day distribution of the comparable taxa shows that they occur mostly in evergreen and sometimes moist deciduous forests of north-east India, Bangladesh, Myanmar and South-east Asian region (Malaya, Java, Phillipines & Borneo; Table 1). It may therefore be surmised that a warm and humid climate prevailed in the Seria Naka area at the time of sedimentation, in contrast to the relatively present day dry climate. Most of the species, except *Mangifera indica* and *Dalbergia volubilis,* do not grow in the Himalayan foot-hills in this region. This indicates a change in climate after the deposition of Siwaliks. These changes in climate since Middle Miocene may be due to uplift of Himalaya and shallowing of the Tethys Sea which progressively changed from a marine through estuarine to fresh water environment (Mukherjee, 1984). The observation on the physiognomic characters of the fossil assemblage recovered from the Siwalik sediments of Seria Naka has also been carried out in order to infer the climate of the area. The present assemblage includes the texa with entire margin, except *Flacourtia catafracta* with higher venation density and most of them have medium size leaves. Further, the extended leaf tips (drip tips), an important physiognomic feature, have also been found in *Mitrephora miocenica, Fissistigma senii, Securidaca miocenica, Mangifera someshwarica, Dracontomelon sertaensis* and *Diospyros tulsipurensis*. These foliar physiognomic characters of fossil leaves indubitably indicate the prevalence of tropical climate during the Siwalik sedimentation (Wolf, 1969; Richards, 1952; Givnish, 1979).

The analysis of present day distribution of the assemblage recovered from Seria Naka indicates that out of 10 genera, only two genera now grow along the foot-hills, while the remaining other taxa have migrated to other suitable regions like north - east India, south India, Myanmar, Bangladesh and South east Asian region (Malaya, Java & Philipines) where they received favourable climate and higher rainfall (Brandis, 1971; Hooker, 1872; Gamble, 1972; Kanjilal, 1928; Desch, 1957). The occurrence of four taxa, viz., *Mitrephora macrophylla, Goniothalamus meboldii, Nephelium glabrum* and *Dracontomelon sylvestre* in the South-east Asian regions indicates that either these taxa have migrated from South-east Asian region to the Indian subcontinent during Palaeocene and flourished along the Himalayan foot-hills or they must have originated themselves in the Indian subcontinent and flourished around Seria Naka area; then migrated to South-east Asian region after Middle Miocene due to change in climate caused by the

uplift of Himalaya. Likewise, the floral exchange between India and South-east Asia must have taken place as indicated by the presence of taxa like *Flacourtia catafracta, Securidaca inappendiculata, Mangifera indica* and *Dracontomelon sylvestre* both in India and South-east Asia.

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