

# Morphotaxonomic study of some more fossil leaves from the Lower Siwalik sediments of West Bengal, India

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The leaf-impressions from the Lower Siwalik sediments exposed near Oodlabari in Darjeeling District, West Bengal belonging to extant genera, viz., *Uvaria* Linn., *Alsodeia* Thouars., *Hopea* Roxb., *Grewia* Linn., *Beddomea* Hook.f. and *Terminalia* Linn. of the families Anonaceae, Flacourtiaceae, Dipterocarpaceae, Tiliaceae, Meliaceae and Combretaceae, respectively have been described in this paper. Of them four species, viz., *Uvaria ghishia* sp. nov., *Alsodeia palaeoechinocarpa* sp. nov., *Grewia tiliaefolia* sp. nov. and *Beddomea palaeoindica* sp. nov. are new records to the existing Siwalik flora. Amongst these six taxa four are found in the evergreen forests and the remaining two in the moist evergreen forests of India and Malaya Peninsula, which collectively suggest the prevalence of warm and humid climate in the area during deposition of these sediments.

**Key words**—Plant megafossils, Morphotaxonomy, Leaf-impressions, Middle Miocene, West Bengal (India).

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## सारांश

पश्चिम बंगाल (भारत) के अधरि शिवालिक अवसादों से प्राप्त कुछ और अश्मित पत्तियों का आकार—वर्गिकीय अध्ययन

जसवन्त सिंह अन्तल एवं महेश प्रसाद

इस शोध-पत्र में पश्चिम बंगाल में दार्जिलिंग जनपद में ओदलाबाड़ी के पास अनावरित अधरि शिवालिक अवसादों से प्राप्त पर्ण-छापों का वर्णन किया गया है जो एनोनेसी, फ्लैकोरिंएसी, डिप्टेरोकार्पेसी, टिलिएसी, मीलिएसी एवं कॉम्ब्रीटेसी नामक कुलों के क्रमशः यूवेरिया, आल्सोडिया, होपिया, ग्रीविया, बेडोमिया एवं टर्मिनेलिया नामक वर्गों से सम्बद्ध हैं। इनमें से चार जातियाँ—यूवेरिया घिशिया नव जाति, आल्सोडिया पेलियोइकाइनोकार्पा नव जाति, ग्रीविया टिलीफोलिया नव जाति एवं बेडोमिया इन्डिका नव जाति शिवालिक वनस्पतिजात के लिये नये अभिलेख हैं। इन वर्गों में से चार वर्गक भारत एवं मलाया प्रायद्वीप के सदाहरित एवं आर्द्र सदाहरित वनों में पाये जाते हैं। इनकी उपस्थिति से इस क्षेत्र में इन अवसादों के निक्षेपण के समय नम एवं उष्ण प्रकार की जलवायु का होना इंगित होता है।

THE Siwalik sediments of West Bengal are divisible into Lower, Middle and Upper Siwaliks (Acharyya, 1972, 1975). The Lower and Middle Siwalik sediments are rich in plant megafossils comprising well-preserved leaf-impressions and carbonised woods. So far a number of leaf-impressions, fossil fruits/seeds as well as three fossil woods have been described from Ghish River, Ramthi River, Lish River and Sevoke Road Sections in the area (Antal & Awasthi, 1993; Antal & Prasad, 1995, 1996a, 1996b, 1996c, 1997). The Upper Siwalik sediments which are best exposed in Ghish River, Lish River and Dudhia River do not contain any plant megafossil.

The material for the present study was collected from a Lower Siwalik section exposed in Ghish River from about 1 km upstream from

the mouth of the river and Sevoke Road section about 2 km after crossing Tista River Bridge towards Washbari. For the description of these leaf-impressions the terminology given by Hickey (1973) and Dilcher (1974) has been followed.

All the figured specimens have been deposited in the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow.

## SYSTEMATIC DESCRIPTION

Family—Anonaceae

Genus—*Uvaria* Linn.

*Uvaria ghishia* sp. nov.

Pl. 1, fig. 1

*Material*—It is represented by one specimen with counter part.

*Description*—Leaf simple, symmetrical, wide elliptic, preserved length 9.8 x 5.6 cm; apex broken; base broken; margin entire; texture coriaceous; petiole not preserved; venation pinnate, simple brochidodromous; primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) 8 pairs visible, 0.7 to 1.7 cm apart, alternate to subopposite, basal secondaries not preserved, angle of divergence 60°-75°, wide acute, unbranched, uniformly curved up and join their superadjacent secondaries before the margin forming a loop, intersecondary veins present, frequent, unbranched; tertiary veins (3°) moderate, angle of origin usually RR, percurrent, mostly sinuous, branched, oblique in relation to mid-vein, predominantly alternate, close to nearly distant; quaternary veins (4°) still fine with angle of origin usually RR, branched forming meshes.

*Holotype*—BSIP Specimen no. 381165.

*Paratype*—BSIP Specimen no. 381166.

*Locality*—Ghish River Section about one km upstream on the right side from its mouth near Oodlabari, Darjeeling District, West Bengal.

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

*Affinities*—The distinguishing morphological features of the leaf such as wide elliptic shape, entire margin, wide acute angle of divergence of secondaries, brochidodromous type of venation where secondaries join each other before the margin making a loop and presence of inter-secondaries indicate that the fossil leaf belongs to the family Anonaceae. The course of secondary and tertiary veins suggests its resemblance with the extant taxon *Uvaria hirsuta* Jack. (C.N. Herbarium sheet nos 10610, 10618; Pl. 1, fig. 2) of the family Anonaceae. During the course of study it was also observed

that this leaf superficially resembles *Salacia oblonga* Vahl. of the family Celastraceae but differs in the course of venation pattern of tertiary veins.

The fossil leaves resembling the genus *Uvaria* are known so far under the form species *U. siwalica* Prasad 1994a from the Siwalik sediments of Kathgodam, Nainital District, Uttar Pradesh. These show close affinity with the extant species *Uvaria hamiltonii* Hook.f. Thom. and distinctly differs from the present fossil leaf in having eucamptodromous venation. Therefore it has been described here under a new species *Uvaria ghishia*.

The modern comparable taxon *Uvaria hirsuta* Jack. resembling the fossil leaf is distributed in the evergreen forests of Myanmar and Malaya Archipelago (Brandis, 1971).

Family—Flacourtiaceae

Genus—*Alsodeia* Thouars.

*Alsodeia palaeoechinocarpa* sp. nov.

Pl. 2, fig. 1

*Material*—It is represented by two well preserved specimens.

*Description*—Leaves simple, symmetrical, oblanceolate, preserved length 6.5 x 14.0 cm; apex seemingly acute to acuminate; base acute, normal; margin non-entire, dentate; texture coriaceous; petiole preserved in one specimen, 1.7 cm, normal; venation pinnate, simple, craspedodromous; primary vein (1°) prominent, stout, moderate, almost straight; secondary veins (2°) about 13 pairs visible, 0.4 to 1.4 cm apart, alternate to subopposite, unbranched, angle of divergence about 60°, acute, uniformly curved up, meeting at the margin at the point of dentation; tertiary veins (3°) moderate, prominent, angle of origin RR, percurrent, sometimes branched, rarely straight but mostly sinuous, branched, oblique

#### PLATE 1



1. *Uvaria ghishia* sp. nov.—Fossil leaf showing shape, size and venation pattern.
2. *Uvaria hirsuta* Jack.—Modern leaf showing similar shape, size and venation pattern.
3. *Hopea kathgodamensis* Prasad—Fossil leaf showing shape, size and venation pattern.
4. *Hopea micrantha* Roxb.—Modern leaf showing similar shape, size and venation pattern.
5. *Beddomea palaeoindica* sp. nov.—Fossil leaf showing shape, size and venation pattern.
6. *Beddomea indica* Hook.f.—Modern leaf showing similar shape, size and venation pattern.



3



6



5



4



1



2

PLATE 1

in relation to mid-vein, alternate to opposite and close; quaternary veins ( $4^{\circ}$ ) poorly preserved.

*Holotype*—BSIP Specimen no. 38167

*Paratype*—BSIP Specimen no. 38168

*Locality*—Ghish River Section about one km upstream on the right side from its mouth near Oodlabari, Darjeeling District, West Bengal.

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

*Affinities*—The most characteristic features of the present fossil leaves are symmetrical oblanceolate shape, seemingly acute apex and base, dentate margin, coriaceous texture, presence of long petiole and simple craspedodromous venation. These features are found common in the modern leaves of the genera *Dillenia* Linn. and *Tetracera* of the family Dilleniaceae and *Alsodeia* Thours. of the family Flacourtiaceae. After critical study of the modern leaves of *Dillenia* and *Tetracera* it has been observed that they differ in the nature of dentation and origin and arrangement of tertiary veins. Thus it is apparent that the present fossil leaves show close resemblance with *Alsodeia* Thours. of Flacourtiaceae. In order to find out the specific affinity all the available modern species were examined and concluded that the extant leaves of *Alsodeia echinocarpa* Korth. (C.N. Herbarium sheet no. 32326; Pl. 2, fig. 2) show nearest affinity with the fossil leaves and thus have been described as *Alsodeia palaeoechinocarpa* sp. nov.

The fossil leaves belonging to the family Flacourtiaceae are known from the Siwalik sediments of India and Nepal. They show their close resemblance with the genera *Flacourtia*, *Ryparosa*, *Hydnocarpus* and *Alsodeia* (Prasad, 1990; Prasad & Awasthi, 1996; Antal & Prasad, 1997). Antal and Awasthi (1993) described a fossil leaf resembling the modern leaves of *Alsodeia zeylanica* under *Alsodeia palaeozeylanica* from the same area. The present fossil leaves differ from the above

species in being larger in size and nature and arrangement of tertiary veins. The margin in the above already known species *A. palaeozeylanica* is entire as compared to *A. echinocarpa* and hence has been described as a new species *A. palaeoechinocarpa*.

The modern comparable taxon *Alsodeia echinocarpa* Korth. is a small tree as much as 30 ft tall and found in the evergreen forests of Sumatra and Cochin-China (Ridley, 1967).

Family—Dipterocarpaceae

Genus—*Hopea* Roxb.

*Hopea kathgodamensis* Prasad 1994b

Pl. 1, fig. 3

*Material*—It is represented by one specimen with counterpart.

*Description*—Leaf simple, symmetrical, narrow ovate, preserved size 7.2 x 3.5 cm; apex acute; base nearly obtuse, normal; margin entire; texture coriaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein ( $1^{\circ}$ ) single, stout, prominent, slightly curved; secondary veins ( $2^{\circ}$ ) about 10 pairs preserved, less than 0.5 to 1.0 cm apart, usually alternate, basal secondaries closely placed and arise at greater angle as compared to above secondaries, unbranched, angle of divergence  $50^{\circ}$  to  $70^{\circ}$ , narrow to wide acute, uniformly curved up; tertiary veins ( $3^{\circ}$ ) fine with angle of origin RR, sometime percurrent, seemingly branched, oblique in relation to mid-vein, predominantly alternate and close; further details could not be seen.

*Holotype*—BSIP Specimen no. 38169.

*Paratype*—BSIP Specimen no. 38170.

*Locality*—Ghish River Section about one km upstream on the right side from its mouth near Oodlabari, Darjeeling District, West Bengal.

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

## PLATE 2

1. *Alsodeia palaeoechinocarpa* sp. nov.—A fossil leaf in natural size.

2. *Alsodeia echinocarpa* Korth.—Modern leaf in natural size showing similarity with the fossil leaf.



1



2

PLATE 2

*Affinities*—Narrow ovate shape, acute apex, nearly obtuse base, coriaceous texture, eucamptodromous venation, nature and arrangement of secondary and tertiary veins indicate its resemblance with the modern leaves of *Hopea* Roxb. of the family Dipterocarpaceae. After detail examination of a number of modern species it has been found that the present fossil leaf shows closest affinity with the leaves of extant taxon *Hopea micrantha* Roxb. of the family Dipterocarpaceae (C.N. Herbarium sheet no. 51941, Pl. 1, fig. 4).

A fossil leaf closely resembling the above modern species is known from the Siwalik sediments of Kathgodam as *Hopea kathgodamensis* Prasad 1994b. This fossil leaf resembles the present fossil leaf in almost all morphological features except in more number of secondary veins and therefore it is being described under the same species.

The modern comparable taxon *Hopea micrantha* Roxb. is a lofty tree growing in Malacca, Myanmar and Borneo (Hooker, 1872).

Family—Tiliaceae

Genus—*Grewia*

*Grewia tistaensis* sp. nov.

Pl. 3, fig. 1

*Material*—It is represented by only one specimen.

*Description*—Leaf simple, symmetrical, wide elliptic, preserved length 11.3 x 5.8 cm; apex broken, probably acute; base not preserved, margin seemingly serrate; texture chartaceous; petiole not preserved; venation pinnate, simple craspedodromous; primary vein (1<sup>o</sup>) single, stout, thinner towards apex, almost straight; secondary veins (2<sup>o</sup>) 5-6 pairs preserved, 2.0 to more than 5.0 cm apart, basal pair of secondaries seemingly arising from base and run towards to the greater length of the leaf, alternate, basal secondaries branching towards margin, angle of divergence

55°, wide acute, uniformly curved up; tertiary veins (3<sup>o</sup>) fine and prominent, angle of origin RR, percurrent, straight to sinuous, branched, relation to mid-vein nearly right angle, predominantly alternate, close to distant; quaternary veins (4<sup>o</sup>) still fine, angle of origin RR, branched forming rectangular to polygonal meshes.

*Holotype*—BSIP Specimen no. 38171.

*Locality*—Sevoke Road Section after crossing Tista River Bridge about 2.5 km towards Washbari, Darjeeling District, West Bengal.

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

*Affinities*—The distinguishing features of the present fossil leaf such as wide elliptic shape, poorly serrate margin, seemingly acute apex, simple craspedodromous venation, basal secondaries curving upwards to a greater length of lamina with lateral branches towards margin, percurrent straight to sinuous tertiaries having nearly right angle relation to mid-vein and formation of rectangular to polygonal meshes by the quaternary veins indicate its close affinity with the modern leaves of *Grewia tiliaefolia* Vahl. (C.N. Herbarium sheet no. 30152; Pl. 3, fig. 2).

So far, two fossil leaves resembling the genus *Grewia* Linn. are known from the Tertiary sediments of India. Of them, *Grewia ghishia* Antal & Awasthi 1993 has been recorded from the Siwalik sediments of Ghish River Section near Oodlabari, Darjeeling District, West Bengal. This species shows close resemblance with the extant species *G. umbellifera* Bedd. which is smaller in size as compared to the present leaf. Another fossil leaf is known from the Late Cenozoic sediments of Mahuadanr, Palamu District, Bihar (Srivastava *et al.*, 1992). This specimen has been compared with the same extant species *G. tiliaefolia* Vahl. but it has not been assigned to any form species. Therefore the present fossil is being described

PLATE 3



1. *Grewia tistaensis* sp. nov.—A fossil leaf in natural size.

2. *Grewia tiliaefolia* Vahl.—A modern leaf in natural size showing similarity with the fossil leaf.



PLATE 3

under a new form species *G. tistaensis*. The specimen reported by Srivastava *et al.* (1992) is conspecific.

The modern comparable taxon *Grewia tiliaefolia* Vahl. is a moderate sized tree distributed in sub-Himalayan tracts of India and Nepal. It is also found in central and southern India (Pearson & Brown, 1932).

**Family—Meliaceae**

Genus—*Beddomea* Hook.f.

*Beddomea palaeoindica* sp. nov.

Pl. 1, fig. 5

*Material*—It is represented by one specimen with counter part.

*Description*—Leaf simple, almost symmetrical, wide elliptic, preserved size 7.6 x 2.5 cm (one half); apex broken; base seemingly obtuse; margin entire; texture coriaceous; petiole 0.5 cm, normal; venation pinnate, eucamptodromous to brochidodromous; primary vein (1°) single, stout, almost straight; secondary veins (2°) five pairs visible, 0.7 to 1.6 cm apart, alternate, angle of divergence 65°, moderate, acute, uniformly curved up and join to their superadjacent secondary before the margin forming a loop, unbranched, intersecondary veins present; tertiary veins (3°) fine, angle of origin AR to RR, percurrent, branched, almost straight, oblique in relation to mid-vein, predominantly alternate, close to nearly distant; further details not visible.

*Holotype*—BSIP Specimen no. 38172.

*Paratype*—BSIP Specimen no. 38173.

*Locality*—Sevoke Road Section about 2.5 km after crossing Tista River Bridge towards Washbari; Darjeeling District, West Bengal.

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

*Affinities*—The characteristic features of the present fossil leaf are wide elliptic shape, seemingly

obtuse base, entire margin, coriaceous texture, brochidodromous venation, distantly placed secondaries, presence of intersecondary veins and close to nearly distant, percurrent tertiaries. These features are found common among the genus *Beddomea* Hook.f. of the family Meliaceae.

A critical examination of all the available species of the genus *Beddomea* Hook.f. shows that the present fossil leaf resembles closely *Beddomea indica* Hook.f. (C.N. Herbarium sheet no. 62705; Pl. 1, fig. 6).

Several fossil leaves belonging to the family Meliaceae are known from the Siwalik sediments of India and Nepal resembling extant genera *Chloroxylon*, *Dysoxylon*, *Cedrela* and *Chickrasia* (Prasad, 1990, 1994a, 1994b; Awasthi & Prasad, 1996). The present fossil leaf resembling closely the genus *Beddomea* of the family Meliaceae is reported for the first time under the form species *Beddomea palaeoindica* sp. nov.

The modern equivalent taxon *Beddomea indica* Hook.f. is a large shrub distributed in the evergreen forests of Western Ghat, South Canara and Coorg down to Travancore (Gamble, 1972).

**Family—Combretaceae**

Genus—*Terminalia*

*Terminalia miobelerica* Prasad 1994

Pl. 4, fig. 1

*Material*—It is represented by only one specimen.

*Description*—Leaf simple, symmetrical, wide ovate to elliptic, preserved size 12 x 9 cm; apex acuminate; base broken; margin entire; texture thick, chartaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, almost straight, slightly curved at the tip; secondary veins (2°) 7 pairs preserved, 1.4 to 3.7 cm apart, alternate, unbranched, angle of divergence about 50°-60°, wide acute, uniformly curved up, join to their

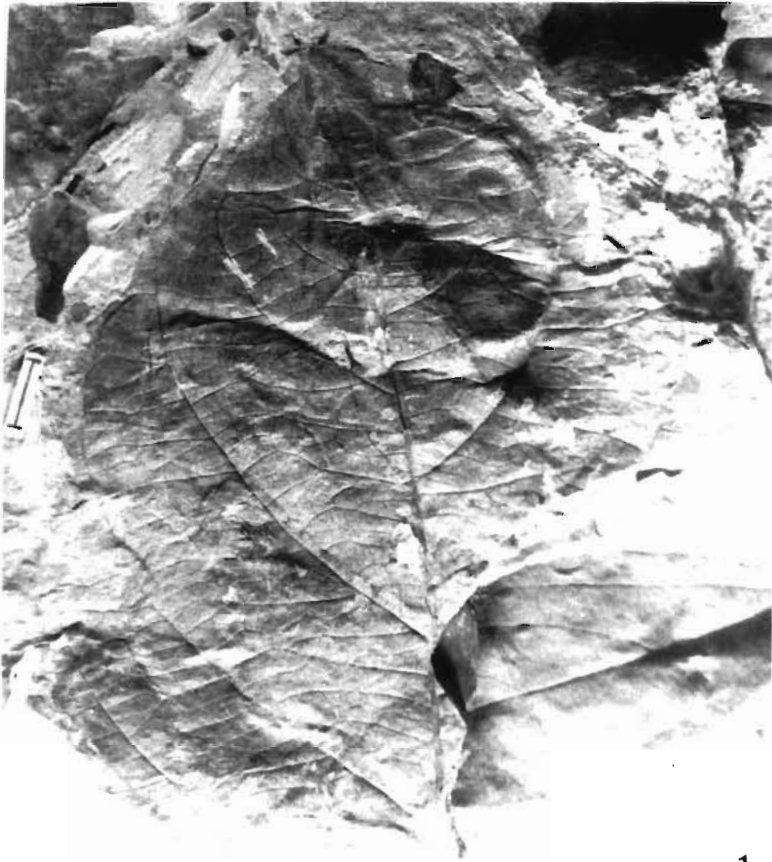
**PLATE 4**



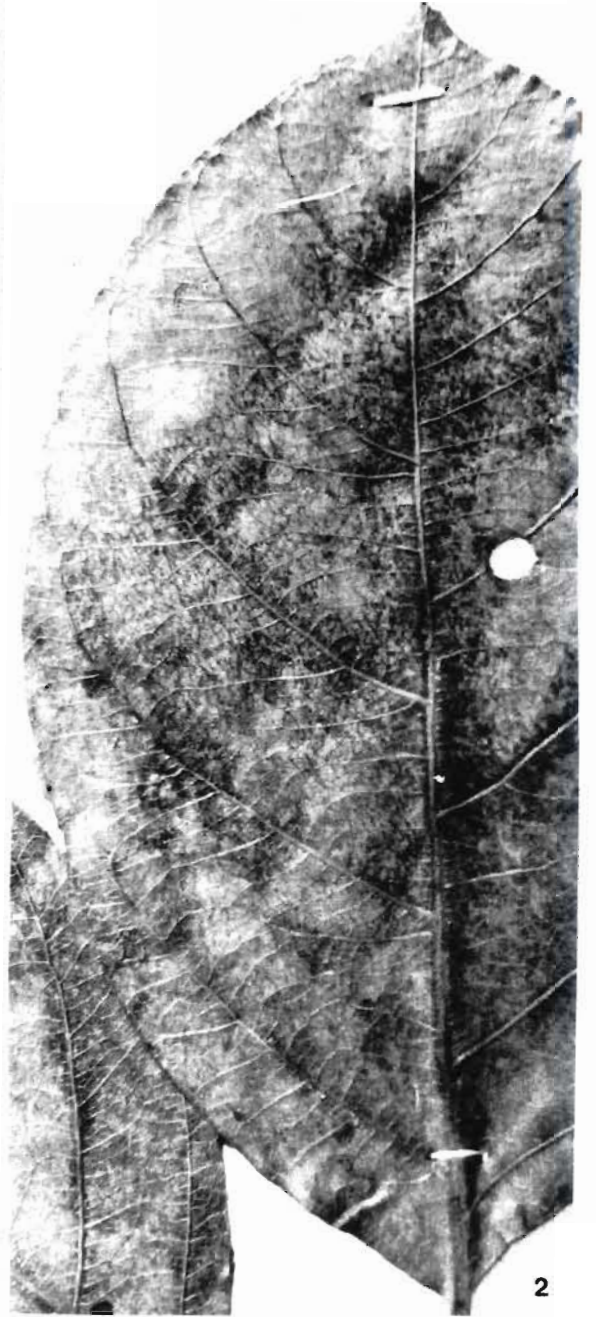
1. *Terminalia miobelerica* Prasad—A fossil leaf in natural size.

2. *Terminalia belerica* Roxb.—A modern leaf in natural size showing similarity with the fossil leaf.





1



2

PLATE 4

superadjacent secondaries near the margin, intersecondary veins present, simple to composite; tertiary veins ( $3^{\circ}$ ) prominent sometimes looking like intersecondary veins, angle of origin RR, percurrent, straight to sinuous, branched, oblique to right angle in relation to mid-vein, predominantly alternate, close to distant; quaternary veins ( $4^{\circ}$ ) well preserved, still fine with angle of origin RR, percurrent, branched forming rectangular to polygonal meshes; areoles not clearly visible.

*Specimen*—BSIP no. 38174.

*Locality*—Sevoke Road Section after crossing Tista River Bridge about 2.5 km towards Washbari; Darjeeling District, West Bengal.

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

*Affinities*—The main diagnostic features such as wide ovate to elliptic shape, acuminate apex, entire margin, eucamptodromous venation, presence of intersecondary veins and nature and arrangement of primary veins indicate its resemblance with the modern leaves of *Terminalia belerica* Roxb. (C.N. Herbarium sheet nos 560585 and 51411; Pl. 4, fig. 2).

A number of fossil leaves resembling various extant species of *Terminalia* are known from the Tertiary sediments of India and abroad (Prasad, 1990, 1994). After examination of all above fossil leaves it has been found that the present fossil leaf closely resembles *Terminalia miobelerica* Prasad 1994 described from the Siwalik sediments of Kathgodam, Nainital District, Uttar Pradesh and therefore is being described under the same species.

A fossil leaf reported earlier under the form species *Conemorpha miocenica* Awasthi & Prasad 1996 belonging to the family Apocynaceae from the Siwalik sediments of Surai Khola, Nepal was also critically examined during the course of study and found that it also shows close resemblance with the above same form species *Terminalia miobelerica* and hence has also been transferred under it.

*Terminalia belerica* Roxb., with which the present fossil leaf resembles, is an evergreen to deciduous large tree distributed in sub-Himalayan tracts, common throughout India and Myanmar except the arid regions of Sindh, Western Rajasthan and southern Punjab. It is also found in Malaya Peninsula (Brandis, 1971).

## DISCUSSION

In the present paper six well preserved leaf-impressions of dicotyledonous plants have been described from the Siwalik foot-hills of Darjeeling District, West Bengal. They show close affinities with the extant taxa *Uvaria hirsuta* Jack. of Anonaceae, *Alsodeia echinocarpa* Korth. of Flacourtiaceae, *Hopea micrantha* Roxb. of Dipterocarpaceae, *Grewia tiliaefolia* Vahl. of the family Tiliaceae, *Beddomea indica* of Meliaceae and *Terminalia belerica* of the family Combretaceae. Out of these six taxa, four are new records to the existing Siwalik flora. However, the occurrence of these evergreen and moist evergreen taxa in the present assemblage indicates the prevalence of warm and humid conditions during the deposition of these sediments in the area contrary to the present tropical moist deciduous forests (Champion & Seth, 1968) and also further supports the migration of plants from South-East Asia to India and vice-versa sometime in Early Miocene when the land connections between Malaya, Myanmar and India were established. The change in the vegetational pattern of the Himalayan foot-hills of West Bengal may also be attributed to the northward movement of the Indian Plate and further uplift of Himalaya causing a fall in the annual average temperature and rainfall.

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