Fossil flora from the Himalayan foot-hills of Darjeeling District, West Bengal and its palaeoecological and phytogeographical significance

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An assemblage of plant megafossils comprising leaf-impressions, fruits and a culm-impression recovered from the Lower-Middle Siwalik sediments near Oodlabari, Darjeeling District, West Bengal (India) has been described. It consists of 32 species of dicots and one species of monocots (Bamboo) belonging to 32 genera of 22 families. Out of them, 11 genera, viz., *Mitrephora*, *Casearia*, *Alsodeia*, *Pterospermum*, *Grewia*, *Nothopegia*, *Combretum*, *Vernonia*, *Alstonia*, *Callicarpa* and *Macaranga* are new to the Siwalik flora. An analysis of the floral assemblage with respect to the distribution pattern of modern equivalent taxa reveals the presence of three types of elements, viz., (i) evergreen (60.61%), (ii) evergreen to moist-deciduous (18.18%), and (iii) moist-deciduous (21.21%), which indicate the prevalence of warm and humid climate in the region during the deposition of Siwalik sediments. It is also interesting to mention that the assemblage is dominated by 19 Indo-Malayan elements revealing a fair exchange of floral elements between the two subcontinents during Miocene.

Key-words—Megafossils, Leaf-impressions, Palaeoecology, Phytogeography, Lower-Middle Siwalik (Middle Miocene-Pliocene), West Bengal (India).

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सारॉंश

पश्चिम बंगाल में दार्जिलिंग जनपद के हिमालयी गिरि-पादो से अश्मित वनस्पतिजात तथा इसका पुरापारिस्थितिक एवं पुराभौगोलिक महत्व

जसवन्तसिंह अन्तल एवं नीलाम्बर अवस्थी

पश्चिम बंगाल (भारत) में दार्जिलिंग जनपद में ऊदलाबाडी के समीपस्थ अधरि-मध्य शिवालिक अवसादों से उपलब्ध पर्ण-छापों, अश्मित फलों एवं एक कल्म-छाप से युक्त एक गुल्मपादपाश्म समुच्चय का वर्णन किया गया है। इस समुच्चय में 32 प्रजातियों एवं 22 कुलों से सम्बद्ध द्विबीजपत्रीयों की 32 जातिया तथा एकबीजपत्री (बास) की एक जाति उपलब्ध हुई हैं। इनमें से *मिट्रेफोरा, केसियेरिया, आल्सोडिआ, टेरोस्पर्मम, ग्रीविआ, नोथोपीजिआ, काम्ब्रीटम, वर्नोनिआ, आल्सटोनिआ, केलिकार्पा* एवं *मकेरेगा* नामक 11 प्रजातिया शिवालिक वनस्पतिजात के लिए नई हैं। वर्तमान समतुल्य वर्गकों के वितरण के आधार पर किये गये विश्लेषण से तीन प्रकार के अवयवों--(क) सदाहरित (60.61 प्रतिशत), (ख) सदाहरित नम-पर्णपाती (18.18 प्रतिशत), तथा (ग) नम पर्णपाती (21.21 प्रतिशत) की उपस्थिति व्यक्त हुई है जिससे शिवालिक अवसादों के निक्षेपण के समय इस क्षेत्र में गर्म एवं नम जलवायु का होना इंगित होता है। उल्लेखनीय है कि यह समुच्चय 19 भारतीय-मलाया अवयवों से प्रभावी है जिससे मध्यनूतन कल्प में दोनों उपमहाद्वीपों के मध्य वनस्पतिजातीय अवयवों का आदान-प्रदान व्यक्त होता है।

THE Siwalik sediments in Darjeeling District, West Bengal are exposed all along the foot-hills. These hills vary considerably in their slope and do not occur continuously. They disappear in the east of Lethi River and reappear after a gap of about 10 km between Murti and Jaldhaka rivers, but with reduced width of outcrops (Acharyya, 1972). They are well-exposed and occur continuously from Sivok Khola in the West to Lethi River in the east, which is the area of present study.

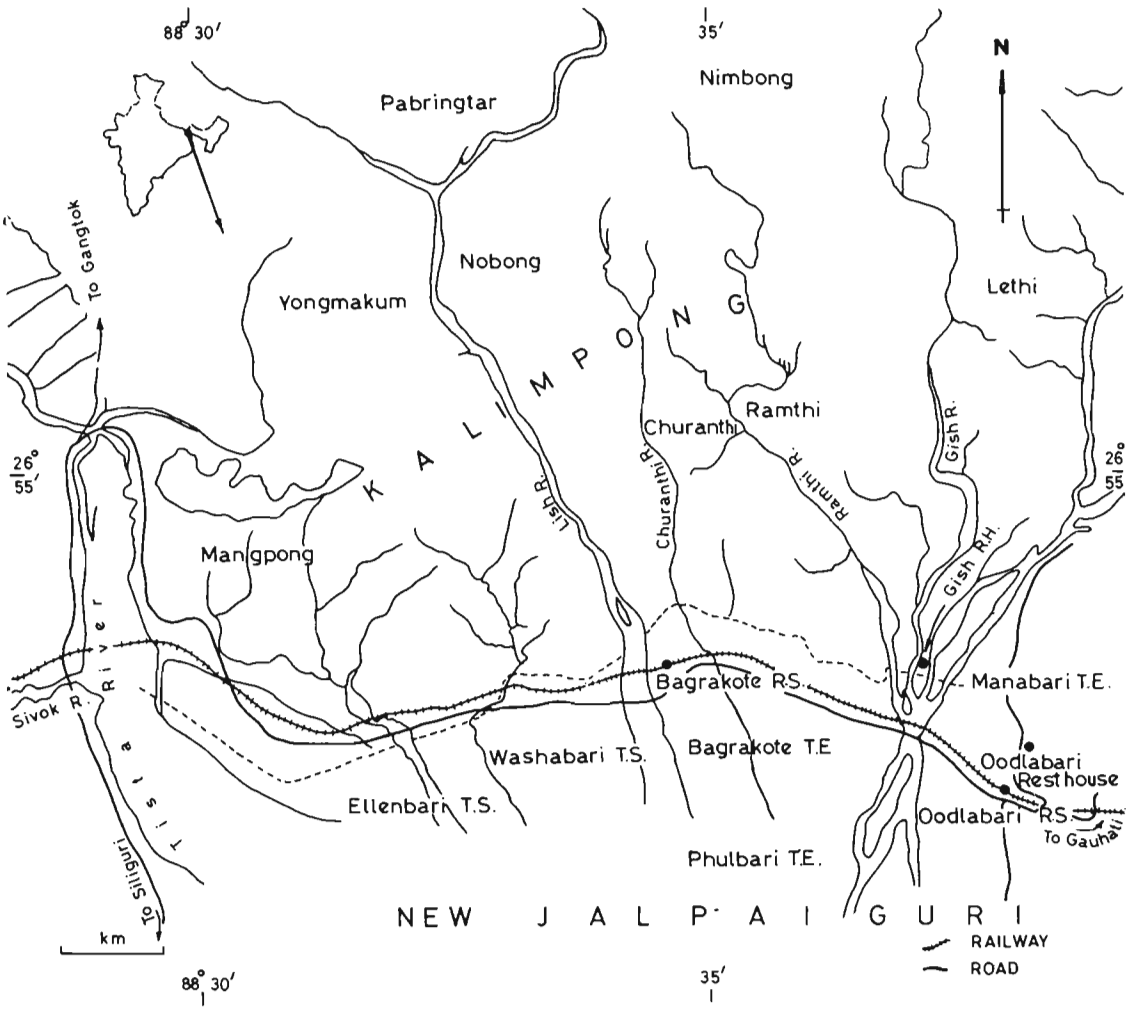
Mallet (1875) and Bose (1890, 1891) were the first who carried out the lithological studies in the area. On the basis of lithological similarity, Mallet (1875) correlated the Siwalik of Darjeeling foot-hills with Nahan (Lower Siwalik). Later, Auden (1935), Heim and Gansser (1939), Kurien (1962) and Pawde (1966, 1972) also studied the geology of the area in detail. In 1970, Ganguly and Rao opined that the lithology of major part of Sivok Group appears to have closer resemblance with that of Middle Siwalik Group of Uttar Pradesh and Himachal Pradesh, and Tipam Series of Assam. According to Acharyya (1972), the Siwalik sequence of the area is broadly subdivided into (i) upper pebbly sandstone and conglomerate unit, (ii) middle sandstone unit, and (iii) the lower claystone unit. The Lower Unit is best

exposed in Ghish River, which consists of claystone, siltstone and fine-grained sandstone alternations; the Middle Unit is exposed along Lish and Ghish rivers. On the basis of lithological similarity Acharyya (1972, p. 87) opined that the Siwaliks of the area are more closely related to the Middle Siwalik. An interesting feature of these Siwalik sediments is the progressive dominance of sandstones over shaly and clayey units. During the major part of sedimentation the palaeocurrent appears to be broadly longitudinal with frequent reversals. Misra (unpublished G.S.I. Report-1980-81) also surveyed the area and reported the occurrence of leaf-impressions.

The material for the present study was collected from Ghish and Ramthi river sections (26°52′ to 26°56′N; 88°28′ to 88°38.5′E—Map 1), about 4 km from Oodlabari, a small town on the Siliguri-Guwahati National Highway. The other river sections, viz., Lish and Churanthi, except Tista and Lethi, were also traversed but no plant fossil could be recovered from them. The sections of Tista River in the area are very steep as well as deep and therefore not accessible for collection of fossil plants. In Ghish River area there are two exposures, one on the left bank just close to its mouth, and the other on the right side at about 3.5 km upstream. The material collected from first exposure comprises impressions of bigger and well-preserved leaves belonging to Lower-Middle Siwaliks (Middle Miocene-Pliocene). The second exposure also belonging to the same age yielded comparatively smaller leaves alongwith few fruits preserved in ash coloured hard shales, overlain and underlain by thick massive fine to medium-grained sandstones.

In Ramthi River section, the sediments assigned to Lower and Middle Siwalik are exposed on both the sides at about 1.5 km upstream from its mouth. They have yielded impressions of leaves and fruits preserved in fine grey shales overlying and underlying thick sandstones.

The megafossils have been identified and compared with the modern taxa in the herbaria at Birbal Sahni Institute of Palaeobotany, Lucknow; Forest Research



Map 1—Showing the fossil localities in the area.

Institute, Dehradun; and Central National Herbarium, Howrah. To describe leaf-impressions the terminology proposed by Hickey (1973) and Dilcher (1974) has been adopted with some changes.

Present day vegetation—Gamble (1895, 1928) classified the forests of this region into Lower Hill Forest, Middle Hill Forest, and Upper Hill Forest. Thereafter, Cowan (1929) in his "Forest Working Plan" of the area divided the whole forests into five ranges, viz., (i) Tista range, (ii) Chel range, (iii) Neora range, (iv) Jaldhaka range, and (v) Pankasari range. Later, he again categorised the forests of foot-hills into Sal forest and mixed forest. But Champion and Seth (1968, p. 49) not only described the forest of this region as 'tropical moist deciduous' type but also followed Cowan's systematic work. In this way four associations, viz., (i) *Shorea - Terminalia - Garuga*, (ii) *Shorea - Stereospermum*, (iii) *Schima - Bauhinia*, and (iv) *Eugenia - Phoebe* have been recognized in the area.

At and around the fossil localities the principal constituents of the forest are: *Shorea robusta*, *Stereospermum tetragonum*, *Terminalia crenulata*, *Schima wallichii*, *Bauhinia purpurea*, *Gmelina arborea*, *Dillenia pentagyna*, *Sterculia villosa*, *Talauma hodgsoni*, *Garuga pinnata*, *Albizia* spp., *Michelia champaca*, *Amoora wallichii*, *Duabanga sonneratioides*, *Terminalia belerica*, *Chuckrasia tabularis*, *Jambosa ramosissima*, *Lagerstroemia parviflora*, *Beilschmedia roxburghiana*, *B. sikkimensis*, *Meliosma simplicifolia*, *Gynocardia odorata*, *Machilus* spp., *Grewia vestita*, *Syzygium* spp. and *Elaeocarpus aristatus*.

The other species which occur comparatively less in frequency are *Terminalia chebula*, *T. myriocarpa*, *Jambosa formosa*, *Ficus infectoria*, *Ficus cunia*, *Dillenia indica*, *Bridelia* spp., *Ailanthus grandis*, *Macaranga* spp., *Mallotus* spp., *Vitex heterophylla*, *Styrax* spp., *Engelhardtia indica*, *Cinnamomum obtusifolia*, *Bombax malabaricum*, *Melia composita*, *Spondias axillaris*, *Castanopsis tribuloides*, *Sapindus detergens*, *Pterospermum acerifolium*, *Actinodaphne obovata*, *A. angustifolia*, *Knema* spp., *Litsea* spp., *Ficus nemoralis*, *Castanopsis indica*, *Elaeocarpus* spp., *Garcinia stipulata*, *Alstonia scholaris*, etc.

Besides, a number of climbers like *Buettnaria pilosa*, *Millettia auriculata*, *Bauhinia vahlli*, *Smilax* spp., *Pararea tuberosa*, *Paederia scandens*, several species of *Combretum* and *Piper* are present. Amongst these, *Combretum decandrum* is the most dominant creeper throughout the forest.

Amongst monocots, the wild species of *Musa* are found growing in pockets. In shady and moist places pteridophytes (ferns) as well as bryophytes can be seen with moderate growth. Tree ferns are also seen in moist and shady places. The vegetation on the outer hills is mixed with bamboos. In this way the overall scenario of vegetation shows the presence of moist deciduous forest.

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

SYSTEMATIC DESCRIPTION

Family Dilleniaceae

Genus *Dillenia* Linn.

Dillenia palaeoindica Prasad & Prakash 1984

Pl. 1, figs 1, 3

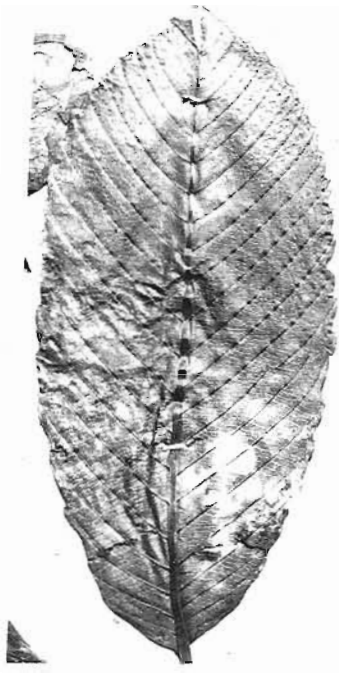
This species is represented by five well-preserved leaf-impressions; one of them has counterparts.

Description—Leaf simple, almost symmetrical, narrow obovate; preserved lamina length 8.5 cm, maximum width 4.3 cm; apex broken; petiole partly broken; base acute, normal; margin serrate with regular spacing, serration straight-concave, a small spine present at tooth apex; texture chartaceous; venation pinnate, simple, craspedodromous, primary vein prominent, stout, almost straight; secondary veins 11 pairs visible with angle of divergence acute, moderate (50°-60°), upper veins more acute than those at the base, mostly alternate, 0.3 to 0.7 cm apart, uniformly curving up and running parallel to each other, moderately thick reaching up to the margin, unbranched; tertiary veins fine with angle of origin AO-AR, pattern percurrent, usually unbranched, straight to slightly wavy, predominantly alternate, oblique in relation to midvein, close; higher order of venation not preserved.

Affinities—The diagnostic characters of the fossil leaves, such as narrow obovate shape, acute base, serrate margin, simple craspedodromous venation, tertiaries oblique in relation to midvein and percurrent collectively indicate their resemblance with the leaves of *Dillenia* Linn. of the family Dilleniaceae.

Modern leaves of five species of *Dillenia*, viz., *D. indica* Linn., *D. aurea* Smith, *D. pentagyna* Roxb. and *D. pulcherrima* Kurz were examined in order to find out the nearest living counterpart of the fossil. Of these, *D. indica* (F.R.I. Herbarium Sheet no. 74092; Pl. 1, figs 2, 4) shows close similarity with our fossil in size, shape and other characters. The leaves of *D. pentagyna* though show similarity in venation pattern, differ being bigger in size as compared to the present specimen.

So far, three species of fossil leaves of the genus *Dillenia* Linn., viz., *D. palaeocenica* Saporta & Marion 1878 from the Tertiary of Belgium, *D. alaskana* Hollick 1936 from the Tertiary of Alaska and *D. palaeoindica* Prasad & Prakash 1984 from the Lower Siwalik beds of



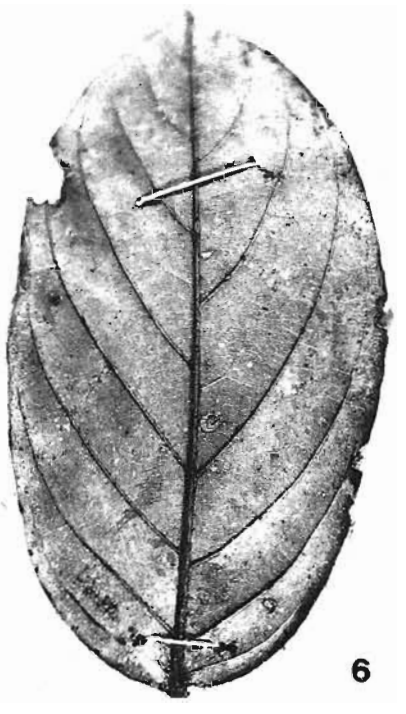


PLATE 1

Dillenia palaeoindica Prasad & Prakash 1984

1 Fossil leaf in natural size showing shape, size and venation pattern; Specimen no. BSIP 36909.

2. *Dillenia indica*—modern leaf in natural size showing similar shape, size and venation pattern.

3 A part of fossil leaf magnified to show the details of venation, × 4

4 A part of modern leaf magnified to show similar details of venation, × 4

Mitrephora siwalika sp. nov.

5. Fossil leaf in natural size showing shape, size and venation pattern, Specimen no. BSIP 36910.

6 *Mitrephora maingayi*—a modern leaf in natural size showing similar shape, size and details of venation

Koilabas, Nepal are known. Out of them, the present fossil specimens indicate close resemblance almost in all features with *Dillenia palaeoindica* Prasad & Prakash 1984, except for the minor difference in the distance between two successive secondaries, which is relatively more in the present fossil specimens. Therefore, the present fossil specimens are placed under the same species.

The genus *Dillenia* comprises about 60 species of trees and shrubs widely distributed in the tropical regions of the world, in which the maximum species (11) are confined to India and South-east Asia. In India, *D. indica* Linn. occurs in the moist evergreen forests of sub-Himalayan tracts from Nepal extending eastward to Myanmar. It also grows in the moist parts of Madhya Pradesh, Andhra Pradesh, Tamil Nadu and South-east Asia (Majumdar, 1979; Chowdhury & Ghosh, 1958).

Specimen — No. BSIP 36909.

Locality—Right bank of the upstream of Ghish River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Family—Anonaceae

Genus—*Mitrephora* Bl.

Mitrephora siwalika sp. nov.

Pl. 1, fig. 5

This species is based on a single well-preserved leaf-impression.

Description—Leaf simple, almost symmetrical, elliptical, preserved lamina length 8.5 cm, maximum width 4.9 cm, apex slightly broken; base obtuse to normal; margin entire; texture chartaceous; petiole not preserved; venation pinnate, simple, eucamptodromous; primary vein moderate, almost straight; secondary veins six pairs visible, angle of divergence acute, moderate (50°-60°), apical secondaries more acute, alternate, each 0.8 to 1.2 cm apart, curving upward and running quite high along margin, unbranched; tertiary veins fine, angle of origin AR-RR, pattern percurrent, branched, predominantly alternate, close, oblique to right angle in relation to midvein; higher order of venation not preserved.

Affinities—The diagnostic features of the fossil leaf like elliptic shape, obtuse to normal base, chartaceous texture, entire margin, angle of divergence acute and eucamptodromous venation indicate its resemblance with the genus *Mitrephora* H.f.Th. of Anonaceae. In order to find out its nearest living counterpart among *Mitrephora* species the leaves of *M. reticulata* Hook. f. & Th., *M. tomentosa* Hook. f. Th., *M. thorelli* Pierre, *M. celebica* Scheff., *M. macarantha* Hassk., *M. maingayi* Hook. f. & Th., *M. polypyrena* Miq., *M. heyneana* Thw., *M. excelsa* Hook. f. & Th., *M. macrophylla* Olive, *M. reticulata* Hook. f. & Th., *M. eugosa*, *M. teysmanni* Scheff., *M. lanotan*, *M. ferruginea*, *M. merillie* and *M. reflexa* were examined. Out of them, the leaves of *M. maingayi* Hook. f. & Th. (C.N. Herbarium Sheet no. 13231; Pl. 1, fig. 7) show close resemblance with the fossil, while those of *M. tomentosa* and *M. teysmanni* show similarity in some characters only. On careful comparison they have been found markedly different from the fossil leaf.

So far, as the authors are aware, there is no fossil record of this taxon. Thus it forms the first record of the genus and has been described as *Mitrephora siwalika* sp. nov.

The genus *Mitrephora* Bl. consists of about 10 species of small to moderate sized trees distributed in Myanmar, Java, Malaya, Sri Lanka and tropical evergreen forests of Assam and Chittagong. *M. maingayi* Hook. f. & Th. occurs in the evergreen forests of Assam, Chittagong (Bangla Desh), Martaban Hills (Myanmar), Malaya Peninsula, Java and Sri Lanka (Brandis, 1971; Gamble, 1972).

Holotype—Specimen no. BSIP 36910.

Locality—Left bank of the upstream of Ramthi River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Family—Flacourtiaceae

Genus—*Casearia* Jacq.

Casearia pretomentosa sp. nov.

Pl. 2, figs 1, 2, 4

This species is represented by two almost complete and well-preserved specimens.

Description—Leaf simple, asymmetrical, narrow ovate to elliptic, preserved lamina length 10.5 cm, maximum width 5.2 cm; apex slightly broken; base asymmetrical, oblique; petiole normal, preserved length 0.7 cm; margin entire; texture coriaceous; venation pinnate, eucamptodromous; primary vein prominent, stout, straight to slightly curved, unbranched; secondary veins 8 pairs visible, angle of divergence moderate (50°-60°), nearly uniform, alternate to subopposite, moderately thick, uniformly curving up towards margin; tertiary veins AR-RR, percurrent, branched, mostly alternate, oblique in relation to midvein, close; quaternary veins thin, randomly oriented forming polygonal meshes; areoles well-developed.

Affinities—The important morphological features of the fossil like leaves asymmetrical, shape ovate elliptic,

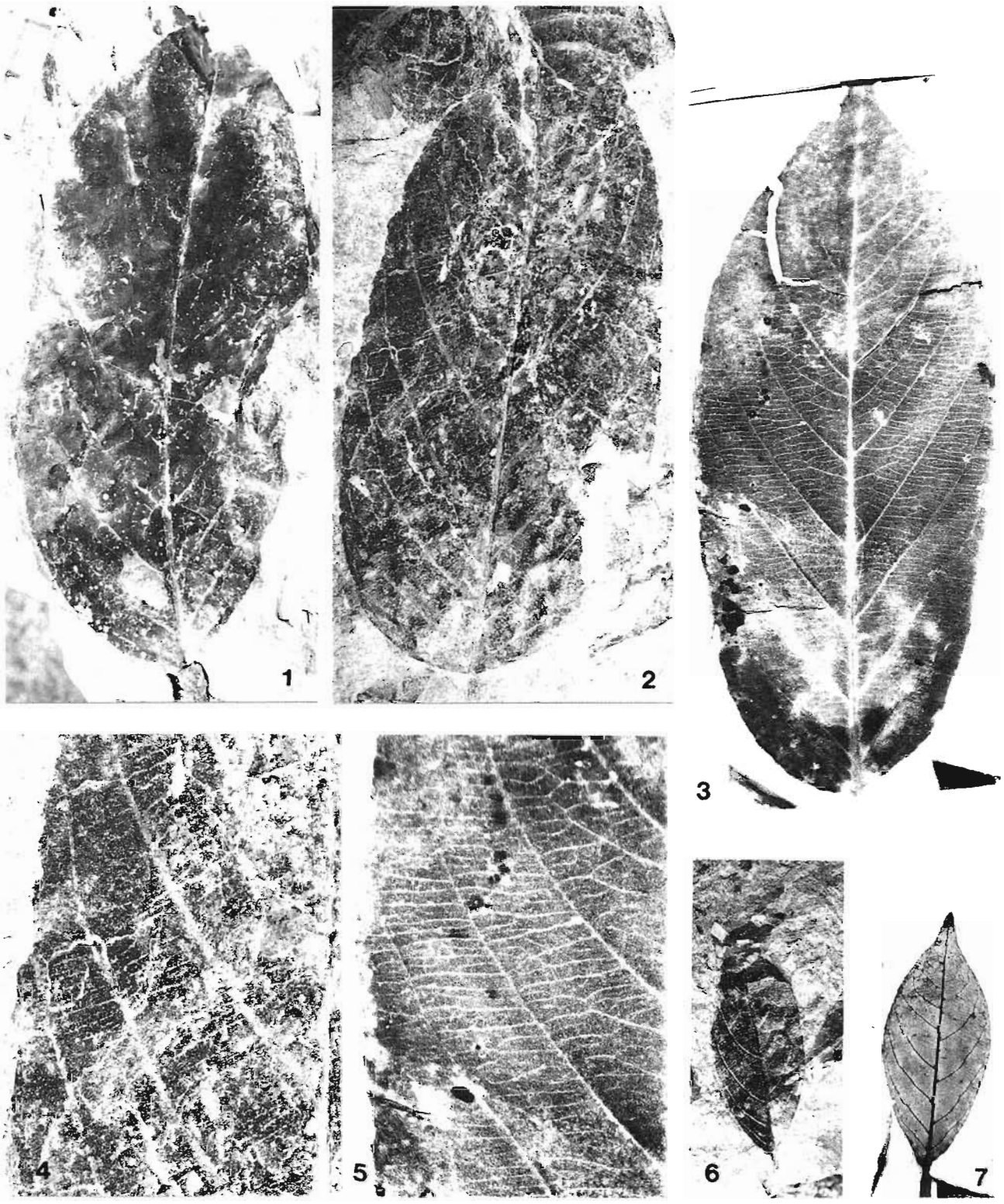


PLATE 2

Casearia pretomentosa sp nov.

1 A fossil leaf in natural size showing shape, size and venation pattern: Specimen no. BSIP 36911

2. Another fossil leaf in natural size showing variation in shape and size, Specimen no BSIP 36912

3 *Casearia tomentosa*—modern leaf in natural size showing similar shape, size and venation

4. A part of fossil leaf magnified to show details of venation, × 2

5. *Casearia tomentosa*—modern leaf in natural size showing similar details of venation, × 2.

Alsodeia palaeozeylanica sp. nov.

6 A fossil leaf in natural size showing shape, size and venation, Specimen no BSIP 36913

7 *Alsodeia zeylanica*—modern leaf showing similar shape, size and venation, × Nat. size

base asymmetrical, oblique, margin entire, secondary veins uniformly curved and tertiary veins percurrent show their resemblance with that of the genus *Casearia* Willd. of Flacourtiaceae.

Leaves of about 14 species of *Casearia*, viz., *C. tomentosa* Roxb., *C. vareca* Roxb., *C. glomerata* Roxb., *C. kurzii* C.B. Clarke, *C. graveolens* Dalz., *C. ovata* Wall., *C. championi* Thw., *C. glauciramia*, *C. albicans* Wall., *C. clarkei*, *C. lobbiana* Turez., *C. tuberculata* Bl., etc. were examined. Out of them, the fossil leaf shows relationship with *C. elliptica* (=*C. tomentosa*), *C. vareca* and *C. ovata*. However, in *C. vareca* the apex is rounded and the secondaries take a deep curve to reach the margin; in *C. ovata* the secondaries are less in number and thus differ distinctly from the fossil leaves. Therefore the fossil specimen closely resembles *C. tomentosa* Roxb. (C.N. Herbarium Sheet no. 179785; Pl. 2, figs 3, 5). As far as the authors are aware there is no fossil record of the genus *Casearia* Jacq. Therefore, the present fossil leaves are named as *Casearia pretomentosa* sp. nov.

The genus *Casearia* Jacq. consists of 160 species distributed in the tropical region of the world (Willis, 1973). *C. tomentosa* Roxb., with which the fossil leaves show close resemblance, grows in the deciduous forests of sub-Himalayan tract from Indus eastward to Nepal, Oudh, central, northern and south India and Bangladesh (Brandis, 1971, p. 379).

Holotype—Specimen no. BSIP 36911.

Paratype—Specimen no. BSIP 36912.

Locality—Right bank of the upstream of Ramthi River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Genus—*Alsodeia* Thouars

Alsodeia palaeozeylanica sp. nov

Pl. 2, fig. 6; Pl. 3, fig. 2

This species is based on a single specimen with counterpart.

Description—Leaf simple, symmetrical, elliptic, preserved length 4.1 cm, lamina length 3.5 cm, maximum width 1.5 cm; apex broken; base acute, normal; margin entire; texture chartaceous; petiole 0.6 cm long, normal; venation pinnate, eucamptodromous; primary vein prominent, moderate, straight; secondary veins 7 pairs visible, angle of divergence acute (40°), narrow, nearly uniform; moderately thick, uniformly curving up towards margin, sub-opposite to alternate, unbranched; tertiary veins mostly RR, percurrent, rarely branched, those arising from primary vein convex, oblique in relation to midvein, mostly opposite, closely placed; quaternary veins not clearly visible.

Affinities—The distinguishing characters like symmetrical leaf, elliptic shape, acute base, entire margin, chartaceous texture, eucamptodromous venation and fine and closely placed tertiaries indicate that the fossil leaf shows close resemblance with the genus *Alsodeia* Thouars of the family Flacourtiaceae. Besides, it resembles the leaves of *Combretum acuminatum* Roxb. and *Lagerstroemia microcarpa* Kurz in some features. However, they can be differentiated from the fossil on the basis of number and course of secondaries which are more and closely placed in *C. acuminatum* Roxb. and less and distantly placed in *L. microcarpa* Kurz.

In order to find out the nearest modern equivalent species of the fossil, the leaves of a number of *Alsodeia* species, viz., *Alsodeia zeylanica* Thw., *A. heteroclita* Roxb., *A. longiracemosa* Kurz., *A mollis* Hook., *A wallichiana* Hook.f.& Th., *A cinerea* King, *A echinocarpus* Korth., *A. hirtella* Mor., *A. floribunda* O. Ktze, *A wrayi* King and *A. kunstleriana* King were examined. Out of them, the fossil leaf shows best resemblance with *A zeylanica* Thw (C.N. Herbarium Sheet no. 32240; Pl. 2, fig. 7; Pl. 3, fig. 1). As far as we are aware there is no fossil record of the genus *Alsodeia* Thouars. Since the present fossil leaf closely compares with those of *Alsodeia zeylanica* Thw., its has been assigned to a new species *A. palaeozeylanica*.

The genus *Alsodeia* Thouars consists of 50 species found in tropics of both hemispheres. *A. zeylanica* Thw. is a ±3 metre shrub widely distributed in the evergreen forests of Malabar, Travancore (Kerala) and Sri Lanka (Brandis, 1971, p. 37).

Holotype—Specimen no. BSIP 36913.

Locality—Right bank of the upstream of Ghish River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Genus—*Hydnocarpus* Gaertn.

Hydnocarpus palaeokurzii sp. nov.

Pl. 3, fig. 3

This species is based only on the leaf-impression.

Description—Leaf simple, symmetrical, narrow-oblong, preserved lamina length 8.5 cm, maximum width 3.5 cm; apex broken; base acute, normal; margin entire; texture coriaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein in moderate thickness , slightly curved, prominent; secondary veins 5 pairs visible with angle of divergence moderate (45°-65°), arising uniformly, moderate, deeply curving upwards taking a long course towards apex to reach at margin; unbranched tertiary veins not preserved.

Affinities—The distinguishing features of the fossil leaf are : narrow oblong shape, acute base, entire margin,

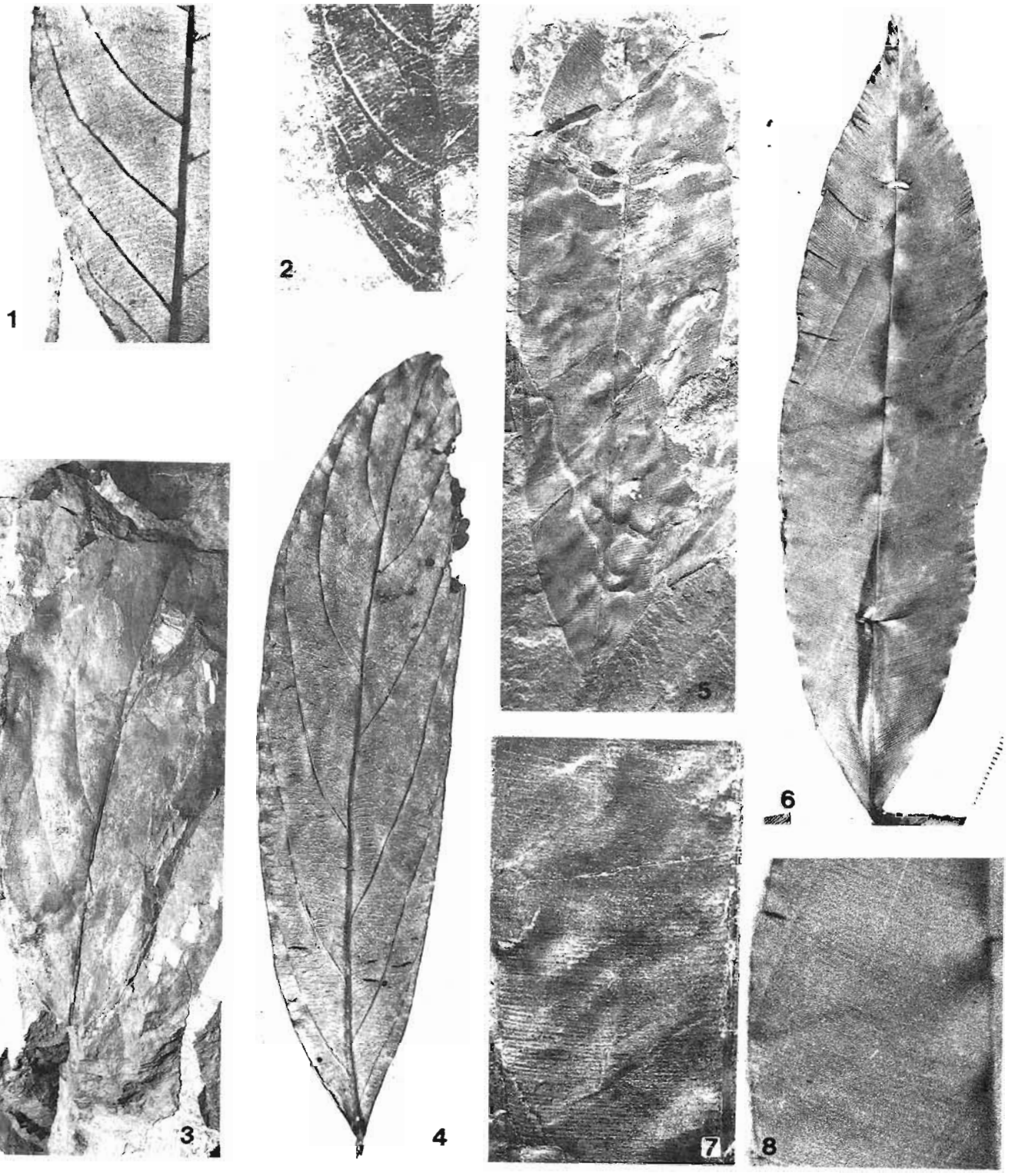


PLATE 3

Alsodeia palaeozeylanica sp. nov.

1 *Alsodeia zeylanica*—a part of modern leaf magnified to show similar venation pattern, × 2 5

2 A part of fossil leaf magnified to show details of venation, × 2.5.

Hydnocarpus palaeokurzii sp. nov.

3. A fossil leaf in natural size showing shape, size and venation pattern. Specimen no BSIP 36914

4. *Hydnocarpus kurzii*—a modern leaf showing similarity in shape. size and venation, × Nat size

Calophyllum suraikholaensis Awasthi & Prasad 1990

5. A fossil leaf in natural size showing shape, size and venation pattern; Specimen no. BSIP 36915.

6. *Calophyllum polyanthum*—a modern leaf showing similar shape, size and venation, × Nat. size.

7 A part of fossil leaf magnified to show details of venation, × 3.

8. A part of modern leaf magnified showing similar details of venation, × 3

secondary veins curving deeply upwards before reaching at margin which collectively show its resemblance with the leaves of the genus *Hydnocarpus* Gaertn. of the family Flacourtiaceae.

The fossil leaf has been compared with the leaves of about 25 modern species of the genus *Hydnocarpus* Gaertn. The extant species with those it shows gross resemblance are : *H. laurifolia* (syn. = *H. wightiana* Bl.), *H. kurzii* (King) Warb., *H. castanea* H.k.f., and *H. kunstleri* King. *H. laurifolia* (syn. = *H. wightiana* Bl.) though resembles the fossil leaf in shape and size, differs in having less secondary veins. In *H. castanea* H.k.f. the secondary veins are distantly placed and the basal ones reach almost up to the middle part of lamina. In *H. kunstleri* King the leaves are relatively smaller. Lastly, it is only *H. kurzii* King cf. *Taraktogenos kurzii* (King) Warburg (C.N. Herbarium Sheet no. 34090; Pl. 3, fig. 4) whose leaves exhibit identical characters as that of fossil. The leaf described here as *H. palaeokurzii* sp. nov. is the first record of the fossil leaf of *Hydnocarpus* from India.

The fossil woods of this genus are already known as *Hydnocarpoxylon mandlaensis* (Bande & Khatri, 1980) from the Deccan Intertrappean beds of Mandla District, Madhya Pradesh, *H. keralaensis* (Awasthi & Srivastava, 1990) from the Warkalli beds, Kerala and from the Deccan Intertrappean sediments of Kutch (Guleria, 1991).

The genus *Hydnocarpus* comprises 40 Indo-Malayan species. *H. kurzii*, with which the fossil shows resemblance, is an evergreen tree found in eastern and southern slopes of Pegu, Yoma and frequent in Martaban Hills (Brandis, 1971, p. 40).

Holotype—Specimen no. BSIP 36914.

Locality—Right bank of the upstream of Ramthi River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Family—Clusiaceae

Genus—*Calophyllum* Linn.

Calophyllum suraikholensis Awasthi & Prasad 1990

Pl. 3, figs 5, 7

There are six well-preserved leaf-impressions, of them one is almost complete.

Description—Leaf simple, symmetrical, narrow-oblong, preserved lamina length 10.5 cm, maximum width 3.5 cm; apex slightly broken; base somewhat cuneate, normal; margin entire; texture chartaceous; petiole not preserved; venation pinnate, simple, craspedodromous; primary vein stout, straight, tapering towards apex; secondary veins with angle of divergence right angle or nearly so, secondary veins near apex with slightly acute angle than at the base, relative thickness fine to hair-like, straight or slightly curved in the apical part; tertiary veins not visible due to close, parallel and fine secondaries.

Affinities—Symmetrical narrow-oblong shape, entire margin, somewhat cuneate base and secondary veins closely parallel and fine are those characters of the fossil leaves which indicate their resemblance with the leaves of the genus *Calophyllum* Linn. of Clusiaceae. To find out the nearest modern counterpart of the fossil specimens, leaves of about 28 species of *Calophyllum* Linn. were examined and found that three species, viz., *Calophyllum floribundum* H.k.f., *C. polyanthum* Wall. and *C. spectabile* Willd. show resemblance with the present fossil leaves. However, in *C. floribundum* H.k.f. the leaves are smaller in size, while in *C. spectabile* Wall. the secondaries in the basal part are slightly acute. Thus it is only *C. polyanthum* Wall. with which the fossil leaves resemble most.

The fossil leaves comparable with those of extant genus *Calophyllum* Linn. reported so far from the Tertiary sediments are : *C. pliocenicum* Krasser 1903 from Ouricanga, Germany; *C. nathorsti* (Geyler) Kräusel and *Calophyllum* sp. (Kräusel, 1929) from Sumatra, *C. mesaensis* Pons 1978 from Columbia, U.S.A. and *C. suraikholaensis* from the Siwalik sediments of Nepal (Awasthi & Prasad, 1990). Of these, our fossil leaves are very similar to *C. suraikholaensis* Awasthi & Prasad 1990 and therefore have been assigned to it.

The genus *Calophyllum* Linn. is well known for its fossil woods in the Neogene of India, such as from the Cuddalore Series, south India; Tipam Series near Hailakandi, Assam; Dupitila Series in Deomali, Arunachal Pradesh; Tertiary of West Bengal; Neogene of Varkala beds, south India (Lakhanpal & Awasthi, 1965; Prakash, 1966a; Prakash & Awasthi, 1971; Ghosh & Roy, 1979) respectively. Besides India, the fossil woods of this genus are known from the Neogene of Java (Kramer, 1974) and Ethiopia (Lemoigne, 1978).

The genus *Calophyllum* Linn. consists of about 100 species of trees occurring in northern as well as southern hemispheres, but a majority of them are found in tropical Asia and East Indies. Gamble (1972) enumerated it as a large genus of chiefly tropical trees of which many species occur in Malaya Peninsula and Sri Lanka. *C. polyanthum* Wall. with which the present specimen resembles grows in the tropical evergreen forests of Tenasserim, Andamans and Nicobar Islands, Malaya Peninsula and Sri Lanka (Brandis, 1971, p. 55).

Specimen—No. BSIP 36915.

Locality—Right bank of the upstream of Ghish River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

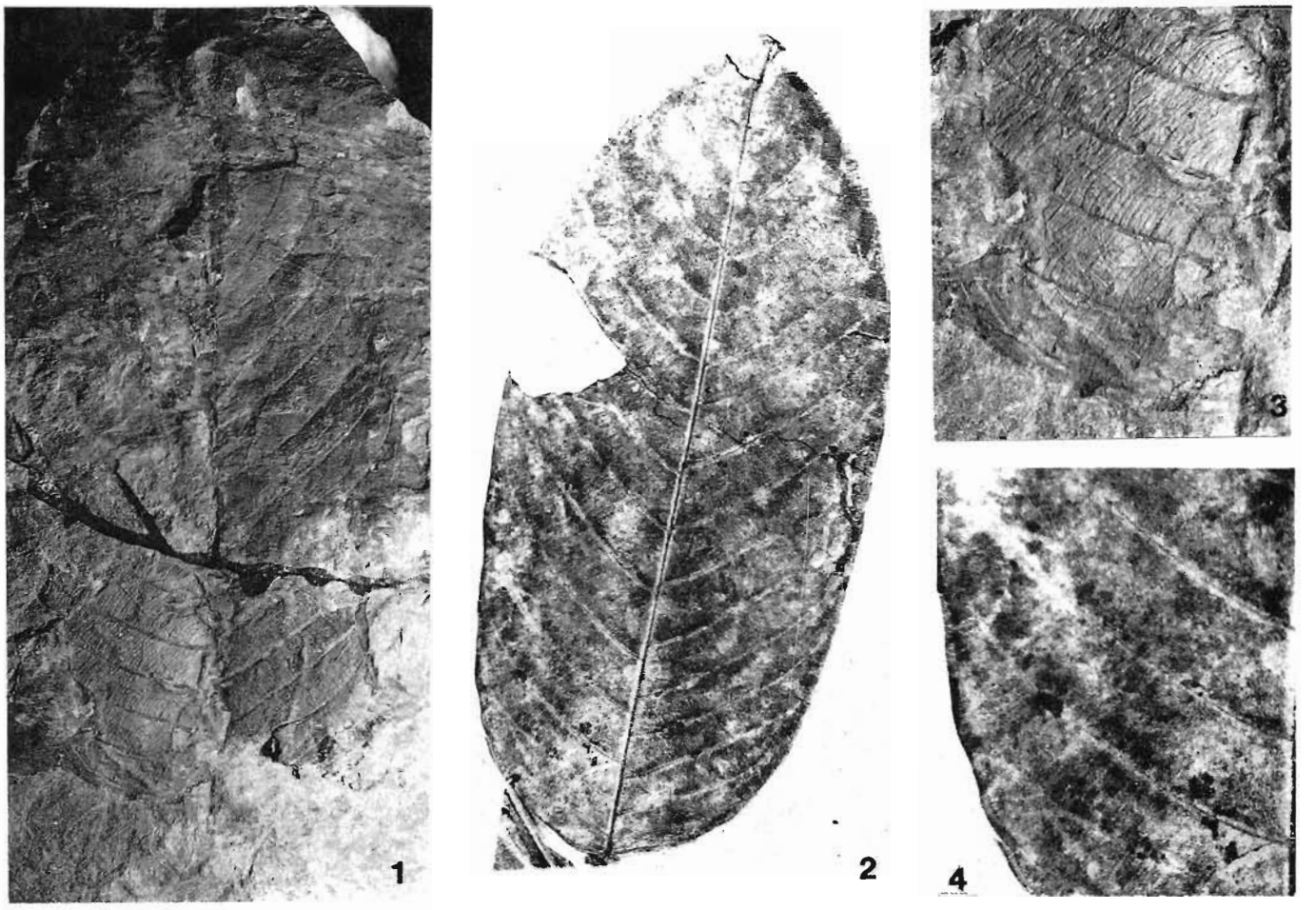


PLATE 4

Shorea siwalika sp. nov.

1. A fossil leaf in natural size showing shape, size and venation; Specimen no. BSIP 36916.
2. *Shorea assamica* (= *S. sericifolia*)—a modern leaf in natural size showing similar shape, size and venation.
3. A part of fossil leaf magnified to show the details of venation pattern, × 2.5.
4. A part of modern leaf magnified to show similar details of venation, × 2.5.

Family—Dipterocarpaceae

Genus—*Shorea* Roxb.

Shorea siwalika sp. nov.

Pl. 4, figs 1, 3

There are five well-preserved leaf-impressions in the collection.

Description—Leaf simple, symmetrical, preserved lamina length 10.3 cm, maximum width 4.9 cm, narrow elliptic; apex broken; base seemingly obtuse, normal; margin entire; texture chartaceous; petiole preserved but poorly visible; venation pinnate, craspedodromous; primary vein stout, prominent, straight; secondary veins 12 pairs visible, angle of divergence moderate (45°-60°), moderate in thickness, uniformly curving upward, unbranched; tertiary veins fine, angle of origin AR-OR, percurrent, sometimes curve before joining the other secondary vein, relationship to midvein nearly oblique, predominantly opposite, close; quaternary veins thin, orthogonal to polygonal; veinlets not visible; areoles well-developed.

Affinities—The distinguishing characters of the fossil leaves like narrow-elliptic shape, obtuse base, entire margin; craspedodromous venation, tertiary veins percurrent, predominantly opposite collectively indicate their resemblance with the leaves of the genus *Shorea* Linn. of Dipterocarpaceae. From a detailed comparison with the leaves of about 49 modern species of *Shorea*, it was found that the fossil leaves show closest resemblance with the leaves of *Shorea assamica* (= *S. sericifolia*) Dyer. Therefore, *S. assamica* (C.N. Herbarium Sheet no. 51546; Pl. 4, figs 2, 4) resembles the fossil leaves in gross features and has therefore been assigned to it.

Recently, Bande and Srivastava (1990) reported a leaf as *Shorea robusta* from the shales of Mahuadanr Valley, Palamu District, Bihar. These shales have been considered to be younger to Mio-Pliocene by them. Since the present fossil leaves closely resemble *S. assamica*, they have been described as *S. siwalika* sp. nov.

The fossil woods of the genus *Shorea* are also well known both from the Neogene sediments of India and South-east Asia. In India, they have been reported from Uttar Pradesh (Prasad & Prakash, 1987), Assam and West Bengal (Prakash & Awasthi, 1971; Roy & Ghosh, 1979; Bande & Prakash, 1980) and Tamil Nadu (Ramanujam & Rao. 1967, 1969). These records indicate the wide spread distribution of the genus during Neogene.

Genus *Shorea* Roxb. comprises 167 species widely distributed all over the world. In South-east Asia, it occurs in Sri Lanka, India, Burma, Malaysia and Philippines. Out of these, nearly 100 species of trees grow throughout the tropical parts of Indo-Malayan region (Pearson & Brown, 1932, p. 109). *Shorea assamica* Dyer, with which the fossil specimen resembles, is a large gregarious tree growing in the evergreen forests of Upper Assam at the foot of Naga Hills, in Sibsagar and Lakhimpur District (Gamble, 1972, p. 83).

Holotype—Specimen no. BSIP 36916.

Locality—Right bank of the upstream of Ramthi River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Genus—*Hopea* Roxb.

Hopea siwalika sp. nov.

Pl. 5, fig. 1

This species is based on a single well-preserved leaf.

Description—Leaf simple, symmetrical, preserved lamina length 6.7 cm, maximum width 2.4 cm, narrow ovate; apex nearly acute; base obtuse, normal; margin entire; texture chartaceous; petiole not preserved; venation pinnate, simple, eucamptodromous; primary vein prominent, moderate, markedly curved; secondary veins 8 pairs visible with angle of divergence acute (45°), narrow, nearly uniform, moderate, uniformly curving upwards, unbranched; tertiary veins with angle of origin nearly RR, percurrent, rarely forked, oblique to nearly right angle in relation to midvein, predominantly alternate, close; quaternary veins not visible.

Affinities—The distinguishing morphological features like symmetrical lamina, narrow ovate shape, obtuse base, markedly curved primary vein, nearly RR angle of origin of tertiary veins of the fossil leaf indicate its affinities with the genus *Hopea* Roxb. of the family Dipterocarpaceae.

About 33 modern species of the genus *Hopea* Roxb. were examined to compare the fossil leaf and it has been observed that the leaves of *H. parviflora* Bedd., *H. glabra* W. & A., *H. odorata* Roxb., *H. philippinensis* Dyer and *H. wightiana* Wall. more or less resemble the fossil leaf in general morphology. However, certain differences have also been seen in them. In *H. parviflora* the base of the leaf is acute and the secondaries take a short course and sometimes bifurcate before reaching at margin. While in *H. glabra* the secondaries are less in number and distantly placed. *H. philippinensis* has oblique base and closely placed secondaries which are more in number. *H. odorata* differs from the fossil leaf in the angle of divergence and course of secondaries. Thus, the modern leaf of *H. wightiana* Wall. (C.N. Herbarium Sheet no. 51877; Pl. 5, fig. 2) only resembles the present fossil leaf.

Like other members of Dipterocarpaceae the genus *Hopea* is also well known from the Tertiary of India. Two fossil woods, viz., *Hopenium kalagarhensis* Prasad & Prakash 1987 and *H. prenutansoides* Prasad & Prakash 1987 are known from the Siwalik sediments of Kalagarh, Uttar Pradesh. Besides, *Hopenium pondicheriense* Awasthi 1980 and *H. neyveliensis* Awasthi 1984 are known from the Cuddalore sandstone and Neyveli lignite of south India, respectively.

Since there is no record of the fossil leaf of *Hopea* Roxb. from India, the present finding forms the first authentic record of a fossil leaf from the Siwalik

PLATE 5 →

Hopea siwalika sp. nov.

1. A fossil leaf in natural size showing shape, size and venation pattern; Specimen no. BSIP 36918.
2. *Hopea wightiana*—a modern leaf showing similar shape, size and venation, × Nat. size.

Pterospermum palaeoheynianum sp. nov.

3. A fossil leaf in natural size showing shape, size and venation; Specimen no. BSIP 36919.
4. *Pterospermum heynianum*—a modern leaf in natural size showing similar shape, size and venation pattern.

Grewia ghishia sp. nov.

5. A fossil leaf in natural size showing shape, size and venation; Specimen no. BSIP 36920.
6. *Grewia umbellifera*—a modern leaf in natural size showing similar shape, size and venation pattern.
7. A part of fossil leaf magnified to show details of venation pattern, × 3.

Bursera preserrata sp. nov.

8. Fossil leaf in natural size showing shape, size and venation pattern; Specimen no. BSIP 36921.
9. *Bursera serrata*—a modern leaf in natural size showing similar shape, size and venation pattern.

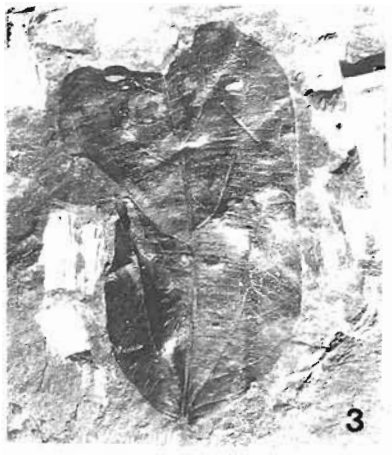


PLATE 5

sediments and has been described as *Hopea siwalica* sp. nov.

The genus *Hopea* Roxb. consists of about 55 species of large trees occurring throughout the Indo-Malayan region. Out of them, about 11 species are found in India and 35 in Malaya peninsula (Pearson & Brown, 1932, p. 92; Ridley, 1967, pp. 235-236; Gamble, 1972, p. 74). *H. wightiana* Wall., with which the fossil leaf resembles, is a large tree growing in the tropical evergreen forests of the Indo-Malayan region.

Holotype—Specimen no. BSIP 36918.

Locality—Right bank of the upstream of Ghish River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Family—Sterculiaceae

Genus—*Pterospermum* Schreb.

Pterospermum palaeoheyneanum sp. nov.

Pl. 5, fig. 3

It consists of only one well-preserved leaf-impression.

Description—Leaf simple, symmetrical, narrow obovate, preserved lamina length 5.3 cm, maximum width 3.1 cm; apex partly broken; base wide obtuse; margin entire; texture chartaceous; petiole not preserved; venation pinnate, simple, craspedodromous; primary vein prominent, stout, almost straight; secondary veins 4 pairs visible, angle of divergence acute, narrow (30°-45°), upper secondary veins with more angle than the lower secondaries, moderate, uniformly curved upward, first pair of basal secondaries extending up to apex and giving rise to four-five pairs of convexly-curved veins outwardly towards margin with a slight curve; tertiary veins with angle of origin RR, percurrent, usually unbranched, straight, approximately at right angles to midvein, towards margin in basal part oblique, predominantly opposite, close; quaternary veins fine, orthogonal to polygonal, branched; areoles well-developed; veinlets not seen.

Affinities—A combination of important distinguishing features like narrow obovate shape, wide obtuse base, entire margin, 4-5 pairs of secondary veins, first pair of basal secondaries with four to five pairs of outwardly convex-curved veins, tertiary veins with angle of origin RR indicates the affinity of the fossil leaf with that of the genus *Pterospermum* Schreb. of the family Sterculiaceae.

For a detailed comparison of the fossil leaf, about 20 species of *Pterospermum* Schreb. were examined and it was found that the fossil specimen closely resembles *P. heynianum* Wall. and to some extent with the leaves of *P. obtusifolium* Wight, *P. acerifolium* Willd. and *P. blumeanum* Korth. In *P. obtusifolium*, however, the leaves are generally bigger in size and the course of first basal secondaries markedly differs from the fossil specimen, while in *P. blumianum* Korth. the secondary veins take a rounded curve before reaching the margin. This kind of curve is not seen in the fossil leaf. The shape of the leaves of *P. acerifolium* Willd. and *P. heyneanum* Wall. is quite similar, but they differ in the venation pattern from each other. However, in venation pattern as well as in other morphological features *P. heyneanum* Wall. (C.N. Herbarium Sheet no. 4904; Pl. 5, fig. 4) and the present fossil leaf are identical.

As far as the authors are aware, no fossil leaf of *Pterospermum* Schreb. has been recorded so far from the Tertiary sediments. Therefore the present fossil leaf has been assigned to a new species, *Pterospermum palaeoheyneanum*. Nevertheless, a fossil wood *Pterospermoxylon kachchhensis* Awasthi, Guleria & Lakhanpal 1980 has been recorded from the Pliocene beds of Mothala District in Kachchh, western India. Thus it supports the existence of this genus during Tertiary period.

The genus *Pterospermum* Schreb. comprises 40 species growing in eastern Himalaya, South-East Asia and western Malaysia. In India, 12 species of *Pterospermum* are found. Two of them occur in north-western India, three in north-east India, seven in south India, five in Myanmar, and only one in Sri Lanka. *P. heyneanum* Wall. is a tall tree and found in the Deccan forests and drier parts of hills southwards. It is also common in Cuddapah and Dharwar region (Gamble, 1972, p. 102).

Holotype—Specimen no. BSIP 36919.

Locality—Right bank of the upstream of Ghish River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Family—Tiliaceae

Genus—*Grewia* Linn.

Grewia ghishia sp. nov.

Pl. 5, figs 5, 7

This species is based on a well-preserved leaf-impression.

Description—Leaf simple, symmetrical, narrow elliptic, preserved length 6.2 cm and maximum width 1.9 cm; apex acuminate; base nearly obtuse; margin dentate; texture chartaceous; petiole not preserved; venation pinnate, simple craspedodromous; primary vein prominent, stout, straight; secondary veins six pairs visible with angle of divergence acute, narrow (<45°),

divergence angle nearly uniform, moderate, uniformly slightly curving upward, opposite to alternate, first pair of basal secondaries arising at more acute angle and extending high up to middle part of lamina, branching laterally into curved veins reaching towards margin; tertiary veins with angle of origin mostly percurrent, sometimes branched, oblique to right angle in relation to midvein, predominantly opposite, close; quaternary veins not sharply preserved.

Affinities—Symmetrical narrow elliptic shape, acuminate apex, obtuse base, dentate margin, secondary veins with angle of divergence acute, narrow, basal secondaries reaching upwards almost up to about half of lamina and laterally branching into convexly curved veins are the characteristic features of the fossil leaf which collectively indicate its affinities with the leaves of the genus *Grewia* Linn. of Tiliaceae.

The present fossil leaf was compared with 28 modern species of *Grewia* Linn. and found closely resembling *G. umbellifera* Bedd. In some characters the leaves of *G. multiflora* Juss. and *G. obtusa* Wall. also show affinity with the fossil leaf, but on the whole differ. In *G. obtusa*, the first pair of secondaries extends very high towards apex as compared to the fossil specimen. The leaves of *G. multiflora* are smaller in size and therefore differ from the present fossil leaf. Thus, in shape, size and venation pattern the fossil leaf comes closest to *G. umbellifera* Bedd. (C.N. Herbarium Sheet no. 746; Pl. 5, fig. 6).

Recently, Srivastava *et al.* (1992) described a fossil leaf as *Grewia tiliaefolia* Vahl from the shales of Mahuadanr Valley, Palamu District, Bihar. Although, the fossil woods resembling *Grewia* and described as *Grewioxylon* sp. (Lakhanpal, Prakash & Bande, 1978) from Intertrappean beds of Mandla District, Madhya Pradesh and *Grewioxylon mahurzariense* Prakash & Dayal 1965 from the Deccan Intertrappean beds of Mahurzari, Madhya Pradesh are known. These records obviously support the occurrence of *Grewia* Linn. during the Tertiary period. Being an authentic record from Siwaliks the present fossil leaf has been described as *Grewia ghishia* sp. nov.; the specific name stands after Ghish River from where the specimen was collected.

The genus *Grewia* Linn. consists of 150 species growing specifically in the tropical region of Asia, Africa and Australia (Willis, 1973, p. 499). Out of these, 34 species are found in the Indian subcontinent. *Grewia umbellifera* Bedd., with which the fossil leaf resembles, is a lofty scandent shrub or tree growing in the evergreen forests of Western Ghats from Konkan southwards.

Holotype—Specimen no. BSIP 36920.

Locality—Right bank of the upstream of Ghish River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Family—Burseraceae

Genus—*Bursera* Jacq. ex Linn.

Bursera preserrata sp. nov.

Pl. 5, fig. 8

Only two well-preserved leaf-impressions are in the collection.

Description—Leaf simple, symmetrical, narrow elliptic, preserved length 4.4 cm, maximum width 2.2 cm; apex acute; base acute; margin seemingly entire; texture chartaceous; petiole not preserved; venation pinnate, brochidodromous, forming loops with supradjacent veins; primary vein prominent, moderate, markedly curved upward; secondary veins 10 pairs visible, angle of divergence nearly right angle (85°-90°), moderate, uniformly curved up, joining supradjacent secondary at about right angle; intersecondary veins simple, sub-opposite, unbranched; tertiary veins with angle of origin AR-OR, reticulate, random, relationship to midvein appearing oblique; quaternary veins not distinctly visible.

Affinities—The main distinguishing features of the fossil leaf are : narrow elliptic shape, acute apex and base, margin seemingly entire, secondary veins forming loops with supradjacent ones, angle of divergence nearly right angle and uniformly curved up intersecondary veins. These characters suggest the affinities of the fossil leaves with those of the genus *Bursera* Jacq. ex Linn. of Burseraceae.

A number of extant species of the genus *Bursera* Jacq. ex Linn. were examined and found that our fossil leaves are closely comparable with the only Indian species—*B. serrata* Colebr. (C.N. Herbarium Sheet no. 78097; Pl. 5, fig. 9). Therefore they have been described as *B. preserrata* sp. nov.

So far, to the best information to the authors, there is no record of the fossil leaves of *Bursera* from the Tertiary of India. Nevertheless, there are records of the fossil woods of *Bursera* Jacq. ex Linn. from Tipam sandstones near Hailakandi, Assam (Prakash & Tripathi, 1975) and Deccan Intertrappean beds near Shahpura in Madhya Pradesh (Bande & Prakash, 1983). These fossil woods have also been compared with the same extant species—*B. serrata*, by these workers.

The genus *Bursera* Jacq. ex Linn. comprises 80 species generally found in tropical America (Willis, 1973; p. 167). *B. serrata,* with which the fossil leaves resemble, is the only species found in India. It is a large evergreen tree with serrate or nearly entire margined leaves. It occurs commonly in Assam, Cachar, Chittagong, Chhota Nagpur, Orissa and Myanmar (Brandis, 1971, p. 132).

Holotype—Specimen no. BSIP 36921.

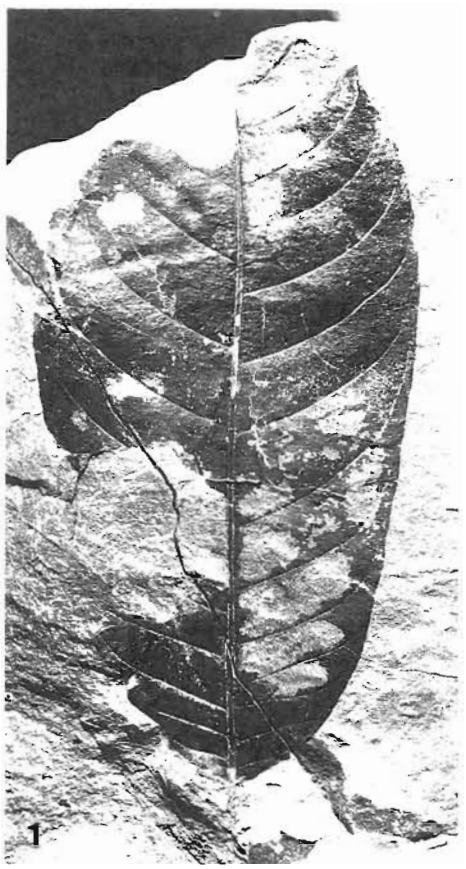


PLATE 6

Nothopegia eutravancorica sp. nov.

1 A fossil leaf in natural size showing shape, size and venation pattern; Specimen no. BSIP 36922.

2. *Nothopegia travancorica*—a modern leaf in natural size showing shape, size and venation pattern.

Locality—Left bank of the upstream of Ghish River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Bursera serratoides sp. nov.

Pl. 19, fig. 6

It is represented by a single fossil fruit (cast) preserved in dark grey shales.

Description—Fruit single, attached to a thick peduncle, maximum length 0.9 cm, width 0.7 cm, somewhat globose in shape, a sharp furrow present dividing the fruit into two lobes.

Affinity—The shape, size, nature of furrow and attachment to the peduncle are suggestive of its affinity with the fruits of extant genus *Bursera serrata* Colebr. of Burseraceae and *Grewia umbellifera* Bedd. of Tiliaceae. In the present collection both these genera are represented by fossil leaves. However, on the basis of length and width of each lobe and the typical nature of furrow it closely resembles the fruits of *B. serrata*. Thus the occurrence of fossil leaves as well as fruit of *B. serrata* in the same sediments confirms that it was

growing in this region during Siwalik sedimentation. However, this stands the first record of the fruit of *B. serrata* and therefore has been described as *Bursera serratoides* sp. nov. The fossil leaf has been described here as *B. preserrata* sp. nov. while its fossil fruit as *B. serratoides* sp. nov. to distinguish them from each other.

Holotype—Specimen no. BSIP 36948.

Locality—Right bank of the upstream of Ghish River, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Family—Anacardiaceae

Genus—*Nothopegia* Bl.

Nothopegia eutravancorica sp. nov.

Pl. 6, fig. 1

This species is represented by several specimens, of which only one leaf is almost complete and well-preserved.

Description—Leaf simple, symmetrical, oblong, preserved length 10.6 cm, lamina length 10.2 cm, maximum width 5.0 cm; apex broken; base widely acute, normal; margin entire; texture coriaceous; petiole normal, preserved length 0.4 cm; venation pinnate, simple, craspedodromous; primary vein prominent, stout, straight; secondary veins 15 pairs visible, angle of divergence moderate (60°-65°), first 2-3 basal pairs of closely placed secondaries arise with greater angle of divergence, nearly uniform, uniformly curving upward near margin to meet the supradjacent vein; tertiary veins with angle of origin AO-RO, percurrent, usually unbranched, relationship to midvein oblique, predominantly opposite, close; quaternary veins thin, orthogonal to polygonal.

Affinities—The distinguishing features like leaf symmetrical, base acute, secondary veins uniformly curved up near the margin and first 2-3 basal pairs of closely placed secondaries arising at greater angle of divergence show their affinities with the leaves of Anacardiaceae in general and *Nothopegia* Bl. io particular.

The fossil leaves were compared in detail with six available modern species of the genus *Nothopegia* Bl. Out of these, *N. travancorica* Bedd. (C.N. Herbarium Sheet no. 65295; Pl. 6, fig. 2) was found closely related with the specimens, while *N. beddomei* though resembles to some extent the fossil specimens, differs in having smaller and lanceolate leaves. Therefore, the present fossil leaves have been referred to *N. travancorica* Bedd. Dalvi and Kulkarni (1982) also described the cuticle of *Nothopegia* resembling *N. colebrookiana* Blume from the lignite beds of Ratnagiri District, Maharashtra.

The genus *Nothopegia* Bl. consists of seven species growing in India, Sri Lanka and Borneo. Of them, three species are found in India. *N. travancorica* Bedd. is a shrub occurring at about 550 m height in the tropical evergreen forests of Travancore and Tirunelveli in Kerala (Gamble, 1972, p. 222).

Holotype—Specimen no. BSIP 36922.

Locality—Right bank of the upstream of Ramthi River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Genus—*Bouea* Meissn.

Bouea premacrophylla sp. nov

Pl. 7, fig. 1, Pl. 8, fig. 2

The material comprises only a single well-preserved leaf-impression. The apical and basal parts are detached and preserved in the same piece of shale.

Description—Leaf simple, symmetrical, preserved length 20.4 cm, lamina length 20.0 cm, maximum width 7.0 cm, narrow oblong; apex slightly broken, appearing acuminate; base obtuse, normal; petiole normal, about 0.4 cm in length; margin entire; texture coriaceous; venation pinnate, simple, craspedodromous; primary vein prominent, stout, nearly straight; secondary veins 22 pairs visible (in both parts), angle of divergence wide acute (75°-80°), moderate, uniformly curving upwards, sub-opposite to alternate, first two pairs of secondary veins in the basal part closely placed as compared to secondaries arisen above; tertiary veins with angle of origin AR-OR, percurrent, appearing retroflexed, relationship to midvein oblique, predominantly opposite, close; quaternary veins thin, orthogonal to polygonal; areoles well-developed, predominantly quadrangular.

Affinities—In its general appearance, venation pattern and angle of divergence the fossil leaf is typical anacardiaceous type. The other distinguishing characters like leaf symmetrical, apex acuminate, first two pairs of secondaries closely placed as compared to the secondaries arisen above, angle of divergence wide acute and tertiaries appearing retroflexed and oblique make it comparable with the leaves of *Bouea* Meissn. of Anacardiaceae.

The leaves of two modern species, viz., *B burmanica* Griff. and *B. macrophylla* Griff. could be available for its close comparison. However, in both the species the venation pattern appears somewhat similar, but in *B. burmanica* the leaves are comparatively smaller and narrow lanceolate. While *B. macrophylla* (C.N. Herbarium Sheet no. 99011; Pl. 8, figs 1, 3) has

PLATE 7

Bouea premacrophylla sp nov.
1. Fossil leaf in natural size represented by basal as well as apical parts showing shape, size and venation; Specimen no. BSIP 36923.

been found closely resembling the present fossil leaf in all features.

In general appearance the fossil leaf also somewhat resembles *Knema elmeri* Merr. (= *Myristica elmeri*) of the family Myristicaceae, but markedly differs in the angle of divergence of secondaries and pattern of tertiary veins, too.

Recently, a fossil wood resembling the genus *Bouea* Meissn. has been reported from Neyveli Lignite, south India (Agarwal, 1988). But so far there is no record of fossil leaf of *Bouea* from the Tertiary sediments of India and thus it is the first record of *Bouea* leaf from the Siwalik sediments. In view of its close similarity with *B. macrophylla* it has been described as *Bouea premacrophylla* sp. nov.

The genus *Bouea* Meissn. consists of 3-4 species growing in Indo-Malayan regions (Brandis, 1971, p. 204). *Bouea macrophylla* Griff., with which the fossil

PLATE 8

1 *Bouea macrophylla*—a modern leaf in natural size resembling in shape and venation pattern.
2. A part of fossil leaf magnified to show the details of venation pattern. × 1 5
3 A part of modern leaf magnified to show details of venation pattern, × 1 5.

leaf closely compares, grows in the evergreen forests of Sunderbans, Myanmar, Andaman islands and Malaya Peninsula (Desh, 1957, p. 7).

Holotype—Specimen no. BSIP 36923.

Locality—Right bank of the upstream of Ramthi River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Family—Fabaceae

Genus—*Bauhinia* Linn.

Bauhinia ramthiensis sp. nov.

Pl. 9, fig. 1

This species is based on a single leaf-impression, of which only one lobe is preserved.

Description—Leaf bilobed, symmetrical, elliptic, lamina length 9.0 cm, maximum width 4.3 cm; apex not preserved; base appearing cordate; margin entire; texture chartaceous; petiole not preserved; venation acrodromous; four primary veins originating from a single point at base, moderate, running markedly curved towards apex; secondary veins numerous between two primaries and joining the adjacent primary veins fine, curved to wavy; tertiary veins fine, pattern random to reticulate, distant to closely arranged; areoles well-developed, arrangement oriented, appearing mostly quadrangular, size large.

Affinities—Bilobed symmetrical leaf, cordate base, venation acrodromous and four primary veins in a lobe originating from a single point at the base are the diagnostic characters which suggest the affinities of the fossil specimen with the leaves of *Bauhinia* Linn. of Fabaceae.

Morphological study of the leaves of about 25 modern species of the genus *Bauhinia* Linn. was carried out and it was observed that the leaf morphology, particularly the venation pattern, is quite homogeneous due to which it often becomes difficult to designate any fossil leaf with the living ones. Nevertheless, the fossil specimen closely resembles *B. acuminata* Linn. In *B. tomentosa* the primary veins divide further into branches and thus differs from the fossil. *B. malabarica* Roxb. though shows similarity with the fossil leaf in shape and size but it differs in having 5-6 pairs of veins; in *B. acuminata* these are in 3-4 pairs. Thus in shape, size and venation pattern our fossil leaf resembles *B. acuminata* Linn. (C.N. Herbarium Sheet no. 1395; Pl. 9, fig. 2).

There are several fossil records of *Bauhinia* leaves both from India and abroad. They have been described under two generic names—*Bauhinia* Linn. and *Bauhinites* Seward & Conway 1935. From India, Lakhanpal and Awasthi (1984) reported the occurrence of *Bauhinia* leaf, viz., *B. siwalika* from west Champaran District of Bihar. Another leaf—*B. kachchhensis* Lakhanpal & Guleria 1982 was reported from the Lower Miocene of Kachchh. Later, Awasthi and Prasad (1990) reported one more species *B. nepalensis* sp. nov from the Siwalik sediments of Surai Khola, Nepal.

The present fossil leaf differs from *B. kachchhensis* Lakhanpal & Guleria 1982 in being larger in size and having only four primaries in one lobe of the leaf as against 4-6 primaries in the specimen of Lakhanpal and Guleria. *B. siwalika* also differs from it in being smaller in size. Similarly, *B. nepalensis* Awasthi & Prasad 1990 can also be differentiated in being smaller in size with 5 primary veins in a lobe. Since the present leaf differs from all above known species, it has therefore been described as *B. ramthiensis* sp. nov. The specific name is after Ramthi River from where the leaf has been collected.

The genus *Bauhinia* is represented by trees, shrubs and vines. Brandis (1971) listed 30 species from India and Myanmar, of them six attain tree size. *B. acuminata*, with which the fossil specimen resembles, occurs in the moist deciduous forests in the sub-Himalayan tract, Lower Himalaya from Indus eastwards and Bengal, Andaman Islands, Chittagong hill tracts, Myanmar and Malaya Peninsula (Gamble, 1972).

Holotype—Specimen no. BSIP 36924.

Locality—Right bank of the upstream of Ramthi River, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Genus—*Cynometra* Linn.

Cynometra tertiara sp. nov.

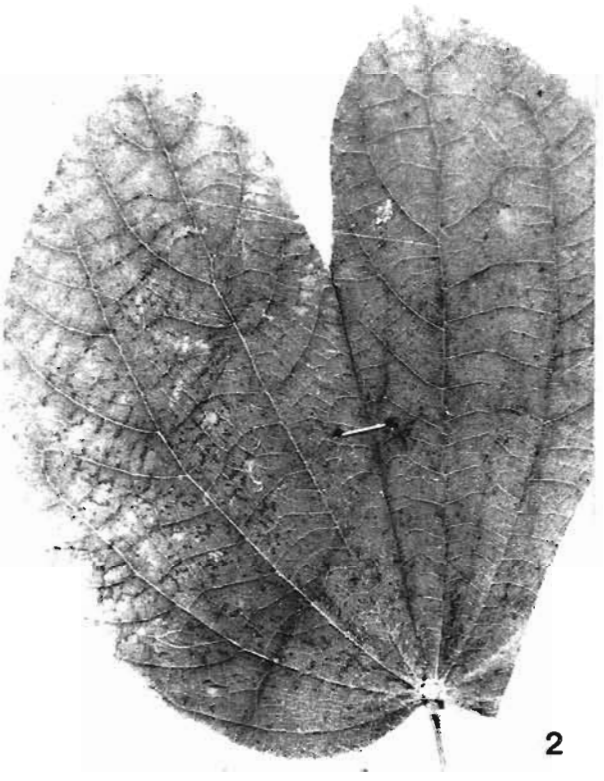
Pl. 9, fig. 3

This species is based on 10 leaflet-impressions; of them four are almost complete.

Description—Whole lamina and base asymmetrical, shape variable from narrow-obovate to oblanceolate, preserved length 8 cm, maximum width 2.4 cm; apex acute; base inequilateral, acute, oblique; margin entire; texture chartaceous; venation pinnate, eucamptodromous; primary vein prominent, moderate, unbranched, slightly curved; secondary veins with angle of divergence acute, narrow (30°-35°), angle of divergence almost uniform, appearing subopposite, fine, uniformly curving upwards, joining supradjacent at acute angles, intramarginal vein poorly developed; tertiary veins ramified, relationship to midvein oblique, close; quaternary veins not clearly visible.

Affinities—Leaflet asymmetrical, shape obovate to oblanceolate, inequilateral base, apex acute and venation eucamptodromous are those distinguishing morphological features on the basis of which the present fossil leaflets are assignable to the genus *Cynometra* Linn. of the family Fabaceae.

The leaflet-impressions have been compared with 12 extant species of the genus *Cynometra* Linn. Amongst them, they show resemblance with *C. cauliflora* Linn. and *C. ramiflora* Linn. However, the leaves of *C. ramiflora* differ in being smaller in size with deeply



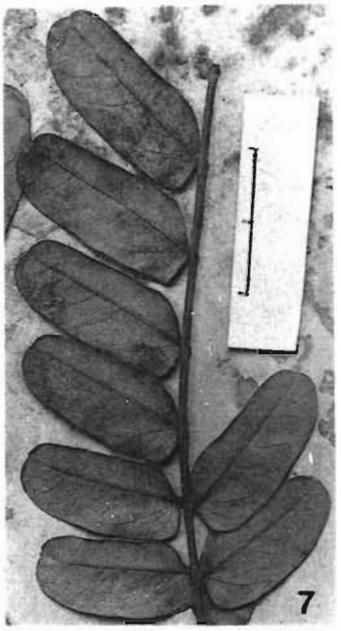


PLATE 9

Baubinia ramthiensis sp nov

1 A fossil leaf in natural size showing shape, size and venation; Specimen no BSIP 36924

2. *Baubinia acuminata*—a modern leaf in natural size showing similar shape, size and venation

Cynometra lertiara sp nov

3 A fossil leaflet in natural size showing shape, size and venation, Specimen no. BSIP 36925

4. *Cynometra cauliflora*—a modern leaflet showing similarity in shape, size and venation

Albizia palaeolebbek sp. nov.

5, 6. Fossil leaflets in natural size showing shape, size and venation, Specimen no. BSIP 36926 (part and counterpart).

7 *Albizia lebbek*—modern leaflets showing similarity in shape, size and venation.

curved secondary veins. Thus in shape, size and venation pattern the fossil specimens closely resemble the extant species *C. cauliflora* (C.N Herbarium Sheet no. 138798; Pl. 9, fig. 4). Recently, Awasthi and Prasad (1990) have also reported a fossil leaflet *C. siwalika* sp. nov. from the Siwalik sediments of Surai Khola, western Nepal and compared it with modern *C. polyandra* Roxb. Since the present leaflet-impressions differ from *C. siwalika* Awasthi & Prasad 1990 in shape and size and are closely comparable with modern *C. cauliflora*, hence these are being described as *Cynometra tertiara* sp. nov.

There are several records of fossil woods of the genus *Cynometra* from the Siwalik sediments of Uttar Pradesh and Himachal Pradesh (Prakash, 1975, 1979), Tertiary of Kutch (Guleria, 1983), Tipam and Dupitila Series of Assam (Prakash, 1966a, b; Prakash & Awasthi, 1971), Cuddalore Series (Ramanujam & Rao, 1966), Tertiary of West Bengal (Bande & Prakash, 1980) and Tertiary of Thailand (Prakash, 1979). The presence of fossil leaves as well as woods of the genus collectively indicates its wider distribution during Neogene in the Indian subcontinent.

The genus *Cynometra* Linn consists of 60 species (Willis, 1973, p. 329) of evergreen trees or shrubs distributed throughout the tropics in the Indo-Malayan region, Philippines, Australia, Pacific Island, Mexico, Brazil and Africa. In India, it is represented by six species. *C. cauliflora* Linn. is distributed in Molucca, Sri Lanka and chiefly in Malaya Peninsula (Hooker, 1878, p. 268).

Holotype—Specimen no. BSIP 36925.

Locality—Right bank of the upstream of Ghish River, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Genus—*Albizia* Durraz

Albizia palaeolebbek sp. nov.

Pl. 9, figs 5, 6

It is represented by six well-preserved leaf-impressions.

Description—Leaflets asymmetrical, oblong, preserved lamina length 2.2 cm, maximum width 0.9 cm; apex rounded; base obtuse-oblique; margin entire; texture chartaceous; petiole absent; venation pinnate, eucamptodromous; primary vein prominent, moderate, almost straight; secondary veins with angle of divergence narrow (acute), second basal secondary arising at more acute angle, uniformly curving upwards, joining supradjacent veins, branched near margin; tertiary veins not clearly visible.

Affinities—The distinguishing features like asymmetrical leaflets, oblong shape, oblique base, rounded apex, venation eucamptodromous, second basal secondary arising at more acute angle and running high upwards show that the leaflet-impressions are comparable wih the genus *Albizia* Durraz. of Fabaceae.

The leaves of about 14 modern species of *Albizia* were studied to find out their specific affinity. But the fossil specimens show close similarity with *Albizia lebbek* Benth. and in some characters with *A odoratissima* Benth. But in *A. odoratissima*, the leaves are larger in size as compared to the fossil leaflets and thus can not be compared. However, all morphological details of the specimens match closely with *A. lebbek* Benth. (F.R.I. Herbarium Sheet no. 3079; Pl. 9, fig. 7).

There are three records of the fossil leaflets of *Albizia*, viz., *A miokalkara* (Hu & Chaney) Ishida 1970 from Miocene of Japan, *Leguminosites* Geyler 1875 from the Tertiary of Borneo and *A. siwalica* Prasad 1990 from the Siwalik sediments of Koilabas, Nepal. The latter species has been compared with *A. gambleii* Prain. A close examination of all the above known species reveals that the present specimens are altogether different from the above known species and therefore described as *Albizia palaeolebbek* sp. nov.

The fossil woods closely resembling *Albizia lebbek* have also been reported from the Siwalik sediments of Himachal Pradesh (Prakash, 1975), Tertiary of West Bengal (Ghosh & Roy, 1981), Dupitila Series, Assam (Lakhanpal, Prakash & Awasthi, 1981) and from the Tertiary of Kutch Basin (Guleria, 1983). This, obviously, indicates its abundant occurrence during the Tertiary period in the Indian subcontinent.

The genus *Albizia* Durraz. is represented by about 150 species distributed in tropical and subtropical regions (Willis, 1973) all over the world. However, 14 species have been reported from India. *A. lebbek* Benth., with which the fossil specimens resemble, is a large deciduous tree and occurs in sub-Himalayan tracts from Indus eastwards ascending to about 5,000 ft., Bengal, central and south India, Myanmar, Andamans and dry regions of Sri Lanka (Gamble, 1972, p. 303).

Holotype—Specimen no. BSIP 36926.

Locality—Right bank of the upstream of Ghish River, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Genus—*Pongamia* Vent.

Pongamia siwalika Awasthi & Lakhanpal 1990

Pl. 10, fig. 1

There are four well-preserved leaflets in the collection.

Description—Leaflets simple, symmetrical, wide elliptic, lamina length 6.6 cm, maximum width 5.1 cm; apex acuminate (preserved in another specimen); base

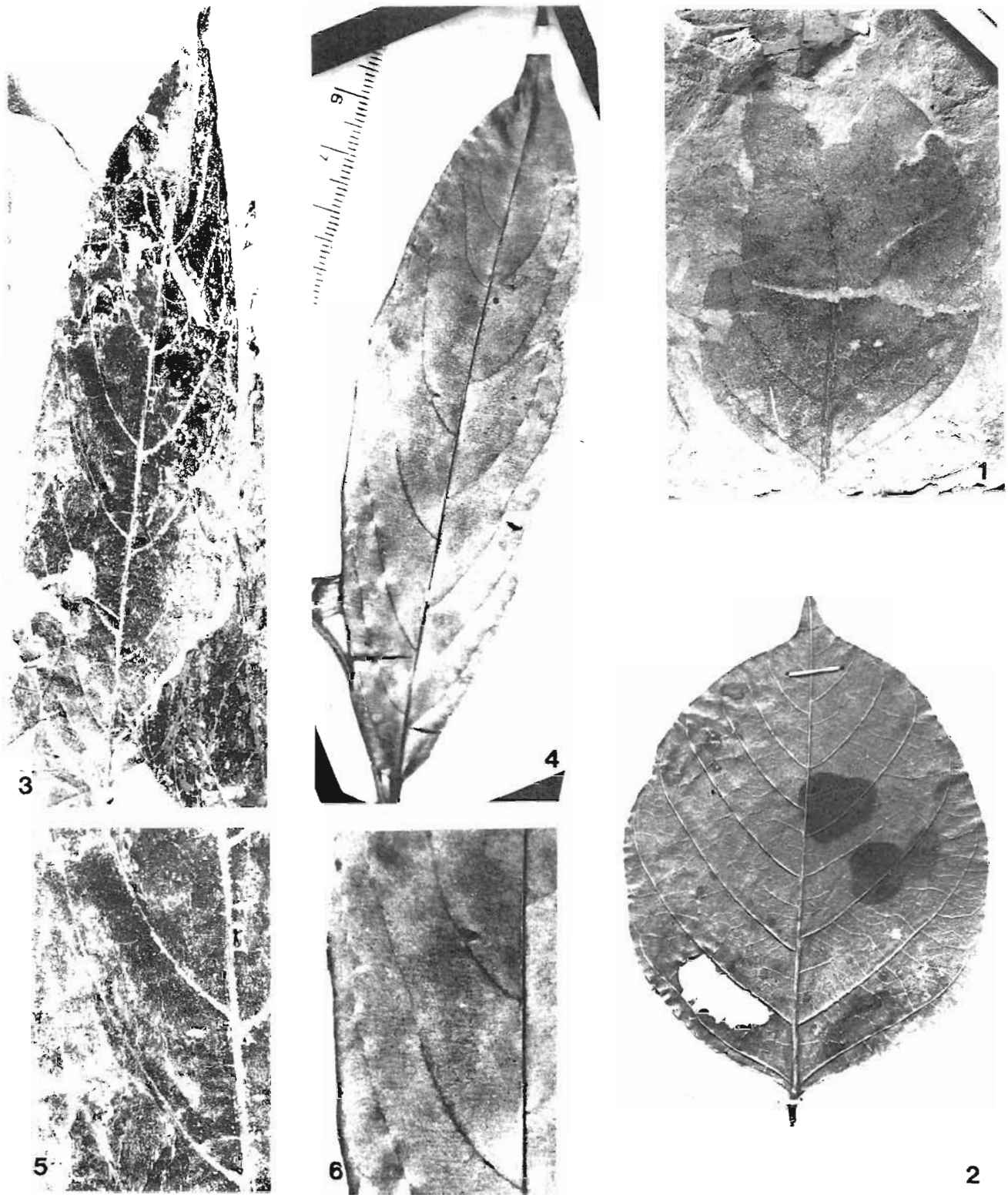


PLATE 10

Pongamia siwalika Awasthi & Lakhanpal 1990

1 A fossil leaflet in natural size showing shape, size and venation. Specimen no. BSIP 36927

2 *Pongamia pinnata*—a modern leaflet showing close similarity in shape, size and venation pattern

Combretum sahnii sp. nov.

3. An almost complete fossil leaf in natural size showing shape, size and venation pattern. Specimen no. BSIP 36928

4 *Combretum decandrum*—a modern leaf in natural size showing similarity in shape, size and venation pattern

5. A part of fossil leaf magnified to show the details of venation. × 1.5

6 A part of modern leaf magnified to show details of venation. × 1.5

nearly obtuse; margin entire; texture chartaceous: petiole not preserved; venation pinnate, brochidodromous; primary vein prominent, stout, almost straight; secondary veins five pairs visible, angle of divergence moderate (45°-50°), almost uniform, moderate in thickness, uniformly curving upwards, opposite to alternate, joining supradjacent at obtuse angle; inter-secondary veins not visible; tertiary veins with angle of origin AR-OR, percurrent, branched, relationship to midvein oblique, close; quaternary veins not visible.

Affinities—Symmetrical wide elliptic leaflet, acuminate apex, nearly obtuse base, brochidodromous venation, secondary veins joining supradjacent at obtuse angle and percurrent tertiaries are the important features of the fossil leaves which indicate their affinity with the genus *Pongamia* Vent. of the family Fabaceae.

A detailed comparison of the fossil specimens show their closest affinity with the extant species *P. pinnata* (= *P. glabra* Vent.; C.N. Herbarium Sheet no. 22746; Pl. 10, fig. 2).

Pongamia is a monotypic genus and recently Awasthi and Lakhanpal (1990) reported a leaflet as *P siwalika* from near Bhikhnathoree, Bihar. The preservation of their specimen is not so good as compared to the present specimens. However, in shape, size and other characters they appear more or less similar to the above known species. Therefore, the present fossil leaves have been assigned to the same species.

The fossil woods resembling *Pongamia* and *Millettia* W. & A. have been described from various Neogene sediments of India (Awasthi, 1992; Guleria, 1992), which also indicate its wide spread distribution during Neogene.

Genus *Pongamia* Vent., represented by a single species *P. pinnata*, is a moderate-sized evergreen tree and occurs in the tidal and beach forests and along river banks and water course throughout the country extending northwards to the Himalaya up to an elevation about 650 to 1,000 m. It is also found in Sri Lanka and Myanmar (Gamble, 1972, p. 262).

Specimen—No. BSIP 36927.

Locality—Right bank of the upstream of Ramthi River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Family—Combretaceae

Genus—*Combretum* Linn.

Combretum sahnii sp. nov.

Pl. 10, figs 3, 5

There are eight well-preserved leaf-impressions in the collection representing this species.

Description—Leaf simple, symmetrical, narrow oblong, preserved length 12.8 cm, lamina length 12.5 cm, maximum width 3.2 cm; apex attenuate; base acute, normal; margin entire; texture coriaceous; petiole preserved, about 0.3 cm in length, normal; venation pinnate, eucamptodromous; primary vein prominent, stout, straight; secondary veins 7 pairs visible, angle of divergence moderate (45°-50°), almost uniform, moderate in thickness, unbranched, uniformly curving upwards, sub-opposite to alternate; tertiary veins with angle of origin RR, percurrent, sometimes branched, relationship to midvein approximately at right angles, predominantly opposite, close; quaternary veins not visible.

Affinities—The features of the leaf like symmetrical shape, narrow-oblong, margin entire, apex attenuate, base acute, texture coriaceous, percurrent tertiary veins with right angle in relation to midvein collectively indicate their resemblance with the leaves of the genus *Combretum* Linn. of Combretaceae. About 18 modern species of this genus were examined, out of which only three species, viz., *C. wallichii* DC., *C. acuminatum* Roxb. and *C. decandrum* Roxb. show similarity with the fossil specimens in general. However, *C. acuminatum* Roxb. has relatively bigger leaves with acuminate apex, while in *C. wallichii* DC. the leaves are smaller as compared to the fossil leaves. Thus it is only *Combretum decandrum* Roxb. (C.N. Herbarium Sheet no. 164531; Pl. 10, figs 4, 6) with which the fossil leaves resemble in all characters. Bande and Srivastava (1990) also reported a leaf-impression as *Combretum decandrum* Roxb. from the shales of Mahuadanr Valley, Palamu District, Bihar but their identification is not convincing. Therefore the present fossil leaves are described as *Combretum sahnii* sp. nov., the specific name is after the late Professor Birbal Sahni.

The genus *Combretum* Linn. includes about 250 spcies, mostly large climbing shrubs or sometimes trees of the tropical and subtropical regions of the old and new world (Brandis, 1971, p. 312). *C. decandrum* Roxb. is a large climbing shrub distributed in deciduous forests from Punjab to Bhutan all along Himalayas (Gamble, 1972, p. 349). In fact, it is one of the most rampant and troublesome climbers of the forest.

Holotype—Specimen no. BSIP 36928.

Locality—Right bank of the upstream of Ramthi River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

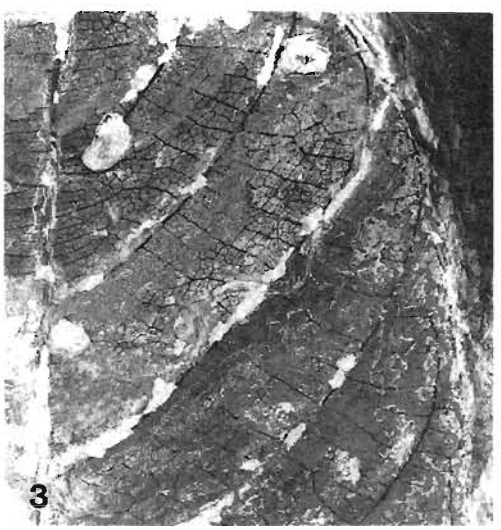
Family—Lythraceae

Genus—*Lagerstroemia* Linn.

Lagerstroemia patelii Lakhanpal & Guleria 1981

Pl. 11, figs 1, 3; Pl. 12, figs 1, 2

This species is based on a number of well-preserved specimens.



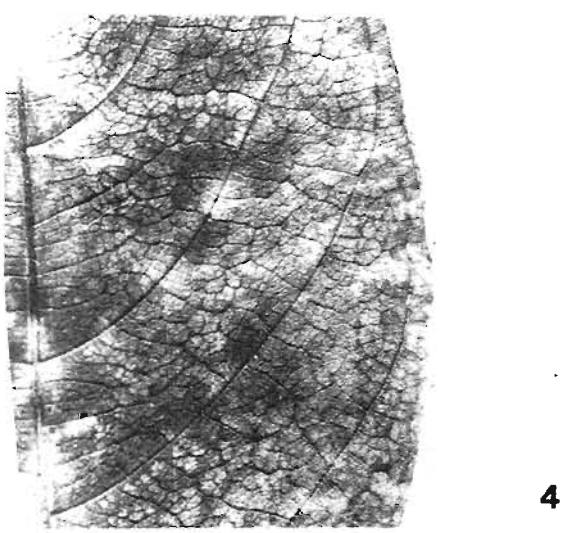


PLATE 11

Lagerstroemia patelii Lakhanpal & Guleria 1981

1. A fossil leaf in natural size showing shape, size and venation pattern; Specimen no. BSIP 36929
2. *Lagerstroemia speciosa*—modern leaf in natural size showing resemblance in shape, size and venation pattern.
3. A part of fossil leaf magnified to show details of venation pattern, × 2.5
4. A part of modern leaf magnified to show details of venation pattern, × 2.5

Description—Leaves simple, almost symmetrical, elliptic to oblong, preserved lamina length 12.5 cm, maximum width 5.7 cm; apex acuminate; base seemingly acute, normal; margin entire; texture coriaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein prominent, stout, almost straight; secondary veins 13 pairs visible, angle of divergence moderate (45°-60°), uniformly curving upwards, distance between first two pairs of basal secondaries less than the upper secondaries, moderate intersecondary veins sometimes present, simple, opposite to alternate; tertiary veins with angle of origin AR-RO, percurrent, branched, relationship to midvein oblique; quaternary veins very fine, reticulate forming triangular to polygonal meshes; areoles present.

Affinities—Shape elliptic-oblong, apex acuminate, base acute, venation eucamptodromous, distance between first two basal pairs of secondary veins less than the upper successive secondaries and percurrent tertiaries are the distinguishing characters which indicate that the fossil leaves show resemblance with the genus *Lagerstroemia* Linn. of the family Lythraceae. The fossil leaves were compared with 18 available modern species of *Lagerstroemia* Linn. and found that the present fossil leaves closely resemble *L. speciosa* L. Pers. (C.N. Herbarium Sheet no. 176995; Pl. 11, figs 2, 4; Pl. 12, fig. 3) in shape, size, texture and venation pattern.

The authors are aware of only four records of the fossil leaves of *Lagerstroemia* Linn. from the Indian Tertiary sediments. Two of them are from the Deccan Intertrappean beds (Shukla, 1950; Trivedi, 1956), while the third one *Lagerstroemia* sp. is from the Siwalik beds of Balugoloa, Himachal Pradesh (Lakhanpal & Dayal, 1966). The fourth one, i.e., *L. patelii* Lakhanpal & Guleria 1981 has been reported from the Tertiary of Kutch. The leaf-impressions described by Shukla (1950) and Trivedi (1956) have been compared with *L. indica*, while Lakhanpal and Guleria (1981) compared their specimen with *L. speciosa*. Since the present leaves also show close resemblance with *L. speciosa* we have therefore described them under *L. patelii* Lakhanpal & Guleria 1981.

There are nine validly published records of fossil woods of *Lagerstroemia* described as *Lagerstroemioxylon durum* Mädler 1939 from West Germany, *L. parenchymatosum* Prakash 1965 and 1973 from Myanmar, *L. eoflosreginum* Prakash & Tripathi 1970a,b from Assam and Kachchh (Lakhanpal *et al.*, 1984), Sumatra (Kramer, 1974) and Rajasthan (Guleria, 1990, 1991), *L. irravadiensis* Prakash & Bande 1980 from Myanmar, *L. arcotense* Awasthi 1981 from near Pondicherry, *L. deomaliensis* Lakhanpal *el al.* 1981, *Lagerstroemioxylon* sp. (Kramer, 1974) and *L. benkolense* Du 1988 both from Sumatra, and *L. tomentosum* Prakash *et al.* 1992 from Tipam Sandstones of Nagaland and Assam.

Genus *Lagerstroemia* Linn. comprises 50 species widely distributed in the tropical moist deciduous and evergreen forests. *L. speciosa* Pers. is a large deciduous tree and occurs in Assam Valley, eastern Bengal, Chhota Nagpur, Western Coast, Chittagong, Myanmar and Sri Lanka. It chiefly grows along the river-banks and on low swampy ground (Gamble, 1902, p. 373).

Specimen—Nos. BSIP 36929, 36930 and 36931.

Locality—Left bank of the upstream of Ghish River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Family—Rubiaceae

Genus—*Randia* Linn.

Randia miowallichii Prasad 1990

Pl. 12, figs 4, 5

It includes seven well-preserved leaf-impressions.

Description—Leaf simple, symmetrical, narrow elliptic, preserved lamina length 8.7 cm, maximum width 3.5 cm; apex broken; base slightly broken, seemingly acute; margin entire; texture coriaceous; petiole not preserved; venation pinnate, simple, craspedodromous; primary vein prominent, stout, markedly curved; secondary veins 9 pairs visible, angle of divergence moderate (55°), nearly uniform, moderate in thickness, uniformly curving upward, subopposite to alternate, unbranched; intersecondaries not clearly visible; tertiary veins with angle of origin AR-OR, percurrent, sometimes sinuous, relationship to midvein oblique, predominantly opposite, close; quaternary veins thin, forming orthogonal to polygonal meshes.

Affinities—The important diagnostic characters such as narrow-elliptic shape, acute base, craspedodromous venation, subopposite to alternate secondary veins and

PLATE 12 →

Lagerstroemia patelii Lakhanpal & Guleria 1981

1, 2. Fossil leaves in natural size showing variation in shape and size; Paratype—Specimen no. 36930 and 36931

3. *Lagerstroemia speciosa*—a modern leaf in natural size showing similarity with Fig. 2.

Randia miowallichii Prasad 1990

4, 5. Fossil leaves in natural size showing shape, size and venation pattern; 4, Specimen no. BSIP 36932; 5, Another Specimen no. BSIP 3692 A.

6. *Randia wallichii*—a modern leaf in natural size showing similarity in shape, size and venation.

PLATE 12

percurrent tertiaries reveal that the fossil leaf belongs to the genus *Randia* Linn. of the family Rubiaceae.

To compare the fossil leaves about 18 modern species of the genus *Randia* Linn. were examined. Out of them, the fossil leaves stand closest to *R. wallichii* Hook.f. (C.N. Herbarium Sheet no. 286; Pl. 12, fig. 6) and to some extent to *R. densiflora* Benth. However, the latter differs from the present fossil leaves in possessing bigger size of leaves with secondaries placed distantly.

Uptil now there are four records of the fossil leaves of *Randia*—(i) *R. prodroma* Ung. from the Miocene of Sarmat, Germany (Solomon, 1934); (ii) *R. gossferiana* Kschun. from the Tertiary of Kamerum, Gebietes, Germany (Menzel, 1920); (iii) *R. mohavensis* Axelrod 1950 from the Miocene of Kinnick, North America, and (iv) *R. miowallichii* Prasad 1990 from Koilabas, Nepal. Amongst them, the present fossil leaves resemble the latter species, almost in all features, and have therefore been described under *R. miowallichii* Prasad 1990.

Randia Linn. is a large genus consisting of about 250 species represented by shrubs and trees distributed throughout the tropical and subtropical regions of the world. In India, about a dozen species occur as shrubs and small trees (Pearson & Brown, 1932, pp. 639-640; Purkayastha, 1982). *R. wallichii* Hook.f. is a tree found in the moist deciduous to evergreen forests of the eastern Himalaya, Sikkim, Khasi Hills, Sylhet and Chittagong (Gamble, 1902, pp. 411-412). It also grows in Andaman Island, Pegu, Tenasserim, Bangla Desh, Myanmar and Malaya Peninsula (Brandis, 1971, p. 384; Purkayastha, 1982).

Specimen—No. BSIP 36932.

Locality—Right bank of the upstream of Ramthi River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Family—Compositae

Genus—*Vernonia* Schreb.

Vernonia palaeoarborea sp. nov.

Pl. 13, fig. 1

This species is based on only one well-preserved leaf-impression.

Description—Leaf simple, symmetrical, narrow-elliptic, preserved length 11.00 cm, maximum width 5.2 cm; apex broken, appearing acute; base acute; margin entire; texture chartaceous; petiole indistinct; venation pinnate, eucamptodromous; primary vein prominent, stout, straight; secondary veins 10 pairs visible, angle of divergence moderate (55°-60°), basal secondaries more acute, moderate, opposite to alternate, uniformly curving upward, unbranched; inter-secondary veins present, simple; tertiary veins with angle of origin AO-RO, reticulate, relationship to midvein oblique, arrangement distant; quaternary veins still fine, randomly oriented, forming triangular to polygonal meshes; areoles well-developed.

Affinities—The main distinguishing features are symmetrical leaf, narrow-elliptic shape, acute base, eucamptodromous venation, and tertiary veins randomly reticulate. These features indicate its affinity with the leaves of *Vernonia* Schreb. of Compositae.

In order to find out the nearest modern comparable species, examination of about 25 different species was done. Out of them, the fossil leaf shows some affinity with *V. talaumifolia* Hook. f. and *V. travancorica* Hook. f., while closely resembles *V. arborea* Ham. In *V. travancorica* Hook. f. the base is decurrent and the leaves are bigger in size. *V. talaumifolia* Hook. f. has quite big-sized leaves and the base is somewhat cuneate as compared to acute base in the present specimen, hence, both the species differ from the fossil specimens. Therefore the specimen has been compared with *V. arborea* Ham. (C.N. Herbarium Sheet no. 375; Pl. 13, fig. 2). Uptil now there is no fossil record of the leaves of *Vernonia arborea* Ham. from the Siwalik sediments. Therefore, the present fossil leaf is assigned to a new species, *V. palaeoarborea*.

The genus *Vernonia* includes about 1,000 species distributed in America, Australia, Africa and Asia. It is also very common in grassy places (Willis, 1973, p. 1177). Gamble (1972) enumerates 8 Indian species of *Vernonia*. *Vernonia arborea*, the nearest comparable species, is a middle-sized tree growing in the evergreen forests of Western Ghats and adjoining mountain ranges from Bababudan Hills southwards, Assam, Bengal, Khasi Hills, Andaman and Nicobar Island and Myanmar (Brandis, 1971, p. 399).

Holotype—Specimen no. BSIP 36934.

Locality—Right bank of the upstream of Ghish River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Family—Ebenaceae

Genus—*Diospyros* Linn.

Diospyros koilabasensis Prasad 1990

Pl. 14, figs 1, 3

It is represented by only one well-preserved leaf-impression.

Description—Leaf simple, symmetrical, narrow ovate, preserved lamina length 5.2 cm, maximum width 1.6 cm; apex acute; base cordate; margin entire; texture

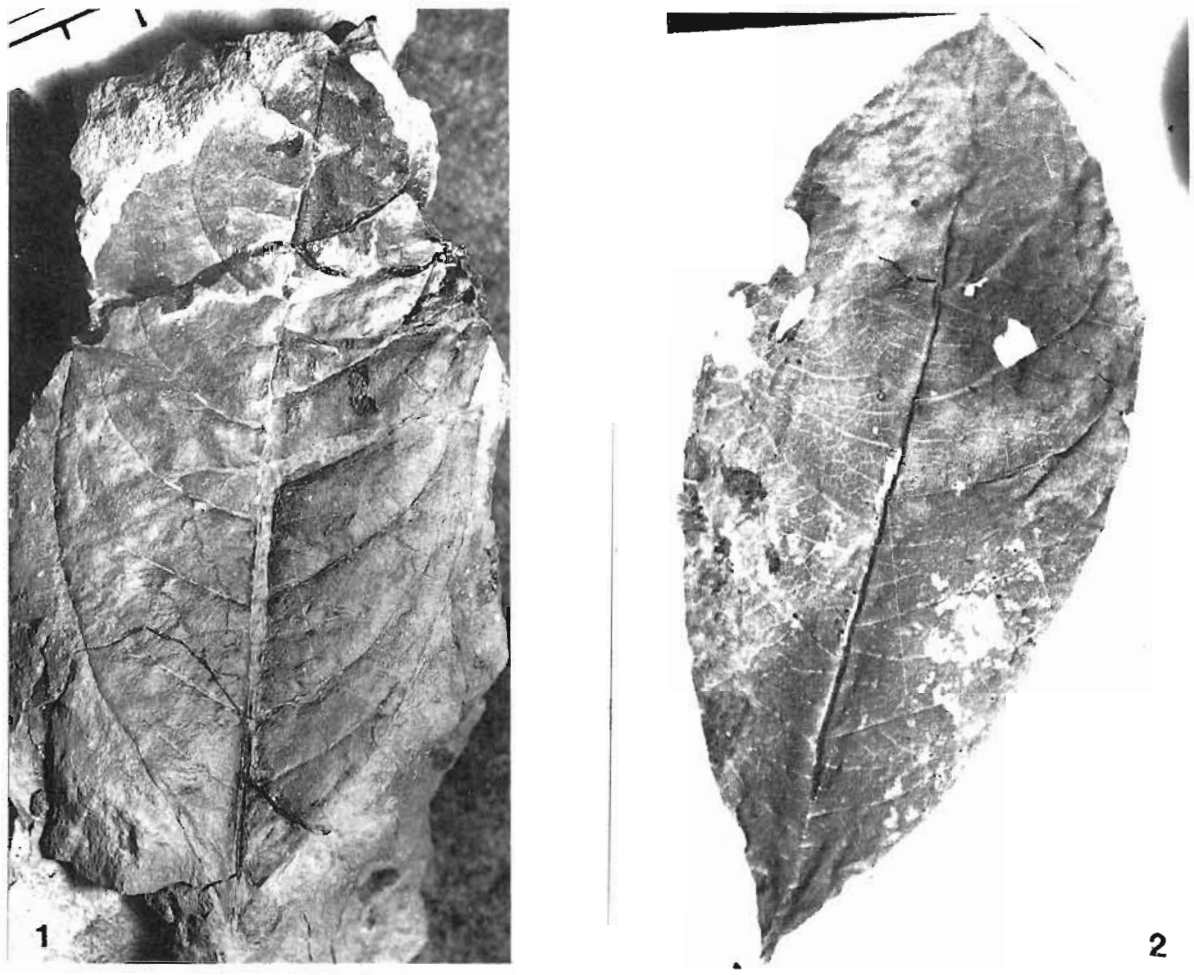


PLATE 13

Vernonia palaeoarborea sp. nov

1 A fossil leaf in natural size showing shape, size and venation pattern; Specimen no. BSIP 36934

2. *Vernonia arborea*—a modern leaf showing similarity in shape, size and venation pattern

chartaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein prominent, moderate, almost straight; secondary veins five pairs visible, angle of divergence narrow (40°), fine, uniformly curving upward joining supradjacent secondaries, inter-secondary veins present, simple to composite; tertiary veins with angle of origin usually RR, reticulate, percurrent, branched, relationship to midvein oblique; areoles developed.

Affinities—The important morphological characters of the fossil leaf like shape narrow ovate, base cordate, apex acute, margin entire, venation eucamptodromous, tertiary veins percurrent and branched show that the fossil leaf belongs to the genus *Diospyros* Linn. of the family Ebenaceae.

The present fossil leaf has been compared with 41 available modern species of the genus *Diospyros* Linn. Out of those, it shows resemblance with *D. nigrecans* Wall. in some characters and closely with *D. montana* (var. *cordifolia*) Heyne ex A. DC. (C.N. Herbarium Sheet no. 281980; Pl. 14, figs 2, 4). *D. nigrecans* Wall. differs in having more number of secondary veins and their course too.

The fossil leaves resembling *Diospyros* Linn. are described under two genera : *Diospyros* Linn. and *Diospyrophyllum* Velenovsky; the latter comprises only one species *Diospyrophyllum provectum* Velenovsky 1989 from the Upper Cretaceous of Bohemia. Under the genus *Diospyros*, about 66 species of fossil leaves have been described from Africa, Bohemia, Canada, Europe, England and U.S.A. Dalvi and Kulkarni (1982) also reported leaf cuticles of the genus *Diospyros* resembling modern *D. microphylla* Bedd. from the lignite beds of Ratnagiri District, Maharashtra. Recently, three new species of the fossil leaves, viz., *D. koilabasensis* Prasad 1990, *D. miokake* Awasthi & Prasad 1990 and *D. pretoposia* Prasad 1990 have been recorded from the Siwalik sediments of Koilabas and Surai Khola in

Nepal, respectively The present fossil leaf also resembles *D. koilabasensis* in shape, size and other features and therefore placed under the same species.

Genus *Diospyros* Linn. comprises about 500 species of trees, rarely shrubs, distributed in the tropical and mild temperate regions of the world (Hooker, 1882; Purkayastha, 1982). In India, about 40 species are found. *D. montana* (var. *cordifolia*), with which the present fossil leaf resembles, is a small to moderate-sized tree growing throughout in moist deciduous to evergreen forests of India and Myanmar (Gamble, 1972, p. 454).

Specimen—No. BSIP 36935.

Locality—Right bank of the upstream of Ghish River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Family—Apocynaceae

Genus—*Alstonia* R. Br.

Alstonia mioscholaris sp. nov.

Pl. 14, figs 5, 7

There are a number of well-preserved specimens in the collection representing this species.

Description—Leaf simple, symmetrical, oblanceolate, preserved length 6.5 cm, maximum width 2.2 cm; apex bluntly acute; base cuneate; margin entire; texture thick coriaceous; petiole indistinct; venation pinnate, brochidodromous; primary vein prominent, stout, almost straight; secondary veins with angle of divergence moderate (about 60°), running almost parallel to each other, moderate in thickness, slightly curved up, branched, intramarginal vein present just near the margin; inter-secondary veins present, normal, tertiary veins with angle of origin AO, ramified, transverse to exmedial, relationship to midvein oblique, distant; quaternary veins not distinctly visible.

Affinity—Oblanceolate shape, acute apex, cuneate base, entire margin, brochidodromous venation, presence of both inter-secondary and inramarginal veins are the important diagnostic features which indicate that the fossil leaves belong to the genus *Alstonia* R. Br. of the family Apocynaceae.

An examination of the leaves of various extant species of *Alstonia* R.Br. was done and it was observed that the fossil leaves resemble those of *A. scholaris* R. Br. in shape, size and venation pattern (F.R.I. Herbarium Sheet no. 15227; Pl. 14, figs 6, 8). Therefore, the fossil leaves are described as *A. mioscholaris* sp. nov. Bande and Srivastava (1990) also described the leaf-impression as *Alstonia scholaris* Brown from the shales in Mahuadanr Valley, Palamu District, Bihar which have been regarded by them to be younger than Mio-Pliocene.

The genus *Alstonia* R. Br. is represented by 50 species distributed in the Indo-Malayan region. In India, only four species are found, which occur throughout the sub-Himalayan tract ascending up to about 1,000 m, eastern Bengal and Assam, deciduous forests of Burma, western and southern India and Sri Lanka. *Alstonia scholaris* is a large evergreen tree with whorled leaves found throughout moist regions of India and Myanmar (Gamble, 1972, p. 483).

Holotype—Specimen no. BSIP 36936.

Locality—Right bank of the upstream of Ghish River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Family—Verbenaceae

Genus—*Callicarpa* Linn.

Callicarpa siwalika sp. nov.

Pl. 15, fig. 1

In all there are five well-preserved leaf-impressions; of them, one specimen is almost complete.

Description—Leaves simple, symmetrical, elliptic, preserved length 13.0 cm, lamina length 12.5 cm; apex broken; base obtuse; margin entire; texture chartaceous; petiole normal, preserved length 0.5 cm; venation pinnate, eucamptodromous; primary vein massive, almost straight; secondary veins 8 pairs visible, opposite to alternate, angle of divergence moderate (50°), uniform, thick, uniformly curved upward, joining supradjacent through arches; tertiary veins with angle of origin usually RR, percurrent, sinuous, mostly unbranched, relationship to midvein oblique to nearly right angle, predominantly

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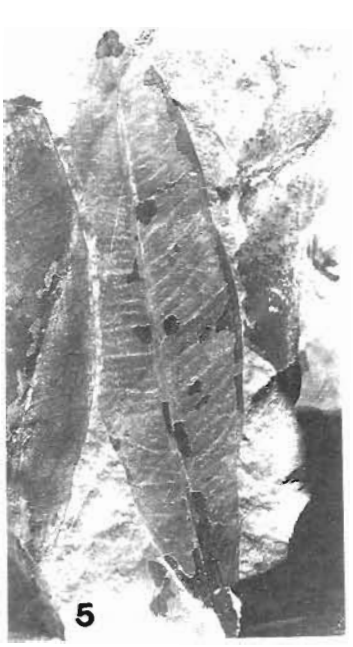
PLATE 14 →

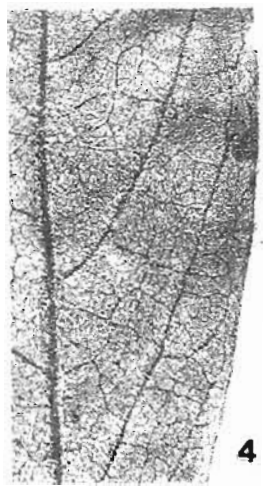
Diospyros koilabasensis Prasad 1990

1. A fossil leaf in natural size showing shape, size and venation pattern; Specimen no. BSIP 36935.
2. *Diospyros montana*—a modern leaf in natural size showing similarity in shape, size and venation pattern.
3. A part of fossil leaf magnified to show details of venation, × 2.5.
4. A part of modern leaf magnified showing similarity in venation pattern, × 2.5.

Alstonia mioscholaris sp. nov.

5. A fossil leaf in natural size showing shape, size and venation; Specimen no. BSIP 36936.
6. *Alstonia scholaris*—a modern leaf showing similarity in shape, size and venation pattern.
7. A part of fossil leaf magnified to show details of venation, × 3.
8. A part of modern leaf magnified to show details of venation pattern, × 3.





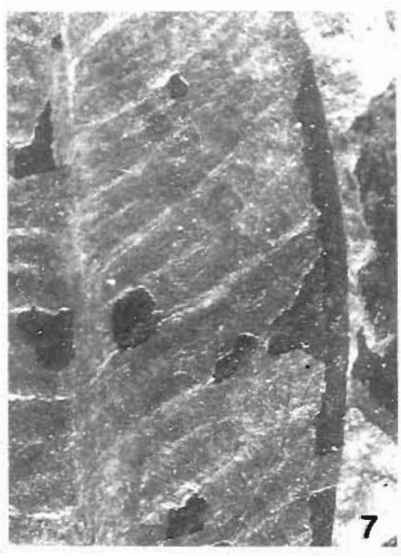


PLATE 14

alternate, distantly placed; quaternary veins well-preserved, thin, forming orthogonal meshes; areoles well-developed, mostly quadrangular, medium-sized; veinlets not distinctly visible.

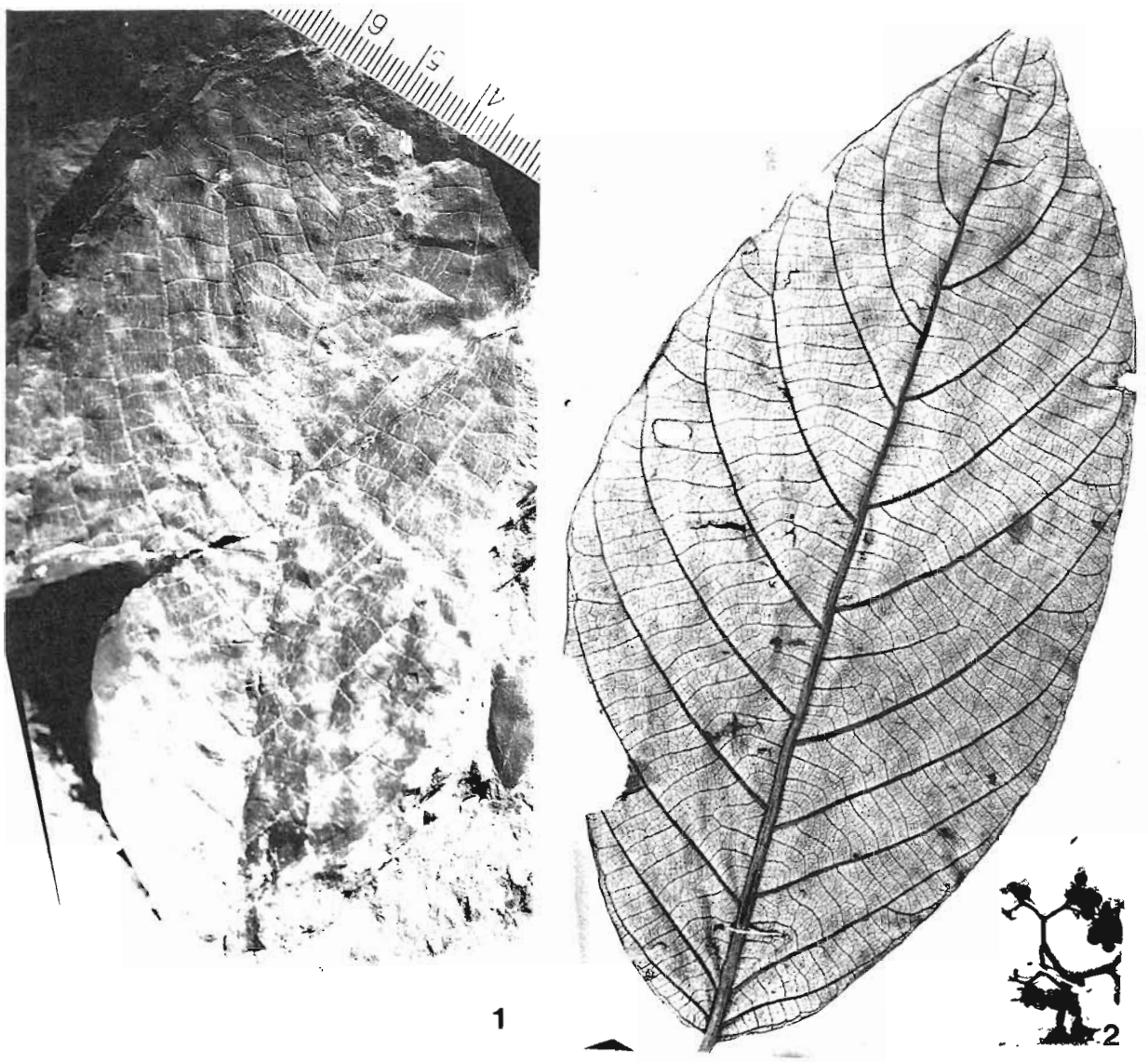


PLATE 15

Callicarpa siwalika sp nov.

1 A fossil leaf in natural size showing shape, size and details of venation, Specimen no BSIP 36937

2. *Callicarpa arborea*—a modern leaf showing close similarity in shape, size and details of venation.

Affinities—The distinguishing features of the fossil leaves are shape elliptic, base obtuse, margin entire, texture chartaceous, venation eucamptodromous, primary vein massive and almost straight, tertiary veins percurrent, distant and quaternary veins orthogonal which collectively indicate their resemblance with the leaves of *Callicarpa* Linn. of the family Verbenaceae. The fossil leaves have been compared with 35 modern species of *Callicarpa* Linn., in which they show close resemblance with *C arborea* Roxb. and in some characters with *C. wallichiana* Walp. and *C. tomentosa* Murr But in *C. wallichiana* Walp. the tertiary veins make fine meshwork as compared to the fossil, while the leaves of *C. tomentosa* Murr. are more thick and coriaceous due to which the venation, particularly of tertiary veins cannot be seen. Thus the fossil leaves show close similarity with those of *C arborea* Roxb. (C.N. Herbarium Sheet no. 47789; Pl. 15, fig. 2).

As far as we are aware, so far there is no fossil record of the genus *Callicarpa* Linn. and therefore a new species *C. siwalika* has been established to accommodate the fossil leaves.

The genus *Callicarpa* Linn. is represented by 140 species of shrubs or trees distributed in tropical to subtropical regions of the world. *C. arborea* Roxb. is a moderate-sized tree occurring in deciduous to

evergreen forests. It commonly occurs in the sub-Himalayan tract from Ganga River eastwards up to 1,350 m, Rajmahal and Chhota Nagpur Hills, eastern Bengal, Darjeeling Hills, Chittagong and Myanmar in upper mixed forests. It is also found in terai area in the dry mixed forests and savannahs (Gamble, 1972, p. 525).

Holotype—Specimen no. BSIP 36937.

Locality—Right bank of the upstream of Ghish River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Family—Lauraceae

Genus—*Cinnamomum* Schaeffer.

Cinnamomum sp.

Pl. 16, figs 1-3

There are three leaf-impressions in the collection representing this genus.

Description—Leaf simple, symmetrical, narrow oblong, preserved length 12.5 cm, maximum width 4.0 cm; apex broken (acute, preserved in one specimen; Pl. 16, fig. 3); base nearly obtuse; margin entire; texture coriaceous; petiole not preserved; venation parallelodromous, three veins arising at the base running parallel and converging at the apex; primary vein prominent, stout, slightly curved; secondary veins arising from the outer primaries, angle nearly uniform, moderate in thickness, uniformly curving upward taking a deep long course along margin, joining adjacent secondaries; tertiary veins with angle of origin RR, percurrent, usually unbranched, relationship to midvein approximately at right anlges, predominantly opposite, nearly distant; quaternary veins thin, orthogonal; areoles well-developed.

Affinities—Leaf narrow oblong, apex acute, base somewhat obtuse, venation parallelodromous, three primary veins arising from the base and converging at the apex, tertiary veins with angle of origin RR and percurrent are those distinguishing features which clearly indicate their affinity with the genus *Cinnamomum* Schaeffer. of Lauraceae.

The fossil leaves have been compared with a number of modern species of *Cinnamomum* Schaeffer. but it has been observed that there is a great variation in the size and shapes of leaves and even in the point of origin of primary veins. This has been observed in case of fossil leaves too (Pl. 16, figs 1, 2, 3). Therefore, it is rather difficult to reach up to specific level merely on the basis of limited morphological characters of *Cinnamomum* leaves. Thus the leaf-impressions are preferably described as *Cinnamomum* sp.

The fossil leaves described so far by various workers have been reported under four genera, viz., *Cinnamomum* Schaeffer., *Cinnamomiphyllum* Nothorst 1888, *Cinnamomoides* Seward 1925 and *Cinnamomophyllum* Krausel & Weyland 1950. According to Lakhanpal and Guleria (1981), 86 species of *Cinnamomum* Nothorst, nine species of *Cinnamomophyllum* Krausel & Weyland and five species of *Cinnamomoides* are known so far both from India and abroad.

From India, there are four fossil records of *Cinnamomum* leaves. Pathak (1969) reported a leaf—*Cinnamomum* sp. cf *C. tamala* Nees from the Middle Siwalik sediments in Mahanadi River Section, near Darjeeling. *C. eokachchhensis* Lakhanpal & Guleria 1981 was reported from the Eocene of Kachchh, western India; while *C. palaeotamala* Lakhanpal & Awasthi 1984 was described from the Siwalik sediments of Bhikhnathoree West Champaran District, Bihar. Recently, a new species, viz., *C. mioinuctum* Prasad 1990 has also been described from the Siwalik sediments exposed near Koilabas, Nepal.

The genus *Cinnamomum* Schaeffer. comprises 250 species of evergreen trees and shrubs occurring in tropical and subtropical regions of East Asia and Indo-Malaya (Willis, 1973, p. 255). Gamble (1972) enumerated 24 species of this genus from India.

Specimen—Nos. BSIP 36938, 36939 and 36940.

Locality—Right and left banks of Ghish River and right bank of the upstream of Ramthi River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Genus—*Actinodaphne* Nees

Actinodaphne palaeoangustifolia sp. nov.

Pl. 16, figs 4, 5

This species is based on four leaf-impressions showing satisfactory preservation.

Description—Leaf simple, symmetrical, narrow lanceolate; preserved lamina length 5.8 cm, maximum width 1.3 cm; apex acute; base acute; margin entire; texture chartaceous; petiole not preserved; venation pinnate, craspedodromous; primary vein prominent, moderate, straight; secondary veins six pairs visible, angle of divergence acute (about 50°), narrow, opposite to alternate, uniformly curving upward and running to a greater distance along margin, unbranched; tertiary veins not clearly visible.

Affinities—The diagnostic features of the leaves such as leaf symmetrical, narrow lanceolate in shape, apex acute, base acute, venation craspedodromous, secondary veins with acute angle of divergence and running to a greater distance along the margins indicate their affinity with those of the genus *Actinodaphne* Nees of the family Lauraceae.

The leaves of about 35 extant species of *Actinodaphne* Nees were examined and observed that they resemble the leaves of *A. angustifolia* Nees (C.N. Herbarium Sheet no. 385780; Pl. 16, fig. 6) and to some extant *A. campanulata* Hook. and *A. sikkimensis* Meissn. But *A. campanulata* Hook. differs from the fossil specimen in having somewhat broad-lanceolate leaves. The secondaries are also comparatively distantly placed. *A. sikkimensis* Meissn., though resembles in shape, the secondary veins arise comparatively at more acute angle as compared to the fossil leaves and thus differs from them.

So far, there are six records of the fossil leaves of *Actinodaphne* but all from outside India. These are : *A. hoelttingensis* Ett. and *A. frangula* Ett. from the Tertiary of Hoelting, *A. dolichophylla* Takhtajan 1963 from U.S.S.R., *A. germari* (Heer) Fried from the Oligocene of Germany, *A. martiniana* Crie 1888 from the Pliocene of Java, and *A. nipponica* Tanai & Suzuki 1963 from the Tertiary of northern Honshu, Japan. The present fossil leaves do not resemble any of the above known species and therefore have been described as *Actinodaphne palaeoangustifolia* sp. nov.

The genus *Actinodaphne* Nees consists of about 60-70 species distributed in eastern Asia and Indo-Malayan regions. It is represented by evergreen shrubs or trees (Willis, 1973, p. 18). *Actinodaphne angustifolia* is a large evergreen tree and occurs in Assam, Khasi Hills, Sylhet, Rinkheong Valley, Chittagong Hills and Myanmar (Gamble, 1972, p. 569).

Holotype—Specimen no. BSIP 36942.

Locality—Right bank of the upstream of Ghish River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Family—Euphorbiaceae

Genus—*Mallotus* Lour.

Mallotus kalimpongensis sp. nov.

Pl. 16, fig. 7

It comprises only one well-preserved leaf-impression.

Description—Leaf simple, almost symmetrical, narrow elliptic, preserved lamina length 8.1 cm, maximum width 3.4 cm; apex slightly broken; base acute; margin entire; texture chartaceous; petiole not preserved; venation pinnate, simple, craspedodromous; primary vein moderate, slightly curved; secondary veins five pairs visible, angle of divergence acute, narrow (35°-45°), basal pair of secondary veins more acute than upper ones, alternate to opposite, moderate in thickness, uniformly curving upward, basal secondary veins forming several convex arches terminating at margin; tertiary veins with angle of origin RR, percurrent, unbranched, relationship to midvein oblique to right angle, predominantly opposite, close; quaternary veins fine, orthogonal, distinctly visible, areoles well-developed, mostly quadrangular.

Affinities—The diagnostic features of the fossil leaf are : narrow elliptic shape, acute base, entire margin, craspedodromous venation, basal pair of secondary veins forming convex branches which terminate at the margins and tertiary veins percurrent and opposite. These features strongly indicate the affinities of fossil leaf with those of *Mallotus* Lour. of the family Euphorbiaceae.

In order to compare and find out the specific affinity of the present fossil leaf about 45 modern species were examined. Of them, *M. philippinensis* Muel. Arg. shows closest similarity with the specimen. *M. kurzii* Hook.f. also have some characters resembling the fossil specimen but differs in having larger size of leaves (C.N. Herbarium Sheet no. 415525; Pl. 16, fig. 8).

So far, there are three fossil records of *Mallotus* leaves from the Tertiary of India. Pathak (1969, pl. 2, fig. 9) described *M. philippinensis* from Mahanadi River section, Darjeeling District, but the specimen is fragmentary and the identification does not convince. Mathur (1978) reported *Mallotus* sp. from near Jawalamukhi, Himachal Pradesh; its identification is also doubtful. An incomplete leaf referred to *Mallotus philippinensis* has also been recorded by Puri (1947b) from the Karewa beds (Plio-Pleistocene), Kashmir. However, this is the first record of *Mallotus* leaves from the Siwalik sediments and has been described as *Mallotus kalimpongensis* sp. nov., the specific name is after the Kalimpong Forest Division, from where the fossil leaf was collected.

Besides, a fossil wood—*Mallotoxylon keriense* Lakhanpal & Dayal 1964 has been reported from the

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PLATE 16 →

Cinnamomum sp.

1-3. Fossil leaves in natural size showing variation in shapes and size: Specimen no. BSIP 36938; 2, BSIP 36939; 3, BSIP 36940.

Actinodaphne palaeoangustifolia sp. nov.

4. A fossil leaf in natural size showing shape, size and venation: Specimen no. BSIP 36941.

5. Another fossil leaf in natural size showing variation in shape and size; Specimen no. BSIP 36942.

6. *Actinodaphne angustifolia*—a modern leaf in natural size showing similarity in shape, size and venation pattern.

Mallotus kalimpongensis sp. nov.

7. A fossil leaf in natural size showing shape, size and details of venation; Specimen no. BSIP 36943.

8. *Mallotus philippense*—a modern leaf showing similarity in shape, size and venation pattern.

PLATE 16

Deccan Intertrappean beds, which further supports its occurrence during the Tertiary Period in India.

Mallotus Lour. is a large genus and comprises about 140 species widely distributed in tropical Africa, east and South-east Asia, Indo-Malaya, New Celedonia, Fiji, North and East Australia (Willis, 1973, p. 689). *M. philippinensis*, with which the fossil leaf resembles, is a large shrub or small tree growing in deciduous to evergreen forest of the sub-Himalayan tract from Punjab eastward ascending to 1,500 m, Bengal, western, central and southern India, Andaman Island, Myanmar and Sri Lanka (Gamble, 1972, p. 620; Brandis, 1971, p. 590).

Holotype—Specimen no. BSIP 36943.

Locality—Right bank of the upstream of Ghish River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Genus—*Macaranga* Thouars

Macaranga siwalika sp. nov.

Pl. 17, figs 1, 2

There is only one leaf-impression with counterpart.

Description—Leaf slightly asymmetrical, ovate, preserved lamina length 6.5 cm, maximum width 5.6 cm; apex broken; base peltate; margin appearing entire; texture chartaceous-coriaceous; petiole not preserved; venation pinnate, simple, craspedodromous; primary vein prominent, moderate, straight; secondary veins only 3 pairs visible, first pair of secondaries originating from a single point at the base giving rise branches in the basal portion of leaf in radiating manner and terminating at margins, nearly sub-opposite, angle of divergence (50°-55°), moderate, uniformly curved upward; tertiary veins with angle of origin mostly RR, percurrent, relationship to midvein oblique, predominantly opposite; quaternary veins still fine, orthogonal; areoles developed.

Affinities—The important characteristic features of the fossil leaf like base peltate, shape ovate, margin entire, venation craspedodromous, first pair of secondary originating from a single point in the basal part producing branches in radiating manner, tertiary veins predominantly opposite, percurrent with angle of origin RR collectively suggest the affinity of the fossil leaf with those of *Macaranga* of the family Euphorbiaceae.

The fossil leaf was compared with four modern available species, viz., *M. peltata* Muell. Arg., *M. pustulata* King, *M. denticulata* Muell. Arg. and *M. indica* Wight. Out of them, the fossil leaf closely resembles *M. peltata* (C.N. Herbarium Sheet no. 416212; Pl. 17, fig. 3) in all features.

Uptil now no fossil wood or leaf of the genus *Macaranga* Thouars are known from the Tertiary of India. To designate this new finding, a new species *Macaranga siwalika* has been established.

The genus *Macaranga* Thouars consists of 280 species of trees or shrubs found in Africa, Madagascar, Australia and Indo-Malayan regions (Willis, 1973, p. 680). *M. peltata* Muell. Arg. is a middle-sized evergreen tree growing in Western Ghats from Konkan southwards, very common in evergreen forests, Hills of Orissa, Bengal and Sri Lanka (Brandis, 1971, p. 592).

Holotype—Specimen no. BSIP 36944.

Locality—Right bank of the upstream of Ghish River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Family—Urticaceae

Genus—*Ficus* Linn.

Ficus retusoides Prasad 1990

Pl. 17, figs 4, 6

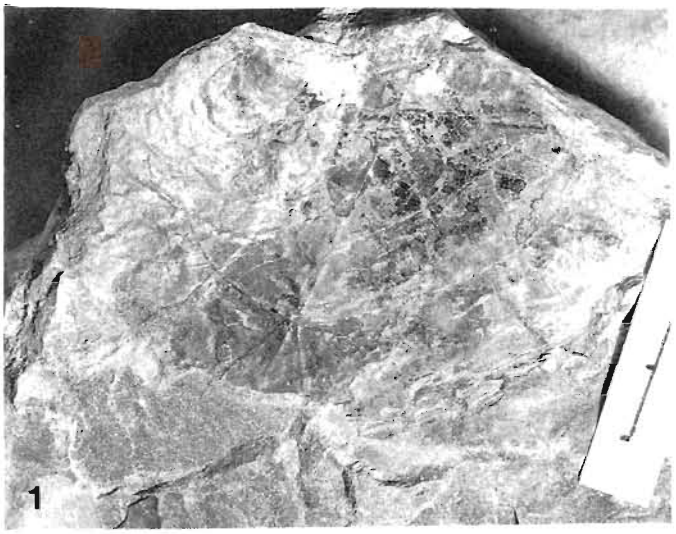
In consists of only one well-preserved leaf impression.

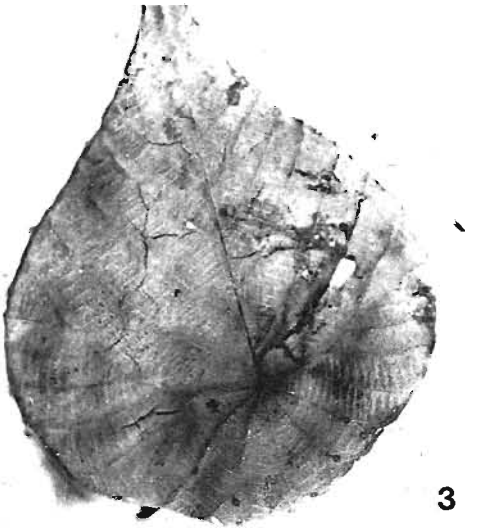
Description—Leaf simple, symmetrical, wide elliptic, preserved lamina length 4.5 cm, maximum width 4.0 cm; apex appearing acuminate (slightly broken); base broken; margin entire; texture coriaceous; venation pinnate, brochidodromous; primary vein prominent, moderate, straight; secondary veins with about 15 pairs visible, angle of divergence wide acute (65°-70°), closely placed, nearly uniform, moderate, slightly curving upward, branched, forming an intramarginal vein; intersecondary veins simple, frequent; tertiary veins with angle of origin AR-OR, percurrent to reticulate, relationship to midvein oblique, quaternary veins fine.

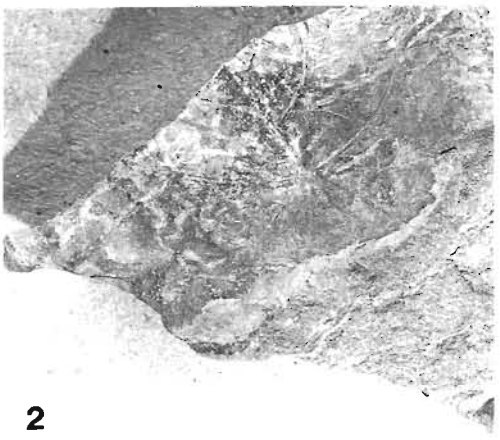
Affinities—The important distinguishing features of the fossil leaf are shape wide elliptic, apex acuminate, margin entire, venation brochidodromous and secondary veins closely placed forming intramarginal vein which indicate its affinity with those of *Ficus* Linn. of Moraceae.

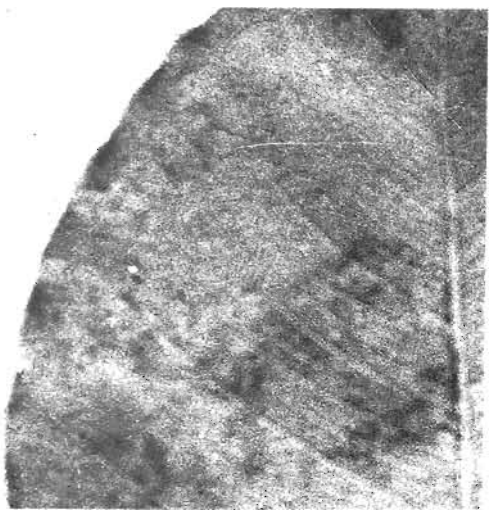
In order to find out the nearest resembling species with the present fossil specimen about 60 modern species of *Ficus* were examined and it was observed that the fossil leaf shows closest similarity with *F. retusa* Linn. *F. obtusifolia* Roxb. also possesses some common characters but differs in having more prominent and distantly placed secondary veins. Further, the angle of divergence of secondaries is also different from the fossil leaf. Thus in all morphological features the fossil leaf has been found closest to *F. retusa* (C.N. Herbarium Sheet no. 436620; Pl. 17, figs 5, 7).

The genus *Ficus* Linn. has a good representation of fossil leaves from the Tertiary of India and abroad. From India, there are 10 records of the fossil leaves of









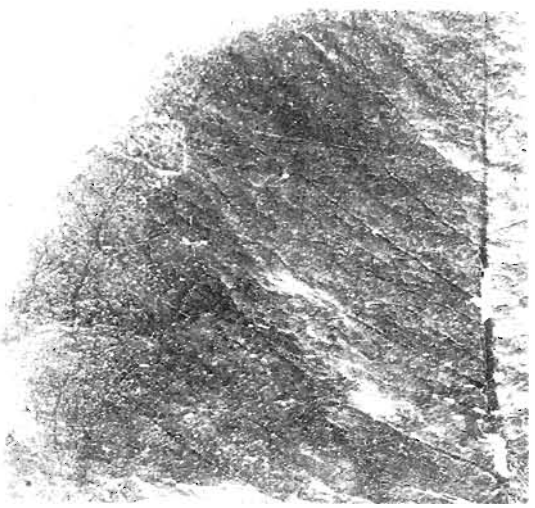


PLATE 17

Macaranga siwalika sp. nov.

1, 2 Fossil leaf in natural size showing shape, size and venation; Specimen no BSIP 36944 (with counterpart).

3 *Macaranga peltata*—a modern leaf in natural size showing similarity in shape, size and venation

Ficus retusoides Prasad 1990

4 A fossil leaf in natural size showing shape, size and details of venation; Specimen no. BSIP 36945

5 *Ficus retusa*—a modern leaf in natural size showing similarity in shape, size and venation pattern.

6. A part of fossil leaf magnified to show details of venation, × 2.

7 A part of modern leaf magnified showing details of venation, × 2

this genus. They are *F. cunia* Puri 1947a and *F. nemoralis* Puri 1948 from the Karewa beds, Kashmir; *F. cunia* Gupta & Jiwan 1972 from Dharamsala beds of Bilaspur, Himachal Pradesh; *F. precunia* Lakhanpal 1969 from Siwalik beds of Jawalamukhi; *F. arnottiana* Mahajan & Mahabale 1973 and *F khariensis* Lakhanpal & Guleria 1982 from the Miocene of Kutch; *F. champarense* Lakhanpal & Awasthi 1984 from the Siwalik beds exposed near Bhikhnathoree; *F. retusoides* Prasad 1990 (comparable with extant *F. retusa*), *F. precunia* Lakhanpal and *F. nepalensis* Prasad 1990 all from Koilabas, Nepal. Bande and Srivastava (1990) also reported three species, viz., *F. foveolata* Wall. ex Miq., *F. glaberrima* Bl. syn. *F. infectoria* Roxb. and *F. tomentosa* Roxb. from the shales (younger to Mio-Pliocene) of Mahuadanr Valley, Palamu District, Bihar. Of these, the present fossil specimen resembles *F. retusoides* Prasad 1990 described from the Siwalik sediments of Koilabas.

There are as many as 800 species of *Ficus* Linn. chiefly growing in Indo-Malayan region. *Ficus retusa* Linn., with which the fossil leaf resembles, is a large evergreen tree growing in sub-Himalayan tracts from Kumaon eastwards, Assam, Khasi Hills, eastern Bengal and forests of Sunderbans, Myanmar, Andaman Islands and Sri Lanka (Gamble, 1972, p. 644).

Specimen—No. BSIP 36945.

Locality—Right bank of the upstream of Ghish River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Ficus oodlabariensis sp. nov.

Pl. 18, figs 1, 2, 4

There are three well-preserved leaf-impressions, one with counterpart.

Description—Leaf simple, symmetrical, narrow elliptic, preserved length 7.4 cm, lamina length 7.0 cm, maximum width 4.4 cm; apex broken; base obtuse, margin entire; texture coriaceous; petiole normal, 0.4 cm in length; venation pinnate, brochidodromous forming prominent intra-marginal vein; primary vein prominent, stout, straight; secondary veins with angle of divergence wide acute (70°-75°), nearly uniform, somewhat moderate in thickness, curving upward, opposite to alternate, intersecondary veins present, simple, frequent; intramarginal veins prominent; tertiary veins with angle of origin AR-OR, percurrent to reticulate, branched, relationship to midvein oblique, close; quaternary veins still fine, randomly oriented, trigonal to polygonal meshes; areoles well-developed.

Affinities—Leaf symmetrical, shape narrow elliptic, base obtuse, margin entire, venation brochidodromous, secondary veins wide acute, closely placed, presence of intra-marginal and inter-secondary veins are such morphological characters on the basis of which the fossil leaf is comparable to the leaves of *Ficus* Linn.

Critical examination of about 60 extant species of *Ficus* Linn. revealed that the fossil leaves show close similarity with those of *F. benjamina* Linn. (F.R.I. Herbarium Sheet no. 108480; Pl. 18, figs 3, 5).

Besides, all the fossil species described so far by various authors were examined and it has been found that the present specimen differs from them in all morphological characters and venation and hence described as *Ficus oodlabariensis* sp. nov. The specific name signifies its occurrence from near Oodlabari, a small town near Siliguri.

Ficus benjamina Linn., with which the present fossil specimens show close resemblance, is a very large tree with dooping branches. It occurs in the eastern Himalayan valleys, sub-Himalayan tract, Assam, eastern Bengal, Chittagong, Bihar and Chhota Nagpur and throughout Myanmar. It also commonly occurs in Java (Gamble, 1972, pp. 640, 641).

Holotype—Specimen no. BSIP 36946.

Locality—Right bank of the upstream of Ghish River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

OTHER FRUITS

Family—Sapindaceae

Genus—*Euphoria* Comm. ex Juss.

Euphoria longanoides sp. nov.

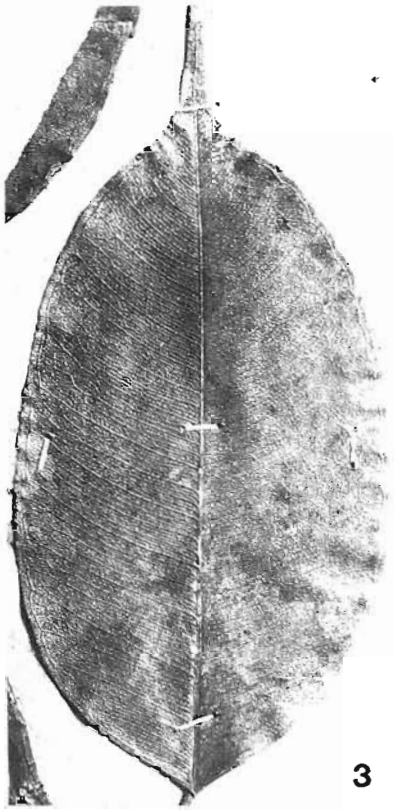
Pl. 19, fig. 4

It is based on a single specimen (with counterpart) comprising three fossil fruits attached with peduncle.

Description—Three fruits preserved in a fascicle, ovate in shape, maximum length 1.00 cm, width 0.5 to 0.6 cm, a prominent central longitudinal mark visible, fruits show characteristic ornamentation, probably due to drying of pulpy aril.

Affinities—In shape, size, their mode of attachment to peduncle and ornamentation of fruit wall, the fossil fruits show their affinity with the fruits of extant *Euphoria longan* (Lour.) Steud (Pl. 19, fig. 5) of Sapindaceae and thus have been described as *E. longanoides* sp. nov.

Euphoria longan (Lour.) Steud, with which the present fossil resembles, is a large evergreen tree and occurs commonly in tropical forests of Western Ghats, Konkan, Kanara, Malabar, Anamalai, Travancore and Tinnelvelly hills, Sri Lanka and scarcely in Myanmar, Pegu and Yoma (Gamble, 1972, p. 198).



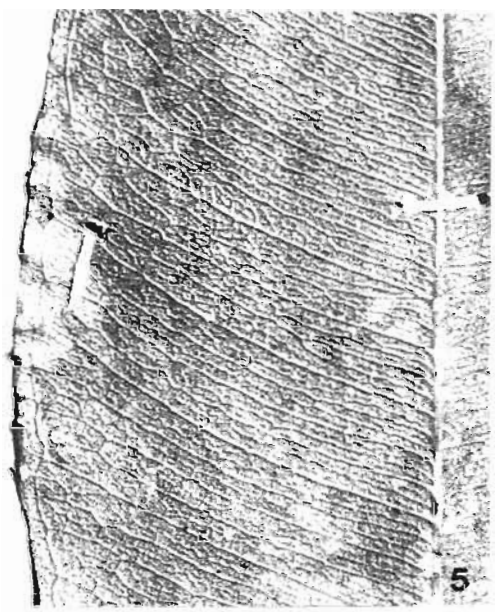


PLATE 18

Ficus oodlabarensis sp nov.

1, 2 Fossil leaf in natural size showing shape, size and details of venation: Specimen no. 36946

3 *Ficus benjamina*—a modern leaf in natural size showing similarity in shape, size and details of venation

4 A part of fossil leaf magnified to show details of venation, × 3.

5 A part of modern leaf magnified to show details of venation, × 3

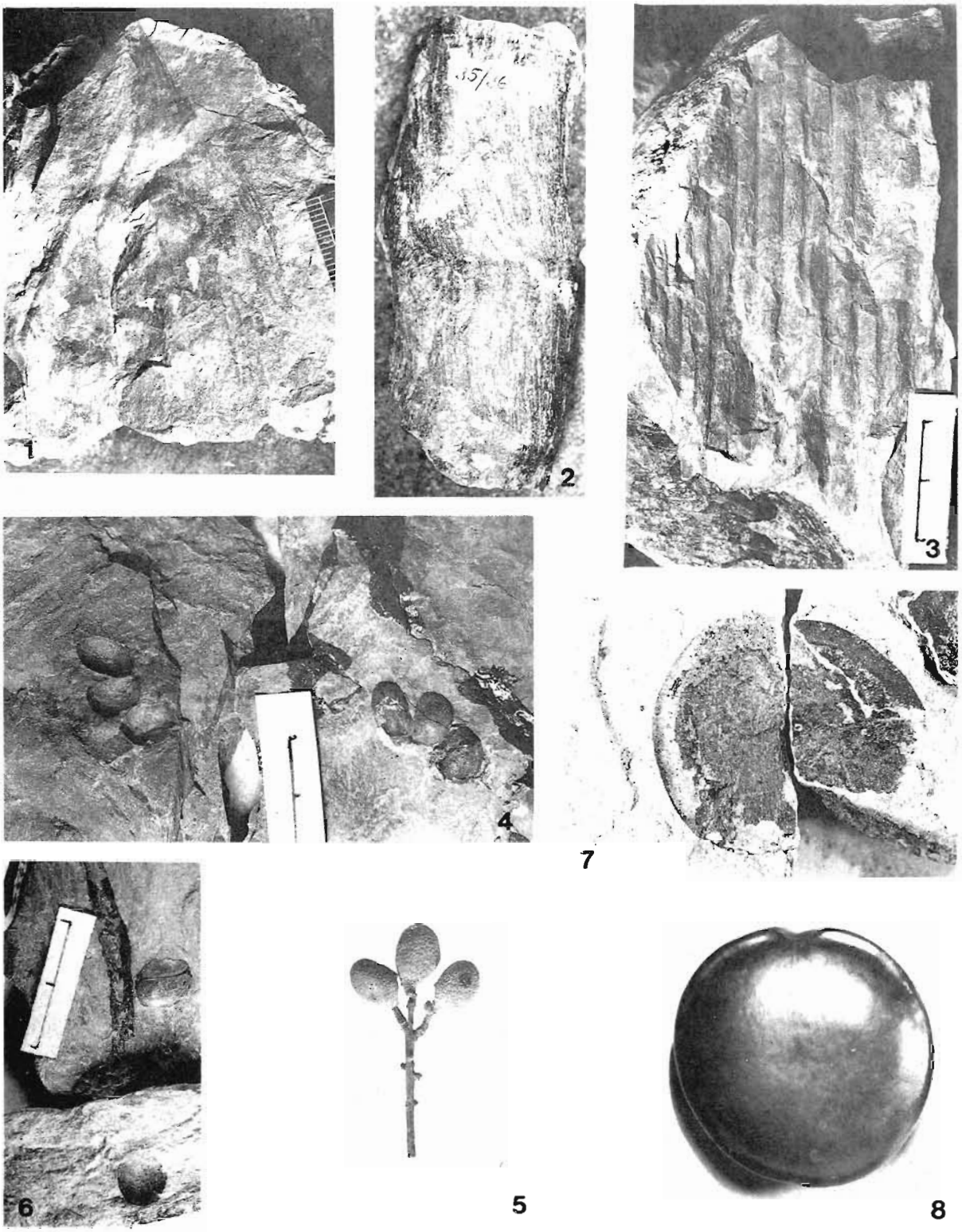


PLATE 19

1 3. *Bambusa* sp.—leaf impressions; 1, An apical part of fossil leaf, specimen no. BSIP 36950; 3, A middle part of leaf, Specimen no. BSIP 36952.

2 A bamboo fossil cast, Specimen no BSIP 36951

4 Fossil fruit type - 1, *Euphoria longanoides*; Specimen no. BSIP 36947.

5. Modern fruits of *Euphoria longan* showing close similarity in shape, size and mode of attachment in bunch.

6 Fossil fruit type - 2 (part and counterpart), *Bursera serratoides* sp. nov . Specimen no BSIP 36948

7 Fossil fruit type - 3, *Entada palaeoscandens* Awasthi & Prasad 1990, Specimen no. BSIP 36949

8 Modern fruit of *Entada scandens* showing similarity in overall shape and size.

Holotype—Specimen no. BSIP 36947.

Locality—Right bank of the upstream of Ghish River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

Family—Fabaceae

Genus—*Entada* Adans

Entada palaeoscandens Awasthi & Prasad 1990

Pl. 19, fig. 7

It is based on a single specimen preserved as cast in the sandstone.

Description—Seed flat thick, large in size, nearly orbicular in shape, about 4.5 cm in diameter, notch clearly visible.

Affinity—In shape, size, thickness and other morphological features, the fossil seed indicates its closest similarity to *Entada scandens* Benth. of Fabaceae (Pl. 19, fig. 8). Awasthi and Prasad (1990) have already described a similar seed—*Entada palaeoscandens*, belonging to the extant species *E. scandens*, from the Siwalik sediments of Suraikhola, western Nepal. Since the present fossil seed exhibits similar characters and also shows close resemblance with the same modern species, therefore it has been referred to *E. palaeoscandens* Awasthi & Prasad 1990. The present additional evidence of *Entada* fossil seed further confirms its wider distribution in the Himalayan foot-hills during Middle Miocene-Pliocene.

Entada scandens Benth., which resembles the fossil specimen, is a large climber and occurs in the forests of eastern Himalaya, eastern Bengal, west and south India, Andaman Islands, Sri Lanka and Myanmar (Gamble, 1972, p. 287).

Specimen—No. BSIP 36949.

Locality—Right bank of the upstream of Ghish River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

MONOCOTYLEDON

Family—Bambusaceae

Genus—*Bambusa* Schreb.

Bambusa sp.

Pl. 19, figs 1, 2, 3

There are two fragmentary leaf-impressions and one culm-impression in the collection.

Description—Leaves linear, preserved apical part of the leaf 7.6 cm long and 5.0 cm wide (Pl. 19, fig. 1); apex attenuate; preserved central part of another leaf 7.2 cm long and 5.0 cm wide (Pl. 19, fig. 3); midrib not visible; venation parallelodromous, lamina bearing parallel longitudinal veins of two types, prominent veins (in the apical part) placed at an interval of 0.2-0.3 mm, in central part at an interval of 0.7-0.8 mm, each interval with 8-9 fine interstitial veins visible on both sides without any cross-veins.

Culm-fragment 7.5 cm in length and 3.5 cm in width appearing to be the lower-part of the culm as it bears impressions of vegetative bud and roots at the node. The root-impressions are preserved as dots while the vegetative bud is oval, outwardly projected.

Affinity—The presentation of leaves as well as culm-impressions is not satisfactory and therefore it is rather difficult to relate them to any extant species of *Bambusa* of the family Bambusaceae. So far, there are two records of *Bambusa* (Bamboo) from the Siwalik sediments. Of them, Lakhanpal *et al.* (1987) described the impressions of leaf and culm from near Ranital, Himachal Pradesh and *Bambusa siwalika* Awasthi & Prasad 1990 resembling extant *Bambusa tulda* Roxb. was reported from the Chor Khola beds, Surai Khola area, Nepal. Like the present specimens, the material of Lakhanpal *et al.* was also fragmentary. However, the width of our leaf specimens is more as compared to the specimens of Awasthi and Prasad (1990) and thus do not exactly match with them. Therefore, the present specimens are being preferably described as *Bambusa* sp. On the basis of these records of *Bambusa* (Bamboo) it is obvious that it was widely distributed in the Himalayan foot-hills from Himachal Pradesh to West Bengal during Middle Miocene-Pliocene.

Specimen—Nos. BSIP 36951 (culm impression), 36950 and 36952 (leaf-impressions).

Locality—Left bank of the upstream of Ghish River and right bank of Ramthi River near Oodlabari, Darjeeling District, West Bengal.

Horizon—Lower-Middle Siwalik.

DISCUSSION

Floristics

The present assemblage recovered from the Siwalik sediments exposed near Oodlabari, Darjeeling District, West Bengal is represented by angiospermic plant remains comprising 33 species of impressions of leaves, fruits and a culm of Bamboo, belonging to 32 genera of 21 dicotyledonous families and a monocot family. Out of them, 11 genera are new to the Siwalik flora and eight have been identified as new to the Neogene flora of India. Besides, two families, viz., Tiliaceae and Compositae have been reported for the first time.

A systematic list of fossil plants representing the assemblage is as follows :

Dilleniaceae
Dillenia palaeoindica Prasad & Prakash 1984
Anonaceae
Mitrephora siwalika sp. nov.
Flacourtiaceae
Casearia pretomentosa sp. nov.
Alsodeia palaeozeylanica sp. nov.
Hydnocarpus palaeokurzii sp. nov.
Clusiaceae
Calophyllum suraikholaensis Awasthi & Prasad 1990
Dipterocarpaceae
Shorea siwalika sp. nov.
Hopea siwalika sp. nov.
Sterculiaceae
Pterospermum palaeobeyneanum sp. nov.
Tiliaceae
Grewia ghishia sp. nov.
Burseraceae
Bursera preserrata sp. nov.
B. serratoides sp. nov.
Sapindaceae
Euphoria longanoides sp. nov.
Anacardiaceae
Nothopegia eutravancorica sp. nov.
Bouea premacrophylla sp. nov.
Fabaceae
Bauhinia ramthiensis sp. nov.
Cynometra tertiara sp. nov.
Albizia palaeolebbek sp. nov.
Pongamia siwalika Awasthi & Lakhanpal 1990
Entada palaeoscandens Awasthi & Prasad 1990
Combretaceae
Combretum sahnii sp. nov.
Lythraceae
Lagerstroemia patelii Lakhanpal & Guleria 1981
Rubiaceae
Randia miowallichii Prasad 1990
Compositae
Vernonia palaeoarborea sp. nov.
Ebenaceae
Diospyros koilabasensis Prasad 1990
Apocynaceae
Alstonia mioscholaris sp. nov.
Verbenaceae
Callicarpa siwalika sp. nov.
Lauraceae
Cinnamomum sp.
Actinodaphne palaeoangustifolia sp. nov.
Euphorbiaceae
Mallotus kalimpongensis sp. nov.
Macaranga siwalika sp. nov.
Urticaceae
Ficus retusoides Prasad 1990
Ficus oodlabariensis sp. nov.
Bambusaceae
Bambusa sp.

It is obvious from the above list that family Fabaceae, represented by five genera, is most dominant in the assemblage followed by Flacourtiaceae and Dipterocarpaceae comprising three and two genera, respectively. The dominance of Fabaceae and presence of Dipterocarpaceae is quite significant both from palaeoecological and phytogeographical point of view.

Palaeoecology

Plant fossils are the reliable indicators of past climate, particularly when they are related to extant taxa. In a plant, the leaves are the most sensitive organs to the changing environment and thus allow to draw important conclusions for deciphering palaeoenvironment. According to Bailey and Sinnot (1916) there is a clear marked correlation between leaf margins and environment. They also opined that the leaves and leaflets with entire margin are overwhelmingly predominant in lowland tropical regions. Incidentally, the present fossil assemblage is chiefly represented by leaf-impressions (without cuticle) and therefore it has been possible to draw interesting conclusions on palaeoecology.

The plant megafossils recovered from the Siwalik sediments can be effectively used in interpreting palaeoecology and phytogeography of the region, because most of them closely resemble modern taxa. But before making such an attempt it is necessary to explore the distribution pattern of their corresponding extant taxa.

Present day distribution of the fossil taxa and their modern counterparts in different forest types is given in Table 1. The distribution pattern of the corresponding modern taxa of the present Siwalik florule clearly points towards a tropical climate with heavy rainfall in the foot-hills of West Bengal during Middle Miocene-Pliocene when the Siwalik sediments were deposited. Champion and Seth (1968) divided the tropical forests of India into seven types, viz., (i) Wet evergreen forests, (ii) semi-evergreen forests, (iii) moist deciduous forests, (iv) dry deciduous forests, (v) littoral and swamp forests, (vi) thorny deciduous forests, and (vii) dry evergreen forests. However, the present assemblage comprises such elements which can be broadly classified into first three types of forests.

The wet evergreen elements constitute 63.61 per cent of the total assemblage. They are *Dillenia palaeoindica, Mitrephora siwalika, Alsodeia palaeozeylanica, Hydnocarpus palaeokurzii, Calophyllum suraikholaensis, Shorea siwalika, Hopea siwalika, Grewia ghishia, Bursera preserrata, Nothopegia eutravancorica, Bouea premacrophylla, Pongamia siwalika, Cynometra tertiara,*

Table 1—Present day distribution of fossil taxa and their modern counterparts in different forest types

Fossil Taxa	Allied modern comparable species	Forest types						
		Wet evergreen forests	Semi-evergreen forests	Moist deciduous forests	Littoral and swamp forests	Dry deciduous forests	Thorn deciduous forests	Dry evergreen forests
Bambusa sp.	Bamboo			+				
Dillenia palaeoindica Prasad & Prakash 1984	*Dillenia indica* Linn.	+	+		+			
Mitrephora siwalika sp. nov.	*Mitrephora maingayi* Hook.f.Th.	+						
Casearia pretomentosa sp. nov.	*Casearia tomentosa* Roxb.		+	+				
Alsodeia palaeozeylanica sp. nov.	*Alsodeia zeylanica* Thw.	+						
Hydnocarpus palaeo-kurzii sp. nov.	*Hydnocarpus kurzii* King	+	+					
Calophyllum suraikholaensis Awasthi & Prasad 1990b	*Calophyllum polyanthum* Wall.	+						
Shorea siwalika sp. nov.	*Shorea assamica* Dyer	+	+					
Hopea siwalika sp. nov.	*Hopea wightiana* Wall.	+						
Pterospermum palaeo-heyneanum sp. nov.	*Pterospermum heyneanum* Wall.			+				
Grewia ghishia sp. nov.	*Grewia umbellifera* Bedd.	+						
Bursera preserrata sp. nov. (leaf)	*Bursera serrata* Colebr.	+	+					
B. serratoides sp. nov. (fruit)	*B. serrata* Colebr.							
Nothopegia eutravan-corica sp. nov.	*Nothopegia travancorica* Bedd.	+						
Bouea premacrophylla sp. nov.	*Bouea macrophylla* Griff.	+						
Bauhinia ramthiensis sp. nov.	*Bauhinia acuminata* Linn			+				
Cynometra tertiara sp. nov.	*Cynometra cauliflora* Linn.	+						
Albizia palaeolebbek sp. nov.	*Albizia lebbek* Benth.		+	+				
Pongamia siwalika Awasthi & Lakhanpal 1990	*Pongamia pinnata* Vent.				+	+		
Entada palaeoscandens Awasthi & Prasad 1990 (seed)	*Entada scandens* Benth.		+	+				
Combretum sahnii sp. nov.	*Combretum decandrum* Roxb.		+					
Lagerstroemia patelii Lakhanpal & Guleria 1981	*Lagerstroemia speciosa* Pers.			+	+			
Randia miowallichii Prasad 1990	*Randia wallichii* Hook. f.		+					
Vernonia palaeoarborea sp. nov.	*Vernonia arborea* Ham.	+	+					
Diospyros koilabasensis Prasad 1990	*Diospyros montana* Linn.	+		+				
Alstonia mioscholaris sp. nov.	*Alstonia scholaris* R. Br.	+						
Callicarpa siwalika sp. nov.	*Callicarpa arborea* Roxb.	+	+	+				

Cinnamomum sp.	*Cinnamomum* spp.	+	+	
Actinodaphne palaeo-angustifolia sp. nov	*Actinodaphne angusti-folia* Nees	+		+
Mallotus kalimpongensis sp. nov.	*Mallotus philippensis* Muel-Arg.		+	+
Macaranga siwalika sp. nov.	*Macaranga peltata* Muel-Arg.		+	+
Ficus retusoides Prasad 1990	*Ficus retusa* Linn.	+	+	
Ficus oodlabariensis sp. nov.	*Ficus benjamina* Linn.	+	+	
Euphoria longanoides sp. nov.	*Euphoria longan* (Lour.) Steud	+		

Vernonia palaeoarborea, *Alstonia mioscholaris*, *Cinnamomum* sp., *Actinodaphne palaeoangustifolia*, *Ficus retusoides*, *F. oodlabariensis* and *Euphoria longanoides*.

The evergreen and moist deciduous elements are represented by *Entada palaeoscandens*, *Randia miowallichii*, *Diospyros koilabasensis*, *Callicarpa siwalika*, *Macaranga siwalika* and *Bambusa* sp. which constitute 18.18 per cent of the total present assemblage.

The remaining 21.21 per cent elements are moist deciduous which include *Pterospermum palaeoheyneanum*, *Bauhinia ramthiensis*, *Albizia palaeolebbek*, *Lagerstroemia patelii*, *Mallotus kalimpongensis*, *Casearia pretomentosa* and *Combretum sahnii*.

The occurrence of mostly tropical evergreen with few moist deciduous elements in the present assemblage indicates the existence of luxuriant tropical evergreen forest during Siwalik sedimentation. On the contrary, according to Champion and Seth (1968) the present forests of this region are of tropical moist deciduous type which shows that there has been a considerable change in the climate of this region since Pliocene. The assemblage also includes some taxa resembling modern *Dipterocarpus alatus*, *Shorea assamica*, *Callicarpa arborea*, *Lagerstroemia speciosa*, etc. which have broader leaves with entire margins. The plants having leaves or leaflets with entire margins are overwhelmingly predominant in the low land area. But it is not certain that all the species should respond equally to the changing environment with equal rapidity. However, heavy rain-fall must have been quite helpful in providing them a fertile soil cover for their luxuriant growth.

It is worth mentioning that in excessive wet conditions the leaves of many plants develop "drip-tip" which serve to drain off rain water quickly. These drip tips have been observed especially in the tropical to sub-tropical rain forests; they are unusual in the rain defficient areas (Richards 1952; Schwarzbach, 1963). Incidentally, the present floral assemblage comprises 28 such species which bear conspicuous "drip-tip". Thus it may be further inferred that the vegetation in the foot-hills of Bengal comprised mixed mesophytic and broad-leaved forests communities with overwhelming majority of evergreen elements.

Phytogeography

It is generally believed that after land connections had established between India and South-east Asia, a number of plants migrated from South-east Asia to India and vice-versa. This is evidenced by the plant fossil records of a number of taxa which were present during Palaeogene in South-east Asia, appeared in Neogene in the Indian subcontinent (Lakhanpal, 1970; Bande & Prakash, 1986). It is also worth to mention that during migration and adaptation to new environment some species became extinct. This process of extinction and migration of endemic plants from one land mass to another or vice-versa must have been controlled by several important factors like physiography, environment, climate, wind, rains, light, dispersal mechanism of seeds, floods, fertility of soil, etc.

It is interesting that out of 33 fossil taxa of the present assemblage, the modern equivalent of 19 taxa occur both in India and Malaya. These are *Bambusa* sp., *Mitrephora maingayi*, *Hydnocarpus kurzii*, *Calophyllum polyanthum*, *Hopea wightiana*, *Cynometra cauliflora*, *Pongamia pinnata*, *Entada scandens*, *Lagerstroemia speciosa*, *Randia wallichii*, *Vernonia arborea*, *Diospyros montana*, *Alstonia scholaris*, *Callicarpa arborea*, *Cinnamomum* sp., *Mallotus phillippinensis*, *Ficus retusa*, *F. benjamina* and *Euphoria longana*. These undoubtedly indicate that there has been a fair exchange of plants during Neogene between the two subcontinents.

Besides, the present assemblage consists of eight such taxa which do not occur at present in West Bengal. They are *Mitrephora maingayi*, *Grewia umbellifera*, *Nothopegia travancorica*, *Hydnocarpus kurzii*, *Calophyllum polyanthum*, *Shorea assamica*, *Hopea wightiana* and *Bouea macrophylla*. *Mitrephora maingayi* Hook.f.Th. presently grows in the tropical evergreen forests of Java, Malaya Peninsula, Chittagong (Bangla Desh), Martaban Hills (Myanmar), and Sri Lanka. It is also surviving in the evergreen forests of north-east

India (Assam). *Grewia umbellifera* Bedd. has migrated to southern India where it occurs in the evergreen forests of Western Ghats and Konkan. *Nothopegia travancorica* Bedd. is now confined to the evergreen forests of Kerala, where the conditions are more suitable for its luxuriant growth. *Hydnocarpus kurzii* King, an evergreen tree, is found in the evergreen forests of Pegu, Yoma and most frequent in Martaban Hills in Myanmar. *Calophyllum polyanthum* Wall. occurs in the evergreen forests of Malaya Peninsula, Andaman and Nicobar Islands and Sri Lanka. *Shorea assamica* Dyer which has failed to survive in the foot-hills region of West Bengal, is now confined to the evergreen forests of Naga Hills, Sibsagar and Lakhimpur District (Upper Assam). *Hopea wightiana* Wall., which is also an evergreen element, now occurs in the evergreen forests of Malaya Peninsula region. *Bouea macrophylla* Griff. has also shifted from the foot-hill zone of West Bengal to the evergreen forests of Myanmar, Andaman Island and Sunderbans.

Thus the migration of these eight taxa from West Bengal to other suitable regions obviously reflects a change in the climate from Siwalik onwards. Besides, this also suggests that the plants have a sense of selecting suitable climate as well as their adaptability in the changing environment for their longer survival.

The occurrence of the members of two phytogeographically important families—Fabaceae and Dipterocarpaceae in the assemblage is also significant. Family Fabaceae is represented by five species, viz., *Bauhinia ramthiensis* sp. nov., *Cynometra tertiara* sp. nov., *Albizia palaeolebbek* sp. nov., *Pongamia siwalika* Awasthi & Lakhanpal 1990 and *Entada palaeoscandens* Awasthi & Prasad 1990. While two taxa—*Hopea siwalika* sp. nov. and *Shorea siwalika* sp. nov. belong to Dipterocarpaceae. The frequency distribution of fossil plants of different families known so far from various Siwalik localities indicates the dominance of Fabaceae followed by Dipterocarpaceae. Dipterocarpaceae which is known in India from Miocene onwards, most probably migrated from western Malaysia to Philippine, northwards to Myanmar and then to India where the conditions were favourable for its luxuriant growth. 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 the Himalaya causing a fall in the annual average temperature and precipitation.

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REFERENCES

Acharyya SK 1968. A note on the geology of the eastern Himlayan foot-hills of Darjeeling-Western Duars area. *Q. J. geol. Min. metall. Soc. India* **40** : 43-44.

Acharyya SK 1972. Geology of the Darjeeling Coalfield with a reference to its intrusives. *Rec. geol. Surv. India* **99** (2) : 75-101.

Acharyya SK 1975. Structure and stratigraphy of the Darjeeling frontal zone, eastern Himalaya. *Recent geol. studies in Himalaya, geol. Surv. India, Misc Publ.* **24** (1) : 71-90.

Agarwal A 1988. Occurrence of *Bouea* in the Neyveli lignite deposits, India. *Geophytology* **18** (2) : 166-168.

Auden JB 1935. Traverses in the Himalayas. *Rec. geol. Surv. India* **69** (2) : 133-167.

Awasthi N 1974a. Occurrence of some dipterocarpaceous woods in the Cuddalore series of south India. *Palaeobotanist* **21** (3) : 339-351.

Awasthi N 1974b. Neogene angiospermous woods. *In* Surange KR *et al.* (editors)—*Aspects & appraisal of Indian Palaeobotany* : 341-354. Birbal Sahni Institute of Palaeobotany, Lucknow.

Awasthi N 1977 Revision of *Hopeoxylon indicum* Navale and *Shoreoxylon speciosum* Navale from the Cuddalore series near Pondicherry. *Palaeobotanist* **24** (2) : 102-107

Awasthi N 1979. Three new leguminous woods from the Cuddalore series near Pondicherry. *Palaeobotanist* **26** (2) : 157-166.

Awasthi N 1980. Two new dipterocarpaceous woods from the Cuddalore series near Pondicherry. *Palaeobotanist* **26** (3) : 248-256.

Awasthi N 1981. Fossil wood belonging to Sterculiaceae and Lythraceae from Cuddalore series near Pondicherry. *Palaeobotanist* **27** (2) : 182-189.

Awasthi N 1984. Studies on some carbonised woods from Neyveli Lignite deposits, India. *Geophytology* **14** (1) : 82-95.

Awasthi N 1992. Changing patterns of vegetation through Siwalik succession. *In* Venkatachala BS & Singh HP (editors)—*Four Decades of Indian Palaeobotany, Palaeobotanist* **40** : 312-327

Awasthi N, Guleria JS & Lakhanpal RN 1980. A fossil dicotyledonous wood from the Pliocene of Mothala District, Kutch, western India. *Palaeobotanist* **26** (3) : 199-205.

Awasthi N & Lakhanpal RN 1990. Additions to the Neogene florule from near Bhikhnathoree, west Champaran District, Bihar. *Palaeobotanist* **37** (3) : 278-283.

Awasthi N & Prasad M 1990a. Some more leaf-impressions from the Lower Siwalik beds of Koilabas, Nepal. *Palaeobotanist* **37** (3) : 299-305.

Awasthi N & Prasad M 1990b. Siwalik plant fossils from Surai Khola area, western Nepal. *In* Jain KP & Tiwari RS (editors)—*Proc. Symp. Vistas in Indian Palaeobotany, Palaeobotanist* **38** : 298-318.

Awasthi N & Srivastava Rashmi 1990. Some new carbonised woods from Neogene of Kerala Coast and their bearing on palaeoclimate. *In* Jain KP & Tiwari RS (editors)—*Proc. Symp. Vistas in Indian Palaeobotany, Palaeobotanist* **38** : 285-292.

Bailey IW & Sinnot EW 1916. Investigations on the phylogeny of the angiosperm-6. The climatic distribution of certain types of angiosperm leaves. *Am. J. Bot.* **3** 23-29.

Bande MB & Khatri SK 1980. Some more fossil woods from the Deccan Intertrappean beds of Mandla District, Madhya Pradesh, India. *Palaeontographica* **173B** (4-6) : 147-165.

Bande MB & Prakash U 1980. Fossil woods from the Tertiary of West Bengal, India. *Geophytology* **10** (2) : 146-157

Bande MB & Prakash U 1983. Fossil dicotyledonous woods from the Deccan Intertrappean beds near Shahpura, Mandla District, Madhya Pradesh. *Palaeobotanist* **31** (1) : 13-29.

Bande MB & Prakash U 1986. The Tertiary flora of South-east Asia

wih remarks on its palaeoenvironment and phytogeography of the Indo-Malayan region. *Rev. Palaeobot. Palynol.* **49** : 203-233.

Bande MB & Srivastava GP 1990. Late Cenozoic plant-impressions from Mahuadanr Valley, Palamu District, Bihar. *Palaeobotanist* **37** (3) : 331-336.

Bose PN 1890. Darjeeling coal between Lish and Ramthi rivers, etc. *Rec. geol. Surv. India* **23** (4) 237-258.

Bose PN 1891. Further note on the Darjeeling coal exploration. *Rec geol. Surv. India* **24** (4) : 212.

Brandis D 1971 *Indian trees.* Bishen Singh Mahendra Pal Singh, Dehradun.

Brandis D 1972. *The flora of north, west and central India.* Bishen Singh Mahendra Pal Singh, Dehradun.

Champion HG & Seth SK 1968. *A revised survey of the forest types in India.* Manager of Publications, Delhi.

Chowdhury KA & Ghosh SS 1946. On the anatomy of *Cynometroxylon indicum* gen. et sp. nov., a fossil dicotyledonous wood from Nailalung, Assam. *Proc. natn. Inst. Sci. India* **12** (8) : 435-447.

Chowdhury KA & Ghosh SS 1958. *Indian woods*—**1**. Manager of Publications, Delhi.

Cowan AM & Cowan JM 1927 The trees of northern Bengal. *The 3rd working plan for the Kalimpong Forest Division.*

Cowan JM 1929. The forests of Kalimpong : an ecological account. *Rec. bot. Surv. India* **12** (1) : 1-72.

Crie ML 1988. Researches sur la flora Pliocene de Java. *Samml. Geol. Reichsmus Leiden Beitr. Geol. Ost. Asiens Austr.* **5**.

Dalvi NS & Kulkarni AR 1982. Leaf cuticles from lignite beds of Ratnagiri District, Maharashtra. *Geophytology* **12** : 223-232.

Dayal R & Chaudhri RS 1967 Dicotyledonous leaf-impressions from Nahan beds, north-west Himalayas. *Curr. Sci.* **36** (7) : 181-182.

Desch HE 1954. Manual of Malayan timbers II. *Malayan For. Rec.* **15** : 329-762.

Desch HE 1957. Manual of Malayan timbers. *Malaya For Rec.* **15** : 1-328.

Dilcher DL 1974. Approaches to the identification of angiosperm leaf remains. *Bot. Rev.* **40** (1) 1-157.

Gamble JS 1895. List of trees, shrubs and large climbers of the Darjeeling District. *Indian For.* **1**.

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

Ganguly S & Rao DP 1970. Stratigraphy and structure of Tertiary foot-hill region, Darjeeling District, West Bengal with special reference to Daling, Darjeeling and Gondwana rocks. *Proc. Him. Geol. Sem., New Delhi.*

Geyler H Th. 1875. *Uber fossile pflanzen von Borneo.*

Ghosh AK & Roy SK 1979. A new species of *Calophyllum* from the Miocene beds of Birbhum District, West Bengal, India. *Curr. Sci.* **48** (18) : 823-824.

Ghosh AMN 1956. Recent advances on geology and structure of eastern Himalayas. *Proc. 43rd Indian Sci. Congr.* **2** : 85-89.

Ghosh PK & Roy SK 1979. A new species of *Callophyllum* from the Miocene beds of Birbhum District, West Bengal, India. *Curr. Sci.* **48** (18) : 823-824.

Ghosh PK & Roy SK 1981 Fossil woods of *Millettia* and *Albizia* from the Tertiary beds of West Bengal, India. *Curr. Sci.* **50** (6) : 288.

Guleria JS 1983. Some fossil woods from the Tertiary of Kachchh, western India. *Palaeobotanist* **31** (2) : 109-128.

Guleria JS 1984. Leguminous woods from the Tertiary of district Kachchh, Gujarat, western India. *Palaeobotanist* **31** (3) : 238-254.

Guleria JS 1986. Fossil woods from the Tertiary sediments near Jaisalmer, Rajasthan and their bearing on the age of Shumar Formation. *Spec. Indian geophytol. Conf., Pune* (Abstract).

Guleria JS 1990. Fossil dicotyledonous woods from Bikaner, Rajasthan, India. *Geophytology* **19** : 182-188.

Guleria JS 1991. Fossil dicotyledonous woods from the Intertrappean beds of Kutch, Gujarat *Birbal Sahni Birth Centenary Palaeobotanical Conference, Lucknow* (Abstract), p. 41.

Guleria JS 1992. Neogene vegetation of peninsular India. *In* Venkatachala BS & Singh HP (editors)—*Four Decades of Indian Palaeobotany, Palaeobotanist* **40** : 285-311.

Gupta VJ & Jiwan JS 1972. Plant fossils from the Dharamsala beds of Bilaspur District, Himachal Pradesh. *Sci. Cult.* **38** : 99.

Heim A & Gansser A 1939. Central Himalaya. *Mem. Soc. Helv. Sci. Nat.* **73** : 1-245.

Hickey LJ 1973. Classification of the architecture of dicotyledonous leaves. *Am. J. Bot.* **60** : 17-33.

Hollick A 1936. The Tertiary floras of Alaska. *U.S. geol. Surv. profess. paper* **182** : 1-173.

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

Hooker JD 1878. *The flora of British India.* **II**. London.

Hooker JD 1882. *The flora of British India.* **III**. Kent.

Hooker JD 1885. *The flora of British India.* **IV** Kent.

Ishida SK 1970. The Noroshi flora of Noto peninsula, central Japan. *Mem. Fac. Sci., Kyoto Univ.*, ser. *Geol. Min.* **37** (1) : 1-112.

Kramer K 1974a. Die tertiären hölzer Sudost-Asians (Unter Ausschluss der Dipterocarpaceae) 1. Teil. The Tertiary woods of Southeast Asia (Dipterocarpaceae excluded)—Part 1. *Palaeontographica* **145B** : 45-181

Kramer K 1974b. Die tertiären hölzer Sudost-Asians (Unter Ausschluss der Dipterocarpaceae). 2. Teil. The Tertiary woods of Southeast Asia (Dipterocarpaceae excluded)—Part 2. *Palaeontographica* **145B** : 1-150.

Krasser F 1903. Konstatin von Ettingshausen's studien uber die fossile flora von Auricanga in Brasilien. *Sber. Acad. Wiss. Wien.* **112** : 1-19.

Kräusel R 1929. Fossile Pflanzen aus dem Tertiär von Sud-Sumatra. *Verh. K. ned. geol. Mijnb.* **9** : 1-44.

Kräusel R & Weyland H 1950. Kritischen Untersuchungen Kutikularanalyse Tertiarer blatter—1 *Palaeontographica* **91B** : 8-92.

Kurien TK 1962. Geological mapping in parts of Jalpaiguri and Darjeeling District, West Bengal, in Toposheets—78B/9, 13F/10. *Geol. Surv. India Progr. Report (Unpublished) for field season 1961-62.*

Lakhanpal RN 1969. A new *Ficus* from the Siwalik beds near Jawalamukhi (Himachal Pradesh). *Publ. Centre Adv. study Geol., Punjab Univ., Chandigarh* **5** : 17-19.

Lakhanpal RN 1971. Geological history of the Dipterocarpaceae. *In* Lakhanpal RN (Editor)—*Symp. Origin & phytogeography of angiosperms* : 30-39. Birbal Sahni Institute of Palaeobotany, Lucknow.

Lakhanpal RN & Awasthi N 1965. Fossil woods of *Calophyllum* from the Tertiary of south India. *Palaeobotanist* **13** (3) : 328-336.

Lakhanpal RN & Awasthi N 1984. A Late Tertiary florule from near Bhikhnathoree in West Champaran District, Bihar. *In* Sharma AK *et al.* (editors)—*Proc. Symp. Evol. Bot. & Biostratigr., A.K. Ghosh Commem. Vol., 1979 : Curr. trends in life Sci.* **10** : 587-596.

Lakhanpal RN & Dayal R 1964. *Mallotoxylon keriense* gen. et sp. nov., a fossil dicotyledonous wood from the Deccan Intertrappean series, India. *Palaeobotanist* **11** (3) : 143-153.

Lakhanpal RN & Dayal R 1966. Lower Siwalik plants from near Jawalamukhi, Punjab. *Curr Sci.* **35** (3) : 209-211.

Lakhanpal RN & Guleria JS 1981. Leaf-impressions from the Eocene of Kachchh, western India. *Palaeobotanist* **28-29** : 353-373.

Lakhanpal RN & Guleria JS 1982. Plant remains from the Miocene of Kachchh, western India. *Palaeobotanist* **30** (3) : 279-296.

Lakhanpal RN & Guleria JS 1987. Fossil leaves of *Dipterocarpus* from the Lower Siwalik beds near Jawalamukhi, Himachal Pradesh. *Palaeobotanist* **35** (3) : 258-262.

Lakhanpal RN, Guleria JS & Awasthi N 1984. The fossil floras of Kachchh III—Tertiary megafossils. *Palaeobotanist* **33** : 228-329.

Lakhanpal RN, Prakash U & Awasthi N 1981. Some more dicotyledonous woods from the Tertiary of Deomali, Arunachal Pradesh, India. *Palaeobotanist* **27** (3) : 232-252.

Lakhanpal RN, Prakash U & Bande MB 1978. Fossil dicotyledonous

woods from the Deccan Intertrappean beds of Mandla District in Madhya Pradesh. *Palaeobotanist* **25** : 190-204.

Lakhanpal RN, Tewari AP & Awasthi N 1987. Occurrence of Bamboo in the Siwalik beds near Jawalamukhi, Himachal Pradesh. *Palaeobotanist* **35** (3) : 258-262.

Lemoigne Y 1978. Flora Tertiares de la haute valuee de l' Omo (Ethiopie). *Palaeontographica* **165B** : 89-157.

Mahajan DR & Mahabale TS 1973. Quaternary flora of Maharashtra-I. The Pravera River Basin, district Ahmednagar, Maharashtra. *Geophytology* **2** (2) : 175-177

Majumdar NC 1979. Dilleniaceae. *Fasc. flora of India* **2** : 1-16.

Mallet FR 1875. On the geology and mineral resource of the Darjiling District and the western Duars. *Mem. geol. Surv. India* **11** (1) : 1-96.

Mani MS 1974. *Ecology and biogeography of India.* The Hague, Netherlands.

Mathur AK 1978. Some fossil leaves from the Siwalik Group. *Geophytology* **8** (1) : 98-102.

Menzel P 1920. Uber pflanzen reste aus basalttuffen des Kamorun gebeites. *Beitr. geol. Erfossch Schutzieb.* **18** : 16-32.

Mishra VP 1984. Report on the search for fossils in the Siwalik beds between Tista River and Lethi Nala (Darjeeling District), West Bengal. *Progress report for the field season 1980-81 (unpublished). Geol. Surv. India.*

Nathorst AG 1888. Zur fossilen flora Japan. *Palaeont. Abh.* **4** : 195-250.

Pathak NR 1969. Megafossils from the foot-hills of Darjeeling District, India. *In* Santapau H *et al.* (editors)—*J. Sen Mem. Vol.* : 379-384. Bot. Soc. Bengal, Calcutta.

Pawde MB 1966. Geological mapping in parts of Darjeeling District, West Bengal. *Progr. Report (unpublished) for field season 1965-66, Geol. Surv. India.*

Pawde MB 1972. A note on the geology of the area to the east and south-east of Kalimpong, Darjeeling District, West Bengal. *Rec. geol. Surv. India* **99** (2) : 67-74.

Pearson RS & Brown HP 1932. *Commercial timbers of India.* **1** & **2**. Manager of Publications, Calcutta.

Pithawala MB 1942. Physiographic division of India, Burma and Ceylon. *Sci. Cult.* **7** (11) : 533-543.

Pons D 1978. *Calophyllites mesaensis* nov. gen. nov. sp., Guttiferae fossil de Falan (Formation Mesa Colombie). *Congr. natn. Soc. Sav. Nancy* **103** : 201-209.

Prakash U 1965. Fossil wood of *Lagerstroemia* from the Tertiary of Burma. *Curr. Sci.* **34** (16) : 484-485.

Prakash U 1966a. Some fossil dicotyledonous woods from the Tertiary of eastern India. *Palaeobotanist* **14** (1-3) : 223-235.

Prakash U 1966b. Fossil woods of *Cassia* and *Cynometra* from the Tertiary beds of Mikir Hills, Assam. *Cent. Adv. Study Geol., Punjab Univ., Chandigarh* **3** : 93-100.

Prakash U 1973. Fossil woods from the Tertiary of Burma. *Palaeobotanist* **20** (1) : 48-70.

Prakash U 1975. Fossil woods from the Lower Siwalik beds of Himachal Pradesh, India. *Palaeobotanist* **22** (3) : 192-210.

Prakash U 1978. Fossil woods from the Lower Siwalik beds of Uttar Pradesh, India. *Palaeobotanist* **25** : 376-392.

Prakash U 1979. Some more fossil woods from the Lower Siwalik beds of Himachal Pradesh, India. *Him. Geol.* **8** : 61-68.

Prakash U 1981. Further occurrence of fossil woods from the Lower Siwalik beds of Uttar Pradesh, India. *Palaeobotanist* **28-29** : 374-388.

Prakash U & Awasthi N 1971. Fossil woods from the Tertiary of eastern India—11. *Palaeobotanist* **18** (3) : 219-225.

Prakash U & Dayal R 1965. Fossil woods of *Grewia* from the Deccan Intertrappean Series, India. *Palaeobotanist* **13** (1) : 17-24.

Prakash U, Du Nai-Zheng & Tripathi PP 1992. Fossil woods from Tipam sandstone of north-east India with remarks on palaeoenvironment of the region during the Middle Miocene. *Biol. Mem.* **18** (3) : 1-26.

Prakash U & Prasad M 1984. Wood of *Bauhinia* from the Lower Siwalik beds of Uttar Pradesh, India. *Palaeobotanist* **32** (2) : 192-210.

Prakash U & Tripathi PP 1970a. Fossil woods from the Tertiary of Hailakandi, Assam. *Palaeobotanist* **18** (1) : 20-31.

Prakash U & Tripathi PP 1970b. Fossil woods from the Tipam sandstones near Hailakandi, Assam. *Palaeobotanist* **18** (2) : 183-191

Prakash U & Tripathi PP 1974. Fossil woods from the Tertiary of Assam. *Palaeobotanist* **21** (3) : 305-316.

Prakash U & Tripathi PP 1975. Fossil dicotyledonous woods from the Tertiary of eastern India. *Palaeobotanist* **22** (1) : 51-62.

Prasad M 1988. Some more fossil woods from the Lower Siwalik sediments of Kalagarh, Uttar Pradesh, India. *Geophytology* **18** (2) : 135-144.

Prasad M 1990a. Some more leaf-impressions from the Lower Siwalik beds of Koilabas, Nepal. *Palaeobotanist* **37** (3) : 299-305.

Prasad M 1990b. Fossil flora from the Siwalik sediments of Koilabas, Nepal. *Geophytology* **19** (1) : 79-105.

Prasad M 1990c. Occurrence of lauraceous wood from the Siwalik sediments, India. *Geophytology* **19** (2) : 191-192.

Prasad M 1993. Siwalik (Middle Miocene) woods from the Kalagarh area in the Himalayan foot-hills and their bearing on palaeoclimate and phytogeography. *Rev. Palaeobot. Palynol.* **76** : 49-82.

Prasad M & Prakash U 1984. Leaf-impressions from the Lower Siwalik beds of Koilabas, Nepal. *Proc. V Indian geophytol. Conf., Lucknow, Spec. Publ.* : 246-256. The Palaeobotanical Society, Lucknow.

Prasad M & Prakash U 1987. Occurrence of Malayan dipterocarps in the Siwalik sediments of Uttar Pradesh. *Geophytology* **17** (2) : 245-255.

Puri GS 1947a. The occurrence of tropical Fig (*Ficus cunia* Buch. Ham.) in the Karewa beds of Liddarmarg, Pir Panjal Range, Kashmir with remarks on the subtropical forests of the Kashmir Valley during the Pleistocene. *J. Indian bot. Soc* **26** (3) : 131-135.

Puri GS 1947b. Some fossil leaves of *Mallotus philippensis* from the Karewa beds at Laredura and Liddarmarg, Pir Panjal, Kashmir *J. Indian bot. Soc.* **26** (3) 125-129.

Puri GS 1948. The flora of the Karewa Series of Kashmir and its phytogeographical affinities with chapters on the methods in identification. *Indian forests* **24** (3) : 105-122.

Purkayastha SK 1982. *Indian woods* **4**. Dehradun.

Ramanujam CGK & Rao MRR 1966a. Occurrence of *Cynometroxylon indicum* Chowdhury & Ghosh from the Cuddalore Sandstone series. *Curr Sci.* **35** (6) : 158-159.

Ramanujam CGK & Rao MRR 1966b. A fossil wood resembling *Bauhinia* from the Cuddalore series of south India. *Curr Sci.* **35** (22) : 575-577.

Ramanujam CGK & Rao MRR 1967. A new species of *Shoreoxylon, S. krauselii* sp. nov. from the Tertiary of south India. *Curr. Sci.* **36** (6) : 439-441.

Ramanujam CGK & Rao MRR 1969. *Shoreoxylon krauselii* sp. nov., a new dipterocarpaceous wood from the Cuddalore series of south India. *In* Santapau H *et al.* (editors)—*J. Sen Mem. Vol.* : 253-258. Bot. Soc. Bengal, Calcutta.

Rawat MS 1964-65. *Bauhinioxylon indicum* gen. et sp. nov., a new dicotyledonous fossil wood from India. *Proc. combined 51st & 52nd Indian Sci. Congr.* **23** : 425.

Richards PW 1981. *The tropical rain forest.* Cambridge Univ. Press, Cambridge.

Ridley HN 1967 *The flora of the Malaya peninsula*—**1**. Reeve & Co., Great Britain.

Roy SK & Ghosh PK 1979. *Shoreoxylon bengalensis* sp. nov., a fossil wood of Dipterocarpaceae from the Miocene beds of West Bengal, India. *Proc. Indian Sci. Congr., Hyderabad* **3** : 64.

Santapau H & Henry AN 1973. *A dictionary of the flowering plants in India.* New Delhi.

Schwarzbach M 1963. *Climates of the past : an introduction to paleoclimatology.* D. Van Nostrand Co. Ltd., London (translated & edited by Richard O. Muir).

Seward AC 1925. Notes sur la flore Cretacique du Greenland etude critique. *Soc. Geol. Belg. Publ.* : 229-262.

Seward AC & Conway VM 1935. Additional Cretaceous plants from the Western Greenland. *K. Svensk. Vetensk-Akad. Handl.* **15** : 1-51.

Shukla VB 1950. *Sahnipushpam* gen. nov. and other plant remains from the Deccan Intertrappeans. *Palaeobot. India.* 7in : *J. Indian bot. Soc* **29** (1) : 29.

Singh T & Prakash U 1980. Leaf-impressions from the Siwalik sediments of Arunachal Pradesh. *Geophytology* **10** (1) : 104-107.

Soloman-Calvi W 1934. Die pflanzen des Neozoi Kums. *Oberrheinischer Fossil Katalog Lieferunge* **3** (10) : 1-153.

Srivastava GP & Bande MB 1992. Fossil wood of *Terminalia* and *Lagerstroemia* from the Late Cenozoic beds of Mahuadanr, Palamu District, Bihar *Palaeobotanist* **39** (3) : 333-337.

Srivastava GP, Mishra VP & Bande MB 1992. Further contribution to the Late Cenozoic flora of Mahuadanr, Palamu District, Bihar *Geophytology* **22** : 229-234.

Takhtajan A 1969. *Flowering plants : origin and dispersal.* Smithsonian Inst. Press, Washington.

Tanai T & Suzuki N 1963. Miocene flora of South-western Hokkaido, Japan Part-2. Systematic consideration. *Tertiary floras of Japan* **1-2** : 97-149. Assoc. Commem. *80th Anniv. Geol. Surv. Japan, Tokyo* : 9-149.

Trivedi T 1956. Fossil dicotyledonous leaf-impressions from the Intertrappean beds of Bharatwara, Nagpur District. *J. palaeont. Soc. India* **1** : 186-188.

Velenovsky J 1889. Kvetenaveskeho Conomanu. *Razpr. Matprir. K. Ceske spol. Nauk* **3** : 1-75.

Verma CP 1968. On a collection of leaf-impressions from Haridwar. Uttar Pradesh. *J. palaeont. Soc. India* **5-9** : 93-98.

Willis JC 1973. *A dictionary of the flowering plants and ferns.* Cambridge Univ. Press, Cambridge.