Siwalik plant fossils from Surai Khola area, western Nepal

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A part of the collection of plant fossils comprising leaf-impressions and a seed from the Siwalik sediments of Surai Khola area, south of Dang Valley, has been studied. The leaves have been assigned to 21 species belonging to 19 genera and 18 families of monocotyledons and dicotyledons, viz., Marantaceae, Poaceae (Gramineae), Arecaceae (Palmae), Annonaceae, Flacourtiaceae, Clusiaceae (Guttiferae), Dipterocarpaceae, Anacardiaceae, Fabaceae (Leguminosae), Combretaceae, Ebenaceae, Myristicaceae and Euphorbiaceae. The assemblage consists of mostly tropical evergreen to semi evergreen elements indicating tropical and warm humid conditions during their deposition. However, gradual changes in the climatic conditions in the area from tropical and humid to tropical and dry towards Upper Siwalik is reflected by the fossil leaves.

Key-words—Leaf-impressions, Seed, Siwalik sediments, Neogene (Nepal).

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साराँश

पश्चिमी नेपाल में सुराई खोला क्षेत्र से शिवालिक अश्मित पादप

नीलाम्बर अवस्थी एवं महेश प्रसाद

डाँग घाटी के दक्षिण में सुराई खोला क्षेत्र के शिवालिक अवसादों से एकत्र अश्मित पौधों के संग्रह के एक भाग की पर्ण-छापों तथा बीजों का अध्ययन किया गया। पर्ण-छापों को द्विबीजपत्रीयों एवं एकबीजपत्रीयों के 13 कुलों से सम्बद्ध 19 प्रजातियों एवं 21 जातियों से अभिनिर्धारित किया गया है। ये मैरेन्टेसी, पोएसी, अॅरेकेसी, ऍनोनेसी, फ़्लेकोर्शिएसी, क्लूसियेसी, डिप्टेरोकार्पेसी, ऍनाकार्डिएसी, फैबेसी, कॉम्ब्रीटेसी, ऍबीनेसी, मिरिस्टीकेसी एवं यूफ़ोर्बिएसी नामक कुल हैं। इस समुच्चय में अधिकतर सदाहरित से अर्धसदाहरित अवयव विद्यमान हैं जिससे निक्षेपण के समय उष्णकटिबन्धीय से नम एवं गर्म परिस्थितियों का होना इंगित होता है। हालाँकि, अश्मित पत्तीयों की उपस्थिति से इस क्षेत्र में उपरि शिवालिक की ओर उष्णकटिबन्धीय एवं नम से उष्णकटिबन्धीय एवं शुष्क जलवायवी परिस्थितियों में धीरे-धीरे परिवर्तन व्यक्त होता है।

THE sedimentary rocks exposed along Mahendra Rajmarg (National Highway) between Surainaka and Rangsing Khola covering a distance of about 16 km in the foot-hills of the Surai Khola area, South of Dang Valley, Nepal represent a complete and uninterrupted sequence of the Siwalik Group (see locality map in: Corvinus, 1990, p. 295). Considering the thickness of 5,500 m the sediments (Corvinus 1988a, 1988b) and the amount of plant material deposited therein, this sequence is one of the best and richest in plant fossils among the known Siwalik exposures in India and Nepal. Therefore, the main object of undertaking systematic study of plant fossils of the Surai Khola area is to build up the floral succession in stratigraphic sequence in order to understand the floral history and palaeoecological and phytogeographical implications. This would serve as a model for the Siwalik studies.

The litho- and biostratigraphic studies of the Surai Khola sequence have been carried out by Corvinus (1988a, 1988b) and the supplimentary data pertaining to this have also been published in this volume. She recognised the whole Siwalik sediments of Surai Khola area into six units, viz., (i) Bankas beds, (ii) Paira Khola beds, (iii) Chor Khola beds, (iv) Surai Khola beds, (v) Dobata beds, and (vi) Dhan Khola beds in ascending order (Corvinus, 1990, p. 296). Of these, the first four units are rich in plant fossils comprising mostly leaves, carbonised woods and occasionally seeds and fruits. Leaves,

seeds and fruits are generally found in carbonaceous shales and calcareous sandstones, sandy shales, clays and mudstones whereas the carbonised woods occur in pockets or lenses within the sandstones.

Photographs of modern comparable species have been provided to show similarity with the fossil leaves/leaflets.

FLORISTICS

The leaves and a seed described here represent only a part of a big collection of fossil plants from Surai Khola sequence and have been assigned to 21 species belonging to 19 genera and 13 families of both monocotyledons and dicotyledons. The terminology used for describing them is after Hickey (1973) and Dilcher (1974).

SYSTEMATIC DESCRIPTION

Monocotyledons
Family—Marantaceae

Genus—*Clinogyne* Salisb.

Clinogyne ovatus sp. nov.
Pl. 1, figs 6, 7, 8; Pl. 2, fig. 1

This species is represented by four specimens, two of them are almost complete.

Description—Leaves simple, seemingly asymmetrical, one side of lamina is bigger than the other, ovate; preserved length and width 4.0 × 2.0 cm, 5.2 × 3.0 cm and 5.2 × 3.0 cm and 5.2 × 4.8 cm respectively; apex broken, appearing acute; base not clearly discernible; margin entire; texture chartaceous; petiole missing; venation eucamptodromous; primary vein prominent, almost straight, moderately thick at the base, gradually thining and ultimately diminishing towards apex; secondary veins numerous, arising from midrib, curving up and running parallel towards apex and gradually diminishing, lower secondaries running upwards along margin, angle of divergence narrow acute (20°-40°), maximum distance between two secondaries 1 mm; tertiary veins absent.

Discussion—The above features of the fossil leaves clearly indicate that they are monocotyledonous and resemble those of the genus *Clinogyne* Salisb. On comparison with the leaves of several species of *Clinogyne* it was found that in shape, size, number of secondary veins and their course, the fossil leaves resemble those of *Clinogyne grandis* Benth. & Hook.

There are about 8 species of *Clinogyne*, known to occur in the Indian subcontinent. *C. grandis* is a woody shrub found in savanah of Burma, Sub-Himalayan tract and Andaman Islands and Malay peninsula (Hooker, 1884).

Holotype—Specimen no. BSIP 36479.

Paratype—Specimen no. BSIP 36480, 36481.

Horizon & locality—Surai Khola beds (stratigraphically highest leaf containing horizon of the Surai Khola sequence); near Surai Khola bridge, Surai Khola area.

Family—Arecaceae

Genus—*Caryota* Linn.

Caryota siwalika sp. nov.
Pl. 1, figs 3, 4

There are three leaflets (pinnules) representing this species, two having nearly 2/3 basal part and the third middle part. One of the pinnules is attached to the rachis.

Description—Pinnules simple, asymmetrical; oblanceolate to traingular in shape, preserved length and width of pinnules 5.0 × 4.0 cm 5.0 × 2.0 cm and 7.0 × 4.0 cm respectively; apex of one of the pinnules seemingly praemorsly lobed; base cuneate, margin of lower half seems to be entire; texture coriaceous; petiolule indistinguishable from basal part of lamina; venation parallelodromous, about 10-12 primary veins arising from the base of lamina and running parallel towards apex, secondary and tertiary veins absent.

Discussion—In shape, size, venation pattern and mode of attachment to the rachis, the fossil leaflets (pinnules) compare with *Caryota* Linn. in general and *C. urens* Linn. in particular. Among other members of the family Arecaceae, the pinnules of *Didymosperma* H. Wendle. & Drude and *Wallichia* Roxb. are more or less similar to our fossil pinnules. However, in the absence of a prominent midrib the fossil pinnules can easily be differentiated from them.

Caryota urens, the likely modern counterpart of *Caryota siwalika* sp. nov. is distributed in the sub-Himalayan tract from Nepal eastwards ascending to 1,600 m, Assam, Khasi Hills (Meghalaya), Manipur, Chittagong in Bangladesh, Upper Burma, Pegu Yoma, in the evergreen forests of Western Ghats (India), Sri Lanka and Malaya (Brandis, 1971, p. 564).

Holotype—Specimen no. BSIP 36482.

Paratype—Specimen no. BSIP 36483.

Locality—Surai Khola beds; Kaila Khola, Surai Khola area.

Family—Poaceae

Genus—*Bambusa* Schreber

Bumbusa siwalika sp. nov.
Pl. 1, fig. 1

This species is based on five leaf-impressions, two of them are almost complete.

Description—Leaves simple, symmetrical lanceolate, preserved length varies from 5.0 × 9.7 cm, width 1.5 cm; apex missing, base nearly acute, slightly inequilateral; margin entire; texture chartaceous; petiole missing, venation parallelodromous; 7-8 pairs arising at the base, running parallel to adjacent veins, midvein prominent, secondary and tertiary veins absent.

Discussion—In having lanceolate shape and parallelodromous venation the fossil leaves are comparable with those of *Bambusa* Schreber, *Dendrocalamus* Nees, *Oxytenanthera* Munro, *Teinostachyum* Munro and *Thyrsostachya* Gamble of the family Poaceae. On detail comparison it has been found that the fossil leaves show closest resemblance with those of *Bambusa* Schreber, particularly *B. tulda* Roxb. However, the leaves of other genera differ as they are, in general, bigger in size than those of the fossil.

Leaves of *Bambusa* have so far not been reported from any Tertiary sediments of India and elsewhere. *Bambusa tulda* Roxb. the modern analogue of the fossil leaves is a gregarious, densely tufted culm, about 6-24 m high, occurring in Bengal, Assam, Chittagong (Bangladesh), Burma, common on flat grounds and along streams (Brandis, 1971, p. 668).

Holotype—Specimen no. BSIP 36484.

Paratype—Specimen no. BSIP 36485.

Horizon & locality—Chor Khola beds; Limestone section, Surai Khola area.

DICOTYLEDONS

Family—Annonaceae

Genus—*Polyalthia* Bl.

Polyalthia palaeosimiarum sp. nov.
Pl. 2, figs 3, 5

This species is based on a single specimen.

Description—Leaf simple, symmetrical, elliptic, preserved length and width 8.0 × 4.0 cm; apex broken; base acute; margin entire; texture chartaceous; petiole normal, preserved length 0.8 cm, venation pinnate, eucamptodromous; primary vein stout straight, secondary veins 12 pairs visible, alternate, uniformly curving upwards, unbranched, angle of divergence acute, 50°-60°, moderate in thickness, apical secondaries more acute; tertiary veins fine, angle of origin mostly RR, rarely AO, percurrent, branched, oblique in relation to midvein, predominantly alternate and close

Discussion—The above characters collectively indicate that the fossil leaf belongs to the genus *Polyalthia* Bl. of Annonaceae. Amongst the species of *Polyalthia* the fossil leaf shows close similarity with that of *Polyalthia simiarum* Benth. & Hook. f.

In shape, size and venation pattern the two known species, *Polyalthia crassipes* Engl. described from the Tertiary of Germany (in Menzel, 1920) and *P. chaneyi* Sanborn (1935) reported from the Eocene of North America, are different from our species, *P. palaeosimiarum*.

Polyalthia simiarum Bl. is a tall tree found in Assam, Chittagong Hills in Bangladesh, Burma and Andamans (Brandis, 1971, Gamble, 1972).

Holotype—Specimen no. BSIP 36486.

Horizon & locality—Bankas beds; Bankas, Surai Khola area.

Family—Flacourtiaceae

Genus—*Flacourtia* Commers

Flacourtia nepalensis sp. nov.
Pl. 2, fig. 6

Description—Leaf simple, slightly asymmetrical, wide elliptic, 2.3 × 1.3 cm in length and width; apex obtuse; base obtuse, slightly inequilateral; margin crenate, texture seemingly chartaceous; petiole 0.2 cm long, normal, venation pinnate, simple craspedodromous, primary vein prominent, almost straight, secondary veins 5 pairs, alternate, curving up towards margin, rarely branched, angle of divergence narrow acute (about 40°), intersecondary veins present, simple, tertiary veins fine, with angle of origin usually RR, percurrent branched, almost straight, oblique in relation to midvein, predominantly alternate and close.

PLATE 1 →

(All figures are of natural size unless otherwise mentioned).

1. *Bambusa siwalika* sp. nov., specimen no. BSIP 36484.
2. *Bambusa tulda* Roxb.
3,4. *Caryota siwalika* sp. nov., specimen nos. BSIP 36482, 36483.
5. *Caryota urens* Roxb.
6,7,8. *Clinogyne ovatus* sp. nov., specimen nos. BSIP 36479, 36480, 36481
9. *Clinogyne grandis* Benth. & Hook. f.

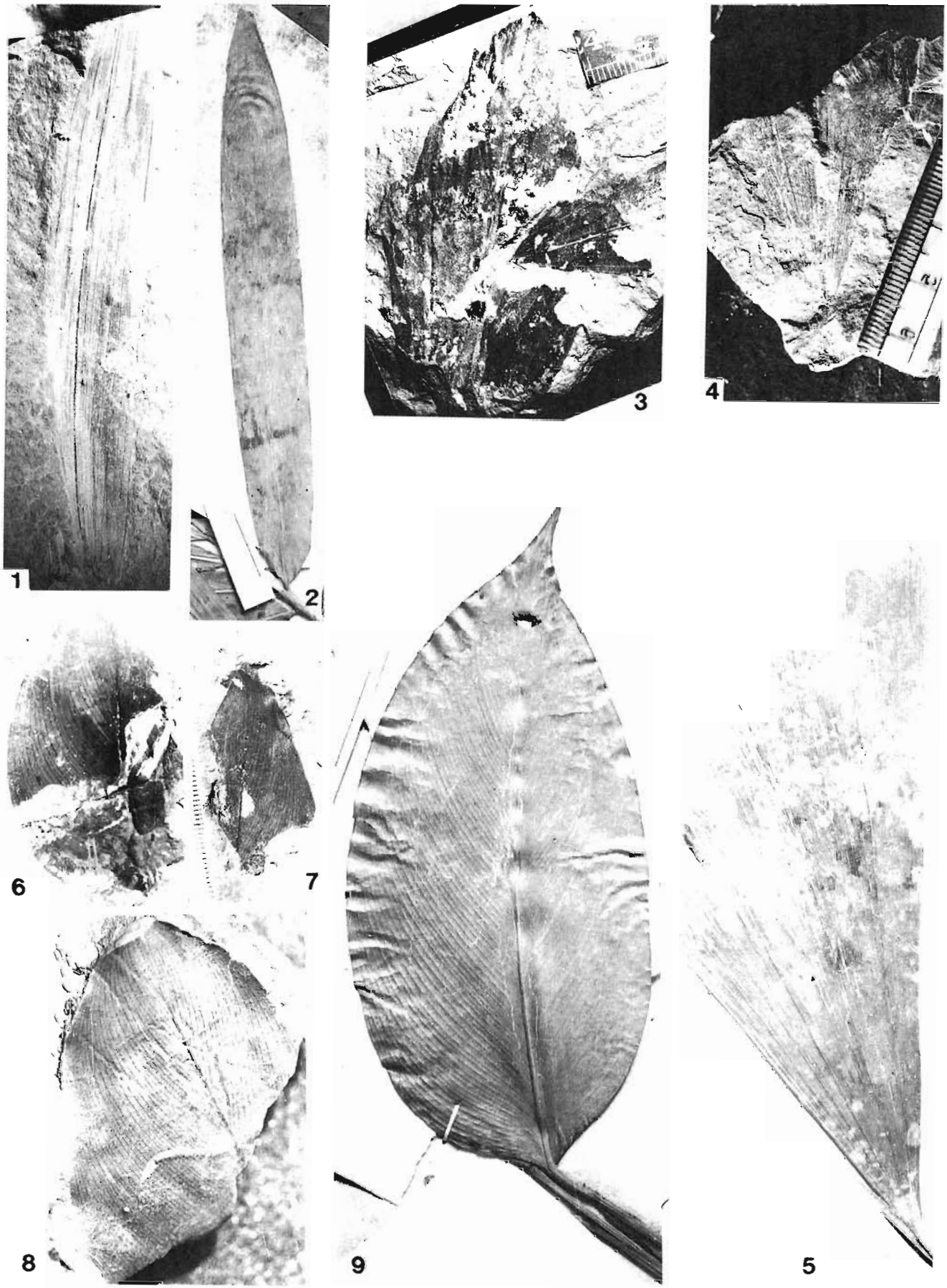

PLATE 1

Discussion—Among the living species the fossil leaf, assigned here as a new species *Flacourtia nepalensis*, shows resemblance with *Flacourtia ramontchi* L. Herit.

Except a single report of doubtful *Flacourtia, F intertrappea* Nambudiri 1966 from the Deccan Intertrappean beds of central India, there is no other record of fossil leaves of the genus *Flacourtia* from India.

Flacourtia ramontchi L. Herit. is a small deciduous tree found throughout India mostly in dry open places and on rocky hills. It also occurs in Sri Lanka and Malay Archipelago (Gamble, 1972; Brandis, 1971).

Holotype—Specimen no. BSIP 36487.

Locality—Surai Khola beds, near Surai Khola bridge, Surai Khola area

Family—Clusiaceae

Genus—*Calophyllum* Linn.

Calophyllum suraikholaensis sp. nov.
Pl. 2, figs 8, 10

The following description is based on two well-preserved specimens.

Description—Leaves simple, symmetrical; narrow oblong, preserved length and width 7.5 × 2.2 and 7.0 × 2.9 cm respectively; tip missing, seemingly obtuse; base acute, normal, equilateral; margin entire, texture seemingly coriaceous; petiole normal, preserved length 0.7 and 1.0 cm, 2 mm thick; venation pinnate, simple, craspedodromous primary veins prominent, straight, stout, secondary veins numerous, in one specimen about 130 pairs could be counted, very closely placed, about 2 veins per mm, opposite to alternate, unbranched, secondaries of basal region arising nearly at right angle, angle of divergence of secondaries of upper half slightly acute towards apex; tertiary veins not seen.

Discussion—The fossil leaves in general resemble the genus *Calophyllum* L. Among 40 species of *Calophyllum* examined, the fossil leaves show resemblance with atleast 13 species, viz., *C. blancoi* Planch & Triana, *C. canum* Hook. F., *C. elatum* Bedd., *C. flavoramulum* Hend. & Wyatt-Smith, *C. kunstleri* King, *C. rekoi* Standley, *C. macrocarpum* Hend. & Wyatt. Smith ex. P.F. Stevens, *C. spectabile* Willd. and *C. wallichianum* Planch. & Triana The leaves of these species are so similar that their distinction on the basis of leaf architecture is rather difficult Thus no further attempt has been made to determine with certainty to which modern taxon they are closest. However, keeping in view the geographical distribution of *Calophyllum polyalthum*, which occurs in the evergreen forests of Khasi Hills, Chittagong in Bangladesh; Pegu Yoma and Martaban in Burma ascending to 1,600 m (Gamble, 1972), we consider it as a probable modern equivalent of the above described fossil leaves.

Fossil leaves showing close resemblance with those of *Calophyllum* are described as *Calophyllum pliocenicum* Krasser 1903 from the Tertiary of Ouricanga, Germany, *C. nathorsti* Geyler 1887 and *Calophyllum* sp. (Kräusel, 1929) from the Tertiary of Sumatra and *Callophyllites mesaensis* Pons 1978 from the Tertiary of Colombia, South America. On comparison with these species it was found that the present fossil leaves are quite different. *Calophyllum pliocenicum* Krasser which is comparable to the leaves of *Calophyllum calaba* Linn. differs from *Calophyllum suraikholaensis* in the shape and size. *Calophyllum* sp. Kraüsel and *C. nothorsti* (Geyler) Kräusel can also be differentiated in its narrow elliptic shape and obtuse base. Besides, in the fossil leaves reported from Sumatra the secondary veins are less in number and distantly placed. Similarly, *C.mesaensis* Pons can easily be differentiated in its being smaller in size (5.5 × 2.0 cm) having only 23-27 pairs of secondaries and with attenuate base as

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PLATE 2 →

(All figures are of natural size unless otherwise mentioned).

1. *Clinogyne ovatus* sp. nov., a part of the leaf magnified to show details of secondary veins, × 2.
2. *Clinogyne grandis* Benth. & Hook. f., a part of the leaf magnified to show similar details of secondary veins, × 2.
3. *Polyalthia palaeosimiarum* sp. nov., specimen no. BSIP 36486.
4. *Polyalthia simiarum* Bl.
5. *Polyalthia palaeosimiarum* sp. nov., a part of the same leaf magnified to show details of secondary and tertiary veins, × 3
6. *Flacourtia nepalensis* sp. nov., specimen no. BSIP 36487.
7. *Flacourtia ramontchi* L. Herit.
8. *Calophyllum polyanthum* Wall.
9. *Calophyllum suraikholaensis* sp. nov., specimen no. BSIP 36488.
10. *C. suraikholaensis* sp. nov., a part of same leaf magnified to show details of secondary veins, × 2.
11. *Mangifera someshwarica* Lakhanpal & Awasthi, specimen no. BSIP 36491

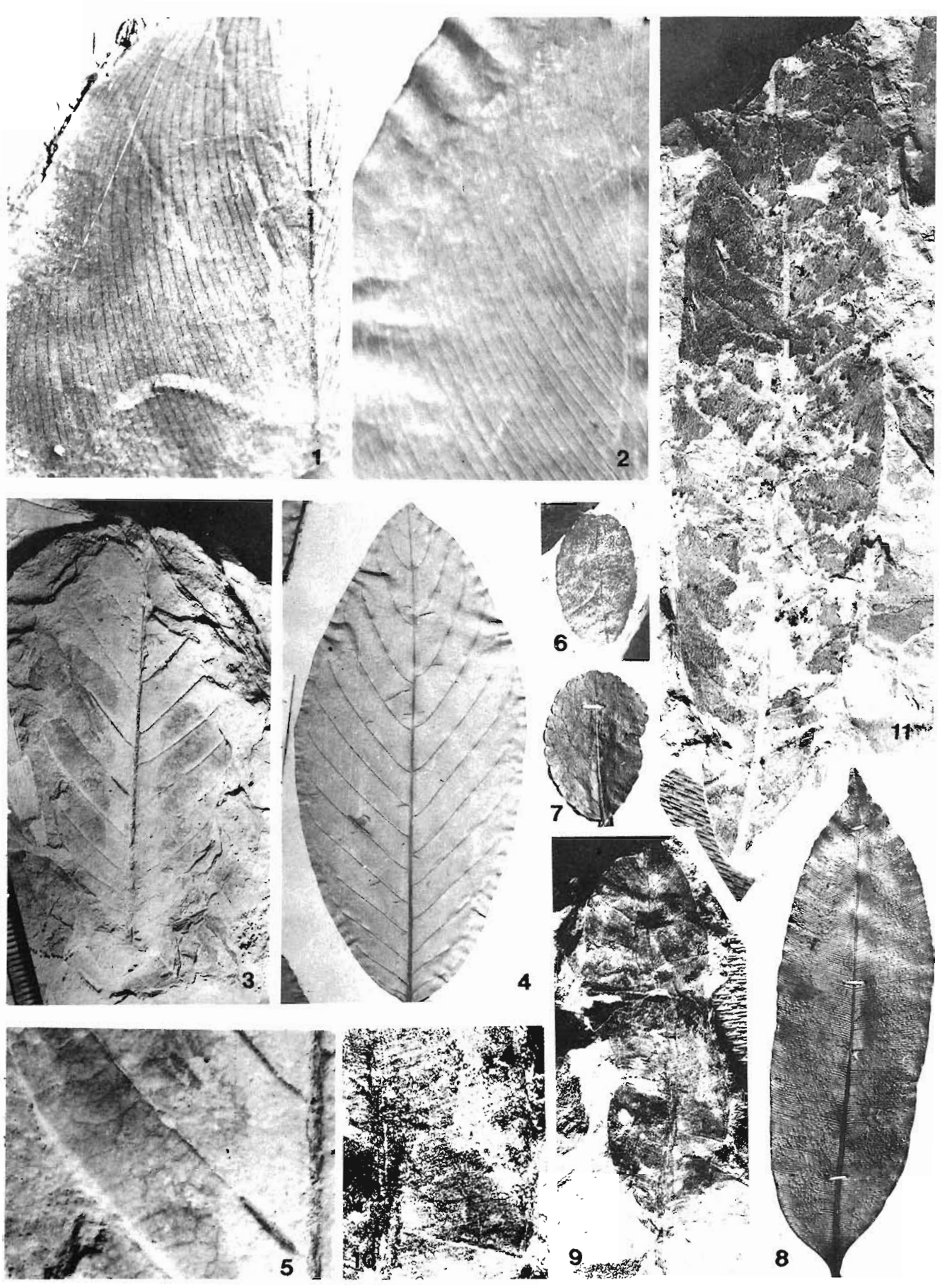

PLATE 2

compared to our fossil leaves which are relatively larger (6.9-7.2 × 2.2-2.9 cm) with about 130 pairs of secondaries and acute base.

Holotype—Specimen no. BSIP 36488.

Paratype—Specimen no. BSIP 36489.

Locality—Chor Khola beds; Chor Khola, Surai Khola area.

Family—Dipterocarpaceae

Genus—*Dipterocarpus* Gaertn.

Dipterocarpus siwalicus Lakhanpal & Guleria 1987
Pl. 3, fig. 6

About half a dozen well-preserved specimens of this species are represented in our collection.

Supplimentary description—Leaves almost symmetrical, in one specimen the basal part of one side slightly biggest, ovate to elliptic, preserved length and width one of the biggest leaf 13 × 8 cm; apex missing, base more or less round to cordate; margin entire to slightly undulate; texture thick chartaceous; petiole missing; venation pinnate, eucamptodromous, primary vein prominent, moderate in thickness, more or less straight to slightly curved; secondary veins about 16 pairs visible, subopposite to alternate, angle of divergence acute (about 45°-70°), decreasing from base to apex, course straight, slightly curving upward before reaching the margin, unbranched, intersecondary veins absent, tertiary veins fine with angle of origin about 70°-80°, pattern percurrent, course somewhat wavy, unbranched, running obliquely in relation to midvein, arrangement mostly alternate, usually close, higher order of venation not seen.

Discussion—Among living species, the present fossil leaves resemble those of *Dipterocarpus tuberculatus* Roxb., *D. turbinatus* Gaertn. f. and are therefore placed under *Dipterocarpus siwalicus* Lakhanpal & Guleria 1987 which is already reported from the Lower Siwalik sediments near Balugoloa, Himachal Pradesh.

Specimen—Specimen no. BSIP 36490.

Horizon & locality—Chor Khola beds; Chor Khola, Surai Khola area.

Family—Anacardiaceae

Genus—*Mangifera* Linn.

Mangifera someshwarica Lakhanpal & Awasthi 1984
Pl. 2, fig. 11; Pl. 3, figs 1, 3, 5

The leaf-impressions referred to this species are four in number.

Supplimentary description—Leaves simple, symmetrical; narrow elliptic preserved length and width of two leaves 15.5 × 4.0 cm and 9.0 × 3.2 cm respectively, apex missing; base acute; margin entire to slightly wavy; texture thick chartaceous; petiole normal, 0.6 cm in length; venation pinnate, eucamptodromous; primary veins prominent, stout, almost straight; secondary veins about 13 pairs visible, subopposite to alternate, gradually curving up towards margin and running parallel to it, unbranched, angle of divergence moderate to wide acute (60°-80°), those of basal secondaries vary from wide acute to right angle, intersecondary veins present, simple, tertiaries with angle of origin usually RR, rarely RO, percurrent, branched, almost straight, predominantly alternate and close, further details not seen.

Discussion—These fossil leaves compare favourably with those of Anacardiaceae in general and *Mangifera indica* Linn. in particular. Among the known species of fossil leaves *Mangifera someshwarica* Lakhanpal & Awasthi 1984 described from the Siwalik sediments of Bhikhnathoree, Bihar, the only species whose determination is unquestionable, displays such characters as that of the present fossil leaves. Therefore, the leaves are placed under the same species.

Mangifera takashimensis Matsuo 1967 is yet another record of the fossil leaves compared with those of extant *Mangifera indica* by Matsuo (1967)

PLATE 3 →

(All figures are of natural size unless otherwise mentioned).

1. *Mangifera someshwarica* Lakhanpal & Awasthi, specimen no. BSIP 36492.
2. *Mangifera indica* Linn.
3. *Mangifera someshwarica* Lakhanpal & Awasthi, a part of the same leaf magnified to show details of secondary and higher order of venation, × 3.
4. *Mangifera indica* Linn., a part of the leaf magnified to show similar details of secondary and higher order of venation, × 3.
5. Another specimen of *Mangifera someshwarica* with basal part, specimen no. 36493.
6. *Dipterocarpus siwalicus* Lakhanpal & Guleria, specimen no. BSIP 36490.
7. *Millettia palaeoracemosa* sp. nov., specimen no. BSIP 36497
8. *Millettia racemosa* Benth.
9. *Millettia palaeocubithii* sp. nov., specimen no. BSIP 3649.
10. *Millettia cubithii*

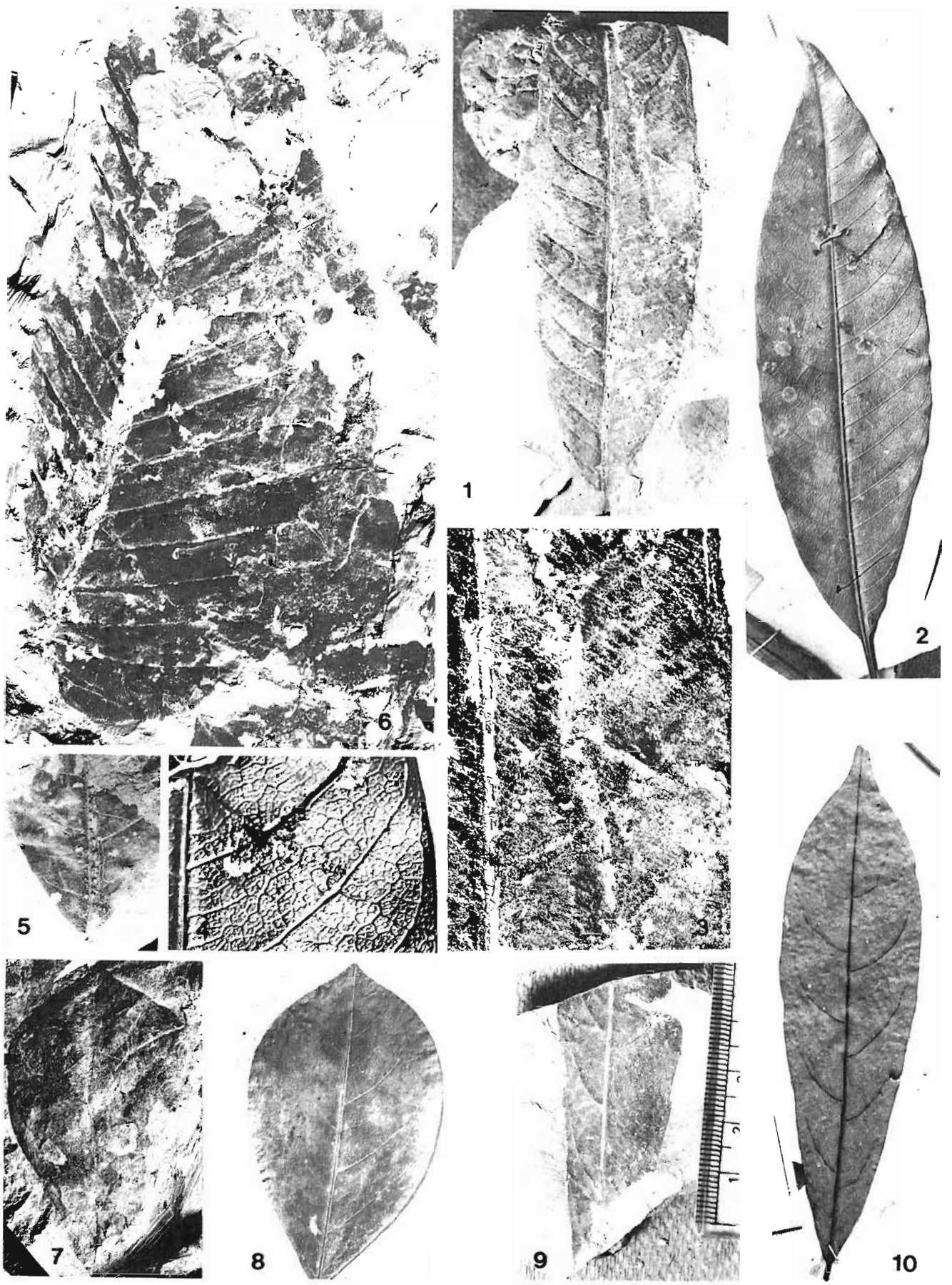

PLATE 3

from the Palaeogene of Kyushu and from the Eocene of South west Honshu, Japan. From its illustration the identification of leaf appears to be doubtful. The leaf is ovate, gradually narrowed towards apex and the venation is brochidodromous. Such a distinctive feature is not seen in the leaves of *Mangifera*.

Mangifera indica is a medium to large evergreen tree found almost in all the forests of the plains of India in the sub-Himalayan tract and in the outer hills of Kumaon and Garhwal. It also grows in Chittagong Hill tract in Bangladesh, Burma, Thailand, Vietnam and the Malay Peninsula (Gamble, 1972).

Hypotype—Specimen nos. BSIP 36491, 36492, 36493.

Horizon & locality—Surai Khola beds; Kaila Khola, Surai Khola area.

Genus—*Gluta* Linn.

Gluta siwalika sp. nov.
Pl. 4, fig. 3

This species is based on two complete and well-preserved leaf-impressions.

Description—Leaves simple, symmetrical, narrow elliptic, preserved length and width 13.8 × 3.8 cm; apex broken, seemingly acute; base cuneate, normal; margin slightly undulated; texture coriaceous; petiole 0.6 cm in length, normal; venation pinnate, eucamptodromous; primary vein prominent, stout, slightly curved; secondary veins 16 pairs visible, basal 2-4 secondaries closely placed, alternate to sub-opposite, uniformly curving up towards margin, rarely branched, angle of divergence acute (50°-60°), moderate in thickness; intersecondary veins present, simple to composite; tertiary veins fine with angle of origin usually RR, percurrent, branched, almost straight, oblique in relation to midvein, alternate to opposite and close, quaternary veins very fine, randomly oriented, forming trigonal to polygonal meshes.

Discussion—In shape, size, venation pattern and other features the fossil leaves described here as *Gluta siwalika* show similarity with those of the genus *Gluta* Linn. in general and *C. renghas* in particular. Although this is the first report of the leaf of *Gluta*, the fossil woods of this genus have already been described from several Neogene sediments of India including Siwaliks, Burma and Southeast Asia (Awasthi, 1966; Prakash & Tripathi, 1969; Trivedi & Ahuja, 1978; Roy & Ghosh, 1979; Awasthi & Panjwani, 1984; Awasthi, 1984; Guleria, 1984; Kramer, 1974).

Holotype—Specimen no. BSIP 36494.

Paratype—Specimen no. BSIP 36495.

Horizon & locality—Surai Khola beds; Kaila Khola, Surai Khola area.

Genus—*Swintonia* Griff.

Swintonia miocenica sp. nov.
Pl. 4, fig. 1

This species is based on a single, almost complete and well-preserved leaf-impression.

Description—Leaf simple, symmetrical; narrow elliptic, lamina 11.6 × 2.6 cm in length and width; apex broken, most probably acuminate; base acute, normal; margin entire, slightly wavy; texture thick chartaceous; petiole missing; venation pinnate, eucamptodromous; primary vein prominent, stout, almost straight; secondary veins about 20 pairs visible, angle of divergence moderately acute (about 60°), distance between two secondaries 0.3-0.8 cm, alternate to subopposite, uniformly curving up towards margin, unbranched; intersecondary veins present, frequent, seemingly simple to composite; tertiary veins fine, with angle of origin AR-RO, percurrent, branched, oblique in relation to midvein, predominantly alternate and close.

Discussion—The fossil leaf in general shows resemblance with Anacardiaceous leaves. However, on closer examination of herbarium sheets of many genera and species of this family it was found that the fossil leaf resembles that of *Swintonia floribunda* Griff. Hence, the fossil leaf is assigned to new species, *Swintonia miocenica*.

Swintonia floribunda Griff. occurs in the Chittagong hills (Bangladesh); Pegu Yoma and in

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PLATE 4 →

(All figures are of natural size unless otherwise mentioned).

1. *Swintonia miocenica* sp. nov., specimen no. BSIP 36496.
2. *Swintonia floribunda* Griff.
3. *Gluta siwalika* sp. nov., specimen no. BSIP 36494.
4. *Gluta renghas*.
5. *Entada palaeoscandens* sp. nov., specimen no. BSIP 36504.
6. *Entada scandens* Benth.
7,9. *Cynometra siwalika* sp. nov., specimen nos. BSIP 36499, 36500.
8. *Cynometra polyandra* Roxb.
10,12. *Breynia prerhamnoides* sp. nov., specimen nos. BSIP 36512, 35513.
11,13. *Breynia rhamnoides* Muell.

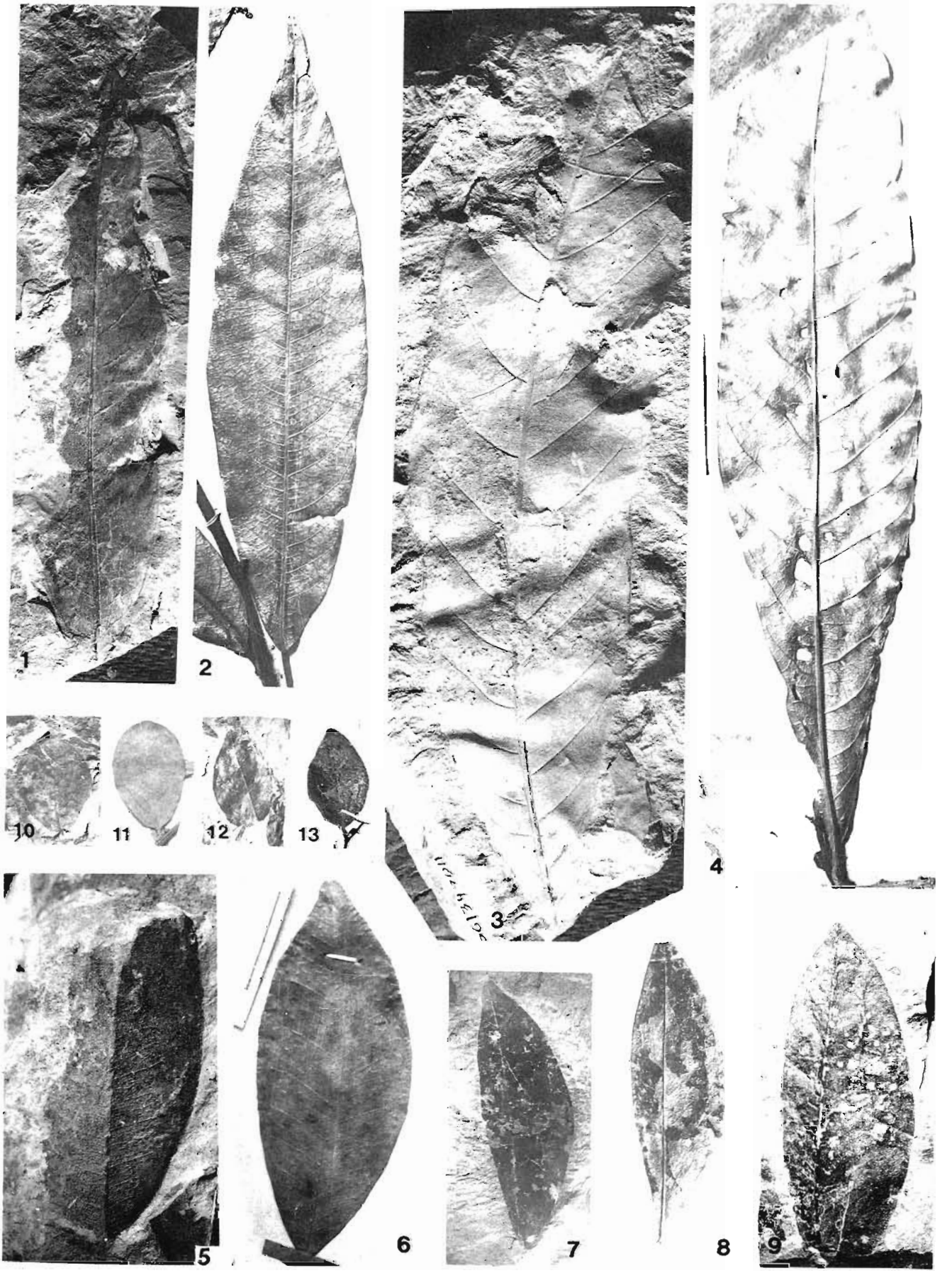

PLATE 4

Tenasserim, Burma, where it is common near the coast but also inland (Brandis, 1971; p. 202).

Holotype—Specimen no. BSIP 36496.

Horizon & locality—Surai Khola beds, Kaila Khola, Surai Khola area.

Family—Leguminosae

Genus—*Millettia* W. & A.

Millettia palaeoracemosa sp. nov.
Pl. 3, fig. 7

This species is based on a single, well-preserved impression of leaflet.

Description—Leaflet simple, symmetrical; wide obovate, 4.7 × 3.0 cm in length and width; apex, acuminate; base cuneate, normal; margin entire; texture seemingly coriaceous; petiole indistinct; venation pinnate, eucamptodromous; primary vein prominent, moderate, almost straight; secondary veins about 6 pairs visible, usually alternate, uniformly curving up towards margin, rarely branched, angle of divergence acute (50-60°), moderate in thickness; intersecondary veins present, simple; tertiary veins fine with angle of origin usually RR, rarely AO, percurrent, branched, oblique in relation to midvein, predominantly alternate and close.

Discussion—The fossil leaflet shows general resemblance with those of Fabaceae. However, considering the shape, size and details of venation patterns the fossil leaflet closely resembles those of *Millettia*, particularly *M. racemosa* Benth. This fossil leaflet although resembling those of *Cassia tora* in gross features such as, shape and size, differs significantly in venation pattern and in having less intersecondary veins.

Five species of fossil leaflets resembling those of *Millettia* are known so far, viz., *Millettia impressa* Menzel 1920 from the Tertiary of West Africa; *M. notoensis* Ishida 1970 from the Middle Miocene of Central Japan; *Millettia* sp. Huzioka & Takahasi 1970 from the Late Eocene of South West Honshu, Japan; *M. asymmetrica* and *M. miocenica* Lakhanpal & Guleria 1982 from the Miocene of Kachchh, India; and *M. koilabasensis* Prasad & Prakash 1989 from the Siwalik sediments of Koilabas, Nepal. The present fossil leaflet is different from all these species in its shape, size and details of venation pattern, and hence it is assigned to a new species, *Millettia palaeoracemosa*.

Millettia racemosa Benth. is a woody climber found in the deciduous forests of Konkan, North Kanara, Orissa, coastal Andhra Pradesh, South Deccan as far as Sundur Hills of Bellary, Shan Hills of Upper Burma, Pegu and Tenasserim (Ramesh Rao & Purkayastha, 1972, p. 114; Gamble, 1972, p. 223).

Holotype—Specimen no. BSIP 36497.

Horizon & locality—Chor Khola beds; Woodseam, Surai Khola area.

Millettia palaeocubithii sp. nov.
Pl. 3, fig. 9

This species is based on an incomplete impression of a leaflet.

Description—Leaflet simple, symmetrical; seemingly oblanceolate, preserved length and width 6.0 × 2.5 cm, apex missing; base missing; venation pinnate, simple, eucamptodromous; primary vein single, prominent, stout, almost straight; secondary veins only 4 pairs present in the available part, nearly opposite to alternate, uniformly curving up towards margin and diminishing before reaching the margin, unbranched, angle of divergence acute (70°-80°), wide; tertiary veins fine, angle of origin RR, percurrent, rarely branched, straight, oblique to right angle in relation to midvein, predominantly alternate and close.

Discussion—The leaflet though incomplete, without tip and base, the shape, size and venation pattern of the available middle part of lamina suggests its close similarity with the leaflets of *Millettia cubithii*. This species is quite different from *Millettia palaeoracemosa* as well as other known species of the genus in shape, size and venation pattern. Therefore it is named as *Millettia palaeocubithii* sp. nov., *Millettia cubithii* known to occur in the Malayan region.

Holotype—Specimen no. BSIP 36498.

Horizon & locality—Chor Khola beds; Woodseam, Surai Khola area.

Genus—*Cynometra* Linn.

Cynometra siwalika sp. nov.
Pl. 4, figs 7, 9

This species is based on two specimens of leaflets.

Description—Leaflets simple, whole lamina asymmetrical, elliptic, 6.0 × 2.5 in length and width; apex acute; base acute; margin entire; texture chartaceous; petiolule not preserved; venation pinnate; brochidodromous; primary vein prominent, moderate, straight; secondary veins about 12 pairs visible, alternate to sub-opposite, curving upward towards margin, angle of divergence 50°-80°, less acute towards apex, course uniformly curved, branched, forming loop with superadjacent secondaries before reaching the margin; intersecondary veins present, simple to composite,

tertiary veins angle of origin usually RR, pattern orthogonal reticulate, forked, relation to midvein oblique, close; higher order of venation not clearly visible.

Discussion—In shape, size, asymmetrical lamina and venation pattern the fossil leaflets closely resemble those of the genus *Cynometra*, particularly with *C. polyandra* Roxb. Hence they are placed under a new species, *Cynometra siwalika*. This is the first record of the fossil leaflet representing the genus *Cynometra*, although the fossil woods of this genus are already known since long from several Neogene sediments of India, Burma and Southeast Asia.

Cynometra polyandra is an evergreen tree occurring in Khasi Hills, Cachar Hills (northeast India) and in the Malaya peninsula.

Holotype—Specimen no. BSIP 36499.

Paratype—Specimen no. BSIP 36500.

Horizon & locality—Bankas beds; Bankas, Surai Khola area.

Genus—*Bauhinia* Linn.

Bauhinia nepalensis sp. nov.
Pl. 5, figs 6-8

There are 10 specimens of leaf-impressions in our collection representing this species. All are well preserved and almost complete and variable in size.

Description—Leaves bilobed, symmetrical; each lobe ovate to elliptic, lamina (one lobe) of biggest leaf 7.5 × 5.7 cm and smallest leaf 4.5 × 2.8 cm; apex of each lobe obtuse to rounded; base auriculate, normal, equilateral; margin entire; texture thick chartaceous; petiole present in some specimens, 3.8 cm in length, normal; venation actinodromous, perfect, reticulate, basal; primary veins 5, given off to each lobe from the base, veins prominent, moderate in thickness, curving up toward margin; secondary veins about 4-6 pairs, usually arising from one side of primary veins and in upper 1/2 part secondaries given off from mid primary vein to both the sides; each 0.2-0.8 cm apart, alternate, uniformly curving up, angle of divergence acute (about 60°), moderate in thickness; tertiary veins with angle of origin nearly RR, percurrent, rarely branched, acute to nearly right angle in relation to primary veins, alternate to opposite and close.

Discussion—The characteristic features of the fossil leaves are: bilobed, each lobe ovate to elliptic in shape, obtusely emarginate apex, auriculate base, entire margin and the basal venation actinodromous which strongly suggest their affinity with the leaves of the genus *Bauhinia* Linn. and to some extant *Hardwickia* Roxb. However, the leaves of *Hardwickia* differ from those of fossil as well as extant *Bauhinia* in their being completely bilobed and due to which the margins of both the lobes form curvature, whereas in the latter the margin of one side of each lobe form curvature and the other side remain straight. From a closer examination of the herbarium sheets of 40 species of *Bauhinia*, it was found that the fossil leaves are very similar to those of *Bauhinia malabarica* Roxb. and *B. variegata* Linn.

Fossil leaves comparable to those of extant *Bauhinia* are described under two genera *Bauhinia* Linn. and *Bauhinites* Seward & Conway 1935. The latter consists of a single species, *Bauhinites greenlandica* Seward & Conway 1935 while *Bauhinia* Linn. includes 18 species, described mostly from the Tertiary sediments of India, Australia, Bolivia, Czechoslovakia, Equador, West Germany; Greece, Greenland and North Vietnam (Berry, 1908, 1916, 1919, 1945, Newberry, 1886, 1895; Unger, 1850, 1867; Engelhardt in Muller-Stoll 1934; Heer, 1859; Cockerell in: Knowlton, 1919; Chaney & Sanborn 1933; Brown, 1962; Lakhanpal & Awasthi, 1984, Lakhanpal & Guleria, 1982).

Considering all the characters collectively such as shape, size, number of secondaries and their course, the present fossil leaves appear somewhat different from all the known fossil leaves. Therefore these leaves are described as *Bauhinia nepalensis* sp. nov.

Bauhinia malabarica Roxb. and *B. variegata* Linn. are moderate-sized trees growing in sub-Himalayan tracts from the Indus eastward. These also occur in dry to moist deciduous forests of central and south India and Burma (Ramesh Rao & Purkayastha, 1972; Gamble, 1972).

Holotype—Specimen no. BSIP 36501.

Paratype—Specimen nos. BSIP 36502, 36503.

Horizon & locality—Surai Khola beds; near Surai Khola bridge, Surai Khola area.

Genus—*Entada* Adans.

Entada palaeoscandens sp. nov
Pl. 4, fig. 5; Pl. 5, figs 3, 4

This species is based on a single leaf-impression and about 10 seeds.

Description—Leaflet simple, almost symmetrical, elliptic, preserved length and width 5.2 × 2.6 cm; apex missing; base slightly incomplete, probably acute; margin entire; texture chartaceous; petiole missing, venation pinnate, semicraspedodromous; primary vein prominent, moderate in thickness, almost straight; secondary

veins about 8-9 pairs visible, mostly alternate, nearly straight, branching just within the margin, one of the branches seemingly terminating at the margin and the other joining superadjacent secondary, angle of divergence acute (about 60-70), moderate in thickness; intersecondary veins present, simple, abundant, tertiary veins fine, with angle of origin AR-RO, ramified, branched, oblique to right angle in relation to midvein, alternate and close.

Seed large in size, about 4.5 cm in diameter, slightly flattened, circular to orbicular, cordate or reniform with a pronounced sinus at the hilum.

Discussion—Among extant species such features, as displayed by the fossil leaflet and seeds, are characteristic of *Entada phaseoloides* Benth.

Leaflets and seeds comparable to those of *Entada* are known from the Tertiary of Austria (Unger, 1862), Japan (Tanai 1955; Ishida, 1970; Huzioka, 1972; Takahasi, 1954), U.S.A. (Mac Ginitie, 1969) and Venezuela, South America (Berry, 1921). The present fossil leaflet is different from them in many respects. Berry (1921) reported some seeds from the Tertiary of Venezuela and tentatively referred them to *Entada phaseoloides*. As Berry's report does not furnish photographs and detailed description of the seeds, it is difficult to judge whether they belong to *Entada* or any other taxon.

Since the fossil leaflet and seeds are closely comparable to those of *Entada phaseoloides*, we prefer to place them under one species, *Entada palaeoscandens* sp. nov.

Entada phaseoloides Benth. (= *E. scandens*) is a large woody climber found in the sub-Himalayan tract from Nepal eastwards ascending to about 700 m, in Sylhet, Manipur, Burma, Andamans, Nicobar and Western Ghats (Brandis, 1971, pp. 261-262).

Holotype—Specimen no. BSIP 36504 (leaflet), 36505 (seed).

Paratype—Specimen no. BSIP 36506 (seed).

Horizon & locality—Seeds—Surai Khola beds, Kaila Khola; Leaflet—Chor Khola beds; Woodseam, Surai Khola area.

Family—Combretaceae

Genus—*Terminalia* Linn.

Terminalia panandhroensis Lakhanpal & Guleria 1981
Pl. 6, fig. 3

This species is represented in the collection by two incomplete specimens.

Supplimentary description—Leaf simple, symmetrical, elliptic, 16.0 × 10.5 cm in length and width; apex missing; base also missing; margin entire; texture seemingly thick chartaceous to coriaceous; venation pinnate; eucamptodromous; primary vein prominent, stout, almost straight; secondary veins 10 pairs, angle of divergence 75-90°, basal secondaries arising at right angle and running almost straight to some distance and then curving upwards and upturned just before reaching the margin, occasionally branched; intersecondary veins present, simple; tertiary veins fine, angle of origin AR to RO, percurrent; forked, almost straight, oblique in relation to midvein, alternate to opposite and close; further details not clearly seen.

Discussion—The present fossil leaf shows close similarity with *Terminalia panandhroensis* Lakhanpal and Guleria 1981 from the Eocene of Panandhro, Kutch. Among extant species of *Terminalia* the fossil leaf resembles those of *Terminalia coriacea* (Roxb.) W & A. (FRI, Dehradun herbarium sheet nos. 62/2 and 5582).

Terminalia coriacea is distributed in drier and hotter parts of Tamil Nadu and central India and occasionally in Lower Burma.

Holotype—Specimen no. BSIP 36507.

Horizon & locality—Surai Khola beds; Kaila Khola, Surai Khola area.

Terminalia palaeochebula sp. nov.
Pl. 5, fig. 1; Pl. 6, fig. 1

There are two specimens in the collection representing the species, one is complete while the

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PLATE 5 →

(All figures are of natural size unless otherwise mentioned).

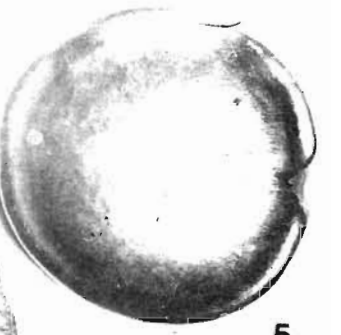
1 *Terminalia palaeochebula* sp. nov., specimen no. BSIP 36508.

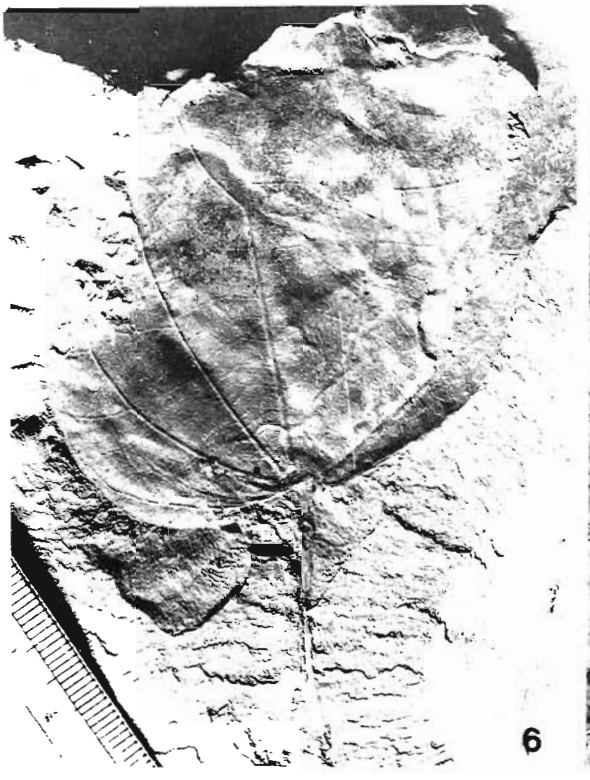
2. *Terminalia chebula* Retz.

3,4. *Entada palaeoscandens* sp. nov. (seed), specimen nos. BSIP 36505, 36506.

5. *Entada scandens* Benth.

6,7,8. *Bauhinia nepalensis* sp. nov., specimen nos. BSIP 36501, 36502, 36503.





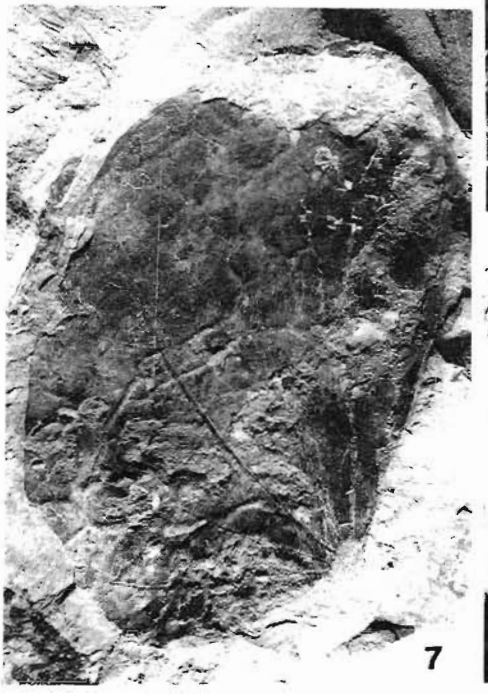


PLATE 5

other is incomplete having only the basal part and petiole.

Description—Leaf simple, symmetrical; elliptic; 12.0 × 6.5 cm in length and width; apex broken; base nearly obtuse; margin entire; texture coriaceous, petiole normal, 0.2 cm in length; venation pinnate, eucamptodromous; primary veins prominent, moderate in thickness, almost straight; secondary veins 8-9 pairs, sub-opposite to alternate, uniformly curving up towards margin, branched, angle of divergence acute, about 60°, moderate in thickness, tertiary veins fine, with angle of origin usually RR, percurrent, branched, straight, oblique in relation to midvein, further details not seen.

Discussion—The present leaf-impression assigned to a new species, *Terminalia palaeochebula*, resembles in all the features those of the extant species *Terminalia chebula* Retz. It can easily be distinguished from *Terminalia panandhroensis* Lakhanpal & Guleria by its smaller size, both in length and width, and the angle of divergence of secondaries which is acute (about 60°) in *Terminalia palaeochebula* and acute to right angle (75-90°) in *T. panandhroensis*.

Terminalia chebula Retz. is small to large deciduous tree found in the sub-Himalayan tracts from Punjab eastward ascending to about 1,600 m, common throughout India and Burma. It is very common in Bengal, Assam, Garo Hills, Western Ghats and Sri Lanka (Ramesh Rao & Purkayastha, 1972, p. 188; Brandis, 1971, p. 308).

Holotype—Specimen no. BSIP 36508.

Horizon & locality—Surai Khola beds; Kaila Khola, Surai Khola area.

Family—Ebenaceae

Genus—*Diospyros* Linn.

Diospyros miokaki Hu & Chaney
Pl. 6, fig. 4

Single well-preserved and almost complete leaf-impression.

Description—Leaf simple, symmetrical, elliptic; 8.0 × 5.1 cm in length and width; apex acuminate, slightly curved; base missing; margin entire; texture seemingly thick chartaceous; petiole missing; venation pinnate, eucamptodromous; primary vein prominent, moderate in thickness; secondary veins about 6-7 pairs visible, usually alternate, uniformly curving up towards margin, branched near the margin, branches joining with those of adjacent secondaries forming loop, angle of divergence acute (about 40°), narrow, intersecondary veins present, simple; tertiary veins fine with angle of origin usually RR, rarely AO, percurrent, branched, oblique in relation to midvein, predominantly alternate and close.

Discussion—The present fossil leaf in all its features shows close similarity with those produced by *Diospyros kaki* Linn.

A large number of leaves (about 66 spp.) resembling those of *Diospyros* are known from the Upper Cretaceous onwards from several parts of the world, viz., Africa, Canada, Europe, Greenland, India, Japan, and U.S.A. (Heer, 1874; Schimper, 1874; Lesquereux, 1874, 1891-92; Berry, 1916, 1918, 1919, 1930; Principi, 1921; Ball, 1931; Gothan, 1933; Hollick, 1936; MacGnitie, 1937, 1941; LaMottee, 1952; Jahnichen, 1958; Channey & Axelrod 1959; Tanai & Suzuki, 1963; Huzioka & Umera, 1973; Tanai, 1976). Among the known fossil leaves those described as *Diospyros miokaki* Hu & Chaney (Tanai & Suzuki, 1963) from the Tertiary of Japan are similar to our present Siwalik leaf.

Diospyros kaki Linn. f. is a tree or rarely a shrub found in Khasi Hills in Assam, Upper Burma, China and Japan (Gamble, 1972, p. 455).

Hypotype—Specimen no. BSIP 36509.

Horizon & locality—Surai Khola beds near Surai Khola bridge, Surai Khola area.

Family—Myristicaceae

Genus—*Myristica* (*Knema*) Linn.

Myristica palaeoglomerata sp. nov.
Pl. 6, fig. 6; Pl. 7, fig. 1

This species is based on two well-preserved leaf-impressions, one is with counter part while the

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PLATE 6

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(All figures are of natural size unless otherwise mentioned).

1. *Terminalia palaeochebula* sp. nov., a part of the same leaf magnified to show details of secondary and tertiary venation, × 2.
2. *Terminalia chebula*, a part of the modern leaf magnified to show similar details of secondary and tertiary venation, × 2.
3. *Terminalia panandhroensis* Lakhanpal & Guleria, specimen no. BSIP 36507
4. *Diospyros miokaki* Hu & Chaney, specimen no. BSIP 36509.
5. *Diospyros kaki* Linn.
6. *Myristica palaeoglomerata* sp. nov., leaf showing notched apex.

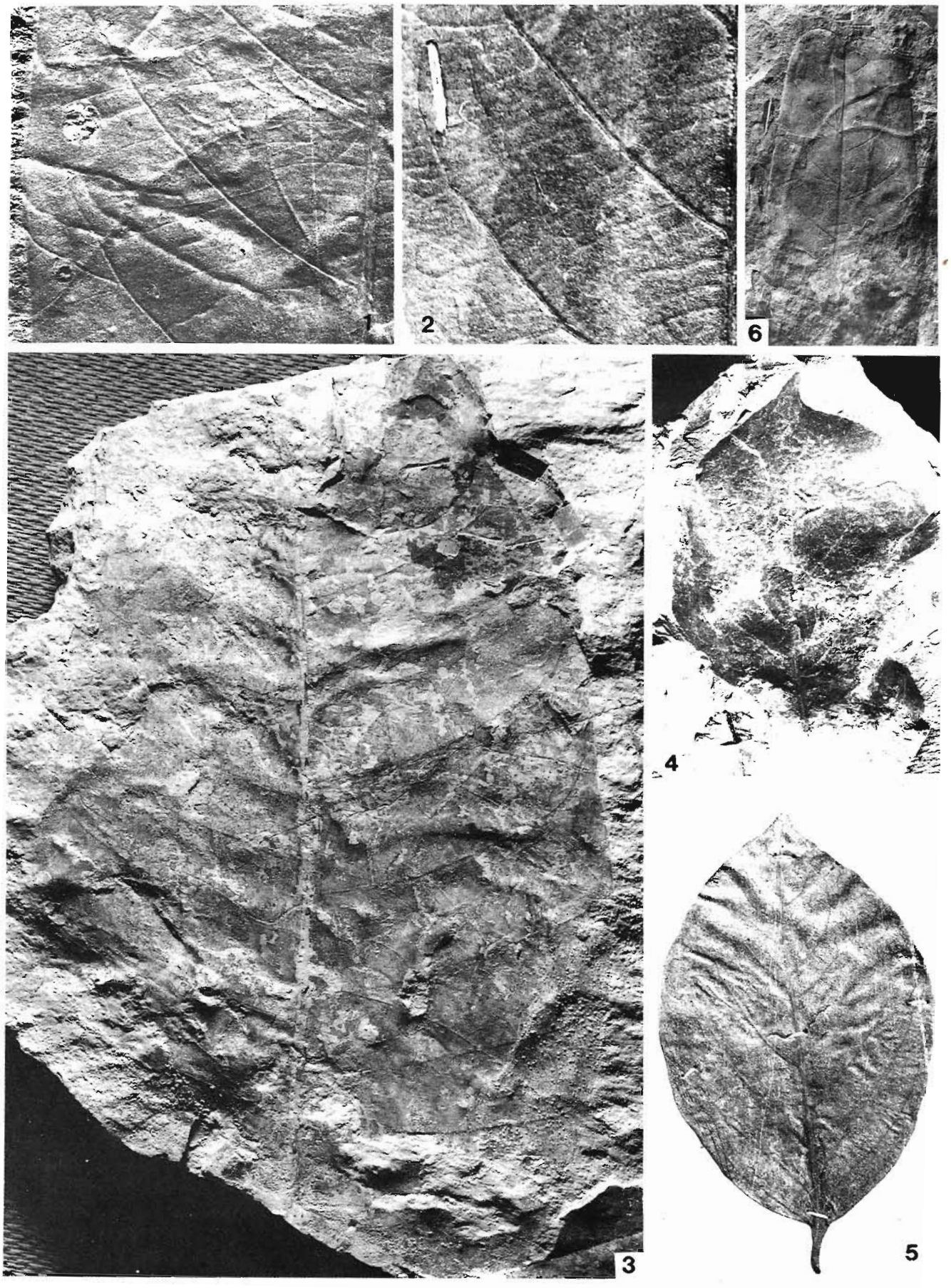

PLATE 6

other is small representing the apical portion only.

Description—Leaf simple symmetrical, narrow ellipitic, 15.5 × 5.0 cm in length and width; apex obtuse, sometimes notched; base missing, margin entire; texture thick chartaceous, petiole missing; venation pinnate, eucamptodromous to brochidodromous; primary vein prominent, stout, slightly curved, secondary veins about 13 pairs visible, usually alternate, unbranched, uniformly curving up towards margin, each secondary joins to its upper adjacent secondary at acute angle before reaching the margin, angle of divergence moderate to wide acute (60-80°), intersecondary veins present, simple, tertiary veins fine with angle of origin AR-RO, percurrent, branched, oblique in relation to midvein, alternate to opposite and close

Discussion—In its shape, size, venation pattern and notched apex the fossil leaf shows strong resemblance with those of *Myristica* (*Knema*) *glomerata* (Bl.) Merr which presently occurs in the Malayan region

Fossil leaves comparable to those of *Myristica (Knema)* are known as a *Myristicophyllum minus* and *M. majus* (Geyler, 1987) from the Tertiary of Labuan, *M. panamense* (Berry, 1918) from Gubbra Formation, Panama, *Myristica apocynophylloides* (Krasser, 1903) from the Tertiary of Uricanga, Germany, *Myristica* sp. and *Knema* sp. (Wolfe, 1977) from Kushtaka Formation, Alaska and *Myristica (Knema) tertiara* (Ettingshausen, 1869) from the Tertiary of Germany. Besides, a fruit of *Myristica* is known from the upper most Eocene of Texas (Berry, 1918).

The present leaf-impression is different from all the known fossil leaves.

Holotype—Specimen no. BSIP 36510.

Paratype—Specimen no. BSIP 36511.

Horizon & locality—Surai Khola beds; Kaila Khola, Surai Khola area.

Family—Euphorbiaceae

Genus—*Breynia* Forst.

Breynia prerhamnoides sp. nov.
Pl. 7, figs 10, 12

This species is based on two leaflets.

Description—Leaflets simple, symmetrical, wide obovate, 2.0 × 1.2 cm in length and width; apex acute to obtuse; base obtuse, normal; margin entire; texture chartaceous; petiole about 0.2 cm long, normal; venation pinnate, simple craspedodromous; primary vein prominent, moderate in thickness; secondary veins 5-6 pairs visible, alternate to opposite, uniformly curving up towards margin, unbranched, angle of divergence acute (about 50°), moderate in thickness; tertiary veins fine, angle of origin usually RR, percurrent, rarely branched, almost straight, oblique in relation to midvein, mostly alternate and close.

Discussion—The fossil leaflets display close relationship to those produced by living species, *Breynia rhamnoides* Muell. Arg. and hence they are placed under a new species, *Breynia prerhamnoides*.

Breynia rhamnoides is a small tree growing in the Forests of Oudh, Gangetic plain, central India, western peninsula, Andamans, Arakan in Burma, chiefly near sea, and Sri Lanka. It is common in the moist region of the Malaya Peninsula and Archipelago and China (Gamble, 1972; Brandis, 1971).

Holotype—Specimen no. BSIP 36512.

Paratype—Specimen no. BSIP 36513.

Horizon & locality—Surai Khola beds near Surai Khola bridge, Surai Khola area.

Genus—*Excoecaria* Linn.

Excoecaria palaeocrenulata sp. nov.
Pl. 7, fig. 7

This species is represented by a single well-preserved leaf-impression

Description—Leaf simple, symmetrical narrow elliptic, laminae 7.2 × 2.3 cm in length and width; apex obtuse; base missing; margin crenulate; texture coriaceous; petiole missing; venation pinnate, brochidodromous; primary vein prominent, stout in thickness, almost straight; secondary veins 11 pairs visible, alternate to opposite, uniformly curving up, branched near the margin and joining the superadjacent secondaries at nearly acute angle,

PLATE 7 →

(All figures are of natural size unless otherwise mentioned).

1. *Myristica palaeoglomerata* sp. nov., specimen no. BSIP 36510.
2. 3. *Myristica glomerata* (Bl.) Merr
4. *Myristica palaeoglomerata* sp. nov., an apical part of another leaf magnified to show details of venation, × 2; specimen no. BSIP 36511
5. *Myristica glomerata*, an apical part of the leaf magnified to show similar venation, × 2.
6. *Excoecaria palaeocrenulata* sp. nov., specimen no. BSIP 36514.
7. *Excoecaria crenulata* Wight K. t.

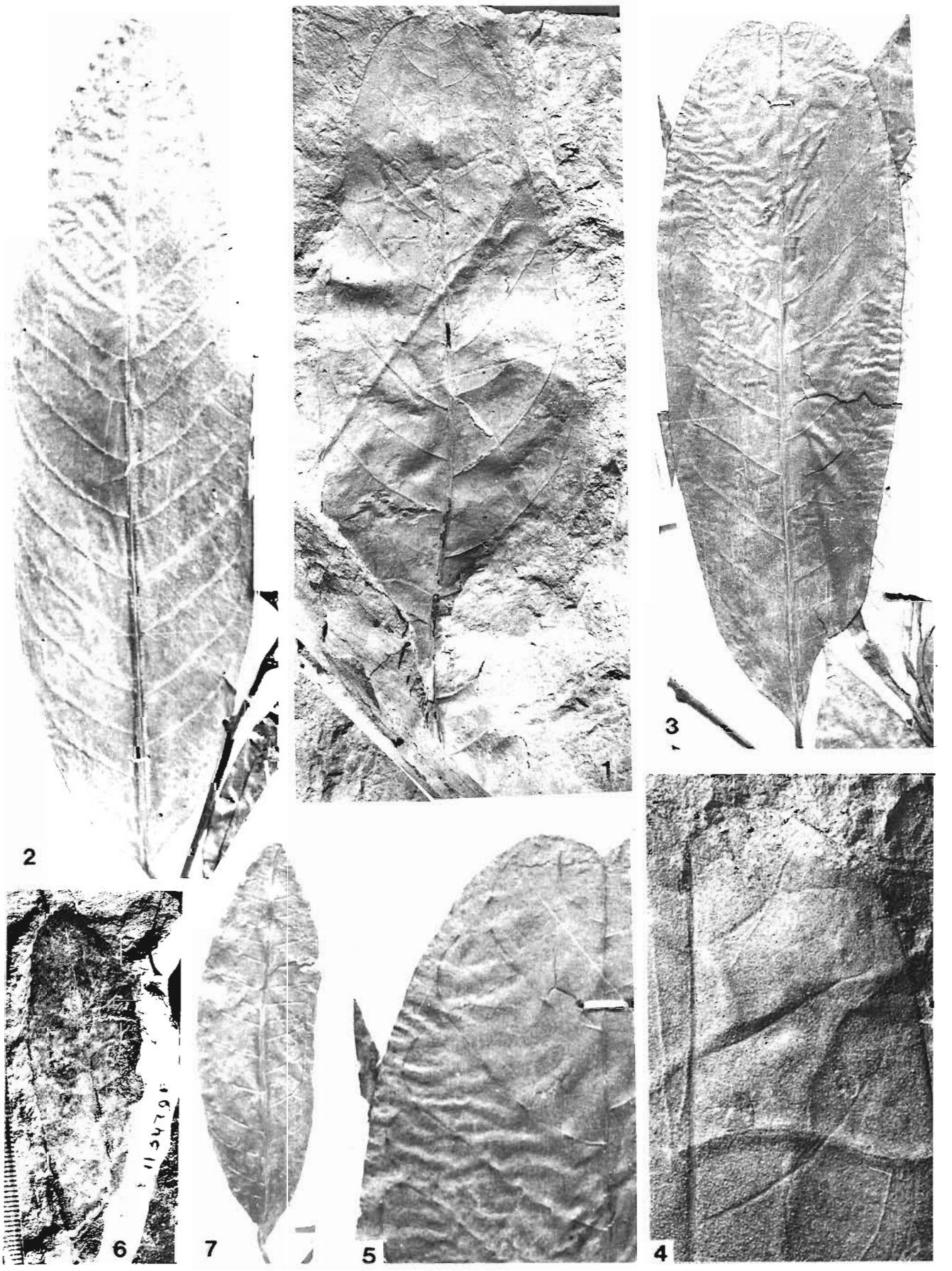

PLATE 7

angle of divergence wide acute (about 70°), intersecondaries simple; tertiary veins fine with angle of origin usually RR, percurrent, branched, almost straight, oblique in relation to midvein, predominantly alternate and close.

Discussion—The characteristic features of the fossil leaf, such as narrow elliptic shape, obtuse apex, crenulate margin, coriaceous texture, brochidodromous type of venation and presence of intersecondary veins, suggest its affinity with the leaves of *Excoecaria crenulata* Wight K. t.

Excoecaria crenulata is a small evergreen tree or shrub occurring in the Western Ghats from Coorg southward, Nilgiris and Anamalais (Brandis, 1972, p. 585).

Holotype—Specimen no. BSIP 36514.

Horizon & locality—Chor Khola beds; Woodseam, Surai Khola area.

PALAEOCLIMATE

Considering the enormous amount of fossil material comprising a great variety of leaf-impressions collected from the Surai Khola sequence of the Siwalik Group, the number of taxa identified with the modern species is yet too small to draw precise conclusion since only a small part of it has been studied so far. Nevertheless, even this is quite significant for drawing some broad inference regarding the climatic conditions. As mentioned earlier, most of the extant taxa, with which the fossil leaf-impressions show resemblance, occur in the tropical, evergreen and moist deciduous forests of Assam, Bangladesh, Burma and the Malayan region; obviously it indicates a very warm and humid condition in the vicinity of Surai Khola at the time when the Siwaliks were deposited. It is interesting to note that the Surai Khola sequence depicts a gradual change in the floral composition (Table 1). The basal sediments, belonging to the Lower Siwalik, have more of evergreen elements, the most important being *Polyalthia, Dipterocarpus, Calophyllum* and *Cynometra*, while those of Surai Khola beds assigned to lower part of the Upper Siwalik (according to Corvinus, *pers. comm.* 1989) consist of mostly moist deciduous to dry deciduous elements (such as *Clinogyne, Flacourtia, Millettia,*

Table 1—Distribution of fossil plants in Surai Khola sequence and the forest types indicated

BEDS	FOSSIL PLANTS	COMPARABLE EXTANT SPECIES	TYPE OF FOREST
Dhan Khola beds	Not recorded		
Dobata	Not recorded		
Surai Khola beds	*Clinogyne ovatus*	*Clinogyne grandis*	Moist deciduous
	Flacourtia nepalensis	*Flacourtia ramnotchi*	Dry deciduous
	Millettia pataeocubithii	*Millettia cubithii*	Moist deciduous
	Bauhinia nepalensis	*Bauhinia malabarica* *Bauhinia variegata*	Moist to dry deciduous
	Diospyros miokaki	*Diospyros kaki*	Moist deciduous
	Breynia prerhamnoides	*Breynia rhamnoides*	Moist deciduous
	Caryota siwalika	*Caryota urens*	Evergreen to moist deciduous
	Mangifera someshwarica	*Mangifera indica*	Evergreen to moist deciduous
	Gluta siwalika	*Gluta renghas*	Evergreen
	Swintonia miocenica	*Swintonia floribunda*	Evergreen
	Entada palaeoscandens	*Entada scandens*	Moist deciduous to semi-evergreen
	Terminalia palaeochebula	*Terminalia chebula*	Moist deciduous to evergreen
	Terminalia panandhroensis	*Terminalia coriacea*	Moist deciduous
Chor Khola beds	*Myristica palaeoglomerata*	*Myristica palaeoglomerata*	Evergreen
	Bambusa siwalika	*Bambusa tulda*	Moist deciduous
	Millettia palaeoracemosa	*Millettia racemosa*	?Evergreen to deciduous

Contd.

	Entada palaeoscandens	*Entada scandens*	Moist deciduous to semi evergreen.
	Excoecaria palaeocrenulata	*Excoecaria crenulata*	Evergreen
	Calophyllum suraikholaensis	*Calophyllum polyanthum*	Evergreen
	Dipterocarpus siwalicus	*Dipterocarpus tuberculatus*	Evergreen
		D. turbinatus	Evergreen
Paira Khola beds	*Fragmentary leaves*	—	—
Bankas beds	*Polyalthia palaeosimiarum*	*Polyalthia simiarum*	Evergreen
	Dipterocarpus siwalicus	*Dipterocarpus turbinatus* *D. tuberculatus*	Evergreen Evergreen
	Cynometra siwalika	*Cynometra polyandra*	Evergreen

Bauhinia, Diospyros kaki, Breynia, etc.). Thus, it may be inferred that there has been a gradual shift in the floral patterns reflecting changes in the climate during the Siwaliks which was caused by the northern movement of the Indian Plate and the uplift of Himalaya.

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