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Middle Miocene flora from Siwalik foreland basin of Uttarakhand, India and its phytogeographic and palaeoclimatic implications

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ABSTRACT

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Morphotaxonomical study on the plant fossils (leaf and fruit impressions) collected from Lower Siwalik sediments of Tanakpur area, Uttarakhand revealed the occurrence of 57 species of 25 angiospermous families. Of these, 39 species have been recorded new to the fossil flora of Himalayan foot hills and remaining 18 species are reported already from different Siwalik fossil localities of India, Nepal and Bhutan. The family Fabaceae (Legume family) represented by 15 species is the most dominant family in present assemblage followed by Annonaceae (8 species), Sapindaceae (5 species), Lauraceae and Euphorbiaceae (4 species) and Dipterocarpaceae and Rutaceae (3 species). The family Fabaceae which appeared in Upper Palaeocene became a major component of the evergreen forest during Middle Miocene times all along the Himalayan foot hills. In the present assemblage the evergreen floral taxa (54%) are dominant in contrast to mixed deciduous taxa at present. The predominance of evergreen elements in the Siwalik fossil assemblage indicates the prevalence of warm and humid climate with plenty of rain fall during the deposition of Siwalik sediments.

The analysis of present day distribution of all the recovered species from the Siwalik foreland basins of Tanakpur area shows that they are mostly known to occur in North–east India, Bangladesh, Myanmar and Malaysia wherever favourable climatic conditions exist. Only about 14% taxa of the total assemblage are found to grow presently in the Himalayan foot hills and the remaining 86% taxa are locally extinct, suggesting changes in the climatic condition. Nearest Living Relative (NLR) suggests that the Tanakpur area enjoyed a tropical climate having Mean Annual Temperature (MAT) 24–28ºC and Mean Annual Precipitation (MAP) 2100–2800 mm during the deposition of the sediments.

Key–words—Plant megafossils (Leaf and fruit impressions), Morphotaxonomy, Floristic analysis, Palaeoclimate, Siwalik Group, Himalayan foot hills, Uttarakhand, India.

भारत में उत्तराखंड की शिवालिक अग्रभूमि द्रोणी से प्राप्त मध्य मध्यनूतन वनस्पतिजात तथा इसके पुराभौगोलिक एवं पुराजलवायवी निहितार्थ

महेश प्रसाद, आलोक, अंकित कुमार कन्नौजिया, संजीव कुमार एवं संजय कुमार सिंह

सारांश

उत्तराखंड में टनकपुर क्षेत्र के अधो शिवालिक अवसादों से संगृहीत पादप जीवाश्मों (पत्ता एवं फल मुद्राश्म) पर आकारवर्गीकीय अध्ययन से 25 आवृतबीजी कुटुंबों की 57 जातियों की प्राप्ति का खुलासा हुआ। इनकी 39 जातियॉ हिमालयी गिरिपादों की जीवाश्म वनस्पतिजात में नूतन

अभिलिखित हुई हैं और बाकी 18 जातियाँ भारत, नेपाल एवं भूटान की विविध शिवालिक जीवाश्म उपबस्तियों से पहले ही अभिलिखित की जा चुकी हैं। विद्यमान समुच्चय में 15 जातियों से रूपायित फैबेसी कुटुंब (लेग्यूम कुटुंब) प्रबलतम कुटुंब है। एन्नोनेसी (8 जातियाँ), सैपिनडेसी (5 जातियाँ) लॉरेसी व यूफोर्बिएसी (4 जातियाँ) एवं डिप्टेरोकार्पेसी तथा रूटेसी (3 जातियाँ) अनुगामी प्रबल कुटुंब है। फैबेसी कुटुंब जो ऊपरी पुरानूतन में प्रकट हुआ था मध्य मध्यनूतन के दरम्यान हिमालयी गिरिपादों के सदाहरित वन का प्रधान घटक बन गया। मौजूदा समुच्चय में वर्तमान मिश्रित पतझड़ी टैक्सा के मुकाबले सदाहरित पुष्पी वर्गक (54%) प्रभावशाली हैं। शिवालिक जीवाश्म समुच्चय में सदाहरित तत्वों की पूर्व प्रधानता शिवालिक अवसादों के निक्षेपण के दरम्यान प्राचुर्य वर्षा सहित कोष्ण एवं आर्द्र जलवायु की व्यापकता द्योतित करती है। टनकपुर क्षेत्र की शिवालिक अग्रभूमि द्रोणियों से समस्त प्राप्त जातियों का वर्तमान वितरण का विश्लेषण दर्शाता है कि ये उत्तर–पूर्व भारत, बॉग्लादेश, म्यांमार एवं मलेशिया में जहाँ कहीं भी अनुकूल जलवायवी स्थिति विद्यमान रहती है वहाँ ज़्यादातर पाए जाते हैं। समग्र समुच्चय का लगभग केवल 14% वर्गक हिमालयी गिरिपादों में इस समय मिलते हैं तथा शेष 86% वर्गक स्थानीय रूप से विलुप्त हैं अतैव ये जलवायवी स्थिति में परिवर्तन द्योतित कर रहे हैं। निकटतम जीवित आपेक्षिक (एनएलआर) सुझाता है कि अवसादों के निक्षेपण के दरम्यान माध्य वार्षिक तापमान (एम ए टी) 24–28° सेल्सियस तथा माध्य वार्षिक वर्षण (एम ए पी) 2100–2800 मिमी के साथ उष्णकटिबंधीय जलवायु टनकपुर क्षेत्र में व्याप्त थी।

सूचक शब्द—पादप स्थूलजीवाश्म (पत्ता एवं फल मुद्राश्म), आकारवर्गिकी, पादप विश्लेषण, पुराजलवायु, शिवालिक समूह, हिमालयी गिरिपाद, उत्तराखंड, भारत।

INTRODUCTION

THE Siwalik Group attains an average thickness of 6000 m and are exposed all along the Himalayan foot hills from the Potwar Plateau in the north–west to Brahmaputra in the north–east covering a distance of 2400 km in length. The Siwalik sediments are made up of rock materials resulting from denudation of slopes of the Himalayan mountains and deposited on the flood plains of the foreland basins since Middle Miocene.

The Siwalik beds in the Tanakpur area are found running in the north–east direction and are well exposed at the bank of Sarda River near Thuligad, and on Thuligad–Purniyagiri Road, Tanakpur–Pithoragarh Road and Karaurhi Nala near Bastia (Fig. 1). The Siwalik sediments are characterized by the alternate presence of sandstone and mudstone facies, the later very often containing abundant plant fossils. A little palaeobotanical work has been carried out from Tanakpur area and a few leaf impressions were reported from there. Firstly, Lakhanpal & Guleria, 1978 reported a lauraceous leaf impression resembling the genus *Persea.* Later on Shashi *et al*. 2006; 2008 described some more leaf impressions under 13 form species belonging to the families Annonaceae, Sterculiaceae, Fabaceae, Apocynaceae and Lauraceae. During the last three decades authors have recovered enormous amount of plant megafossils including petrified woods leaves, fruits and seeds from the Siwalik sediments of Tanakpur and nearby area. An investigation has been carried out to explore and workout systematically the plant megafossils (leaf and fruit impressions) from the Siwalik sediments exposed mainly all along the Purniyagiri road in the Himalayan foot–hills of Uttarakhand (Fig. 3) and on the basis of available data the reconstruction of the palaeofloristics and palaeoclimate/ palaeoecology of the area have been interpreted.

GEOLOGICAL SETTING

The sediments of the Siwalik Group were deposited continuously by various rivers in the Himalayan foreland for last 20 Ma (Johnson *et al*., 1985). These sediments provides on excellent opportunity to study on the plant megafossils entombed in alluvial sediments. The Siwalik sediments in India, Nepal and Bhutan are exposed in the southern frontal area of the Himalaya and are bounded by the Main Boundary Thurst (MBT) to the north and the Himalayan Frontal Thurst (HFT) to the south. The beds generally dip north or north eastward. On the basis of lithic nature and palaeontological data the Siwalik Group has been subdivided into Lower, Middle and Upper Siwalik (Pilgrim, 1913). The Siwalik deposits are one of the most comprehensively studied fluvial sequences in the world. They comprise mudstones, sandstones and coarsely bedded conglomerates laid down when the region was a vast basin during Middle Miocene to Upper Pleistocene times (Fig. 2). In the broadest sense, the rocks become coarser grained upward through the Group being dominated by claystone, mudstone and siltstone in the lower part and terminating with conglomerates beds in the uppermost units. The sediments were deposited by rivers flowing southwards from the Greater Himalayas, resulting in extensive multi–ordered drainage systems. Following this deposition, the sediments were uplifted through intense tectonic regimes (commencing in Upper Miocene times), subsequently resulting in a unique topographical entity–the Siwalik Hills (Falconer, 1835).

The area of present study falls in Kumaun Himalaya. The Siwalik Group lies south of the Main Boundary Thrust. Its thickness varies due to development of valley in the region. The detailed lithology and stratigraphy of the Siwalik have been given by Mishra & Valdiya, 1961; Sahni & Mathur, 1964; Chaudhuri, 1971; Tandon, 1976; Karunakaran & Ranga Rao, 1979; Ranga Rao *et al*., 1979; Shukla, 1984; Kumar & Tandon, 1985.

The Siwalik beds in the Tanakpur area are found running in the north–east direction and are well exposed at the bank of Sarda River near Thuligad, and on Thuligad–Purniyagiri road about 15 km from Tanakpur and Tanakpur–Pithoragarh road and Karaurhi Nala near Bastia. The sediments are coarsing upwards reflecting an increase in transport energy

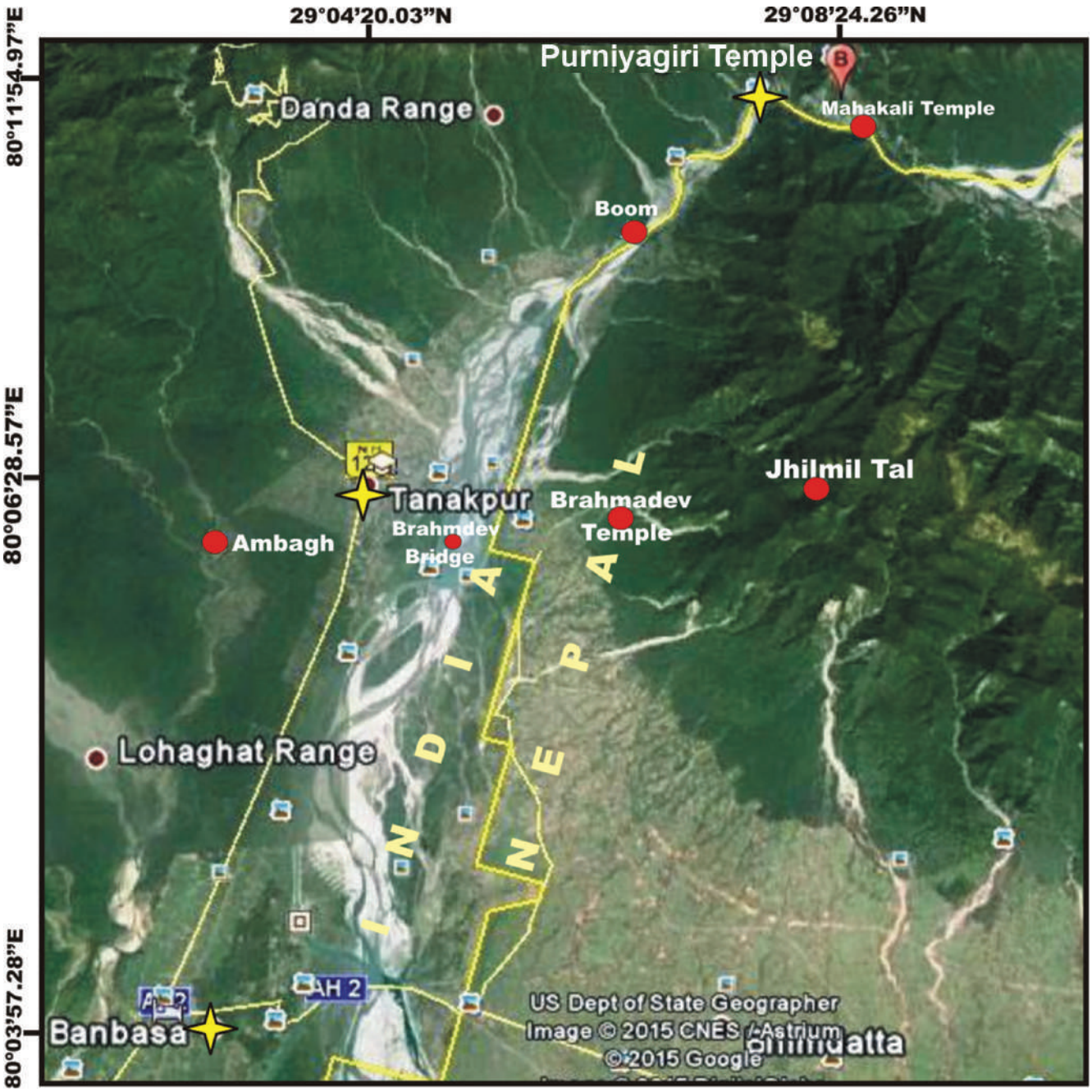

Fig. 1—Map showing the location of fossil locality.

with time. The Lower and Middle Siwalik sediments consist of alternation of sandstone and mudstone beds while the Upper Siwalik sediments are characterized by alternation of conglomerate and mudstone beds with local lenses of sandstone.

An uninterrupted section of Lower Siwalik sub–group is exposed along the Purniyagiri Temple Road between Thuligad and Bhairav Mandir. The lower part of the section is composed of fine to medium grained sandstones alternating with variegated red, grey and yellow palaeosols and bedded flood plain sediments (Fig. 4A–D). This part is rich in plant fossils comprising leaf, fruit and seed impressions/ compressions. The middle part of the section is composed of thick, multistoried medium to coarse grained sandstone beds and mostly devoid of plant fossils. Only carbonised woods and wood fragments are present in small packets or as lenses within sandstones.

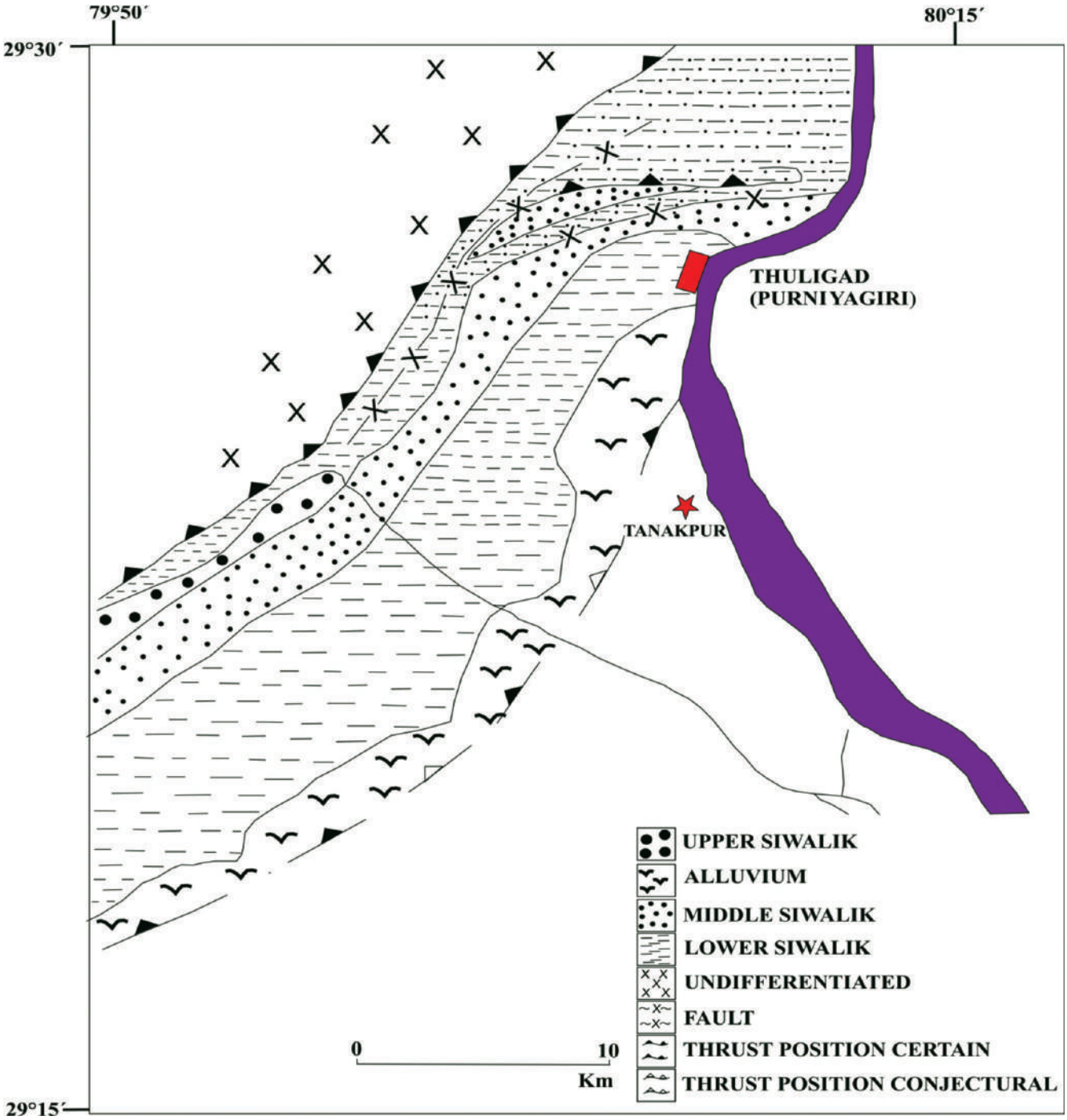

Fig. 2—Geological map showing Siwalik outcrops in the study area (after Ranga Rao *et al*., 1979).

MATERIAL AND METHODS

The fossil locality, Tanakpur (29º04': 80º07') is situated in the foothills of district Champawat, Uttarakhand and very rich in plant fossils comprising petrified and carbonized woods, leaf, fruit and seed impressions. This lies at Indo–Nepal border in the eastern part of Uttarakhand and easily approachable by road from both India and Nepal side (Fig. 1). The sections belonging to the Lower Siwalik beds containing excellently preserved leaf and fruit impressions are well exposed on both the sides of Sarda River near Thuligad, Tanakpur–Pithoragarh road and Thuligad–Purniyagiri road (Figs 3, 4A–D). The leaf–impressions are found on both grey as well as brown calcareous shales but they are more common and well preserved in the grey shale.

More than 1500 specimens of well preserved, complete as well as fragmentary leaf and fruit impressions/ compressions were collected from fossiliferous beds exposed in a road cutting section near Purniyagiri about 15 km north of Tanakpur in Champawat District of Uttarakhand. The leaf impressions are devoid of cuticle and found to be preserved on grey and purple shales and few of them on fine grained sandstone. The leaf impressions have been studied morphologically with the help of either hand lens or low power microscope under reflected light. A large number of herbarium sheets of several extant families and genera was examined at the Central National Herbarium, Sibpur, Howrah, West Bengal in order to identify these leaf impressions. For the description of leaf impressions, the terminology given by Hickey (1973) and Dilcher (1974) has been followed. Photographs of the leaves of the modern comparable species have been provided to show similarity with the fossil leaves. The fossil specimens studied here are preserved in the Museum of the Birbal Sahni Institute of Palaeosciences, Lucknow, India.

SYSTEMATICS

Class—LILIOPSIDA

Family—MARANTACEAE

Genus—DONAX Lour.

Donax ovatus Awasthi & Prasad n. comb.

(Pl. 1.1–4)

Basionym—*Clinogyne ovatus* Awasthi & Prasad, 1990.

Homonym—*Donax ovatus* (Awasthi & Prasad) n. comb.

Material—There are four, well preserved leaf impressions devoid of cuticle.

Description—Leaves simple, slightly asymmetrical, preserved size 4.0 x 2.5 cm, 8.0 x 4.0 cm, 7.0 x 3.0 cm, ovate to elliptic; apex seemingly acute; base not preserved; margin entire; texture chartaceous; petiole indistinct; venation pinnate, eucamptodromous; primary vein (1º) single, straight, moderate; secondary veins (2º) numerous, angle of divergence 20º–40º, narrow acute, less than 1 mm apart, opposite to alternate, uniformly curved up, lower pairs of secondary run upward along the margin to a greater length, unbranched. Tertiary veins (3º) not preserved.

Figured specimen—BSIP Museum Specimen Nos. 41285–41287.

Locality—Spot No. 4 (29º8'51.3": 80º11'16.3"), Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinities—The most characteristic features of the present fossil leaves such as slightly asymmetrical ovate to elliptic shape, entire margin, numerous, fine, very closely placed secondary with narrow acute angle of divergence suggest that these leaves belong to the genus *Donax* Lour (*Clinogyne* Salisb.) of the family Marantaceae. In order to find out its specific affinity the herbarium sheets of all the available species of this genus have been examined and found that these leaves resemble closely to the modern leaves of *Donax grandis* Benth. & Hook. in shape, size and venation pattern.

The fossil leaves resembling the genus *Donax* (*Clinogyne*) have been described earlier under the form species *C. ovatus* Awasthi & Prasad (1990) from the Siwalik sediments of Surai Khola area, Nepal and *Clinogyne* cf. *C. ovatus* from Kasauli Formation, Himachal Pradesh (Arya & Awasthi, 1995). These

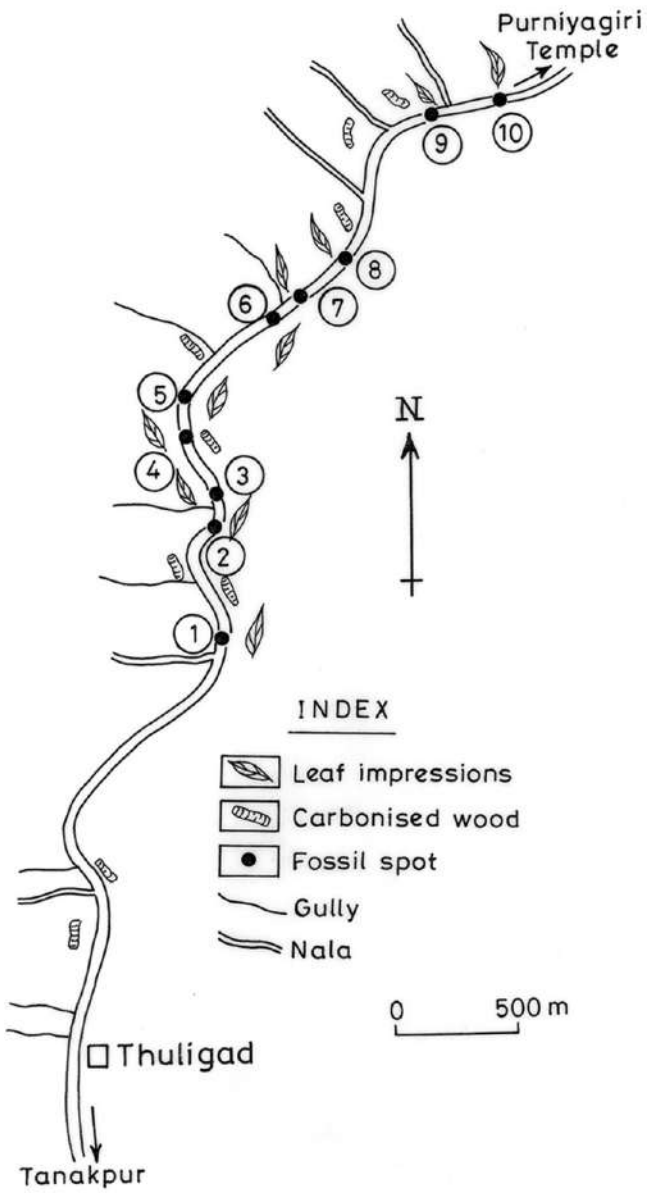

Fig. 3—Thuligad–Purniyagiri road traverse indicating the location of 10 fossil spots from where leaf/ fruit impressions were collected.

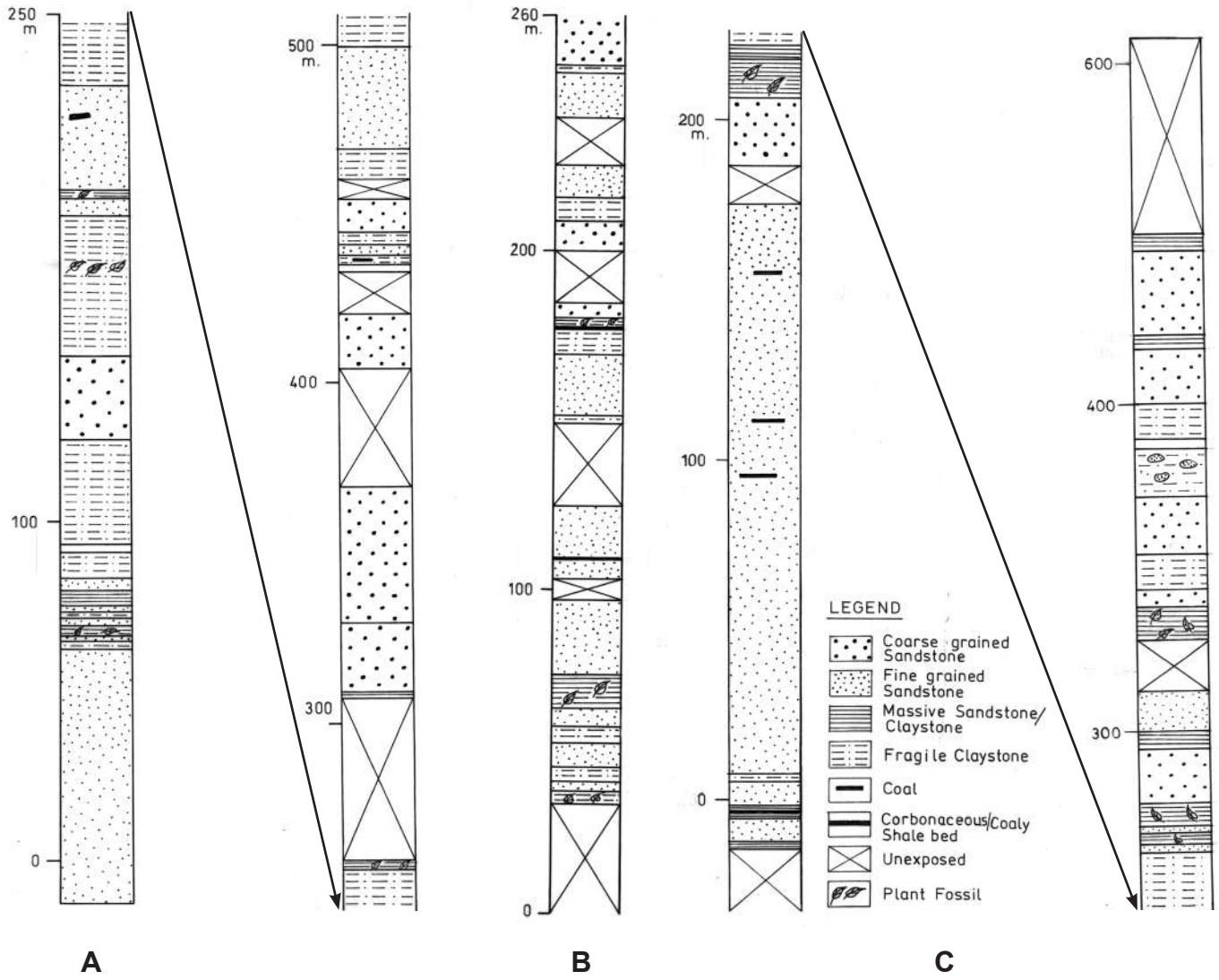

Fig. 4A–C—Lithocolumn of the exposed section indicating the fossil bearing beds.

leaves have been compared with the same extant species, *C. grandis* and also found similar to the present fossils. Antal and Prasad (1995) described another fossil leaf showing affinity with *Clinogyne dichotoma* Salisb. from the Siwalik sediments of Oodlabari area in Darjeeling District, West Bengal. This fossil leaf differs in the nature and course of secondary veins which arise comparatively less angle. Two fossil leaves resembling *Donax cannaeformis* Lour have been described from the Kasauli Formation, Himachal Pradesh and Siwalik sediments of Koilabas, Nepal respectively under a form species *D. kasauliensis* (Prasad & Dwivedi, 2008; Srivastava & Guleria, 2002). On comparison, it has been found that both the fossil leaves of *D. kasauliensis* exhibit unmatched morphological characters as well as larger in size. In view of this the present fossil is described as *D. ovatus* Awasthi & Prasad n. comb.

The genus *Donax* Lour consists of 20 species which are mostly distributed in tropical Africa (Willis, 1973). The extant species *Donax ovatus* Benth. & Hook. with which fossil shows closest affinity is a large shrub that found in savannah of Myanmar, sub–himalayan tract, Andaman Islands and Malaya peninsula (Hooker, 1884).

Class—MAGNOLIOPSIDA

Family—ANNONACEAE

Genus—ANNONA Linn.

Annona miocenica sp. nov.

(Pl. 1.5, 6, 8; Pl. 2.10)

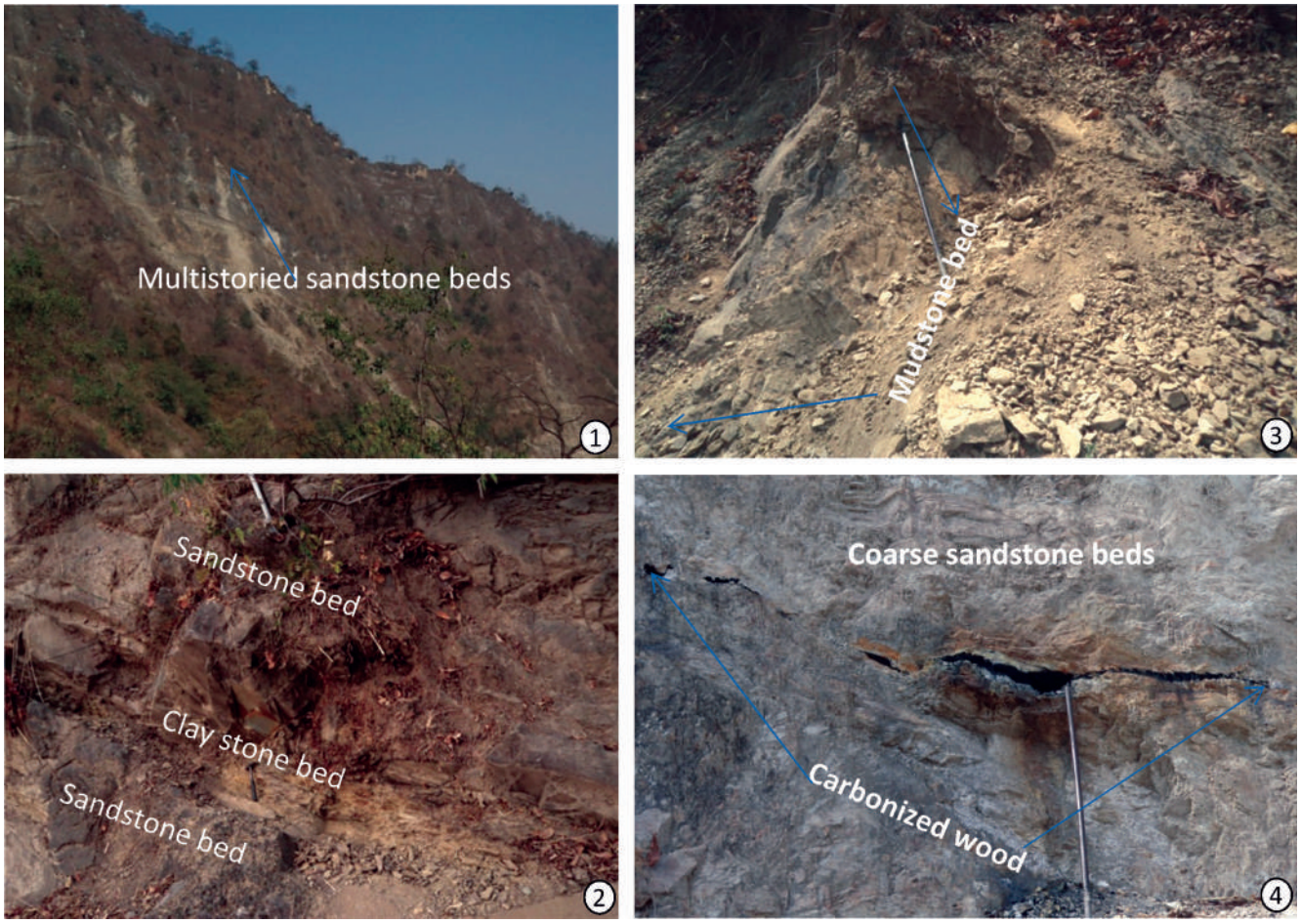

Fig. 4D—Siwalik locality photograph of Tanakpur area showing plant fossil bearing beds and in situ occurrence of Carbonized fossil wood log. (1) Siwalik section showing Multistoried sandstone beds of Middle Siwalik. (2) Spot No.1 near Hanumanchatti in Purniyagiri Road section from where a lot of well preserved leaf fossils were collected from clay stone beds. (3) Spot No. 4 of Purniyagiri Road section showing collection of leaf fossils from bluish and brown coloured mudstone beds. (4) Multistoried thick sandstone beds in the Siwalik section showing in situ occurrence of carbonized wood log.

Material—This species consists of three, well preserved leaf impressions. The apex is broken in the entire specimen.

Description—Leaf simple, almost symmetrical, narrow elliptic, preserved size 4.8 x 1.9 cm and 10.5 x 3.5 cm; apex broken; base acute; margin entire; texture chartaceous; petiole not preserved; venation pinnate, eucamptodromous, primary vein (1º) single, prominent, stout, slightly curved; secondary veins (2º) 10 pairs visible, 0.5–1.5 cm apart, alternate to subopposite, angle of divergence 60º–80º, wide acute, uniformly curved up, moderate, basal secondaries less acute, unbranched; tertiary veins (3º) fine, angle of origin AO–RR, per current, almost straight, branched, oblique in relation to midvein, alternate to opposite and close.

Holotype—BSIP Museum Specimen No. 41288.

Paratype—BSIP Museum Specimen Nos. 41289, 41290.

Locality—Spot No. 1 (29º8'27.4": 80º11'6.9"), near Hanuman Chatti, Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—After the name of Miocene epoch.

Affinities—The characteristic features of the present fossils such as narrow elliptic shape, acute base, entire margin, eucamptodromous venation and wide acute angle of divergence of secondary veins suggest their affinity with the modern leaves of the genus *Annona* Linn. of the family Annonaceae. The herbarium sheets of different species of this genus have been examined in order to find out its specific affinity and concluded that the leaves of *Annona reticulata* Linn. show closest similarity with the fossil leaves in shape, size and venation pattern (C.N.H. Herbarium Sheet Nos. 11387, 54190, 28551, 215; Pl. 1.7).

Prasad *et al.* (1999) described a fossil leaf showing resemblance with *Annona laurifolia* Linn. under the form species, *A. koilabasensis* from the Siwalik sediments of Nepal. Although this fossil leaf shows close similarity in the nature and arrangement of tertiary veins but differs in having lorate shape with obtuse base. The course of secondary veins is also different as compared to the present fossil leaves. In view of this the present fossils are being described here as a new species *Annona miocenica.*

The genus *Annona* Linn consists of 137 species of shrubs distributed in the tropical regions of America, Brazil, Africa (Mabberley, 1997). Only four introduced species are found to grow in India (Willis, 1973). The comparable species, *Annona reticulata* Linn. is a small tree naturalized in West Bengal and elsewhere (Hooker, 1872).

Genus—POPOWIA Endl.

Popowia siwalica sp. nov.

(Pl. 1.9, 10)

Material—There are two well preserved leaf impressions.

Description—Leaf simple, symmetrical, elliptic, preserved size 3.8 x 1.9 cm and 3.5 x 2.6 cm; apex broken in both specimens; base obtuse; margin entire; petiole not preserved; texture chartaceous; venation pinnate, eucamptodromous; primary vein (1º) single, slightly curved, stout; secondary vei ns (2º) 6–7 pairs visible, 0.5 to 0.8 cm apart, alternate to sub opposite, angle of divergence about 55º, moderately acute, uniformly curved up, secondary veins run upward to a little distance, unbranched; tertiary veins (3º) fine, angle of origin usually RR, percurrent, almost straight, rarely branched, oblique in relation to midvein, predominantly alternate and close.

Holotype—BSIP Museum Specimen No. 41291.

Locality—Spot No.10 (29º9'12.1": 80º11'38.5"), Bhairav Mandir, Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—After the name of Siwalik Group.

Affinities—The diagnostic features of the present fossil leaves are elliptic shape, obtuse base, eucamptodromous venation with secondary veins running upward for a little distance before joining their superadjacent secondary veins, RR, percurrent, predominantly alternate tertiaries. During identification it has been observed that these features are found common in the modern leaves of the genus *Popowia* Endl. of the family Annonaceae. The comparative study with modern leaves of all the available species of this genus suggests that the present fossil leaves show closest affinity with the leaves of *Popowia ramosissiana* Bedd. (Syn. *P. beddomeana* Hook. f. & Th.; C.N.H. Herbarium Sheet No. 12559).

There is no record of fossil leaf resembling the genus *Popowia* Endl. from the Tertiary sediments of India. This fossil leaf represents its first occurrence in the Siwalik sediments of Uttarakhand, hence it is being described as *Popowia siwalica* sp. nov.

The genus *Popowia* Endl. comprises 30 species distributed in the tropical regions from Asia to Australia. *Popowia ramosissiana* Bedd. with which fossils show closest affinity is a evergreen, small tree or shrub found commonly between Tinnvelli and Travancore (Brandis, 1971).

Genus—MILIUSA Leschen ex A. DC.

Miliusa (Saccopetalum) pretomentosa Prasad *et al.,* 2004

(Pl. 2.1, 3)

Material—There is a single, well preserved leaf impression.

Description—Leaf simple, symmetrical, wide ovate; preserved size 6.0 x 4.0 cm; apex seemingly acute; base obtuse; margin entire; texture chartaceous; venation pinnate, eucamptodromous; primary vein (1º) single, prominent, stout; secondary veins (2º) 7–8 pairs, 0.4 to 1.5 cm apart, alternate, angle of divergence about 40º, narrow acute, branched, lower secondaries with 2–3 branches, curved up and run for a greater length towards apex; tertiary veins (3º) moderate in thickness, angle of origin usually RR, percurrent, straight to sinuous, oblique to right angle in relation to midvein, predominantly alternate and close.

Specimen—BSIP Museum Specimen No. 41292.

Locality—Spot No.10 (29º9'12.1": 80º11'38.5"), Bhairav Mandir, Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinity—The characteristic features of the present fossil leaf are ovate shape, acute apex, obtuse base, eucamptodromous venation, narrow acute angle of divergence of secondary veins with profusely branches, percurrent, straight to sinuous tertiary veins with oblique to right angle in relation to midvein. These features are found commonly in

PLATE 1

(All figures are of natural size unless otherwise mentioned)

1–3. *Donax ovatus* (Awasthi & Prasad) n. comb.–Fossil leaves showing shape, size and venation pattern. BSIP Museum Specimen No. 41285–41287.

4. *Donax ovatus* (Awasthi & Prasad) n. comb. Part of fossil leaf magnified to show details of venation pattern. X 2.5. BSIP Museum Specimen No. 41286.

5, 6. *Annona miocenica* sp. nov.–Fossil leaves showing shape, size and venation pattern. BSIP Museum Specimen No. 41288 (Holotype), 41289 (Paratype).

7. *Annona reticulata* Linn.–Modern leaf showing similar shape, size and venation pattern.

8. *Annona miocenica* sp. nov.–Part of the fossil leaf magnified to show similar details of venation pattern. X 4. BSIP Museum Specimen No. 41288.

9. *Popowia siwalica* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41291 (Holotype).

10. *Popowia siwalica* sp. nov.–Part of fossil leaf magnified to show details of venation. X 4. BSIP Museum Specimen No. 41291.

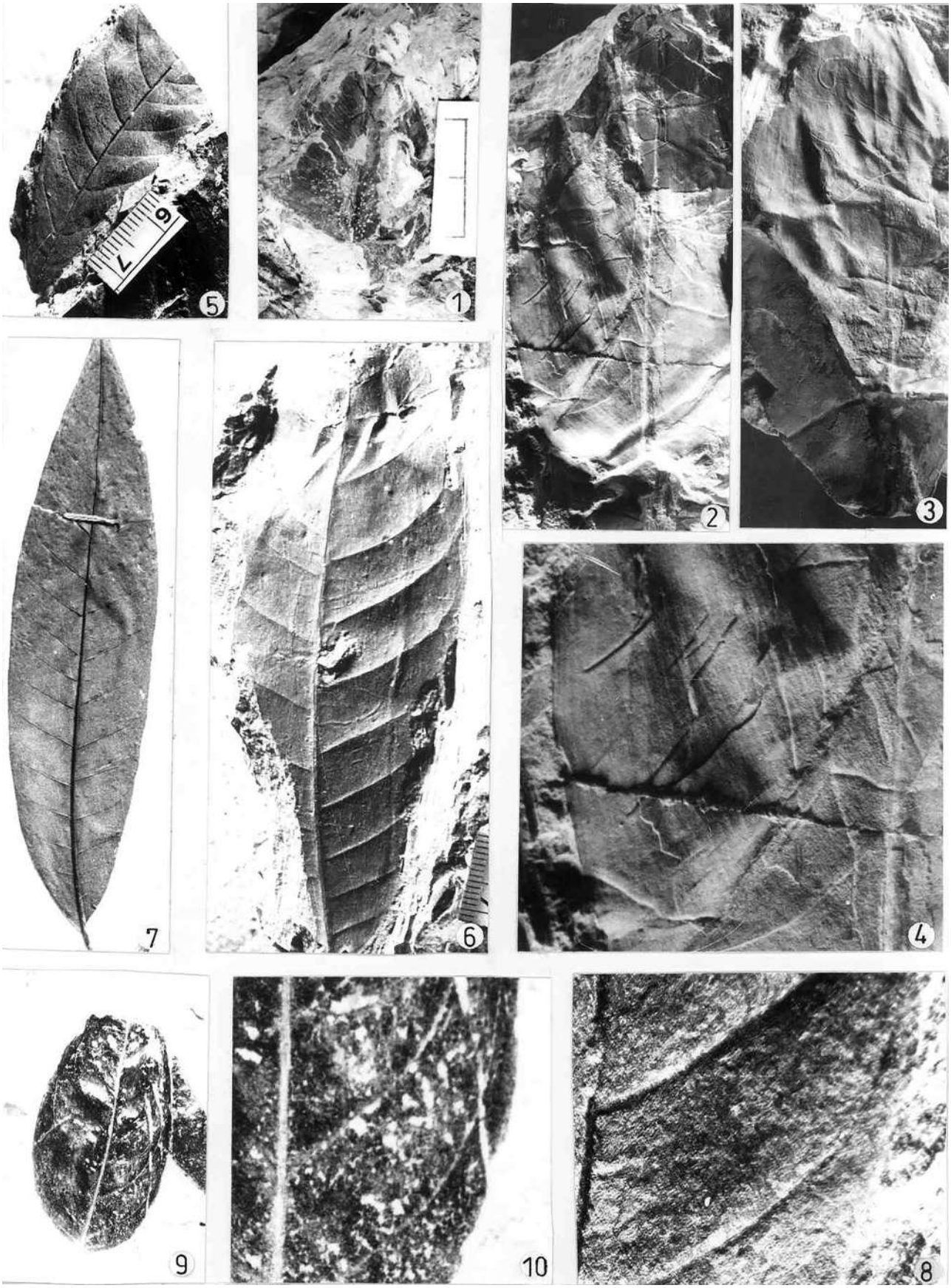

PLATE 1

the extant leaves of *Miliusa* Leschen ex A.DC. of the family Annonaceae. After comparative study of all the available species of *Miliusa* Leschen ex A.DC., it was observed that the fossil leaf shows similarity with the leaves of *Miliusa* (*Saccopetalum) tomentosa* (Roxb.) J. Sinclair (C.N.H. Herbarium Sheet No. 14330; Pl. 2.2).

So far, five fossil leaves resembling the genus *Miliusa* (*Saccopetalum)* Leschen ex A. DC. have been described from the Tertiary sediments of India. Of these, three fossil leaves were described under the genus *Miliusa* Leschen ex A.DC. These are *M. siwalica* Prasad *et al.* (1999) and *M. brochidodroma* Konomatsu & Awasthi (1999) from Siwalik sediments of Nepal and *M. miovelutina* Tripathi *et al.* (2002) from Siwalik sediments of Jarwa, India. Awasthi and Mehrotra (1995) described a fossil leaf as *Saccopetalum palaeolongiflorum* from the Oligocene sediments of Makum Coalfield, Assam. The fossil leaf has larger size (18 cm in length) with wide elliptic shape as compared to ovate shape in the present fossil. Later on, Prasad *et al*., 2004 reported a fossil leaf, *Saccopetalum pretomentosum* from Lower Siwalik sediments of Kathgodam, Uttarakhand. The fossil shows similarity with the extant leaves of *M. tomentosa* Leschen ex A.DC. (syn. *S. tomentosum)* and also possesses similar morphological features as the present fossil. Hence, it is being described under the same species, *Miliusa (Saccopetalum) pretomentosa* Prasad *et al*.

The genus *Miliusa* Leschen ex A.DC. consists of 40 species distributed in the Indo–Malayan region and Australia (Mabberley, 1997). The modern comparable species *Miliusa tomentosa* (Roxb.) J. Sinclair *(Saccopetalum tomentosum* Hook. f. & Th.) is a deciduous tree and found to grow in Oudh, Nepal Terai upto Gorakhpur and Southwards throughout the peninsula (Brandis, 1971).

Genus—MEIOGYNE Miq.

Meiogyne purniyagiriensis sp. nov.

(Pl. 2.4, 6)

Material—This species is based on a single, will preserved and complete leaf impression.

Description—Leaf simple, asymmetrical, narrow ovate; size 4 x 1.5 cm; apex sharply acute; base wide acute to nearly obtuse; slightly inequilateral; margin entire; texture chartaceous; petiole broken; venation pinnate; eucamptodromous to brochidodromous; primary vein (1º) single; prominent, weak, straight; secondary veins (2º) 9–10 pairs visible, 0.2 to 0.6 cm apart, alternate to opposite; angle of divergence 40º–70º, narrow to wide acute, uniformly curved up; secondaries of one side of lamina arise at wide acute angle towards basal region, sometimes branched, few secondaries joins each other before reaching the margin, intersecondary veins present, simple; tertiary veins (3º) fine, angle of origin usually RR, percurrent, almost straight, sometimes branched, oblique in relation to midvein, predominantly alternate and close; quaternary veins (4º) poorly preserved arising at right angle, forming triangular to polygonal meshes.

Holotype—BSIP Museum Specimen No. 412293.

Locality—Spot No.1 (29º8'27.4": 80º11'6.4"), near Hanuman Chatti, Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—After the name of Purniyagiri Temple.

Affinity—The present fossil leaf is characterized by narrow ovate shape, sharply acute apex, slightly asymmetrical, nearly obtuse base, entire margin, eucamptodromous to brochidodromous venation, narrow to wide acute angle of divergence of secondary veins, RR, percurrent tertiaries having an oblique angle in relation to midvein. The nature of few basal secondaries which are joining to their superadjacent secondaries before reaching the margin is also an important character. A comparative study of the herbarium sheets of different families and genera shows that the above features are found commonly in the extant leaves of *Meiogyne pannosa* Dalz. of the family Annonaceae (C.N.H. Herbarium Sheet No. 11449; Pl. 2.5).

The fossil leaf resembling the genus *Meiogyne* Miq. is not known so far from the Tertiary sediments of India and abroad. The present fossil is recorded for the first time

PLATE 2

(All figures are of natural size unless otherwise mentioned)

1. *Miliusa* (*Saccopetalum) pretomentosa* Prasad *et al*.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41292.
2. *Saccopetalum tomentosum* Hook F. & Th.–Modern leaf showing similar shape, size and venation pattern. X 0.8.
3. *Miliusa* (*Saccopetalum) pretomentosa* Prasad *et al*.–Part of fossil leaf magnified to show details of venation. X 2.5. BSIP Museum Specimen No. 41292.
4. *Meiogyne purniyagiriensis* sp. nov.–Fossil leaf showing shape, size, nature of apex and base and venation pattern. BSIP Museum Specimen No. 41293.
5. *Meiogyne pannosa* Dalz. Modern leaf showing similar shape, size, apex, base and venation pattern.
6. *Meiogyne purniyagiriensis* sp. nov.–Part of fossil leaf magnified to show details of venation pattern. X 4. BSIP Museum Specimen No. 41293.
7. *Dendrokingstonia palaeonervosa* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41294 (Holotype).
8. *Dendrokingstonia nervosa* (Hook. f. & Th.) Rauschert–Modern leaf showing similar shape, size and venation pattern.
9. *Dendrokingstonia palaeonervosa* sp. nov.–Part of fossil leaf magnified to show the details of venation pattern. X 4. BSIP Museum Specimen No. 41294.
10. *Annona miocenica* sp. nov.–An other fossil leaf showing nature of apex. BSIP Museum Specimen No. 41290 (Paratype).

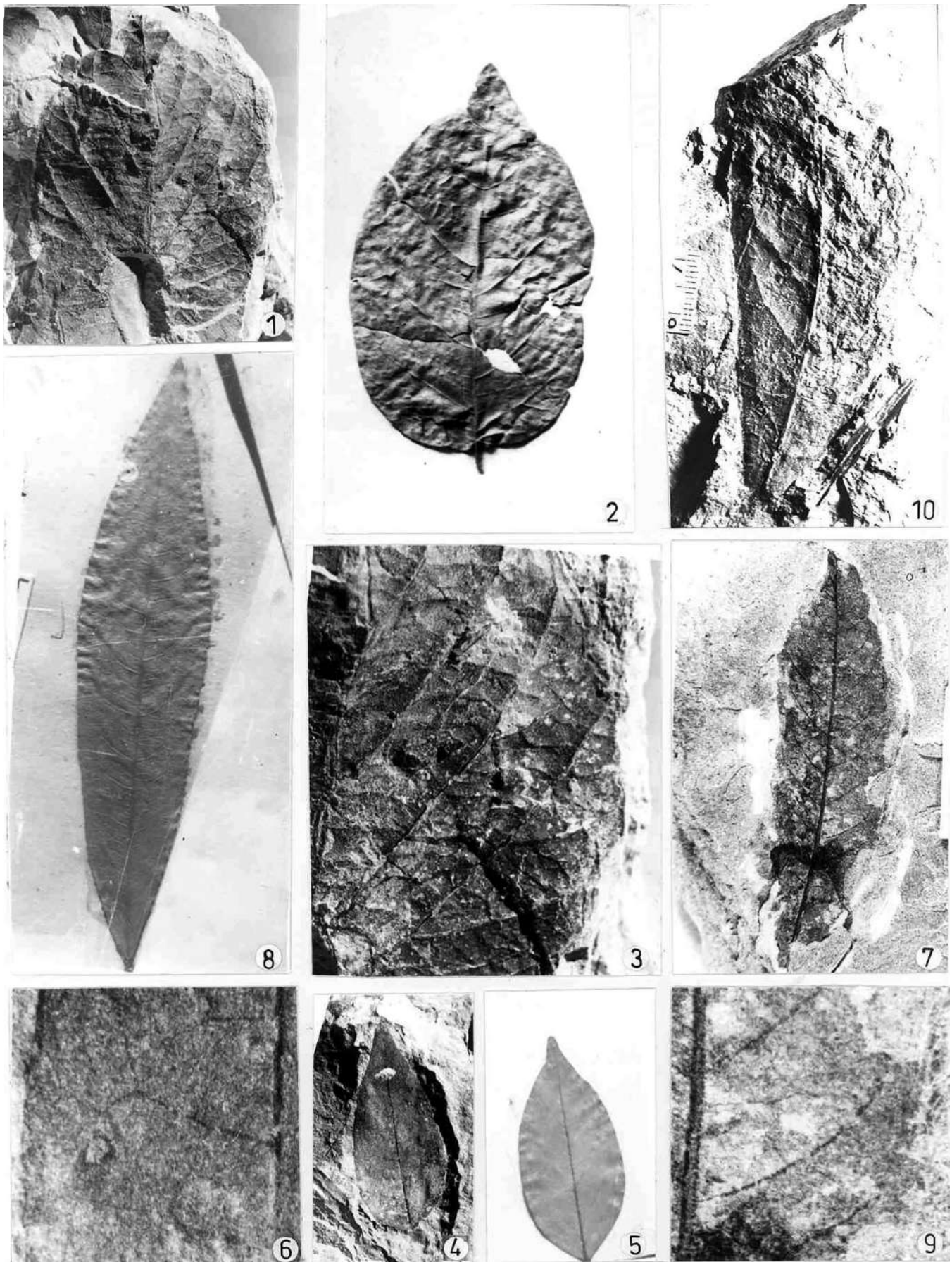

PLATE 2

from the Siwalik sediments of Uttarakhand and therefore, it has been described under the new specific name *Meiogyne purniyagiriensis* sp. nov. The genus *Meiogyne* Miq. consists of nine species distributed in the Indo–Malayan region (Mabberley, 1997). The modern comparable taxon. *M. pannosa* Dalz. is a shrub or small tree distributed in the evergreen forests of Western Ghat. It is more common in South and Central Sahyadri and rare in Maharashtra Sahyadri.

Genus—DENDROKINGSTONIA (Hook. f. Thomson) Rauschert

Dendrokingstonia palaeonervosa sp. nov.

(Pl. 2.7, 9)

Material—Only one, well preserved leaf impression.

Description—Leaf simple, asymmetrical, very narrow elliptic; size 7.5 x 1.8 cm; apex seemingly acute; base acute; margin entire; texture chartaceous; venation pinnate, eucamptodromous; primary vein (1º) single, prominent, slightly curved, stout; secondary veins (2º) about 11 pairs visible, 0.4 cm to 0.8 cm apart, angle of divergence 60º–70º, moderately to wide acute, uniformly curved up, seemingly unbranched; intersecondary veins present, simple; tertiary veins (3º) fine, angle of origin usually RR, rarely AO, percurrent, straight to sinuous, branched, oblique in relation to midvein, predominantly alternate and close.

Holotype—BSIP Museum Specimen No. 41294.

Locality—Spot No.10 (29º8'12.1": 80º11'38.5"), Bhairav Mandir, Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—By adding prefix 'Palaeo' to the name of comparable species, *D. nervosa.*

Affinity—In being asymmetrical, very narrow elliptic shape with an acute apex and base, eucamptodromous type of venation along with RR, percurrent, straight to sinuous tertiary veins, the present fossil shows its nearest affinity with the extant taxon, *Dendrokingstonia nervosa* (Hook. f. Thomson) Rauschert of the family Annonaceae (C.N.H. Herbarium Sheet No. 4774; Pl. 2.8).

There is no record of fossil leaf of the genus *Dendrokingstonia* (Hook. f. Thomson) Rauschert from the Cenozoic sediments of India and abroad. This fossil leaf represents its first occurrence and has been described as *Dendrokingstonia palaeonervosa* sp. nov.

The genus *Dendrokingstonia* (Hook. f. Thomson) Rauschert comprises single species, *Dendrokingstonia nervosa* (Hook. f. Thomson) Rauschert (Syn. *Kingstonia nervosa* Hook. f. Thomson) with which fossil shows close affinity is a tree and distributed in the evergreen forests of Malayan peninsula, Java, Malacca and Maingay (Hooker, 1872).

Family—POLYGALACEAE

Genus—SECURIDACA Linn.

Securidaca precorymbosa sp. nov.

(Pl. 3.1, 3)

Material—There is a single, fairly preserved, almost complete leaf impression.

Description—Leaf simple, symmetrical, wide ovate; size 3.5 x 2.5 cm; apex broken ; base obtuse, normal; margin entire; texture coriaceous; petiole broken; venation pinnate, eucamptodromous; primary vein (1º) single, prominent, moderate, straight; secondary veins (2º) about 7 pairs visible, 0.3 to 0.7 cm apart, angle of divergence acute, about 60º, moderate, uniformly curved up, seemingly branched, upper secondaries arise with less angle; intersecondary veins present, frequent; tertiary veins (3º) fine, poorly preserved, angle of origin AO, percurrent, almost straight, oblique in relation to midvein, predominantly alternate and close.

Holotype—BSIP Museum Specimen No. 41295.

Locality—Spot No. 8 (29º9'07": 80º11'21.5"), Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

PLATE 3

(All figures are of natural size unless otherwise mentioned)

1. *Securidaca precorymbosa* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41295 (Holotype).
2. *Securidaca corymbosa* Triana & Planch–Modern leaf showing similar shape, size and venation pattern.
3. *Securidaca precorymbosa* sp. nov.–Part of fossil leaf magnified to show details of venation. X 4. BSIP Museum Specimen No. 41294.
4, 5. *Xanthophyllum mioglaucum* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41296 (Holotype), BSIP Museum Specimen No. 41297 (Paratype).
6. *Xanthophyllum glaucum* Wall.–Modern leaf showing similar shape, size and venation pattern.
7. *Xanthophyllum mioglaucum* sp. nov.–Part of fossil leaf magnified to show details of venation. X 4. BSIP Museum Specimen No. 41296.
8 *Calophyllum suraikholaensis* Awasthi & Prasad–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41301.
9 *Calophyllum suraikholaensis* Awasthi & Prasad–Part of fossil leaf magnified to show details of venation. X 4. BSIP Museum Specimen No. 41301.
10., 11. *Kayea kalagarhensis* Prasad–Fossil leaf showing nature of apex. BSIP Museum Specimen Nos 41298, 41299.

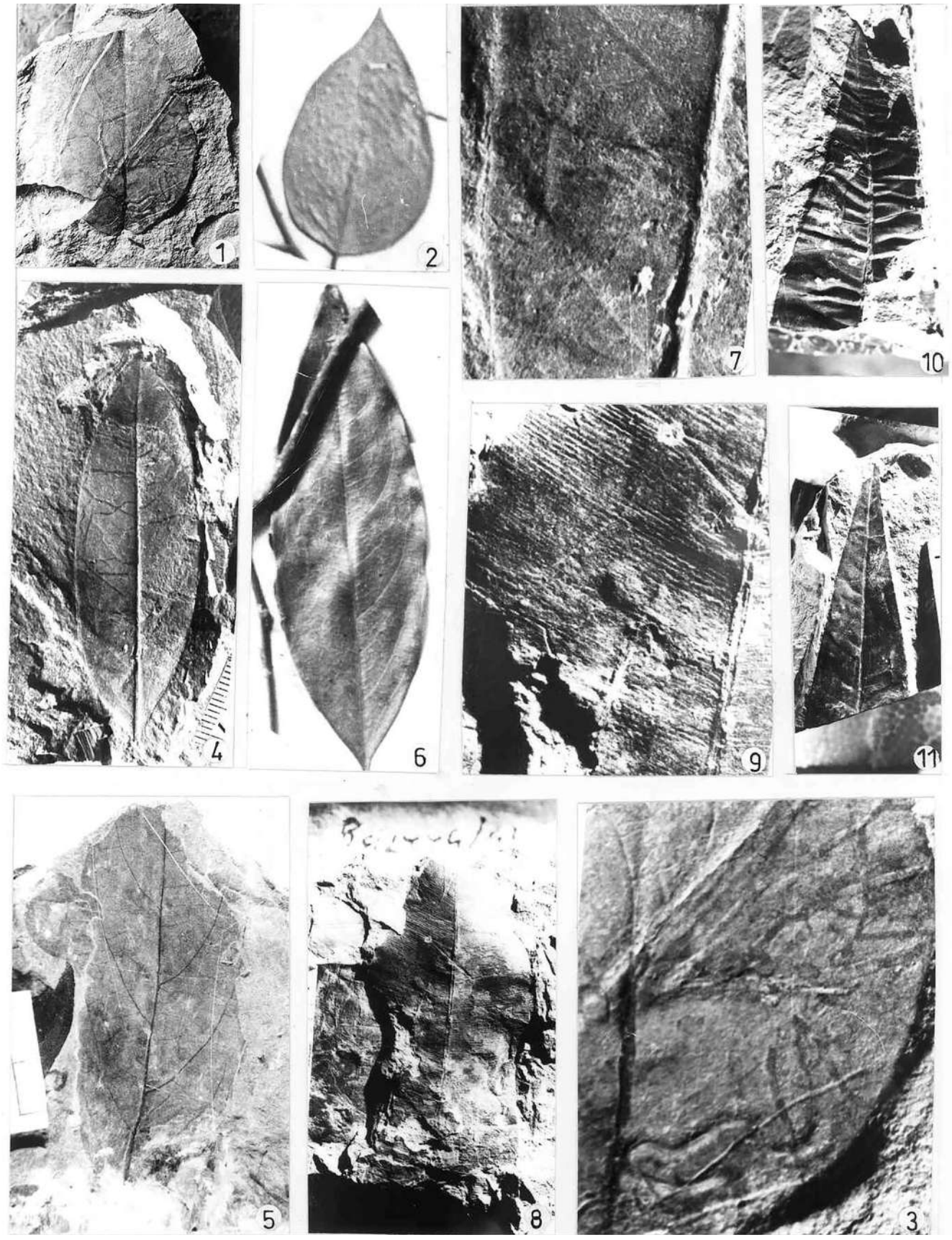

PLATE 3

Etymology—By adding prefix 'pre' to the name of modern comparable species, *S. corymbosa.*

Affinity—The fossil leaf is characterized by wide ovate shape, obtuse base, entire margin, eucamptodromous venation, moderately acute angle of divergence of secondary veins and AO, percurrent tertiary veins. These features undoubtedly indicate that the present fossil leaf closely resembles the extant leaf of *Securidaca corymbosa* Triana & Planch of the family Polygalaceae (C.N.H. Herbarium Sheet No. 36423; Pl. 3.2).

So far, two fossil leaves resembling the extant leaves of *Securidaca inappendiculata* Hask. have been known under the form species *Securidaca miocenica* Prasad *et al.* 1997 from the Siwalik sediments of Seria Naka, Uttar Pradesh, India and Koilabas, Nepal respectively. These fossil leaves differ entirely from the present fossil leaf in having large, elliptic shape as compare to small, wide ovate shape in this fossil leaf. On account of its distinctiveness this fossil specimen has been described as a new species *Securidaca precorymbosa*.

The genus *Securidaca* Linn. comprises about 114 species of trees and scramblers. The modern comparable species *S. corymbosa* Triana & Planch is presently distributed in north–east Indian region.

Family—XANTHOPHYLLACEAE

Genus—XANTHOPHYLLUM Roxb.

Xanthophyllum mioglaucum sp. nov.

(Pl. 3.4, 5, 7)

Material—There are two, well preserved and complete leaf impressions.

Description—Leaf simple, symmetrical, narrow elliptic; size 7 x 2.4 cm, 7 x 2.8 cm; apex acute; base acute; margin entire; texture thick coriaceous; petiole broken; venation pinnate, eucamptodromous; primary vein (1º) single, prominent, stout, almost straight; secondary veins (2º) 6–7 pairs visible, 0.8 to 2.0 cm apart, alternate, angle of divergence about 55º, moderately acute, seemingly unbranched, uniformly curved up and run for a short distance toward apex; intersecondary veins present, simple; tertiary veins (3º) fine, angle of divergence usually RR, rarely AO, percurrent, straight to sinuous, sometimes branched, oblique in relation to midvein, predominantly alternate and close.

Holotype—BSIP Museum Specimen No. 41296.

Paratype—BSIP Museum Specimen No. 41297.

Locality—Spot No.1 (29º8'27.4": 80º11'6.9"), near Hanuman Chatti, Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—By adding prefix 'mio' to the name of extant species, *X. glaucum.*

Affinity—The diagnostic features of the present fossil leaf such as symmetrical, narrow elliptic shape, acute apex and base, entire margin, eucamptodromous venation, alternate secondary with moderately acute angle of divergence, usually RR, percurrent and close tertiaries indicate that the present fossil shows resemblance with the modern leaves of the genus *Xanthophyllum* Roxb. of the family Xanthophyllaceae. In order to find out specific affinity, the herbarium sheets of all the available species of this genus were critically examined and it was concluded that the leaves of *Xanthophyllum glaucum* Wall. (C.N.H. Herbarium Sheet Nos 2953, 209, 505; Pl. 3.6) show close similarity with the fossil leaf in shape, size and venation pattern.

Antal and Prasad (1996a) reported a fossil leaf resembling the genus *Xanthophyllum* Roxb. under a form species *X. mioflavecens* from the Siwalik sediments of Darjeeling District, West Bengal. This species differs from the present fossil in being larger size with few sparsely arranged secondary veins. Besides, a fossil wood resembling this genus has also been reported from the Mio–Pliocene beds of Cuddalore Series, South India (Awasthi, 1987). As the present fossil leaf is distinct from already known fossil leaf, this has been described under a new species, *Xanthophyllum mioglaucum*.

The genus *Xanthophyllum* Roxb. is chiefly an Indo–Malayan genus comprising about 93 species (Mabberley, 1997). *Xanthophyllum glaucum* Wall. (*X. macrocarpum*) with which fossil leaf shows closest resemblance is a large, evergreen tree distributed in moist places of Upper and Lower Myanmar and Malayan peninsula (Brandis, 1971; Ridley, 1967).

PLATE 4

(All figures are of natural size unless otherwise mentioned)

1. *Kayea kalagarhensis* Prasad–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41300.
2. *Kayea floribunda* Wall.–Modern leaf showing similar shape, size and venation pattern.
3. *Kayea kalagarhensis* Prasad–Part of fossil leaf magnified to show the details of venation. X 2. BSIP Museum Specimen No. 41300.
4. *Kayea floribunda* Wall.–Modern leaf magnified to show the similar details of venation. X 2.

5, 6. *Hopea kathgodamensis* Prasad–Fossil leaves showing shape, size and venation pattern. BSIP Museum Specimen Nos. 41306.–41307.

7. *Hopea kathgodamensis* Prasad–Part of fossil leaf magnified to show details of venation. X 4. BSIP Museum Specimen No. 41307.
8. *Dipterocarpus suraikholaensis* Prasad & Pandey–Fossil leaf showing incomplete shape, size and distinct venation pattern. BSIP Museum Specimen No. 41302.
9. *Dipterocarpus turbinatus* Gaertn. (Syn. *D. alatus*)–Modern leaf showing similar venation pattern.

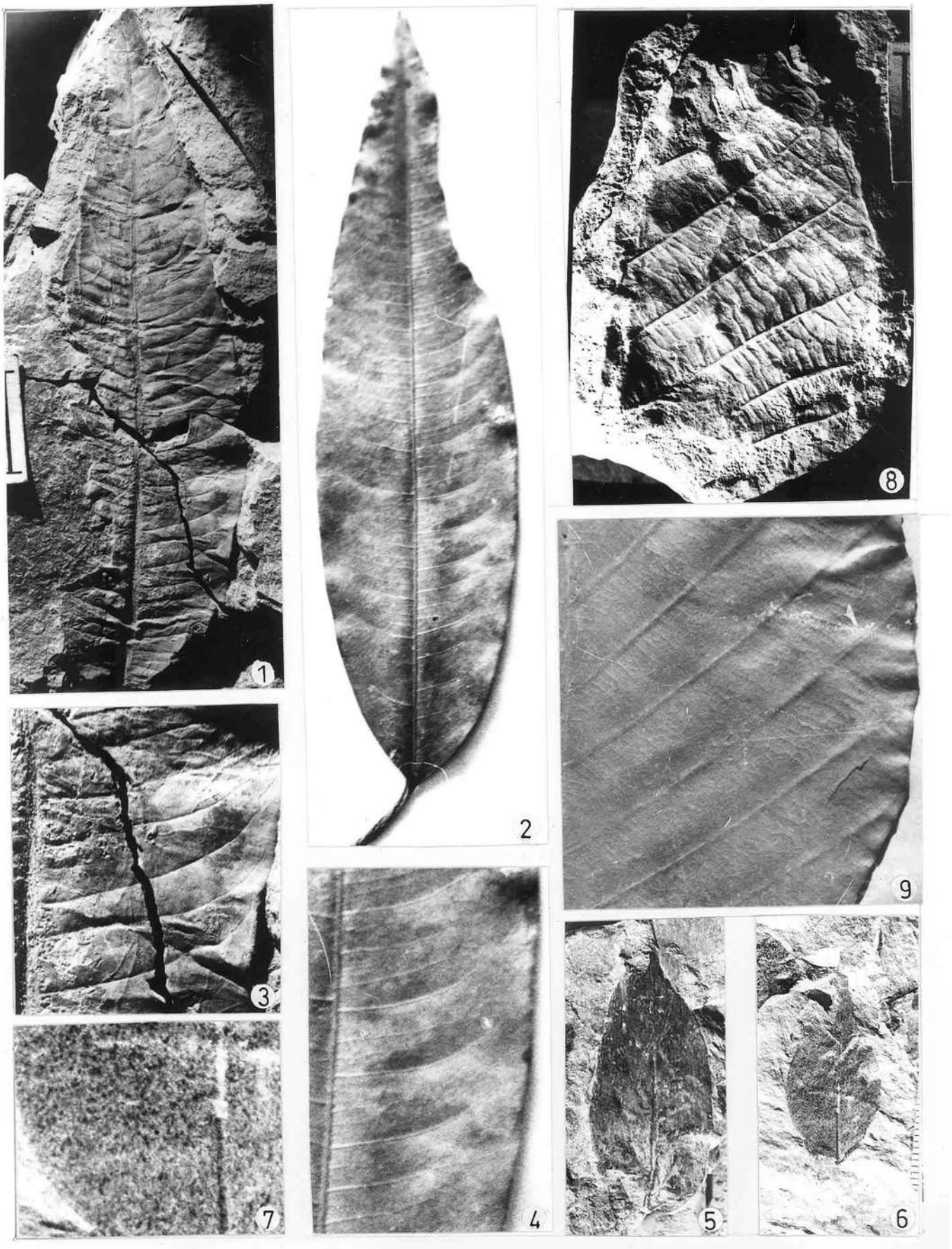

PLATE 4

Family—CLUSIACEAE

Genus—KAYEA Wall.

Kayea kalagarhensis Prasad, 1993

(Pl. 3.10, 11; Pl. 4.1, 3)

Material—There are three specimens of well preserved leaf impression.

Description—Leaf simple, symmetrical, narrow elliptic; preserved length 12.5 x 3.0 cm, 5.5 x 1.8 cm, 4.0 x 1.5 cm; apex attenuate, base wide acute, normal; margin entire; texture coriaceous; petiole broken; venation pinnate, eucamptodromous; primary vein (1º) single, prominent, massive, almost straight; secondary veins (2º) about 36 pairs visible, closely placed, less than 0.5 cm apart, angle of divergence 80º–90º, right angle decreasing towards apex, uniformly curved up, opposite to alternate, rarely branched; intersecondary veins present, simple, frequent; tertiary veins (3º) fine, poorly preserved, angle of origin AO–RR, almost, percurrent, sometimes branched, oblique in relation to midvein, predominantly alternate and close. Further details could not be seen.

Specimen—BSIP Museum Specimen Nos. 412298–41300.

Locality—Spot No. 3 (29º8'51.3": 80º11'16.3"), Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinity—The characteristic features of the present fossil leaves are symmetrical, narrow elliptic shape, attenuate apex, wide acute base, entire margin, eucamptodromous venation, closely placed secondary veins with nearly right angle of divergence and usually RR, percurrent, branched tertiary veins. A detail study of the herbarium sheets of different genera and species, it was seen that the above features are found common in the modern leaves of *Alstonia scholaris* R. BR. and *Kayea floribunda* Wall. of the family Apocynaceae and Clusiaceae respectively. Of these, the leaves of *Alstonia scholaris* R. BR. differ in having intramarginal veins which are not found in the fossil. Thus, these leaf impressions show closest resemblance with the modern leaves of *Kayea floribunda* Wall. (C.N.H. Herbarium Sheet Nos. 47570, 47560; Pl. 4.2, 4).

Two fossil leaves resembling the genus *Kayea* Wall. have been described as *Kayea kalagarhensis* Prasad from Siwalik sediments of Kalagarh, Uttarakhand (Prasad, 1993) and Koilabas, Nepal (Prasad, 1994e). These fossil leaves have also been compared with the extant species *K. floribunda* Wall. and very similar to the present fossil leaf in almost all the morphological features. In view of this, the present fossils are being described under the same species, *Kayea kalagarhensis* Prasad.

The modern comparable taxon, *Kayea floribunda* Wall. is an evergreen, medium sized tree growing in the forests of Sikkim, Khasi Hills and Martaban Hills in Myanmar (Chowdhury & Ghosh, 1958).

Genus—CALOPHYLLUM Linn.

Calophyllum suraikholaensis Awasthi & Prasad, 1990

(Pl. 3.8, 9)

Material—There is a single, well preserved and incomplete leaf impression.

Description—Leaf simple, symmetrical; seemingly narrow oblong; preserved size 5.5 x 3.0 cm; apex broken; base broken; margin undulated; texture coriaceous; venation pinnate, craspedodromous; primary vein (1º) single, prominent, straight, stout; secondary veins (2º) fine, numerous, very closely placed, alternate to opposite, angle of divergence right angle, uniformly curved up, unbranched, tertiary veins (3º) not seen.

Specimen—BSIP Museum Specimen No. 41301.

Locality—Spot No. 3 (29º8'51.3": 80º11'16.3"), Purniyagiri Road section, Tanakpur Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinity—The characteristic features of the present fossil leaf such as narrow oblong shape, undulated margin, closely

PLATE 5

(All figures are of natural size unless otherwise mentioned)

1, 2. *Parashorea mioplicata* sp. nov.–Fossil leaves showing shape, size and venation pattern. BSIP Museum Specimen No. 41304 (Holotype), BSIP Museum Specimen No. 41305 (Paratype).

3. *Parashorea plicata* Brandis–Modern leaf showing similar shape, size and venation pattern.

4. *Parashorea mioplicata* sp. nov.–Part of fossil leaf magnified to show details of venation. X 3. BSIP Museum Specimen No. 41305.

5. *Parashorea plicata* Brandis–Part of modern leaf magnified to show details of venation. X 3.

6. *Parashorea mioplicata* sp. nov.–Part of fossil leaf magnified to show the details of tertiary venation pattern. X 4. BSIP Museum Specimen No. 41305.

7, 8. *Balanites siwalica* sp. nov.–Fossil leaves showing shape, size and venation pattern. BSIP Museum Specimen No. 41312 (Holotype), BSIP Museum Specimen No. 41313 (Paratype).

9. *Balanites roxburghii* Del.–Modern leaf showing similar shape, size and venation pattern.

10. *Balanites siwalica* sp. nov.–Part of fossil leaf magnified to show details of venation. X 4. BSIP Museum Specimen No. 41313.

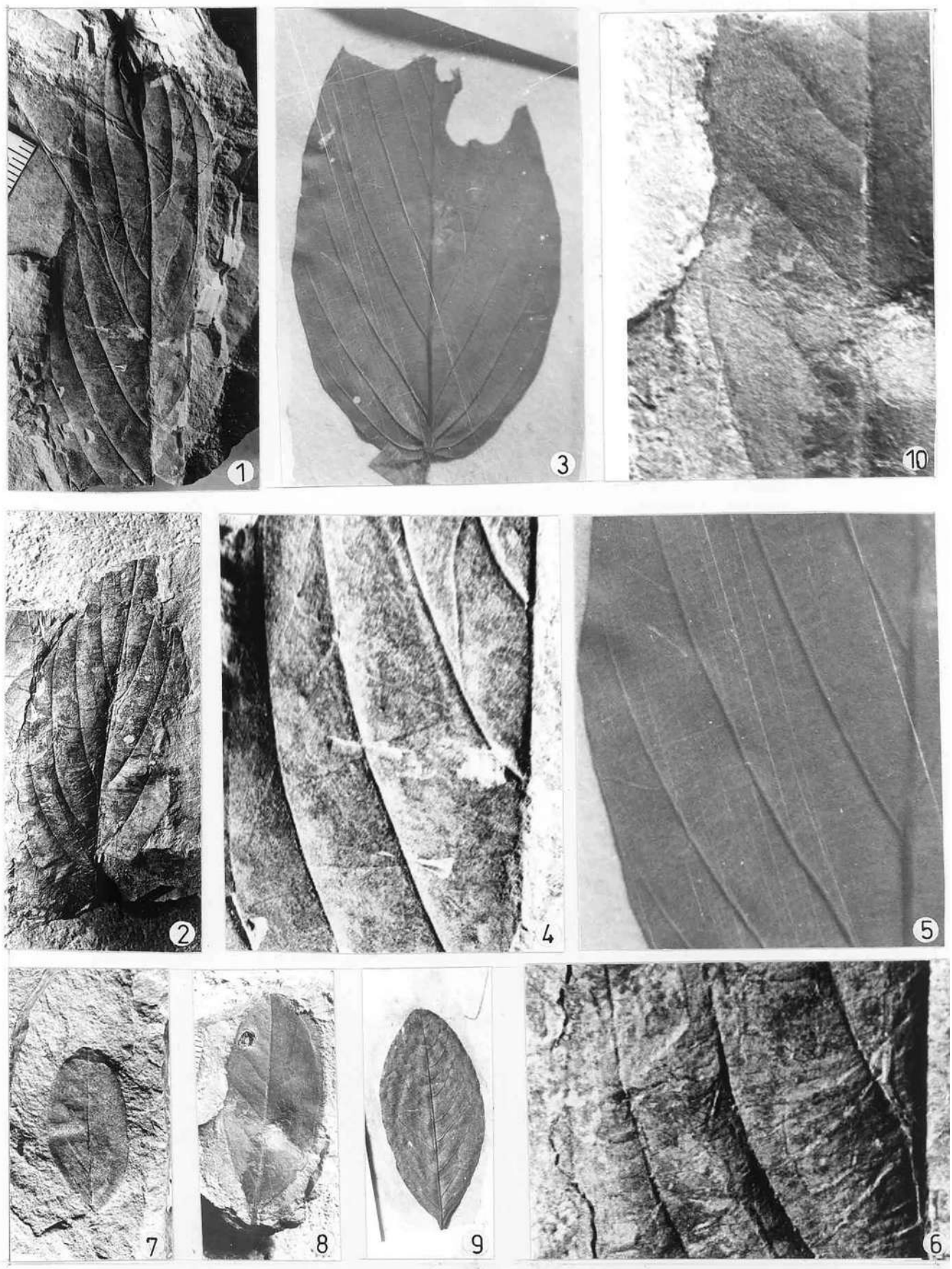

PLATE 5

placed, almost parallel secondary veins and craspedodromous type of venation undoubtedly indicate its resemblance with the extant leaves of *Calophyllum* sp. specially *C. polyanthum* Wall. of the family Clusiaceae.

Five fossil species of the genus *Calophyllum* Linn. have been reported so far from the Tertiary sediments of India and abroad. These are *Calophyllum pliocenicum* Krasser (1903) from Ouricanga, Brazil, *C. nathorstii* (Geyler) Krausal and *Calophyllum* sp. Krausel (1929) from Sumatra, *Calophyllum masensis* Pons (1978) from Colombia and *C. suraikholaensis* from the Siwalik sediments of Surai Khola, Nepal (Awasthi & Prasad, 1990), Oodlabari, West Bengal (Antal & Awasthi, 1993), Kathgodam, Uttarakhand (Prasad, 1994c), Kerala Coast (Awasthi & Srivastava, 1992), Plio–Pleistocene Siwalik sediments of Arunachal Pradesh (Khan *et al.,* 2011), Palaeocene of Cherapunji (Ambwani, 1991), Oligocene of Makum Coalfield, Assam (Awasthi & Mehrotra, 1995). A comparative study of the above known fossil leaves shows that the fossil leaf, *Calophyllum suraikholaensis* Awasthi & Prasad described from the Siwalik sediments of Kathgodam, Uttarakhand is almost identical to the present fossil leaf and hence it has been described under the same species.

The genus *Calophyllum* Linn. comprises about 187 species of trees distributed in both the hemispheres. *C. polyanthum* Wall. with which fossil resembles closely is presently growing in the evergreen forests of Tenasserim, Andaman and Nicobar Island, Malaya peninsula and Sri Lanka (Brandis, 1971).

Family—DIPTEROCARPACEAE

Genus—DIPTEROCARPUS F. Gaertn.

Dipterocarpus suraikholaensis Prasad & Pandey, 2008

(Pl. 4.8; Pl. 7.10)

Material—It consists of two, well preserved and incomplete leaf impressions.

Description—Leaf simple, symmetrical, seemingly wide elliptic; preserved size 8.0 x 5.0 cm, 10.0 x 4.0 cm (one side of lamina); apex broken; base broken; margin entire; texture chartaceous; venation pinnate, craspedodromous; primary vein (1º) single, prominent, stout, almost straight; secondary veins (2º) only 7–8 pairs visible, 1.4–2.0 cm apart, running straightly before joining to the margin or their superadjacent secondary, angle of divergence about 55º, moderately acute, unbranched; tertiary veins (3º) fine, angle of origin usually RR, percurrent, straight to sinuous, oblique in relation to midvein, predominantly alternate and close.

Specimen—BSIP Museum Specimen Nos. 41302, 41303.

Locality—Spot No. 9, near Krishnapuri Village (29º8'12.1": 80º11'38.5"), Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinity—The distinguishing characters of the present fossil leaf such as wide elliptic shape, entire margin, craspedodromous venation, moderately acute angle of divergence of secondary veins and RR, percurrent, straight to sinuous tertiary veins collectively indicate its resemblance with extant leaves of the genus *Dipterocarpus* F. Gaertn. A critical examination of herbarium sheets of all the available species of this genus shows that the leaves of *Dipterocarpus turbinatus* Gaertn. (Syn. *D. alatus* Roxb.) have closest affinity with the present fossil leaf (C.N.H. Herbarium Sheet No. 52699; Pl. 4.9).

Several fossil leaves showing close similarity with the genus *Dipterocarpus* Gaertn. have been recorded from the Tertiary sediments of India and abroad. They are listed in Table 1.

After comparison of the present fossil leaves with the already known fossil leaves it has been observed that the fossil leaf, *Dipterocarpus suraikholaensis* Prasad & Pandey, 2008 shows closest similarity with the present fossils and hence it has been described under the same species.

The genus *Dipterocarpus* F. Gaertn. comprises about 69 species distributed in India and Malaysia (Mabberley, 1997). *Dipterocarpus turbinatus* Gaertn. (Syn. *D. alatus* Roxb.) with which fossils show closest resemblance is a large, evergreen tree presently distributed in the forests of Chittagong Hills, Myanmar, Andaman and Malayan peninsula (Brandis, 1971; Hooker, 1872).

Genus—PARASHOREA Kurz.

Parashorea mioplicata sp. nov.

(Pl. 5.1, 2, 4)

Material—The species is based on two, well preserved leaf impressions with slightly broken apex.

Description—Leaf simple, almost symmetrical, elliptic; preserved size 8.5 x 3.5 cm, 6.5 x 3.0 cm; apex broken; base broken; margin entire; texture coriaceous; venation pinnate, eucamptodromous; primary vein (1º) single, prominent, stout, slightly curved; secondary veins (2º) about 7 pairs visible, 0.8 to 2.5 cm apart, alternate, unbranched, angle of divergence 45º–50º, narrow acute, uniformly curved up and running parallel to each other for a long distance, basal secondary arises closely, tertiary veins (3º) fine, angle of origin RR, percurrent, branched, straight to sinuous, oblique to nearly right angle in relation to midvein, predominantly alternate and close.

Holotype—BSIP Museum Specimen No. 41304.

Paratype—BSIP Museum Specimen No. 41305.

Locality—Spot No. 3 (29º8'51.3": 80º11'16.3"), Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Table 1—Fossil leaves showing close similarity with the genus *Dipterocarpus* Gaertn. recorded from the Tertiary sediments of India and abroad.

Fossil taxa	Horizon/age	Reference
Dipterocarpus antiquus	Tertiary of Sumatra	Heer, 1883
D. atavinus	Tertiary of Sumatra	Heer, 1883
D. tabuanus	Pliocene of Java	Geyler, 1887
D. nordenspioldi	–do–	–do–
Phyllites dipterocarpoides	–do–	Crie, 1888
D. siwalicus	Siwalik of Jawalamukhi, H.P.	Lakhanpal & Guleria, 1987
	Siwalik of Koilabas, Nepal	Prasad, 1990b
	Siwalik of Suraikhola, Nepal	Awasthi & Prasad, 1990
	Siwalik of Kathgodam, Uttarakhand	Prasad,1994c
	Siwalik of Surkhet, Nepal	Prasad & Pradhan, 1998
	Siwalik of Bhutan	Prasad & Tripathi, 2000
	Siwalik of West Bengal	Antal & Prasad, 1996b
	Siwalik of Arunachal Pradesh	Khan *et al*., 2011
	Siwalik of Arjun Khola, Nepal	Prasad & Gautam, 2016
D. koilabasensis	Siwalik of Koilabas, Nepal	Prasad *et al*., 1999
D. suraikholaensis	Siwalik of Suraikhola, Nepal	Prasad & Pandey, 2008
	Siwalik of Nahan, H.P.	Prasad, 2012
D. miocenicus	Siwalik of Arjun Khola, Nepal	Prasad & Gautam, 2016
D. nepalensis	Siwalik of Arjun Khola, Nepal	Prasad & Gautam, 2016

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—By adding prefix ‘mio' to the modern comparable species, *P. plicata.*

Affinity—Medium size of leaves with elliptic shape, eucamptodromous venation, narrow acute angle of divergence of secondary veins, closely placed basal secondary veins, RR, percurrent, straight to sinuous tertiary with oblique to nearly right angle in relation to midvein are the important features of the present fossils. These features suggest that the fossil leaves belong to the extant genus *Parashorea* Kurz. of the family Dipterocarpaceae. A critical examination of the herbarium sheets of a number of species of this genus indicates that the leaves of *Parashorea plicata* Brandis (C.N.H. Herbarium Sheet No. 31779; Pl. 5.3, 5) show closest resemblance with the present fossils in shape, size and venation pattern.

As far as authors are aware, there is a authentic record of fossil leaf resembling the genus *Parashorea* Kurz. as *Parashorea palaeostellata* comb. nov. from the Tippam Group of Assam (Mehrotra *et al.,* 2011). On comparison it has been found that the present fossil differs in having smaller size with only 7 pairs of secondary veins as compared to large size with 12 pairs of secondaries in *P. palaeostellata* (Mehrotra *et al.*, 2011) and thus, present fossil has been assigned as *Parashorea mioplicata* sp. nov.

The genus *Parashorea* Kurz. consists of about 19 species (Mabberley, 1997). It is reported to be a small genus and is represented over a wide area from Myanmar, Indo–China, Sumatra, and Malaya Peninsula in the West to Borneo and the Philippines in the east. *Parashorea plicata* Brandis with which fossil leaves resemble closely, is a large tree found to occur in the Philippines.

Genus—HOPEA Roxb.

Hopea Kathgodamensis Prasad 1994d

(Pl. 4.5, 6, 7)

Material—There are two, fairly preserved and complete leaf impressions.

Description—Leaf simple, symmetrical, ovate to lanceolate, preserved size 5.2 x 2.2 cm and 3.0 x 1.5 cm; apex acuminate; base wide acute; margin entire, texture coriaceous: venation pinnate, eucamptodromous; primary vein (1º) single, prominent, stout, almost straight; secondary veins (2º) about 12 pairs visible, less than 0.5 cm apart, seemingly unbranched, usually alternate, angle of divergence 55º–65º, acute, moderate uniformly curved up; intersecondary veins present, simple; tertiary veins (3º) poorly preserved, fine, angle of origin RR, percurrent, straight to sinuous, branched, oblique in relation to midvein, predominantly alternate and close.

Specimen—BSIP Museum Specimen Nos 41306–41307.

Locality—Spot No. 3 (29º8'51.3": 80º11'16.3"), Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinities—The characteristic features of the present fossil leaves such as symmetrical, ovate to lanceolate shape, acuminate apex, obtuse base, entire margin, eucamptodromous venation, closely placed secondary veins which arise at moderate angle and joined superadjacent secondary, presence of intersecondary veins and RR, percurrent tertiaries indicate that the present fossil leaves show close resemblance with the modern leaves of *Hopea* Roxb. of the family Dipterocarpaceae. In order to find out its specific affinity, the herbarium sheets of available species of this genus were critically examined and it was concluded that the leaves of *Hopea dryobalanoides* Miq. (Syn. *H. borneensis* Heim. *H. micrantha* (Hook F.) King; C.N.H. Herbarium Sheet Nos 51956, 511194) show closest affinity with the present fossils.

From Siwalik sediments, there are five fossil records of *Hopea* leaves. These are *Hopea siwalica* Antal & Awasthi (1993) from the Lower Siwalik sediments of Darjeeling District, West Bengal, India, *H. mioglabra* Prasad (1994e) from Lower Siwalik sediments of Koilabas, Nepal, *H. kathgodamensis* Prasad (1994c) from Lower Siwalik sediments of Kathgodam, India and *H. mioparviflora* Prasad & Pradhan (1998) from the Middle Siwalik sediments of Surkhet area, Nepal and *H. masotkholaensis* Prasad *et al*. (2016) from Siwalik of Arjun Khola, Nepal. On comparison of the present fossil leaves with all the above known fossils it has been observed that they resemble closely with those of *H. kathgodamensis* Prasad in shape, size and venation pattern. This already known fossil has also been compared with the extant species of *Hopea micrantha* (Hook F.) King (= *G. dryobalanoides* Miq.) as the present fossil. There is a difference in the number of secondary veins which is greater in the above known fossil species.

The genus *Hopea* Roxb. consists of about 102 species distributed in the Indo–Malayan regions. *H. dryobalanoides* Miq. with which fossils show affinity is a tall tree and found to grow in undisturbed, mixed dipterocarps forests of Malayan peninsula, Sumatra, Borneo and Philippines.

Family—RUTACEAE

Genus—TODDALLIA Juss.

Toddalia purniyagiriensis sp. nov.

(Pl. 6.1, 3)

Material—This species is based on a single, well preserved leaf impression. There are three other incomplete leaf impressions.

Description—Leaf asymmetrical, narrow elliptic; size 6.0 x 2.5 cm; apex broken; base acute; inequilateral; margin entire; texture chartaceous; petiole broken; venation pinnate, eucamptodromous; primary vein (1º) single, prominent, stout, almost straight; secondary veins (2º) more than 12 pairs visible, less than 0.8 cm apart, alternate to subopposite, angle of divergence about 55°, moderately acute, uniformly curved up, seemingly unbranched; intersecondary veins present, simple, frequent, 2–3 veins in between two secondaries; tertiary veins (3º) fine, poorly preserved, angle of origin AO–RR, percurrent, almost straight, sometimes branched, oblique in relation to midvein, alternate to opposite close.

Holotype—BSIP Museum Specimen No. 41308.

*Localities–S*pot No. 4 (29º9'8": 80º11'19.7"), Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—After the name of Purniyagiri Temple.

Affinity—The diagnostic features of the present fossil leaf are narrow elliptic shape, acute base, entire margin, eucamptodromous venation, closely placed secondaries with moderate angle of divergence, presence of frequent intersecondary veins and AO–RR, percurrent tertiary veins. These characters suggest the affinity of fossil leaf with those of the genus *Toddalia* Juss. of the family Rutaceae. The extant species of the monotypic genus *Toddallia* Juss. were examined and found that the present fossil leaf is closely comparable with the leaves of *Toddalia asiatica* Lamk. (Syn. *T. aculeata* Pers.; C.N.H. Herbarium Sheet Nos 5669, 22798).

As far as the authors are aware, there is only one record of the fossil leaf of *Toddalia* Juss. as *Toddalia miocenica* (Prasad *et al*., 2015) from the Siwalik sediments of Darjeeling District, West Bengal. It differs from present fossil leaves in being smaller size (4.3 x 2.2 cm) with secondary vein arising at greater angle, India. In view of this, the present fossil leaf

PLATE 6

(All figures are of natural size unless otherwise mentioned)

1. *Toddalia purniyagiriensis* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41308.
2. *Toddalia asiatica* (L.) Lam.–Modern leaf showing similar shape, size and venation pattern.
3. *Toddalia purniyagiriensis* sp. nov.–Part of fossil leaf magnified to show details of venation. X 4. BSIP Museum Specimen No. 41308. (Holotype).
4. *Toddalia asiatica* (L.) Lam.–Part of modern leaf magnified to show similar details of venation. X 2.
5. *Aglaia siwalica* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41314.
6. *Aglaia bicolor* Merr.–Modern leaf showing similar shape, size and venation pattern.
7. *Aglaia siwalica* sp. nov.–Part of fossil leaf magnified to show details of venation. X 2.5. BSIP Museum Specimen No. 41314.
8. *Aglaia bicolor* Merr.–Part of modern leaf magnified to show similar details of venation X 2.5.
9, 10. *Atalantia siwalica* sp. nov.–Fossil leaves showing shape, size and venation pattern. BSIP Museum Specimen No. 41309. (Holotype), BSIP Museum Specimen No. 41310 (Paratype).
11. *Atalantia siwalica* sp. nov.–Part of fossil leaf magnified to show details of venation. X 2.5. BSIP Museum Specimen No. 41310

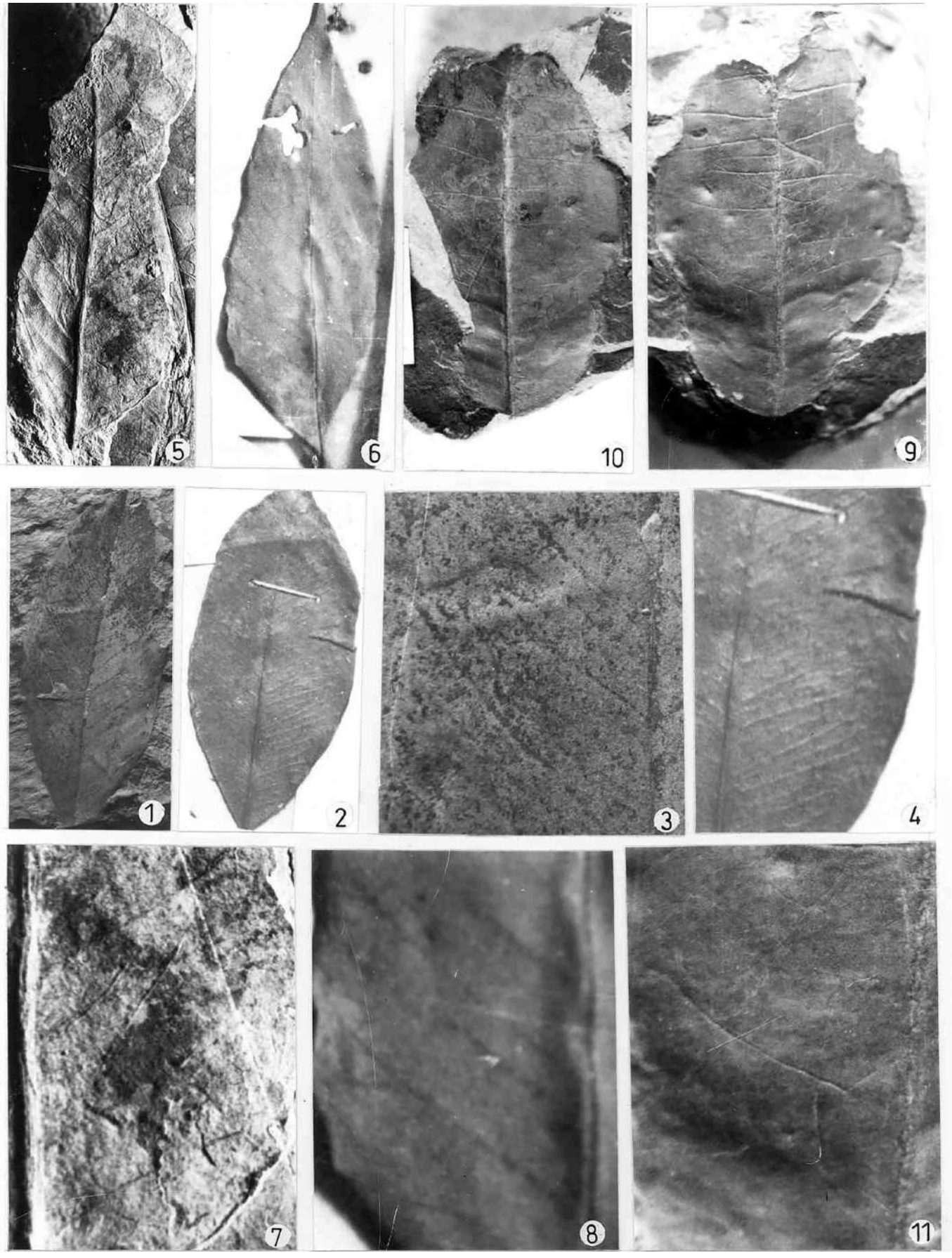

PLATE 6

is being described as a new species *Toddallia purniyagiriensis* n. sp.

The genus *Toddalia* Juss. includes only one species, *T. asiatica* Lamk. with which fossil leaf shows closest affinity. This is an evergreen shrub and distributed in Sumatra, Java, China and Philippines (Hooker, 1872).

Genus—ATALANTIA Correa

Atalantia siwalica sp. nov.

(Pl. 6.9, 10, 11)

Material—There are two, well preserved, almost complete leaf impressions.

Description—Leaf slightly asymmetrical, elliptic; preserved size 6.5 x 3.0 cm, 6.5 x 3.5 cm; apex broken; base obtuse, inequilateral; texture coriaceous; petiole broken; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) about 6 pairs visible, closely placed, less than 0.5 cm apart, angle of divergence 65°–75°, moderately acute, uniformly curved up; intersecondary veins present, simple; tertiary veins (3°) poorly preserved, angle of origin usually AO, rarely RR, percurrent, straight to wavy, sometimes branched, oblique in relation to midvein, alternate to opposite and close.

Holotype—BSIP Museum Specimen No. 41309.

Paratype—BSIP Museum Specimen No. 41310.

Locality—Spot No. 1 (29º8'27.4": 80º11'6.9"), near Hanuman Chatti, Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—After the name of Siwalik Group.

Affinity—The characteristic features exhibited by the present fossil leaves such as slightly asymmetrical, elliptic shape, obtuse base, entire margin, eucamptodromous venation, closely placed secondaries with moderately acute angle of divergence, presence of intersecondary veins, usually AO angle of origin of tertiary veins indicate that the present fossil leaves show close resemblance with the modern leaves of the genus *Atalantia* Correa (*Paramignya* Wight) of the family Rutaceae. In order to find out specific affinity, the herbarium sheets of all the available species of this genus were critically examined and it was concluded that the leaves of *Atlantia* (*Paramignya*) *monophylla* Correa (Syn. *A. floribunda* Wall.) show close similarity with the present fossil leaves in shape, size and venation pattern (C.N.H. Herbarium Sheet No. 76259).

The fossil leaves resembling the exant species *Atlantia monophylla* Correa have been described as *A. miocenica* Prasad (1994e) from Siwalik sediments of Koilabas, Nepal and *A. palaeomonophylla* Mehrotra (2000) from the Tura Formation, Meghalaya. Both the above fossil leaves show their affinity with the extant species, *A. monophylla* Correa as the present fossils but differ entirely in being smaller size with very closely placed secondary veins which arise at narrow acute angle. In light of the above facts the present fossil leaves have been described here as *Atalantia siwalica* sp. nov.

The genus *Atalantia* Correa consists of about 12 Indo–Malayan species of shrubs or small trees. *Atlantia* (*Paramignya*) *monophylla* Correa with which fossil leaves resemble closely is a small evergreen tree presently distributed in Kanara, western district of Mysore, Nilgiris, Hills of the northern Circars, Cedded district and Karnataka, Khasi Hills and Myanmar (Brandis, 1971).

Genus—CLAUSENA Burm. F.

Clausena miocenica sp. nov.

(Pl. 7.1, 3)

Material—This species is based only on well preserved and complete leaf impression.

Description—Leaf asymmetrical, elliptic; preserved size 7.0 x 3.0 cm; apex acute; base acute; margin entire; texture thick chartaceous; petiole broken; venation pinnate, eucamptodromous; primary vein (1º) single, prominent, stout, curved; secondary veins (2º) about 7 pairs visible, 0.6 to 1.5 cm apart, usually opposite, angle of divergence about 65º, acute, moderate, uniformly curved up, seemingly unbranched, intersecondary veins present, simple, rare; tertiary veins (3º)

PLATE 7

(All figures are of natural size unless otherwise mentioned)

1. *Clausena miocenica* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41311 (Holotype).
2. *Clausena anisum–olens* (Blanco.) Merr.–Modern leaf showing similar shape, size and venation pattern.
3. *Clausena miocenica* sp. nov.–Part of fossil leaf magnified to show details of venation. X 3. BSIP Museum Specimen No. 41311.
4. *Clausena anisum–olens* (Blanco.) Merr.–Part of modern leaf magnified to show similar details of venation. X 3.

5–7. *Gomphandra palaeocoriacea* sp. nov.–Fossil leaves showing shape, size and venation pattern. BSIP Museum Specimen No. 41315 (Holotype), BSIP Museum Specimen No. 41316–41317 (Paratypes).

8. *Gomphandra coriacea* Wight–Modern leaf showing similar shape, size and venation pattern.
9. *Gomphandra palaeocoriacea* sp. nov.–Part of fossil leaf magnified to show details of venation. X 2.5. BSIP Museum Specimen No. 41315.
10. *Dipterocarpus suraikholaensis* Prasad & Pandey–An other fossil leaf showing venation pattern near the margin. BSIP Museum Specimen No. 41303.

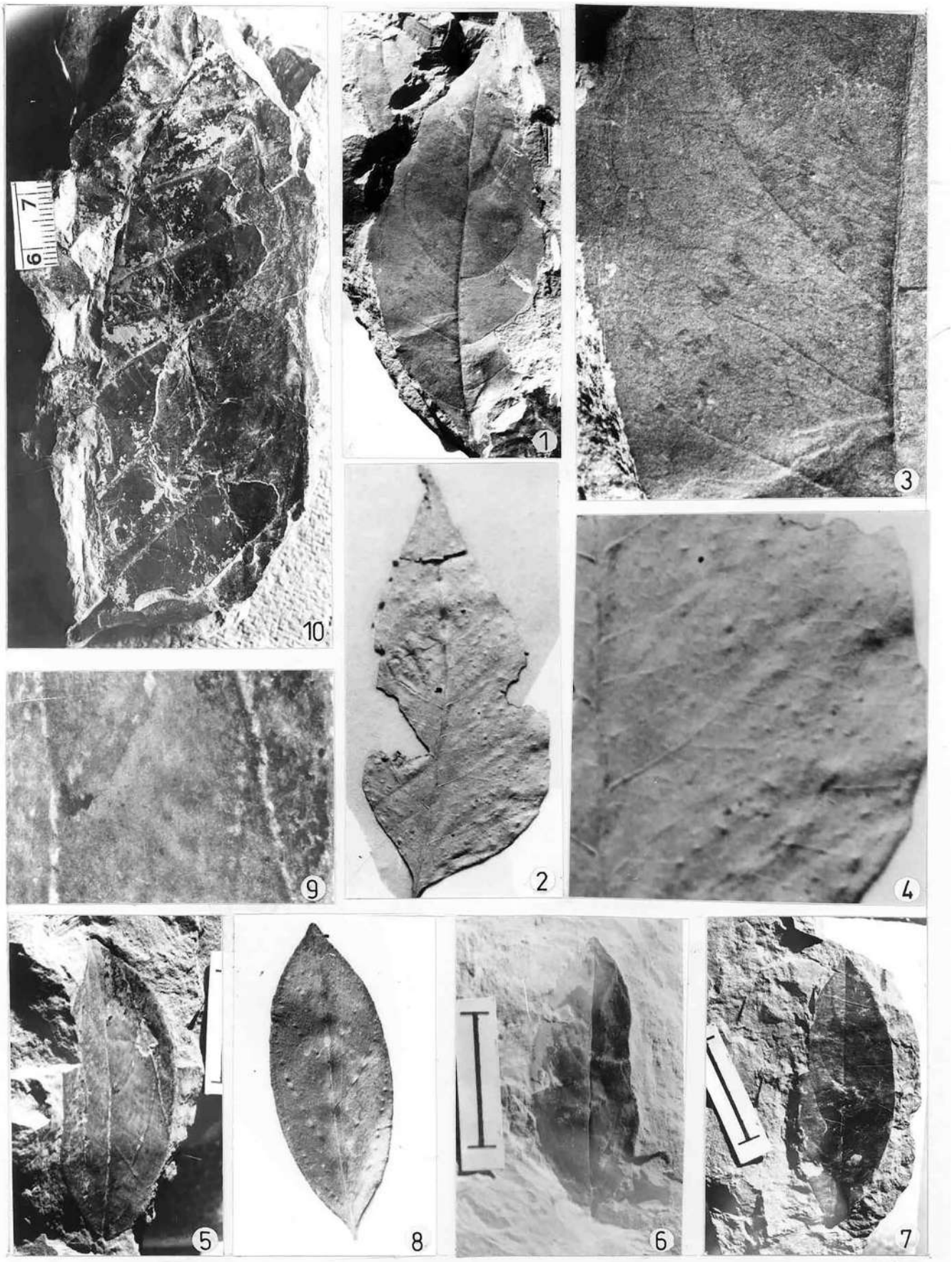

PLATE 7

fine, angle of origin AO–RR, percurrent, straight to sinuous, branched, oblique in relation to midvein, predominantly alternate and close.

Holotype—BSIP Museum Specimen No. 41311.

Locality—Spot No. 1 (29º8'27.4": 80º11'6.9"), near Hanuman Chatti, Purniyagiri Road section, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—After the Miocene epoch.

Affinity—Asymmetrical, elliptic shape, acute apex and base, entire margin, eucamptodromous venation, presence of intersecondary veins, AO–RR, percurrent and close tertiary veins are the diagnostic features which indicate that the fossil leaf belong to the genus *Clausena* Burm. F. of the family Rutaceae. An examination of the leaves of various extant species of this genus was done and it was observed that the fossil leaf resembles those of *C. anisum–olens* (Blanco.) Merr. (C.N.H. Herbarium Sheet No. 2525; Pl. 7.2, 4) in shape, size and venation pattern.

So far, no fossil wood or leaf of the genus *Clausena* Burm F. are known from the Tertiary of India. To designate this new finding, a new species *Clausena miocenica* has been established.

The genus *Clausena* Burm. F. includes about 25 species distributed in the old world, Tropical Africa and South east Asia. The comparable species, *C. anisum–olens* (Blanco.) Merr. (Syn. *C. laxiflora* Quis. & Merr.) is an evergreen shrub or small tree growing naturally in the rain forests. It is endemic to Philippines and Borneo.

Family—ZYGOPHYLLACEAE

Genus—BALANITES Del.

Balanites siwalica sp. nov.

(Pl. 5.7, 8, 10)

Material—It is represented by two well preserved and complete leaf impressions.

Description—Leaf symmetrical, narrow elliptic; preserved size 3.0 x 1.5 cm and 4.0 x 1.7 cm; apex obtuse; base acute, slightly oblique; margin entire; texture chartaceous; petiole 0.3 cm long, normal; venation pinnate; eucamptodromous; primary vein (1º) single, prominent, stout, almost straight; secondary veins (2º) 9–10 pairs visible, closely placed, less than 0.7 cm apart, alternate to opposite; angle of divergence about 55º, acute moderate, uniformly curved up, seemingly unbranched; intersecondary veins present, simple; tertiary veins (3º) fine, angle of origin usually RR, sometimes AO, percurrent, straight to sinuous, branched, oblique in relation to midvein, predominantly alternate and close.

Holotype—BSIP Museum Specimen No. 41312.

Paratype—BSIP Museum Specimen No. 41313.

Locality—Spot No. 10 (29º9'12.1": 80º11'38.5"), Bhairauv Mandir, Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—After Siwalik Group.

Affinity—The characteristic features of the present fossil leaves are narrow elliptic shape, obtuse apex, slightly asymmetrical, acute base, entire margin, eucamptodromous venation, closely placed secondary veins with moderate angle of divergence, usually RR, percurrent tertiaries and presence of intersecondary veins. After a detailed comparative study it has been found that these features are common in the modern leaves of *Balanites* Del. of the family Zygophyllaceae. Among the *Balanites* species the present fossils show closest affinity with those of *Balanites roxburghii* (Syn. *B. aegyptica* (L.) Del. (C.N.H. Herbarium Sheet No. 2624; Pl. 1.9) in almost all the morphological features.

The genus *Balanites* Del. was previously not known as fossil. The present fossils form its first occurrence from the Siwalik sediments of Uttarakhand, India and described as a new species *Balanites siwalica.*

The genus *Balanites* Del. consists of about 25 species distributed in the tropics of Africa and Myanmar. *B. roxburghii* (Syn. *B. aegyptica* (L.) Del. with which fossils resemble closely is a small tree or shrub growing chiefly in the drier part of India and Myanmar.

Family—MELIACEAE

Genus—AGLAIA Lour.

Aglaia siwalica sp. nov.

(Pl. 6.5, 7)

PLATE 8

(All figures are of natural size unless otherwise mentioned)

1, 2. *Ventilago miocalyculata* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41318 (Holotype), BSIP Museum Specimen No. 41319 (Paratype).

3. *Ventilago calyculata* Tul.–Modern leaf showing similar shape, size and venation pattern.

4. *Ventilago miocalyculata* sp. nov.–Part of fossil leaf magnified to show details of venation. X 2.5. BSIP Museum Specimen No. 41319.

5. *Ventilago calyculata* Tul.–Part of modern leaf magnified to show similar details of venation. X 2.5.

6, 7. *Sapindus eotrifoliatus* sp. nov.–Fossil leaves showing shape, size and venation pattern. BSIP Museum Specimen No. 41320 (Holotype), BSIP Museum Specimen No. 41321 (Paratype).

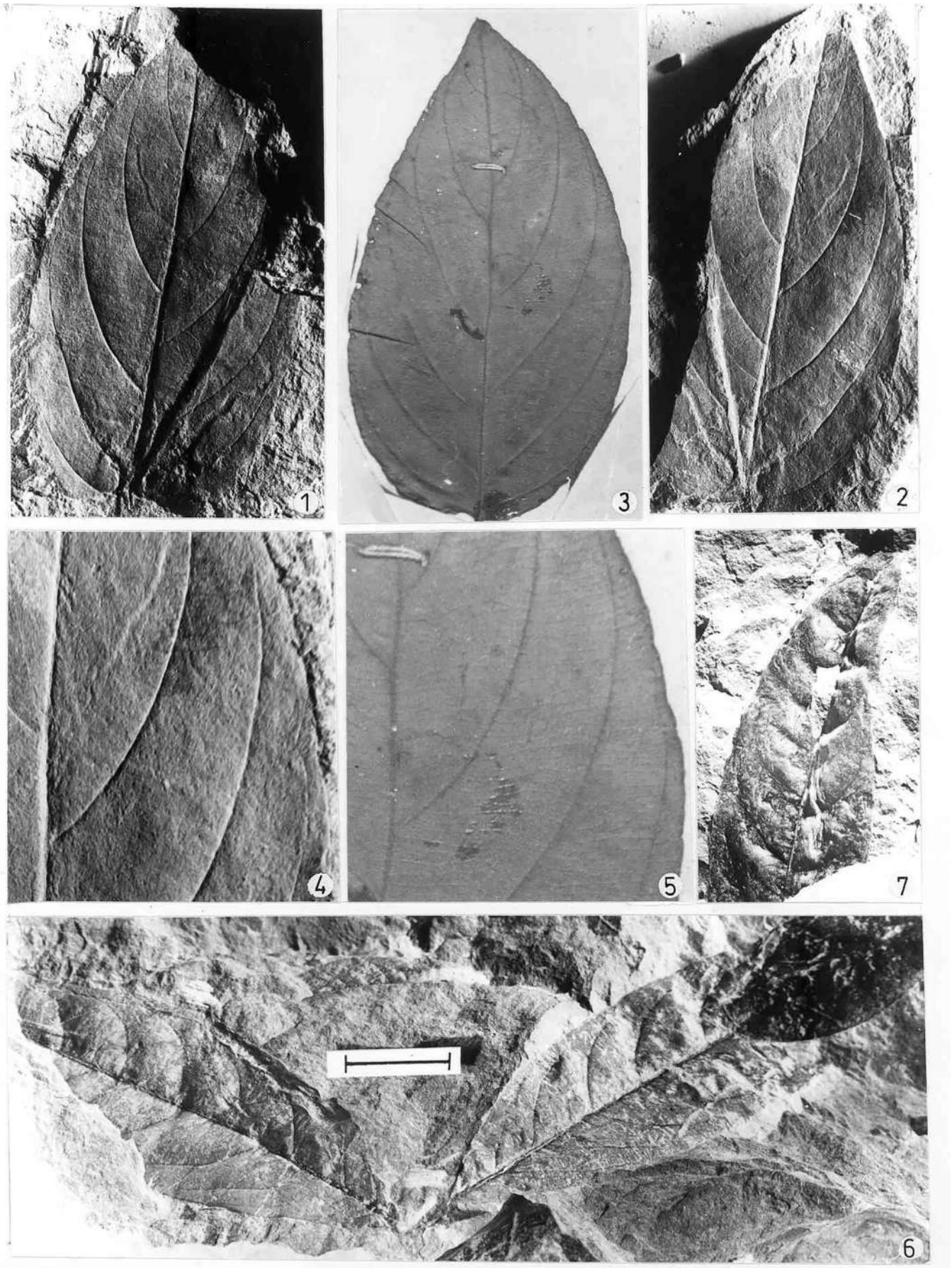

PLATE 8

Material—There is a single, well preserved, almost complete leaf impression.

Description—Leaf asymmetrical, lanceolate; preserved size 8.0 x 2.7 cm; apex slightly broken; base acute, inequilateral; margin seemingly entire; texture chartaceous; petiole 0.2 cm visible, normal; venation pinnate, craspedodromous to eucamptodromous; primary vein (1°) single, stout, almost straight; secondary veins (2°) about 10 pairs visible, 0.5 to 1.0 cm apart, angle of divergence about 60°, acute, moderate, arise straightly and curved up uniformly, seemingly unbranched, alternate to opposite; intersecondary veins present, simple; tertiary veins (3°) fine, angle of origin RR, percurrent, usually straight, sometimes branched, oblique in relation to midvein, predominantly alternate, close.

Holotype—BSIP Museum Specimen No. 41314.

Locality—Spot No 9, near Krishnapuri Village (29º9'19.7": 80º11'27.2"), Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—After the name of Siwalik Group

Affinity—The distinguishing features of the present fossil leaf are asymmetrical base, lanceolate shape, acute, inequilateral base, craspedodromous to eucamptodromous venation, straight curving of secondary veins, presence of intersecondary veins and RR, percurrent tertiaries. Such features are found in the modern leaves of the genus *Aglaia* Lour of the family Meliaceae. A careful examination of the leaves of about 25 species of *Aglaia* Lour indicates that *A. bicolor* Merr. (C.N.H. Herbarium Sheet No. 80737; Pl. 6.6, 8) shows closest similarity with the present fossil.

So far, there is no record of fossil leaf resembling the genus *Aglaia* Lour from the Tertiary of India, though a fossil wood of this genus has been reported from the Siwalik sediments of Himachal Pradesh (Yadav, 1989). In view of this the present fossil leaf is being described here as a new species, *Aglaia siwalica.*

The genus *Aglaia* Lour comprises about 105 species distributed in the Indo–Malayan region, South east Asia and New Guinea. *Aglaia bicolor* Merr. with which fossil leaf shows closest affinity is a large evergreen tree presently distributed in Philippines.

Family—STEMONURACEAE

Genus—GOMPHANDRA Wallich ex Lindley

Gomphandra palaeocoriacea sp. nov.

(Pl. 7.5, 6, 7, 9)

Material—This is represented by three, fairly preserved, complete leaf impressions.

Description—Leaves simple, slightly asymmetrical, one lamina lobe is slightly greater in width, narrow elliptic; preserved size 5.5 x 1.8 cm, 5.0 x 1.8 cm and 5 x 1.6 cm; apex acute; base acute; margin entire; texture coriaceous; petiole 0.2 cm long, normal; venation pinnate, eucamptodromous; primary vein (1º) single, prominent, stout, almost straight, secondary veins (2º) 5–6 pairs visible, 0.8 to 1.8 cm apart, alternate, angle of divergence 55º–60º, acute, moderate, uniformly curved up and run for a little distance and joined to their superadjacent secondary vein; unbranched; tertiary veins (3º) fine, angle of origin usually RR, percurrent, straight to sinuous, branched, oblique in relation to midvein, predominantly alternate and close.

Holotype—BSIP Museum Specimen No. 41315.

Paratype—BSIP Museum Specimen Nos. 41316–41317.

Locality—Spot No. 8 (29º9'7.6": 80º11'21.5"), Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—By adding a prefix ‘Palaeo' to the name of comparable species, *G. coriacea.*

Affinity—The diagnostic features of the present fossil leaves such as slightly asymmetrical, narrow elliptic shape, acute apex and base, entire margin, eucamptodromous venation, sharp curvature of secondary veins, and RR, percurrent, branched and close tertiaries indicate that the modern leaves of extant *Gomphandra coriacea* Wight of the family Stemonuraceae (Icacinaceae) (C.N.H. Herbarium Sheet No. 2639; Pl. 7.8) have closest affinity with the present fossils.

So far, the fossil leaf resembling the genus *Gomphandra* Wallich ex Lindley is not yet known though a fossil wood, *Gomphandroxylon samnapurensis* Bande & Khatri (1980) is known from the Deccan Intertrappean beds of Madhya Pradesh, India. Thus this fossil leaf is the first report from the Siwalik sediments of Uttarakhand, India and hence described here as *Gomphandra palaeocoriacea* sp. nov.

The genus *Gomphandra* Wallich ex Lindley consists of 33 species of trees or shrubs distributed in South east Asia to Solomon Island (Mabberley, 1997). The modern comparable species, *G. coriacea* Wight is a glabrous shrub presently

PLATE 9

(All figures are of natural size unless otherwise mentioned)

1, 3. *Sapindus eotrifoliatus* sp. nov.–Fossil leaves showing variation in shape and size. BSIP Museum Specimen Nos 41322, 41323 (Paratypes)

2. *Sapindus trifoliatus* Linn.–Modern leaf showing similar shape, size and venation pattern.

4. *Sapindus eotrifoliatus* sp. nov.–Part of fossil leaf magnified to show details of venation. X 2. BSIP Museum Specimen No. 41322.

5. *Sapindus trifoliatus* Linn.–Part of modern leaf magnified to show similar details of venation. X 3.

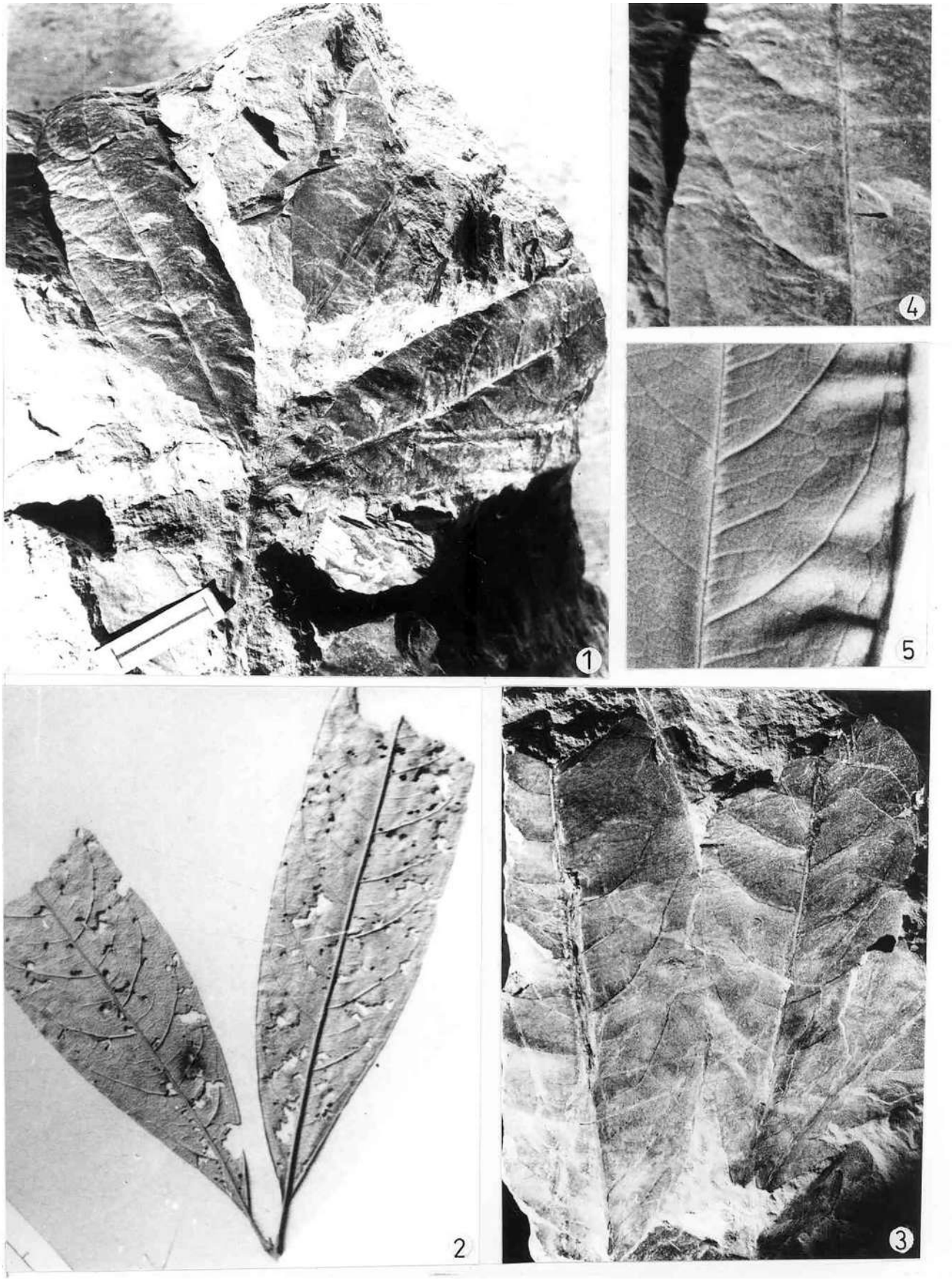

PLATE 9

distributed in the evergreen forests of Western Ghats from north Kanara southwards (Brandis, 1971).

Family—RHAMNACEAE

Genus—VENTILAGO Gaertn.

Ventilago miocalyculata sp. nov.

(Pl. 8.1, 2, 4)

Material—There is a single well preserved, almost complete leaf impression with its counter part.

Description—Leaf simple, symmetrical, ovate; preserved size 8.5 x 4.5 cm; apex broken, seemingly acute; base obtuse; margin entire; texture coriaceous; petiole broken, venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) 5 pairs visible, 0.8 to 2.5 cm apart, alternate, unbranched, sharply curved up and joined to their superadjacent secondary through a series of cross veins, angle of divergence acute (55°–60°), moderate; tertiary veins (3°) fine, angle of origin RR, rarely AO, percurrent, branched, straight to sinuous, nearly right angle in relation to midvein, predominantly alternate, close.

Holotype—BSIP Museum Specimen No. 41318.

Paratype—BSIP Museum Specimen No. 41319.

Locality—Spot No. 1 (29º8'27.4": 80º 11'6.9"), near Hanuman Chatti, Purniyagiri Road section, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—By adding a prefix ‘Palaeo' to the modern comparable species, *V. calyculata*.

Affinity—The important diagnostic features of the present fossil leaf such as ovate shape, seemingly acute apex, obtuse base, entire margin, eucamptodromous venation, sharply curved secondary veins with moderate angle of divergence and RR, percurrent, straight to sinuous tertiary veins with nearly right angle in relation to midvein strongly indicate its close affinity with the leaves of the genus *Ventilago* Gaertn. of the family Rhamnaceae. After critical examination of the modern leaves of five species of this genus it has been found that the leaves of *Ventilago calyculata* Tul. (Syn. *V. madraspatana* Gaertn.) show closest affinity with the present fossil (C.N.H. Herbarium Sheet No. 22052; Pl. 8.3, 5).

So far, two fossil species having affinity with the genus *Ventilago* Gaertn. have been reported from the Siwalik sediments. Antal and Prasad (1997) described a fossil leaf as *Ventilago tistaensis* from the Lower Siwalik sediments of Darjeeling District, West Bengal. Later on, Konomatsu and Awasthi (1999) described another fossil leaf *V. ovatus* from the Middle Siwalik sediments of Dumkibas, western Nepal. The same species has also been described from the Siwalik of Sarkaghat, H.P. (Prasad *et al*., 2013). The present fossil leaf can easily be differentiated from both the above fossils in possessing only few pairs of secondaries with very sharp curvature before reaching the margin. In view of this, the present fossil is designated as *Ventilago miocalyculata* sp. nov.

The genus *Ventilago* Gaertn. comprises 35 species, presently distributed in the old world, tropical Africa and Madagascar. The modern comparable taxon, *V. calyculata* Tul. (= *V. madraspatana* Gaertn.) is a small tree found to grow in the Sub–himalayan tract, Jammu easternwards, Oudh forests, Nepal, Central India and the Peninsulas, Silhet and Myanmar (Brandis, 1971).

Family—SAPINDACEAE

Genus—SAPINDUS Linn.

Sapindus eotrifoliatus sp. nov.

(Pl. 8.6, 7; Pl. 9.1, 3, 4)

Material—There are four specimens of leaf impression which are well preserved almost complete and also arranged on a twig.

Description—Leaf compound, symmetrical, very narrow elliptic; preserved size 8.5 x 3.0 cm, 6.5 x 2.2 cm, 7.0 x 2.5 cm and 8.5 x 3.5 cm; apex acute; base acute; margin entire; texture chartaceous; petiole 1.0 cm long, normal; venation pinnate, eucamptodromous, primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) about 9 pairs visible, 0.3 to 2.0 cm apart, alternate to opposite, seemingly unbranched, angle of divergence 60°–70°, moderate to wide acute, uniformly curved up and joined to superadjacent secondary; intersecondary veins present, simple; tertiary veins (3°) with moderate angle of origin, usually RR, percurrent, zigzag,

PLATE 10

(All figures are of natural size unless otherwise mentioned)

1, 2. *Drimycarpus siwalicus* sp. nov.–Fossil leaves showing shape, size and venation pattern. BSIP Museum Specimen No. 41329 (Holotype), BSIP Museum Specimen No. 41330 (Paratype).

3. *Drimycarpus racemosus* Hook. f.–Modern leaf showing similar shape, size and venation pattern.

4. *Drimycarpus siwalicus* sp. nov.–Part of fossil leaf magnified to show details of venation. X 2.

5. *Drimycarpus racemosus* Hook. f.–Part of modern leaf magnified to show similar details of venation. X 2.

6. *Harpullia siwalica* Prasad & Awasthi–Part of fossil leaf magnified to show details of venation. X 2.5. BSIP Museum Specimen No. 41326.

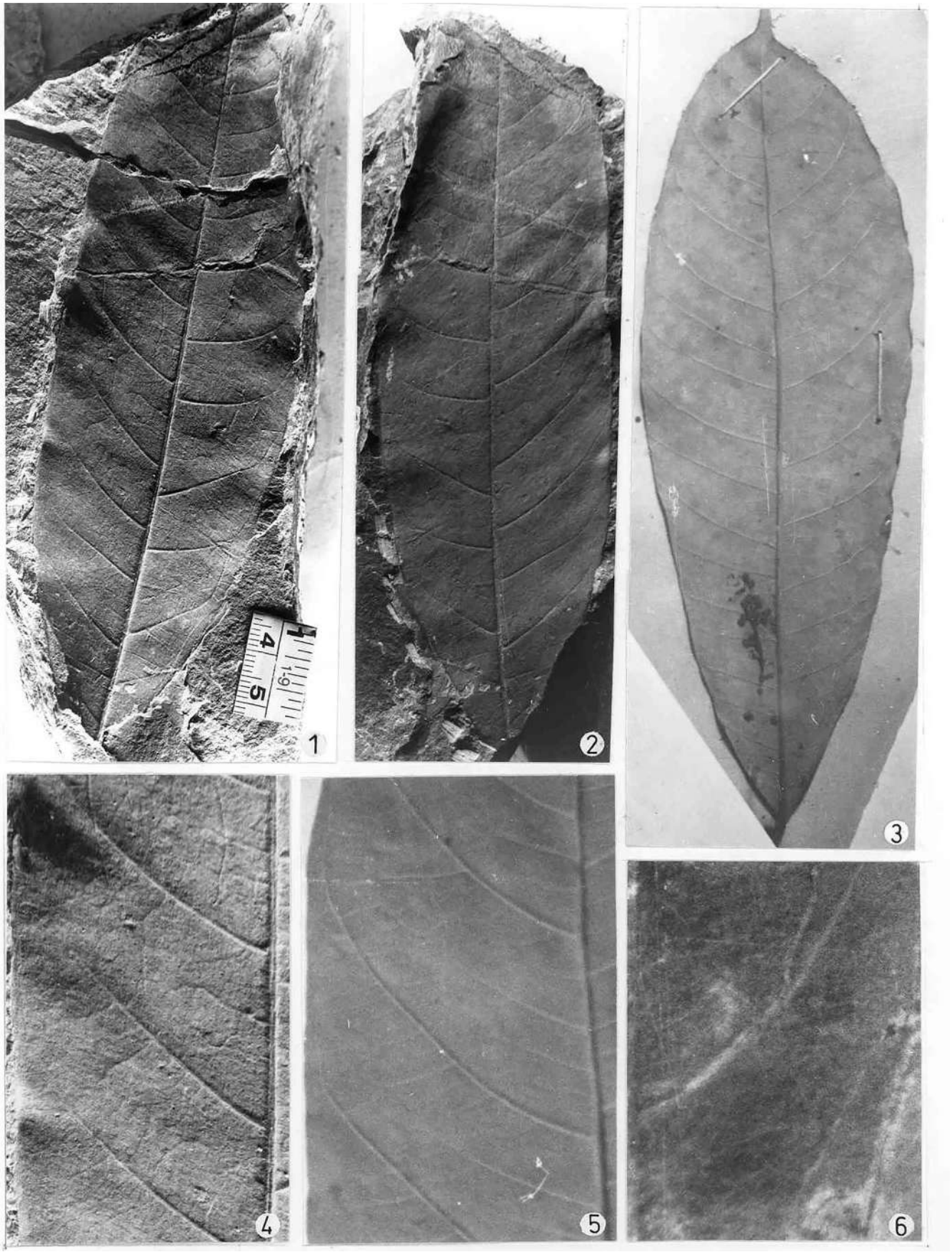

PLATE 10

sometimes branched, nearly right angle in relation to midvein, predominantly alternate and close.

Holotype—BSIP Museum Specimen No. 41320.

Paratype—BSIP Museum Specimen Nos. 41321–41323.

Locality—Spot No. 10 (29º9'12.1": 80º11'38.5"), Bhairauv Mandir, Purniyagiri Road section, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—By adding a prefix 'Palaeo' to the modern comparable species, *S. trifoliatus*.

Affinity—The distinguished morphological features of the fossil leaves such as compound leaf, very narrow elliptic shape, acute apex and base, entire margin, eucamptodromous venation, wide acute angle of divergence of secondary veins, presence of intersecondary veins, percurrent, RR, zigzag tertiary veins having nearly right angle in relation to midvein strongly indicate that the fossil leaves belong to the genus *Sapindus* Linn. of the family Sapindaceae. After critical study of the modern leaves of different species of this genus it has been found that the present fossil leaves show closest affinity with the extant leaves of *Sapindus trifoliatus* Linn. (Syn. *S. emarginatus* Wall.; *S. laurifolius* Vahl.) in shape, size and venation pattern (C.N.H. Herbarium Sheet No. 95064; Pl. 9.2, 5).

The fossil leaves resembling the genus *Sapindus* Linn. have been described as Leaf type D and Leaf type E from the Eocene of Barmer Rajasthan, India (Deshmukh & Sharma, 1978). These fossils show their resemblance with *Sapindus bilinicus* and *S. falcifolius* Al. respectively. Recently, two fossil leaves have been reported under the genus *Sapindus* Linn. from the Tertiary sediments of Indian subcontinents. *Sapindus arjunkholaensis* (Prasad *et al*., 2016) has been reported from Middle Siwalik sediments of Arjun Khola, Nepal and *S. palaeoemerginatus* Srivastava & Mehrotra (2013) from Oligocene sediments of Assam, India. On critical study of the fossil leaves (Leaf type D & E) it has been observed that these are identical (one type) and differ from present fossil leaves in having larger size (10–16 x 3.5–4.5 cm) with more number of secondary veins which arise comparatively at narrow acute angle of divergence. *S. arjunkholaensis* differ from present fossil leaf in having brochidodromous type of venation pattern as compared to eucamptodromous in the Tanakpur fossil. Besides, the later possesses tertiary veins which are nearly right angle in relation to midvein. However, *S. palaeoemerginatus* can be differentiated in being suborbiculate elliptic shape with emerginate apex. Thus, in being different from above already known fossil leaves, the present fossils have been assigned to a new specific name, *Sapindus eotrifoliatus*.

The genus *Sapindus* Linn. consists of 13 species distributed in the tropical and subtropical regions of Africa and Australia (Willis, 1973). *Sapindus trifoliatus* Linn. with which fossil leaves show closest affinity is a large tree presently found to grow in the evergreen forests of Kokan and Canara as well as in the dry region of Sri Lanka (Gamble, 1972).

Genus—LEPISANTHES Blume

Lepisanthes miocenica sp. nov.

(Pl. 11.1, 2)

Material—This species is based on single, fairly preserved and almost complete leaf impression.

Description—Leaf simple, symmetrical, very narrow elliptic; preserved size 11.0 x 3.0 cm; apex broken; base acute; margin entire; texture coriaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein (1°) single prominent, stout, almost straight; secondary veins (2°) about 14 pairs visible, 0.4 x 1.2 cm apart, alternate to subopposite, angle of divergence 60°–70°, wide acute, uniformly curved up, seemingly unbranched, intersecondary veins present, simple, frequent; tertiary veins (3°) fine, angle of origin usually RR, percurrent, straight to sinuous, sometimes branched, oblique in relation to midvein, predominantly alternate, close.

Holotype—BSIP Museum Specimen No. 41324.

Locality—Sukhidang (29º9'48.8": 80º5'39.3"), near Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—After Miocene age of the sediments.

Affinity—The distinguishing features of the present fossil leaf such as very narrow elliptic shape, acute base, eucamptodromous venation, moderate to wide acute angle of divergence of secondary veins, presence of intersecondary

PLATE 11

(All figures are of natural size unless otherwise mentioned)

1. *Lepisanthes miocenicus* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41324 (Holotype).
2. *Lepisanthes miocenicus* sp. nov.–Part of fossil leaf magnified to show details of venation. X 2. BSIP Museum Specimen No. 41324.
3. *Harpullia siwalica* Prasad & Awasthi–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41326.
4. *Harpullia arborea* (Blanco) Radlk.–Modern leaf showing similar shape, size and venation pattern.
5, 6. *Filicium koilabasensis* Prasad–Fossil leaves showing shape, size and venation pattern. BSIP Museum Specimen No. 41327, BSIP Museum Specimen No. 41328.
7. *Filicium decipiens* Thw.–Modern leaf showing similar shape, size and venation pattern.
8. *Bouea premacrophylla* Antal & Awasthi–Fossil leaf (Apical part) showing shape, size and venation pattern. BSIP Museum Specimen No. 41331.
9. *Bouea macrophylla* Griffith.–Modern leaf (Apical part) showing similar shape, size and venation pattern.

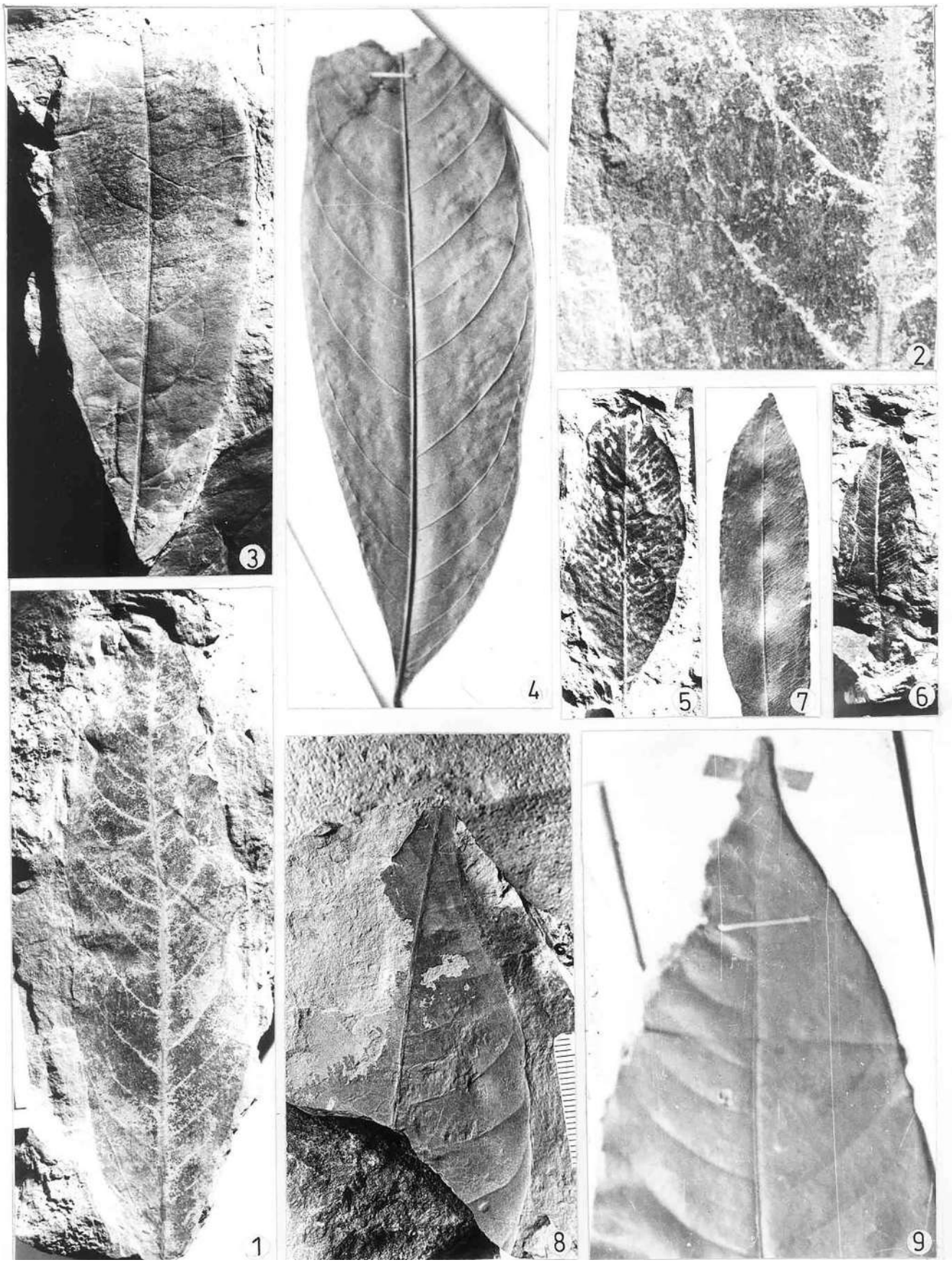

PLATE 11

veins and RR, percurrent tertiary veins collectively suggest its closest affinity with the modern leaves of *Lepisanthes fruticosa* (Roxb.) Leenh. (Syn. *Otophora fruticosa* (Roxb.) Blume, Basionym *Sapindus fruticosa* Roxb.) of the family Sapindaceae (C.N.H. Herbarium Sheet No. 95326). During its identification it has been seen that this fossil leaf shows superficial resemblance with the modern leaves of *Sapindus attenuatus* Wall. of the family Sapindaceae in shape and size but it differ in the curvature and arrangement of secondary veins.

There is no record of fossil leaves resembling the genus *Lepisanthes* Blume from the Tertiary sediments of India and abroad. This fossil leaf reports it first occurrence in the Siwalik sediment of Tanakpur area, Uttarakhand and hence it is being described as *Lepisanthes miocenica* sp. nov.

The genus *Lepisanthes* Blume comprises about 24 species of trees or shrubs. The modern comparable taxon, *L. fruticosa* (Roxb.) Leenh. is a evergreen tree distributed in Indo–China, Myanmar, Thailand, Malaya, Java, Malacca, Sumatra and Philippines.

Genus—LEPISANTHES Blume

Lepisanthes tanakpurensis sp. nov.

(Pl. 12.1, 3)

Material—There is a single, fairly preserved leaf impression without apex.

Description—Leaf simple, symmetrical, very narrow elliptic; preserved size 14.5 x 3.5 cm; apex broken, base attenuate; margin entire; texture coriaceous; petiole broken; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, massive, straight; secondary veins (2°) about 12–13 pairs visible, 0.5 to 1.8 cm apart, alternate to opposite, seemingly unbranched, angle of divergence 50°–60°, moderately acute, uniformly curved up, sometimes joining superadjacent secondary vein before reaching the margin; intersecondary veins present, simple, frequent; tertiary veins (3°) fine, fairly preserved, angle of origin RR, percurrent, straight to curved, sinuous, branched, oblique to nearly right angle in relation to midvein, predominantly alternate and close.

Holotype—BSIP Museum Specimen No. 41325.

Locality—Spot No. 6, Purniyagiri Road section, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—After the name of town, Tanakpur near the fossil localities.

Affinity—The most important morphological characters of the fossil leaf like its large size, attenuate base, entire margin, eucamptodromous venation, moderately acute angle of divergence, RR, percurrent, oblique to nearly right angle of tertiary veins in relation with midvien show that the fossil leaf belongs to the genus *Lepisanthes* Blume of the family Sapindaceae. In order to find out the nearest specific affinity of the present fossil, the herbarium sheets of all the available species of the genus *Lepisanthes* have been examined and it was concluded that the extant leaves of *L. tetraphylla* Radlk. show closest similarity with the fossil specimen (C.N.H. Herbarium Sheet No. 5902; Pl. 12.2).

The earlier described fossil leaf, *Lepisanthes miocenica* has been compared with the present fossil and found that it differs in being small size having less number of secondary veins which arise at wide acute angle of divergence as compared to moderate acute angle in the present fossil leaf. In view of these differences, the present fossil leaf is described under a new specific name, *Lepisanthes tanakpurensis.*

The extant taxon, *Lepisanthes tetraphylla* Radlk. with which fossil leaf shows closest similarity is a middle sized tree, presently distributed in Deccan and east side of the Peninsula. It is also found commonly in Kokon, Tenasserim and Pondicherry (Brandis, 1971).

Genus—HARPULLIA Roxb.

Harpullia siwalica Prasad & Awasthi, 1996

(Pl. 11.3; Pl. 10.6)

Material—There is single, well preserved leaf impression without apex.

PLATE 12

(All figures are of natural size unless otherwise mentioned)

1. *Lepisanthes tanakpurensis* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41325 (Holotype).
2. *Lepisanthes tetraphylla* Radlk.–Modern leaf showing similar shape, size and venation pattern.
3. *Lepisanthes tanakpurensis* sp. nov.–Part of fossil leaf magnified to show details of venation. X 2. BSIP Museum Specimen No. 41325.
4. *Sabia eopaniculata* Prasad–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41332.
5. *Sabia eopaniculata* Prasad–Part of fossil leaf magnified to show details of venation. X 3. BSIP Museum Specimen No. 41332.
6. *Gnestis purniyagiriensis* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41333.
7. *Gnestis ramiflora* Griff.–Modern leaf showing similar shape, size and venation pattern.
8. *Gnestis purniyagiriensis* sp. nov.–Part of fossil leaf magnified to show details of venation. X 4. BSIP Museum Specimen No. 41333.
9. *Filicium koilabasensis* Prasad–Part of fossil leaf magnified to show details of venation. X 4. BSIP Museum Specimen No. 41328.

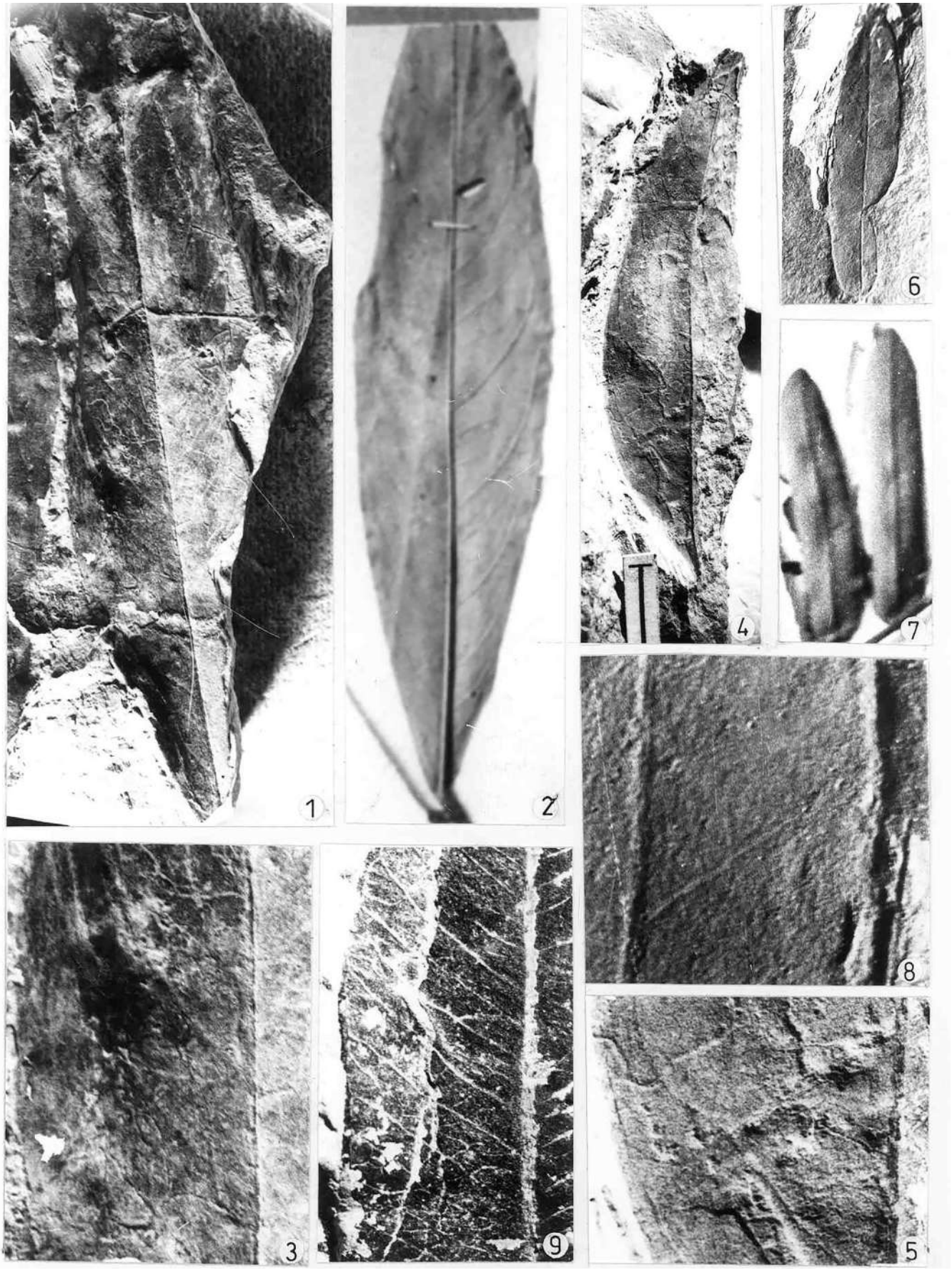

PLATE 12

Description—Leaf simple, narrow elliptic; preserved size 9.5 x 3.5 cm; apex broken; base broken, seemingly asymmetrical; margin entire; texture chartaceous; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) 7–8 pairs visible, 0.6 to 2.0 cm apart, alternate, to subopposite, angle of divergence 55°–60°, uniformly curved up and running parallel to the margin to a considerable distance, unbranched; intersecondary veins present simple; tertiary veins (3°) fine, angle of origin RR, rarely AO, percurrent, straight to sinuous, branched, oblique in relation to midvein, predominantly alternate and close.

Specimen—BSIP Museum Specimen No. 41326.

Locality—Spot No. 1 (29º8'27.4": 80º11'6.9"), near Hanuman Chatti, Purniyagiri Road section, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinity—The present fossil leaf is characterized by narrow ovate shape, inequilateral base, entire margin, eucamptodromous venation, course of secondary veins and usnally RR, percurrent tertiary veins. In all the above characters it shows close similarity with the modern leaves of *Harpullia arborea* (Blanco.) Radlk. of the family Sapindaceae (C.N.H. Herbarium Sheet No. 61270; Pl. 11.4).

Prasad and Awasthi (1996) reported a fossil leaf resembling the genus *Harpullia* Roxb. under a form species, *Harpullia siwalica* from the Siwalik sediments of Suraikhola, Nepal. On comparison with the present fossil leaf it has been observed that *H. siwalica* shows close similarity with this fossil in almost all the morphological features and hence described here under the same species *H. siwalica* Prasad & Awasthi.

The genus *Harpullia* Roxb. comprises of 37 species distributed presently in tropical Asia and Australia. The modern comparable taxon, *Harpullia arborea* (Blanco.) Radlk. is a tall evergreen tree reported to be commonly found in the thickest and secondary forests of North–east India, Sri Lanka, Myanmar, Malaysia, Australia, Thailand and Indo–China.

Genus—FILICIUM Thwaites

Filicium koilabasensis Prasad, 1994e

(Pl. 11.5, 6; Pl. 12.9)

Material—There are two well preserved, almost complete leaflet impressions.

Description—Leaflet almost symmetrical, sometimes one lamina lobe is wider than other, narrow elliptic; preserved size 5.5 x 2.0 cm; apex slightly broken; seemingly acute; base acute, normal; margin entire; texture chartaceous; petiolule 0.2 cm visible, normal; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) about 16 pairs visible, 0.2–0.5 cm apart, closely placed, angle of divergence about 60°, acute, moderate, alternate to opposite, branched; `intersecondary veins present, simple, 1–2 intersecondary veins in between two secondaries; tertiary veins (3°) fine, angle of origin AO–RR, percurrent, almost straight, branched, oblique in relation to midvein, predominantly alternate, close.

Specimen—BSIP Museum Specimen Nos. 41327–41328.

Locality—Spot No. 4 (29º9'8": 80º11'19.7"), Purniyagiri Road section, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinity—The important features of the present fossil leaves are slightly asymmetrical, narrow elliptic shape, acute apex and base, entire margin, chartaceous texture, very closely placed secondary veins with moderate angle, and AO–RR, percurrent tertiaries. A critical examination of a number of herbarium sheets of different genera of dicotyledonous families indicates that the above features are found common in the modern leaflets of *Toddallia asiatica* (L.) Lam. and *T. lanceolata* of Rutaceae and *Filicium decipiens* (Wight & Arn.) Hook. f. of family Sapindaceae. Of these, the leaves of *Toddallia* spp. differ from the fossil leaves in the course of secondary veins which do not join each other before the margin as in the fossils. Thus, the extant leaves of *Filicium decipiens* (Wight & Arn.) Hook. f. (C.N.H. Herbarium Sheet Nos. 78732, 65968; Pl. 11.7) show closest affinity with the fossils in all the morphological features.

Prasad (1994e) described a fossil leaf resembling the genus *Filicium* Thw. ex Hooker f. under a form species *Filicium koilabasensis* from Siwalik sediments of Koilabas

PLATE 13

(All figures are of natural size unless otherwise mentioned)

1, 2. *Bauhinia nepalensis*. Awasthi & Prasad–Fossil leaves showing shape, size and venation pattern. BSIP Museum Specimen Nos 41334, 41335.

3. *Bauhinia purniyagiriensis* sp. nov.–Fossil leaves showing shape, size and venation pattern. BSIP Museum Specimen No. 41336 (Holotype).

4. *Bauhinia finlaysoniana*–Modern leaf showing similar shape, size and venation pattern.

5. *Millettia mioinermis* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41337 (Holotype).

6. *Millettia mioinermis* sp. nov.–Part of fossil leaf magnified to show details of venation. X 3. BSIP Museum Specimen No. 41337.

7,9,10,11. *Millettia siwalica* Prasad–Fossil leaves showing shape, size and venation pattern. BSIP Museum Specimen Nos 41338–41341.

8, 12. *Millettia ovalifolia* Kurz.–Modern leaves showing similar shape, size and venation pattern.

13. *Millettia siwalica* Prasad–Part of fossil leaf magnified to show details of venation. X 3. BSIP Museum Specimen No. 41339.

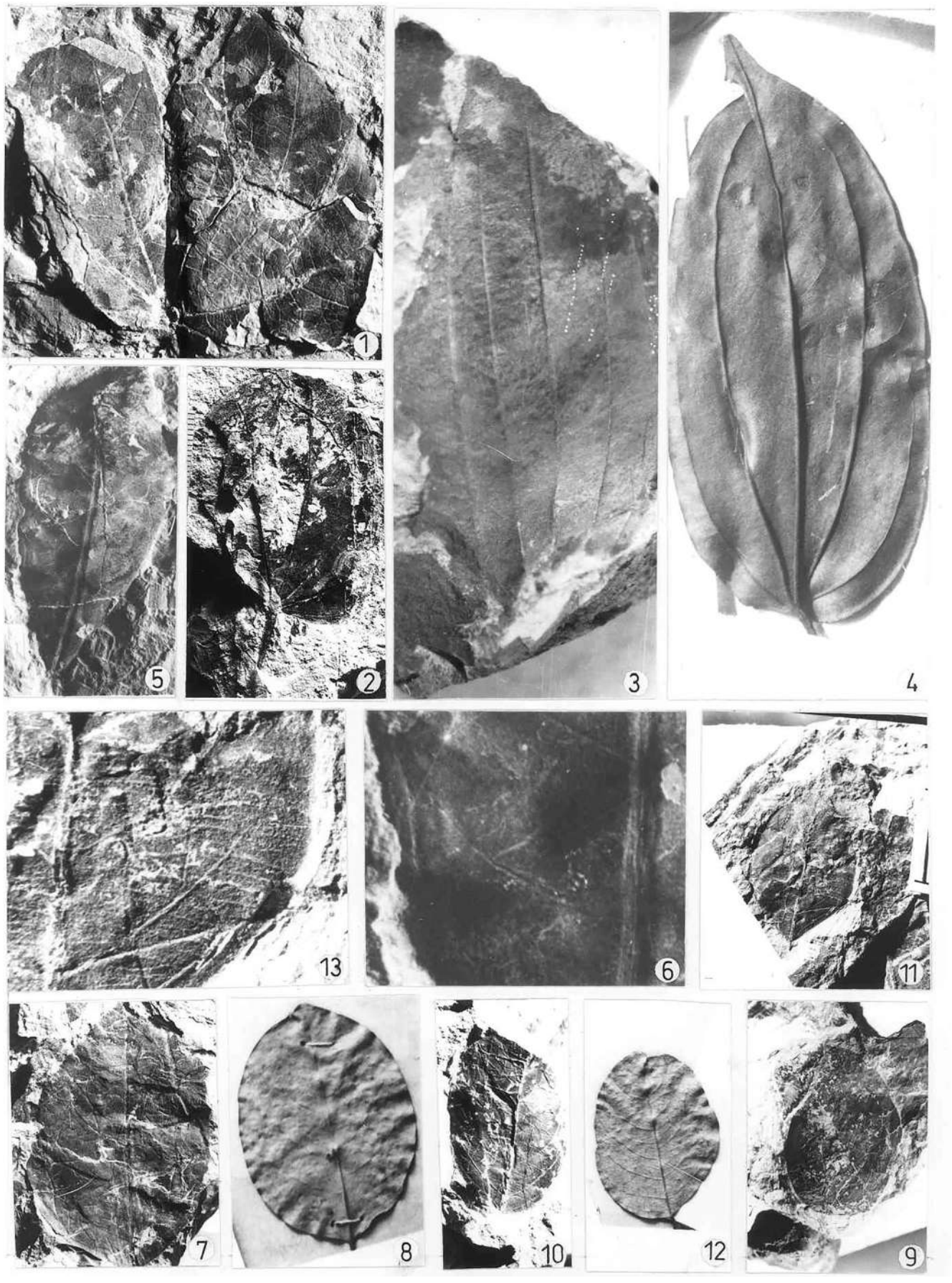

PLATE 13

area, western Nepal. Later on, the same species has been reported from Siwalik sediments of Darjeeling District, West Bengal, India (Prasad *et al*., 2015) and Miocene of Neyveli Lignite, Tamil Nadu, India. On comparative study it has been observed that the present fossil leaves exhibit similar morphological features as the above known species *F. koilabasensis* Prasad hence, these fossils have been described under the same species.

The genus *Filicium* Thw. ex Hook. f. comprises three species presently distributed in the tropical region of old world (Mabberley, 1997). *Filicium decipiens* (Wight & Arn.) Hook. f. with which fossils resemble closely is a medium sized, evergreen tree occurring in the forests of Western Ghat, from the Nilgiris southwards. It also shows in Sri Lanka and tropical Africa (Brandis, 1971).

Family—ANACARDIACEAE

Genus—DRIMYCARPUS Hook. f.

Drimycarpus siwalicus sp. nov.

(Pl. 10.1, 2, 4)

Material—There is single, well preserved leaf impression with counterpart.

Description—Leaf simple, almost symmetrical, narrow elliptic to oblong; size 13.5 x 4.2 cm; apex slightly broken; base acute; margin entire; texture chartaceous; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, massive, almost straight; secondary veins (2°) about 12 pairs visible, 0.1–1.8 cm apart, usually alternate, angle of divergence varies randomly, 60°–85°, uniformly curved up, curvature is more pronounced near the margin, unbranched; intersecondary veins present, simple; tertiary veins (3°) fine, angle of origin usually RR, percurrent, mostly sinuous or zigzag, sometimes branched, oblique in relation to midvein, predominantly alternate and close.

Holotype—BSIP Museum Specimen No. 41329.

Paratype—BSIP Museum Specimen No. 41330.

Locality—Spot No. 1 (29º8'27.4": 80º11'6.9"), near Hanuman Chatti, Purniyagiri Road section, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—After Siwalik Group.

Affinity—The important morphological characters of the fossil leaf like, its narrow elliptic to oblong shape, seemingly acute apex and base, entire margin, eucamptodromous venation, variation in the angle of divergence of secondary veins which have pronounce curvature near the margin, RR, percurrent, mostly sinuous or nearly zigzag tertiary veins collectively indicate that the present fossil leaf resembles very closely with the extant leaves of *Drimycarpus racemosus* Hook. f. (C.N.H. Herbarium Sheet No. 99552; Pl. 10.3, 5) of the family Anacardiaceae. The present Siwalik fossils have also been compared with some other anacardaceous taxa showing near resemblance with the fossils like, *Semicarpus anacardium* Linn., *Gluta renghas* Linn., *G. travancorea* Bedd., *G. usitata* (Wall.) Ding–Hou, *Mangifera indica* Linn., *M. sylvatica* Roxb. and *Swintonia floribunda* Grifth. and *S. schwenckii* Teysm. & Bennend. and concluded that these differ in being either different shape, size or secondary and tertiary venation pattern. The leaves of *S. anacardium* Linn differ from the fossils in having larger size with different pattern of secondary and tertiary venation pattern. The few basal secondary veins arise at right angle and are recurved and closely placed. The tertiary veins are usually in zigzag pattern and distantly placed. The extant leaves of two species of *Gluta* Linn. (*G. travancorea* Bedd., *G. usitata* (Wall.) Ding–Hou) are almost similar in shape, size and venation pattern. These differ from present fossils in being possessing greater number of comparatively closely placed secondary veins and the intersecondary veins are in distinct and not frequently occur as in the present fossil leaves. The leaves of *Gluta renghas* Linn. are narrow lanceolate in shape with usually acute angle of divergence of basal secondary veins however, in the present fossil leaves, there are few secondary veins in both the basal region as well as mid lamina region arise at nearly right angle. *Mangifera indica* Linn. and *M. sylvatica* Roxb. differ mainly in the angle of divergence of secondary veins which arise

PLATE 14

(All figures are of natural size unless otherwise mentioned)

1. *Humboldtia miocenica* sp. nov.–Fossil fruit showing shape, size and other details. BSIP Museum Specimen No. 41342 (Holotype).
2. *Humboldtia vahliana* Wight–Modern fruit showing similar shape, size and other details.
3. *Wagatea miospicata* sp. nov.–Fossil fruit showing shape, size and other details. BSIP Museum Specimen No. 41343 (Holotype).
4. *Wagatea spicata* Dalz.–Modern fruit showing similar shape, size and other details.
5. *Dalbergia tanakpurensis* sp. nov.–Fossil fruit showing shape, size and other details. BSIP Museum Specimen No. 41344 (Holotype).
6. *Dalbergia indana*–Modern fruit showing similar shape, size and other details.
7. *Derris prakashii* Prasad *et al*.–Fossil fruit showing shape, size and other details. BSIP Museum Specimen No. 41345.
8. *Derris trifoliata* Lour–Modern fruit showing similar shape, size and other details.
9. *Bauhinia purniyagiriensis* sp. nov.–Part of fossil leaf magnified to show details of venation. X 3. BSIP Museum Specimen No. 41336.
10. *Bauhinia finlaysoniana* (Benth) Backer–Part of modern leaf magnified to show similar details of venation.
11. *Derris prakashii* Prasad *et al*.–Fossil fruit magnified to show nature of striations on the surface. X 2. BSIP Museum Specimen No. 41345.

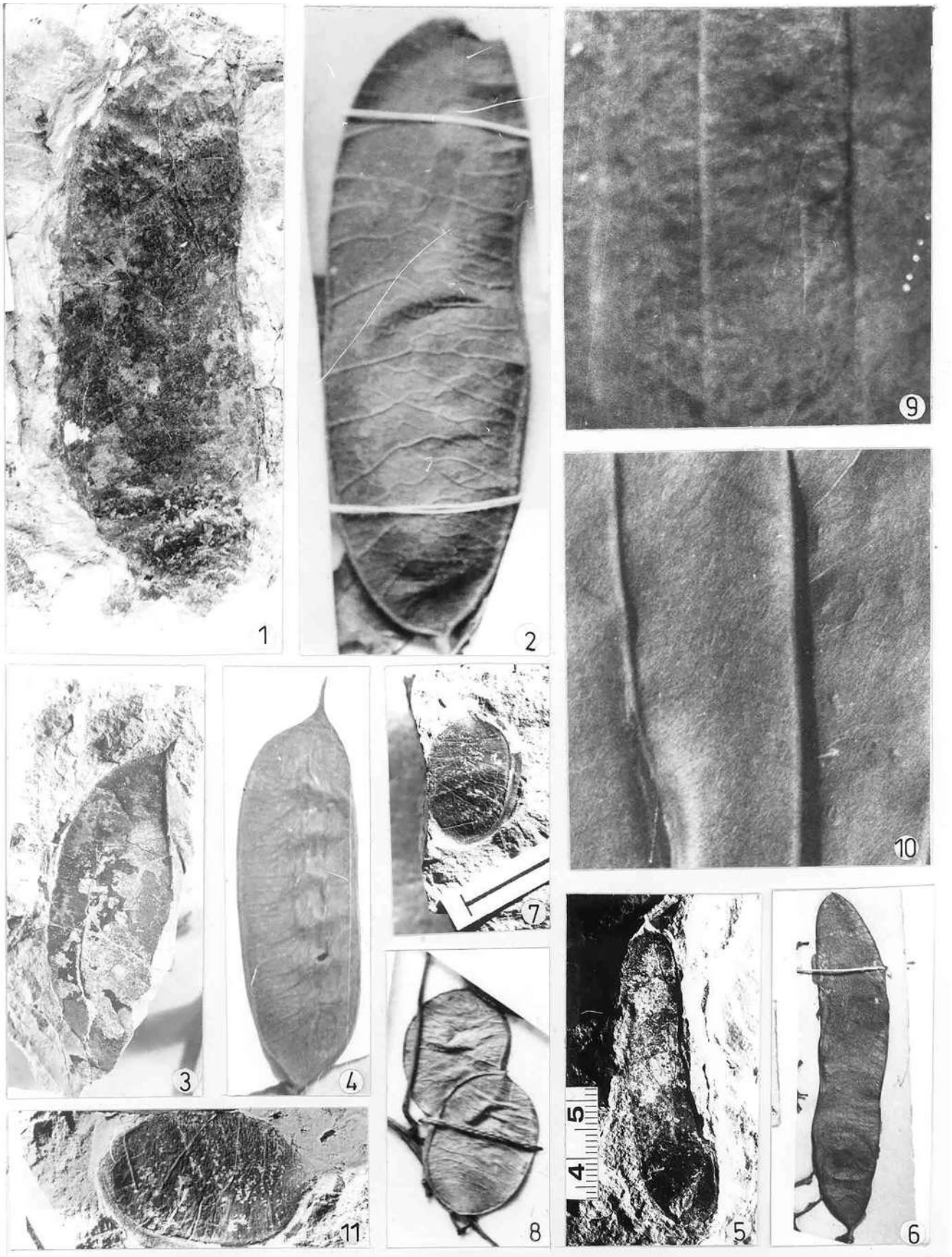

PLATE 14

usually at acute angle in comparison to acute to nearly right angle in the present fossils. Moreover, the intersecondary veins are frequently (2–3 veins in between two secondary veins) occur in the leaves of *Mangifera*. The leaves of *Swintonia floribunda* Grifth. and *S. schwenckii* Teysm. and Bennend. can be differentiated in being closely placed secondary veins and AO–RR angle of origin of tertiary veins. Furthur, the tertiary veins are not as thick as in the present fossils.

So far, there is no record of fossil leaves of the genus *Drimycarpus* Hook F. from the Tertiary sediments of India. Thus, the present fossil leaf is the first record from the Siwalik sediments of Uttarakhand and has been described here as *Drimycarpus siwalicus* sp. nov.

The genus *Drimycarpus* Hook. f. consists of more than two species of trees and distributed in the Indo–Malayan region. The extant taxon, *D. racemosus* Hook. f. with which the fossil shows resemblance, is an evergreen tree growing in north–east India, Bangladesh and Bhutan (Brandis, 1971).

Genus—BOUEA Meissn.

Bouea premacrophylla Antal & Awasthi, 1993

(Pl. 11.8)

Material—There is single fossil leaf representing only apical portion.

Description—Almost symmetrical, preserved size 8.0 x 4.5 cm; apex acuminate; margin entire; texture chartaceous; venation pinnate, craspedodromous to eucamptodromous; primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) about 9–10 pairs visible, 0.7–1.5 cm apart, angle of divergence 75°–80°, wide acute, seemingly alternate, uniformly curved up, unbranched; intersecondary veins present, simple; tertiary veins (3°) fine, angle of origin usually AO–RR, percurrent, usually straight, oblique in relation to midvein, predominantly alternate and close.

Figured specimen—BSIP Museum Specimen No. 41331.

Locality—Spot No. 1 (29º8'27.4": 80º11'6.9"), near Hanuman Chatti, Purniyagiri Road section, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinity—The fossil leaf is incomplete but its characteristic morphological features like, acuminate apex, wide acute angle of divergence of secondary veins, craspedodromous to eucamptodromous venation, nature and arrangement of secondary and tertiary veins undoubtedly indicate its affinity with the modern leaves of *Bouea macrophylla* Grifth. (C.N.H. Herbarium Sheet No. 99041; Pl. 11.9) of the family Anacardiaceae.

So far, two fossil leaves resembling the extant taxon, *Bouea macrophylla* Grifth. have been described under a form species, *B. premacrophylla* from Siwalik sediments of Darjeeling District, West Bengal (Antal & Awasthi, 1993) and Serianaka, western Nepal. A comparison of present fossil leaf with the above known fossils suggests that the present fossil leaf shows close similarity with the known species. Therefore, it has been described under the same species, *B. premacrophylla* Antal & Awasthi.

The genus *Bouea* Meissn. consists of 3 species (Mabberley, 1997) distributed in Indo–Malayan region. The modern comparable taxon, *B. macrophylla* Grifth. is a large evergreen tree presently found to grow in Myanmar, Andaman, Sunderbans and Malaya peninsula (Desch, 1957).

Family—SABIACEAE

Genus—SABIA Colebr.

Sabia eopaniculata Prasad, 1994e

(Pl. 12.4, 5)

Material—Single, well preserved and complete leaf impression.

Description—Leaf simple, symmetrical, narrow elliptic; preserved size 9.5 x 2.4 cm; apex acute to attenuate;

PLATE 15

(All figures are of natural size unless otherwise mentioned)

1. *Pongamia siwalika* Awasthi & Lakhanpal–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41347.
2. *Pongamia pinnata* Vent.–Modern leaf showing similar shape, size and venation pattern.
3. *Pongamia siwalika* Awasthi & Lakhanpal–Part of fossil leaf magnified to show details of venation. X 2.5. BSIP Museum Specimen No. 41347.
4. *Pongamia pinnata* Vent.–Part of modern leaf magnified to show similar details of venation.X 2.5.
5. *Cynometra palaeoiripa* Prasad *et al*.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41348.
6. *Cynometra iripa* Kotel–Modern leaf showing similar shape, size and venation pattern.
7. *Derris mioscandens* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41346.
8. *Derris scandens* Benth.–Modern leaf showing similar shape, size and venation pattern.
9. *Derris mioscandens* sp. nov.–Part of fossil leaf magnified to show details of venation. X 3. BSIP Museum Specimen No. 41346.
10. *Terminalia bhairauvensis* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41350 (Paratype).
11. *Terminalia bhairauvensis* sp. nov.–Part of fossil leaf magnified to show details of venation. X 3. BSIP Museum Specimen No. 41349.

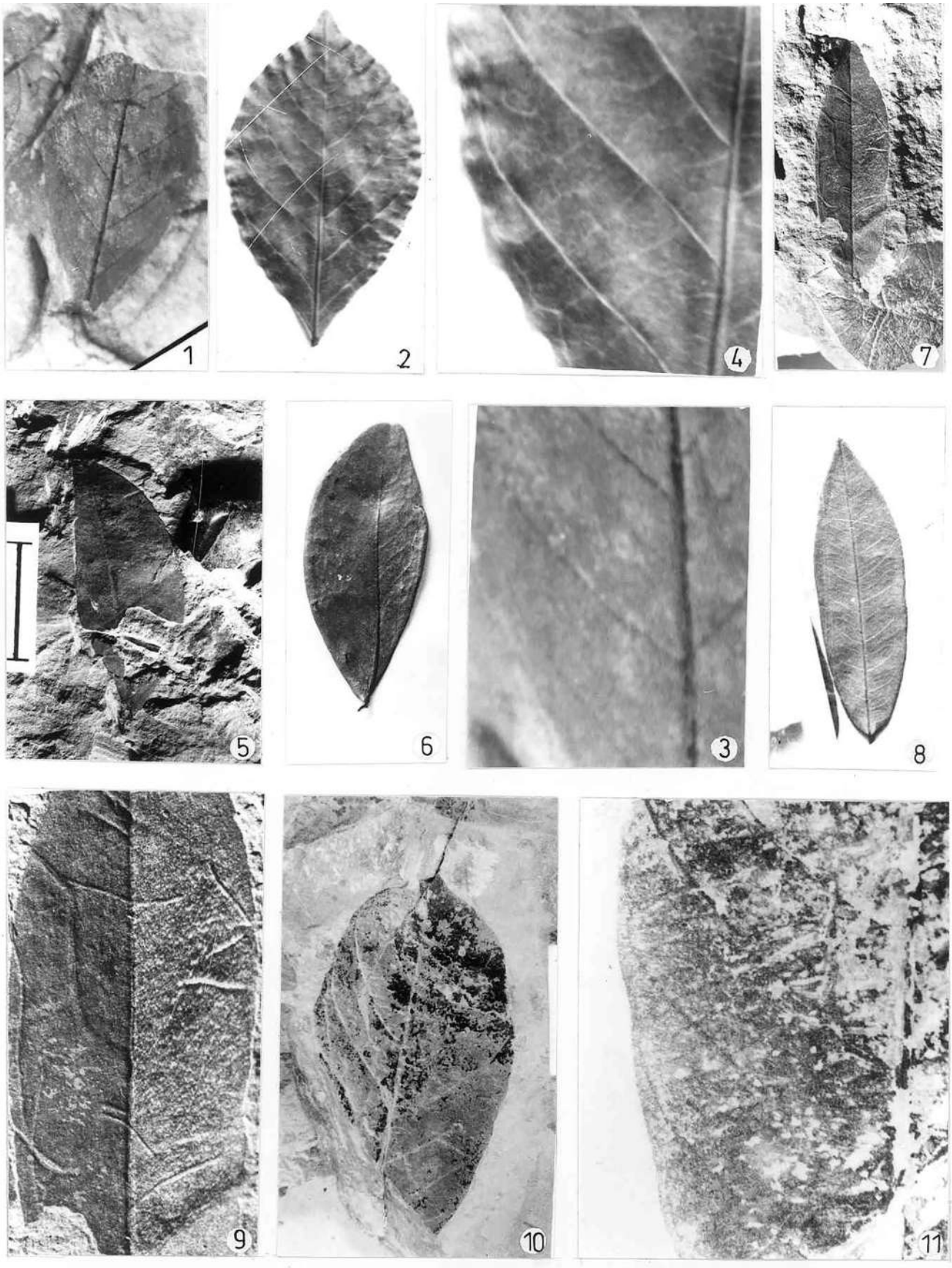

PLATE 15

base broken; margin entire; texture chartaceous; petiole 0.5 cm visible, normal; venation eucamptodromous to brochidodromous; primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) 6–7 pairs visible, 0.8–2.0 cm apart, seemingly alternate, branched, angle of divergence about 65°–75°, wide acute, uniformly curved up, and running parallel to the margin for a little distance and joined to the superadjacent secondary veins; intersecondary veins present, simple, arising from midvein at wide acute angle and joined to their upper secondary veins; tertiary veins (3°) fine, angle of origin RR, percurrent, almost straight, branched, right to nearly oblique angle in relation to midvein, predominantly alternate and close.

Specimen—BSIP Museum Specimen No. 41333.

Locality—Spot No. 2, Purniyagiri Road section, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinity—Symmetrical, narrow elliptic shape, acute to attenuate apex, acute base, entire margin, eucamptodromous to brochidodromous venation, closely placed upper and lower secondaries, wide acute angle of divergence of secondary veins which running parallel to the margin and joined to superadjacent secondary vein and forming the loop, RR, percurrent tertiary veins at usually nearly right in relation to midvein collectively indicate that the fossil leaf closely resembles the modern leaves of *Sabia paniculata* Seem. of the family Sabiaceae (C.N.H. Herbarium Sheet No. 97520).

Two fossil leaves resembling the genus *Sabia* Colebr. have been described from the Siwalik sediments of Koilabas area, Nepal and Darjeeling District, West Bengal as *S. eopaniculata* Prasad (Prasad, 1994e; Prasad *et al*., 2015). These fossil leaves also show resemblance with the extant species *S. paniculata* Seem. and possesses more or less similar morphological characters as the present fossil. Therefore, the present fossil leaf is being described under the same species *S. eopaniculata* Prasad.

The genus *Sabia* Colebr. consists of 19 species distributed in south–east Asian region. *Sabia paniculata* Seem. is a large shrub presently distributed throughout himalayan foot–hills, Myanmar and Malayan region (Brandis, 1971).

Family—CONNARACEAE

Genus—GNESTIS Juss.

Gnestis purniyagiriensis sp. nov.

(Pl. 12.6, 8)

Material—This species is based on single, well preserved and complete leaf impression.

Description—Leaf symmetrical, narrow oblong; preserved size 5.5 x 1.2 cm; apex acute; base seemingly obtuse; margin entire; texture chartaceous; petiole broken, venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) more than 12 pairs visible, less than 0.5 cm apart, closely placed, alternate, to opposite, seemingly unbranched, angle of divergence acute, about 55°–65°, narrow to wide acute, uniformly curved up; intersecondary veins present, simple; tertiary veins (3°) fine, poorly preserved, angle of origin RR, percurrent, straight to sinuous, branched, oblique in relation to midvein, predominantly alternate and close.

Holotype—BSIP Museum Specimen No. 41332.

Locality—Spot No. 9, (29º98'19.7": 80º11'27.2"), near Krishnapuri Village, Purniyagiri Road section, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—After the name of Purniyagiri Temple.

Affinity—The distinguishing features of the present fossil leaf are symmetrical, narrow oblong shape, chartaceous texture, obtuse apex and base, entire margin, closely placed secondary veins arising at narrow acute angle, presence of intersecondary veins and RR, percurrent, straight to sinuous tertiary veins. Such features are found common in the extant leaves of the genus *Gnestis* Juss. of the family Connaraceae. A careful examination of the leaves of 20 species of this genus

PLATE 16

(All figures are of natural size unless otherwise mentioned)

1. *Combretum purniyagiriense* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41351 (Holotype).
2. *Combretum sundaicum* Miquel–Modern leaf showing similar shape, size and venation pattern.
3. *Combretum purniyagiriense* sp. nov.–Part of fossil leaf magnified to show details of venation. X 1.5. BSIP Museum Specimen No. 41351.
4. *Combretum sundaicum* Miquel–Part of modern leaf magnified to show similar details of venation. X 2.
5. *Terminalia bhairauvensis* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41349 (Holotype).
6. *Terminalia argyrophylla* King & Prain–Modern leaf showing similar shape, size and venation pattern.
7. *Medinilla siwalica* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41352 (Holotype).
8. *Medinilla ramiflora* Merr.–Modern leaf showing similar shape, size and venation pattern.
9. *Medinilla siwalica* sp. nov.–Part of fossil leaf magnified to show details of venation. X 4. BSIP Museum Specimen No. 41352.
10. *Medinilla ramiflora* Merr.–Part of modern leaf magnified to show similar details of venation. X 4.

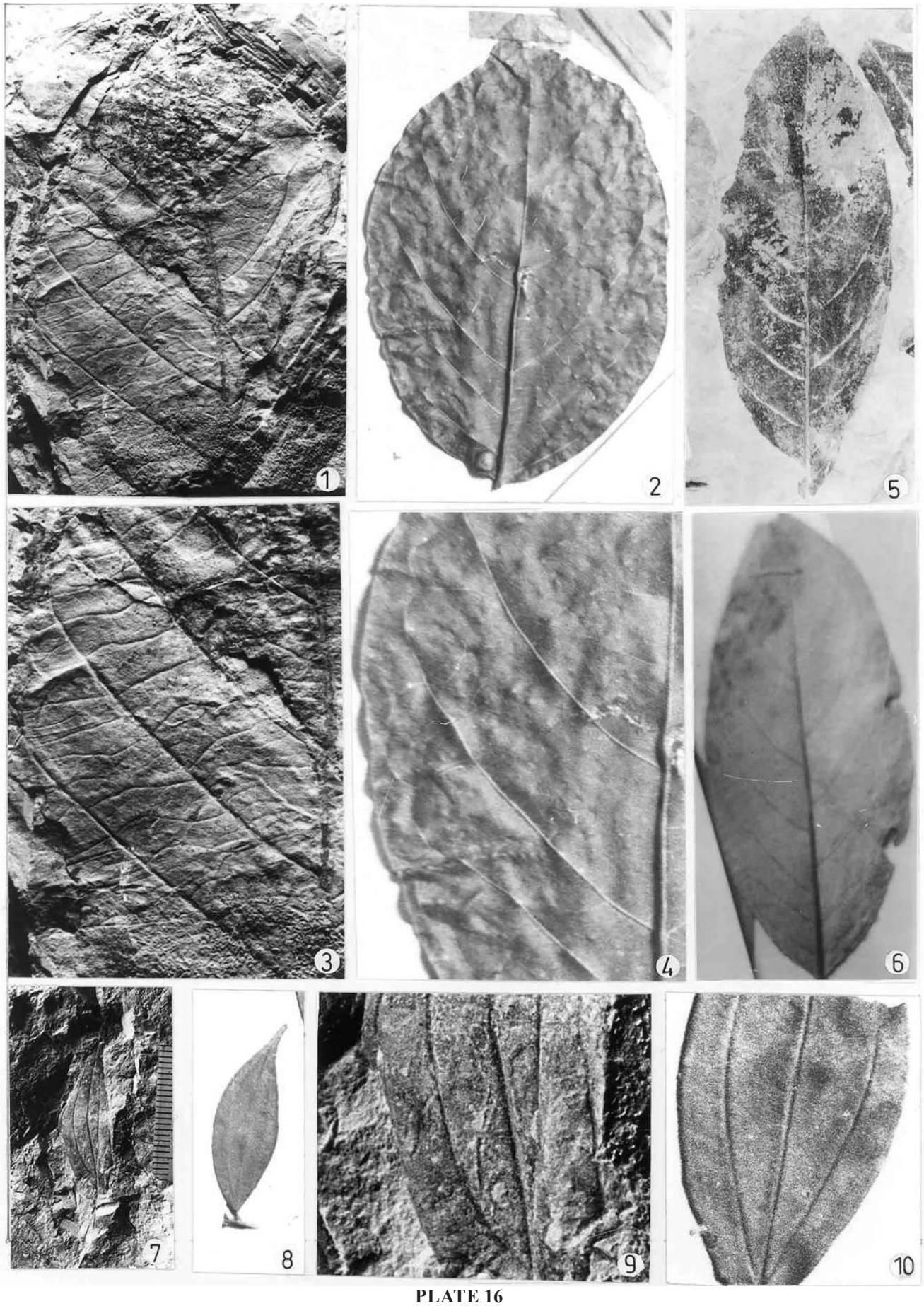

PLATE 16

indicates that *G. ramiflora* Grifth. (= *G. platantha* Grifth.) shows closest affinity with the present fossil leaf (C.N.H. Herbarium Sheet No. 101091; Pl. 12.7).

So far, there is no fossil record of the genus *Gnestis* Juss. from India and other places. Thus, it is recorded for the first time from Siwalik of Uttarakhand and described here as *Cnestis purniyagiriensis* sp. nov.

The genus *Gnestis* Juss. consists of about 13 species distributed presently in the Indo–Malayan regions and Tropical Africa (Mabberley, 1997). The modern comparable taxon, *G. ramiflora* Grifth is a shrub or small tree found to grow in the evergreen forests of lower Myanmar and Andaman.

Family—FABACEAE

Genus—BAUHINIA Linn.

Bauhinia nepalensis Awasthi & Prasad, 1990

(Pl. 13.1, 2)

Material—There are two specimens of well preserved leaf impression, one is with open bilobed and other with closed lobe.

Description—Leaf symmetrical, bilobed, each lobe elliptic; lamina size 6.0 x 6.0 cm (open bilobed specimen) and 4.5 x 3.4 cm (close lobed specimen); apex obtuse to rounded; base auriculate, equilateral; margin entire; texture coriaceous; petiole preserved, 1.6 cm long, normal; venation pinnate, actinodromous; perfect, basal; primary vein (1°) 5, given off to each lobe from the base, prominent, moderate, curving upward; secondary veins 5–6 pairs, arising from one or both side of the primary veins, usually alternate, angle of divergence 60°–65°, moderately acute, curving up and joined to their superadjacent secondary veins, 0.7–1.8 cm apart, seemingly unbranched; tertiary veins (3°) with angle of origin nearly RR, percurrent, rarely branched, nearly right angle in relation to primary veins, predominantly alternate and close.

Specimen—BSIP Museum Specimen Nos. 41334–41335.

Locality—Spot No. 4 (29º9'8": 80º11'19.7"), Purniyagiri Road section, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinity—The diagnostic features of the present fossil leaf such as bilobed, wide elliptic shape, obtusely emarginate apex (in open lobed specimen), auriculate base, entire margin, basal, actinodromous venation, wide acute angle of divergence of secondary veins, RR, percurrent tertiaries which are nearly right angle in relation to primary veins undoubtedly suggest their affinity with the extant leaves of the genus *Bauhinia* Linn. of the family Fabaceae. From a critical examination of the herbarium sheets of all the available species of this genus, it was found that the fossil leaves are similar to those of *Bauhinia malabarica* Roxb. and *B. variegata* Linn.

Fossil leaves resembling the genus *Bauhinia* Linn. are reported under two generic name *Bauhinia,* Linn. and *Bauhinites* Seward & Conway. The latter consist of a single species *Bauhinites greenlandica* from Tertiary sediments of Greenland (Seward & Conway, 1935). However, the genus *Bauhinia* Linn. comprises about 20 species reported from Tertiary sediments of all over the world (India, Australia, Bolivia, Czechoslovkia, Equador, West Germany, Greece, Greenland and North Vietnam, (Berry, 1916, 1919, 1945; Newberry, 1886,; Unger, 1850, 1867; Muller–Stoll, 1934; Heer, 1859; Knowlton, 1919; Chaney & Sanborn, 1933; Brown, 1962; Lakhanpal & Awasthi, 1984; Lakhanpal & Guleria, 1982; Antal & Awasthi, 1993; Awasthi & Prasad, 1990; Tiwari *et al*., 2015). Out of these, only three species have been reported from the Siwalik sediments of India and Nepal. They are *Bauhinia siwalika* from Upper Siwalik sediments of Bhikhnathoree, Bihar, India (Lakhanpal & Awasthi, 1984) and from Middle Siwalik sediments of Dumkibas, Nepal (Konomatsu & Awasthi, 1999), *Bauhinia nepalensis* from Middle Siwalik sediments of Suraikhola area, western Nepal (Awasthi & Prasad, 1990) and *Bauhinia ramthiensis* from the Lower–Middle Siwalik sediments of Darjeeling District, West Bengal, India (Antal & Awasthi, 1993). A critical comparison of the present fossil leaves with those of known fossil leaves indicates that the fossil leaf, *Bauhinia nepalensis* Awasthi & Prasad is very similar to the present fossils in almost all the morphological features and hence, these are being described under the same species, *Bauhinia nepalensis* Awasthi & Prasad.

The genus *Bauhinia* Linn. consists of about 300 species of pan tropical. They are often lianas with flattened stem. The modern comparable species, *B. malabarica* Roxb. and *B. variegata* Linn. are moderate sized trees growing in Sub–himalayan tract. These also occur in dry to moist deciduous forests of central and south India and Myanmar (Ramesh Rao & Purkayastha, 1972; Gamble, 1972).

Genus—BAUHINIA Linn.

Bauhinia purniyagiriensis sp. nov.

(Pl. 13.3; Pl. 14.9)

PLATE 17

(All figures are of natural size unless otherwise mentioned)

1. *Lagerstroemia prakashii* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41353 (Holotype).

2. *Lagerstroemia flosreginae* Retz.–Modern leaf showing similar shape, size and venation pattern.

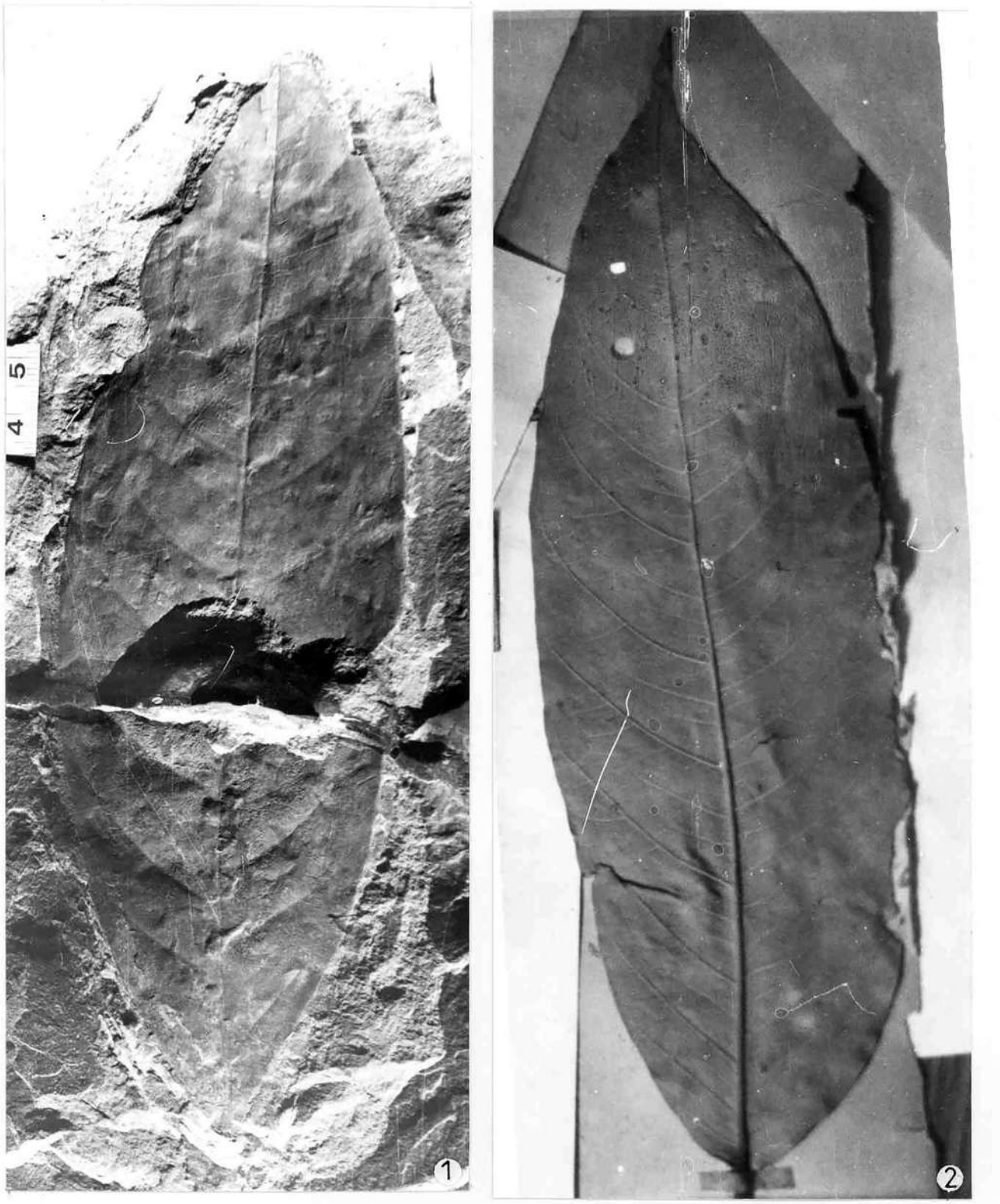

PLATE 17

Material—There are three specimens of leaf impression. Apex and base are slightly broken in all of them.

Description—Leaves symmetrical, elliptic to oblong; preserved size 10 x 4.5 cm; apex and base slightly broken; margin entire, texture coriaceous; venation acrodromous, basal, perfect; primary vein (1º) 5 pairs (one mid and two lateral) arising from the base and running upward towards the apex, mid primary almost straight, lateral primaries curved, secondary veins numerous, closely placed, sometimes branched, angle of origin varies from wide acute to nearly right angle, (60–80º), curved up and joined to their adjacent primary veins at acute to right angle; tertiary veins (3º) poorly preserved, arising from secondary veins at usually right angle, percurrent, almost straight, nearly parallel to oblique in relation to midvein, predominantly alternate and close.

Holotype—BSIP Museum Specimen No. 41336.

Locality—Spot No. 1, (29º8'27.4": 80º11'6.9"), near Hanuman Chatti, Purniyagiri Road section, Champawat District, Uttarakhand.

Horizon–Lower Siwalik; Middle Miocene.

Etymology—After Purniyagiri Temple.

Affinity—The characteristic features of the present fossil leaves are: symmetrical elliptic to oblong shape, entire margin, coriaceous texture, basal, perfect, acrodromous type of venation, presence of five primary veins and numerous secondary veins arising at acute to nearly right angle from the primaries and usually RR, percurrent tertiaries having oblique to nearly parallel in relation to primaries. An extensive survey of the herbarium sheets of a number of genera and species of the dicotyledonous families indicates that such features are found in the extant leaves of *Cinnamomum* spp. (Lauraceae), *Astronia gitingensis*, *Marumia nemorosa* and *Melastoma malabaricum*, (Melastomaceae), *Anisophyllea apitala* (Anisophylleaceae), *Allomorphia axiqua*, *Celtis philippinensis* (Urticaceae) and *Bauhinia finlaysoniana* (Benth.) Baker (Fabaceae). After critical examination of the herbarium sheets of all the above taxa it has been concluded that the extant leaves of *Bauhinia finlaysoniana* (Benth.) Baker (C.N.H. Herbarium Sheet No. 3589; Pl. 13.4; Pl. 14.10) of the family Fabaceae show closest affinity with the present fossil leaves. The leaves of remaining taxa differ from present fossils either in having only 3 primary veins or in the nature and arrangement of the primary and secondary veins.

So far, about 20 fossil species of the genus *Bauhinia* Linn. based on leaf impression have been reported from the Tertiary sediments of India and abroad (Awasthi & Prasad, 1990; Antal & Awasthi, 1993; Konomatsu & Awasthi, 1999). A comparative study of the present fossils with the already reported fossil leaves (including the species described in this text) has been carried out and found that they differ from the present fossil leaves mainly in the shape, size, number and arrangement of primary and secondary veins. Thus, in being different, the present fossil has been assigned to a new species, *Bauhinia purniyagiriensis*.

The extant taxon, *Bauhinia finlaysoniana* (Benth.) Baker (Syn. *B. Cordifolia* Roxb.) with which fossils resemble closely is a perennial evergreen shrub presently distributed in Indonesia, Java, Malaysia, Moluccas, Philippines and Sumatra.

Genus—MILLETTIA W. & A.

Millettia mioinermis sp. nov.

(Pl. 13.5, 6)

Material—This species is based on a single, fairly preserved leaf impression.

Description—Leaf almost symmetrical, obovate; preserved size 5.0 x 2.8 cm; apex slightly broken; base acute, slightly asymmetrical; margin entire; texture coriaceous; petiole broken; venation pinnate, eucamptodromons; primary vein (1º) single, prominent, stout, almost straight; secondary veins (2º) 8–9 pairs visible, 0.6–1.0 cm apart, alternate to sub–opposite, angle of divergence 55º–60º, moderate, uniformly curved up and joined to superadjacent secondary vein, sometimes forming loop; intersecondary veins present, tertiary veins (3º) fine, angle of origin usually AO, percurrent, almost straight, rarely branched, oblique in relation to midvein, predominantly alternate and close.

Holotype—BSIP Museum Specimen No. 41337.

Locality—Spot No. 5 (29º8'49.1": 80º11'16"), Purniyagiri Road section, Champawat District, Uttarakhand.

PLATE 18

(All figures are of natural size unless otherwise mentioned)

1. *Lagerstroemia prakashii* sp. nov.–Part of fossil leaf magnified to show details of venation. X 2.
2. *Lagerstroemia flosreginae* Retz.–Part of modern leaf magnified to show similar details of venation. X 2.
3. *Lagerstroemia prakashii* sp. nov.–An other fossil leaf showing nature of apex and base. BSIP Museum Specimen No. 41354. (Paratype) .
4–6. *Lagerstroemia mioparviflora* Dwivedi *et al*.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen Nos 41355, 41356, 41357.
7. *Lagerstroemia parviflora* Roxb. Modern leaf showing shape, size and venation pattern.
8, 9. *Lagerstroemia mioparviflora* Dwivedi *et al*.–Other fossil leaves showing variation in shape and size. BSIP Museum Specimen Nos 41358, 41359.
10. *Lagerstroemia parviflora* Roxb.–Modern leaf showing similar variation in shape and size.
11. *Lagerstroemia mioparviflora* Dwivedi *et al*.–Part of fossil leaf magnified to show details of venation. X 3.5.

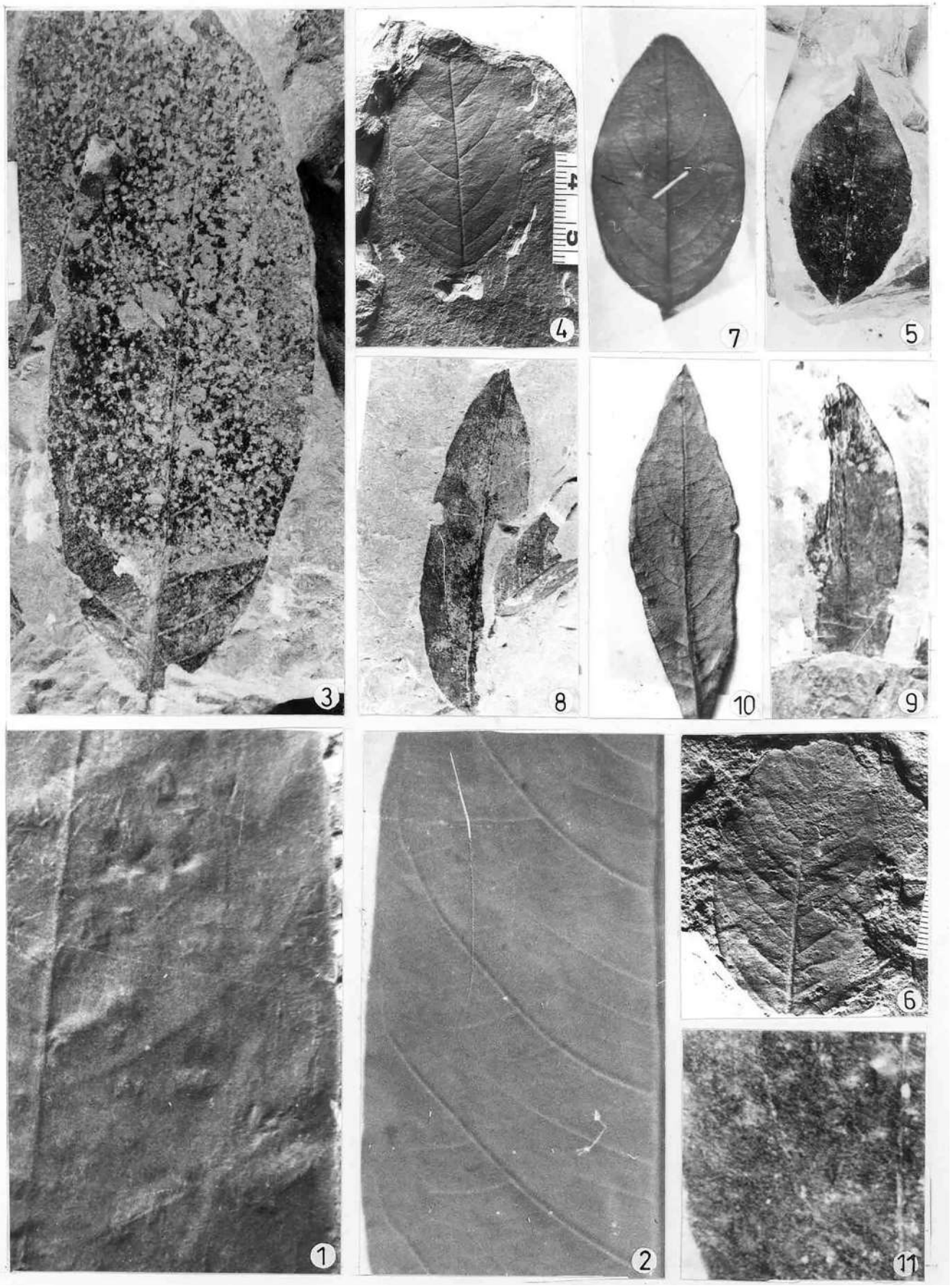

PLATE 18

Horizon—Lower Siwalik; Middle Miocene.

Etymology—By adding a prefix 'mio' to the name of modern comparable species, *M. inermis.*

Affinity—The characteristic features of the present fossil leaf are almost symmetrical, obovate shape, acute base, entire margin, eucamptodromous venation, moderate angle of divergence of secondary veins, usually AO, percurrent, almost straight tertiary veins and presence of intersecondary veins. On going through the herbarium sheets of different genera and species of dicotyledonous families, it has been observed that the present fossil resembles closely with the extant leaves of *Millettia inermis* (=*Andira inermis*) (Wright) DC. of the family Fabaceae (C.N.H. Herbarium Sheet No. 112713).

About 37 fossil leaves resembling the genus *Millettia* W. & A. have been reported from the Tertiary sediments of India and abroad. They are listed in Table 2

The present fossil leaf has been compared with all the above known species and it was found that none of them show similarity with the present fossil leaf. They differ mainly either in shape, size or in the nature and orientation of secondary veins. Thus, the present fossil has been described under a new specific name, *Millettia mioinermis.*

The genus *Millettia* W. &. A. consists of about 90 species of trees, shrubs and climbers distributed in tropical regions of Africa, Asia and Australia (Mabberley, 1997). The modern comparable species, *M. inermis* (Wright) DC. is a tall evergreen tree distributed in West Africa, West Indies and tropical America.

Genus—MILLETTIA W. & A.

Millettia siwalica Prasad, 1990a

(Pl. 13.7, 9, 10, 11, 13)

Material—There are several leaf impressions of different shape and size with fair preservation.

Description—Leaf symmetrical to asymmetrical, ovate to elliptic, preserved size 4.8 x 2.7 cm, 3.0 x 1.8 cm, 3.0 x 2.0 cm and 3.0 x 1.8 cm; apex acute to obtuse; base acute to obtuse, sometimes inequilateral; texture coriaceous; venation eucamptodromous; primary vein (1º) single, prominent, stout, almost straight; secondary veins (2º) about 9 pairs visible, 0.3 to 0.6 cm apart, alternate to opposite, angle of divergence 55º–65º, acute, moderate, uniformly curved; intersecondary veins present, rare; tertiary veins (3º) fine, angle of origin usually AO, percurrent, almost straight, branched, oblique in relation to midvein, predominantly alternate and close.

Specimen—BSIP Museum Specimen Nos. 41338–41348.

Locality—Spot No.5 (29º8'49.1": 80º11'16"), Purniyagiri Road section, Champawat District, Uttarakhand.

Horizon and Age—Lower Siwalik, Middle Miocene.

Affinity—The most important features of the present fossil leaves such as symmetrical to asymmetrical, elliptic to ovate shape, acute to obtuse apex and base, entire margin, eucamptodromous venation, presence of intersecondary veins, AO, percurrent tertiary veins collectively suggest that the present fossil leaves show closest affinity with the extant leaves of *Millettia ovalifolia* Kurz. of the family Fabaceae (C.N.H. Herbarium Sheet Nos. 112378, 112379, Pl. 13.8, 12).

So far, about 37 fossil leaves resembling the genus *Millettia* W. & A. have been recorded from the Tertiary sediments of India and abroad (listed earlier in this text). After a detailed comparative study of all the known fossil leaves of *Millettia* W. & A., it has been concluded that *M. siwalica* Prasad, 1990a shows closest similarity with the present fossil leaves in almost all the morphological features and hence they have been described under the same species, *M. siwalica* Prasad.

The modern comparable species, *M. ovalifolia* Kurz. is an evergreen tree distributed in the lower and upper Myanmar (Gamble, 1972).

Genus—HUMBOLDTIA Vahl.

Humboldtia miocenica sp. nov.

(Pl. 14.1)

Material—This species is based on a single, well preserved and complete fruit impression.

Description—Pod flat, thin; 10 cm long, 3.2 cm wide; oblong; apex rounded; base rounded; one side margin curved in middle portion, distinct venation on surface. Vein arises from one margin side and run up to the other side, distance between two veins vary from 0.4–1.2 cm, veins branched, branching irregular.

Holotype—BSIP Museum Specimen No. 41342.

Locality—Sukhidang (29º9'48.8": 80º5'39.3"), near Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—After Miocene epoch.

Affinity—Narrow oblong shape, obtuse apex and base, nature of margin and venation pattern on the surface collectively indicate its resemblance with the genus *Humboldtia* Vahl. of the family Fabaceae. In order to find out specific affinity the herbarium sheets containing fruits of all the available species of this genus have been critically examined and found that the fruits of *Humboldtia vahliana* Wight (C.N.H. Herbarium Sheet No. 76598; Pl. 14.2) show close affinity with the present fossil fruit in shape, size and venation pattern.

There is no fossil record of the fruit of the genus *Humboldtia* Vahl. from Tertiary sediments of India and Nepal. The present fossil fruit shows the first occurrence in the Siwalik sediments of Uttarakhand and therefore, has been described as *Humboldtia miocenica* sp. nov.

Table 2—Fossil leaves resembling the genus *Millettia* W. & A. reported from the Tertiary sediments of India and abroad.

Species	Fossil Locality/ Period	Reference
Millettia impressa	Tertiary of the West Africa	Menzel, 1920
M. notoensis	Middle Miocene of Central Japan	Ishida, 1970
Millettia sp.	Eocene of SW Honshu, Japan	Huzioka & Takahasi, 1970
M. asymmetrica	Miocene of Kachchh	Lakhanpal & Guleria,1982
M. miocenica	Miocene of Kachchh	Lakhanpal & Guleria,1982
M. koilabasensis	Siwalik of Bhutan	Prasad & Tripathi, 2000
M. koilabasensis	Siwalik of Koilabas, Nepal	Prasad, 1990b
M. koilabasensis	Siwalik of Suraikhola, Nepal	Prasad & Pandey, 2008
M. palaeoracemosa	Siwalik of Suraikhola, Nepal	Awasthi & Prasad,1990
M. palaeoracemosa	Siwalik of Kathgodam, Uttarakhand	Prasad, 1994c
Millettia cf. *extensa*	Kimin Formation, Arunachal Pradesh	Khan *et al*., 2011
M. siwalica	Siwalik of Kathgodam, Uttarakhand	Prasad, 1994d
M. siwalica	Kimin Formation, Arunachal Pradesh	Khan *et al*., 2011
M. siwalica	Siwalik of Koilabas, Nepal	Prasad, 1990a
M. miobrandisiana	Siwalik of Koilabas, Nepal	Prasad, 1994e
M. imlibasensis	Siwalik of Koilabas, Nepal	Prasad *et al*., 1999
M. churiensis	Siwalik of Suraikhola, Nepal	Prasad & Awasthi, 1996
M. churiensis	Miocene of Neyveli lignite	Agarwal, 2002
M. oodlabariensis	Siwalik of Darjeeling, West Bengal	Antal & Prasad, 1996a
M. kathgodamensis	Siwalik of Kathgodam, Uttarakhand	Prasad *et al.*, 2004
M. palaeopachycarpa	Miocene of Neyveli lignite	Agarwal, 2002
M. palaeocubithi	Siwalik of Suraikhola, Nepal	Awasthi & Prasad, 1990
M. ovatus	Siwalik of Koilabas, Nepal	Tripathi *et al*., 2002
M. purniyagiriensis	Siwalik of Tanakpur, Uttaranchal	Shashi *et al*., 2006
M. prakashii	Siwalik of Tanakpur, Uttaranchal Siwalik of Darjeeling, West Bengal	Shashi *et al.*, 2008 Prasad *et al*., 2015
M. palaeomanii	Siwalik of Koilabas, Nepal	Dwivedi *et al.*, 2006a
M. bilaspurensis	Siwalik of Bilaspur, Himachal Pradesh Siwalik of Nahan, Himachal Pradesh	Prasad, 2006 Prasad, 2012
M. auriculata	Late Cenozoic of Mahuadanr, Jharkhand	Bande & Srivastava,1990
M. indakabalensis	Neogene of Rajasthan	Mathur & Mathur, 1998
M. singhii	Kasauli Formation, Himachal Pradesh	Mathur *et al*., 1996
Millettia sp.	Dagshai Formation, Himachal Pradesh	Mishra & Mathur, 1992
Millettia sp.	Kasauli Formation, Himachal Pradesh	Mathur *et al.*, 1996
M. miosericea	Siwalik of Darjeeling, West Bengal	Prasad *et al*., 2015
M. Purniyagiriensis	Siwalik of Darjeeling, West Bengal	Prasad *et al*., 2015
M. sevokensis	Siwalik of Darjeeling, West Bengal	Prasad *et al*., 2015
M. miocinerea	Siwalik of Arjun Khola, Nepal	Prasad *et al*., 2016

The genus *Humboldtia* Vahl. comprises 352 species of trees and shrubs. Out of which 14 species are found in India and Sri Lanka. *H. vahliana* Wight with which fruit resembles is a small, evergreen tree found to grow along the stream, in swamp around low elevation in the evergreen forests of Western Ghats, Nilgiris to Travancore up to 2000 ft.

Genus—WAGATEA Delz.

Wagatea miospicata sp. nov.

(Pl. 14.3)

Material—Single, well preserved almost complete fruit impression.

Description—Pod flat, thin, elliptical to obliquely oblong; size 6.4 x 2.0 cm. apex acute, pointed, base acute, seed chamber slightly distinct, margin entire, slightly broken; venation distinct on surface. Thick veins arise from one side margin and run up to other margin side, in between two thick veins there are 3–5 comparatively thin veins running almost parallel to thick veins.

Holotype—BSIP Museum Specimen No. 41343.

Locality—Spot No. 4 (29º9'8": 80º11'19.7"), Purniyagiri Road section, Champawat District, Uttarakhand.

Horizon and Age—Lower Siwalik; Middle Miocene.

Etymology—By adding a prefix 'mio' in the modern comparable species, *W. spicata.*

Affinity—The shape, size and the nature of apex, base and venation pattern of the surface suggest its affinity with the fruit of the genus *Wagatea* Dalz. of the family Fabaceae. The herbarium sheets containing fruits of all the available species of *Wagatea* Dalz. were thoroughly examined and it was found that the fruits of *Wagatea spicata* Dalz. show closest affinity with the present fossil fruit (C.N.H. Herbarium Sheet No. 134789; Pl. 14.4).

As there is no record of fossil fruit of the genus *Wagatea* Dalz. from Tertiary sediments of India and abroad. The present fossil fruit forms the first record from the Siwalik sediments of Uttarakhand, India and has been described here as *Wagatea miocenica* sp. nov.

The genus *Wagatea* Dalz. consists of 11 species, one of them is found in south India. The modern comparable species, *W. spicata* Dalz. is a woody climber presently distributed in dry and moist forests of west side of peninsula (Brandis, 1971).

Genus—DALBERGIA Linn. f.

Dalbergia tanakpurensis sp. nov.

(Pl. 14.5)

Material—This species is consisting of a single, well preserved and complete fruit impression.

Description—Pod flat, thin, narrow oblong; size 5.7 x 1.8 cm; apex rounded; base obtuse, venation faint; margin entire, slightly thick; variation in width at some places; 3–4 seed chambers distinct, rounded.

Holotype—BSIP Museum Specimen No. 41344.

Locality—Spot No. 4 (29º9'8": 80º11'19.7"), Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—After fossils locality, Tanakpur.

Affinity—The characteristic features of the present fossil fruit such as narrow oblong shape, rounded apex, obtuse base, nature of venation and distinct seed chambers strongly suggest that the present fossil fruit shows resemblance with the extant fruit of *Dalbergia* Linn. of the family Fabaceae. In orders to find out the specific affinity, the herbarium sheets containing fruits of all the available species of *Dalbergia* Linn. f. have been critically examined and found that the fruits of *Dalbergia indana* show closest affinity with the present fossil fruit in shape, size and other morphological feature.

As far as authors aware, there are five records of fossil fruits resembling the genus *Dalbergia* Linn. f. from Tertiary sediments of India and abroad. Two fossil fruits, *D. derrisocarpoides* Kolakovsky and *D. primaeva* known from outside of Indian subcontinents (Shakryl, 1992). The other fossil fruits resembling *Dalbergia sissoo* have been reported from Siwalik sediments of Balugoloa, Himachal Pradesh (Lakhanpal & Dayal, 1966) and from Late Tertiary sediments of Mahuadanr Valley, Jharkhand, India and *D. prelatifolia* from Siwalik sediments of Arunachal Pradesh (Khan & Bera, 2014). These above known fossil fruits have been compared with the present fruit and found that they differ mainly from present fossil in being wider and having different nature of

PLATE 19

(All figures are of natural size unless otherwise mentioned)

1,3,4,5. *Ixora purniyagiriensis* sp. nov.–Fossil leaves showing shape, size, nature of base, apex and venation pattern. BSIP Museum Specimen No. 41360. (Holotype) , BSIP Museum Specimen Nos 41361, 41362, 41363. (Paratypes).

2. *Ixora lobbii* Loudon–Modern leaf showing similar shape, size and venation pattern.

6. *Ixora purniyagiriensis* sp. nov.–Part of fossil leaf magnified to show details of venation. X 2.5. BSIP Museum Specimen No. 41360. (Paratype).

7. *Ixora lobbii* Loudon–Part of modern leaf magnified to show similar details of venation. X 2.

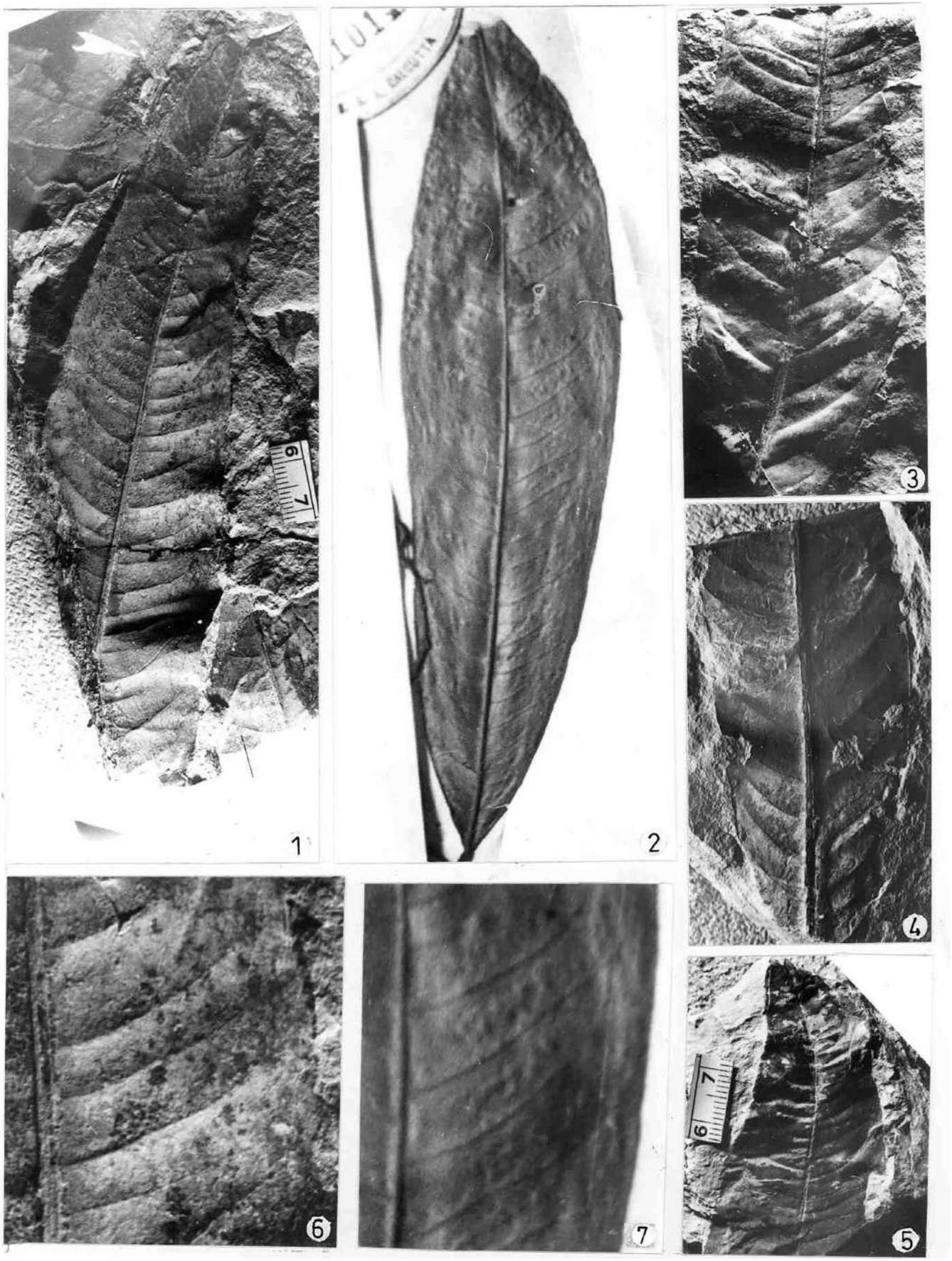

PLATE 19

apex and base. In view of this, the present fossil fruit has been designated as *Dalbergia tanakpurensis* sp. nov.

The genus *Dalbergia* Linn. f. consists of 100 species of trees, shrubs and lianas distributed in tropical to subtropical regions of World (Willis, 1973). The modern comparable taxon, *D. indana* presently distributed in South–east Asian region.

Genus—DERRIS Lour.

Derris prakashii Prasad *et al*., 2004

(Pl. 14.7, 11)

Material—There is a single, well preserved and complete fruit impression.

Description—Fruit flattened, wide elliptic to oval, ends decurved, margin thick, distinctly veined; size 2.5 x1.5 cm, wings absent.

Specimen—BSIP Museum Specimen No. 41345.

Locality—Spot No. 4 (29º9'8": 80º11'19.7"), Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinity—The morphological features such as wide elliptic to oval shape, thick margin and nature of striation on surface of the fruit suggest its affinity with the extant fruits of *Derris trifoliatus* Lour (C.N.H. Herbarium Sheet Nos 210140, 210141; Pl. 14.8) of the family Fabaceae.

Prasad *et al.,* 2004 reported a fossil fruits, *Derris prakashii* resembling the same extant species *Derris trifoliatus* Lour from the Siwalik sediments of Kathgodam, Uttarakhand. Later on, Mitra & Bannerjee (2004) described another fossil fruit, *Derrisocarpon miocenicum* from Siwalik of West Bengal. Both the above fossil fruits possess similar morphological features as the present fossil fruit hence, it has been described under the same species, *Derris prakashii* Prasad *et al.,* 2004.

The genus, *Derris* Lour comprises about 40 species of mostly climbers distributed in South–east Asia, North Australia, and East Africa. *Derris trifoliatus* Lour (*D. uliginosa* Benth.) with which fossil fruit shows closest affinity is a glabrous evergreen climbers, presently distributed in the tidal forest of both Peninsula and Andamans. It is also found in the Coast of Sri Lanka, eastern Africa and in Western Polynesia (Brandis, 1971).

Genus—DERRIS Lour.

Derris mioscandens sp. nov.

(Pl. 15.7, 9)

Material—This consists of single, fairly preserved and complete leaf impression.

Description—Leaf symmetrical, narrow elliptic; preserved size 4.4 x1.2 cm; apex acute, base mainly obtuse; margin entire; texture thick chartaceous; venation pinnate, eucamptodromous; primary vein (1º) single, prominent, stout, almost straight; secondary veins (2º) about 12 pairs visible, 0.3 to 0.6 cm apart, closely placed, angle of divergence about 60º, acute moderate, uniformly curved up, seemingly unbranched; intersecondary veins present, simple, frequent; tertiary veins (3º) fine, poorly preserved, angle of origin usually AO, percurrent, straight to sinuous, branched, oblique is relation to midvein, alternate to opposite and close.

Specimen—BSIP Museum Specimen No. 41346.

Locality—Spot No. 10 (29º9'12.1": 80º11'38.5"), Bhairauv Mandir, Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinity—The diagnostic features of the present fossil leaf such as almost symmetrical, narrow elliptic shape, nearly obtuse base, eucamptodromous venation, closely placed secondary veins with moderate angle of divergence, presence of intersecondary veins and AO, percurrent tertiaries collectively indicate that the present fossil leaf resembles closely with the extant leaves of *Derris scandens* Benth. (C.N.H. Herbarium Sheet No. 10016; Pl. 15.8) of the family Fabaceae.

So far, two fossil leaves resembling the genus *Derris* Lour, have been known from the Siwalik sediments of India. These are *Derris champarensis* from Upper Siwalik sediments of Bhikhnathoree, Bihar (Awasthi & Lakhanpal, 1990) and *Derrisophyllum siwalicum* from Lower Siwalik sediments of West Bengal (Mitra & Banerjee, 2004). Both the above known fossil leaves differ from present fossil leaf mainly in the nature and arrangement of secondary veins. Moreover, the intersecondary vein is not seen in the above fossil leaves however, it is frequently seen in the present fossil leaf. Thus, the present Siwalik fossil leaf has been assigned as *Derris mioscandens* sp. nov.

PLATE 20

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

1. *Ixora purniyagiriensis* sp. nov.–Another fossil leaf showing variation in shape. BSIP Museum Specimen No. 41364 (Paratype).
2. *Ixora lobbii* Loudon–Modern leaf showing similar variation in shape.
3. *Randia tanakpurensis* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41365. (Holotype).
4. *Randia dumentorum* Lam.–Modern leaf showing similar shape, size and venation pattern.
5. *Randia tanakpurensis* sp. nov.–Part of fossil leaf magnified to show details of venation. X 2.5. BSIP Museum Specimen No. 41365.
6. *Palaquium palaeograndis* sp. nov.–Fossil leaf showing shape, size and nature of base. BSIP Museum Specimen No. 41367 (Paratype).

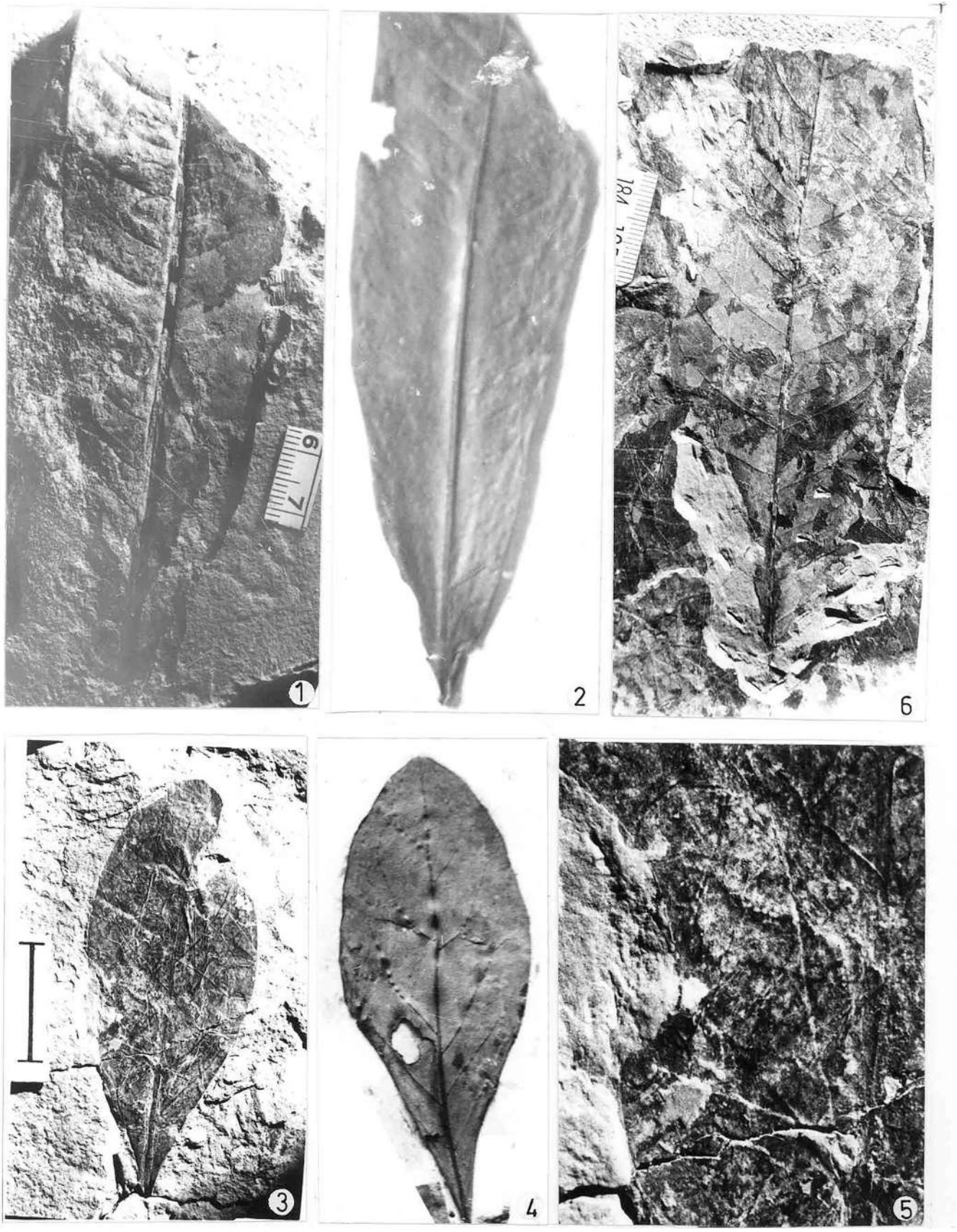

PLATE 20

The modern comparable taxon, *Derris scandens* Benth. is a large climber presently distributed in central, western and southern India extending north to the forest of Oudh and north–east to eastern Bengal, Chittagong, throughout Myanmar and Andaman Islands (Brandis, 1971).

Genus—PONGAMIA Vent.

Pongamia siwalika Awasthi & Lakhanpal, 1990

(Pl. 15.1, 3)

Material—There is a single, well preserved and almost complete leaf impression.

Description—Leaf symmetrical, obovate to elliptic; preserved size 4.5 x 2.8 cm; apex slightly broken; base nearly attenuate; margin entire; texture coriaceous; venation pinnate, eucamptodromous; primary vein (1º) single, prominent, stout, straight; secondary veins (2º) 6 pairs visible, 0.4 to 1.0 cm apart, lowest secondary closely placed; alternate to subopposite, unbranched, angle of divergence about 55º, acute, uniformly curved up; intersecondary veins present, simple; tertiary veins (3º) fine, angle of origin AO, percurrent, straight to sinuous, branched, oblique in relation to midvein, predominantly alternate, and close.

Specimen—BSIP Museum Specimen No. 41347.

Locality—Spot No. 1 (29º8'27.4": 80º11'6.9"), near Hanuman Chatti, Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinity—The distinguishing characters of the present fossil leaf are symmetrical obovate to elliptic shape, nearly attenuate base, entire margin, eucamptodromous venation, presence of intersecondary veins, AO, percurrent, straight to sinuous tertiary veins. An extensive survey of herbarium sheets of different genera and species of dicotyledonous families suggests that the extant leaves of *Pongamia pinnata* (L.) Pierre (Syn. *Derris indica* Bennet.) of the family Fabaceae (C.N.H. Herbarium Sheet No. 50061; Pl. 15.2, 4) show closest affinity with the present fossil leaf.

Three fossil leaves resembling the extant species *Pongamia pinnata* (L.) Pierre (= *P. glabra* Vent.) have been known from Siwalik sediments of India. Awasthi and Lakhanpal (1990) described a fossil leaf, *Pongamia siwalika* from the Upper Siwalik sediments of Bhikhnathoree, Bihar. Antal and Awasthi (1993) and Khan *et al*., 2011 reported the same species from Siwalik sediments of West Bengal and Arunachal Pradesh respectively. Later on, Prasad (1994d) described another fossil leaf, *Pongamia* cf. *P. glabra* Vent. from the Middle Siwalik of Haridwar, India. All the above known fossil leaves are almost identical. They differ slightly in shape and size. The present fossil leaf has been compared with those of known fossil leaves and found that the fossil leaf *P. siwalika* described from West Bengal exhibits similar morphological features as the present fossil leaf and therefore, described under the same species, *P. siwalika* Antal & Awasthi.

The genus *Pongamia* Vent. comprises single species *P. pinnata* (L.) Pierre with which fossil resembles closely is a moderate sized evergreen tree distributed in the tidal and beach forests and along river banks and water course throughout the country. It is also found in Sri Lanka and Myanmar (Gamble, 1972).

Genus—CYNOMETRA Linn.

Cynometra palaeoiripa Prasad *et al.*, 1999

(Pl. 15.5)

Material—There are two, fairly preserved and complete leaf impressions.

Description—Leaf asymmetrical, elliptic; preserved size 4.7 x 2.0 cm; apex, bluntly acute; base acute; inequilateral; margin entire; texture chartaceous; petiole less than 0.2 cm visible, normal; venation pinnate, eucamptodromous to brochidodromous; primary vein (1º) single, prominent, straight, stout; secondary veins (2º) poorly preserved, about 12 pairs visible, less than 0.6 cm apart, alternate to opposite, angle of divergence about 50º, acute, moderate, uniformly curved up and joined to their superadjacent secondaries, sometimes forming loop; tertiary veins (3º) fine, angle of origin RR–AO, percurrent, straight to sinuous, oblique in relation to midvein, predominantly alternate and close.

Specimen—BSIP Museum Specimen No. 41348.

PLATE 21

(All figures are of natural size unless otherwise mentioned)

1. *Myristica siwalica* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 413371. (Holotype).
2. *Myristica crassa* King–Modern leaf showing similar shape, size and venation pattern.
3. *Chrysophyllum bhairauvensis* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41368.
4. *Chrysophyllum viridifolium* Wood & Franks–Modern leaf showing similar shape, size and venation pattern.
5. *Chrysophyllum bhairauvensis* sp. nov.–Part of fossil leaf magnified to show details of venation. X 2. BSIP Museum Specimen No. 41368.
6. *Chrysophyllum viridifolium* (Wood & Franks)–Part of modern leaf magnified to show details of venation. X 2.
7. *Myristica siwalica* sp. nov–Other fossil leaf showing nature of base. BSIP Museum Specimen No. 41371A. (Paratype).
8. *Palaquium palaeograndis* sp. nov.–Part of fossil leaf magnified to show details of venation. X 2.5. BSIP Museum Specimen No. 41366. (Holotype).

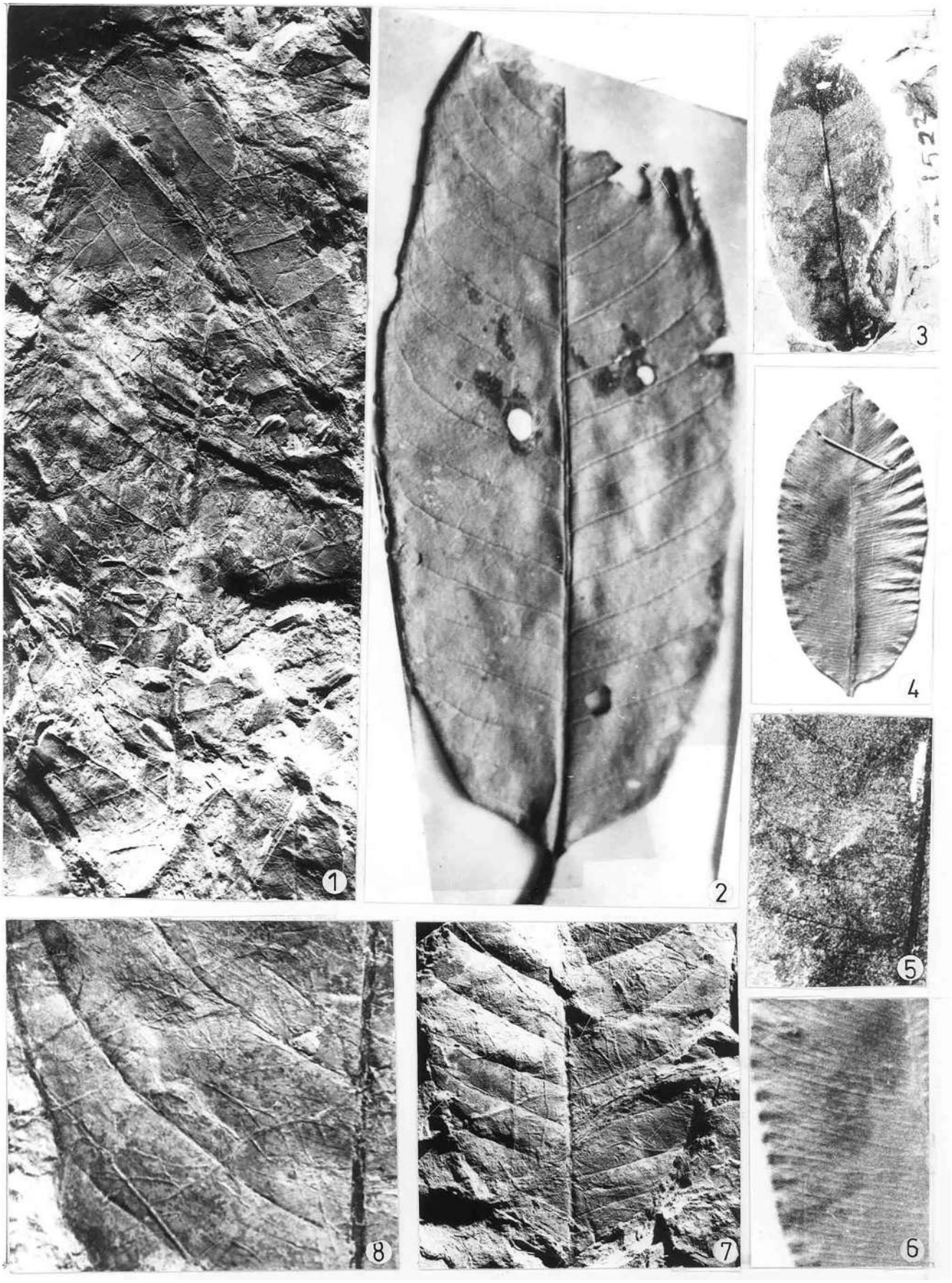

PLATE 21

Locality—Spot No. 10 (29º9'12.1": 80º11'38.5"), Bhairauv Mandir, Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinity—The diagnostic features of the present fossil leaf are asymmetrical, elliptic shape, bluntly acute apex, acute base, entire margin, eucamptodromous to brochidodromous venation, acute angle of divergence of secondary veins which joining the superadjacent secondary and making a loop and AO–RR, percurrent tertiary veins. Such features are found common in the modern leaves of *Cynometra* Linn. of the family Fabaceae. A critical examination of the herbarium sheets of all the available species of this genus suggests that the extant leaves of *Cynometra iripa* Kotel show closest affinity with the present fossil leaf in all the morphological features (C.N.H. Herbarium Sheet No. 1387 45; Pl. 15.6).

The fossil leaves resembling the genus *Cynometra* Linn. have been described under three specific names from Siwalik sediments of India and Nepal. These are *Cynometra siwalika* from Middle Siwalik sediments of Suraikhola, Nepal (Awasthi & Prasad, 1990) and Middle Siwalik of Nahan, H. P. (Prasad, 2012). *Cynometra tertiara* from Lower–Middle Siwalik of Oodlabari, Darjeeling District, West Bengal and *C. palaeoiripa* from Middle Siwalik sediments of Koilabas area, western Nepal (Prasad *et al.,* 1999), Lower Siwalik sediments of Kathgodam, Uttarakhand (Prasad *et al.,* 2004) and Middle Siwalik of Ghish River section, West Bengal (Prasad *et al*., 2015). A comparative study shows that *C. palaeoiripa*. Prasad *et al.* has the nearest affinity with the present fossil in possessing asymmetrical, elliptic shape with similar course of secondary and tertiary veins. In view of this, the present fossil has been assigned to the same species, *C. palaeoiripa* Prasad *et al.*

The genus *Cynometra* Linn. comprises about 70 tropical species, of which five are found in India. The modern comparable species C. *iripa* Kotel is presently distributed in Indo–Malayan region.

Family—COMBRETACEAE

Genus—TERMINALIA Linn.

Terminalia bhairauvensis sp. nov.

(Pl. 15.10, 11; Pl. 16.5)

Material—This species is represented by three, well preserved leaf impressions.

Description—Leaf simple, symmetrical, narrow elliptic; preserved size 8.0 x 3.0 cm; apex wide acute; base wide acute to nearly obtuse; slightly asymmetrical; margin entire; texture chartaceous; venation pinnate, eucamptodromous; primary vein (1º) single, prominent, stout, almost straight; secondary veins (2º) 8–9 pairs, 0.4–1.4 cm apart, usually alternate, angle of divergence, 60º–65º, acute, moderate, uniformly curved up, unbranched; tertiary veins (3º) fine, angle of origin usually RR, percurrent, almost straight, alternate and close; quaternary veins (4º) very fine, arising at nearly right angle, branched to form polygonal meshes.

Holotype—BSIP Museum Specimen No. 41349.

Paratype—BSIP Museum Specimen No. 41350.

Locality—Spot No. 10 (29º9'12.1": 80º11'38.5"), Bhairauv Mandir, Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—After the name of Bhairauv Mandir situated just near the fossil spot.

Affinity—The present fossil leaves are characterized by narrow elliptic shape, wide acute apex, slightly asymmetrical, nearly obtuse base, entire margin, eucamptodromous venation, moderately acute angle of divergence of secondary veins, and RR, percurrent, straight to sinuous tertiaries. The closely placed basal secondary vein is also an important character of the fossil leaf. A comparative study of the herbarium sheets of different families shows that the above features are found common in the modern leaves of the genus *Terminalia* Linn. of the family Combretaceae. A critical examination of the modern leaves of all the available species of this genus revealed that these fossil leaves show their closest affinity with the leaves of *Terminalia argyrophylla* King & Prain (C.N.H. Herbarium Sheet No. 63675; Pl. 16.6) in shape, size and venation pattern.

Fossil leaves resembling the genus *Terminalia* Linn. have been reported under three generic names, viz. *Terminalia* Linn.

PLATE 22

(All figures are of natural size unless otherwise mentioned)

1. *Palaquium palaeograndis* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41366. (Holotype).
2. *Palaquium grandis* (Thwaites) Engl.–Modern leaf showing similar shape, size and venation pattern.
3. *Palaquium grandis* (Thwaites) Engl.–Part of modern leaf magnified to show similar venation pattern as fossil (Pl. 21 fig. 8).

4, 5. *Mallotus kalimpongensis* Antal & Awasthi–Fossil leaves showing shape, size and venation pattern. BSIP Museum Specimen Nos 41375, 41376.

6. *Mallotus philippinensis* Muell. Arg.–Modern leaf showing similar shape, size and venation pattern.
7. *Mallotus prejaponicus* sp. nov.–Part of fossil leaf magnified to show details of venation. X 2. BSIP Museum Specimen No. 41373.
8. *Mallotus japonicus* Spreng–Part of modern leaf magnified to show similar details of venation. X 2.
9. *Myristica siwalica* sp. nov.–Fossil leaf showing nature of apex. BSIP Museum Specimen No. 41372. (Paratype).

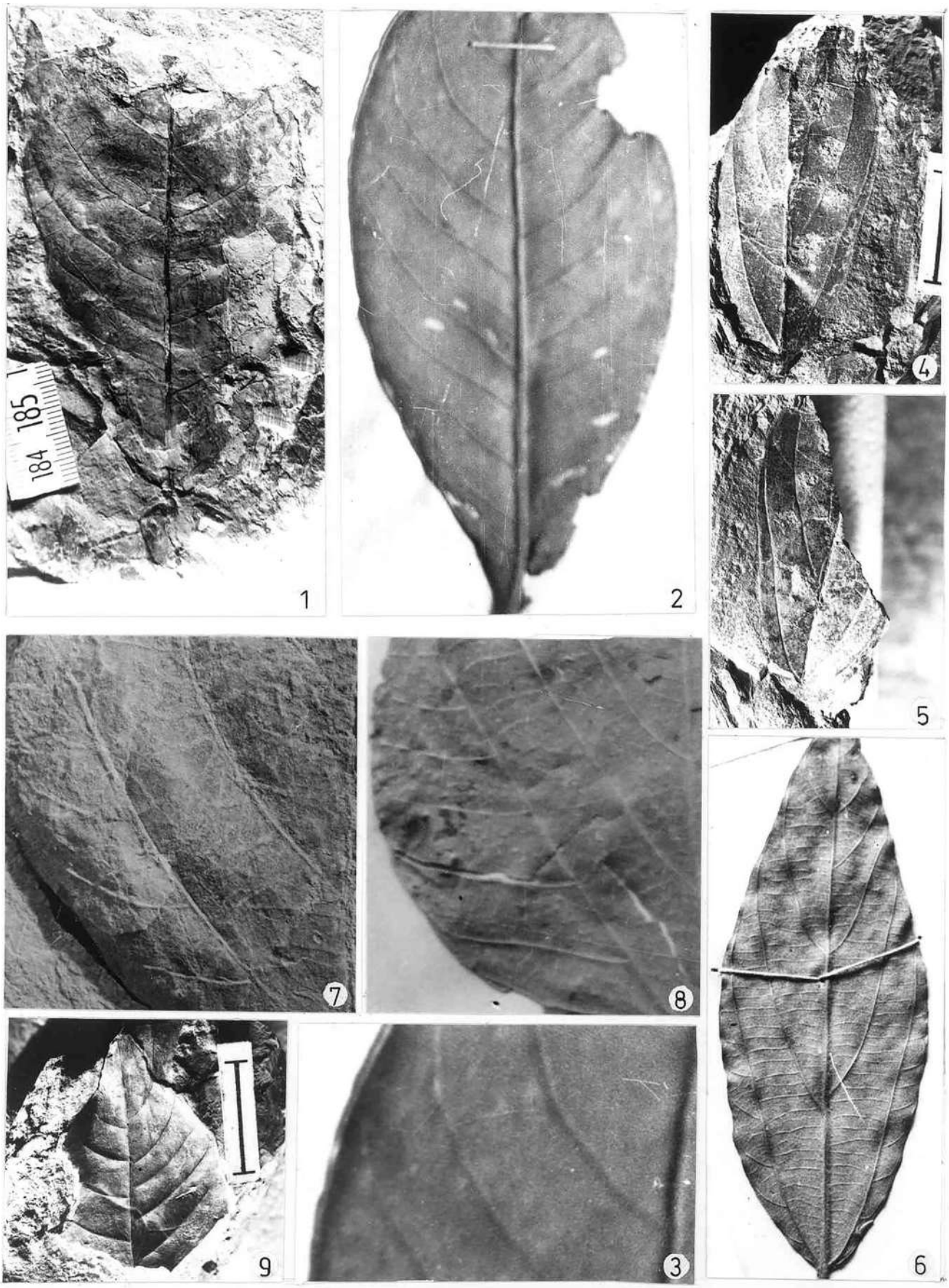

PLATE 22

Terminaliphyllum Velenovsky and *Terminaliophyllum* Geyler from Tertiary–Cretaceous sediments of India and abroad. These are listed in Table 3.

Thus, the genus *Terminalia* was cosmopolitan in distribution during geological past. The fossil leaves and woods of this genus have been reported from all over the world. The earliest record of *Terminalia* leaf, i.e. *Terminaliphyllum* goes back to the Upper Cretaceous of Bohemia. Thus, it is obvious that the genus *Terminalia* has continued from the Upper Cretaceous to the present day and was more widely spread during the Tertiary Period.

The present fossil leaves have been compared with all the known species of *Terminalia* Linn. and found that these leaves do not match any of them. These differ either in the nature of apex and base or in the course and arrangement of secondary and tertiary veins. In view of this the present fossil leaves have been assigned to new species, *Terminalia bhairauvensis.*

The genus *Terminalia* Linn. now consists of 150 species of large tree and widely distributed in the tropics of the world (Mabberely, 1997) *Terminalia argyrophylla* King & Prain with which fossil leaves closely resemble is a large tree presently found to grow in the forests of Upper Myanmar (Brandis, 1971).

Genus—COMBRETUM Loefl.

Combretum purniyagiriense sp. nov.

(Pl. 16.1, 3)

Material—This species is based on a single, fairly preserved and almost complete leaf impression.

Description—Leaf simple, symmetrical, wide elliptic; preserved size 8.5 x 6.0 cm; apex seemingly acute; base broken; margin entire; texture chartaceous; venation pinnate, eucamptodromous to brochidodromous; primary vein (1º) single, prominent, stout, almost straight; secondary veins (2º) 7 pairs, 0.8–2.0 cm apart, unbranched, alternate, angle of divergence 65º, acute, moderate, uniformly curved up and joining superadjacent secondary veins near the margin by making a loop, unbranched; intersecondary veins present, simple; tertiary veins (3º) moderate, angle of origin usually RR, percurrent, straight to sinuous, sometimes branched, oblique in relation to midvein, predominantly alternate and distant to close.

Holotype—BSIP Museum Specimen No. 413451.

Locality—Spot No. 6, Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—After Purniyagiri Temple.

Affinity—The important morphological characters of the fossil leaf like its wide elliptic shape, acute apex, entire margin, eucamptodromous to brochidodromous venation, wide acute angle of divergence of secondary veins, formation of loop near the margin by joining the secondary veins, presence of intersecondary veins and RR, percurrent, distant to close tertiary veins show that the fossil leaf belongs to the genus *Combretum* Loefl. of the family Combretaceae. In order to find out the nearest affinity of the present fossil leaf, the herbarium sheets of all the available species of this genus have been examined and it was concluded that the extant leaves of *Combretum sundaicum* Miquel show closest similarity with the fossil leaf (C.N.H. Herbarium Sheet No. 65030; Pl. 16.2, 4).

So far, there are five fossil records of *Combretum* Loefl. leaves from the Tertiary of India and abroad. These are *C. europium* Web. from Oligocene of Chivon e Salcedo (Principi, 1926), *C. sarothrosatachyoides* Mass. from Pliocene of Saromaziana (Principi, 1926), *Combretum decandrum* Roxb. from Late Tertiary of Mahuadanr, Jharkhand, *C. sahnii* from Lower–Middle Siwalik of Darjeeling District, West Bengal (Antal & Awasthi, 1993) from Kasauli Formation, H.P., from Lower Siwalik of Koilabas area, Nepal (Prasad, 1994e) and *C. miocenicum* from Lower Siwalik of Bhutan (Prasad & Tripathi, 2000). On comparison of the present fossil leaf with all the above known fossils, it has been observed that only *C. miocenicum* Prasad & Tripathi shows near resemblance in the nature and arrangement of tertiary veins but differs

Table 3—Fossil leaves resembling the genus *Terminalia* Linn. reported from Tertiary–Cretaceous sediments of India and abroad.

Species	Locality/Period	Reference
Terminaliphyllum rectinervis	Upper Cretaceous of Bohemia	Velenovsky, 1884, 1889
Terminaliophyllum sp.	Eocene of Borneo	Geyler, 1887
T. keayi	Post Eocene of Nigeria	Puri, 1966
T. faggei	Post Eocene of Nigrria	Puri, 1966
Terminalia cf. *T. catapa*	Tertiary of Czeckoslovakia	Nemejc, 1975
Terminalia claibornensis Berry	Eocene of Texas	Ball, 1931
T. indicola Berry	Eocene of Texas	Ball, 1931
T. elegans Heer	–	Schimper, 1874

T. estimina	Middle Eocene of Central Sierra, Nevada, USA	MacGinitie, 1941
T. europea	Tertiary of Germany	Weyland, 1942
T. fenzliana Unger	Tertiary of Czeckoslovakia	Nemejc, 1975
T. gypsorum Saporta	–	Schimper, 1874
T. italica	–	Berry, 1919
T. maxima	Tertiary of Brazil	Principi, 1915
T. miocenica	Tertiary of Germany	Weyland, 1942
T. kachchhensis	Tertiary of Kachchh	Lakhanpal & Guleria, 1981
T. lauriana	Tertiary of Brazil	Krasser, 1903
T. lesleyana	Eocene of southeastern N. America	Berry, 1916
T. panandhroensis	Tertiary of Kachchh, India, Siwalik of Koilabas, Nepal	Lakhanpal & Guleria, 1981 Prasad, 1994e
T. panonica	Tertiary of South Guistine	Unger, 1867
T. phaeocarpoides	Eocene of South Carolina, USA	Berry, 1914
T. radobojana	Tertiary of Kumi, Euboea	Unger, 1867
T. rottensis	Tertiary of Germany	Weyland, 1942
T. tallyana Ett.	–	Schimper, 1874
T. trinitense Berry	Cenozoic of North America	LaMotte, 1952
T. ungeri Ett.	Tertiary of Czeckoslovakia	Nemejc, 1975
Terminalia sp.	Tertiary of Alaska	Hollick, 1936
Terminalia sp.	Palaeogene of Japan	Matsuo, 1970
Terminalia sp.	Siwalik of Koilasbas, Nepal	Tripathi & Tiwari, 1983
T. koilabasensis	Siwalik of Koilabas, Nepal	Prasad, 1990a
T. siwalica	Siwalik of Koilabas, Nepal	Prasad, 1990a
T. palaeochebula	Siwalik of Suraikhola, Nepal	Awasthi & Prasad, 1990
T. palaeochebula Awasthi & Prasad	Miocene of Neyveli Lignite, South India	Agarwal, 2002
T. chebula	Late Tertiary of Mahuadanr, Jharkhand	Singh & Prasad, 2007
T. tomentosa	Late Tertiary of Mahuadanr, Jharkhand	Bande & Srivastava, 1990
T. paniculata	Miocene of Neyveli Lignite, South India	Agarwal, 2002
T. miobelerica Prasad	Miocene of Neyveli Lignite, South India	Agarwal, 2002
T. neyvelensis	Miocene of Neyveli Lignite, South India	Agarwal, 2002
T. mulleri	Siwalik of Ranibagh, Uttarakhand	Trivedi & Srivastava, 1985
T. balugoloensis	Siwalik of Balugoloa, H.P.	Lakhanpal & Awasthi, 1992
T. miobelerica	Siwalik of Kathgodam, Uttarakhand Siwalik of West Bengal	Prasad, 1994c, Antal & Prasad, 1998
T. obovata	Oligocene of Makum Coalfield, Assam	Awasthi & Mehrotra, 1995
T. palaeocatapa	Oligocene of Makum Coalfield, Assam Tura Formation, Meghalaya Miocene of Neyveli Lignite, South India	Awasthi & Mehrotra, 1995 Mehrotra, 2000 Agarwal, 2002
T. precatappa	Oligocene of Mizoram	Tiwari & Mehrotra, 2002
T. himachalensis	Siwalik of Himachal Pradesh	Prasad *et al*., 2013

from present fossil leaf in being narrow elliptic shape having different course of secondary veins. The secondary veins arise at more acute angle and run upward for a long distance in comparison to the present fossil leaf. The present fossil is therefore, described as a new species, *Combretum purniyagiriense.*

The genus *Combretum* Loefl. comprises 370 species of trees and shrubs. Of them, 300 species are native of tropical Africa and Asia. *Combretum sundaicum* Miquel with which fossil shows affinity is a shrub growing presently in the Indo–Malayan region.

Family—MELASTOMATACEAE

Genus—MEDINILLA Gaudich.

Medinilla siwalica sp. nov.

(Pl. 16.7, 9)

Material—This species is represented by a single specimen of leaf impression which is complete and well preserved.

Description—Leaf simple, slightly asymmetrical; small; narrow elliptic; preserved size 3.2 x 0.7 cm; apex sharply attenuate; base slightly indistinct, seemingly acute; margin entire; texture chartaceous; venation pinnate, acrodromous, supra basal, perfect; primary vein (1º) three (one mid and two lateral), lateral primary veins arising from above the base, running upward toward the apex, mid primary almost straight and lateral primary veins curved toward mid primary; secondary veins (2º) several, arising at acute angle from lateral primary while it is nearly right angle when arising from mid primary, closely placed seemingly unbranched, the secondaries arising from mid vein joined to their lateral primary veins while the secondaries of lateral primaries joined to the margin; tertiary veins (3º) indistinct.

Holotype—BSIP Museum Specimen No. 41352.

Locality—Spot No. 8, Purniyagiri Road section; Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—After Siwalik Group.

Affinity—The diagnostic features of the present fossil leaf are: slightly asymmetrical, small, narrow elliptic shape, attenuate apex, acute base, entire margin, supra basal, perfect, acrodromous venation and peculiar nature and course of secondary veins. After a detail survey of the herbarium sheets of a large number of genera and species of dicotyledonus families, it has been observed that the above features are found common in the extant leaves of *Medinilla ramiflora* Merr. (C.N.H. Herbarium Sheet Nos 174010, 174035; Pl. 16.8, 10) of the family Melastomataceae.

As far as the authors aware, there is no record of fossil leaf resembling the genus *Medinilla* Gaudich. The occurrence of this characteristic fossil leaf in the Siwalik sediments of Tanakpur area, Uttarakhand represents its first record and is hence described as *Medinilla siwalica* sp. nov.

The genus *Medinilla* Gandich. consists of 400 species distributed mainly in South east Asia and Africa. The modern comparable taxon, *M. ramiflora* Merr. is presently distributed in the evergreen forests of Philippines, Madagascar and Malaya.

Family—LYTHRACEAE

Genus—LAGERSTROEMIA Linn.

Lagerstroemia prakashii sp. nov.

(Pl. 17.1; Pl. 18.1, 3)

Material—There are two, well preserved and complete leaf impressions.

Description—Leaf simple, symmetrical; very narrow elliptic to oblong; preserved size 18.2 x 5.8 cm and 12.4 x 4.7 cm; apex acute; base wide acute, asymmetrical; margin entire; texture coriaceous; venation pinnate, eucamptodromous; primary vein (1º) single, prominent, massive, almost straight; secondary veins (2º) about 14 pairs visible, 0.7 to 1.8 cm apart, alternate to subopposite, sometimes branched, angle of divergence 55º–70º, narrow to wide acute, few pairs of basal secondaries arise more acutely, uniformly curved up and joined to the superadjacent secondaries; intersecondary veins present, simple, frequent; tertiary veins (3º) fine, angle of origin AO–RR, percurrent, straight to sinuous, branched, oblique in relation to midvein, predominantly alternate and close to slightly distant.

Holotype—BSIP Museum Specimen No. 41353.

Paratype—BSIP Museum Specimen No. 41354.

PLATE 23

(All figures are of natural size unless otherwise mentioned)

1. *Mallotus prejaponicus* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41373 (Holotype).
2. *Mallotus japonicus* Spreng–Modern leaf showing similar shape, size and venation pattern.

3, 4. *Cinnamomum palaeotamala* Lakhanpal & Awasthi–Fossil leaves showing shape, size and venation pattern. BSIP Museum Specimen Nos 41369, 41370.

5. *Baccaurea miocenica* sp. nov.–Part of fossil leaf magnified to show details of venation. X 3. BSIP Museum Specimen No. 41377.
6. *Baccaurea tetrandra* Lour–Part of modern leaf magnified to show similar details of venation. X 3.

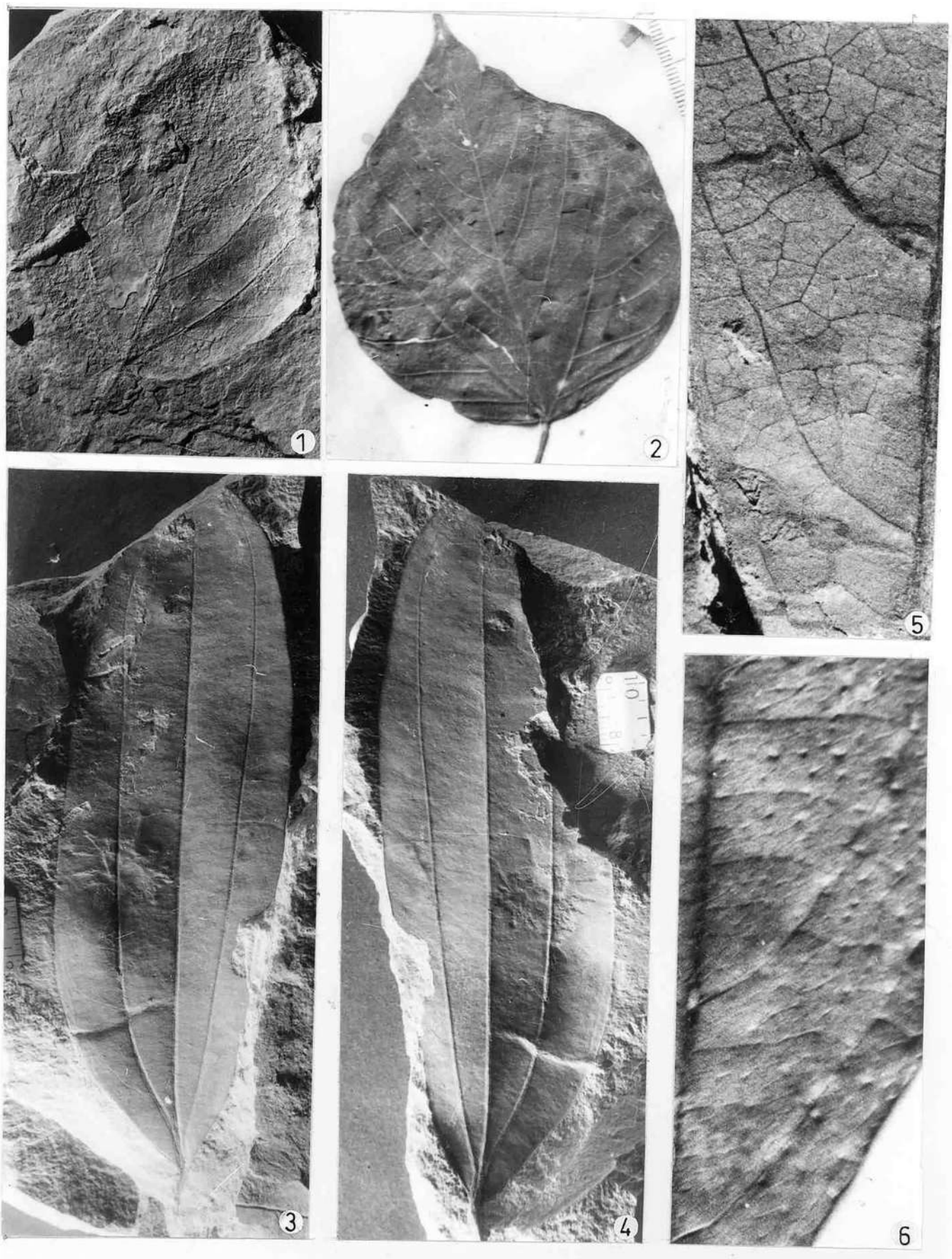

PLATE 23

Locality—Spot No. 1 (29º8'27.4": 80º11'6.9"), near Hanuman Chatti, Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—Named in the honour of Dr. Uttam Prakash, an eminent scientist of Birbal Sahni Institute of Palaeobotany, Lucknow who has done remarkable work on Tertiary plant megafossils.

Affinity—The most important features exhibited by the present fossil leaves are: very narrow elliptic to oblong shape, acute apex, asymmetrical, wide acute base, entire margin, eucamptodromous venation, narrow to wide acute angle of divergence of secondary veins which joined to their superadjacent secondary, presence of frequent inter secondary veins and AO–RR, percurrent tertiaries. These features are found common in the extant leaves of the genus *Lagerstroemia* Linn. of the family Lythraceae. A critical observation of a number of herbarium sheets of different species of this genus indicates that the present fossil leaves show closest affinity with the extant leaves of *Lagerstroemia flosreginae* Retz., (Syn. *L. speciosa*; C.N.H. Herbarium Sheet No. 590190; Pl. 17.2; Pl. 18.2).

So far, eight authentic fossil species under the genus *Lagerstroemia* Linn. have been described from the Tertiary sediments of India and abroad. They are *Lagerstroemia patelii* from the Eocene of Kachchh, Gujarat (Lakhanpal & Guleria, 1981), from Siwalik sediments of Darjeeling District, West Bengal (Antal & Awasthi, 1993), and from Kathgodam, Uttarakhand, India (Prasad, 1994c). *L. siwalica* from Siwalik sediments of Koilabas, Nepal (Prasad, 1994e) Miocene of Neyveli lignite deposits, Tamil Nadu (Agarwal, 2002) and Siwalik of Nahan, H.P. (Prasad, 2012), *L. neyveliensis* from Miocene of Neyveli Lignite deposits, Tamil Nadu (Agarwal, 2002), *L. himalayaensis* from Lower Siwalik sediments of Kathgodam, Uttarakhand (Srivastava *et al*., 2015), *L. jamraniensis* from Lower Siwalik sediments of Jamrani, Kathgodam, Uttarakhand (Prasad *et al.,* 2004), *L. mioparviflora* and *L. eomicrocarpa* from Siwalik sediments of Koilabas area, western Nepal (Dwivedi *et al.,* 2006b) and *L. imamurae* from Oligocene of Honshu, Japan (Tanai & Uemura, 1991). On comparison of the present fossil leaves with the above known species, it has been observed that the only fossil species, *L. jamraniensis* Prasad *et al.* shows some what similarity in shape and size but differs in nature of base and arrangement of tertiary veins. This species possesses symmetrical base and close tertiary veins as compared to asymmetrical base and distant tertiaries in the present fossil leaves. The rest fossil species can be easily differentiated in being smaller size with different course of secondary and tertiary veins. Thus, in being different from already known species of *Lagerstroemia* Linn., the present fossils have been assigned to a new species, *Lagerstroemia prakashii.*

The genus *Lagerstroemia* Linn. comprises about 53 species distributed in the tropical Africa, Asia, Polynesia and pacific region. *L. flosregiane* Retz. with which fossil leaves show resemblance is a large deciduous tree presently found in Assam Valley, Bangladesh, Chhotanagpur and the Circars. It is also found in the Western Coast from South Konkan, Myanmar and Srilanka (Gamble, 1972).

Genus—LAGERSTROEMIA Linn.

Lagerstroemia mioparviflora Dwivedi *et al.* 2006b

(Pl. 18.4, 5, 6, 8, 9, 11)

Material—There are four specimens of leaf impressions. Two are complete and well preserved.

Description—Leaf simple, symmetrical, ovate to narrow elliptic; preserved size 4.2 x 2.3 cm, 4.0 x 2.0 cm, 6.0 x 1.5 cm and 5.0 x 1.4 cm; apex acute; base nearly obtuse; margin entire; texture chartaceous; venation pinnate, eucamptodromous; primary vein (1º) single, prominent, stout, almost straight; secondary veins (2º) 6–9 pairs visible, 0.5 to 1.3 cm apart; alternate, seemingly unbranched, angle of divergence 50º–60º, acute, moderate uniformly curved up; intersecondary veins present, simple; tertiary veins (3º) fine, angle of origin usually RR, percurrent, straight to sinuous, branched, oblique to nearly right angle in relation to midvein, predominantly alternate, close to nearly distant.

Specimen—BSIP Museum Specimen Nos. 41355–41359.

Locality—Spot No. 10 (29º9'12.1": 80º11'38.5"), Bhairav Mandir, Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

PLATE 24

(All figures are of natural size unless otherwise mentioned)

1. *Baccaurea miocenica* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41377 (Holotype).
2. *Baccaurea tetrandra* Spreng–Modern leaf showing similar shape, size and venation pattern.
3. *Sarcochlamys miopulcherima* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41380 (Holotype).
4. *Sarcochlamys pulcherrima* Gaudich.–Modern leaf showing similar shape, size and venation pattern.
5. *Sarcochlamys miopulcherrima* sp. nov.–Part of fossil leaf magnified to show details of venation. X 3. BSIP Museum Specimen No. 41380.
6. *Sarcochlamys pulcherrima* Gaudich.–Part of modern leaf magnified to show similar details of venation. X 3.
7. *Mallotus prejaponicus* sp. nov.–Fossil leaf showing nature of apex and base. BSIP Museum Specimen No. 41374.

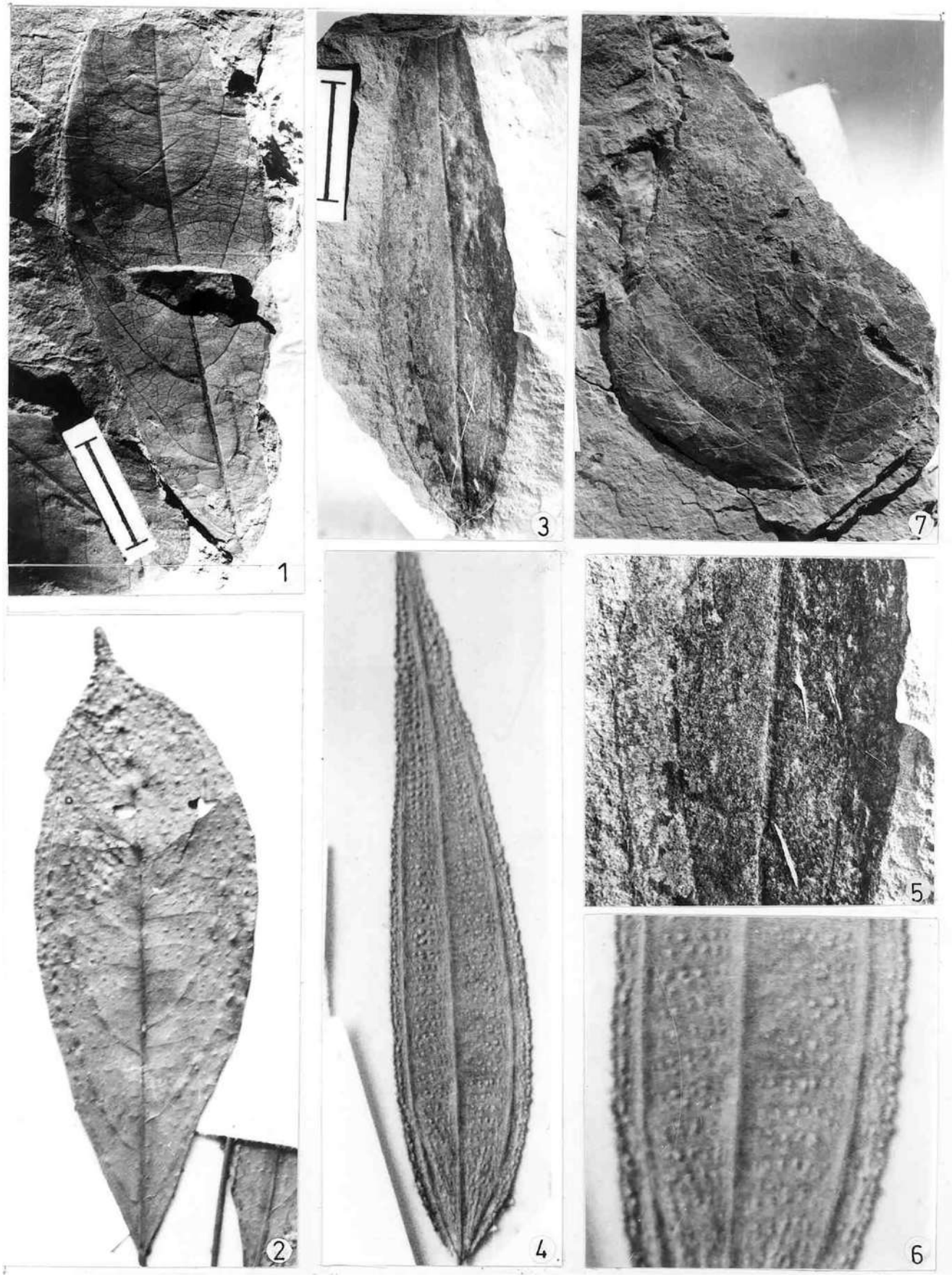

PLATE 24

Affinity—The most important characters exhibited by the present fossil leaves such as ovate to narrow elliptic shape, acute apex, nearly obtuse base, eucamptodromous venation, moderately acute angle of divergence of secondary veins, presence of intersecondary veins and RR, percurrent tertiary veins which are oblique to nearly right angle in relation to midvein collectively indicate their resemblance with the extant leaves of *Lagerstroemia parviflora* Roxb. (C.N.H. Herbarium Sheet Nos 74096, 9745; Pl. 18.7, 10) of the family Lythraceae. During identification, it has been observed that there is much variation in shape and size of the leaves of *Lagerstroemia parviflora* Roxb.

All the fossil leaves resembling the genus *Lagerstroemia* Linn. (mentioned earlier in this text) have been compared with the present fossil leaves and concluded that the fossil leaf, *Lagerstroemia mioparviflora* Dwivedi *et al.,* 2006b shows closest similarity with the fossil leaves and thus these have been described under the same species *L. mioparviflora* Dwivedi *et al.*

The genus *Lagerstroemia* Linn. comprises about 53 species and presently distributed in tropical region of the old world. The modern comparable species *L. parviflora* Roxb. is a large tree found to occur in the sub–Himalayan tract from Jammu eastward ascending to 3000 ft. It also occurs in Assam, West Bengal and Myanmar (Brandis, 1971).

Family—RUBIACEAE

Genus—IXORA Linn.

Ixora purniyagiriensis sp. nov.

(Pl. 19.1, 3, 4, 5, 6; Pl. 20.1)

Material—This species is represented by more than 10 specimens of well preserved leaf impressions.

Description—Leaf simple, symmetrical, lanceolate to very narrow elliptic; preserved size 14.0 x 3.5 cm, 8.5 x 4.0 cm and 7.5 x 3.5 cm; apex seems to be attenuate; base acute, cuneate; margin entire; texture chartaceous; venation pinnate, eucamptodromous, primary vein (1º) single, prominent, massive, straight to curved; secondary veins (2º) about 26 pairs visible, 0.3 to 0.8 cm apart, closely placed, alternate to opposite, seemingly unbranched, angle of divergence 60º–80º, upper secondary veins more acute, moderate to right angle, uniformly curved up and joined to superadjacent secondary veins; intersecondary veins present, simple, abundant; tertiary veins (3º) fine, angle of origin usually RR, percurrent, almost straight, oblique in relation to midvein, predominantly alternate and close.

Holotype—BSIP Museum Specimen No. 41360.

Paratype—BSIP Museum Specimen Nos. 41361–41364.

Locality—Spot No. 3 (29º8'51.3": 80º11'16.3"), Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—After Purniyagiri Temple.

Affinity—The most important features of the present fossil leaves are lanceolate to narrow elliptic shape, attenuate apex, cuneate base, entire margin, eucamptodromous venation, closely placed secondary, presence of intersecondary veins and RR, percurrent, almost straight tertiary veins. These features are found common in the modern leaves of *Terminalia myriocarpa* of the family Combretaceae, *Kayea floribunda* Wall. of the family Clusiaceae and *Ixora lobbii* Loudon of the family Rubiaceae. On critical examination of the herbarium sheets of above taxa, it has been observed that the leaves of *Terminalia myriocarpa* differ from fossils in being absence of intersecondary veins and the basal secondary veins are closely placed than the secondaries in apical and middle portion. The leaves of *Kayea floribunda* Wall. can be differentiated by its nature and arrangement of secondaries which are fine, more in number and very closely placed. Thus, the leaves of *Ixora lobbii* Loudon (C.N.H. Herbarium Sheet Nos 210140, 210141; Pl. 19.2, 7; Pl. 20.2) are only with which the present fossil leaves show closest affinity in shape, size and venation pattern.

So far, there is no record of any fossil leaf resembling the genus *Ixora* Linn. from the Tertiary sediments of Indian subcontinents. The present fossil leaves represent its first record from the Siwalik sediments of Tanakpur area, Uttarakhand and is being described herewith as *Ixora purniyagiriensis* sp. nov.

PLATE 25

(All figures are of natural size unless otherwise mentioned)

1. *Bridelia hanumanchattiensis* sp. nov.–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41378 (Holotype).
2. *Bridelia griffithii* Hook. f.–Modern leaf showing similar shape, size and venation pattern.
3. *Bridelia hanumanchattiensis* sp. nov.–Part of fossil leaf magnified to show details of venation. X 2.5. BSIP Museum Specimen No. 41378.
4. *Bridelia griffithii* Hook. f.–Part of modern leaf magnified to show similar details of venation. X 2.5.
5. *Ficus precunia* Lakhanpal–Fossil leaf showing shape, size and venation pattern. BSIP Museum Specimen No. 41379.
6. *Ficus cunea* Buch.–Ham.–Modern leaf showing similar shape, size and venation pattern.
7. *Ficus precunea* Lakhanpal–Part of fossil leaf magnified to show details of venation and nature of base. X 3. BSIP Museum Specimen No. 41379.
8. *Cinnamomum palaeotamala* Lakhanpal & Awasthi–Part of fossil leaf magnified to show details of venation. X 2.5. BSIP Museum Specimen No. 41370.

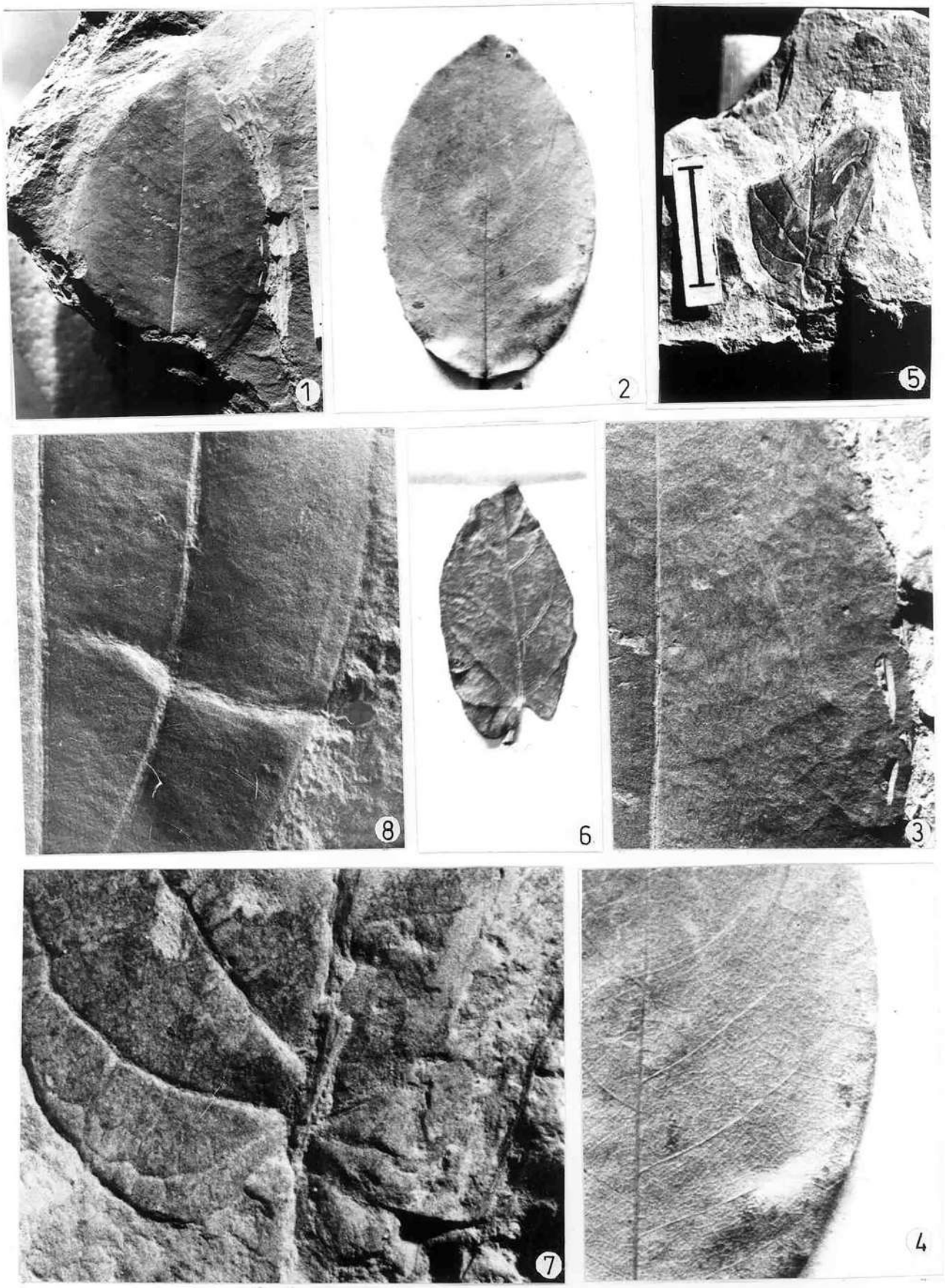

PLATE 25

The genus *Ixora* Linn. consists of 300 tropical species of shrubs or trees. About 30 species are found in tropical Africa. The modern comparable species *Ixora lobbii* Loudon is an evergreen tree presently distributed in Indo–China, Malaya Islands, Java and Borneo.

Genus—RANDIA Linn.

Randia tanakpurensis sp. nov.

(Pl. 20.3, 5)

Material—This species is based on three well preserved leaf impression.

Description—Leaf simple, symmetrical oblanceolate; preserved size 7.6 x 3.0 cm; apex obtuse base cuneate; margin entire; texture coriaceous; venation pinnate, eucamptodromous; primary vein (1º) single; prominent, stout, almost straight; secondary veins (2º) 7 pairs visible, 0.6 to 1.3 cm apart, alternate, seemingly unbranched, angle of divergence 45º–60º, acute, narrow to moderate, uniformly curved up, running upward for a short distance; intersecondary veins present, simple; tertiary veins (3º) fine, angle of origin AO–RR, percurrent, almost straight, branched, oblique in relation to midvein, predominantly alternate and close to distant.

Holotype—BSIP Museum Specimen No. 41365.

Locality—Spot No. 3 (29º8'51.38": 80º11'16.3"), Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—After the name of fossil locality, Tanakpur.

Affinity—The diagnostic features of the present fossil leaf such as symmetrical, oblanceolate shape, obtuse apex, cuneate base; entire margin, eucamptodromous venation nature and course of secondary veins, AO–RR, percurrent, close to distant tertiary veins collectively suggest its affinity with the modern leaves of *Catunaregam spinosa* (Thunb) Tirveng. (Syn. *Randia floribunda* = *R. dumentorum* Lam.) of the family Rubiaceae (C.N.H. Herbarium Sheet No. 205345; Pl. 20.4) in shape, size and venation pattern.

So far, seven fossil species resembling the genus *Randia* Linn. have been reported from India and abroad (Prasad & Dwivedi, 2007). Of these, four species are described from the Siwalik sediments of India and Nepal. These are *Randia miowallichii* Prasad (1990a) from Siwalik sediments of Koilabas, western Nepal and from Oodlabari, Darjeeling District, West Bengal, India (Antal & Awasthi, 1993), *R. siwalica* and *R. palaeofasciculata* from Siwalik sediments of Suraikhola, western Nepal (Prasad & Awasthi, 1996) and *R. miouncaria* Prasad & Dwivedi (2007) from the Siwalik sediments of Serianaka, Koilabas area, western Nepal. On comparison, it has been observed that none of these known species show similarity with the present fossil leaves. They differ mostly either in shape, size or in the nature and course of secondary veins. *R. miowallichii* Prasad differs in having craspedodromous type of venation pattern as compared to eucamptodromous in the present fossils. *R. palaeofasciculata* Prasad & Awasthi can be differentiated in being smaller size (3.4 x 1.4 cm) as compared to 7.6 x 3.0 cm in the present fossils. Similarily, the fossil leaf, *R. siwalica* Prasad & Awasthi differs in being its larger size (18.5 x 5.8 cm) with narrow elliptic shape. Though, the leaf of *R. miouncaria* Prasad & Dwivedi shows similarity in shape and size but differ in the number and course of the secondary veins. The secondary veins are less in number and spacely placed, i.e. 0.8 to 2.4 cm apart. In being different from already known species the present fossil leaves have been assigned to a new specific name, *Randia tanakpurensis.*

The genus *Randia* Linn. consist of 300 species (including *Basanantha* Hook. f.) distributed throughout the tropical to subtropical regions of the world. *Catunaregam spinosa* (Thunb) Tirveng. [Syn. *Randia floribunda (= R. dumentorum* Lam.)] with which fossils show resemblance is a shrub or small tree presently found throughout India extending north to the Beas, Myanmar and Sri Lanka (Brandis, 1971).

Family—SAPOTACEAE

Genus—PALAQUIUM Blanco.

Palaquium palaeograndis sp. nov.

(Pl. 20.6; Pl. 21.8; Pl. 22.1.)

Material—There are two, well preserved leaf impressions without apex.

Description—Leaf simple, symmetrical, oblanceolate, preserved size 11 x 4.8 cm and 9.0 x 5.0 cm, apex broken, base acute to cuneate; margin entire, texture chartaceous; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, straight; secondary veins (2°) about 9–10 pairs visible, 0.6 to 1.8 cm apart, alternate to opposite, seemingly unbranched, angle of divergence 60°–70°, wide acute; uniformly curved up and joined to superadjacent secondary veins, curvature is more pronounced near the margin; intersecondary veins present, simple, rare; tertiary veins (3°) angle of origin usually AO rarely RR, percurrent, sometimes branched, oblique in relation to midvein, predominantly alternate, close to nearly distant.

Holotype—BSIP Museum Specimen No. 41366.

Paratype—BSIP Museum Specimen No. 41367.

Locality—Spot No. 1 (29º8'27.4": 80º11'6.9"), near Hanuman Chatti, Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—By adding a prefix ‘palaeo' to the name of modern comparable species, *P. grandis.*

Affinity—The characteristic features of the present fossil leaves such as symmetrical, oblanceolate shape, acute to cuneate base, entire margin, eucamptodromous venation, wide acute angle of secondary veins having a pronounced curvature near the margin, presence of intersecondary veins, usually AO, percurrent, close to nearly distant tertiary veins strongly indicate their resemblance with the modern leaves of the genus *Palaquium* Blanco. of the family Sapotaceae. A critical study of the herbarium sheets of this genus shows that the leaves of *Plaquium grandis* (Thwaites) Engl. (Syn. *Dichopsis grandis* (Thwaites) C.B. Clarke in shape, size and venation pattern (C.N.H. Herbarium Sheet No. 280694; Pl. 22.2, 3).

As far as authors aware there is no record of fossil leaves resembling the genus *Palaquium* Blanco. As the present fossil form the first occurrence of the fossil leaves of this genus in the Siwalik sediments of Tanakpur, Uttarakhand and have been assigned as *Palaquium palaeograndis* sp. nov.

The genus *Palaquium* Blanco. comprises 60 species mainly confined to Indo–Malayan region. *Palaquium grandis* (Thwaites) Engl. with which fossils resemble closely is an evergreen tree distributed presently in the Indo–Malayan region.

Genus—CHRYSOPHYLLUM Linn.

Chrysophyllum bhairauvensis sp. nov.

(Pl. 21.3, 5)

Material—There is a single, well preserved leaf impression.

Description—Leaf simple, symmetrical, narrow elliptic; preserved size 5.7 x 2.2 cm; apex acute; base obtuse; margin entire; texture chartaceous; venation pinnate, craspedodromous to eucamptodromous; primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) about 28 pairs visible, less than 0.3 cm apart, closely placed, alternate to opposite, unbranched, angle of divergence 70°–85°, acute to right angle, upper secondary more acute, uniformly curved up; inter secondary veins present, simple, frequent, 2–4 intersecondary veins present in between two secondary veins; tertiary veins (3°) fine, angle of origin AO–RR; percurrent, usually straight, sometimes branched, oblique in relation to midvein, alternate to opposite, close.

Holotype—BSIP Museum Specimen No. 41368.

Locality—Spot No. 10 (29º9'12.1": 80º11'38.5"), Bhairauv Mandir, Purniyagiri Road section, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—After the name of Bhairauv Mandir situated just near the fossil spot.

Affinity—The diagnostic features of the present fossil leaf such as narrow elliptic shape, acute apex, obtuse base, craspedodromous to eucamptodromous venation, closely placed secondaries with acute to right angle of divergence, presence of 2–4 intersecondary veins and AO–RR, percurrent tertiary veins collectively suggest that the present fossil shows closest affinity with the leaves of the genus *Chrysophyllum* Linn. of the family Sapotaceae. An examination of the leaves of various extant species of this genus revealed that the fossil leaf resembles those of *Chrysophyllum viridifolium* Wood & Franks (C.N.H. Herbarium Sheet No. 279994; Pl. 21.4, 6).

Mehrotra (2000) described a fossil leaf showing resemblance with the genus *Chrysophyllum* Linn under form species, *C. tertiarum* from Tura Formation of Garo Hills, Meghalaya, India. Later on, Prasad (2007) reported another fossil leaf, *C. churiensis* from Lower Churia sediments of Arjun Khola, western Nepal. On comparison of the present fossil with both the known fossil leaves it has been observed that none of them show similarity with the present fossil leaf. *C. tertiarum* Mehrotra differs in being elliptic shape with fewer number of distantly placed (0.5–0.6 cm) secondary veins as compared to about 28 pairs of closely placed secondary veins in the present fossil leaf. Similarly, the fossil leaf, *C. churiensis* Prasad differs in its larger size having more number (50) of secondary veins. As the present fossil leaf is different from both the known species, it has been described as a new species, *Chrysophyllum bhairauvensis,* the specific name indicates its occurrence near the Bhairauv Mandir in Purniyagiri Road section.

The genus *Chrysophyllum* Linn. consists of about 43 species distributed in Tropical America, Africa, Madagascar and Australia. Few species are also found in the Indo–Malayan region. The comparable species *C. viridifolium* Wood & Franks is an evergreen tree distributed in South–east Africa to South–east Asian region.

Family—LAURACEAE

Genus—CINNAMOMUM Shaeffer

Cinnamomum palaeotamala Lakhanpal & Awasthi, 1984

(Pl. 23.3, 4; Pl. 25.8)

Material—This consists of single, well preserved leaf impression with its counterpart.

Description—Leaf simple, symmetrical, narrow elliptic; preserved size 13.0 x 4.0 cm; apex broken; base acute; margin entire; texture coriaceous; petiole 0.5 cm visible, normal; venation nearly basal acrodromons, perfect; primary vein (1°) three, stout, one mid and two lateral primary veins, mid primary almost straight, and lateral primary veins slightly curved, unbranched; secondary veins (2°) fine numerous, arising from both mid and lateral primaries, the secondary veins arising from primary veins at acute to nearly right angle, few secondary veins arising from outer side of lateral primary veins are more acute and run upward and joined

the superadjacent secondaries near the margin while the secondaries of mid primary veins are joined to their lateral primaries at nearly right angle, sometimes branched.

Specimen—BSIP Museum Specimen Nos. 41369–41370.

Locality—Spot No.1 (29º8'27.4": 80º11'6.9"), near Hanuman Chatti, Purniyagiri Road section, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinity—The diagnostic features of the present fossil leaf such as symmetrical, narrow elliptic shape, acute base, entire margin, basal, perfect acrodromous venation and nature and orientation of primary and secondary veins indicate that the present fossil leaf shows close resemblance with the modern leaves of *Cinnamomum* Schaeffer of the family Lauraceae. In order to find out its specific affinity, the herbarium sheets of available species of this genus were thoroughly examined and it was concluded that the leaves of *Cinnamomum tamala* Nees show closest affinity with the present fossil leaf.

Several fossil leaves resembling the genus *Cinnamomum* Shaeffer have been reported from India and aboard under four generic names, i.e. *Cinnamomum* Shaeffer, *Cinnamomiphyllum* Nathorst, *Cinnamomoides* Seward and *Cinnamomophyllum* Krausel & Weyland (Prasad & Panday, 2008). Eight fossil leaves were reported from the Siwalik sediments of India and Nepal. Pathak (1969) reported a fossil leaf resembling *Cinnamomum tamala* from the Middle Siwalik of Mahanadi River Section, West Bengal, India. *Cinnamomum* sp. has been described by Antal and Awasthi (1993) from Lower–Middle Siwalik of Oodlabari area, West Bengal, India. *C. mioinuctum* Prasad (1990a) and *C. nepalensis* Prasad & Panday (2008) described from the Siwalik sediments of Koilabas and Surai Khola, Nepal respectively. *C. palaeotamala* Lakhanpal & Awasthi (1984) has been described from Upper Siwalik sediments of Bhikhnathoree Bihar, India. Lastly *C. miotavoyanum* (Shashi *et al.,* 2008) reported from the Lower Siwalik sediments of Tanakpur area Uttarakhand, *C. corvinusiana* (Prasad *et al.,* 2016) from Lower Siwalik sediments of Arjun Khola, Western Nepal, *C. eokachchhensis* (Lakhanpal & Guleria, 1981) from Eocene of Kachchh, Western India. A comparative study of the present fossil with all the above known fossils has been suggested that *C. palaeotamala* Lakhanpal & Awasthi show closest similarity with the present fossil, hence it has been described herewith under the same species, *C. palaeotamala* Lakhanpal & Awasthi.

The genus *Cinnamomum* Schaeffer consists of 350 species (including *Phoebe*) of evergreen trees and shrubs distributed mainly in tropical and sub–tropical regions of East and South–east Asia to Australia. About 24 species of this genus occur in the Indian region (Gamble, 1972). *Cinnamomum tamala* Nees with which fossil shows affinity is a moderate sized, evergreen tree occurring in Sub–himalayan tract and outer ranges ascending to 2000 ft. from Jammu eastward chiefly in dam ravines, Khasi Hills, Sylhet and Myanmar (Brandis, 1971).

Family—MYRISTICACEAE

Genus—MYRISTICA Linn.

Myristica siwalica sp. nov.

(Pl. 21.1, 7; Pl. 22.9)

Material—There are three specimens, one almost complete and other two are representing by basal and apical part respectively.

Description—Leaf simple, symmetrical, narrow elliptic to oblong; preserved size 13.5 x 5.8 cm, 6.0 x 5.0 cm and 4.0 x 2.8 cm; apex acute; base wide acute; margin entire; texture coriaceous; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) 14 pairs visible 0.7 to 1.7 cm apart, seemingly unbranched, alternate to opposite, angle of divergence 70°–80°, wide acute, basal secondaries with more angle of divergence, uniformly curved up and joined to their superadjacent secondaries; inter secondary veins present, simple; tertiary veins (3°) fine, angle of origin AO–RR, percurrent, straight to sinuous, sometimes branched, oblique in relation to midvein, predominantly alternate and close.

Holotype—BSIP Museum Specimen No. 41371.

Paratype—BSIP Museum Specimen Nos. 41371a, 41372.

Locality—Spot No. 3 (29º8'51.38": 80º11'16.3"), Purniyagiri Road section, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—After Siwalik Group.

Affinity—The most important features of the present fossil leaves namely large elliptic to oblong shape, acute apex, wide acute base, eucamptodromous venation, wide acute angle of divergence of secondary veins, AO–RR, percurrent tertiaries suggest that the fossil leaf belong to the genus *Myristica* Linn of the family Myristicaceae. Critical survey of herbarium sheet of 25 extant species of *Myristica* Linn. indicate that *M. crassa* King (C.N.H. Herbarium Sheet Nos. 10088, 381869; Pl. 21.2) shows closest affinity with the present fossils.

So far, nine fossil leaves resembling the genus *Myristica* (*Knema)* Linn. have been known from India and abroad. These are *Myristicophyllum minus* and *M. majus* from the Tertiary of Labuan (Geyler, 1887). *M. panamense* from Gubbra Formation, Panama (Berry, 1918), *Myristica apocynophylloides* from the Tertiary of Uricanga, Germany (Krasser, 1903), *Myristica* sp., and *Knema* sp., from Kushtaka Formation, Alaska (Wolfe, 1977), *Myristica* (*Knema) tertiara* from the Tertiary of Germany (Ettingshausen, 1869), *M. mioglomerata* from Siwalik sediments of Surai Khola, Nepal

(Awasthi & Prasad, 1990) and *M. lorata* from Oligocene of Makum Coalfield, Assam (Awasthi & Mehrotra, 1995). The present fossil leaves have been compared with all the above known species of *Myristica* Linn. and *Myristicophyllum* Geyler and concluded that the present fossil leaves are different from all of them. They differ mostly in the number and orientation of the secondary veins. Moreover, the fossil leaf *M. mioglomerata* Awasthi & Prasad further differs in possessing obtuse to notched apex as compared to acute apex in the present fossils. Thus, in being different the present fossils have been designated as a new species, *Myristica siwalica.*

The genus *Myristica* (*Knema*) Linn. consists of 72 species distributed in tropical Asia to Australia (Mabberley, 1997). *Myristica crassa* King (Syn. *M. suavis* King) with which fossils resemble is an evergreen tree found to grow in Indonesia, Sumatra and Malaysia.

Family—EUPHORBIACEAE

Genus—MALLOTUS Lour

Mallotus prejaponicus sp. nov.

(Pl. 22.7; Pl. 23.1; Pl. 24.7)

Material—This species is based on single, well preserved, almost complete leaf impression with counter part.

Description—Leaf simple, symmetrical, ovate, preserved size 8.0 x 5.8 cm; apex acute to nearly attenuate; base obtuse; margin slightly lobed; texture thick chartaceous; petiole 1.0 cm long, normal; venation pinnate, basal acrodromous, imperfect, primary vein (1°) three, one mid and two lateral primaries arise at the base. Mid primary stout, almost straight, lateral primaries curved upward and give off secondary veins towards the margin; secondary veins (2°) arise from both mid and lateral primaries at moderately acute angle of divergence, seemingly unbranched, alternate, uniformly curved up; tertiary veins (3°) fine, angle of origin usually RR, percurrent, straight to sinuous, branched, oblique to right angle in relation to midvein, predominantly alternate, close to nearly distant.

Holotype—BSIP Museum Specimen No. 41373.

Paratype—BSIP Museum Specimen No. 41374.

Locality—Thuligad (29º8'18.7": 80º10'41.1"), near Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—By adding a prefix 'Pre' to the name of modern comparable species, *M. japonicus.*

Affinity—The diagnostic features of the present fossil are symmetrical, ovate shape, acute to nearly attenuate apex, obtuse base, nearly lobed margin, basal, imperfect acrodromous venation, nature and orientation of secondary veins and usually RR, percurrent tertiaries which are close to nearly distant and oblique to right angle in relation to midvein. The comparative study of the herbarium sheets of a number of genera and species of the dicotyledonous families suggests that these features are found common in the extant leaves of the genus *Mallotus* Lour. of the family Euphorbiaceae. The critical examination of all the available species of this genus indicate that the extant leaves of *M. japonicus* Spreng (C.N.H. Herbarium Sheet Nos 415512, 72717; Pl. 22.8; Pl. 23.2) shows closest affinity with the present fossil leaf in shape, size and venation pattern.

So far, two authentic fossil leaves of the genus *Mallotus* Lour. have been reported from the Siwalik sediments of India and Nepal. *M. kalimpongensis* Antal & Awasthi from Lower–Middle Siwalik of Darjeeling District, West Bengal, India (Antal & Awasthi, 1993) and from Middle Siwalik of Surai Khola, western Nepal (Prasad & Pandey, 2008), *M. venkatachalai* Prasad (1994c) from Lower Siwalik sediments of Kathgodam, Uttarakhand, India. On comparison it has been found that both the fossil species possesses basal acrodromous venation but differ from the present fossil in shape as well as orientation of primary and secondary veins. In view of these differences, the present fossil leaf is described under a new specific name, *Mallotus prejaponicus.*

The genus *Mallotus* Lour. consists of about 140 species distributed from Africa to East and South–east Asia, Indo–Malaya, New Calodenia, Fiji, North and East Australia (Willis, 1973). *Mallotus japonicus* Spreng with which fossil shows closest affinity is a woody shrub distributed in East Asia and Philippines.

Genus—MALLOTUS Lour.

Mallotus kalimpongensis Antal & Awasthi, 1993

(Pl. 22.4, 5)

Material—This species is represented by two well preserved leaf impressions which are without apex.

Description—Leaf simple, symmetrical, narrow elliptic, preserved size 6.5 x 2.5 cm and 5.1 x 2.4 cm; apex broken; base wide acute to nearly obtuse; margin entire; texture chartaceous; petiole broken; venation pinnate, acrodromous, basal, imperfect; primary vein (1°) three (one mid primary and two lateral primary veins), mid primary vein almost straight while lateral primaries curved upward to one half of the leaf length; secondary veins (2°) arising form both mid primary and lateral primary veins, angle of divergence 50°–55°, acute, moderate, slightly curved, alternate, the lateral primaries give off secondary veins toward the margin; tertiary veins (3°) fine, angle of origin RR, percurrent, straight, sinuous, sometimes branched, right angle in relation to midvein, predominantly alternate and close.

Specimen—BSIP Museum Specimen Nos. 41375–41376.

Locality—Spot No. 1 (29º9'8": 80º11'19.7"), near Hauman Chatti, Purniyagiri Road section, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinity—Symmetrical, narrow elliptic shape, nearly obtuse base, entire margin, basal, imperfect, acrodromous venation, nature of primary and secondary veins, moderately acute angle of divergence of secondary veins, and RR, percurrent tertiary veins which are right angle in relation to midvein undoubtedly suggest that the present fossil leaves show closest affinity with the extant leaves of *Mallotus philippinensis* Muell. Arg. (C.N.H. Herbarium Sheet No. 1131; Pl. 22.5) of the family Euphorbiaceae.

Fossil leaf resembling the genus *Mallotus* Lour. (mentioned earlier in this text) have been compared and found that the leaf, *M. kalimpongensis* Antal & Awasthi (1993) described from the Lower–Middle Siwalik of Darjeeling District shows closest similarity with the present fossil leaf in shape, size and venation pattern. Hence, the present fossil leaf has been described under the same species, *Mallotus kalimpongensis.*

The modern comparable taxon, *Mallotus philippinensis* Mull. Arg. is a large shrub or small tree growing in the deciduous to evergreen forests of Sub–himalayan tract eastward from Punjab ascending to 1,500 m. It is also found common in western, central and southern India, Andamans, Myanmar and Sri Lanka (Gamble, 1972; Brandis, 1971).

Genus—BACCAUREA Lour.

Baccaurea miocenica sp. nov.

(Pl. 23.5; Pl. 24.1)

Material—There is single, well preserved leaf impression with slightly broken apex.

Description—Leaf simple, symmetrical, oblanceolate; preserved size 9.7 x 3.5 cm; apex broken; base acute, cuneate; margin entire; texture chartaceous; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, slightly curved; secondary veins (2°) 6 pairs visible, 0.5 to 2.0 cm apart, alternate, unbranched, angle of divergence varies from 55°–70°, moderate to wide acute, uniformly curved up and running for a long distance and joined to supradjacent secondaries; inter secondary veins present, simple, rare; tertiary vein (3°) fine, angle of origin, RR, percurrent, straight to sinuous, oblique to nearly right angle in relation to midvein, predominantly alternate, close to distance.

Holotype—BSIP Museum Specimen No. 41377.

Locality—Spot No.1 (29º9'8": 80º11'19.7"), near Hanuman Chatti, Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—After Miocene epoch.

Affinity—The most important features of the present fossil leaf are symmetrical, oblanceolate shape, cuneate base, entire margin, eucamptodromous venation; moderate to wide acute angle of divergence of secondary veins, presence of intersecondary veins, RR, percurrent, close to distant tertiaries with oblique to right angle in relation to midvein. These collectively indicate its resemblance with the extant leaves of *Baccaurea* Lour. of the family Euphorbiaceae. In order to find out its specific affinity, a large number of herbarium sheets of all the available species of this genus were examined and it was concluded that the leaves of *Baccaurea tetrandra* Lour. (C.N.H. Herbarium Sheet No. 2399; Pl. 24.2; Pl. 23.6) shows closest affinity with the present fossil leaf.

There is no record of fossil leaf resembling the genus *Baccaurea* Lour. from the Tertiary sediments of India and abroad. The present fossil represents its first record from the Siwalik sediments of Tanakpur area, Uttarakhand, India and is being described herewith as *Baccaurea miocenica* sp. nov.

The genus *Baccaurea* Lour. comprises about 80 species presently distributed in India, South–east Asia and Pacific region. *Baccaurea tetrandra* Lour. (Syn. *B. cauliflora*) with which fossil resembles closely is a evergreen tree found to grow in North–east India, Myanmar, Vietnam, Thailand and Malaya.

Genus—BRIDELIA Willd.

Bridelia hanumanchattiensis sp. nov.

(Pl. 25.1, 3)

Material—This species is consisting of single, well preserved leaf impression with broken base.

Description—Leaf simple, symmetrical, elliptic; preserved size 6.0 x 3.2 cm; apex bluntly acute, base slightly broken; margin entire; texture coriaceous; venation pinnate, eucamptodromous; primary vein (1°) single, prominent stout; secondary veins (2°) about 9 pairs visible, 0.4–0.8 cm apart, alternate to opposite, unbranched, angle of divergence 60°–65°, acute, moderate, uniformly curved up, joined to their superadjacent secondary; inter secondary veins present, simple; tertiary veins (3°) poorly preserved, fine, angle of origin usually RR, percurrent, straight to sinuous, oblique in relation to midvein, alternate to opposite, close.

Holotype—BSIP Museum Specimen No. 41378.

Locality—Spot No. 1 (29º8'27.4": 80º11'6.9"), near Hanuman Chatti, Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Lower Miocene.

Etymology—After the name of famous place, Hanuman Chatti on Thuligad–Purniyagiri Road from where fossil was collected.

Affinity—The present fossil leaf is characterized by its elliptic shape, bluntly acute apex, entire margin,

eucamptodromous type of venation, closely placed upper secondaries, moderately acute angle of divergence of secondary veins, presence of intersecondary veins, RR, percurrent tertiary veins. Such features are found common in the extant leaves of *Securidaca inappendiculata* Hask. (Polygalaceae), *Diospyros pruriens* Dalz. (Ebenaceae), *Paramignya monophylla* Wight (Rutaceae) and *Bridelia ovata* Kurz. (Euphorbiaceae). On critical examination of a number of herbarium sheets of the above taxa, it has been found that the extant leaves of *Securidaca inappendiculata* Hask. and *Paramignya monophylla* Wight differ from present fossil leaf in having comparatively more angle of divergence of secondary veins than the present fossil leaf. Though, the leaves of *Diospyros pruriens* Dalz. is similar to the present fossil leaf in shape, size and type of venation but differ in number and nature of intersecondary veins which are very rare in the *Diospyros pruriens.* Thus, the leaf of *Bridelia ovata* Kurz is only with which fossil shows close resemblance (C.N.H. Herbarium Sheet No. 400503; Pl. 25.2, 4).

So far, six fossil leaves resembling the genus *Bridelia* Willd., have been known from Tertiary sediments of India and Nepal. Pathak (1969) described two fossil leaves having affinity with the extant taxa *B. stipularis* Bl. and *B. verrucosa* Haines respectively from Middle Siwalik sediments of Mahanadi River Section, West Bengal. Awasthi and Mehrotra (1995) reported another fossil leaf of this genus under the form species *Bridelia oligocenica* from the Oligocene of the Makum Coalfield, Assam, India. Prasad and Pandey (2008) described two fossil leaves, *B. mioretusa* and *B. siwalica* from the Middle Siwalik sediments of Surai Khola area, Western Nepal. Later on, Srivastava and Mehrotra (2014) described an other fossil leaf, *Bridelia makumensis* from Oligocene of Makum Coalfield, Assam. These fossil leaves have been compared with the present fossil leaf and it was found that none of them show resemblance with the present fossil. Both the fossil leaves described by Pathak (1969) are fragmentary in nature and possesses different venation pattern. The fossil leaf *B. oligocenica* Awasthi & Mehrotra can easily be differentiated by its narrow size (2.5 cm in width) of the leaf with narrow acute angle of divergence of secondary veins. Similarly, *B. mioretusa* Prasad & Pandey is a large leaf (12.3 x 7.2 cm) with more acute angle of divergence of secondary veins which run straightly to upward and the lastly *B. siwalica* Prasad & Pandey differs from present fossil in having oblique base with less acute (80°) angle of divergence of secondary veins. *B. makumensis* Srivastava and Mehrotra also differs in being narrow elliptic shape with comparatively more number (11 pairs) of secondary veins. In view of these differences, the present fossil leaf is described under a new specific name, *Bridelia hanumanchattiensis.*

The genus *Bridelia* Willd. comprises about 60 species of trees, shrubs and straggling climbers distributed presently in the tropical regions of old world. *Bridelia ovata* Kurz. with which fossil shows closest affinity is a climbing shrub of Andamans (Brandis, 1971).

Family—MORACEAE

Genus—FICUS Linn.

Ficus precunea Lakhanpal, 1968

(Pl. 25.5, 7)

Material—There is a single, well preserved and incomplete leaf impression.

Description—Leaf simple, asymmetrical, small, elliptic, preserved size 3.5 x 2.0 cm; apex broken, base cordate; margin entire; texture coriaceous; petiole indistinct; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout; secondary veins (2°) 5–6 pairs visible, less than 0.5 cm apart, alternate, unbranched, angle of divergence about 55°, acute, moderate, running upward for a short distance. The basal secondary turned downwards into the lobe and branched, intersecondary veins not distinct; tertiary veins (3°) fine, angle of origin RR, percurrent, branched, oblique to nearly right angle in relation to midvein, predominantly alternate, close to distant.

Specimen—BSIP Museum Specimen No. 41379.

Locality—Spot No. 4, (29º9'8": 80º11'19.7"), Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Affinity—The morphological features exhibited by the present fossil leaf like, small, elliptic shape, cordate base, entire margin, eucamptodromous venation, curvature of basal secondary veins towards downwards into the lobes and its branching, RR, percurrent, close to distant tertiaries collectively suggest its affinity with the extant leaves of *Ficus cunea* Ham. (Syn. *F. semicordata* Buch–Ham; C.N.H. Herbarium Sheet Nos. 37290, 22916; Pl. 25.6) of the family Moraceae.

About 33 fossil leaves resembling the genus *Ficus* Linn. have been described from Cenozoic sediments of India (Prasad *et al*., 2004, 2016). Out of them three fossil leaves resembling the same taxon, *Ficus cunea* Buch–Ham. have been described under the form species, *Ficus precunea* Lakhanpal from Siwalik sediments of Balugoloa H.P. (Lakhanpal, 1968) from Koilabas, Nepal (Prasad, 1990a) and Kathgodam, Uttarakhand, India (Prasad *et al.,* 2004) and show closest similarity with the present fossil leaf. Hence, this fossil leaf has been described under the same species *Ficus cunea* Lakhanpal.

The genus *Ficus* Linn. comprises 750 species of trees, shrubs or root clinging lianas, widely distributed throughout the tropics of both Hemispheres especially Indo–Malaya to Australia. The modern comparable species, *F. cunea* Buch–

Ham. is a small tree distributed in the Sub–Himalayan tract, Assam and Myanmar (Brandis, 1971).

Family—URTICACEAE

Genus—SARCOCHLAMYS Gaudich.

Sarcochlamys miopulcherrima sp. nov.

(Pl. 24.3, 5)

Material—This species is represented by a single specimen of leaf impression.

Description—Leaf, symmetrical, lanceolate; preserved size 8.5 x 2.4 cm; apex slightly broken, seemingly alternate; base obtuse; margin slightly non–entire; texture coriaceous; venation pinnate, basal, perfect, acrodromous; primary vein (1°) three (one mid primary and two lateral primary), lateral primary veins slightly curved; stout; secondary veins (2°) several, arising from both mid and lateral primaries mainly at right angle. Secondaries arising from lateral primaries towards margin joined with intra marginal veins and arising from mid primary vein joined with lateral primaries at nearly right angle; fine, intramarginal veins present on both side of the margin; tertiary veins (3°) indistinct.

Holotype—BSIP Museum Specimen No. 41380.

Locality—Spot No. 10 (29º9'12.1": 80º11'38.5"), Bhairauv Mandir, Purniyagiri Road section, Tanakpur, Champawat District, Uttarakhand.

Horizon & Age—Lower Siwalik; Middle Miocene.

Etymology—By adding the prefix 'mio' to the Modern comparable species, *S. pulcherrima*.

Affinity—The characteristic features of the present fossil leaf such as symmetrical, lanceolate shape, obtuse base, slightly non–entire (serrate) margin, basal, perfect acrodromous venation, right angle of secondary veins and presence of intramarginal veins undoubtedly suggest that the fossil leaf belongs to the genus *Sarcochlamys* Gaudich. of the family Urticaceae. A critical examination of herbarium sheets of all the available species of this genus suggests its affinity with *Sarcochlamys pulcherrima* Gaudich (C.N.H. Herbarium Sheet Nos. 879, 434945; Pl. 24.4, 6).

As far as author awares there is no record of any fossil leaf resembling the genus *Sarcochlamys* Gaudich. from the Tertiary sediments of India and abroad. The present fossil forms its first record from the Siwalik sediments of Tanakpur area, Uttarakhand, India and is being described here as *Sarcochlamys miopulcherrima* sp. nov.

The genus *Sarcochlamys* Gaudich. comprises only one species *S. pulcherrima* Gaudich. with which present fossil shows affinity. It is an evergreen shrubs or small tree distributed into Indo–Malayan region. It grows mainly in the evergreen forests of Assam, Khasi Hills, West Bengal, Bangladesh, Myanmar and Sumatra (Brandis, 1971).

FLORISTIC COMPOSITION AND ANALYSIS

Study on plant mega fossils comprising well preserved leaf and fruit impressions from the Siwalik sediments exposed in Tanakpur area, Champawat District, Uttarakhand is the most comprehensive and systematic work. The floral assemblage recovered from these sediments is impoverished both in quality and quantity as constituted by 57 species belonging to 51 genera and 26 families of Angiosperms. These are as follows:

MARANTACEAE
- *Donax ovatus* (Awasthi & Prasad) n. comb.

ANNONACEAE
- *Annona miocenica* sp. nov.
- *Popowia siwalica* sp. nov.
- *Miliusa pretomentosa* Prasad *et al.* 2004
- *Meiogyne purniyagiriensis* sp. nov.
- *Dendrokingstonia palaeonervosa* sp. nov.

POLYGALACEAE
- *Securidaca precorymbosa* sp. nov.

XANTHOPHYLLACEAE
- *Xanthophyllum mioglaucum* sp. nov.

CLUSIACEAE
- *Kayea kalagarhensis* Prasad 1993
- *Calophyllum suraikholaensis* Awasthi & Prasad 1990

DIPTEROCARPACEAE
- *Dipterocarpus suraikholaensis* Prasad & Pandey 2008
- *Parashorea mioplicata* sp. nov.
- *Hopea kathgodamensis* Prasad 1994c

RUTACEAE
- *Toddalia purniyagiriensis* sp. nov.
- *Atalantia siwalica* sp. nov.
- *Clausena miocenica* sp. nov.

ZYGOPHYLLACEAE
- *Balanites siwalica* sp. nov.

MELIACEAE
- *Aglaia purniyagiriensis* sp. nov.

STEMONURACEAE
- *Gomphandra palaeocoriacea* sp. nov.

RHAMNACEAE
- *Ventilago miocalyculata* sp. nov.

SAPINDACEAE
- *Sapindus eotrifoliatus* sp. nov.
- *Lepisanthes miocenica* sp. nov.
- *Lepisanthes tanakpurensis* sp. nov.
- *Harpullia siwalica* Prasad & Awasthi 1996
- *Filicium koilabasensis* Prasad 1994e

ANACARDIACEAE
- *Drimycarpus siwalicus* sp. nov.
- *Bouea premicrophylla* Antal & Awasthi 1993

SABIACEAE
- *Sabia eopaniculata* Prasad 1994e

CONNARACEAE
Gnestis purniyagiriensis sp. nov.
FABACEAE
Bauhinia nepalensis Awasthi & Prasad 1990
B. purniyagiriensis sp. nov.
Millettia mioinermis sp. nov
M. siwalica Prasad 1990a
Humboldtia miocenica sp. nov.
Wagatia miospicata sp. nov.
Dalbergia tanakpurensis sp. nov.
Derris prakashii Prasad *et al.* 2004
D. mioscandens sp. nov.
Pongamia siwalika Awasthi & Lakhanpal 1990
Cynometra palaeoiripa Prasad *et al.* 1999
COMBRETACEAE
Terminalia bhairauvensis sp. nov.
Combretum purniyagiriense sp. nov.
MELASTOMATACEAE
Medinilla siwalica sp. nov.
LYTHRACEAE
Lagerstroemia prakashii sp. nov.
Lagerstroemia mioparviflora Dwivedi *et al*. 2006b
RUBIACEAE
Ixora purniyagiriensis sp. nov.
Randia tanakpurensis sp. nov.
SAPOTACEAE
Palaquium palaeograndis sp. nov.
Chrysophyllum bhairauvensis sp. nov.
LAURACEAE
Cinnamomum palaeotamala Lakhanpal & Awasthi 1984
MYRISTICACEAE
Myristica siwalica sp. nov.
EUPHORBIACEAE
Mallotus prejaponicus sp. nov.

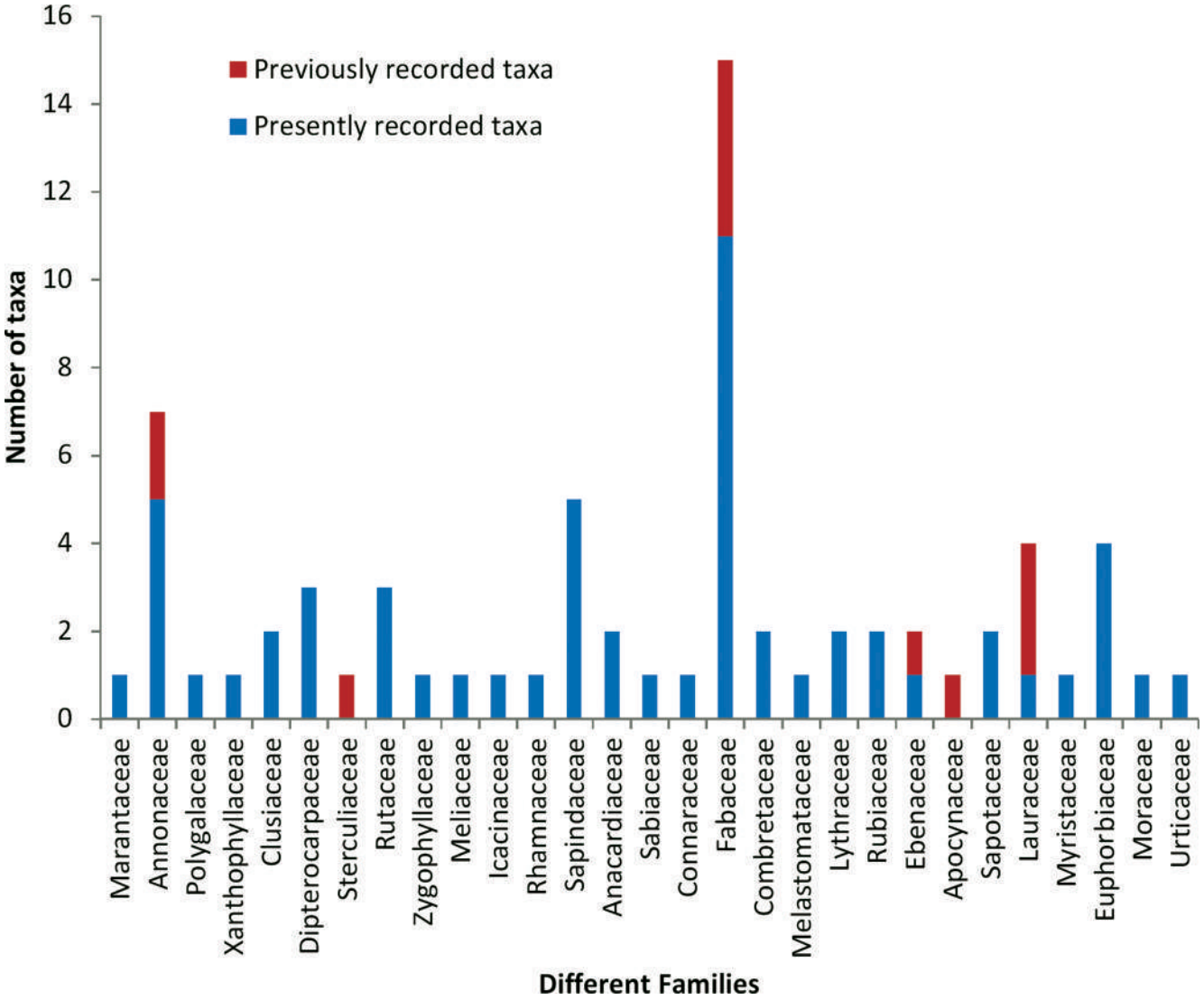

Fig. 5—Diagrammatic representation showing frequency distribution of fossil taxa known from the Siwalik of Tanakpur area, Uttarakhand, India.

M. kalimpongensis Antal & Awasthi 1993
Baccaurea miocenica sp. nov.
Bridelia hanumanchattiensis sp. nov.

MORACEAE

Ficus precunea Lakhanpal 1968

URTICACEAE

Sarcochlamys miopulcherrima sp. nov.

With the addition of 57 new taxa, the floral assemblage of the Siwalik sediments of Tanakpur area now consists of 71 species belonging to 62 genera of 29 angiospermous families (Table 4; Fig. 5). They are mainly based on leaf and fruit impressions. The assemblage is overall dominated by woody plants/trees (68%). The remaining species are small tree and shrubs (21%) and climbers (11%). The herbs are totally absent (Table 4; Fig. 6). The fabaceous taxa show overall dominance consisting of 15 taxa in the assemblage (Fig. 5). The earlier fossil records also show their abundance from other localities in the Siwalik foot–hills of India and Nepal during Mio–Pliocene (Prakash & Tripathi, 1992; Prasad, 1993, 1994a–d, 2008; Prasad *et al*., 1997, 1999, 2004; Antal & Awasthi, 1993; Prasad & Awasthi, 1996; Prasad & Pandey, 2008; Antal & Prasad, 1995, 1996a–c, 1997; Antal *et al.,* 1996). These fabaceous taxa have not been authentically recorded from the Palaeocene sub–period of India and Nepal, which indicate that they might have entered later in the Indian sub–continent during Oligocene Period, after the establishment of land connections from where they were flourishing.

The morphotaxonomical study of the plant megafossils from Tanakpur area revealed the occurrence of exclusively tropical elements during the Siwalik times. The important tropical subdominant families are Dipterocarpaceae, Lythraceae, Sapindaceae, Sapotaceae, Combretaceae and Ebenaceae. They are mainly distributed in India, Nepal and South–east Asian regions. The present day distribution of the modern equivalents of the fossil taxa known from Tanakpur area indicates their wider distribution in different geographical regions all over India and other places (Fig. 8; Table 4). In India they are distributed mostly in North–east and South–east Asian regions due to favourable climatic conditions. The fossil assemblage comprises more than 17 those taxa which are found to grow both in India and Malaya Peninsula. These are *Donax ovatus* Benth. & Hook., *Mitrephora maingayi* Hook. f. & Th., *Xanthophyllum glaucum* Wall., *D. turbinatus* Gaertn., *Calophyllum polyanthum* Wall., *Harpullia arborea* (Blanco.) Radlk., *Bouea macrophylla* Griffith, *Caesalpinia microphylla* G. Don, *Combretum sundaicum* Miquel, *Chonemorpha macrophylla* G. Don, *Plaquium grandis* (Thwaites) Engl., *Persea* spp., *Baccauria tetrandra* Lour., *Sarcochlamys pulcherrima* Gaudich. A good amount of taxa like, *Dendrokingstonia nervosa* Hook. f. & Th., *Ellipeia cuneifolia* Hook. f. & Th., *Parashorea plicata* Brandis, *Comiphora caudata* Engl, *Hopea dryobalanoides* Miq., *Sterculia ensifolia* Mast., *Toddalia asiatica* Lamk., *Clausena anisumolens* (Blanco.) Meer., *Aglaia biclor* Merr., *Lepisanthes fruticosa* (Roxb.) Leenh., *Bauhinia finlaysoniana* (Benth.), *Dalbergia indana, Medinilla ramiflora* Merr., *Ixora lobbii* London, *Chrysophyllum viridifolium* Wood & Franks, *Myristica crassa* King, *Mallotus japonicus* Spreng are restricted to the South–east Asian regions which have also been found in the present assemblage. Besides, few taxa, viz. *Derris trifoliatus* Lour., *Pongamia pinnata* Pierre., *Lagerstroemia flosreginae* Retz., *Mallotus philippinensis* Muell. Arg. are Cosmopolitan. *Millettia inermis* (Wright) DC. found to grow in the tropical regions of other countries like Africa, America and West Indies. Besides, the floral assemblage consists of some south Indian taxa like, *Meiogyne pannosa* Dalz., *Popowia ramosissiana* Bedd. *Lepisanthes tetraphylla* Radlk., *Gomphandra coriacea* Wight, *Sapindus trifoliatus* Linn. *Filicium decipiens* (Wigth & Arn.) Hook. f., *Millettia atropurpuria* Dunn., *Humboldtia vahliana* Wright, *Diospyros ebenum* Kurz., *Wagatia spicata* Dalz., *Cinnamomum tavoyanum* Meiss. and *Bridelia ovata* Kurz.

The present floral assemblage consists of 4 major types of elements: (i) Evergreen: *Gomphandra coriacea* Wight, *Lepisanthes fruticosa* (Roxb.) Leenh., *Harpullia arborea*

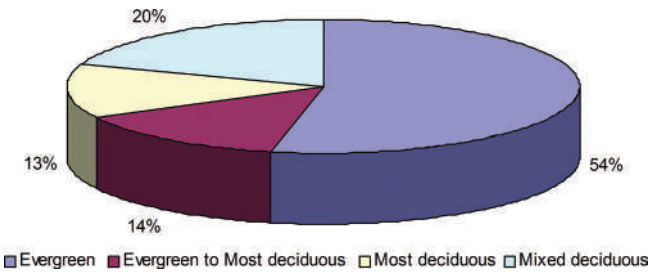

Fig. 6—Diagrammatic representation of vegetation complex during the Siwalik in Tanakpur area, Uttarakhand, India.

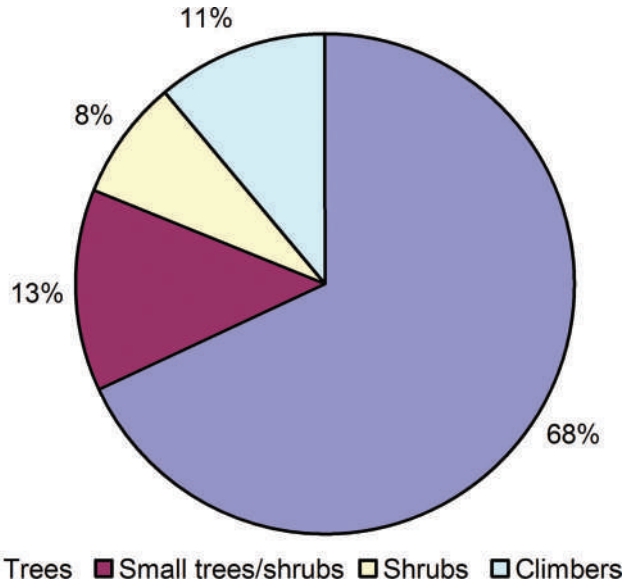

Fig. 7—Diagrammatic representation of different type of forest elements in the Siwalik flora of Tanakpur area, Uttarakhand, India.

Table 4—Present day distribution and forest type of modern comparable taxa of fossil of Tanakpur area, Uttarakhand, India.

Fossil taxa	Modern comparable taxa	Forest type	Present day distribution
LILIOPSIDA			
Marantaceae			
Donax kasauliensis (Awasthi & Prasad) n. comb.	*D. ovatus* Benth. & Hook..	Moist deciduous to Evergreen	Sub–himalayan tract, Andaman, Myanmar
MANGNOLIOPSIDA			
Annonaceae			
Annona miocenica sp. nov.	*A. reticulata* Linn.	Moist deciduous	West Bengal
Popowia siwalica sp. nov.	*P. ramosissiana* Bedd.	Evergreen to Moist deciduous	South India
Miliusa (Saccopetalum) pretomentosa Prasad *et al.*	*S. tomentosum* Hook. f. & Th.	Mixed deciduous	N.E. India, South India
Meiogyne purniyagiriensis sp. nov.	*M. pannosa* Dalz.	Evergreen	South & Central India
Dendrokingstonia palaeonervosa sp. nov.	*K. nervosa* Hook. f. & Th..	Evergreen	Malaya
Ellipeia miocenica Shashi *et al.*	*E. cuneifolia* Hook. f. & Th.	Evergreen	Malaya
Mitrephora siwalika Antal & Awasthi; Shashi *et al.*	*M. maingayi* Hook f, & Th..	Evergreen	N.E. India, Myanmar, Malaya, Sri Lanka
Comiphora precaudata Shashi *et al*.	*C. caudata* Engl.	Mixed deciduous	Malaya, Philippines
Polygalaceae			
Securidaca precorymbosa sp. nov.	*S. corymbosa* Triana & Planch	Moist deciduous	N.E. India
Xanthophyllaceae			
Xanthophyllum mioglaucum sp. nov	*X. glaucum* Wall.	Evergreen	Myanmar, Malaya
Clusiaceae			
Kayea kalagarhensis Prasad	*K. floribunda* Wall.	Evergreen	N.E. India, Myanmar
Calophyllum suraikholaensis Awasthi & Prasad	*C. polyanthum* Wall.	Evergreen	South India, Malaya, Sri Lanka
Dipterocarpaceae			
Dipterocarpus suraikholaensis Prasad & Pandey	*D. turbinatus* Gaertn.	Evergreen	Andaman, Myanmar, Malaya
Parashorea mioplicata sp. nov.	*P. plicata* Brandis	Evergreen	Philippines
Hopea kathgodamensis Prasad	*H. dryobalanoides* Miq.	Evergreen	South East Asia
Sterculiaceae			
Sterculia tertiara Shashi *et al.*	*S. ensifolia* Mast.	Evergreen	Philippines
Rutaceae			
Toddalia purniyagiriensis sp. nov.	*T. asiatica* Lamk.	Evergreen	Sumatra, Java, Philippines, China
Atalantia siwalica sp. nov.	*A. monophylla* Corr.	Moist deciduous	N.E. India, Myanmar, South India
Clausena miocenica sp. nov.	*C. anisumolens* (Blanco.) Meer.	Evergreen	Philippines, Malaya, Borneo
Zygophyllaceae			
Balanites siwalica sp. nov.	*B. roxburghii* (L.) Del.	Mixed deciduous	India and Myanmar
Meliaceae			
Aglaia purniyagiriensis sp. nov.	*A. biclor* Merr.	Evergreen	Philippines

Stemonuraceae			
Gomphandra palaeocoriacea sp. nov.	*G. coriacea* Wight	Evergreen	South India, Western Ghat
Rhamnaceae			
Ventilago miocalyculata sp. nov.	*V. calyculata* Tul.	Moist deciduous	Sub–himalayan tract, Assam, Myanmar
Sapindaceae			
Sapindus eotrifoliatus sp. nov.	*S. trifoliatus* Linn.	Evergreen	South India, Sri Lanka
Lepisanthes miocenica sp. nov.	*L. fruticosa* (Roxb.) Leenh.	Evergreen	Indo–China, South East Asia
Lepisanthes tanakpurensis sp. nov.	*L. tetraphylla* Radlk	Moist deciduous	South and Central India
Harpullia siwalica Prasad & Awasthi	*H. arborea* (Blanco.) Radlk.	Evergreen	N.E. India, Malaya, Myanmar, Sri Lanka, Australia, Thailand
Filicium koilabasensis Prasad	*F. decipiens* (Wight & Arn.) Hook. F.	Evergreen	Western Ghat, Nilgiris, Sri Lanka, Tropical Asia
Anacardiaceae			
Drimycarpus siwalicus sp. nov.	*D. racemosus* Hook. f..	Evergreen	N.E. India, Bangladesh, Bhutan
Bouea premacrophylla Antal & Awasthi	*B. macrophylla* Grifith	Evergreen	Andaman, Sunderban, Malaya
Sabiaceae			
Sabia eopaniculata Prasad	*S. paniculata* Seem.	Moist deciduous	Sub–himalayan tract, Myanmar, Malaya
Connaraceae			
Gnestis purniyagiriensis sp. nov.	*G. ramiflora* Grifith	Evergreen	Myanmar, Andaman
Fabaceae			
Bauhinia nepalensis Awasthi & Prasad	*B. malabarica* Roxb. and *B. variegata* Linn.	Mixed deciduous	Sub–himalayan tract, Central & South India, Myanmar
Bauhinia purniyagiriensis sp. nov.	*B. finlaysoniana* (Benth.) Backer	Evergreen	South East Asia
Millettia mioinermis sp. nov.	*M. inermis* (Wright) DC.	Evergreen & Moist deciduous	Africa, West Indies and Tropical America
Millettia siwalica Prasad	*M. ovalifolia* Kurz.	Evergreen & Moist deciduous	Myanmar
Millettia prakashii Shashi *et al*.	*M. atropurpuria* Dunn.	Evergreen	South India, Myanmar
Humboldtia miocenica sp. nov.	*H. vahliana* Wright	Evergreen	Western Ghat, Nilgiris, Travancore
Wagatia miospicata sp. nov.	*W. spicata* Dalz.	Mixed deciduous	South India
Dalbergia tanakpurensis sp. nov.	*D. indana*	Evergreen and Moist deciduous	South East Asia
Derris prakashii Prasad *et al*.	*D. trifoliatus* Lour.	Moist deciduous	Andaman, Sri Lanka, Africa
Derris mioscandens sp. nov.	*D. scandens* Benth.	Mixed deciduous	India, Myanmar, Andaman
Pongamia siwalica Awasthi & Lakhanpal	*P. pinnata* Pierre	Evergreen to Moist deciduous	India, Myanmar, Sri Lanka
Cynometra palaeoiripa Prasad *et al*.	*C. iripa* Kostel	Mixed deciduous	India, Malaya
Cynometra siwalica Awasthi & Lakhanpal; Shashi *et al*	*C. polyandra* Roxb.	Evergreen	N.E. India, Malaya
Millettia purniyagiriensis Shashi *et al.*	*M. auriculata* Backer	Mixed deciduous	Sub–himalayan tract, Central India
Caesalpinia purniyagiriensis Shashi *et al.*	*C. microphylla* G. Don	Evergreen	N.E. India, Malaya, Peninsula

Combretaceae			
Terminalia bhairauvensis sp. nov.	*T. argyrophylla* King & Prain	Moist deciduous	Myanmar
Combretum purniyagiriense sp. nov.	*C. sundaicum* Miquell	Moist deciduous	India, Malaya
Melastomataceae			
Medinilla siwalica sp. nov.	*M. ramiflora* Merr.	Evergreen	Malaya
Lythraceae			
Lagerstroemia prakashii sp. nov.	*L. flosreginae* Reitz.	Mixed deciduous	N.E. India, South India, Myanmar, Sri Lanka
Lagerstroemia mioparviflora Dwivedi *et al*.	*L. parviflora* Roxb.	Mixed deciduous	Sub–himalayan tract, N.E. India, Myanmar
Rubiaceae			
Ixora purniyagiriensis sp. nov.	*I. lobbii* London	Evergreen	Malaya, Indo–China, Java, Borneo
Randia tanakpurensis sp. nov	*R. floribunda* Lam.	Mixed deciduous	India, Myanmar, Sri Lanka
Ebenaceae			
Diospyros palaeoebenum Shashi *et al*.	*D. ebenum* Kurz.	Evergreen to Moist deciduous	South and Central India, Sri Lanka
Diospyros purniyagiriensis sp. nov.	*D. variegata* Kurz.	Evergreen	N.E. India, Myanmar, Martaban Hills
Apocynaceae			
Chonemorpha miocenica Prasad & Awasthi; Shashi *et al*.	*S. macrophylla* G. Don	Evergreen	N.E. India, Western Ghat, Malaya
Sapotaceae			
Palaquium palaeograndis sp. nov.	*P. grandis* (Thwaits) Engl.	Evergreen	Indo–Malayan region
Chrysophyllum bhairauvensis sp. nov.	*C. viridifolium* Wood & Franks	Evergreen	S.E. Asian region and S.E. Africa
Lauraceae			
Cinnamomum palaeotamala Lakhanpal & Awasthi	*C. tamala* Nees	Evergreen to Moist deciduous	N.E. India, Myanmar, Sub–himalayan tract
C. nepalensis Prasad & Pandey; Shashi *et al.*	*C. caudatum* Nees	Evergreen to Moist deciduous	N.E. India, Myanmar
C. miotavoyanum Shashi *et al.*	*C. tavoyanum* Meiss.	Evergreen	South India and Myanmar
Persea purniyagiriensis Lakhanpal & Guleria	*Persea* spp.	Evergreen	Indo–Malayan region
Myristicaceae			
Myristica siwalica sp. nov.	*M. crassa* King	Evergreen	Indo–China, Sumatra, Malaya
Euphorbiaceae			
Mallotus prejaponicus sp. nov.	*M. japonicus* Spreng	Evergreen	South East Asia, Phillipines,
M. kalimpongensis Antal & Awasthi	*M. phillipinensis* Muel. Arg.	Mixed deciduous	Andaman, Myanmar, Sri Lanka
Baccaurea miocenica sp. nov.	*B. tetrandra* Lour.	Evergreen	N.E. India, Myanmar, Malaya
Bridelia hanumanchattiensis sp. nov.	*B. ovata* Kurz.	Mixed deciduous	Andaman
Moraceae			
Ficus precunea Lakhanpal	*F. cunea* Ham.	Evergreen	Sub–himalayan tract, Assam, Myanmar
Urticaceae			
Sarcochlamys miopulcherrima sp. nov.	*S. pulcherrima* Gaudich	Evergreen	Indo–Malaya

(Blanco.) Radlk., *Filicium decipiens* (Wigth & Arn.) Hook. f., *Drimycarpus racemosus* Hook. f., *Gnestis ramiflora* Grifith, *Bouea macrophylla* Griffith, *Bauhinia finlaysoniana* (Benth.) Baker, *Millettia atropurpuria* Dunn., *Humboldtia vahliana* Wright, *Cynometra polyandra* Roxb., *Caesalpinia microphylla* G. Don, *Medinilla ramiflora* Merr., *Ixora lobbii* London, *Diospyros variegata* Kurz., *Chonemorpha macrophylla* G. Don, *Palaquium grandis* (Thwaites) Engl., *Chrysophyllum viridifolium* Wood & Franks, *Cinnamomum tavoyanum* Meiss. *Persea* spp., *Myristica crassa* King, *Mallotus japonicus* Spreng, *Baccauria tetrandra* Lour. and *Sarcochlamys pulcherrima* Gaudich. (ii) Evergreen and Moist deciduous: *Donax ovatus* Benth. & Hook., *Popowia ramosissiana* Bedd. *Millettia inermis (*Wright) DC., *Millettia ovalifolio* Kurz., *Dalbergia indana, Pongamia pinnata* Pierre., *Diospyros ebenum* Kurz., *Cinnamomum tamala* Nees, *Cinnamomum caudatum* Nees, *Sapindus trifoliatus* Linn. and (iii) Moist deciduous: *Anona reticulate* Linn., *Atalantia monophylla* Corr., *Securidaca corymbosa* Triana & Planceh, *Ventilago calyculata* Tul., *Lepisanthes tetraphylla* Radlk., *Sabia paniculata* Seem., *Derris trifoliatus* Lour., *Terminalia argyrophylla* King & Prain, and *Combretum sundaicum* and (iv) Mixed deciduous: *Miliusa (Saccopetalum tomentosum* Hook. f. & Th.)., *Comiphora caudata* Engl, *Balanites roxburghii* (L.) Del., *Bauhinia malabarica* Roxb. and *Bauhinia variegata* Linn., *Wagatia spicata* Dalz., *Derris scandens* Benth., *Cynometra iripa* Kostel, *Millettia auriculata* Backer, *Lagerstroemia flosreginae* Retz., *Lagerstroemia parviflora* Roxb., *Catunaregam spinosa* (Thunb.) Tirveng (*Randia floribunda* Lam.), *Mallotus philippinensis* Muell. Arg., *Bridelia ovata* Kurz., *Ficus cunea* Buch–Ham. (Fig.7). The evergreen elements dominate the assemblage as compared to other elements. This obviously indicates that the tropical evergreen forests were growing around Tanakpur area during Middle Miocene as compared to the present mixed deciduous forests in the region. It is further inferred that the evergreen taxa which were growing in the vicinity of Tanakpur have got migrated to other phytogeographical regions due to unfavourable climatic conditions prevailed after Mio–Pliocene Period most probably due to the uplift of Himalaya. Thus the evergreen elements dominate the flora of Tanakpur area (Fig. 7; Table, 4) during Siwalik Period in contrast to mixed deciduous vegetation occurring today in the area (Kanji Lal, 1950;). The present day distribution of modern equivalents of all 71 species recovered from the Siwalik of Tanakpur area shows that they are presently known to grow in different geographical regions all over India, Nepal and other places (Table 4; Fig. 8;). In India, they are distributed mostly in North–east and southern regions wherever favourable climatic conditions are available. In this assemblage, there are about 17 those taxa which are found to grow both in India and Malaya peninsula. They are *Donax ovatus* Benth. & Hook., *Mitrephora maingayi* Hook. f. & Th., *Xanthophyllum glaucum* Wall., *D. turbinatus* Gaertn., *Calophyllum polyanthum* Wall., *Harpullia arborea* (Blanco.) Radlk., *Bouea macrophylla* Griffith, *Caesalpinia microphylla* G. Don, *Combretum sundaicum, Chonemorpha macrophylla* G. Don, *Palaquium grandis* (Thwaites) Engl., *Persea* spp., *Baccauria tetrandra* Lour. *Sarcochlamys pulcherrima* Gaudich. which clearly indicate that there has been a fair exchange of floral elements between the two subcontinents after the land connections were established during the Miocene Period.

Besides, 17 taxa in the present assemblage have a restricted distribution in the South–east Asian region. These are *Dendrokingstonia nervosa* Hook. f. & Th. *Ellipeia cuneifolia* Hook. f. & Th., *Parashorea plicata* Brandis, *Comiphora caudata* Engl., *Hopea dryobalanoides* Miq., *Sterculia ensifolia* Mast, *Toddalia asiatica* Lamk., *Clausena anisumolens* (Blanco.) Meer., *Aglaia biclor* Merr., *Lepisanthes fruticosa* (Roxb.) Leenh., *Bauhinia finlaysoniana* (Benth.), *Dalbergia indana, Medinilla ramiflora* Merr., *Ixora lobbii* London, *Chrysophyllum viridifolium* Wood & Franks, *Myristica crassa* King, *Mallotus japonicus* Spreng and obviously suggesting that these taxa either migrated from South–east Asia to India during Neogene and flourished around Tanakpur area at the time of deposition of Siwalik sediments or they disappeared from the area probably due to change in climatic conditions after Late Miocene and diversified towards South–east Asian region.

About 20 taxa in the present assemblage still grow in North–east India, Bangladesh and Myanmar (Table 5). These are *Annona reticulata* Linn., *Saccopetalum tomentosum* Hook. f. & Th., *Securidaca corymbosa* Triana & Planceh, *Kayea floribunda* Wall., *Atalantia monophylla* Corr., *Ventilago calyculata* Tul., *Drimycarpus racemosus* Hook. f., *Gnestis ramiflora* Grifith, *Bauhinia malabarica* Roxb. and *Bauhinia variegata* Linn., *Millettia ovalifolia* Kurz., *Derris scandens* Benth., *Millettia auriculata* Backer, *Terminalia argyrophylla* King & Prain, *Lagerstroemia parviflora* Roxb., *Randia floribunda* Lam., *Diospyros variegata* Kurz., *Cinnamomum tamala* Nees, *Cinnamomum caudatum* Nees, *Ficus cunea* Ham. This suggests that these taxa were present during

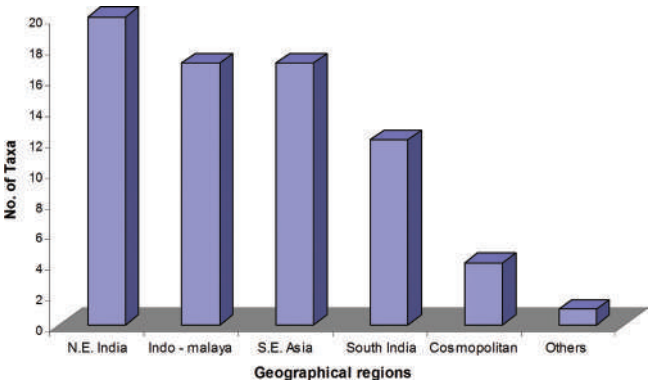

Fig. 8—Diagrammatic representation of fossil flora in different geographical regions.

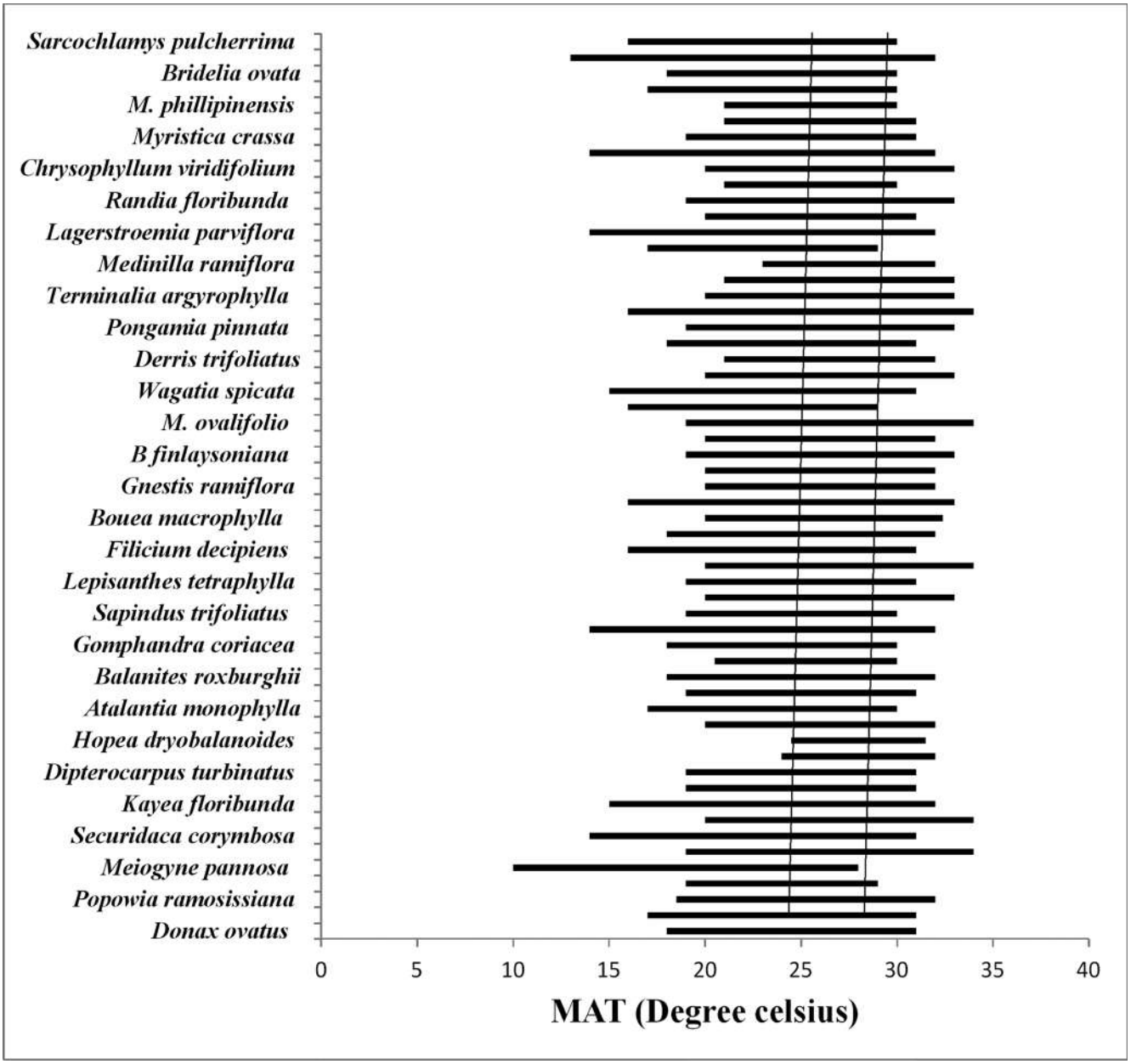

Fig. 9a—Showing the coexistence intervals of climatic parameter, Mean Annual Temperature (MAT) of modern relatives of all the 29 taxa recorded from Tanakpur area, Uttarakhand (▬ indicate the intervals of coexistence) and vertical line indicating the common range of MAT.

Middle Miocene in the foot–hills near Tanakpur area but do not grow now a days there and thus they have migrated toward east in Assam, Bengal, Sikkim, Meghalaya, Bangladesh and Myanmar because of better favourable conditions.

The floral assemblage also indicates that there are few taxa which are found to grow still at different altitudes in the foot–hills around Tanakpur and adjoining areas (Table 4) which suggest that they have susceptibility to adopt in the new climatic conditions prevailing after Middle Miocene mainly due to further rise of Himalaya.

The analysis of the fossil plants recovered from the Lower Siwalik of Tanakpur area and the present day distribution of their modern equivalents indicate that all the taxa can be classified into 3 types:

Extant taxa: Those taxa which have their living counterparts growing in or near the fossil locality.

Exotic taxa: Those taxa which grow in other parts of India.

Extinct taxa: Those taxa which have disappeared from India and now grow in other parts of the world.

The above different patterns of plant distribution suggest that there may be two possible explanations for these distribution patterns. The exotic taxa may have had a wider distribution in the Miocene, which subsequently

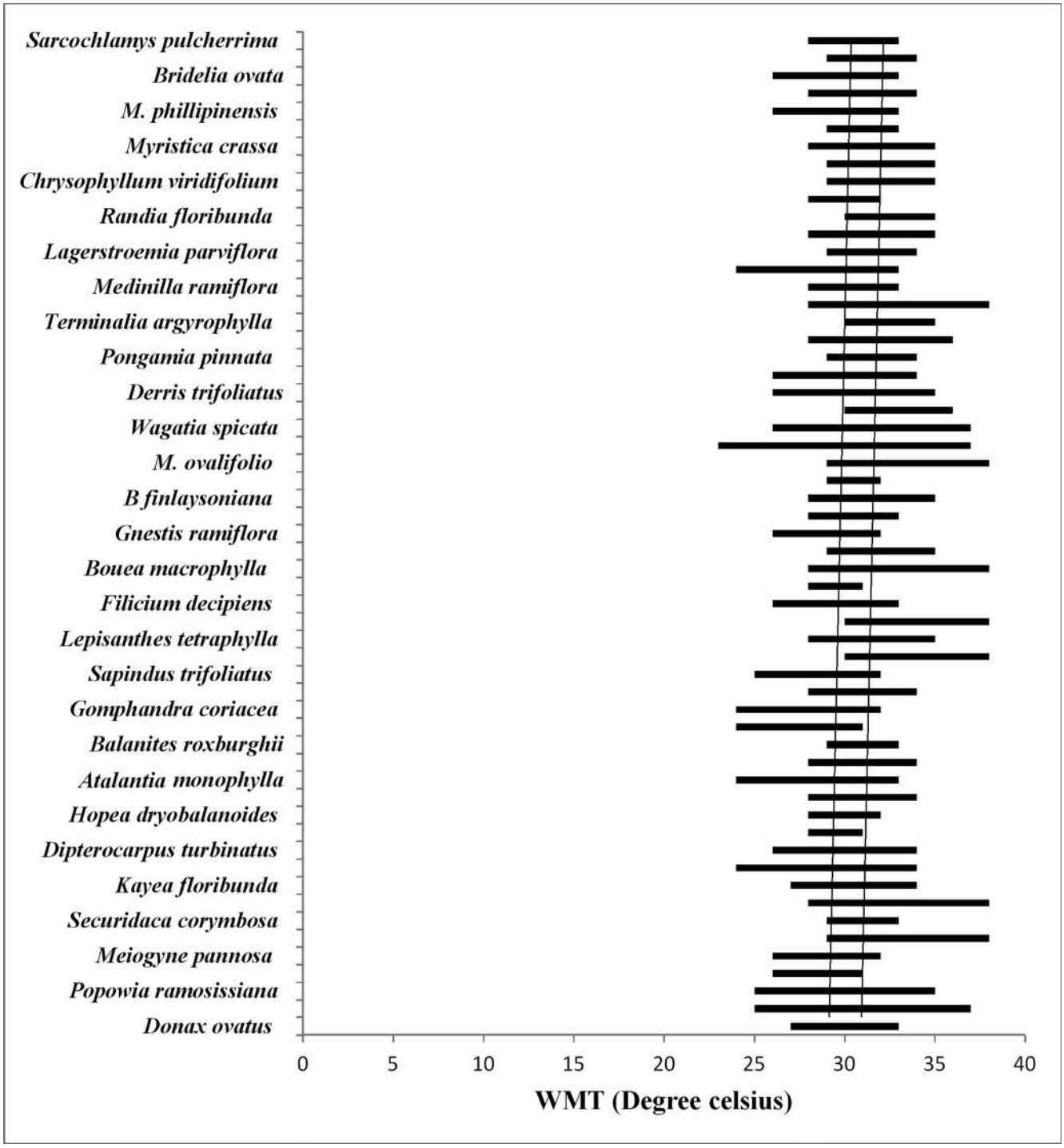

Fig. 9b—Showing the coexistence intervals of climatic parameter, Mean Temperature of Warmest month (WMT) of modern relatives of all the 29 taxa recorded from Tanakpur area, Uttarakhand (▬ indicate the intervals of coexistence) and vertical line indicating the common range of WMT.

contracted perhaps due to a changing climate. On the other hand, these taxa may have reached the Himalayan foot–hills in the Tanakpur area by dispersal mechanism from other subcontinents, most probably at the time of former existed land connections or from other areas of India, but subsequently became extinct.

The present assemblage is mainly represented by the members of the tropical families Annonaceae, Fabaceae, Dipterocarpaceae and Anacardiaceae (Table 4). The fossil record of these families shows that they were abundant in other parts of India and Nepal in the Neogene Period (Bande & Prakash, 1984; Prasad & Awasthi, 1996; Prasad *et al*., 1997;

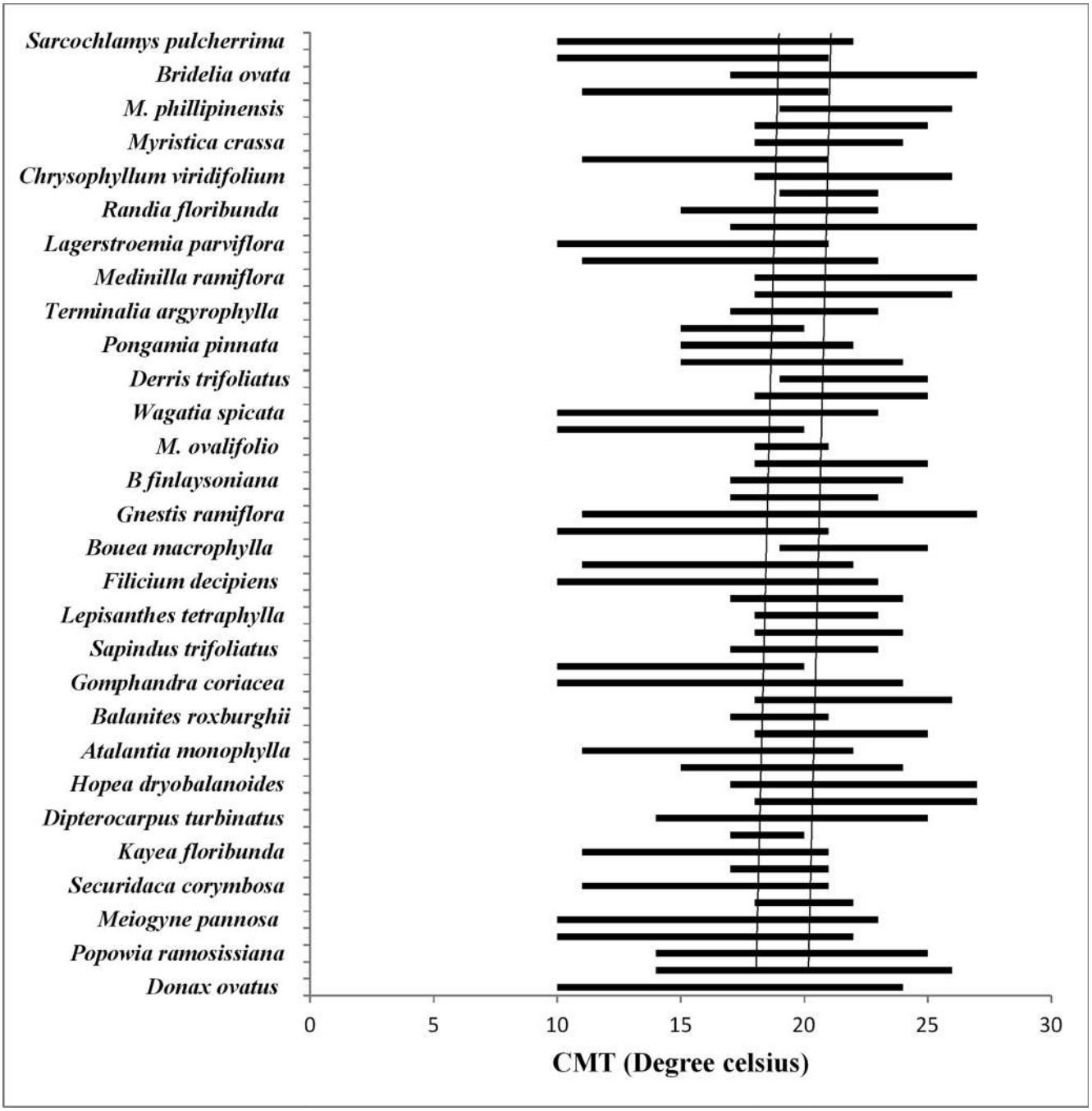

Fig. 9c—Showing the coexistence intervals of climatic parameter, Mean Temperature of Coldest month (CMT) of modern relatives of all the 29 taxa recorded from Tanakpur area,Uttarakhand (▬ indicate the intervals of coexistence) and vertical line indicating the common range of CMT.

Prasad, 2008, 1994a, b), whereas during Palaeogene the family Fabaceae was hardly represented and Dipterocarpaceae was absent throughout the Indian Subcontinent. It indicates that these two families may have entered India during the Neogene after the establishment of land connections with those land area where they were flourishing in the Palaeogene Period.

Dipterocarpaceae may be regarded as one of the most important family. The present and past distribution of this family indicates that it is pan tropical and specially belongs to tropical Asia except that two genera *Marquesa* and *Monotes* which are distributed in the African regions. The fossil record suggests that Dipterocarpaceae originated during the early Middle Oligocene (Merril, 1923; Muller, 1970). Lakhanpal (1974) further envisaged that the family originated in western Malaysia, where about two third of all dipterocarps species occur today (Desch, 1957). This region is also quite rich in the fossil record (Lakhanpal, 1974; Bande & Prakash, 1986). From western Malaysia dipterocarps spread eastward to

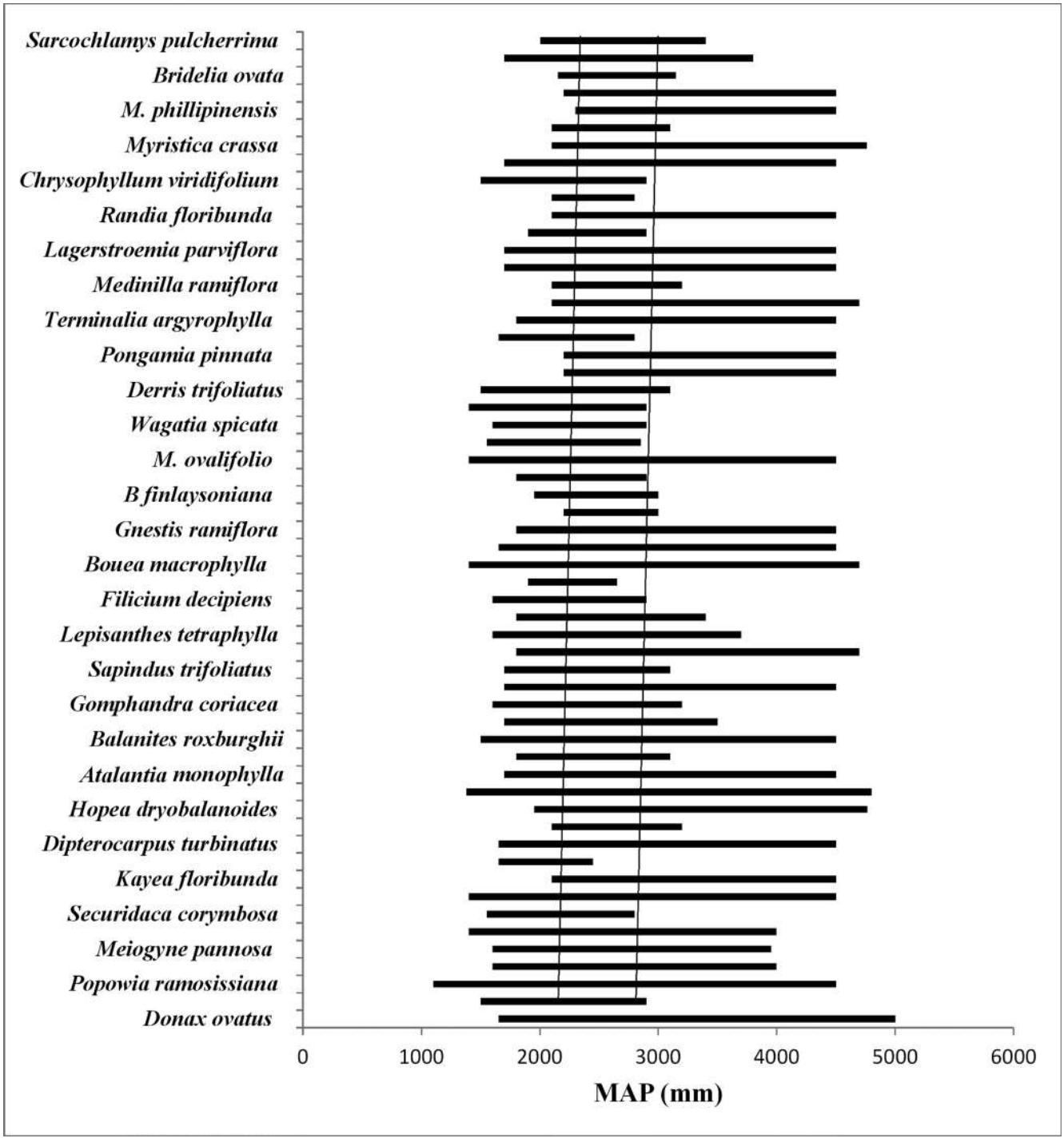

Fig. 9d—Showing the coexistence intervals of climatic parameter, Mean Annual Precipitation (MAP) of modern relatives of all the 29 taxa recorded from Tanakpur area, Uttarakhand (▬ indicate the intervals of coexistence) and vertical line indicating the common range of MAP.

Philippines and northward through Myanmar to India. The possible time of the southwest migration was Early Miocene when the land connections between Malaya, Myanmar and eastern India were established. The abundance of dipterocarps such as *Dipterocarpus, Anisoptera, Isoptera, Shorea, Hopea, Dryobalanops* in eastern India as well as in southern India during Miocene–Pliocene times indicates that they spread from eastern India to south west to Sri Lanka via Himalayan foot–hills where they are still flourishing. The occurrence of dipterocarpaceous remains (fossil woods, leaves, fruits, and impressions) in the Himalayan foot–hills (Antal & Awasthi, 1993; Antal & Prasad, 1996b; Prasad, 1994a, e, 2008; Prasad

& Awasthi, 1996; Prasad *et al.,* 1999, 2004; Table 4) and the Tertiary beds of Africa (Bancroft, 1933; Chiarugi, 1933) suggests that from eastern India the dipterocarps also spread westward into Africa most probably via Arabia (Lakhanpal, 1970; Seward, 1935).

Regarding the phytogeography of the family Dipterocarpaceae, one hypothesis says that the dipterocarpaceous members originated on the Eurasian Plate possibly in the Malaysian region and migrated westward and towards south Asia/ India and Africa. This hypothesis is mainly based on assumption of high species diversity of dipterocarps. These originated there in the Late Mesozoic and migrated into India during Late Cenozoic Era. (Lakhanpal, 1970; Sasaki, 2006). The other hypothesis suggested that the dipterocarps originated in Gondwana (Croizat, 1952; Ashton, 1982) and reach Asia by rafting on the Indian Plate (Dayanandan *et al.*, 1999; Ducousso *et al.*, 2004). Moreover, the fossil resin chemistry and palynological data from 50 Ma old sediments suggest that the Asian dipterocarps migrated from India into Asia as the land connection between the Indian and the Asian Plates was established at ca. 50 Myrs ago (Scotese *et al.*, 1988; Rowly, 1996; Dutta *et al.,* 2011). Conti *et al.* (2002) also opined that many of the Angiosperms did not originate in the South–east Asian region but dispersed into the area from western Gondwana land. This view is strongly supported by the earliest record of fossil dipterocarps from Oligocene sediments (34–23 Ma) of Borneo, a centre of presently high diversity of dipterocarps with more than 280 species (Muller, 1981). According to Morley (2000) the dipterocarps originated within the Late Cretaceous rain forest of Africa or South America before they split. Like the rain forest, the family Dipterocarpaceae probably also experienced widespread expansion under the climatic optimum from the Palaeocene to the Middle Eocene. The diversification of the dipterocarps in Africa and South America are rarely documented in the fossil record (Ashton, 1982) perhaps due to the unfavourable depositional environment. The earliest fossil record of this family based on resin and pollen grain from early Eocene of western India (Dutta *et al*., 2011) indicates the wide spread existence of the Asian sub family Dipterocarpoideae in the early Eocene extremely equatorial climate of the Indian Plate prior to the early Eocene collision of India with Asia (Morley, 2000; Copley *et al*., 2010). Due to climatic change during the Late Eocene and Oligocene the diversification of dipterocarps decreases across the Indian sub–continent (Morley, 2000). The occurrence of fossil leaves of *Dipterocarpus* in the early Miocene sediments of North West India (Guleria *et al.,* 2000) indicates the continuity of this family form Oligocene. In the Middle Miocene climate became warmer and moister due to uplift of the Himalaya (Morley, 2000) and made suitable for a drastic increase in their species diversity and became a dominant group in the forests of the Indian sub continent as evidenced by geological distribution and diversification during Miocene (Prasad, 2008; Guleria, 1992). On increasing aridity and seasonality after Late Miocene and Pliocene the climatic conditions became unsuitable for the growth of dipterocarps and thus started towards their gradual disappearance along with the other moist loving species of Angiosperms form the most part of India (Except South and North–east India) (Morley, 2000; Prasad, 2008). The record of the most of the species in present assemblage also supports this view.

PALAEOCLIMATIC ESTIMATION

Palaeoclimate estimation from fossil plants is one of the most important contributions of palaeobotanical studies. The present is the key to the past. The principal basis to any study of the past is the principle of 'Uniformity in the order of nature'. This principle implies on the physical and biological processes which like today's environment as well as vegetation must have been in the operation since past. Likewise, the type of weather variation and climatic conditions as observed today must also occur in the past. The best approach to the study of palaeoclimate or palaeoecology of a particular area is to compare the fossil floras with the modern vegetation and to know the existing climatic conditions. It is rather difficult to deduce the precise palaeoecology of an area prior to the Tertiary Period, because the modern vegetation is quite different from those of earlier periods. The study becomes more accurate as we go from Palaeocene upward until the Pleistocene as the modern equivalents of the fossil forms still exist in the present day vegetation and obviously the fossils could satisfactorily be compared and identified with the modern taxa.

Thus, the Tertiary fossil plants are supposed to be the reliable indicators of past climate specially those that are referable to modern taxa. The accuracy of interpretations based on them is inversely proportional to the geological ages of the deposits from which the fossils are collected. As the plant fossils for the present study have been collected from the Middle Miocene sediments and the modern equivalents of these fossil forms still exist in the forests of different phytogeographical regions, it has, therefore become easier to deduce the palaeoclimate and palaeoecology of the Tanakpur area in the Himalayan foot–hills of Uttarakhand during Siwalik Period.

The other parameters for deducing palaeoclimate are the physiognomic characters of plant fossils. The presence of fossil leaves in any fossil assemblage plays a deciphering role in interpreting the palaeoclimate and palaeoecology. Further, this is an independent systematic relationship of the species and therefore, it is likely that the errors in interpretation will be less.

Thus, on the basis of plant megafossils especially leaf–impressions, the interpretation regarding palaeoclimate and palaeoecology can be drawn by two methods:

Modern Analog Method i.e. from comparison of the leaf impression with the extant taxa.

Table 5—Physiognomic characters of the fossil leaves recovered from the Siwalik sediments of Tanakpur area, Uttarakhand, India.

Fossil Taxa	Average leaf size sq.cm	Leaf margin Entire (E) Non–entire (N)	Drip tips Presence (P) Absence (A) Indistinct(–)	Nature of Petiole Normal (N) Indistinct (–)	Leaf texture Chartaceous (CH) Coriaceous (CO)	Leaf base shape Acute (A) Obtuse (O) Cuneate (C) Cordate (CR) Attenuate (AT) Indistinct (–)	Leaf Organization Compound vs Simple	Venation pattern Close (C) Distant (D)
Donax kasauliensis	33.60	E	P	–	CH	A	S	C
Annona miocenica	36.75	E	–	–	CH	A	S	C
Popowia siwalica	9.10	E	–	–	CH	O	S	C
Miliusa (Saccopetalum) pretomentosa	24.00	E	–	–	CH	O	S	C
Meiogyne purniyagiriensis	6.00	E	P	–	CH	O	S	C
Dendrokingstonia palaeonervosa	13.90	E	A	–	CH	A	S	C
Ellipeia miocenica	47.52	E	–	–	CO	–	S	C
Mitrephora siwalika	32.00	E	P	–	CH	O	S	C
Comiphora precaudata	7.7	E	P	–	CO	O	C	C
Securidaca precorymbosa	8.75	E	–	–	CO	O	S	C
Xanthophyllum mioglaucum	16.80	E	A	–	CO	A	S	C
Kayea kalagarhensis	37.50	E	P	–	CO	A	S	C
Calophyllum suraikholaensis	16.5	E	–	–	CH	–	S	C
Dipterocarpus suraikholaensis	40.00	E	–	–	CO	–	S	C
Parashorea mioplicata	29.75	E	–	–	CO	O	S	C
Hopea kathgodamensis	11.44	E	P	–	CO	A	S	C
Sterculia tertiara	23.68	E	–	–	CH	A	S	C
Toddalia purniyagiriensis	15.00	E	–	–	CH	A	C	C
Atalantia siwalica	22.75	E	–	–	CO	O	C	C
Clausena miocenica	21.80	E	P	–	CH	A	C	C
Balanites siwalica	7.20	E	A	N	CH	A	C	C
Aglaia purniyagiriensis	21.60	E	–	N	CH	A	C	C
Gomphandra palaeocoriacea	9.9	E	A	N	CO	A	S	C
Ventilago miocalyculata	38.25	E	–	–	CO	O	S	C
Sapindus eotrifoliatus	29.75	E	–	N	CO	A	C	C
Lepisanthes miocenica	33.00	E	–	–	CO	A	S	C
Lepisanthes tanakpurensis	50.75	E	–	–	CO	AT	S	C
Harpullia siwalica	33.25	E	–	–	CH	–	S	C
Filicium koilabasensis	11.00	E	–	–	CH	A	C	C
Drimycarpus siwalicus	56.70	E	–	–	CH	A	S	C

Bouea premicrophylla	36.00	E	P	–	CH	–	S	C
Sabia eopaniculata	22.80	E	P	N	CH	–	S	C
Gnestis purniyagiriensis	6.6	E	A	–	CH	O	C	C
Bauhinia nepalensis	36.00	N	–	N	CO	O	S	C
Bauhinia purniyagiriensis	45.00	E	–	–	CO	–	S	C
Millettia mioinermis	14.00	E	–	–	CO	AT	C	C
Millettia siwalica	12.96	E	A	–	CO	A–O	C	C
Derris mioscandens	5.28	E	A	–	CH	O	C	C
Pongamia siwalica	9.60	E	–	–	CO	AT	C	C
Cynometra palaeoiripa	5.40	E	A	–	CH	A	C	C
Cynometra siwalica	4.28	E	A	–	CO	A	C	C
Millettia purniyagiriensis	46.75	E	–	–	CH	–	C	C
Millettia prakashii	38.00	E	–	–	CO	A	C	C
Caesalpima purniyagiriensis	4.5	E	A	–	CH	O	C	C
Terminalia bhairauvensis	24.0	E	A	–	CH	A–O	S	C
Combretum purniyagiriense	51.00	E	–	–	CH	–	S	C
Medinilla siwalica	2.24	E	P	–	CH	–	S	C
Lagerstroemia prakashii	105.56	E	P	N	CO	A	S	C–D
Lagerstroemia mioparviflora	9.0	E	–	–	CH	O	S	C–D
Ixora purniyagiriensis	49.00	E	–	–	CH	C	S	C
Randia tanakpurensis	22.80	E	A	–	CO	C	S	C–D
Diospyros palaeoebenum	41.6	E	–	N	CO	A	S	C
Diospyros purniyagiriensis	112.00	E	–	–	CO	A	S	C
Chonemorpha miocenica	96.00	E	P	–	CO	O	S	C
Palaquium palaeograndis	52.80	E	–	–	CH	A–C		
Chrysophyllum bhairauvensis	12.54	E	P	–	CH	O	S	C
Cinnamomum palaeotamala	52.00	E	–	N	CO	A	S	C
C. nepalensis	15.75	E	A	–	CO	–	S	C
C. miotavoyamum	48.64	E	–	N	CO	A–C	S	C
Persea purniyagiriensis	31.08	E	–	N	CH	A	S	C
Myristica siwalica	78.30	E	A	–	CH	A	S	C
Mallotus prejaponicus	46.40	N	P	N	CH	A	S	C–D
M. kalimpongensis	16.25	E	–	–	CH	A–D	S	C
Baccaurea miocenica	33.95	E	–	–	CH	C	S	C–D
Bridelia hanumanchattiensis	19.20	E	A	–	CO	–	S	C
Ficus precunea	7.00	E	–	–	CO	CR	S	C–D
Sarcochlamys miopulcherrima	20.4	E–N	–	–	CO	O	S	C

Foliar Physiognomy Method i.e. from study of the structural features of leaf impressions.

MODERN ANALOG METHOD

This deals with the interpretation of past climate by using the climatic preferences of modern plants. Climate reconstruction using fossil assemblage requires three bits of information: (1) a living relative for each fossil species (2) the autoecology of the living relatives of each fossil species and (3) a modern association of species similar to the fossil flora. In the real sense, the modern analogue community should be similar to the fossil assemblage in both species composition and relative abundance of taxa. The plant fossils collected from Tanakpur area have been compared with their modern equivalents and it has been observed that all of them still exist in the different geographical area. Therefore, it is easier to infer the palaeoclimate of the region during the past.

Keeping in mind the few assumptions given by Utescher *et al*. (2014), the quantitative climatic result for the present fossil flora can be constructed by Coexistence Approach (CoA) with consideration of the following four steps–(1). For each fossil taxon, the modern analogs / nearest living relatives (NLR) is determined (2). For each NLR the modern distribution area is compiled (3). For each distribution area the range of climate parameters (MAT, MAP) is determined separately (4). For each climate parameter analysed, the climatic ranges in which maximum number of NLRs of fossil flora can coexist, is determined. Accordingly, the coexistence intervals of each climatic parameter such as MAT (Mean Annual Temperature), temperature of warmest month (WMT), and coldest month (CMT) as well as mean annual precipitation MAP) of all the modern taxa of Tanakpur fossil assemblage have been obtained from published literature (Champion & Seth, 1968) and Climatological table of observation in India (1931–1960) as well as through internet (www.weatherandclimate.com/average-monthly-rainfall-temperature-sunshine-in Malaysia/-in Philippines; www.en.climate-data.org; www.sdwebx.worldbank.org; www.weatherspark.org, etc.) and on its application it has been found that the value of Coexistence interval for MAT, WMT, CMT and MAP are 24.0–28.0ºC, 28.5–31.5ºC, 18–20ºC and 2100–2800 mm respectively under which all the fossil taxa once lived (Figs 9a–d). Thus, the Modern Analog Method/ Coexistence Approach CoA suggests that the Tanakpur area in the Himalayan foot hills of Uttarakhand enjoyed a tropical climate having the value of MAT 24–28°C and MAP 2100–2800 mm) during the Middle Miocene.

The fossil plants recovered so far from the Siwalik sediments of the Tanakpur area comprise 71 fossil taxa and all of them were compared with modern taxa (Table 4). The present habit and habitat of these taxa show that they mostly occur in the tropical evergreen and moist deciduous forests of North–east India, Bangladesh, Myanmar and South–east Asian region (Malaya, Philippines, Java, Borneo, etc.) where they receive higher rainfall (Gamble, 1972; Hooker, 1872, 1882, 1884; Champion & Seth, 1968; Desch, 1957; Table 4). Thus it may be surmised that a warm and humid climate prevailed in Tanakpur area in the Himalayan foot hills during Middle Miocene in contrast to the present relatively dry climate there. The predominance of evergreen elements in the assemblage (Table 4; Fig. 7) further indicates the prevalence of tropical (warm humid) climate with plenty of rainfall. Most of the taxa in the fossil assemblage do not occur in the vicinity of Tanakpur or all along the whole himalayan foot–hills of both India and Nepal (Table 4). This obviously indicates that changes in the climate must have taken place after the deposition of Siwalik sediments in this region.

The change in climate after the Middle Miocene Period can also be explained by a general global cooling and by the events within the region, particularly the Himalayan uplift and swallowing of the Tethys Sea which progressively changed from marine through estuarine to fresh water environment (Mukherjee, 1982; Gupta & Kumar, 2013). These climate and physiographic changes made the environment hostile for the endemic flora which was gradually replaced by the present day mixed deciduous forest.

FOLIAR PHYSIOGNOMY METHOD

The morphological features of the leaves reflect some functional and physiological process of the plant. For example, thick, waxy, succulent leaves indicate arid environment in which plant must conserve water. Leaf physiognomy is used to reconstruct the palaeoclimate either by CLAMP or by leaf margin analysis method. This is particularly useful for deducing temperature and precipitation pattern because the leaf is instrumented in maintaining plant water and temperature balance.

Physiognomic features of the fossil angiospermous leaves such as shape, size, venation, density, texture, margin, tip, etc. have a great relationship with climate and thus provides more reliable results (Table 5). As this method is independent of the systematic relationship of the species, the errors in the interpretation of palaeoclimate are minimized as compared to the above Coexistence method. The detailed physiognomic study of the fossil leaves recovered from the Siwalik sediments of Tanakpur area in the Himalayan foot hills of Uttarakhand provides some significant data for the estimation of climatic conditions prevailing in the foot–hills during Siwalik period.

Wolfe (1995) has studied the physiognomic features of modern angiospermous leaves and correlated them with climate in hundreds of communities throughout the world. He took a multivariate approach which compares many combinations of leaf characters using computer programme which is known as CLAMP Method (Climate Leaf Analysis Multivariate Programme Method). In original CLAMP

Method he used 29 leaf characters related to leaf margin, size, apex, base and shape. Later on Herman and Spicer (1996, 1997) used Wolfe's CLAMP data base with an additional leaf size characters to estimate palaeotemperature and palaeoprecipitation for four fossil assemblages. Kovach and Spicer (1996) also used Wolfe's data for the estimation of palaeotemperature and found that the CLAMP Method worked well for MAT (Mean Annual Temperature) in the range of 10º–20ºC but above or below this range could not be accurately estimated. Thus keeping in view the above fact the application of CLAMP to the present fossil flora for the estimation of palaeoclimate would not be useful. Only a few leaf features such as margin size, drip tips, petiole, texture, apex and base, organization and venation density of the angiospermous fossil leaves of Siwalik sediments of Tanakpur area have been analysed here for reconstruction of the palaeoclimate (Table 5).

One of the best indicators of climate appears to be the leaf margin, viz. entire versus non–entire. The approach, Leaf Margin Analysis (LMA) for the reconstruction of climate is based on the work of Baily and Sinnott (1916), who had found a direct relation between the margin and climate. According to him the typical entire margined leaves of woody families like Annonaceae, Lauraceae, Ebenaceae, Clusiaceae, Sapotaceae, Dipterocarpaceae, Apocynaceae, etc. are practically absent from mesophytic cold temperate regions. On the contrary, non–entire leaved families as Betulaceae, Aceraceae, Platanaceae, etc. are absent from low land tropical areas. Nevertheless, the families, like Malvaceae, Rosaceae, Ulmaceae, Fagaceae, Tiliaceae, Flacourtiaceae, Anacardiaceae and Fabaceae possess both types of leaf margins, i.e. entire and non–entire. According to Bailey and Sinnott (1916) the woody plants of tropical low lands possess entire margins, while in temperate they possess non–entire margins. Similarly, Wolfe (1969) concluded that the tropical rain forests have the highest percentage of entire margined species. This percentage decreases with decreasing temperature either with increasing altitude to the submontane and montane rain forests or with increasing latitude to the warm temperate forest. The leaf margin analysis of the fossil leaf assemblage of Tanakpur area, revealed that all the species except three taxa, i.e. *Bauhinia nepalensis, Mallotus prejaponicus,* and *Sarcochlamys miopulcherrima,* have entire margin indicating a warm tropical climate (Table 5). The remaining taxa (95.5%) in the assemblages are with entire margin. Wolfe (1971) presented a comparison of mean annual temperature (MAT) and percentage of species with entire margined leaves for 19 modern floras which increase from 10–86% of entire margined species corresponding to an increase from 40–28ºC in temperature. Similar models were derived from the plot of MAT and percentage of entire margined species by Wolfe, 1979 for the species of eastern Asia, Greenwood (1992) for the species of Australia and Wilf (1997) for the species of America. Converting the plots into linear equations they have given regression models as follows.

MAT = 1.4 + 0.306 X (% entire) by Wolfe, 1979; Wing & Greenwood, 1993)

(In this equation (% entire) is the percentage of leaves in the assemblage that have entire margins).

When this equation is applied to the present floral assemblage it has been found that the MAT value is 30.6 ºC. This suggests that the MAT (Mean annual temperature) during Middle Miocene time all along the Himalayan foot hills was 30.6 ºC which was reduced by (6.2 ºC) at present day (the present day MAT of the Himalayan foot hill zone is 24.40 ºC (Data of 20 year obtained from Indian Metrological Department and Champion and Seth (1968).

The estimated MAT (30.6 ºC) is very significant as it corresponds to the present day MAT value of North–east India (29.04 ºC) where Maximum (more than 28%) comparable taxa of the fossils of Tanakpur area are found (Table 4; Fig. 8). Similarly more than 17% comparable taxa of the fossil assemblages are growing now–a–days in the south Indian region where MAT value varies from 25º to 27 ºC and is responsible for the existence of evergreen forest (Champion & Seth, 1968).

The ‘Drip tip', an extended leaf tip, is also another important physiognomic feature of angiospermous leaves and is generally seen in wet tropical forest elements (Dorf, 1969). The function of the drip tip is to hasten the run off of water from the leaf. Richards (1952) pointed out that it facilitates them to retard the growth of epiphytes. The deciduous leaves generally lack drip tip because of their short life span. In the present fossil assemblage about 14 taxa possess conspicuous drip tips. In some specimens the tips either got broken or indistinct due to bad preservation (Table 5). Thus it also shows the prevalence of tropical humid climate around Tanakpur area during Siwalik sedimentation.

The dicotyledonous leaves are considered to be reliable indicators of terrestrial palacoclimate. It has been seen that leaf size distribution in any forest type is correlated with available moisture and it is found bigger in the understory elements of evergreen forests but decreases with low temperature or precipitation. Raunkiaer (1934) suggested that the percentage of species having large leaves should be highest on the piedmont somewhat higher on the mountain in order to correlate with precipitation. Further, Givinish (1976) has also postulated that optimal size, as determined by the balance between transpiration rate and phytosynthesis, should be greatest in the tropics, decreases in the subtropics and increases in the warm temperate forests. The leaf size may be measured typically by 5 size classes, viz. leptophyll (up to 0.25 sq cm), nanophyll (0.25–2.25 sq cm), microphyll (2.25–20 sq cm), mesophyll (20–182 sq cm) and macrophyll (182–1640 sq cm; Raunkiar, 1934; Webb, 1959). According to this classification the fossil leaves recovered from Siwalik of Tanakpur area are mainly mesophyll type which indicates

that a tropical humid climate was prevailed in the area during Middle Miocene.

Wilf *et al.* (1998) found a strong relation between the Mean Annual Precipitation (MAP) and average leaf area. He has formulated an equation to estimate the MAP by using the proportion of large size leaves in the assemblage of any region. This equation is as follows:

MAP = 47.5 + 6.18X (% Large leaves)

(% Large leaves) is the percentage of leaves in an assemblage of mesophyll size or larger in area (≥ 33 cm^2).

In order to estimate the Mean Annual Precipitation (MAP) of Himalayan foot–hills in Tanakpur area during Middle Miocene time the above equation is applied to the Tanakpur leaf assemblages and found that the MAP value is 3970 mm. When this MAP value has been compared with the present MAP value of different places in the Himalayan foot hills (i.e. Jammu 890 mm, Kathgodam and Tanakpur 1670 mm., Hardwar 1800 mm, Surai Khola and Koilabas 1060 mm and Siliguri 2790 mm) it has been seen that their average MAP value (1640 mm) is reduced by 2330 mm. This difference in MAP value of the present and past is much higher which can affect the climatic condition as well as the flora of the region.

The MAP value estimated from the fossil leaf assemblages of Tanakpur area has also been compared with the present MAP value of those regions (North–east India and South India) where now a days, most of the comparable species of the fossils are growing luxuriantly. It shows very less difference in the MAP value of North–east Indian (i e. Assam 2740 mm, Kuchagaon 3350 mm, Siliguri 2790 mm) and South India (Kerala 2780 mm and Karnataka 2810 mm).

CONCLUSION

This study added significant data to the Tertiary Palaeobotany. On the basis of present assemblage as well as already known data from the area, the palaeoclimate, palaeoecology and phytogeography of the area during Middle Miocene in the Himalayan foot–hills of Uttarakhand have been deduced. The palaeoclimate estimation has also been made on the basis of leaf features through leaf physiognomy method.

The morphotaxonomical study on the plant fossils (leaf and fruit impressions) collected from Lower Siwalik sediments of Tanakpur area, Uttarakhand revealed the occurrence of 57 species of 26 angiospermous families. Of these, 39 species have been recorded new to the fossil flora of Himalayan foot hills and remaining 18 species are reported already from different Siwalik fossil localities in the Himalayan foot hills of India, Nepal and Bhutan. The family Fabaceae (Legume family) represented by 15 species is the most dominant family in this Siwalik fossil assemblage followed by Annonaceae (8 species), Sapindaceae (5 species), Lauraceae and Euphorbiaceae (4 species) and Dipterocarpaceae and Rutaceae (3 species). The family Fabaceae which appeared in Upper Palaeocene became a major component of the evergreen forest during Middle Miocene times all along the Himalayan foot hills.

The evergreen elements (54%) dominate the fossil flora of Siwalik in Tanakpur area during Middle Miocene in contrast to mixed deciduous elements at present. The predominance of evergreen elements in the Siwalik fossil assemblage indicates the prevalence of tropical warm humid climate with plenty of rainfall during the deposition of Siwalik sediments.

The analysis of present day distribution of all the species recovered from the Siwalik foreland basins of Tanakpur area shows that they are mostly known to occur in North–east India, Bangladesh, Myanmar and Malaysia wherever favourable climatic conditions exist. Only about 14% taxa of the total assemblage are found to grow presently in the Himalayan foot hills and the remaining 86% taxa are locally extinct, suggesting changes in the climatic condition.

Coexistence Approach (CoA) suggests that the Tanakpur area in Himalayan foot–hills, Uttarakhand enjoyed a tropical climate (with MAT 24–28ºC and MAP 2100–2800 mm) along with plenty of rainfall during the Middle Miocene Times. This is, however, contrary to the present day climate of the area with reduced precipitation

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