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Miocene flora from the Siwalik of Arjun Khola area, Nepal and its palaeoclimatic and phytogeographic implications

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ABSTRACT

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An extensive study on the plant fossils (leaf and fruit impressions/compressions) collected from the Miocene of Siwalik sediments, Arjun Khola area, western Nepal has been carried out. It revealed the existence of a variety of angiosperm plant taxa represented by 43 genera and 47 species belonging to 24 families. Of these, 34 species are reported for the first time from the studied area. Quite a number of fossils out of the entire lot, were described much prior to the present study from other represented by the Siwalik localities. Most of the leaf and fruit specimens are assignable to families of dicots but a single fossil leaf *Clinogyne* Salisb. has been assigned to the monocot family Marantaceae. The families which are highly represented in the assemblage are Fabaceae, Sapindaceae, Dipterocarpaceae and Annonaceae. Fabaceae which appeared in Upper Paleocene became a major component of the evergreen forest during middle Miocene. A majority of the families are generally represented by leaf forms but *Sindora* Miq. and *Butea* Roxb. ex Willd. of the Fabaceae and *Terminalia* L. of the Combretaceae are represented by fruits. Most of the fossil leaves in the assemblage showed large to medium size with drip tips, entire margins and apparent greater venation density. All the above characters collectively indicated the existence of tropical to sub–tropical type of vegetation during the Miocene all along the Himalayan foot hills of Nepal. Out of the identified specimens, the majority (more than 69%) resembled modern taxa, distributed in the tropical evergreen forests of different geographical regions of the world and recovery of similar looking fossil elements from the Arjun Khola area, indicated existence of similar forest types in and around the area at the time of Siwalik sedimentation. In contrast, the present day vegetation in and around the area is quite different from the past as it includes elements that generally constitute plants of dry deciduous forests. A number of plants migrated from south–east Asia to India via Myanmar and vice–versa. Consequently, many taxa, especially members of Dipterocarpaceae and Fabaceae, existing in south–east Asia in the Paleogene appeared on the Indian subcontinent and Nepal in the Neogene. Phytogeographical data also suggests that taxa flourishing in the Himalayan foot–hills during Siwalik sedimentation have migrated elsewhere in modern times possibly towards south and southeast in search of favourable conditions for luxuriant growth.

Present day distribution of all the recovered species from the Siwalik Foreland Basins of Arjun Khola area shows that they are found today in the tropical forests of North–east India, Bangladesh, Myanmar and Malaysia where favourable climatic conditions exist and only little amount of taxa are found to grow presently in the Himalayan foothills. Thus, it may infer that a fair change in floral composition has taken since the Miocene. The nearest living relative (NLR) method of palaeoclimate construction suggests that the Arjun Khola area enjoyed a tropical climate having Mean Annual Temperature (MAT) 22–28ºC and Mean Annual Precipitation (MAP) 2200–3200 mm during the deposition of the sediments.

Key–words—Plant megafossils (leaf and fruit impressions), Morphotaxonomy, Floral composition, Palaeoclimate, Phytogeographical implication, Siwalik Foreland Basin, Miocene, Arjun Khola area, Western Nepal.

नेपाल में अर्जुन खोला क्षेत्र के शिवालिक से प्राप्त मध्यनूतन वनस्पतिजात एवं उनके पुराजलवायवी एवं पादप भौगोलिक निहितार्थ

महेश प्रसाद, सोमलता गौतम, नूपुर भौमिक, संजीव कुमार एवं संजय कुमार सिंह

सारांश

पश्चिमी नेपाल में अर्जुन खोला क्षेत्र के शिवालिक में मध्यनूतन अवसादों से संगृहीत पादप जीवाश्मों (पर्ण एवं फल मुद्राश्म/संपीडाश्म) पर गहन अध्ययन किया गया है। इससे आवृतबीजी के 24 कुटुंबों के 43 वंश व 47 प्रजातियां सन्निहित पादप वर्गकों की विविधता की विद्यमानता का पता चला। इनमें से अध्ययन क्षेत्र से 34 प्रजातियों को पहली बार अंकित किया गया है। इस अध्ययन से पूर्व शिवालिक के अन्य अनावरणों से जीवाश्मों के संपूर्ण पुंज में से जीवाश्मों की काफी संख्या का वर्णन किया गया है। अधिकतर पर्ण व फल नमूने द्विबीज के कुटुंबों को नामित हैं किंतु एकल जीवाश्म पर्ण मारंटेसी कुटुंब एकल सपुट को नामित है। समुच्चय में जो कुटुंब अत्यधिक रूपायित हैं वे फैबेसी, सैपिंडेसी, डिप्टेरोकार्पेसी एवं एन्नोनेसी हैं। ऊपरी पुरानूतन में प्रकट हुआ फैबेसी मध्य मध्यनूतन कालों के दरम्यान सदाहरित वन का मुख्य घटक हो गया। ज्यादातर कुटुंब सामान्यतः पर्ण प्ररूपों से रूपायित हैं किंतु कांब्रेटेसी के *टर्मिनेलिया* एल व फैबेसी के *सिंडोरा* मिक् एवं *बुटिया* रॉक्स्ब एक्स वाइल्ड फलों से रूपायित हैं। समुच्चय में ज्यादातर जीवाश्म पर्णों ने द्रप्स टिपों, पूर्ण उपांत एवं आभासी बृहत्तर शिराविन्यास घनत्व सहित विशाल से मध्यम आकार को दर्शाया है। उपर्युक्त समस्त गुणों ने सामूहिक रूप से, नेपाल के हिमालयी गिरिपादों के साथ मध्यनूतन काल में वनस्पति का उष्णकटिबंधीय से उप–उष्णकटिबंधीय प्रकार की विद्यमानता द्योतित की। अभिनिर्धारित नमूनों में से, विश्व के विभिन्न भू–वैज्ञानिक अंचलों के उष्णकटिबंधीय सदाहरित वनों में वितरित आधुनिक वर्गकों की बड़ी संख्या (69% से अधिक) में सदृशता दिखाई दी तथा अर्जुन खोला क्षेत्र से प्राप्त सदृश दिख रहे जीवाश्म पर्णों की प्राप्ति ने शिवालिक अवसादन के दौरान क्षेत्र में चहुंओर सदृश वनों के प्रकार का अस्तित्व दर्शाया। विपरीतता से, क्षेत्र में व चहुंओर मौजूदा वनस्पति गत से बिल्कुल भिन्न है जैसा कि वे तत्व समाहित करते हैं जो सामान्यतः शुष्क पतझड़ी वनों के पादप संघटित करते हैं। बहुत से पादप म्यांमार के जरिए दक्षिण–पूर्व एशिया से भारत एवं विलोमतः गमन कर गए। परिणामतः पैलियोजीन काल में दक्षिण–पूर्व एशिया में विद्यमान बहुत से वर्गकों, विशेषतः डिप्टेरोकार्पेसी एवं फैबेसी के सदस्य नियोजीन काल में भारतीय उपमहाद्वीप और नेपाल में प्रकट हुए। पादप भौगोलीय आंकड़े अंकित करते हैं कि शिवालिक अवधि के दौरान हिमालयी गिरिपादों में फल–फूल रहे वर्गक, आधुनिक काल में अन्यत्र संभवतः प्रचुर वृद्धि हेतु अनुकूल परिस्थितियों की खोज में दक्षिण एवं दक्षिण पूर्व की ओर विस्थापित हो गए हैं।

अर्जुन खोला क्षेत्र की शिवालिक अग्रभूमि द्रोणियों से प्राप्त समस्त प्रजातियों का मौजूदा वितरण दर्शाता है कि पूर्वोत्तर भारत, बांग्लादेश, म्यॉमार एवं मलेशिया के उष्णकटिबंधीय वनों में आज भी मिलते हैं जहॉं अनुकूल जलवायवी परिस्थितियां विद्यमान रहती हैं तथा हिमालयन गिरिपादों में इस समय केवल अल्प मात्रा में वर्गक मिलते हैं। अनुमान लगाया जा सकता है कि मध्यनूतन काल से पुष्पी संघटन में स्पष्ट परिवर्तन हुआ होगा। पुराजलवायु संरचना की निकटतम जीवित सापेक्षिक (एन एल आर) विधि प्रस्तावित करती है कि अवसादों के निक्षेपण के दौरान अर्जुन खोला क्षेत्र में माध्य वार्षिक तापमान एम ए टी 22°–28° सेल्सियस तथा माध्य वार्षिक अवक्षेपण (वर्षण) एम ए पी 2200–3200 मिमी की उपस्थिति में उष्णकटिबंधीय जलवायु अनुभव की गई है।

सूचक शब्द—पादप स्थूलजीवाश्म (पर्ण एवं फल मुद्राश्म), आकृति वर्गीकरणविज्ञान, पुष्पी संघटन, पुराजलवायु, पादप भौगोलिय निहितार्थ, शिवालिक अग्रभूमि, मध्यनूतन, अर्जुन खोला क्षेत्र, पश्चिमी नेपाल।

INTRODUCTION

THE Siwaliks are the southernmost and geologically youngest east–west mountain chain of the Himalayas extending from Potwar Plateau in the north–west to Brahmaputra Valley in the east forming a belt of 2,400 km in length and 20–25 km in width. The Siwalik Group of sediments is one of the well–known Tertiary sequences (23–1.6 Ma) exposed all along the Himalayan foot–hills.

The Siwalik sediments of both India and Nepal are very rich in plant megafossils. Those include fossil woods, leaves, fruits, flowers and seeds belonging mainly to dicotyledonous families of angiosperms (Antal & Awasthi, 1993; Antal & Prasad, 1996a, b, c; Awasthi & Lakhanpal, 1990; Awasthi & Prasad, 1990; Prasad, 1987, 1990a, b, 1993, 1994a, b, c; Prasad & Awasthi, 1996; Prasad & Prakash, 1984; Prasad *et al.,* 1999,1997a, b). Leaves, the most dominant elements of the bed, have aided reconstruction of floristic patterns and climatic conditions of the middle Miocene–Pleistocene times.

The Siwalik Hills extending to Nepal are designated as Churia Hills. Plant megafossils from the Siwalik of western sector are qualitatively and quantitatively better represented compared to other sectors. Plant remains including fossil woods, leaves, fruits, seed–impressions, etc. have been reported from different localities of western Nepal viz., Koilabas, Surai Khola, Butwal, Arung Khola, Binai Khola and Seria Naka areas (Tripathi & Tiwari, 1983; Prasad & Prakash, 1984; Prasad, 1990a, b, 1994e; Awasthi & Prasad, 1990; Prasad & Awasthi, 1996; Prasad *et al.,* 1997a, 1999; Konomatsu & Awasthi, 1999; Dwivedi *et al.,* 2006a, b; Prasad & Dwivedi, 2007, 2008; Prasad, 2007a, 2013; Prasad & Pandey, 2008; Prasad *et al*., 2013a, 2016).

The fossiliferous locality, Arjun Khola lies about 3 km North West of Lamhi in Deokhuri District, in the Dang Section of Nepal (Fig. 1). A well developed Churia Sequence, belonging to Lower and Middle Churia Group, is exposed in Arjun Khola area all along the Arjun River and the road leading to Ghorai, covering a distance of 15 km. The sediments

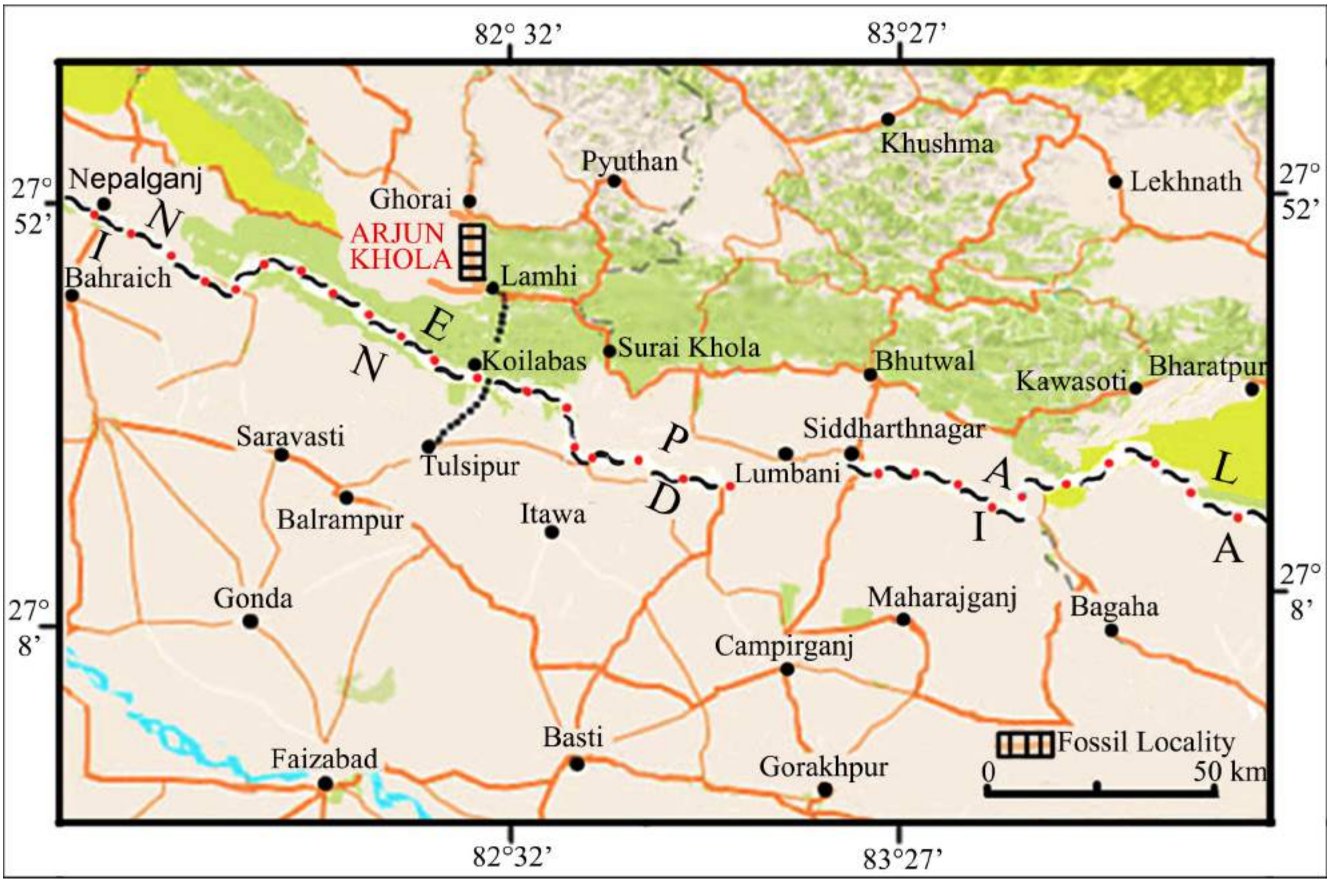

Fig. 1–Map showing physiography and location of Arjun Khola area, western Nepal.

consist of clay, shales, sandstones and siltstones. The shales containing well preserved leaf and fruit impressions are generally thinly bedded and splintery in nature. Almost a complete and uninterrupted sequence of Churia Group is well exposed all along the road from Arjun Khola to Ghorai, ranging in age from middle Miocene–middle Pleistocene. A variety of plant megafossils including fossil woods, leaves, fruits and seed impressions have been collected from Lower and Middle Churia (Siwalik) sediments of Arjun Khola, Nepal. Considering the thickness of sediments and amount of plant materials deposited therein, this can be considered as one of the best and richest plant fossils bearing locality among the known exposures of Churia Group in Nepal. The flora especially abounds in angiospermous plant remains (Table 7). There are several fossiliferous beds of shales, siltstones and few fine grained types of sandstones yielding a variety of well preserved leaf, fruit and flower impressions. The Lower Churia Group comprises alternation of sandstone and mudstone beds of almost same thickness while in the Middle Churia Group, the thickness of sandstone beds is greater than the mudstone beds.

From the Arjun Khola locality too, few megafossils have been reported much prior to the present investigation. As the site is a rich source of Cenozoic plant fossils, the present study was undertaken to build up a complete floristic composition for interpretation of different palaeobotanical inferences. The addition of 34 new elements to the existing report indicates vastness and variety of the flora that existed in the Miocene of Siwalik.

In the present paper, a detailed study on plant megafossils collected from different profiles in Arjun Khola area, is embodied. Along with a systematic description of the fossils, an attempt has also been made to interpret the palaeoclimate of the area during Miocene times as well as on the basis of recovered fossils, phytogeographical changes arising due to altered environmental conditions are also discussed herein.

GEOLOGICAL SETUP OF THE STUDY AREA

Himalaya was formed by the collision of the Indian Plate with Eurasian Plate around 55 million years ago. Many scientists believe that at that time the northward moving Indian Plate first touched the southern edge of Eurasian Plate. The limit of the Himalayas in the east and west is marked by the eastern and western arc of Himalayan bends. Between these bends the Himalayan range is approximately 2400 km long

Table 1—Generalized stratigraphy of the Siwalik foreland basin (after Ranga Rao, 1986).

	Age (Ma) from Palaeomagnetic studies	Formation		Description	Thickness (M)	Source Rock Potential
Quaternary to Upper Pleistocene	–0.22 Ma	Alluvial				
Middle Pleistocene to Middle Miocene	–10.1 Ma	Siwalik Group	Upper Siwalik	Conglm. & Sst., Pink to Reddish Brown Silt, Clay & Claystone	1000–2300	Nil
	—17.0(?) Ma		Middle Siwalik	Sst. Eith Varigated Clay/ Clay Stand Thin Conglm. Band Toward Top	1400–2000	Nil
			Lower Siwalik	Sst. and Clay/ Clay St. Alt. Sst., Grey, Mott. F–M Clay/ Clay St. Reddish Brown with Marly and Siltstone Bands	1300–2000	Poor
Lower Miocene	23.0 Ma (?)	Muree/ Dharamsala Group	U. Murree / U. Dharamsala	Gn_Grey to grey Sst. Purplish Red Silt. to the East Cly/ Cly St. Gn. Gy. to Red	1600(+)	Poor
			L. Murree / L. Dharamsala	Deep Purple to Red Clay/ Clay St. & Silt St. with Veined Calcite & Sst.	1000–2300	Moderate to Fair
Lower To Middle Eocene	40.0 Ma (?) –50.0(?) Ma	Subathu Group	Subathu	Olive Green Shale, Thin Lst. with Foraminifera & Oyster Red Shale Intercalations	120–600(?)	Moderate to Fair
Pre–Cambrian			Sirban / Bandla / Bilaspur Limestone	Dolomitic, Cherty Lst. Stromatolitic	–	–
			Basement Of Indian Shield	Unclassified Granite, Geneiss, Schists, Etc.	–	–

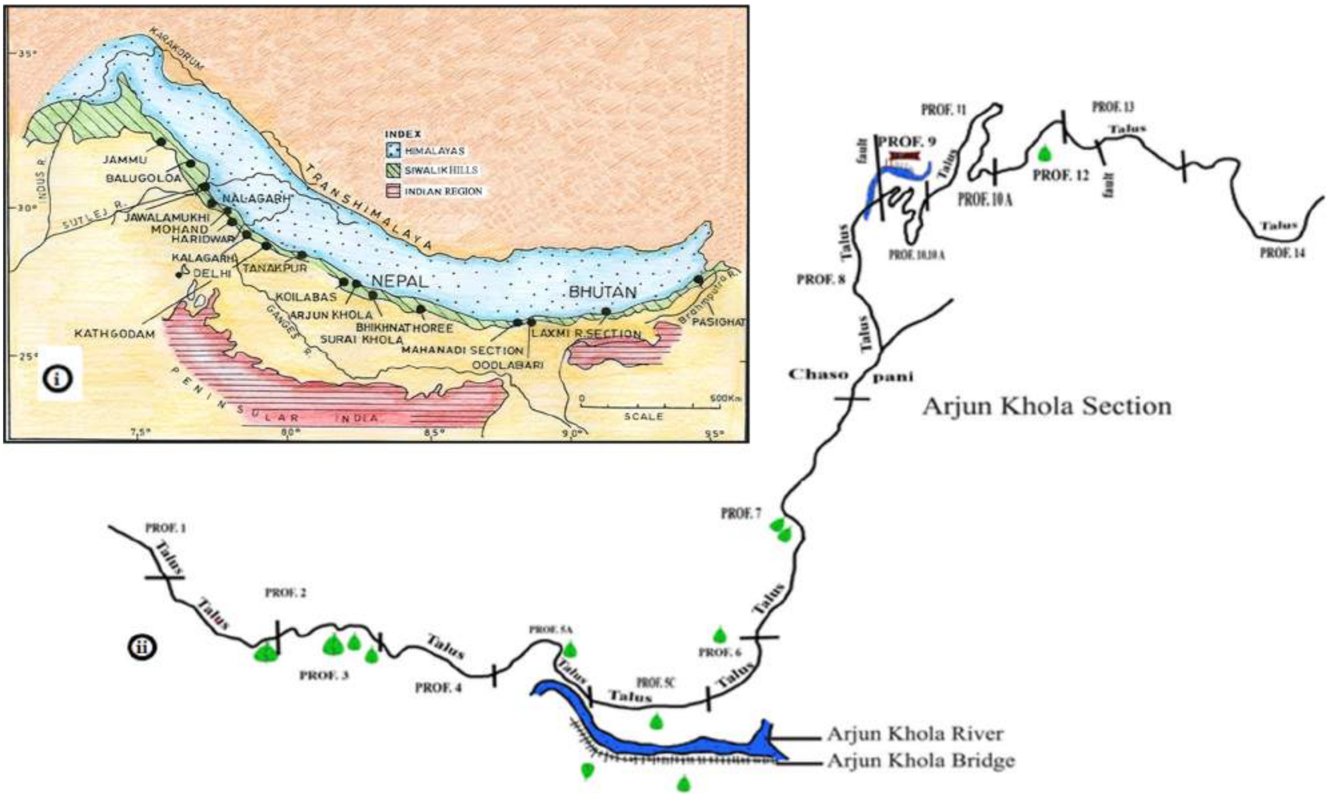

Fig. 2–(i) Map showing extent of Siwalik foreland basin. (ii) Arjun Khola Road section showing 14 profiles with their fossil location.

and 200 to 300 km wide. The Himalaya covers an area of approximately 600,000 sq km in south Asia.

The Siwalik in India and Nepal encompassing the whole Himalayan foot hills (Fig. 2) represents a marginal foreland folds and thrust belt developed as a result of the collision between the Eurasian and Indian plates. It is a complex sedimentary basin covering an area of 2,400 km in length and 20–25 km in width ranging in age from middle Miocene to Lower Pleistocene. The detailed stratigraphy of the entire Himalayan Foreland basin is summarised in Table 1.

Nepal occupies the central sector of Himalayan arc. Nearly one third of the 2400 km long Himalayan range lies within Nepal. Similar to other parts of the Himalaya, from south to north, Nepal can be also subdivided into the following five major tectonic zones. (1) Gangetic Plain, (2) Sub–Himalayan (Siwalik) Zone, (3) Lesser Himalayan Zone, (4) Higher Himalayan Zone, (5) Tibetan–Tethys Himalayan Zone. Each of these zones is characterized by their own lithology, tectonics, structures and geological history (Fig. 3). All these tectonic zones are separated from each other by the thrust faults. The southernmost fault, the Main Frontal Thrust (MFT) separates the Sub–Himalayan (Siwalik) Zone from Gangetic Plains. The Main Boundary Thrust (MBT) separates the Lesser Himalayan Zone from the Siwalik.

The Sub–Himalayan Zone is also called as Siwalik Zone and is delimited on the south by the Main Frontal Thrust (MFT) and on the north by the Main Boundary Thrust (MBT). It consists basically of fluvial deposits of the Neogene age. This zone extends all along the Himalaya forming the southernmost hill range with width of 8 to 50 km. The Lesser Himalayan rocks thrust southward over the rocks of Siwalik along the MBT.

The general dip of beds of Siwalik has northward trend with varying angles and the overall strike is east–west. The Siwalik Zone has number of east–west running thrusts. Siwalik Zone is also rich in fossils. Fossils of plants, pisces, reptiles and mammals (Carnivora, Proboscidea, Artiodactyla, Rodentia and Primates) have been reported from Siwalik (Prasad, 2008; West, 1984; Corvinus, 1990).

The three–fold classification of Siwalik in Potwar region of Pakistan and western Indian Himalaya was freely applied to the equivalent Siwalik of Nepal (Burbank *et al*., 1996) from the beginning of the geological studies in Nepal. According to three fold classification, Siwalik can be classified as Lower, Middle and Upper Siwalik.

The Lower Siwalik consists of irregularly laminated beds of fine grained greenish sandstone and siltstone with mudstone. The alternating mudstone beds are thickly bedded and are variegated, red, purple, and brown coloured. The best exposures of Lower Siwalik are found in Surai Naka, Koilabas, Seria Naka, Arjun Khola, Amlekh Ganj, Arun Khola, Barahchhetra and Rato Khola area of Nepal. The

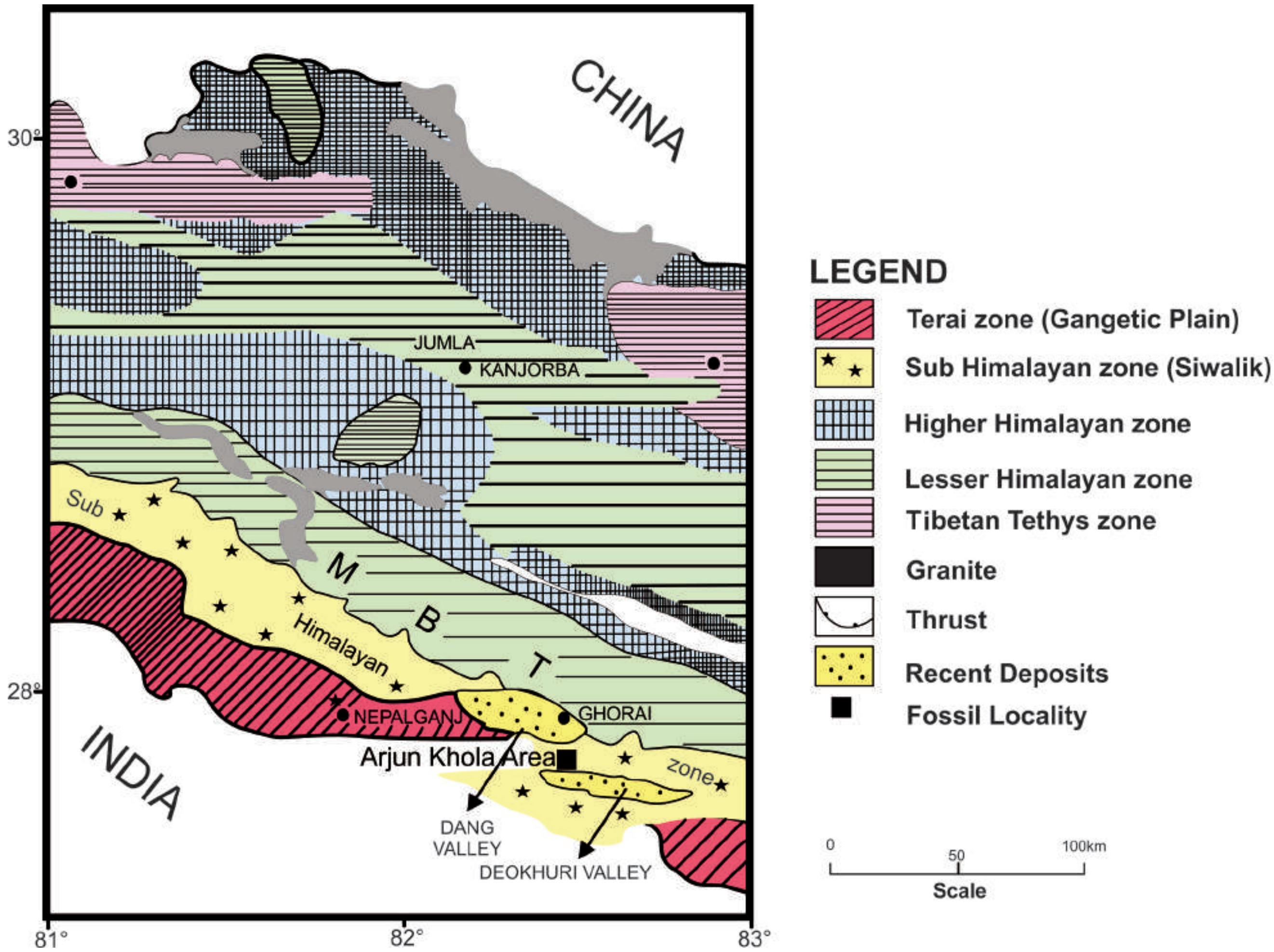

Fig. 3–Geological map of study area showing location of fossil bed in the Sub Himalayan zone (after Upreti & Yoshida, 2005).

Middle Siwalik is composed of medium to coarse grained salt–and–pepper (looks like mixture of salt and black pepper) sandstones interbedded with mudstone. This is differentiated from the Lower Siwalik in lacking variegated mudstone and sandstone. In upper part of the Middle Siwalik, pebbly sandstone beds are also found. In Middle Siwalik the sandstone beds have thickness mostly ranging from 1 to 45 m. The exposures of Middle Siwalik are found mainly in Surkhet, Surai Khola, Hetauda and Butwal. While the Upper Siwalik is comprised of conglomerate and boulder beds and subordinately sand and silt beds. The mudstone beds of the Upper Siwalik are massive and irregularly bedded and contain many invertebrate fossils including brachiopods and gastropods. The upper part of this sequence contains conglomerate beds, which have mostly boulder and cobble size rounded to subangular fragments of Lesser Himalayan rocks. The good exposure of Upper Siwalik can be seen in Bardibas, Hetauda, Bhalubang and Chitwan.

The area of present study falls in Dang section of western Nepal Himalaya. The Siwalik in Nepal is often called Churia Group which lies south of the Main Boundary Thrust (Figs 1, 2). The detailed lithology and stratigraphy of the Siwalik (Churia) Group of Nepal have been given by Auden (1935), Lehner (1943), Hagen (1959), Bordet (1961), Gleinnie and Ziegler (1964), Ohta and Akibna (1973), Sharma (1977) and Gupta (1981), Chaudhuri (1983), West (1984), Tokuoka *et al*. (1986), Corvinus (1990), Appel *et al.* (1991) and Quade *et al.* (1995).

The Churia Group has often been classified into two formations: (i) Lower Churia Formation (Sandstone Facies), and (ii) Upper Churia Formation (Conglomerate Facies) by Hagen (1959), Bordet (1961) and Gleinnie and Ziegler (1964). However, a threefold lithostratigraphical classification of the formation in the western Nepal Himalaya has been suggested by Chaudhuri (1983). The Churia Group consists of basically of fluvial deposits of Neogene age (18 million years to 1.6 million years old). This extends all along the Himalaya forming the southernmost hill range with width of 8–50 km.

A well developed Churia Sequence belonging to Lower and Middle Churia Group is exposed in Arjun Khola area all

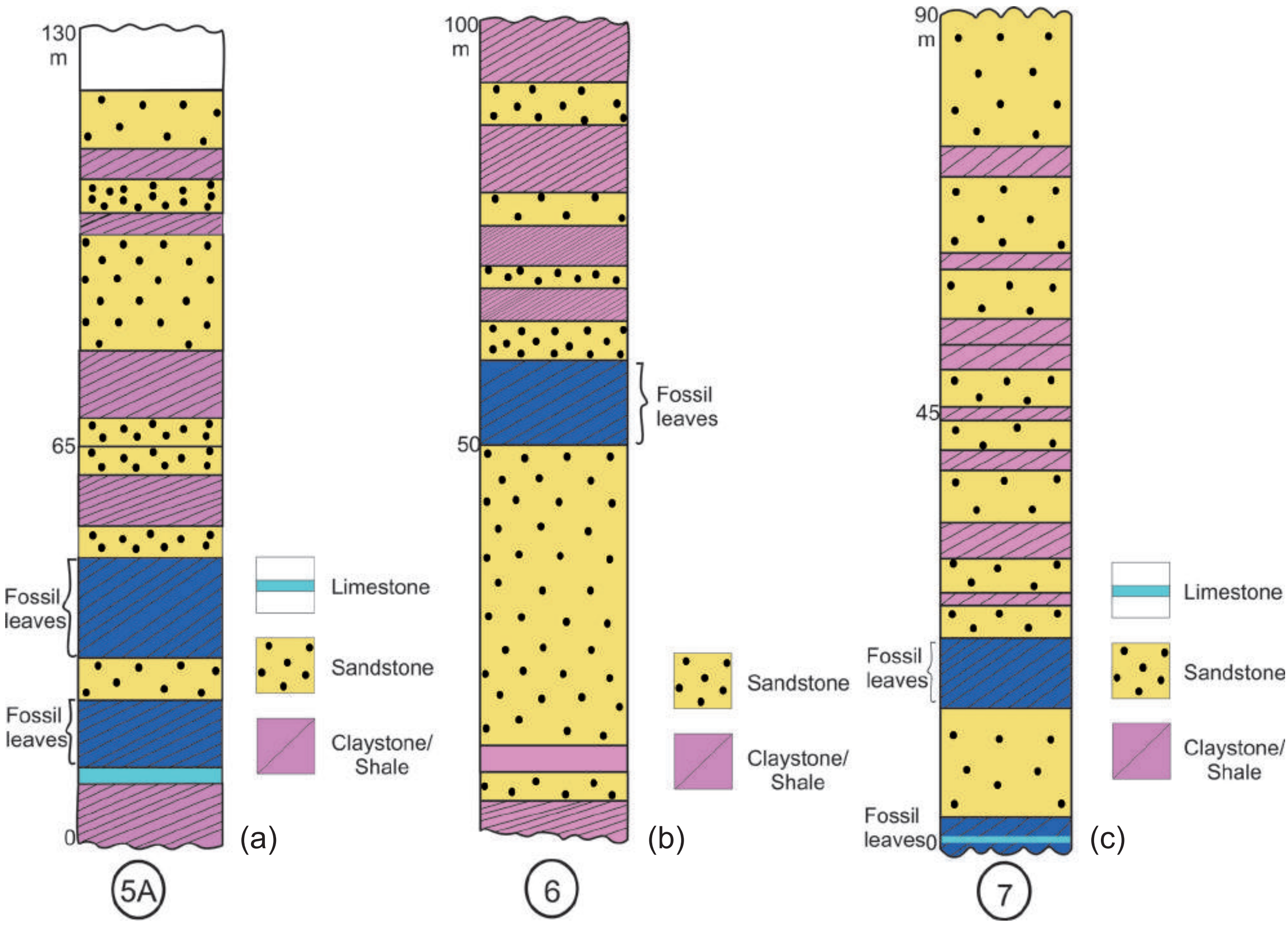

Fig. 4a-c–Showing Lithologs of profiles 5A, 6 and 7 respectively. The Lithologs also indicate fossiliferous beds and embedding matrices of Limestone, Sandstone and Claystone/ Shale.

along the Arjun River and the road leading to Ghorai covering a distance of 15 km (Figs 1, 2, 5). The sediments consist of clays, shales, sandstones and siltstones. The shales containing well preserved leaf and fruit impressions are generally thinly bedded and splintery in nature. Almost a complete and uninterrupted sequence of Churia Group is well exposed all along the road from Arjun Khola to Ghorai ranging in age from middle Miocene–middle Pleistocene (Figs 2, 5a–c). In this area, the Lower Churia Group is observed from Profile–1 to Profile–4 containing fine grained sandstone beds with variegated clay. From Profile–5 to Profile 8 (Masot Khola) the rocks are of Middle Churia Group (Figs 4, 5b, c). Above the Middle Churia Group again lies the Lower Churia Group in Profile 9–14 (Figs 2, 5). There are number of fossiliferous beds of mainly shales, siltstones and few fine grained types of sandstone yielded a variety of well preserved leaf, fruit and flower impressions. The Lower Churia Group comprises alternation of sandstone and mudstone beds of almost same thickness while in the Middle Churia Group, the thickness of sandstone beds is greater than the mudstone beds.

MATERIAL AND METHODS

The fossil locality, Arjun Khola (27º53'42.8''N: 82º30'31.4''E) lies in the Dang District of Rapti Anchal, Nepal and is easily approachable by metalled road originating from Mahendra Highway about 3 km west of Lamhi (27º52'24.9''N: 82º32'22.4''E), a famous town of Deokhuri Valley (Figs 1, 2, 4, 5). The sections belonging to the Lower and Middle Siwalik (Churia) beds containing excellently preserved fossil leaf and fruit impressions are well exposed on both the sides of the road leading to Ghorai and also on both the banks of Arjun Khola River (Figs 2, 4, 5). The leaf–impressions are found on both grey and brown calcareous shales but they are more common and well preserved in the grey shale. A rich collection of well preserved leaf and fruit impressions was made from Profile 5A of Arjun Khola Road section (Figs 2, 4a, 5b). More than 500 specimens of leaves, fruits, seed and flower impressions were collected from nearly all the 14 profiles of the whole section (Figs 2, 4, 5). Out of them leaf impressions of 43 angiospermous genera and three fruits have been studied in the present work.

The leaf impressions were collected from surface exposures of Arjun Khola Siwalik section exposed on Arjun Khola to Ghorai Road in Deokhuri District of Nepal. The leaf impressions, preserved in grey shales, were studied either with hand lens or low power microscope under reflected light. The identification of leaf impressions has been done by the consulting a variety of herbarium sheets of dicotyledonous genera housed at Central National Herbarium (C.N.H), Sibpur Howrah, West Bengal. The photographs of leaf–impressions showing various morphological characters were taken by Nikon SLR Camera. As the recovered leaf–impressions closely resembled modern leaves, photographs of comparable modern leaves showing similar features were also taken in the same magnification and displayed along with those of the fossil leaves for close comparison.

International Code of Botanical Nomenclature (ICBN) has been followed and the fossil leaves have been named according to usual practice prevalent in the country and abroad. For naming the fossil specimens, generic names of extant taxa have been retained. For the description of leaf impressions, the terminology given by Hickey (1973), Dilcher (1974) and Ash *et al.,* (1999) has been followed. The families have been arranged according to Bentham and Hooker's system of classification.

Both the near living relative (NLR) and Foliar Physiognomy methods are used to estimate the palaeoclimate. The Co–existence intervals of MAT of all the near living relative species (comparable species) of Arjun Khola fossil assemblage have been obtained from Internet and through data from Indian Meteorological Department.

DESCRIPTION AND SYSTEMATIC PALAEOBOTANY OF FOSSILS

MONOCOTYLEDONS

Order—ZINGIBERALES

Family—MARANTACEAE

Genus—CLINOGYNE Salisb.

Clinogyne ovatus Awasthi & Prasad, 1990

(Pl. 17.9, 11)

Material—Single specimen.

Fig. 5–(a) Arjun Khola bridge on Mahendra High way Road leading to Ghorai. (b) Part of Profile–5A of Arjun Khola sequence showing exposed Middle Siwalik rocks, a variety of fossil leaves collected. (c) Part of Profile–7 of Arjun Khola sequence showing Middle Siwalik rocks with intercalation of claystone between thick sandstone beds.

Description—Leaf simple, bilaterally symmetrical, seemingly narrowly elliptical; preserved size 9.1 x 3.2 cm; apex slightly broken; base seemingly obtuse; margins entire; texture chartaceous, petiole not preserved; venation pinnate, craspedodromous; primary vein (1º) single, straight, stout, prominent; secondary veins (2º) numerous, very closely placed, angle of divergence (about 30º) narrow acute, opposite, running parallel towards the apex for a long distance; tertiary veins (3º) not clearly seen.

Figured Specimen—BSIP Museum Specimen No. 41079.

Locality—Profile 3 (27º54'24.0" N: 82º30'52.7" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Lower Churia Group, Middle Miocene.

Affinities—The morphological features of the present fossil leaf such as bilaterally symmetrical, elliptical shape, craspedodromous venation, numerous, very closely placed secondary veins with narrow acute angle of divergence of the fossil leaf suggest affinity with the modern leaves of *Clinogyne dichotoma* (Roxb.) Salisb. of the family Marantaceae (C.N.H. Herbarium Sheet No. 468823; Pl. 17.10, 12).

So far three fossil leaves resembling the genus *Clinogyne* Salisb. have been reported from the Miocene sediments of India and Nepal. These are *Clinogyne ovatus* (Awasthi & Prasad, 1990) from upper Miocene of Surai Khola area, western Nepal, *Clinogyne* cf. *Clinogyne ovatus* from lower Miocene of Kasauli Formation, Himachal Pradesh, India (Arya & Awasthi, 1995) and *Clinogyne lishensis* from middle Miocene sediments of Darjeeling District, West Bengal, India (Antal & Prasad, 1995). By comparative study of above mentioned fossil leaves it was observed that, the present fossil leaf specimen showed nearest resemblance with earlier described specimen of Awasthi and Prasad's (1990) in being almost of same size and similar venation pattern especially parallel arrangement of secondary veins. The other specimens differ in their shape and size. Therefore, present fossil leaf has been described as *Clinogyne ovatus* Awasthi and Prasad.

The genus *Clinogyne* Salisb. consists about 20 species distributed in Bago, Taninthayi, Tropical Africa and Indian sub–continent. *Clinogyne dichotoma* (Roxb.) Salisb. is distributed in moist deciduous forests of sub–Himalayan tract, north–east Bangladesh, West Bengal, Assam, Myanmar and Malaysia (Willis, 1973).

DICOTYLEDONS

Order—DILLENIALES

Family—DILLENIACEAE

Genus—DILLENIA L.

Dillenia palaeoindica Prasad & Prakash, 1984

(Pl. 1.1, 3, 5)

Material—Single specimen.

Description—Leaf simple, seemingly bilaterally symmetrical, elliptical; preserved size 6.8 x 3.7 cm; apex broken; base broken; finely serrate; entire undulate margins; texture chartaceous, petiole not preserved; venation pinnate, seemingly eucamptodromous; primary vein (1º) single, prominent, stout; secondary veins (2º) 10 pairs visible, angle of divergence (40º–60º) narrow to moderate, upper ones more acute than basal ones, 0.5 to 0.7 cm apart, alternate, unbranched; tertiary veins (3º) moderate, angle of origin RR type, percurrent, forked, straight to sinuous, predominantly alternate and close, oblique in relation to midvein.

Figured Specimen—BSIP Museum Specimen No. 41080.

Locality—Profile 5B (27º54'53.7" N: 82º31'05.2" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Affinities—The important morphological features of the present fossil leaf such as elliptical shape, eucamptodromous venations, finely serrate margins, narrow to moderate angle of divergence of secondary veins, middle secondary veins more acute than basal ones, moderate, percurrent and sinuous. tertiary veins show close affinity with modern leaves of *Dillenia indica* L. of the family Dilleniaceae (C.N.H. Herbarium Sheet No. 31925; Pl. 1.2, 4, 6). The fossil leaf also resembles leaves of *Dillenia aurea* and *Dillenia parviflora* but differs from them in the nature of secondary veins. The basal secondary veins arise at right angles and are closely placed in the fossil.

Fossil leaf resembling the genus *Dillenia* has been described under the generic name *Dillenia* L. earlier with three known species. These are *Dillenia palaeocenica* Saporta and Marion, (1878) (in Berry, 1916) from the Lower Eocene of Belgium, *Dillenia alaskana* (Hollick, 1936) from the Tertiary of Alaska and *Dillenia palaeoindica* from the Lower Siwalik beds of Koilabas, Nepal (Prasad & Prakash, 1984) and Lower–Middle Siwalik sediments of Oodlabari, Darjeeling District, West Bengal (Antal & Awasthi, 1993). A comparison of the present fossil leaf with above fossil species revealed a close similarity with *Dillenia palaeoindica* (Prasad & Prakash, 1984). They resembled in shape, size and venation pattern. The present fossil leaf differed from the other two fossil leaves in having more acute angled secondary veins. The Arjun Khola fossil leaf is therefore, reported under *Dillenia palaeoindica* Prasad and Prakash.

Dillenia L. comprises about 60 species distributed in Tropical Asia, Indo–Malaysia and Australia. *Dillenia indica* L. is a moderate sized, round headed tree, distributed in moist evergreen forests at the base of Himalayas from Nepal eastwards, Assam, eastern Bengal, Myanmar, Valley of the Circar hills, Konkan, Kanara, Malabar, low country of Sri

Lanka and Malaya Peninsula. It also grows in moist parts of Madhya Pradesh, Andhra Pradesh, Tamil Nadu and South–east Asia (Chowdhury & Ghosh, 1958; Ridley, 1967; Gamble, 1972; Majumdar, 1979).

Order—MAGNOLIALES

Family—ANNONACEAE

Genus—ANAXAGOREA A. St.–Hil.

Anaxagorea mioluzonensis n. sp.

(Pl. 2.1, 2, 3, 4, 8)

Material—Three specimens.

Description—Leaves simple, bilaterally symmetrical, seemingly elliptical; preserved size 6.0–8.4 x 3.6–5.3 cm; apex broken; base seemingly acute; margins entire; petiole not preserved; texture chartaceous; venation pinnate, brochidodromous; primary vein (1º) single, straight, prominent, stout; secondary veins (2º) 4–8 pairs visible, angle of divergence (60º–70º) moderate to wide acute, 0.7 to 1.5 cm apart, straight before the margins but curved sharply before joining the super adjacent secondaries. Secondaries forming loop at acute to obtuse angles; tertiary veins (3º) fine, angle of origin usually RR type, percurrent, straight to sinuous, branched, oblique in relation to midvein, predominantly alternate and nearly distant.

Holotype—BSIP Museum Specimen No. 41081.

Locality—Profiles 5A (27º54'50.6" N: 82º31'00.4" E) and 5B (27º54'53.7"N: 82º31'05.2"E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Etymology—By adding the prefix 'mio' to the modern comparable species, *A. luzonensis*.

Affinities—Distinguishing features of the present fossil leaves such as bilaterally symmetrical, elliptical shape, acute base, brochidodromous venation, moderately acute angle of divergence of secondary veins which are curved sharply upwards toward margins and joined to the super adjacent secondary forming loops at acute to obtuse angles and usually RR type tertiary veins indicate their affinity with modern leaves of *Anaxagorea luzonensis* A.St.–Hil. (C.N.H. Herbarium Sheet No. 12524; Pl. 2.6, 7, 9) of the family Annonaceae. A careful study of several herbarium specimens also revealed that the present fossil leaves also superficially resembled the species *Anaxagorea javanica* besides resembling others like *Erythrochiton* of family Rutaceae, *Pycnarrhana planifolia*, *Pycnarrhana manillensis* of family Menispermaceae and *Sabia paniculata* of the family Sabiaceae. But the latter leaves were distinguishable from the fossil on the basis of their secondary veins which were opposite and close, right to acute angled and greater in numbers.

There is no record of fossil leaves resembling the genus *Anaxagorea* A.St.–Hil., hence this is the first record in the Siwalik sediments of Arjun Khola area in western Nepal.

The genus *Anaxagorea* A.St.–Hil. comprises about 21 species distributed in Tropical regions of the world. Out of them 3 species are distributed in America and 3 in Sri Lanka to western Malaysia. *Anaxagorea luzonensis* A. Gray is a glabrous shrub distributed in Andaman, Penang hills, Malacca, Myanmar, Sri Lanka to Malaya Archipelago, Philippines (Hooker, 1872; Ridley, 1967; Brandis, 1971; Mabberley, 1997).

Genus—MITREPHORA Hook. f. & Thomson

Mitrephora mioreticulata n. sp.

(Pl. 3.1)

Material—Single specimen.

Description—Leaf simple, bilaterally symmetrical, seemingly oblong; preserved size 19.1 x 5.8 cm; apex slightly broken; base seemingly acute; margins entire; petiole not preserved; texture chartaceous; venation pinnate, eucamptodromous. Primary vein (1º) single, slightly curved, prominent, stout. Secondary veins (2º) 12 pairs visible, opposite to alternate, basal secondaries more acute than apical

PLATE 1

(Scale bar = 1 cm)

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1. *Dillenia palaeoindica* Prasad & Prakash–Fossil leaf showing shape, size and venation pattern. Specimen No. 41080.
2. *Dillenia indica* L.–Modern leaf showing shape, size and venation pattern.
3. *Dillenia palaeoindica* Prasad & Prakash–A part of fossil leaf magnified to show details of alternate pattern and narrow to moderately acute angle of secondary veins.
4. *Dillenia indica* L.–A part of modern leaf magnified to show similar details of secondary veins.
5. *Dillenia palaeoindica* Prasad & Prakash–A part of fossil leaf magnified to show details of RR angle of origin of tertiary veins.
6. *Dillenia indica* L.–A part of modern leaf magnified to show similar details of tertiary veins.
7. *Dipterocarpus koilabasensis* Prasad *et al*.–Fossil leaf showing shape, size and venation pattern with obtuse base. Specimen No. 41091.
8. *Dipterocarpus turbinatus* Gaertner–Modern leaf showing similar shape, size and venation pattern with obtuse base.
9. *Dipterocarpus koilabasensis* Prasad *et al*.–A part of fossil leaf magnified to show details of tertiary veins especially its straight to sinuous pattern.
10. *Dipterocarpus turbinatus* Gaertner–A part of modern leaf magnified to show similar details of tertiary veins.

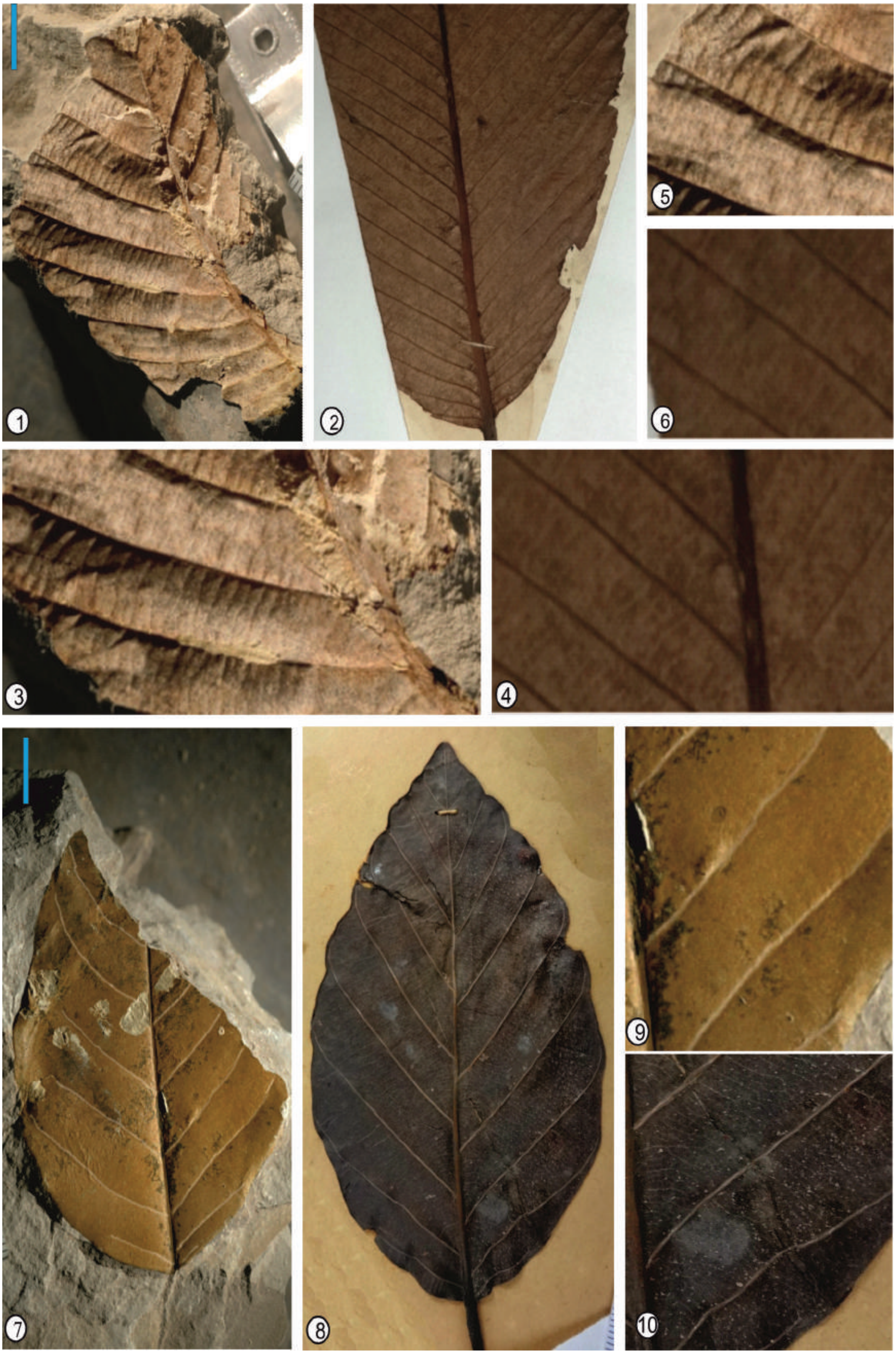

PLATE 1

ones, angle of divergence (40º–50º) acute, narrow to moderate, unbranched, 3.0 to 0.9 cm apart; tertiary veins (3º) fine, angle of origin RR type, pattern percurrent, simple, sometimes branched, opposite to alternate, usually oblique in relation to mid veins, approximately at right angles near the margins, close to sometimes distant.

Holotype—BSIP Museum Specimen No. 41084.

Locality—Profile 5A (27º54'50.6" N: 82º31'00.4" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

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

Affinities—Morphological features exhibited by the present fossil leaf such as oblong shape, acute base, entire margins, eucamptodromous venation, narrow to moderate acute angle of divergence of secondary veins, RR type tertiary veins running nearly right angle to mid vein near the margins, show closest affinity with the modern leaves of *Mitrephora reticulata* (Blume) Hook f. & Thomson of the family Annonaceae. The fossil leaf also resembles *Pseuduvaria reticulata* of the family Annonaceae (C.N.H. Herbarium Sheet No. 13373; Pl. 3.2) and *Terminalia tomentosa* of the family Combretaceae (C.N.H. Herbarium Sheet No. 8710) but differs in having small sized leaves and in angle of divergence of secondary veins.

So far, two fossil species showing resemblance with the extant genus *Mitrephora* Hook. f. & Thomson have been described from Siwalik sediments of India, Nepal and Bhutan. These are *Mitrephora siwalika* (Antal & Awasthi, 1993) from Oodlabari area, West Bengal, Surai Khola area, western Nepal (Prasad & Awasthi, 1996) and Siwalik sediments of Uttaranchal, India (Shashi *et al*., 2006) and from Siwalik sediments of south eastern part of Bhutan (Prasad & Tripathi, 2000) and *Mitrephora miocenica* (Prasad *et al*., 1997a) from Seria Naka, north–west of Tulsipur, Uttar Pradesh. On comparison of the present fossil with the above known species it has been observed that all the fossil leaves were smaller in size and of elliptical shape. Thus the present fossil leaf is described as new species, *Mitrephora mioreticulata*.

The genus *Mitrephor*a Hook. f. & Thomson consists of about 40 species distributed in south–east Asia, western Malaysia, Malaya Peninsula, Tenasserim, Myanmar, Java, Assam, Chittagong and north–east India. *Mitrephora reticulata* (Blume) Hook f. & Thomson is a small tree distributed in evergreen forests of Myanmar, S. Siam (Trang), Tenasserim, Java and Malaya Peninsula (Gamble, 1972; Hooker, 1882; Ridley, 1967; Brandis, 1971; Mabberley, 1997).

Genus—UVARIA L.

Uvaria miolucida n. sp.

(Pl. 8.5, 7)

Material—Single specimen.

Description—Leaf simple, bilaterally symmetrical, narrow oblong; preserved size 14.9 x 3.3 cm; apex acuminate; base broken; margins entire; petiole not preserved; texture chartaceous; venation pinnate; eucamptodromous; primary vein (1º) single, straight, prominent, stout; secondary veins (2º) about 15 pairs visible, angle of divergence (60º–70º) moderate to wide, acute, 0.4 to 1.2 cm apart, branched. All secondary veins uniformly curved upwards and sometimes branched near the margins, apical secondaries much more branched as compare to lower secondaries, intersecondary veins present, simple, branched. Tertiary veins (3º) fine, angle of origin RR type, percurrent, opposite to alternate, random, close, reticulate and oblique in relation to mid vein.

Holotype—BSIP Museum Specimen No. 4108.

Locality—Profile 5A (27º54'50.6" N: 82º31'00.4" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Etymology—By adding the prefix 'mio' to the name of modern comparable species, *Uvaria lucida.*

Affinities—The characteristic features of the present fossil leaf such as bilaterally symmetrical, narrow oblong shape, acuminate apex, entire margins, eucamptodromous venation, uniformly curved upward and branched secondary veins, presence of intersecondary veins; RR, percurrent, opposite to alternate and random, reticulate tertiary veins undoubtedly indicate affinity with the modern leaves of *Uvaria lucida* Benth. (C.N.H. Herbarium Sheet No. 54916; Pl. 8.6, 8) of the family Annonaceae. The fossil leaf also shows near resemblance with *Uvaria narum* (C.N.H. Herbarium Sheet No. 54052) of the family Annonaceae.

PLATE 2

(Scale bar = 1 cm)

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1–3. *Anaxagorea mioluzonensis* n. sp.–Fossil leaves showing shape, size and brochidodromous venation pattern. Specimen Nos. 41081(Holotype) and 41082–41083.

4. *Anaxagorea mioluzonensis* n. sp.–A part of fossil leaf magnified to show details of loop formation of secondary veins at acute to obtuse angle before the margin.

5. *Anaxagorea luzonensis* A. Gray–A part of modern leaf magnified to show similar details of secondary veins.

6, 7. *Anaxagorea luzonensis* A. Gray–Modern leaves showing similar shape, size and venation pattern as Figs 1–3.

8. *Anaxagorea mioluzonensis* n. sp.–A part of fossil leaf magnified to show RR, percurrent and nearly distant tertiary veins.

9. *Anaxagorea luzonensis* A. Gray–A part of modern leaf magnified to show similar details of tertiary veins.

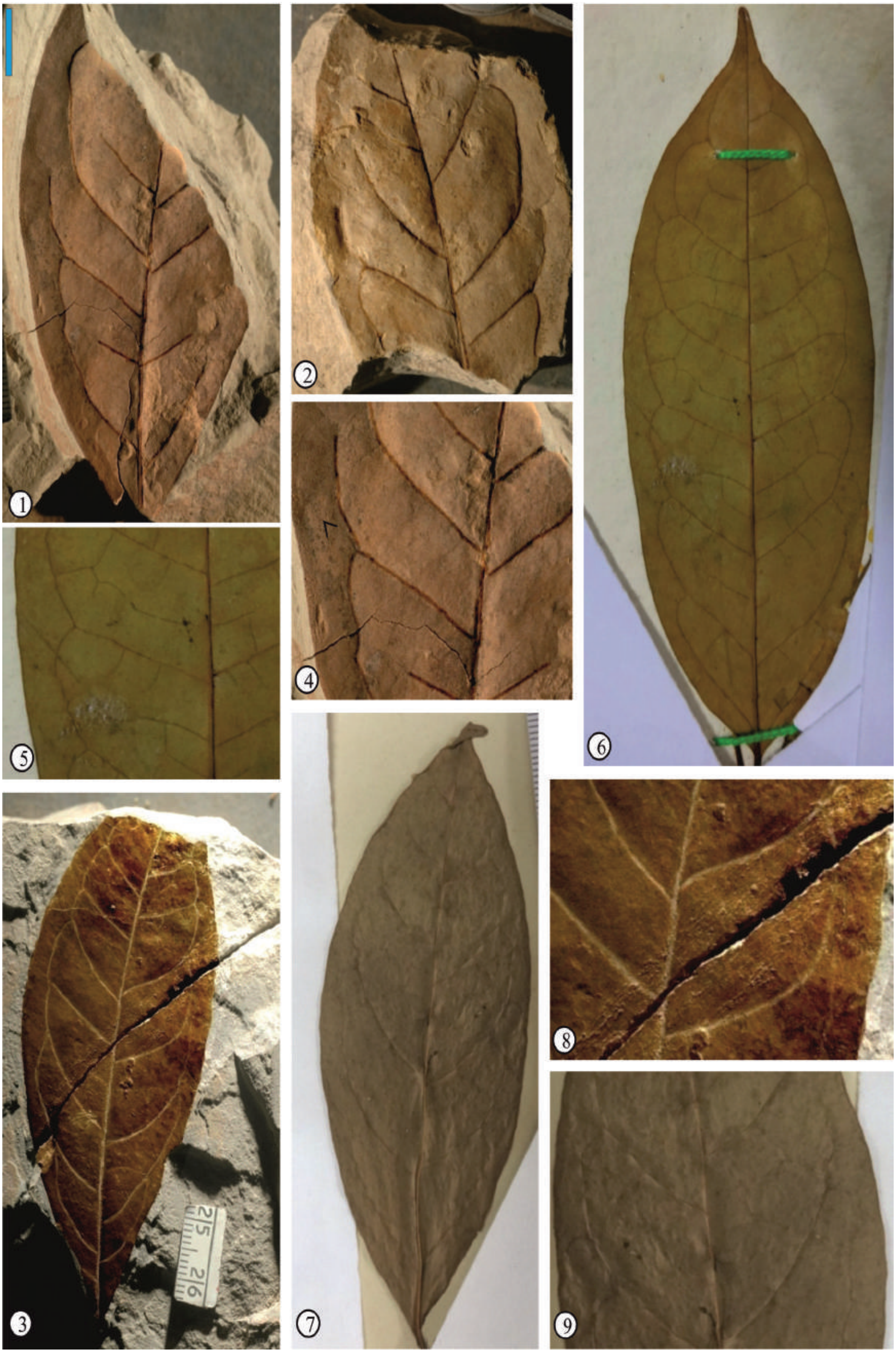

PLATE 2

Three fossil leaves resembling the genus *Uvaria* L. have been previously recorded from the Siwalik sediments of India. These are *Uvaria siwalica*, from Lower Siwalik sediments of Kathgodam, Nainital District, Uttarakhand (Prasad, 1994c); *Uvaria ghisia,* from Lower Siwalik sediment, near Oodlabari, Darjeeling District, West Bengal, India (Antal & Prasad,1998); Middle Miocene (Siwalik) sediments of Sub–Himalayan zone, near Seria Naka and Koilabas, western Nepal (Prasad & Dwivedi, 2008); *Uvaria siwalica,* from Middle Siwalik sediments (Upper Miocene) Darjeeling District, West Bengal (Prasad *et al.,* 2015). A comparison with above mentioned fossils revealed that present fossil leaf was very much different in having a narrow oblong shape and showing different arrangement of secondary and intersecondary veins. Therefore, present fossil leaf is described as a new species, *Uvaria miolucida*.

The genus *Uvaria* L. consists of about 110 species distributed in the tropical to sub–tropical regions of the Eastern Hemisphere, Myanmar and Malaya. *Uvaria lucida* Benth. is an erect or scandent shrub distributed in dry evergreen forest of E. Kenya, Tanzania, Somalia (Harvey & Sonder, 1894; Mabberley, 1997).

Order—RANUNCULALES

Family—MENISPERMACEAE

Genus—TINOSPORA Miers

Tinospora siwalika n. sp.

(Pl. 4.1, 3, 5)

Material—Single specimen.

Description—Leaf simple, bilaterally symmetrical, ovate; preserved size 3.4 x 1.2 cm; apex acute; base cordate; margins entire; texture chartaceous; venation pinnate, eucamptodromous; primary vein (1º) single, straight, prominent, stout; secondary veins (2º) 5–6 pairs visible, alternate to opposite, angle of divergence (about 45º), lower pairs of secondary veins narrow to moderate, unbranched, 0.5 to 0.8 cm apart; tertiary veins (3º) poorly preserved, fine, angle of origin RR type, percurrent, straight to slightly sinuous, branched, predominantly alternate and close, oblique in relation to mid vein.

Holotype—BSIP Museum Specimen No. 41086.

Locality—Profile 5A (27º54'50.6" N: 82º31'00.4" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Etymology—Named after Siwalik Formation.

Affinities—The present fossil leaf shows a close affinity with modern leaves of *Tinospora cordifolia* (Willd.) Miers (C.N.H. Herbarium Sheet No. 15420; Pl. 4.2, 4, 6) of the family Menispermaceae, on account of features such as bilaterally symmetrical, ovate shape; acute apex; cordate base; eucamptodromous venation; secondary veins showing moderately acute angle of divergence, alternate to opposite; tertiary veins with RR, percurrent, straight to slightly sinuous, branched, oblique in relation to mid vein. Besides the above, the fossil leaf also resembles leaves of the following modern taxa *Tinospora sagittata, T. merrilliana, T. dissitiflora* and *T. rumphii* of family Menispermaceae but differs in shape, size and nature of secondary veins which run upward for a long distance.

There is no earlier record of fossil leaf resembling the genus *Tinospora* Miers from the Cenozoic sediments of India. Its record from the Siwalik sediments of Arjun Khola area, western Nepal is the first record and hence it is described as a new species, *Tinospora siwalika* n. sp.

The genus *Tinospora* Miers comprises about 32 species distributed in Tropical Asiatic and African regions. *Tinospora cordifolia* (Willd.) Miers is a glabrous, succulent, climbing shrub, distributed in mixed deciduous forests of India except colder hills, southern India, Kumaon to Assam, Myanmar, Konkan to Ceylon (Gamble, 1972; Hooker, 1882; Mabberley, 1997).

Order—MALPIGHIALES

Family—ACHARIACEAE (FLACOURTIACEAE)

Genus—HYDNOCARPUS Gaertner

Hydnocarpus mioalpinus Prasad, 2006

(Pl. 4.7, 9)

Material—Single specimen.

Description—Leaf simple, slightly asymmetrical, lanceolate; preserved size 8.5 x 3.5 cm; apex acute; base obtuse, asymmetrical; margins entire; petiole indistinct;

PLATE 3

(Scale bar = 1 cm)

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1. *Mitrephora mioreticulata* n. sp.–Fossil leaf showing oblong shape, large size, acute apex and eucamptodromous venation pattern. Specimen No. 41084 (Holotype).
2. *Mitrephora reticulata* Hook f. & Thomson–Modern leaf showing similar shape, size, apex and venation pattern.

PLATE 3

texture coriceous; venation pinnate, eucamptodromous; primary vein (1º) single, prominent, stout; secondary veins (2º) 6–7 pairs visible, 0.6–1.8 cm apart, usually alternate, unbranched, angle of divergence about 60º, moderately acute, uniformly curved upwards and running long distance before joining the super adjacent secondaries; tertiary veins (3º) fine, poorly preserved, angle of origin RR type, percurrent, straight to sinuous, branched, predominantly alternate and close, oblique in relation to mid vein.

Figured Specimen—BSIP Museum Specimen No. 41087.

Locality—Profile 5A (27º54'50.6" N: 82º31'00.4" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene**.**

Affinities—The characteristic features of the present fossil leaf such as lanceolate shape; acute apex; obtuse base; eucamptodromous venation; usually alternate, unbranched, moderately acute angle of divergence of secondary veins which curve upwards and run a long distance before joining the super adjacent secondaries; tertiary veins RR type, percurrent, having oblique relation to mid vein, collectively suggest a close affinity with modern leaves of *Hydnocarpus alpinus* Wight of family Achariaceae (Flacourtiaceae) (C.N.H. Herbarium Sheet No. 3712; Pl. 4.8, 10). The present fossil leaf also resembles modern leaves of *Hydnocarpus subfalcata* (C.N.H. Herbarium Sheet No. 33603) and *Hydnocarpus castanea* (C.N.H. Herbarium Sheet No. 366) but differs in possessing only 4–5 pairs of secondary veins.

Five fossil leaves resembling the genus *Hydnocarpus* Gaertner are reported from Lower and Middle Siwalik sediments of India and Nepal. *Hydnocarpus palaeokurzii,* from Lower–Middle Siwalik sediments of Oodlabari, Darjeeling District, West Bengal (Antal & Awasthi, 1993) and Kathgodam, Uttarakhand (Prasad, 1994c); *Hydnocarpus mioalpinus*, from Lower Siwalik sequence of Himachal Pradesh, India (Prasad, 2006); *Hydnocarpus siwalicus* and *Hydnocarpus chorkholaensis* from Siwalik sediments of Surai Khola sequence, western Nepal (Prasad & Awasthi, 1996) and *Hydnocarpus ghishiensis,* from Middle Siwalik sediment of (Upper Miocene) Darjeeling District, West Bengal, India (Prasad *et al.,* 2015). In comparing the present fossil leaf with all above known species, the new leaf was found to be different from all except *Hydnocarpus mioalpinus* (Prasad, 2006) on account of its lanceolate shape, large size and slightly curved secondary veins. However, it resembled *Hydnocarpus mioalpinus* (Prasad, 2006) in shape, size and venation pattern. Therefore the present fossil leaf is assigned same species, *Hydnocarpus mioalpinus*.

The genus *Hydnocarpus* Gaertner consists of about 40 species distributed in Indo–Malayan regions of tropical Asia. *Hydnocarpus alpinus* Wight is a large tree, commonly found on the eastern side of Nilgiris and Western Ghats in India and Sri Lanka (Hooker, 1872; Brandis, 1971; Gamble, 1972; Mabberley, 1997).

Genus—RYPARIA (RYPAROSA) Blume

Ryparia arjunkholaensis n. sp.

(Pl. 5.1, 2, 4)

Material—Two specimens.

Description—Leaves simple, bilaterally symmetrical, elliptical; preserved size 14.3 x 6.5 cm and 13.5 x 7.6 cm; apex acute; base broken; broadly undulate margins; petiole not preserved; texture chartaceous; venation pinnate, eucamptodromous; primary vein (1º) single, straight, prominent, stout; secondary veins (2º) thick, unbranched, 7 pairs visible, angle of divergence (about 60º) moderately acute, 2.8 to 4.5 cm apart, alternate, uniformly curved upward joining the super adjacent secondary veins; tertiary veins (3º) fine, angle of origin RR type, percurrent, branched, straight to sinuous, predominantly alternate, usually distant, oblique in relation to mid vein.

Holotype—BSIP Museum Specimen No. 41088.

PLATE 4

(Scale bar = 1 cm)

→

1. *Tinospora siwalika* n. sp.–Fossil leaf showing shape, size, and special base and venation pattern. Specimen No. 41086 (Holotype).
2. *Tinospora cordifolia* (Willd.) Miers–Modern leaf showing similar shape, size, base and venation pattern.
3. *Tinospora siwalika* n. sp.–A part of fossil leaf magnified to show details of straight to slightly sinuous pattern of tertiary veins.
4. *Tinospora cordifolia* (Willd.) Miers–A part of modern leaf magnified to show similar details of tertiary veins.
5. *Tinospora siwalika* n. sp.–Apical part of the fossil leaf magnified to show acute apex.
6. *Tinospora cordifolia* (Willd.) Miers–Apical part of the modern leaf magnified to show similar detail of apex.
7. *Hydnocarpus mioalpinus* Prasad–Fossil leaf showing shape, size, nature of base, apex and venation pattern.Specimen No. 41087.
8. *Hydnocarpus alpinus* Wight–Modern leaf showing similar shape, size, apex, base and venation pattern.
9. *Hydnocarpus mioalpinus* Prasad–A part of the fossil leaf magnified to show details of predominantly alternate and close tertiary veins.
10. *Hydnocarpus alpinus* Wight–A part of the modern leaf magnified to show similar details of tertiary veins.
11. *Isoptera siwalica* Prasad *et al.*–Fossil leaf showing shape, size and venation pattern. Specimen No. 41093.
12. *Isoptera boreneensis* Scheff. ex Burck n. sp.–A modern leaf showing similar shape, size and venation pattern.
13. *Isoptera siwalica* Prasad *et al.*–A part of fossil leaf magnified to show details of secondary veins which are sharply curved upward near the margin and RR tertiary veins.
14. *Isoptera boreneensis* Scheff. ex Burck n. sp.–A part of modern leaf magnified to show similar details of secondary and tertiary veins.

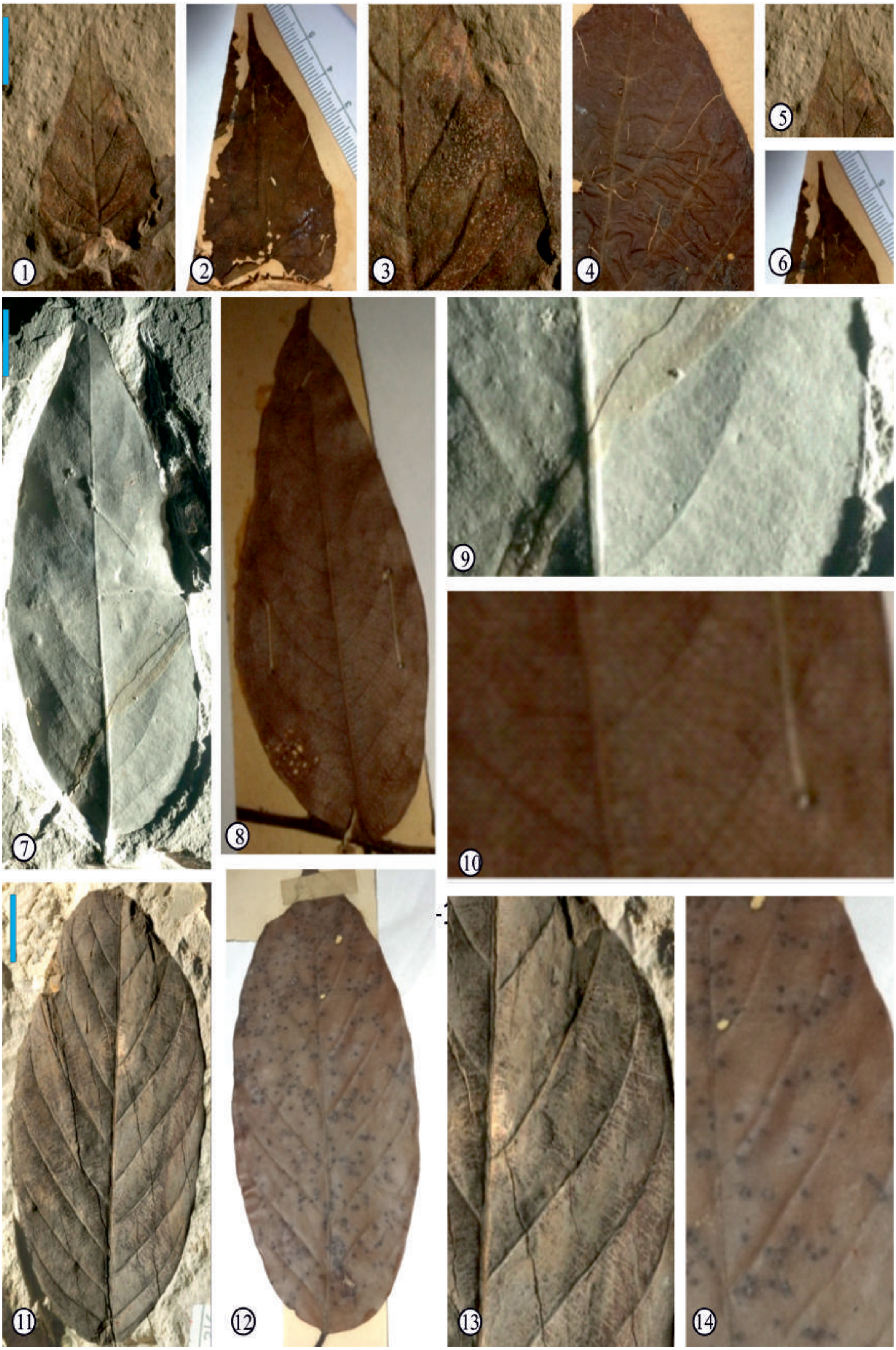

PLATE 4

Locality—Profile 5A (27º54'50.6" N: 82º31'00.4" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Etymology—After the name of fossil locality, Arjun Khola.

Affinities—Features of the present fossil leaves like elliptical shape, acute apex, eucamptodromous venation, unbranched secondary veins showing moderately acute angle of divergence which are uniformly curved upwards joining super adjacent secondaries; usually RR, percurrent and distant tertiary veins strongly indicate a close affinity with modern leaves of *Ryparia caesia* Blume ex Baill. (Syn. *Ryparosa caesia* Kurz ex King.; C.N.H. Herbarium Sheet No. 33850; Pl. 5.3, 5) of family Achariaceae. The fossil leaves also resemble the modern leaves of *Ryparia scratchier*, *Ryparia kunstleri* but differ from them in the nature of secondary and tertiary veins which are distantly placed.

So far, there is only one record of fossil leaves resembling the genus *Ryparia* (*Ryparosa*) Blume from the Siwalik sediments of Koilabas, western Nepal under the form species *Ryparosa prekunstelri* (Prasad, 1990a) which differs from present fossil leaves in being smaller in size and having distantly placed secondary veins. Hence, the Arjun Khola fossil leaf is being described as a new species, *Ryparia arjunkholaensis.*

The genus *Ryparia* (*Ryparosa*) Blume consists of 18 tropical species distributed in Indo–Malaya and Indonesia (Willis, 1973). *Ryparia caesia* Blume ex Baill. is a small tree commonly found in the rain forests of India, often near streams in Andaman and Nicobar Islands, Malaya Peninsula, Indonesia and New Guinea (Brandis, 1971; Mabberley, 1997).

Family—CALOPHYLLACEAE

Genus—CALOPHYLLUM L.

Calophyllum mioelatum n. sp

(Pl. 8.1, 3)

Material—Single specimen.

Description—Leaf simple, bilaterally symmetrical, narrow lanceolate; preserved size 15.7 x 2.4 cm; apex broken; base slightly broken seemingly acute; margins entire; petiole not preserved; texture coriceous; venation pinnate, craspedodromous; primary vein (1º) single, almost straight, prominent, stout; secondary veins (2º) numerous unbranched, angle of divergence (80º–90º) nearly at right angles, less than 0.1 cm apart, very closely placed, opposite to alternate, running almost parallel before joining the margins, unbranched; tertiary veins (3º) not seen.

Holotype—BSIP Museum Specimen No. 41145.

Locality—Profile 7 (27º55'25.7" N: 82º30'57.9" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Etymology—By adding a prefix 'Mio' in the name of comparable species, *C. elatum*.

Affinities—Distinguishing features of the present fossil leaf such as narrow lanceolate shape, seemingly acute base craspedodromous venation, secondary veins opposite to alternate running almost parallel to each other and showing nearly right angle divergence show close similarity with the modern leaves of *Calophyllum elatum* Bedd. (C.N.H. Herbarium Sheet No. 284; Pl. 8.2, 4) of the family Calophyllaceae.

Fossil leaves resembling the genus *Calophyllum* L. have been described under two generic names *Calophyllum* L. and *Calophyllaceophyllum* from the Tertiary sediments of India and abroad. *Calophyllum* L. includes five species, i.e. *Calophyllum pliocenicum* Krasser (1903) from Ouricanga, Brazil, *C. nathorstii* (Geyler) Krausel and *Calophyllum* sp. Krausel (1929) from Sumatra, *C. 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), Papumpare, Arunachal Pradesh (Khan *et al*., 2011), Kerala Coast (Awasthi & Srivastava, 1992), Paleocene of Cherrapunji (Ambwani, 1991) and Oligocene of Makum Coalfield, Assam (Awasthi & Mehrotra, 1995). *Calophyllaceophyllum* constitutes only one species, *C. eocenicum* reported from Eocene sediments of Vastan Lignite, western India(Singh *et al*., 2015).

A comparison with above fossils showed that the present fossil leaf differed from above mentioned ones in being of narrow lanceolate shape, large size with a larger number of secondary veins. Therefore, the present fossil leaf has been described here as new species *Calophyllum mioelatum*.

PLATE 5

(Scale bar = 1 cm)

→

1,2. *Ryparia arjunkholaensis* n. sp.–Fossil leaves showing shape, size and venation pattern especially alternate pattern of secondary veins which are curved upward to join super adjacent secondaries. Specimen No. 41088 (Holotype).

3. *Ryparia caesia* Blume ex Baill.–Modern leaf showing similar shape, size, venation pattern and other morphological features.

4. *Ryparia arjunkholaensis* n. sp.–A part of fossil leaf magnified to show details venation pattern.

5. *Ryparia caesia* Blume ex Baill.–A part of modern leaf magnified to show similar details venation pattern.

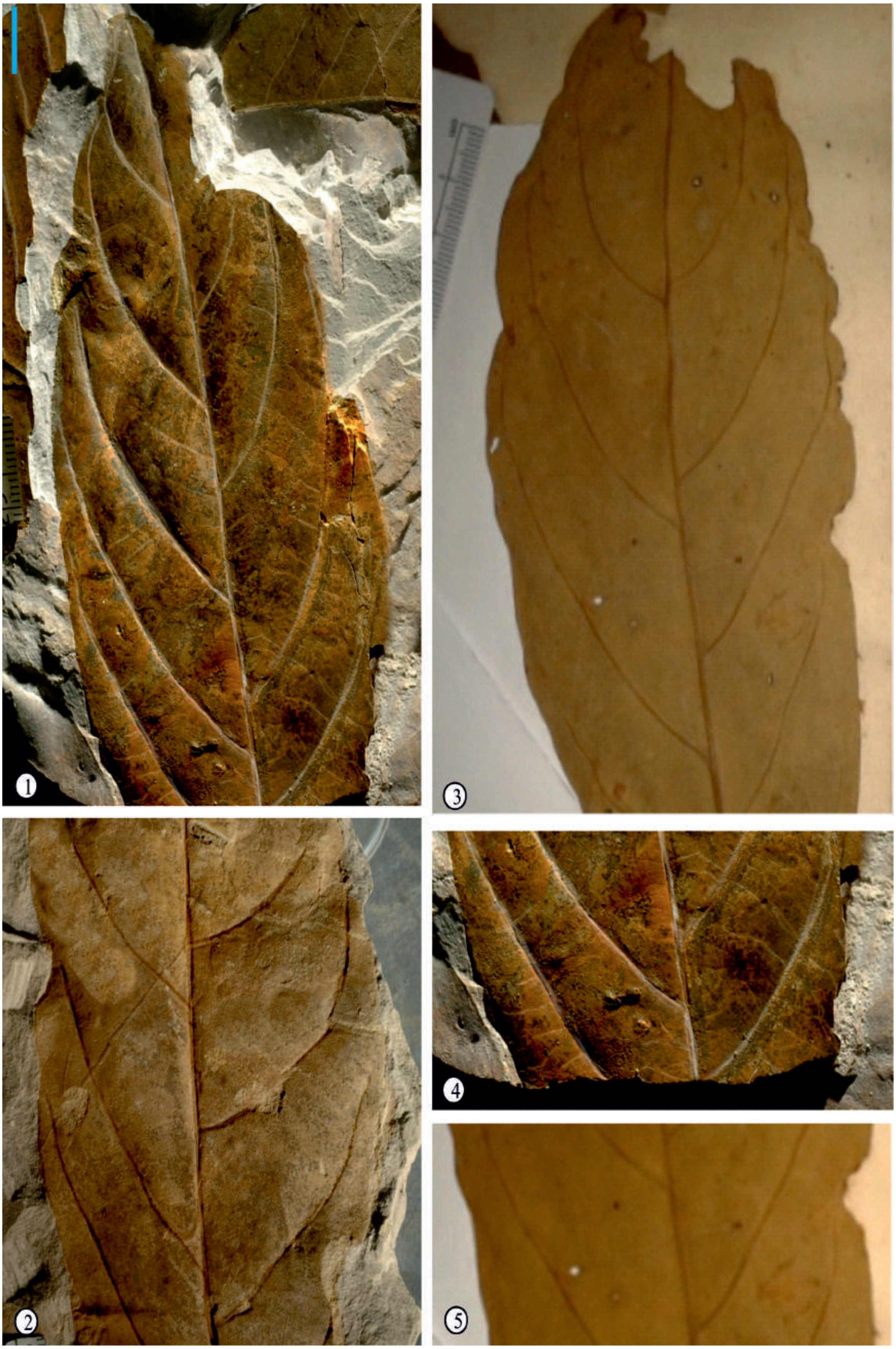

PLATE 5

The genus *Calophyllum* L. comprises about 187 species chiefly distributed in Tropical Asia with a few in America. *Calophyllum elatum* Bedd. is a tall tree growing in evergreen forests of Western Ghats and adjoining hills from North Kanara to Travancore and Sri Lanka (Hooker, 1872; Brandis, 1971; Gamble, 1972; Mabberley, 1997).

Order—MALVALES

Family—DIPTEROCARPACEAE

Genus—ANISOPTERA Korth.

Anisoptera palaeoscaphula n. sp.

(Pl. 9.1)

Material—Single specimen.

Description—Leaf simple, bilaterally symmetrical, elliptical; preserved size 12.1 x 6.0 cm; apex acute to acuminate; base appearing obtuse; margins entire; petiole not preserved; texture chartaceous; venation pinnate, eucamptodromous to brochidodromous; primary vein (1º) single, straight, moderately thick towards base, prominent, stout; secondary veins (2º) about 15 pairs visible, angle of divergence (60º–75º), moderate to widely acute, basal pairs arising at wider angle, 0.5 to 1.2 cm apart, unbranched, uniformly curving upwards sometime joining super adjacent secondary veins and forming a loop in the apical region; tertiary veins (3º) fine with angle of origin RR type, percurrent, straight to sinuous, branched, predominantly alternate and close, oblique in relation to mid vein.

Holotype—BSIP Museum Specimen No. 41089.

Locality—Profile 5A (27º54'50.6" N: 82º31'00.4" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Etymology—By adding the prefix 'palaeo' to the modern comparable species, *Anisoptera scaphula.*

Affinities—Morphological features of the present fossil leaf like elliptical shape, acute to acominate apex, obtuse base eucamptodromous to brochidodromous venation, uniformly upward curving secondary veins sometimes joining super adjacent secondaries and turning upwards to form a loop like structure apically, fine tertiary veins with RR type angle of origin, percurrent, straight to sinuous, branched, oblique in relation to mid vein indicated affinity with modern leaves of *Anisoptera scaphula* (Roxb.) Pierre (C.N.H. Herbarium Sheet No. 51008; Pl. 9.2) of the family Dipterocarpaceae.

So far there is no record of fossil leaf resembling the genus *Anisoptera* Korth. from the Siwalik sediments. Occurrence of present fossil leaf in the Siwalik sediments of Arjun Khola area, western Nepal is the first record and hence is being described as a new species *Anisoptera palaeoscaphula*. Fossil woods and a fruit wing resembling the genus *Anisoptera* Korth. have been reported earlier from Siwalik as well as other Cenozoic sediments of India (Yadav, 1989; Sen & Bera, 2005).

The genus *Anisoptera* Korth. consists of about 5 species distributed in Malaya Peninsula, Archipelago to New Guinea. *Anisoptera scaphula* (Roxb.) Pierre is a tall tree distributed in Bangladesh, Malaysia, Myanmar, Thailand, Vietnam and south east Australia to western Malaya (Hooker, 1882; Mabberley, 1997).

Genus—SHOREA Roxb. ex C.F. Gaertner

Shorea siwalika Antal & Awasthi, 1993

(Pl. 7.1–3, 6, 7, 10, 11)

Material—Three specimens.

Description—Leaves simple, bilaterally symmetrical, oblong to elliptical; preserved size 6.5–10.3 x 2.9–4.1 cm; apex acute; base obtuse to rounded; margins entire; petiole not preserved; texture chartaceous; venation pinnate, eucamptodromous; primary vein (1º) single, straight, prominent, stout; secondary veins (2º) about 14–15 pairs visible, angle of divergence moderate (60º–70º), unbranched, usually alternate, rarely opposite, 0.2, 0.4 or 0.6 cm apart, running straightly upwards to join the margin, curvature more pronounced near the margins, upper secondaries more acute than veins of lower part of lamina; tertiary veins (3º) poorly preserved, almost straight, angle of origin RR to AO–RR type, percurrent, almost straight, branched, alternate to opposite, close, oblique in relation to mid vein.

Figured Specimen—BSIP Museum Specimen No. 41090.

Locality—Profile 7 (27º55'25.7" N: 82º30'57.9" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

PLATE 6

(Scale bar = 1 cm)

→

1. *Dipterocarpus palaeoindicus* n. sp.–Fossil leaf showing shape, size and venation pattern. Specimen No. 41092 (Holotype).
2. *Dipterocarpus indicus* Bedd.–Modern leaf showing similar details of shape, size and venation pattern.
3. *Dipterocarpus palaeoindicus* n. sp–A part of fossil leaf magnified to show details of tertiary veins.
4. *Dipterocarpus indicus* Bedd.–A part of modern leaf magnified to show similar details of tertiary veins.

PLATE 6

Affinities—Characteristic features of the present fossil leaves such as bilaterally symmetrical, oblong to elliptical shape; obtuse base; eucamptodromous venation; moderately acute angle of divergence of secondary veins which run uniformly upwards to join the margins and usually AO–RR, percurrent tertiary veins indicate close similarity with modern leaves of *Shorea* Roxb. of the family Dipterocarpaceae. To determine specific affinity of the fossil leaves, the herbarium sheets of all available species of this genus were critically examined and closest similarity was seen with leaves of *Shorea assamica* Dyer. The fossil leaf of *S. assamica* resembled in shape, size and venation pattern (C.N.H. Herbarium Sheet No. 51752; Pl. 7.4, 5, 8, 9, 12).

Fossil leaves resembling taxon *Shorea* Roxb. ex C. F. Gaertner have been described earlier as *Shorea siwalica* from Siwalik of Darjeeling District of West Bengal (Antal & Awasthi, 1993); *Shorea miocenica* from Siwalik of Oodlabari, Darjeeling District, West Bengal (Antal & Prasad, 1996b) and from Siwalik of Tinau Khola, Nepal (Konomatsu & Awasthi, 1999); *Shorea bengalensis* from Siwalik sediments (Middle Miocene) of Darjeeling District, West Bengal (Antal & Prasad, 1997); *Shorea neoassamica* Prasad from Siwalik of Kathgodam, Uttarakhand (Prasad, 1994c) and the East Kameng District of Arunachal Pradesh (Joshi & Mehrotra, 2007); *Shorea palaeoridleyana* Joshi and Mehrotra (2007) from east Kameng District of Arunachal Pradesh (Joshi & Mehrotra, 2007), *Shorea eutrapizifolia* from Koilabas area western Nepal (Prasad *et al.,*1999); *Shorea palaeostellata* from Siwalik of Surai Khola, western Nepal (Prasad & Pandey, 2008); *Shorea palaeocurtisii* from Middle Miocene of Koilabas, western Nepal (Prasad & Dwivedi, 2008) and *Shorea nepalensis* from the Siwalik of Binai Khola, Nepal (Konomatsu & Awasthi, 1999). A comparison of above mentioned fossil species with the present fossil leaves showed closest similarity with *Shorea siwalika* (Antal & Awasthi, 1993). The fossil leaves are similar in size and venation pattern, Hence the present leaf is assigned to *Shorea siwalika*.

The genus *Shorea* Roxb. ex C. F. Gaertner consists of about 167 species distributed throughout the world mainly in south–east Asia, Sri Lanka, India, Myanmar, Malaysia and Philippines. About 100 species of the taxon grow throughout the tropical parts of Indo–Malayan region. *Shorea assamica* Dyer is a large gregarious tree found growing in evergreen forests of Upper Assam at the foot of Naga Hills, in Sibsagar and Lakhimpur District (Pearson & Brown, 1932; Gamble, 1972).

Genus—DIPTEROCARPUS Gaertner

Dipterocarpus koilabasensis Prasad *et al*., 1999

(Pl. 1.7, 9)

Material—Single specimen.

Description—Leaf simple, bilaterally symmetrical, widely elliptical; preserved size 7.2 x 4.0 cm; apex broken; base obtuse; undulate margins; petiole not preserved; texture chartaceous; venation pinnate, craspedodromous; primary vein (1º) single, straight, moderately thick, prominent, stout; secondary veins (2º) 6 pairs visible, angle of divergence moderately acute (about 50º), opposite to alternate, 0.5 to 1.0 cm apart, arising straightly but curving near the margins; tertiary veins (3º) fine, angle of origin usually RR type, percurrent, straight to sinuous, branched, predominantly alternate and close, oblique in relation to mid vein.

Figured Specimen—BSIP Museum Specimen No. 41091.

Locality—Profile 5A (27º54’50.6" N: 82º31’00.4" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Affinities—Most of the features of the present fossil leaf like bilaterally symmetrical, widely elliptical shape, obtuse base, craspedodromous venation, opposite to alternate secondary veins showing moderately acute angle of divergence but becoming sharply curved near the margins, usually RR, percurrent, straight to sinuous tertiary veins indicate close affinity with the modern leaves of *Dipterocarpus turbinatus* Gaertner of the family Dipterocarpaceae (C.N.H. Herbarium Sheet No. 50540; Pl. 1.8, 10).

About five records of fossil leaves of the genus *Dipterocarpus* Gaertner are known from the Siwaliks of India and Nepal. These are *Dipterocarpus siwalicus* from Balugoloa, Himachal Pradesh (Lakhanpal & Guleria, 1987); Oodlabari, Darjeeling District, West Bengal (Antal & Prasad, 1996b); Siwalik sediments of Kathgodam, Uttarakhand (Prasad, 1994c); Surai Khola area, western Nepal (Awasthi & Prasad, 1990) and Lower Siwalik beds of Koilabas area, western Nepal (Prasad, 1990b); *Dipterocarpus koilabasensis*

PLATE 7

(Scale bar = 1 cm)

→

1–3. *Shorea siwalika* Antal & Awasthi–Fossil leaves showing shape, size and venation pattern. Specimen No. 41090.

4, 5. *Shorea assamica* Dyer–Modern leaves showing similar shape, size and venation pattern.

6, 7. *Shorea siwalika* Antal & Awasthi–Magnified part of fossil leaf showing details of tertiary veins.

8, 9. *Shorea assamica* Dyer–Magnified part of a modern leaf showing similar details of tertiary veins.

10, 11. *Shorea siwalika* Antal & Awasthi–Apical parts of the fossil leaves showing acute apexes and usually alternate to rarely opposite pattern of secondary veins.

12. *Shorea assamica* Dyer–Apical part of the modern leaf showing similar apex and arrangement of secondary veins.

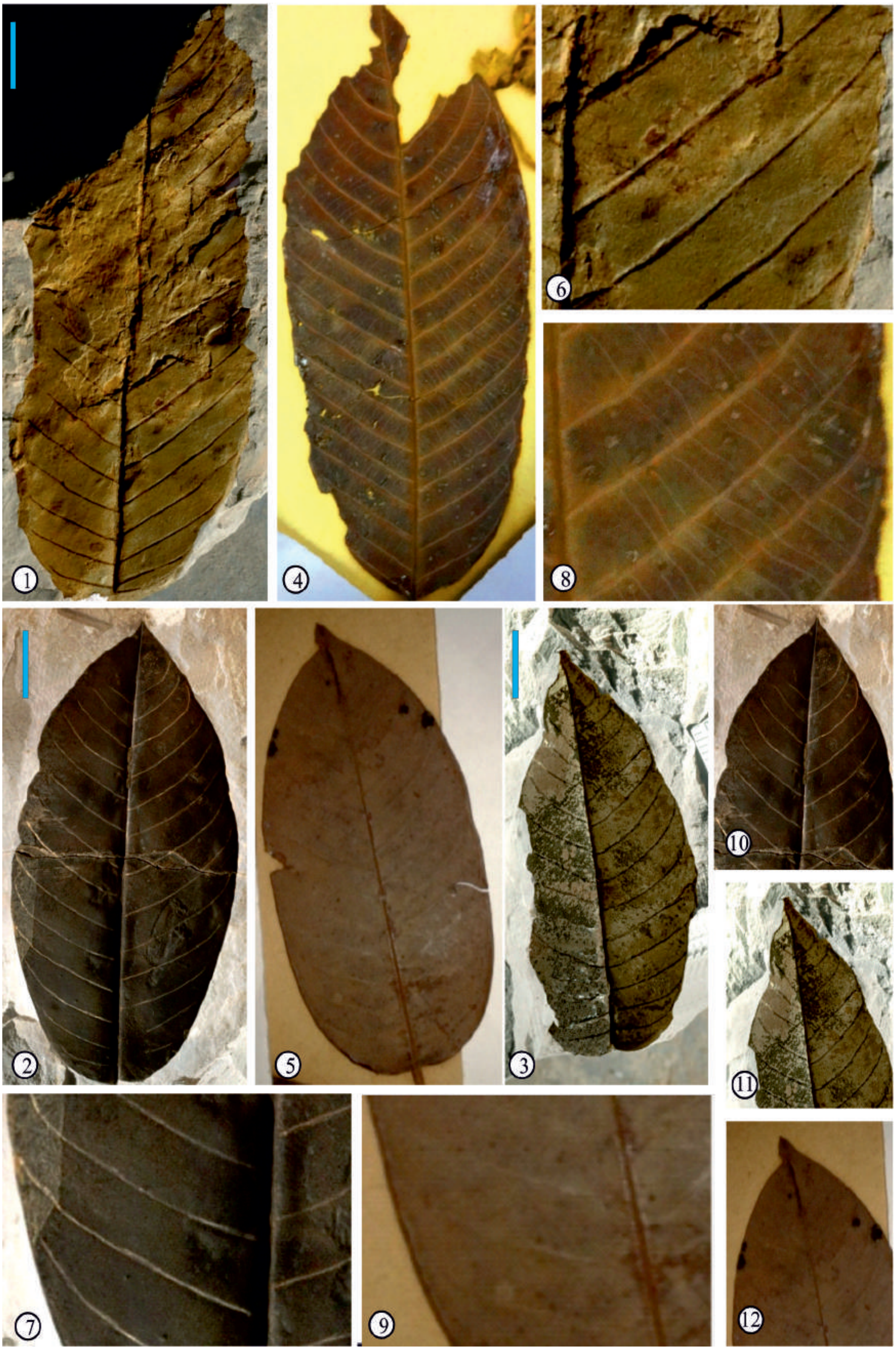

PLATE 7

from Koilabas area, western Nepal (Prasad *et al.,* 1999); *Dipterocarpus suraikholaensis* Prasad and Pandey from Siwalik of Surai Khola (Prasad & Pandey, 2008) and Arjun Khola area in western Nepal (Prasad & Gautam, 2016); *Dipterocarpus miocenicus* and *D. nepalensis* from Siwalik of Arjun Khola area, western Nepal (Prasad & Gautam, 2016).

Comparison of the present fossil leaf with those described earlier showed a similarity with the fossil leaf of *Dipterocarpus koilabasensis* (Prasad *et al.,* 1999), as both leaves had similar venation pattern. The present fossil leaf is therefore, assigned to *D. koilabasensis.*

The presence of *Dipterocarpus* in the Arjun Khola area indicates that the age of the fossil beds may not be older than Lower Miocene since all the known fossil records of *Dipterocarpus* from the Indian sub–continent are confined to Neogene only.

The taxon *Dipterocarpus* Gaertner comprises of about 69 species distributed in The Indo–Malayan regions, South India, East Bengal, Assam, Andaman Island, Sri Lanka and Myanmar. *Dipterocarpus turbinatus* Gaertner is an evergreen tree distributed in evergreen forests of Cachar, Chittagong Hills and in Tropical forest of Myanmar and Andaman Islands (Hooker, 1882; Kanjilal, 1936; Brandis, 1971; Gamble, 1972; Mabberley, 1997).

Genus—DIPTEROCARPUS Gaertner

Dipterocarpus palaeoindicus n. sp.

(Pl. 6.1, 3)

Material—Single specimen.

Description—Leaf simple, bilaterally symmetrical, elliptical; preserved size 15.7 x 4.8 cm; apex and base broken; margins entire; petiole not preserved; texture chartaceous; venation pinnate, craspedodromous to eucamptodromous; primary vein (1º) single, straight, prominent, stout; secondary veins (2º) 11 pairs visible, angle of divergence narrowly acute (about 55º), lower secondaries almost straight but shallowly curved near the margins, opposite to alternate, 0.8 to 1.4 cm apart; tertiary veins (3º) poorly preserved, angle of origin usually RR type, percurrent, straight to sinuous, branched, predominantly alternate and close, oblique in relation to mid vein.

Holotype—BSIP Museum Specimen No. 41092.

Locality—Profile 5A (27º54'50.6" N: 82º31'00.4" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Etymology—By adding the prefix 'palaeo' to the modern comparable species, *Dipterocarpus indicus.*

Affinities—The distinguishing features of the present fossil leaf such as bilateral symmetry, elliptical shape; craspedodromous venation; single, straight, prominent, stout, primary vein; opposite to sub–opposite secondary veins showing narrowly acute angle of divergence but becoming shallowly curved near the margins, usually RR, percurrent oblique, straight to sinuous tertiaries indicated its affinity with the modern leaves of *Dipterocarpus indicus* Bedd. of the family Dipterocarpaceae (C.N.H. Herbarium Sheet No. 62474; Pl. 6.2, 4). The fossil leaf also resembled modern leaves of *Dipterocarpus turbinatus*, but differs in being of smaller size and showing sub–opposite to alternate closely placed secondary veins.

Fossil leaf resembling the genus *Dipterocarpus* Gaertner has been enumerated earlier in this text. A comparison of the present fossil leaf with the earlier known species revealed the new leaf being quite different on account of lesser distance between two lower secondaries. The fossil leaf was thus described as a new species, *Dipterocarpus palaeoindicus* n. sp.

The genus *Dipterocarpus* Gaertner consists of about 69 species distributed in the Indo–Malayan regions, South India, E. Bengal, Myanmar, Andaman Islands and Ceylon. *Dipterocarpus indicus* Bedd. is a lofty tree distributed in the evergreen forests of Malabar, Travancore, Western Ghats from north Kanara to southwards (Brandis, 1971; Gamble, 1972; Mabberley, 1997).

Genus—ISOPTERA Scheff. ex Burck

Isoptera siwalica Prasad *et al.,* 1999

(Pl. 4.11, 13)

PLATE 8

(Scale bar = 1 cm)

1. *Calophyllum mioelatum* n. sp–Fossil leaf showing shape, size and venation pattern. Specimen No. 41145.
2. *Calophyllum elatum* Bedd.–Modern leaf showing similar shape, size and venation pattern.
3. *Calophyllum mioelatum* n. sp.–A part of fossil leaf magnified to show details of numerous and opposite to alternate pattern of secondary veins.
4. *Calophyllum elatum* Bedd.–A part of modern leaf magnified to show similar details of secondary veins.
5. *Uvaria miolucida* n. sp.–Fossil leaf showing shape, size and venation pattern. Specimen No. 41085 (Holotype).
6. *Uvaria lucida* Benth.–Modern leaf showing similar shape, size and venation pattern.
7. *Uvaria miolucida* n. sp.–A part of fossil leaf magnified to show details of intersecondary and tertiary veins.
8. *Uvaria lucida* Benth.–A part of modern leaf magnified to show similar details of intersecondary and tertiary veins.

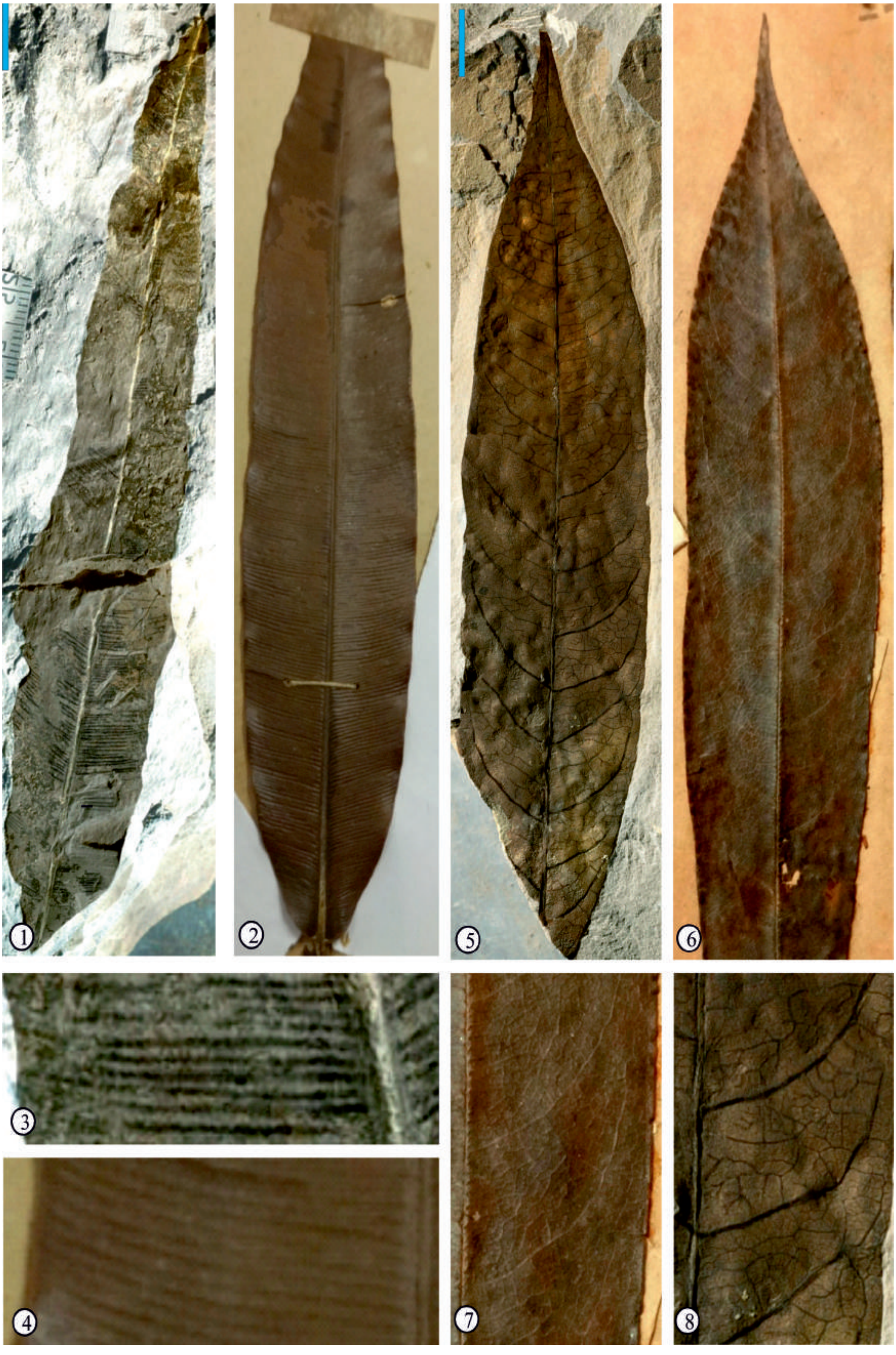

PLATE 8

Material—Single specimen.

Description—Leaf simple, seemingly asymmetrical, elliptical; preserved size 7.4 x 3.9 cm; apex not preserved and base obtuse; margins entire; petiole not preserved; texture chartaceous; venation pinnate, eucamptodromous; primary vein (1º) single, straight, prominent, stout; secondary veins (2º) 9 pairs visible, alternate, unbranched, angle of divergence narrow to moderately acute, 0.8 to 0.9 cm apart, slightly bent upwards and again uniformly curved near the margins (about 40º–50º); tertiary veins (3º) angle of origin RR type, branched, percurrent, almost straight to nearly sinuous, predominantly alternate and close, oblique in relation to mid vein.

Figured Specimen—BSIP Museum Specimen No. 41093.

Locality—Profile 5B (27º54'53.7" N: 82º31'05.2" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Affinities—Distinguishing features of the present fossil leaf like bilaterally symmetrical, elliptical shape, eucamptodromous venation; straight, prominent primary vein; alternate secondary veins with narrowly acute angle of divergence, showing sharp curvature near the margins; RR, percurrent, straight to nearly sinuous tertiary veins indicated an affinity with the modern leaves of *Isoptera boreneensis* Scheff. ex Burck of the family Dipterocarpaceae (C.N.H. Herbarium Sheet No. 52123; Pl. 4.12, 14).

So far, only one fossil leaf resembling modern leaves of *Isoptera boreneensis* Scheff. ex Burck has been reported from Koilabas area, Nepal (Prasad *et al*., 1999) under the form species *Isoptera siwalica*. On comparison, the present fossil leaf was found to be very similar to the above known species in shape, size and venation pattern. Hence the new fossil leaf was assigned to *Isoptera siwalica*.

The genus *Isoptera* Scheff. ex Burck comprises of only three species growing in Tropical forest of western Malaysia (Willis, 1973). *Isoptera boreneensis* Scheff. ex Burck is a large tree distributed in the evergreen forests of Pahang, Tenjai, Borneo, Banka, Myanmar, Java, Sumatra and Malaya Peninsula (Ridley, 1967; Brandis, 1971).

Family—MALVACEAE

Genus—STERCULIA L.

Sterculia arjunkholaensis n. sp.

(Pl. 13.1)

Material—Single specimen.

Description—Leaf simple, bilaterally symmetrical, narrowly oblong, preserved size 15.3 x 3.2 cm; apex attenuate; base seemingly acute; margin apically and basally dentate; texture chartaceous; venation pinnate, eucamptodromous to rarely brochidodromous; primary vein (1°) single, straight, stout, prominent; secondary veins (2°) about 10 pairs visible, 0.5 to 1.5 cm apart, alternate, unbranched, angle of divergence moderately acute (50º–65º), sometimes forming loop near the margins; intersecondary veins simple; tertiary veins (3º) poorly preserved, angle of origin usually RR, percurrent, straight to sinuous, branched, predominantly alternate, close to distant, oblique to right angled in relation to mid vein.

Holotype—BSIP Museum Specimen No. 41098.

Locality—Profile 3 (27º54'24.0"N: 82º30'52.7" E) Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Lower Churia Group, Middle Miocene.

Etymology—After the name of fossil locality, Arjun Khola from where fossil was collected.

Affinities—Characteristic features of the fossil leaf such as bilaterally symmetrical, narrowly oblong shape; attenuate apex; eucamptodromous to brochidodromous venation; moderately acute angle of divergence of alternately arranged secondary veins, forming a loop near the margins; presence of simple intersecondary veins and usually RR, percurrent, predominantly alternate and close to distant tertiaries undoubtedly indicated its affinity with the modern leaves of *Sterculia hamiltonii* (Kuntze) Adelb. (C.N.H. Herbarium Sheet No. 25803; Pl. 13.2). of the family Malvaceae.

So far, four fossil leaves resembling the genus *Sterculia* L. have been reported from Lower and Middle Siwalik sediments of India and Nepal. These are *Sterculia kathgodamense* Prasad from Lower Siwalik sediments of Balia River beds, Kathgodam, Uttarakhand (Prasad, 1994c) and Middle Siwalik sediments of Arjun Khola, Lamhi, Deokhuri District, western Nepal (Prasad *et al.,* 2013); *Sterculia tertiara* (Shashi *et al.,* 2006) from Lower Siwalik sediments of Purniyagiri near Tanakpur, Uttarakhand; *Sterculia mioensifolia* and *Sterculia premontana* from Lower and Middle Siwalik sediments of Surai Khola, western Nepal (Prasad & Pandey, 2008). One fossil fruit having affinity with the same genus has also been reported from Tikat Prabhat Formation of Makum Coalfield,

PLATE 9

(Scale bar = 1 cm)

⟶

1. *Anisoptera palaeoscaphula* n. sp.–Fossil leaf showing shape, size and venation pattern. Specimen No. 41089 (Holotype).
2. *Anisoptera scaphula* (Roxb.) Pierre–Modern leaf showing similar shape, size and venation pattern.
3. *Cayratia palaeojaponica* n. sp.–Fossil leaflet showing shape, size and venation pattern. Specimen No. 41102 (Holotype).
4. *Cayratia japonica* (Thunb.) Gagnep.–Modern leaflet showing similar shape, size and venation pattern.
5. *Cayratia palaeojaponica* n. sp.–A part of fossil leaflet magnified to show details of venation pattern.
6. *Cayratia japonica* (Thunb.) Gagnep.–A part of modern leaflet magnified to show similar venation pattern.

PLATE 9

Tinsukia District, Assam, under the form species *Sterculia palaeovillosa* (Mehrotra, 2000b). A comparison of the present fossil leaf with all the above mentioned fossil species revealed that the former varied from other species in shape, size and venation pattern. The new fossil leaf is narrowly oblong in shape showing more numbers of secondary veins compared to others. Hence, it has been described as a new species, *Sterculia arjunkholaensis*.

The genus *Sterculia* L. comprises about 150 species distributed in Australia, India, Myanmar and tropics of both the hemispheres but is especially abundant in tropical Asia. *Sterculia hamiltonii* (Kuntze) Adelb. is a shrub distributed in North–east India, south–east Asia, sub–Tropical Himalayas (Nepal to Bhutan), Assam and Myanmar (Brandis, 1971; Gamble, 1972; Mabberley, 1997).

Family—TILIACEAE

Genus—GREWIA L.

Grewia palaeodisperma n. sp.

(Pl. 11.1, 2, 5, 7)

Material—Three specimens.

Description—Leaves simple, bilaterally symmetrical, elliptical; preserved size 6.5–7.7 x 2.5–4.6 cm; apex seems to be acute; base obtuse; margins distinctly finely dentate; texture chartaceous; venation acrodromous, basal imperfect; primary vein (1º) three (one mid and 2 lateral) arising from the base; mid and lateral primaries giving off secondary veins; secondary veins from lateral primaries running towards the margins uniformly curving upwards, veins stout, straight, prominent; secondary veins (2º) branched, opposite to sub–opposite, acute angled, showing narrowly acute to moderate angle of divergence (about 40º–50º); intersecondary veins arise from primaries, simple; tertiary veins (3º) fine, opposite to alternate, close, angle of origin AO–RR, percurrent, branched, oblique in relation to mid vein.

Holotype—BSIP Museum Specimen No. 41094.

Locality—Profile 5A (27º54'50.6" N: 82º31'00.4" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Etymology—By adding the prefix ‘palaeo’ to the modern comparable species, *Grewia disperma.*

Affinities—Morphological features exhibited by the present fossil leaves like bilaterally symmetrical, elliptical shape, acute apex, obtuse base, acrodromous imperfect venation, three primary veins (1º), one mid primary arising at leaf base and two lateral primaries sending off secondaries towards the margins, narrow to moderately acute angle of divergence of opposite to sub–opposite secondary veins, presence of intersecondary veins, AO–RR percurrent and branched tertiary veins, all suggest affinity with modern leaves of genus *Grewia* L. of family Tiliaceae. A critical study of Herbarium sheets of different species of this genus showed leaves of *Grewia paniculata* (C.N.H. 61996), *Grewia serrulata* (C.N.H. 124258), *Grewia scrabrida* (C.N.H. 61556) and *Grewia microcos* (C.N.H. 61932) varied in shape, size and number of secondary veins from the present fossil leaves while, the leaves of *Grewia disperma* Rottler ex Spreng (C.N.H. Herbarium Sheet No. 3318; Pl. 11.3, 4, 8) showed closest similarity with the present fossil leaves having similar shape, size and venation pattern.

Fossil leaves resembling the genus *Grewia* L. were earlier reported from Cenozoic sediments of India and Nepal. Two fossil leaves were also reported from Siwalik sediments of Darjeeling District, West Bengal under the name *Grewia ghishia* from Ghish River section (Antal & Awasthi, 1993) and *Grewia tistaensis* (Antal & Prasad, 1998) from Sevoke Road section near Tista River Bridge. Both differ from the present fossil leaves in being of smaller size and showing marked serrations. Another fossil leaf reported from Late Cenozoic sediments of Mahuadanr, Palamau District, Jharkhand (Srivastava *et al.,* 1992) differs from the present fossil leaves especially in venation pattern. Fossil leaves like *Grewia mallotophylla* described from Siwalik of Arung Khola, west Nepal (Konomatsu & Awasthi, 1999) *Grewia sahnii* and *Grewia garoensis* from Tura Formation of Meghalaya, India (Mehrotra, 2000a) differ from the present fossil leaves in the nature of their secondary veins. A comparison of the present fossil with another species *Grewia kathgodamensis* (Prasad *et al*., 2004) from Siwalik of Uttarakhand, India, revealed that the two leaves were quite different as the latter was of small size and showed a different secondary vein pattern.

PLATE 10

(Scale bar = 1 cm)

⟶

1. *Euphoria churiaensis* n. sp.–Fossil leaf showing shape, size and venation pattern. Specimen No. 41104 (Holotype).
2. *Euphoria cinerea* (Turcz.) Radlk.–Modern leaf showing similar shape, size and venation pattern.
3. *Euphoria churiaensis* n. sp.–A part of fossil leaf magnified to show details of tertiary veins.
4. *Euphoria cinerea* (Turcz.) Radlk.–A part of modern leaf magnified to show similar details of tertiary veins.
5. *Harpullia siwalica* Prasad & Awasthi–Fossil leaves showing shape, size and venation pattern. Specimen Nos. 41108–41109.
6. *Harpullia arborea* (Blanco) Radlk.–Modern leaf showing similar shape, size and venation pattern.
7. *Harpullia siwalica* Prasad & Awasthi–A part of fossil leaf in Fig. 5, magnified to show details of tertiary veins.
8. *Harpullia arborea* (Blanco) Radlk.–A part of modern leaf magnified to show similar details of tertiary veins.

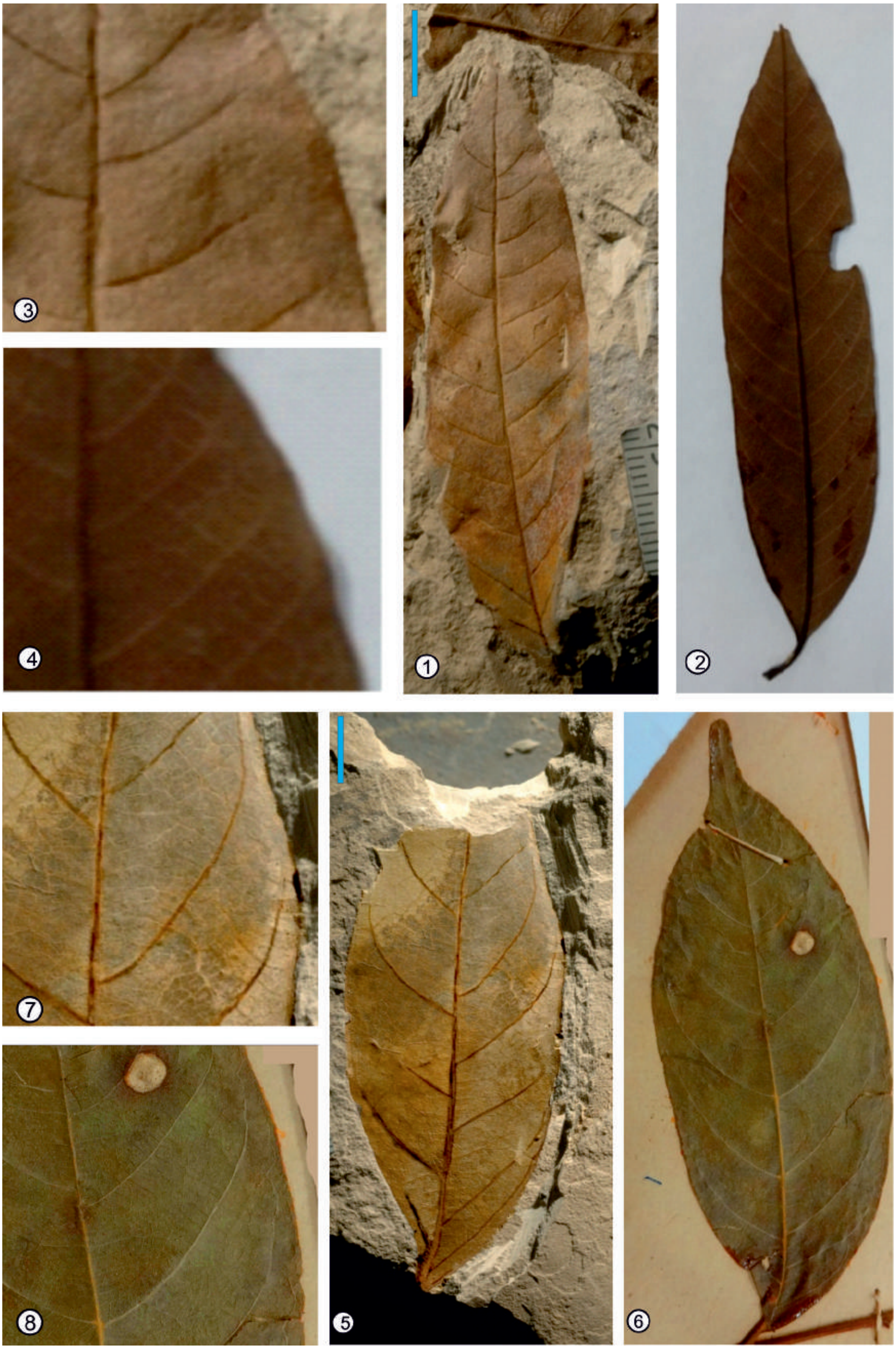

PLATE 10

Therefore, the present fossil leaves are described as a new species, *Grewia palaeodisperma*.

The genus *Grewia* L. comprises of about 150 species distributed in Indo–Malayan and most of the hotter regions of the old world. Some of Indian species are endemic and others common to Tropical Africa. *Grewia disperma* Rottler ex Spreng. is a small tree growing in eastern and southern India from Nepal, Sikkim, Khasi Hills, Martaban, Tropical Africa, Malaya Island and Australia (Hooker, 1872; Mabberley, 1997).

Genus—GREWIA L.

Grewia nepalensis n. sp.

(Pl. 12.1, 3)

Material—Single specimen.

Description—Leaf simple, bilaterally symmetrical, lanceolate; preserved size 14.0 x 3.8 cm; apex seemingly attenuate; base obtuse, equilateral; margins distinctly finely dentate; texture coriaceous; venation acrodromous; primary vein (1°) five (one mid and 4 laterals) basal, one mid primary and two lateral primaries running towards the apex, branching curved towards the apex as secondary vein; veins arising at right angles from mid and lateral primaries at nearly right angle, branched, predominantly alternate and close.

Holotype—BSIP Museum Specimen No. 41097.

Locality—Profile 3 (27º54'24.0" N: 82º30'52.7" E) Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Lower Churia Group, Middle Miocene.

Etymology—Named After the country of Nepal where the fossil localities are situated.

Affinities—Important features of the present fossil leaf like bilaterally symmetrical, lanceolate shaped; obtuse base; acrodromous venation; five primary veins, one mid primary and two lateral primaries running toward the apex and limited secondaries in apical region indicate a strong affinity with modern leaves of *Grewia salvifolia* Heyne ex Roth (C.N.H. Herbarium Sheet No. 35; Pl. 12.2, 4) of the family Tiliaceae.

About six fossil leaves resembling the genus *Grewia* L. have been reported from the Cenozoic sediments of India and Nepal. They are listed below along with their characters (Table 2).

A detailed comparative study of all the above species revealed that the present fossil leaf was entirely different from leaves mentioned in Table 2. Therefore, a new species *Grewia nepalensis* is being instituted for the present fossil leaf.

The extant genus *Grewia* L. consists of 150 species growing specifically in the Tropical region of Asia, Africa and Australia. *Grewia* is confined to the Tropical and sub–Tropical regions of the old World, i.e. Africa, Madagascar, Arabia, India, Myanmar, Ceylon, Andaman–Nicobar, Malaya Peninsula, East Indies, Indo–China, extending to North Australia. The genus is fairly represented in India. About 34 species are found in the Indian sub–continent. *Grewia salvifolia* Heyne ex Roth is a shrub or small tree distributed in dry and arid regions of north–west India and the Deccan Plateau (Brandis, 1971; Gamble, 1972; Willis, 1973; Mabberley, 1997).

Order—SAPINDALES

Family—RUTACEAE

Genus—ERYTHROCHITON Nees & Mart.

Erythrochiton masotkholaensis n. sp.

(Pl. 14.1, 3)

Material—Single specimen.

Description—Leaf simple, bilaterally symmetrical, obovate; preserved size 12.0 x 4.0 cm; apex incomplete; base attenuate; margins entire; texture chartaceous; venation pinnate; brochidodromous; primary vein (1º) single, straight, prominent, stout; secondary veins (2º) 9 pairs visible, 1.2 to 2.0 cm apart, alternate to opposite, unbranched, angle of divergence about 50º–60º, running upwards to join super adjacent secondary at moderately acute to obtuse angle and forming a distinct loop before the margins; intersecondary veins present, simple, rare; tertiary veins (3º) fine, angle of origin AO–RR, percurrent, straight to sinuous, branched, predominantly alternate, close to distant, oblique in relation to mid vein.

PLATE 11

(Scale bar = 1 cm)

⟶

1, 2. *Grewia palaeodisperma* n. sp.–Fossil leaves showing obtuse base and imperfect basal acrodromous venation pattern. Specimen Nos. 41094 (Holotype) and 41095–41096.

3, 4. *Grewia disperma* Rottler ex Spreng.–Modern leaves showing similar obtuse base and acrodromous venation pattern.

5. *Grewia palaeodisperma* n. sp.–Fossil leaf showing acute apex and opposite to sub–opposite pattern of secondary veins.

6. *Grewia disperma* Rottler ex Spreng.–A part of modern leaf showing similar acute apex and opposite to sub–opposite pattern of secondary veins.

7. *Grewia palaeodisperma* n. sp.–A part of fossil leaf magnified to show details of tertiary veins.

8. *Grewia disperma* Rottler ex Spreng.–A part of modern leaf magnified to show similar details of tertiary veins.

9, 10. *Commiphora precaudata* Shashi *et al.*–Fossil leaves showing morphological details such as ovate to elliptic shape, small size, attenuate to sharply acute apex and wide obtuse base. Specimen No. 41100.

11, 12. *Commiphora caudata* (Wight & Arn.) Engl.–Modern leaf showing similar morphological details as the fossil leaves.

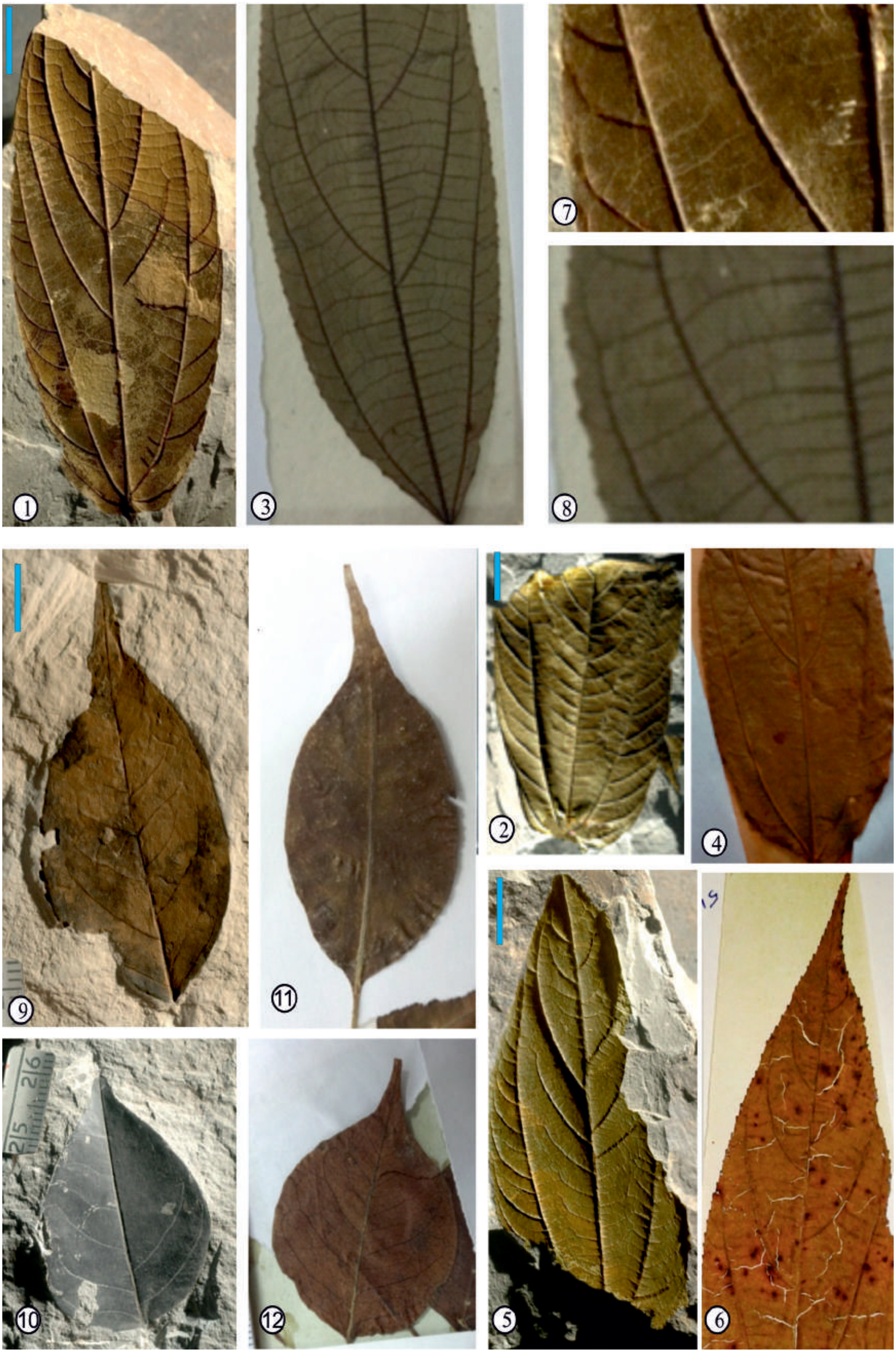

PLATE 11

Table 2—Showing a list of fossil species of *Grewia* L. from the Cenozoic sediments of India and Nepal. ("Characters" indicate features of difference with the present fossil)

Species	Fossil Locality/ Period	Characters
Grewia ghishia Antal & Awasthi, 1993	Lower–Middle Siwalik Oodlabari, Darjeeling District, West Bengal, India	Size smaller (6.2 x 1.9 cm), narrowly elliptical shape and simple craspedodromous venation type.
Grewia tistaensis Antal & Prasad, 1998	Lower Siwalik, Oodlabari, Darjeeling District, West Bengal	Size 11.3 x 5.8 cm, widely elliptical shape, craspedodromous venation type.
Grewia mallotophylla Konomatsu & Awasthi, 1999	Arung Khola and Binai Khola formations of Churia Group (Siwalik), west central Nepal	Size 9.0 x 6.0 cm, ovate to elliptical shape, venation type acrodromous and two strongly developed secondary veins arising from a single point at the base.
Grewia kathgodamensis Prasad *et al.,* 2004	Lower Siwalik, Middle Miocene, Gola River beds near Jamrani, Kathgodam, Nainital District, Uttarakhand	Size smaller (4.4 x 6.2 cm), elliptical to widely elliptic, craspedodromous venation type.
Grewia sahnii (Lakhanpal) Mehrotra, 2000a	Tura Formation (Upper Paleocene) of Nangwalbibra, Garo Hills, Meghalaya, India	Size 9.0 x 4.0 cm, elliptical shape, basal imperfect acrodromous venation type.
Grewia garoensis (Lakhanpal) Mehrotra, 2000a	Tura Formation (Upper Paleocene) of Nangwalbibra, Garo Hills, Meghalaya, India	Size 11.5 x 4.4 cm, asymmetrical, narrowly ovate shape.

Holotype—BSIP Museum Specimen No. 41099.

Locality—Profile 5A (27º54'50.6" N: 82º31'00.4" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Etymology—After the name of small village 'Masot Khola' located near the collection site.

Affinities—On account of features like bilateral symmetry, obovate shape, obtuse apex, attenuate base, brochidodromous venation, alternate to opposite secondary veins running upwards to join super adjacent secondaries at acute to obtuse angle and forming a distinct loop before the margins, presence of intersecondary veins, AO–RR, percurrent, close to distant tertiaries show nearest affinity with the modern leaves of *Erythrochiton brasiliensis* Nees & Mart. (C.N.H. Herbarium Sheet No. 73403; Pl. 14.2, 4) of the family Rutaceae.

There is no record of fossil leaves resembling the genus *Erythrochiton* Nees & Mart. from the Cenozoic sediments of India. Occurrence of present fossil leaf in the Siwalik sediments of Arjun Khola area, western Nepal, is the first record from the area and hence described as a new species *Erythrochiton masotkholaensis*.

The genus *Erythrochiton* Nees & Mart. consists of about 7 species distributed throughout eastern Africa. *Erythrochiton brasiliensis* Nees & Mart. is a small tree or shrub found to grow in America, East Bolivia, Peru, South Brazil, etc. (Mabberley, 1997).

Family—BURSERACEAE

Genus—COMMIPHORA Jacq.

Commiphora precaudata Shashi *et al.,* 2008

(Pl. 11.9, 10)

Material—Two specimens.

PLATE 12

(Scale bar = 1 cm)

→

1. *Grewia nepalensis* n. sp.–Fossil leaf showing shape, size and venation pattern. Specimen No. 41097 (Holotype).
2. *Grewia salvifolia* Heyne ex Roth–Modern leaf showing similar shape, size and venation pattern.
3. *Grewia nepalensis* n. sp.–A part of fossil leaf magnified to show acrodromous venation pattern with five primary veins (one mid vein and 4 laterals), two arising at the base and two are super basal.
4. *Grewia salvifolia* Heyne ex Roth–A part of modern leaf magnified to show similar details of venation pattern.
5. *Berchemia balugoloensis* Lakhanpal–Fossil leaf showing shape, size and venation pattern. Specimen No. 41101.
6. *Berchemia floribunda* (Wall.) Brongn.–Modern leaf showing similar shape, size and venation pattern.
7. *Berchemia balugoloensis* Lakhanpal–A part of fossil leaf magnified to show alternate to sub–opposite secondary and percurrent tertiary veins.

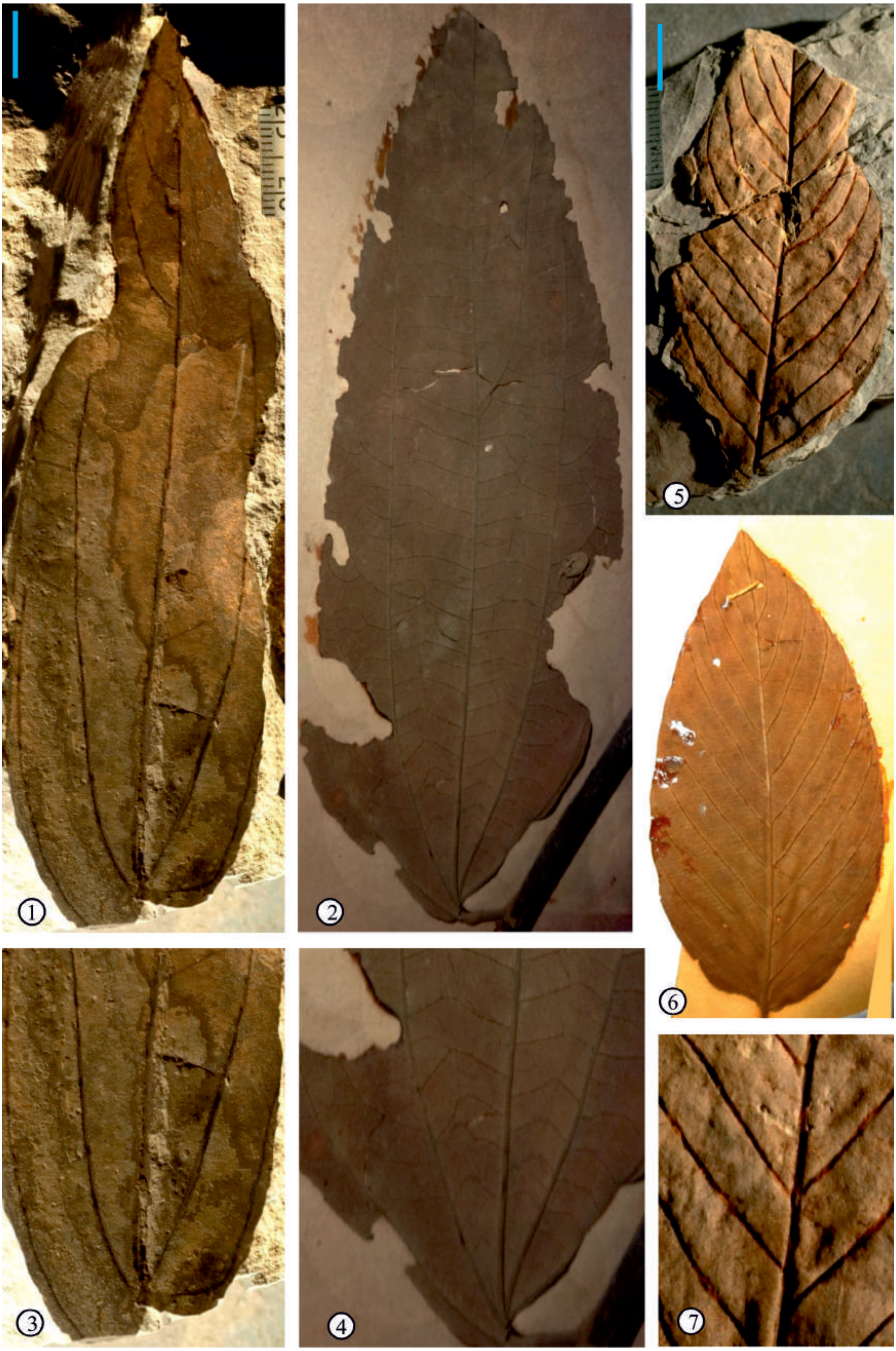

PLATE 12

Description—Leaves simple, bilaterally symmetrical to slightly asymmetrical, ovate to elliptical; preserved size 3.9–5.0 x 2.4–2.7 cm; apex attenuate to acuminate; base obtuse; margins entire; texture chartaceous; venation pinnate, eucamptodromous; primary vein (1º) single, straight, prominent, stout; secondary veins (2º) 6–7 pairs visible, 0.5–0.7 cm apart, usually alternate to rarely opposite, angle of divergence moderately acute (60º), intersecondary veins present, rarely simple; tertiary veins (3º) fine, angle of origin RR to AO, percurrent, straight to sinuous, sometimes branched, alternate to opposite and close, oblique in relation to mid vein.

Figured Specimen—BSIP Museum Specimen No. 41100.

Locality—Profile 5A (27º54'50.6 N": 82º31'00.4" E), 6B (27º55'24.5" N: 82º31'1.3" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Affinities—The characteristic features of the present fossil leaves such as slightly asymmetry, ovate to elliptical shape, attenuate to acuminate apex, widely obtuse base, entire margins, pinnate, eucamptodromous venation; usually alternate to rarely opposite secondary veins, showing moderately acute angle of divergence, presence of intersecondary veins; RR to AO, percurrent, straight to sinuous tertiary veins, show close similarity with modern leaves of *Commiphora caudata* (Wight & Arn.) Engl. of the family Burseraceae (C.N.H. Herbarium Sheet No. 57900; Pl. 11.11, 12).

So far, there is only one report of a fossil leaf resembling the genus *Commiphora* Jacq. from Lower Siwalik sediments of Tanakpur area, Champawat District, Uttarakhand. The form species is named *Commiphora precaudata* (Shashi *et al.,* 2008). A comparison of this specimen with the presently described fossil leaves revealed close similarity in shape, size and venation pattern (especially moderately acute angle of divergence of secondary veins) and predominantly alternate, close tertiary veins. Therefore, the new fossil leaves are assigned to the same species *Commiphora precaudata* (Shashi *et al.,* 2008).

The genus *Commiphora* Jacq. includes about 190 species distributed in Africa, Madagascar, Arabia, Ceylon and south America. *Commiphora caudata* (Wight & Arn.) Engl. is a medium sized deciduous tree, distributed in Peninsular India, Kerala and Sri Lanka (Mabberley, 1997).

Order—ROSALES

Family—RHAMNACEAE

Genus—BERCHEMIA Necker ex DC.

Berchemia balugoloensis Lakhanpal, 1967

(Pl. 12.5, 7)

Material—Single specimen.

Description—Leaf simple, bilaterally symmetrical, elliptical to ovate; preserved size 6.3 x 3.2 cm; apex unknown; base seemingly acute; margins entire; texture chartaceous; venation pinnate; eucamptodromous; primary vein (1º) single, prominent, stout; secondary veins (2º) 10 pairs visible, 0.4 to 0.10 cm apart, alternate to sub–opposite, unbranched, angle of divergence narrowly to moderately acute (40º–50º); tertiary veins (3º) showing angle of origin RR, percurrent, almost straight, branched, predominantly alternate and close, oblique in relation to mid vein.

Figured Specimen—BSIP Museum Specimen No. 41101.

Locality—Profile 5B (27º54'53.7" N: 82º31'05.2" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Formation, Upper Miocene.

Affinities—Bilaterally symmetrical leaf showing elliptical to ovate shape, acute base, entire margins; chartaceous texture, eucamptodromous venation, alternate to sub–opposite unbranched secondary veins with narrowly to moderately acute angle of divergence, percurrent, almost straight, branched tertiary veins, angle of origin RR show closest likeness with modern leaves of *Berchemia floribunda* (Wall.) Brongn. of the family Rhamnaceae (C.N.H. Herbarium Sheet No. 88786; Pl. 12.6).

Three fossil species resembling the genus *Berchemia* Necker ex DC. have been reported from Siwalik sediments of India and Nepal. These are *Berchemia balugoloensis* (Lakhanpal, 1967) from Siwalik sediments of Jawalamukhi Himachal Pradesh, *Berchemia siwalika* (Tripathi *et al*., 2002) from Siwalik sediments of Jarva, Uttar Pradesh and Siwalik

PLATE 13

(Scale bar = 1 cm)

1. *Sterculia arjunkholaensis* n. sp.–Fossil leaf showing narrow oblong shape, large size and eucamptodromous to brochidodromous venation pattern. Specimen No. 41098 (Holotype).
2. *Sterculia hamiltonii* (Kuntze) Adelb.–Modern leaf showing similar shape, size and venation pattern.

3–5. *Arytera* (*Ratonia* DC.) *miolittoralis* n. sp.–Fossil leaf showing ovate shape, attenuate apex and brochidodromous to eucamptodromous venation pattern. Specimen Nos. 41110 (Holotype) and 41111–41112.

6. *Arytera* (*Ratonia* DC.) *littoralis* Blume–Modern leaf showing similar shape, size, apex and venation pattern.
7. *Arytera* (*Ratonia* DC.) *miolittoralis* n. sp.–A part of fossil leaf (Fig. 5) magnified to show details of secondary and tertiary veins.

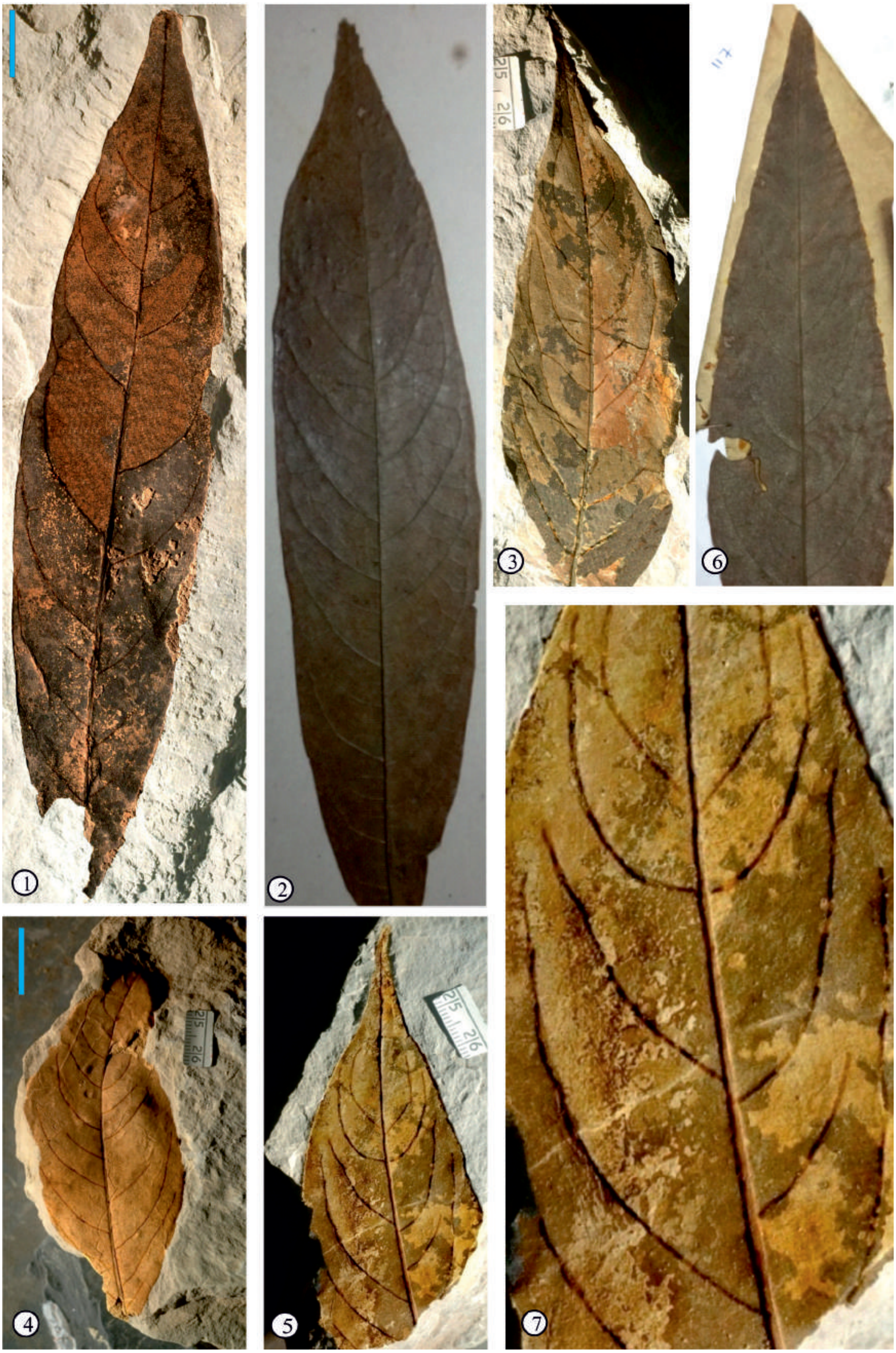

PLATE 13

(Kimin Formation) of Arunachal Pradesh, India (Khan *et al*., 2011) and *Berchemia nepalensis* from Lower Churia (Siwalik) sediments of Koilabas area, western Nepal (Prasad & Dwivedi, 2008). A comparison of the presently described leaf with fossil leaves of *Berchemia siwalika* (Tripathi *et al.,* 2002) and *Berchemia nepalensis* (Prasad & Dwivedi, 2008) showed difference in space between two secondaries and lower secondary veins were more deeply curved. However, when compared to the third species *Berchemia balugoloensis* Lakhanpal, morphological features of the Arjun Khola fossil showed maximum similarity in venation pattern especially in the arrangement of secondary veins, which turned upwards to join the super–adjacent secondaries. The present fossil leaf is therefore, described under the same species, *Berchemia balugoloensis* Lakhanpal.

Berchemia Necker ex DC. consists of 11 species distributed in eastern Asia, Tropical Africa and Tropical region of North America. *Berchemia floribunda* (Wall.) Brongn. is a large, erect climbing shrub distributed in the Himalayan and sub–Himalayan zone of Jhelum to Bhutan and Sikkim, Khasi hills, eastern Bengal and Myanmar (Gamble, 1972; Hooker, 1872; Brandis, 1971; Mabberley, 1997).

Order—VITALES

Family—VITACEAE

Genus—CAYRATIA Juss.

Cayratia palaeojaponica n. sp.

(Pl. 9.3, 5)

Material—Single specimen.

Description—Leaflet bilaterally symmetrical, elliptical; preserved size 3.8–7.0 x 2.2–3.1 cm; apex acute; base acute to nearly attenuate; margins indistinctly dentate; texture thick chartaceous; venation pinnate, eucamptodromous; primary vein (1º) single, straight, prominent; secondary veins (2º) 7 pairs visible, 1.0 to 1.5 cm apart, uniformly curved towards the margins, alternate to opposite, unbranched, angle of divergence moderately acute about (50º–60º); tertiary veins (3º) poorly preserved, angle of origin usually RR, percurrent, almost straight, predominantly alternate, close to nearly distant, oblique in relation to mid vein.

Holotype—BSIP Museum Specimen No. 41102.

Locality—Profile 5A (27º54'50.6" N: 82º31'00.4" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Etymology—By adding prefix 'palaeo' to the name of modern comparable species, *Cayratia japonica.*

Affinities—Morphological features of the fossil leaflet such as bilateral symmetry, elliptical shape; acute apex, acute to attenuate base, indistinctly dentate margins, eucamptodromous venation; secondary veins alternate to opposite, uniformly curving towards margins, and AO–RR, percurrent tertiary veins suggest close resemblance with leaves of the modern *Cayratia japonica* (Thunb.) Gagnep. (C.N.H. Herbarium Sheet No. 1252; Pl. 9.4, 6) of the family Vitaceae. The presently described fossil leaf also resembles some extant leaves of *Vitis bracteolata*, *V. oxyphylla, V. dubians* and *tetrastigma, dubium* but differs in the shape and nature of secondary veins.

So far, there is no fossil record of the genus *Cayratia Juss.* from Cenozoic sediments of Indian sub–continent. The present fossil leaflet from Arjun Khola is the first record of the taxon from the area and hence is described as a new species, *Cayratia palaeojaponica*.

The genus *Cayratia* Juss. consists of about 65 species which are distributed in the Northern Hemisphere, tropics and sub tropics of Asia, Africa and Polynesia. *Cayratia japonica* (Thunb.) Gagnep. is a woody climber found to grow in Khasi Hills, Silhet, Chittagong and Malacca (Hooker, 1872).

Order—SAPINDALES

Family—SAPINDACEAE

Genus—ARYTERA (RATONIA DC.**)** Blume

Arytera (Ratonia DC.***) nepalensis*** n. sp.

(Pl. 15.1, 3)

PLATE 14

(Scale bar = 1 cm)

⟶

1. *Erythrochiton masotkholaensis* n. sp.–Fossil leaf showing shape, size and venation pattern. Specimen No. 41099 (Holotype).
2. *Erythrochiton brasiliensis* Nees & Mart.–Modern leaf showing similar shape, size and venation pattern.
3. *Erythrochiton masotkholaensis* n. sp.–A part of fossil leaf magnified to show morphological character along with forming of distinct loop before the margin and presence of intersecondary veins.
4. *Erythrochiton brasiliensis* Nees & Mart.–A part of modern leaf magnified to show similar morphological characters as of fossil leaf.

5, 6. *Sapindus palaeomukorossi* n. sp.–Fossil leaves showing asymmetrical, narrow elliptic shape, and eucamptodromous venation pattern. Specimen Nos. 41113 (Holotype) and 41114.

7. *Sapindus mukorossi* Gaertner–Modern leaf showing similar shape, and venation pattern.
8. *Sapindus palaeomukorossi* n. sp.–A part of fossil leaf in Fig. 5, magnified to show unequal obtuse base.
9. *Sapindus mukorossi* Gaertner–A part of modern leaf magnified to show similar nature of base.

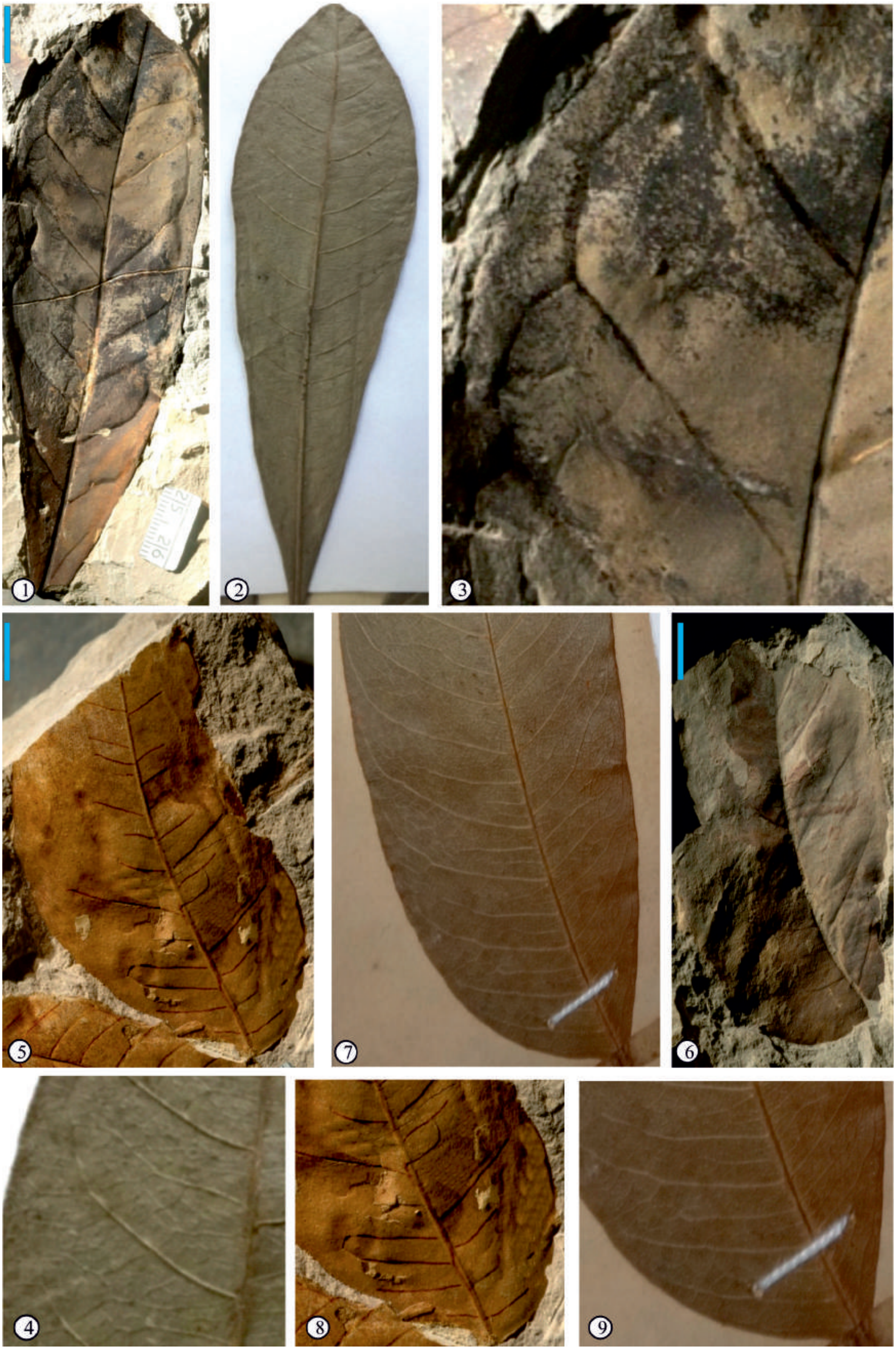

PLATE 14

Material—Single specimen.

Description—Leaf simple, bilaterally symmetrical, widely ovate; preserved size 10.5 x 5.0 cm; apex seemingly acute; base seemingly obtuse; margins apically poorly serrate; texture chartaceous; venation pinnate; eucamptodromous; primary vein (1º) single, straight, stout, prominent; secondary veins (2º) about 10 pairs visible, 0.5 to 2.0 cm apart, alternate to sub–opposite, unbranched, angle of divergence narrowly to moderately acute (40º–60º); tertiary veins (3º), angle of origin RR, percurrent, straight, branched, predominantly alternate and close, oblique in relation to mid vein.

Holotype—BSIP Museum Specimen No. 41103.

Locality—Profile 5A (27º54'50.6" N: 82º3'100.4" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Etymology—Named after the country of Nepal where fossil site is located.

Affinities—Morphological features of the present fossil leaf such as bilateral symmetry, widely ovate shape, acute apex, apically poorly serrate margins, eucamptodromous venation, alternate to sub–opposite secondary veins, RR, percurrent, almost straight tertiary veins are very similar to in the modern leaves of *Arytera* (*Ratonia* DC.) *littoralis* Blume (C.N.H. Herbarium Sheet No. 94393; Pl. 15.2, 4) of the family Sapindaceae.

There is a single record of a fossil leaf showing resemblance with genus *Arytera* (*Ratonia* DC.) Blume from the Lower Siwalik sediments of Seria Naka, western Nepal under the form species *Arytera seriaensis* (Prasad & Dwivedi, 2008). A comparison of the present fossil leaf with above described specimen showed a difference in shape and angle of divergence of secondary veins. Hence, the present fossil leaf is described as a new species *Arytera* (*Ratonia* DC.) *nepalensis.*

Genus *Arytera* (*Ratonia* DC.) Blume consists of about 25 species distributed in Indo–Malayan region and east Australia. *Arytera* (*Ratonia* DC.) *littoralis* Blume is a small evergreen tree distributed in Tenasserim and Malaya Peninsula (Brandis, 1971; Mabberley, 1997).

Genus—ARYTERA (RATONIA) Blume

Arytera (Ratonia) miolittoralis n. sp.

(Pl. 13.3, 4, 5, 7)

Material—Three specimens.

Description—Leaves simple, bilaterally symmetrical, lanceolate to elliptical; preserved size 10.0–13.5 x 3.8–4.2 cm; apex attenuate; base not preserved; margins finely serrate; texture chartaceous; venation pinnate; brochidodromous to eucamptodromous; primary vein (1º) single, slightly curved, moderately thick, prominent, stout; secondary veins (2º) 8 pairs visible, 1.1 to 1.5 cm apart, opposite to alternate, unbranched, angle of divergence narrow to right angled (40º–80º), uniformly curving upwards and running a long distance before joining super adjacent secondaries; intersecondary veins present; tertiary veins (3º) with angle of origin usually RR, percurrent, usually straight, branched, predominantly alternate, close, oblique to right angled in relation to mid vein.

Holotype—BSIP Museum Specimen No. 41110.

Locality—Profiles 5A (27º54'50.6" N: 82º31'00.4" E) and 5B (27º54'53.7" N: 82º31'05.2" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Etymology—Named after adding prefix 'mio' of Miocene age to the modern comparable species, *A. littoralis.*

Affinities—The characteristic features of the present fossil leaves as lanceolate to elliptical shape, attenuated apex, brochidodromous to eucamptodromous venation, opposite to alternate, unbranched, uniformly curving upwards secondary veins showing narrow to moderately acute angle of divergence, frequent presence of intersecondary veins; tertiary veins RR, percurrent, oblique to right angled in relation to mid vein, indicate close similarity with modern leaves of *Arytera* (*Ratonia* DC.) *littoralis* Tejsmand Binn (C.N.H. Herbarium Sheet No. 94412; Pl. 13.6) of family Sapindaceae.

To the best of our knowledge, there are two fossil records of this taxon in the Siwalik sediments of western Nepal. In being different from earlies known fossils, this present fossil is described as a new species *Arytera* (*Ratonia* DC.) *miolittoralis*.

PLATE 15

(Scale bar = 1 cm)

→

1. *Arytera (Ratonia* DC.*) nepalensis* n. sp.–Fossil leaf showing shape, size and venation pattern. Specimen No. 41103 (Holotype).
2. *Arytera (Ratonia* DC.*) littoralis* Tejsmand Binn–Modern leaf showing similar shape, size and venation pattern.
3. *Arytera (Ratonia* DC.*) nepalensis* n. sp.–A part of fossil leaf magnified to show details of tertiary veins.
4. *Arytera (Ratonia* DC.*) littoralis* Tejsmand Binn–A part of modern leaf magnified to show similar details of tertiary veins.

5, 6. *Cynometra siwalika* Awasthi & Prasad–Fossil leaflet showing shape, size and venation pattern. Specimen No. 41122–41123.

7, 8. *Cynometra ramiflora* L.–Modern leaflet showing similar shape, size and venation pattern.

9. *Cynometra siwalika* Awasthi & Prasad–A part of fossil leaflet magnified to show details of tertiary veins.
10. *Cynometra ramiflora* L.–A part of modern leaflet magnified to show similar details of tertiary veins.
11. *Cynometra siwalika* Awasthi & Prasad–A part of fossil leaflet showing nature of base.
12. *Cynometra ramiflora* L.–A part of modern leaflet showing similar nature of base.

PLATE 15

Genus *Arytera* (*Ratonia* DC.) Blume consists of about 18 species. *Arytera* (*Ratonia* DC.) *littoralis* Tejsmand Binn is a tree, distributed in temperate Asia, Hainan (S. China), tropical Asia, Bay of Bengal, (NE India), SE Asia throughout Malaysia up to the Solomon Islands (Gamble, 1972).

Genus—EUPHORIA Comm. ex Juss.

Euphoria churiaensis n. sp.

(Pl. 10.1, 3)

Material—Single specimen.

Description—Leaf simple, bilaterally symmetrical, very narrowly elliptical; preserved size 7.1 x 1.2 cm; apex not preserved; base acute; margins entire; petiole small, curved; texture chartaceous; venation pinnate; craspedodromous to eucamptodromous; primary vein (1º) single, weak, slightly curved; secondary veins (2º) 11–12 pairs visible, 0.5 to 0.7 cm apart, alternate to rarely opposite, unbranched, angle of divergence narrowly acute (about 45º); tertiary veins (3º) poorly preserved, angle of origin RR, percurrent, alternate to opposite and close, oblique in relation to mid vein.

Holotype—BSIP Museum Specimen No. 41104.

Locality—Profile 10 (27º55'50.9" N: 82º29'48.4" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Lower Churia Group, Middle Miocene.

Etymology—Named after the 'Churia' Formation of Nepal.

Affinities—The most important characters of the fossil such as very narrowly elliptical shape, asymmetrically acute and curved base, craspedodromous to eucamptodromous venation, alternate to nearly opposite secondary veins showing narrowly acute angle of divergence indicate closest similarity with modern leaves of *Euphoria cinerea* (Turcz.) Radlk. (C.N.H. Herbarium Sheet No. 7508, Pl. 10.2, 4) of the family Sapindaceae.

So far, there are two records of fossil leaves resembling the genus *Euphoria* Comm. ex Juss. from the Siwalik sediments of India and Nepal. These are *Euphoria nepalensis* from Lower Siwalik sediments of Darwaja, Koilabas, western Nepal (Prasad 1994e) and *Euphoria siwalika* from Lower Siwalik sediments of Balia River beds, Kathgodam, Nainital District, Uttarakhand (Prasad 1994c). A fossil fruit has also been described from Lower–Middle Siwalik sediments of Oodlabari, Darjeeling District, West Bengal under the form species, *Euphoria longanoides* (Antal & Awasthi, 1993). A few fossil woods claiming affinity with the same genus have also been reported from both Palaeogene and Neogene sediments of India under the form genus *Euphorioxylon* (Awasthi *et al*., 1982). A detailed comparison of the above two fossil leaves with the present material indicated the fossil leaf being quite different in having very narrowly elliptical shape with narrowly acute angle of divergence of secondary veins. Hence, the new leaf is described as a new species *Euphoria churiaensis*.

Genus *Euphoria* Comm. ex. Juss. consists of about 7 species distributed in south–east Asian regions. The Comparable species, *Euphoria cinerea* (Turcz.) Radlk. is a large, evergreen tree commonly found in the forests of the western Ghats, Konkan, Kanara, Malabar, Annamalai, Travancore, Tinnevelly hills and Myanmar (Gamble, 1972).

Genus—FILICIUM Thwaites

Filicium koilabasensis Prasad, 1994e

(Pl. 27.7–9, 11)

Material—Three specimens.

Description—Leaves simple, asymmetrical, narrowly elliptical; preserved size 4.3–8.3 x 1.8–3.0 cm; apex acute to obtuse; base acute; margins entire; texture chartaceous, petiole 0.7 cm; venation pinnate, craspedodromous to eucamptodromous; primary vein (1º) single, straight, prominent, stout; secondary veins (2º) 16–20 pairs visible, closely placed, opposite to sub–opposite, angle of divergence moderately to widely acute (50º–75º), intersecondary veins present, simple; tertiary veins (3º) fine, angle of origin AO–RR, percurrent, rarely branched, almost straight, alternate to opposite and close, oblique in relation to mid vein.

Figured Specimen—BSIP Museum Specimen Nos. 41105–41107.

PLATE 16

(Scale bar = 1 cm)

→

1. *Millettia arjunkholaensis* n. sp.–Fossil leaflet showing shape, size and venation pattern. Specimen No. 41124 (Holotype).
2. *Millettia erianthus* Benth.–Modern leaflet showing shape, size and venation pattern.
3. *Millettia arjunkholaensis* n. sp–A part of fossil leaflet magnified to show RR, percurrent, tertiary veins.
4. *Millettia erianthus* Benth.–A part of modern leaflet magnified to show similar details of tertiary veins.
5. *Cassia arjunkholaensis* n. sp.–Fossil leaflet showing shape, size and venation pattern. Specimen No. 41121 (Holotype).
6. *Cassia fistula* L.–A modern leaflet showing shape, size and venation pattern.
7. *Cassia arjunkholaensis* n. sp.–A part of fossil leaflet magnified to show details of tertiary veins.
8. *Cassia fistula* L.–A part of modern leaflet magnified to show similar details of tertiary veins.
9. *Cassia arjunkholaensis* n. sp.–A part of fossil leaflet magnified to show nature of base.

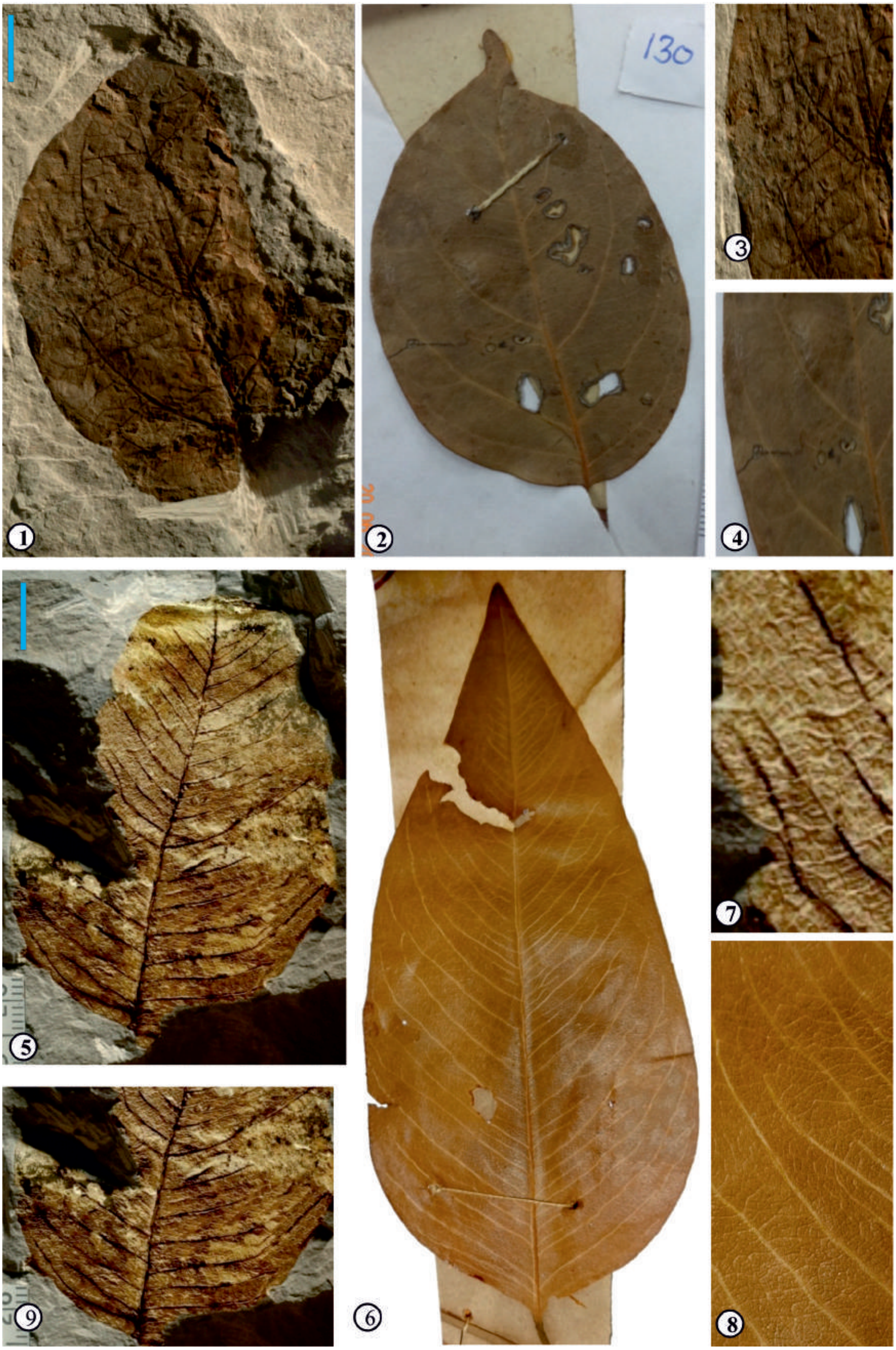

PLATE 16

Locality—Profile 5A (27º54'50.6" N: 82º31'00.4" E), 3 (27º54'24.0" N: 82º30'52.7" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Lower and Middle Churia Group, Middle and Upper Miocene.

Affinities—A number of characters of the present fossil leaves such as narrowly elliptical shape, obtuse apex; acute base, craspedodromous to eucamptodromous venation, opposite to sub–opposite, moderately to widely acute angle of divergence of secondary veins and fine AO–RR, percurrent tertiary veins strongly indicates similarity with the modern leaves of *Filicium decipiens* (Wight & Arn.) Thwaites of the family Sapindaceae (C.N.H. Herbarium Sheet No. 78730; Pl. 27.10, 12).

Three fossil leaves resembling the genus *Filicium* Thwaites have been reported under the form species *Filicium koilabasensis* Prasad from the Lower Siwalik sediments of Koilabas, western Nepal (Prasad, 1994e) and Middle Siwalik of Darjeeling District, West Bengal (Prasad *et al*., 2015) and Miocene of Neyveli Lignite Mine–1, South Arcot District, Tamil Nadu, India (Agarwal, 2002). The fossil leaves were found to be somewhat similar to Prasad's specimen from Koilabas area. The venation pattern especially orientation of secondary and tertiary veins of Prasad's Koilabas specimen are very similar to those of the present fossil leaves. Therefore, the present fossil leaves are being described under the same species, *Filicium koilabasensis* (Prasad 1994e).

The genus *Filicium* Thwaites consists of about 3 species presently distributed in Tropical region of the old World (Mabberley, 1997). *Filicium decipiens* (Wight & Arn) Thwaites is a medium sized evergreen tree distributed in the forests of Western Ghat from Nilgiri southwards to Sri Lanka and Tropical Africa (Brandis 1971).

Genus—HARPULLIA Roxb.

Harpullia siwalica Prasad & Awasthi, 1996

(Pl. 10.5, 7)

Material—Two specimens.

Description—Leaves simple, asymmetrical, elliptical; preserved size 7.0 x 3.2 cm and 7.3 x 3.0 cm; apex not preserved; base asymmetrically acute; margins entire; texture chartaceous; venation pinnate; eucamptodromous; primary vein (1º) single, almost straight, prominent, stout, curved near the base; secondary veins (2º) 6 pairs visible, 1.0 to 1.5 cm apart, alternate, unbranched, curving upwards, angle of divergence, narrowly to moderately acute (about 50º–65º); tertiary veins (3º) angle of origin usually RR, percurrent, straight to nearly sinuous, predominantly alternate and close, oblique to right angled in relation to mid vein.

Figured Specimen—BSIP Museum Specimen No. 41108–41109.

Locality—Profile 12 (27º56'06.1" N: 82º29'32.2" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Lower Churia Group, Middle Miocene.

Affinities—Characteristic features of the present fossil leaves like elliptical shape, asymmetrically acute base, eucamptodromous venation, alternate, unbranched secondary veins with narrow to moderately acute angle of divergence, RR, percurrent, straight to nearly sinuous tertiary veins are commonly found in the modern leaves of *Harpullia ar borea* (Blanco) Radlk. of the family Sapindaceae (C.N.H. Herbarium Sheet No. 1874; Pl. 10.6, 8).

So far, there is only one record of the fossil leaf *Harpullia siwalica* from Middle Siwalik sediments of Surai Khola area, Nepal (Prasad & Awasthi, 1996) and Neyveli Lignite Mine–1, South Arcot District, Tamil Nadu (Agarwal, 2002). The present fossil leaf resembles the earlier described species in shape, asymmetrical base and eucamptodromous type venation pattern. Therefore, the present fossil leaf has been described under the same species.

Genus *Harpullia* Roxb. comprises of about 6 species, distributed in Madagascar, northern Australia and Tropical Asia. *Harpullia arborea* (Blanco) Radlk. is a tree distributed in Indo–Malaysia and Australia. In India, it is common in the

PLATE 17

(Scale bar = 1 cm)

⟶

1. *Sindora eosiamensis* n. sp.–Fossil leaflet showing narrow elliptic shape, small size and eucamptodromous to brochidodromous venation pattern. Specimen No. 41126 (Holotype).
2. *Sindora siamensis* Tejsm. ex Miq.–Modern leaflet showing similar shape, size and venation pattern.
3. *Sindora eosiamensis* n. sp.–A part of fossil leaflet magnified to show details of secondary and tertiary veins.
4. *Sindora siamensis* Tejsm. ex Miq.–A part of modern leaflet magnified to show similar details of secondary and tertiary veins.
5. *Sindora leguminocarpoides* n. sp.–Fossil fruit showing shape, size and surface features. Specimen No. 41127 (Holotype).
6. *Sindora siamensis* Tejsm. ex Miq.–Modern fruit showing similar shape, size and other morphological features.
7. *Terminalia arjunkholaensis* n. sp.–Fossil fruit showing shape, size and other morphological features. Specimen No. 41131 (Holotype).
8. *Terminalia tomentosa* Wight & Arn.–Modern fruit showing similar shape, size and other morphological features.
9. *Clinogyne ovatus* Awasthi & Prasad–Fossil leaf showing shape, size and venation pattern. Specimen No. 41079.
10. *Clinogyne dichotoma* Salisb.–Modern leaf showing similar shape, size and venation pattern.
11. *Clinogyne ovatus* Awasthi & Prasad–A part of fossil leaf magnified to show details of secondary veins especially narrow acute angle of divergence with usually opposite pattern.
12. *Clinogyne dichotoma* Salisb.–A part of modern leaf magnified to show similar details of secondary veins.

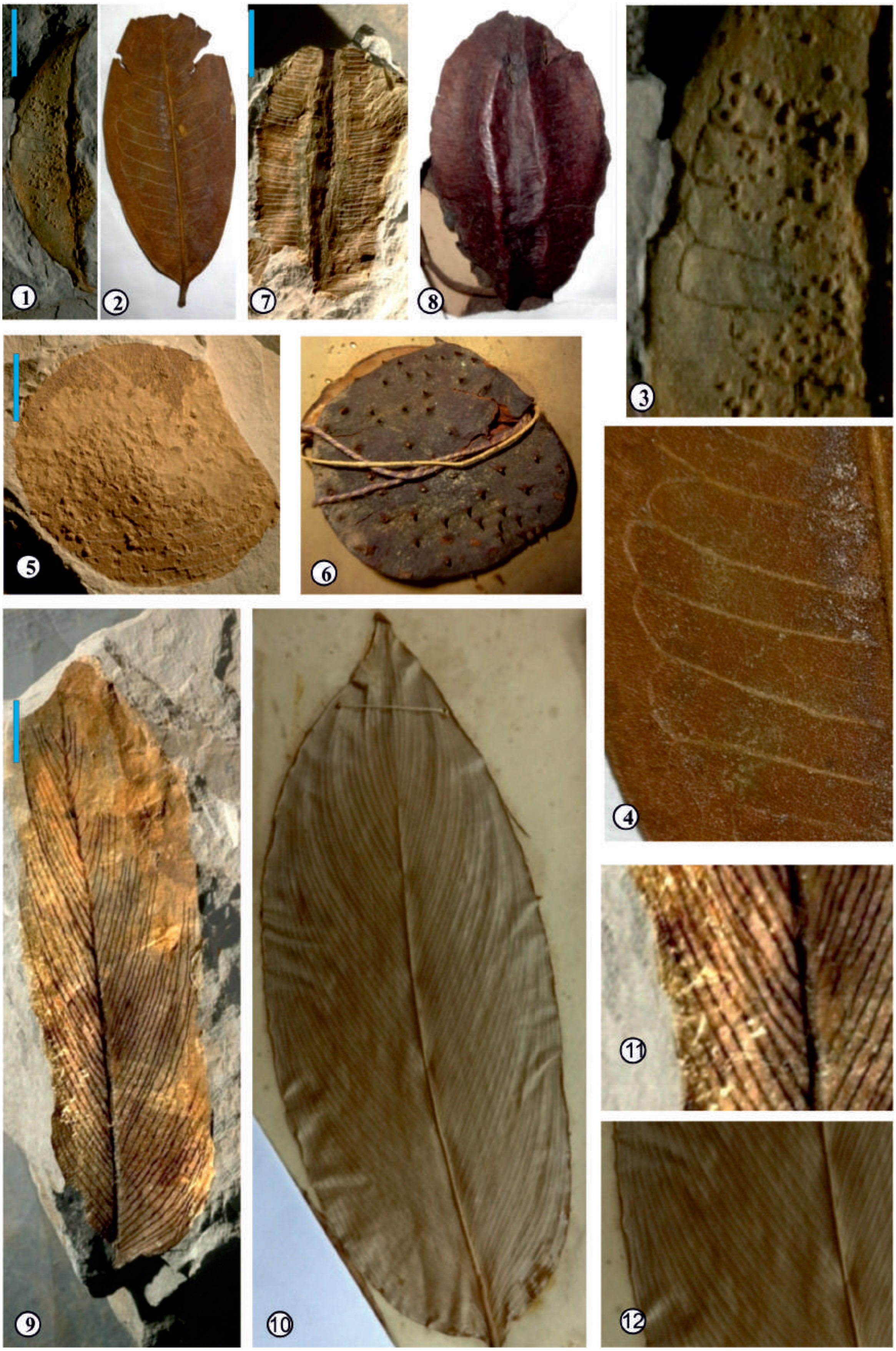

PLATE 17

South and Central Sahyadris (Hooker, 1872; Henery, 1893; Brandis, 1971; Mabberley, 1997).

Genus—SAPINDUS L.

Sapindus palaeomukorossi n. sp.

(Pl. 14.5, 6, 8)

Material—Two specimens.

Description—Leaves simple, seemingly asymmetrical, narrowly elliptical; preserved size 5.3–5.5 x 3.6–4.1 cm; apex not preserved; base asymmetrical, obtuse to acute; margins entire; texture chartaceous; venation pinnate; eucamptodromous; primary vein (1º) single, markedly curved, prominent, stout; secondary veins (2º) about 12 pairs visible, 0.1 to 0.8 cm apart, generally opposite to sub–opposite, seemingly unbranched, angle of divergence widely acute to right angled (about 70º–80º), intersecondary veins, simple, frequent (1–3 veins present in, between two secondaries); tertiary veins (3º) poorly preserved, angle of origin AO, percurrent, ramified, predominantly alternate and close, oblique in relation to mid vein.

Holotype—BSIP Museum Specimen No. 41113.

Locality—Profile 10 (27º55'50.9" N: 82º29'48.4" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Lower Churia Group, Middle Miocene.

Etymology—Named after adding prefix ‘palaeo’ to the modern comparable species, *S. mukorossi.*

Affinities—In being asymmetrical, narrowly elliptical showing unequally obtuse base, eucamptodromous venation, opposite to sub–opposite unbranched secondary veins with widely acute to right angle of divergence, presence of frequent intersecondary veins and AO, percurrent, branched tertiary veins, the present fossil leaves show close similarity with modern leaves of *Sapindus mukorossi* Gaertner (C.N.H. Herbarium Sheet No. 95111; Pl. 14.7, 9) of family Sapindaceae.

Two fossil leaves named leaf type D and Leaf type E somewhat resembling the present fossils have been reported from the Eocene of Barmer, Rajasthan, India (Deshmukh & Sharma, 1978). Very recently, another species, *Sapindus arjunkholaensis* has also been described from the Siwalik of Arjun Khola (Prasad *et al.,* 2016). The fossils, Leaf type D and type E resemble the presently described fossils in being almost of identical shape and size but differ in having narrowly acute angle of divergence of secondary veins. *Sapindus arjunkholaensis* also differs from present leaves in possessing emarginated leaf apex and showing greater interval between secondary veins. In view of this, the present fossil leaves are described as a new species *Sapindus palaeomukorossi*.

Genus *Sapindus* L. includes about 40 species, native to warm Temperate to Tropical regions in both, old World and new World, Tropics of Asia, Africa and Ceylon. The genus includes both deciduous and evergreen species. *Sapindus mukorossi* Gaertner is a handsome tree, distributed in northwest Himalayas from Sutlej eastward, Assam, Silhet, West Bengal and central Japan (Gamble, 1972; Brandis, 1971; Mabberley, 1997).

Family—ANACARDIACEAE

Genus—BUCHANANIA Spreng.

Buchanania raptiensis n. sp.

(Pl. 20.1, 2, 4, 6)

Material—Two specimens.

Description—Leaves simple, bilaterally symmetrical, oblong to narrowly elliptical; preserved size 10.5–15.1 x 2.7–5.0 cm; apex poorly preserved; base seemingly acute; margins entire; texture chartaceous; venation pinnate; craspedodromous to eucamptodromous; primary vein (1º) single, slightly curved, prominent, stout; secondary veins (2º) 11–12 pairs visible, 0. 9 to 1.3 cm apart, opposite to alternate, unbranched, widely acute angle of divergence (about 70º–80º) few lower pairs of secondaries are seemingly recurved; intersecondary veins present, simple, rare; tertiary veins (3º) fine, angle of origin AO rarely RR, percurrent, straight to sinuous, branched, predominantly alternate, close to nearly distant, oblique in relation to mid vein.

Holotype—BSIP Museum Specimen No. 41115.

Locality—Profile 5A (27º54'50.6" N: 82º31'00.4" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

PLATE 18

(Scale bar = 1 cm)

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1. *Bauhinia palaeomonandra* n. sp.–Fossil leaf showing shape, size and venation pattern. Specimen No. 41117 (Holotype).
2. *Bauhinia monandra* Kurz–Modern leaf showing similar details of shape, size and venation pattern.
3. *Bauhinia palaeomonandra* n. sp.–A part of fossil leaf magnified to show nature of base.
4. *Bauhinia monandra* Kurz–A part of modern leaf magnified to show similar nature of base.
5. *Bauhinia palaeomonandra* n. sp.–A part of fossil leaf magnified to show details of venation pattern.
6. *Bauhinia monandra* Kurz–A part of modern leaf magnified to show similar details of venation pattern.

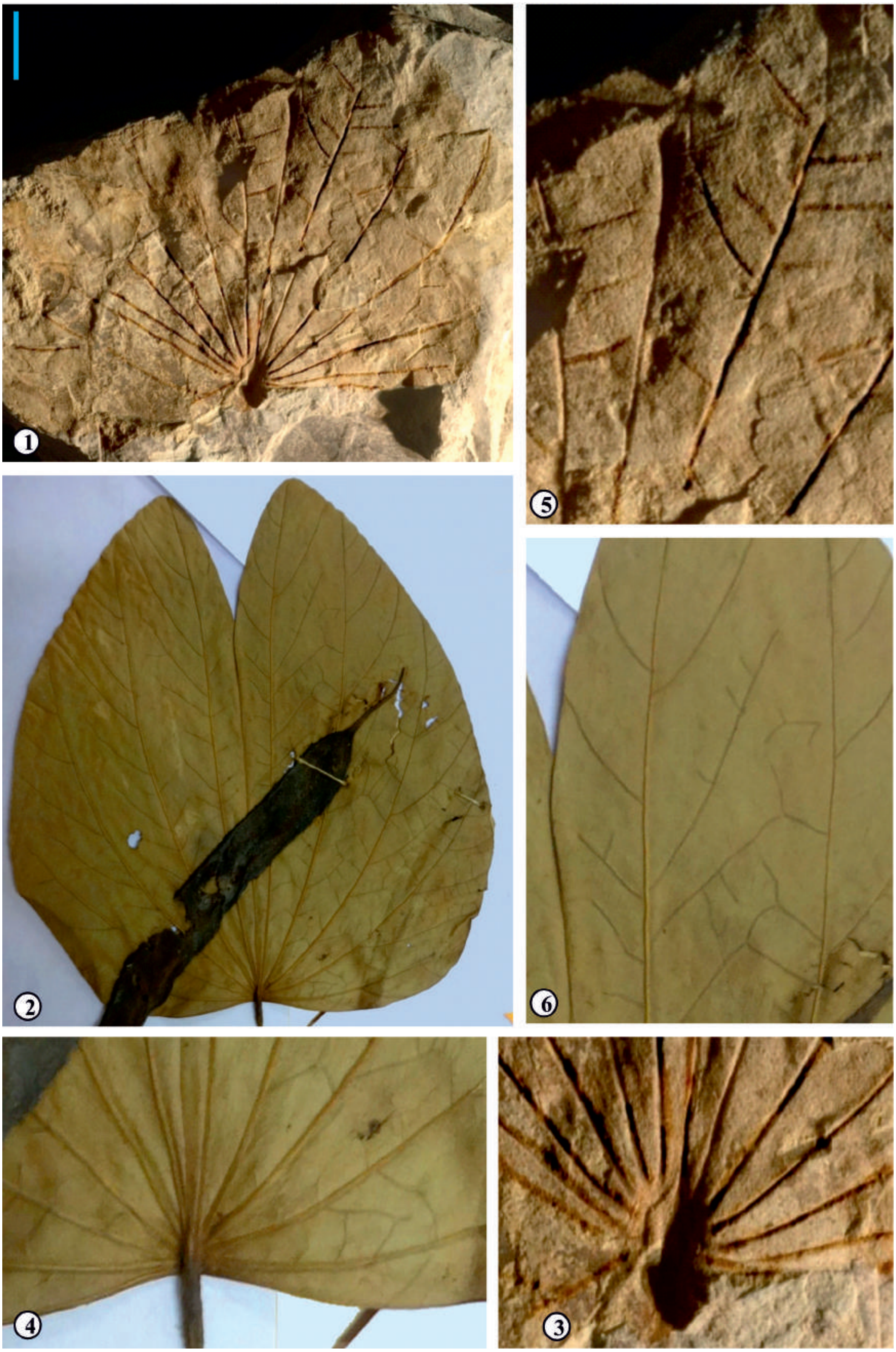

PLATE 18

Etymology—Named after Rapti River, in western Nepal.

Affinities—Morphological features of the present fossil leaves such as bilaterally symmetrical, oblong to narrowly elliptical shape; widely acute base; craspedodromous to eucamptodromous venation; opposite to alternate, unbranched, slightly recurved secondary veins with widely acute angle of divergence, presence of intersecondary veins, AO rarely RR, percurrent tertiaries, indicate close similarity with modern leaves of *Buchanania lancifolia* Roxb. (C.N.H. Herbarium Sheet No. 99256; Pl. 20.3, 5, 7) of the family Anacardiaceae. The fossil leaves also resemble *Buchanani*a *sessilifolia* Blume but differ in angle of divergence of secondary veins.

As far as authors are aware, there is only one fossil record of this genus from the Siwalik sediments of Darjeeling District, West Bengal under the form species *Buchanania palaeosessilifolia* (Prasad *et al*., 2015). The species differs from the present leaf in having more numbers (16 pairs) of secondaries which show acute angle of divergence. The present fossils are therefore being described as a *Buchanania raptiensis* n. sp.

Genus *Buchanania* Spreng. comprises of about 25 species distributed in Indo–Malayan region, West Pacific and all over India. *Buchanania lancifolia* Roxb. is a large evergreen tree distributed in the Tropical forest of Chittagong, Arracan, Myanmar and Andaman (Brandis, 1971; Gamble, 1972; Mabberley, 1997).

Order—FABALES

Family—FABACEAE

Genus—BAUHINIA L.

Bauhinia palaeomonandra n. sp.

(Pl. 18.1, 3, 5)

Material—Single specimen.

Description—Leaf simple, bilaterally symmetrical, elliptical; preserved size 6.5 x 8.5 cm; apex unknown; base seemingly sub–cordate; margins entire; texture chartaceous; acrodromous venation; primary veins (1º) 13–14 in number, straight, running upwards, unbranched, prominent, stout, sometimes primaries giving off secondaries toward the margins; secondary veins (2º) showing at acute angle of divergence (40º); tertiary veins (3º) acute to right angled arising from secondaries of mid primaries on both sides and later joining other adjacent primaries.

Holotype—BSIP Museum Specimen No. 41117.

Locality—Profile 12 (27º56'06.1" N: 82º29'32.2" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Lower Churia Group, Middle Miocene.

Etymology—Named after adding prefix 'palaeo' to the modern comparable species, *B. monandra.*

Affinities—Morphological features of the present fossil leaf such as bilaterally symmetrical, elliptical shape, sub–cordate base, entire margins, acrodromous venation and acute angle of divergence of secondaries with curvature toward the margins and origin of tertiary veins at right angle from primaries indicate similarity with modern leaflets of *Bauhinia monandra* Kurz (C.N.H. Herbarium Sheet No. 137904; Pl. 18.2, 4, 6) of the family Fabaceae.

There are eight records of fossil leaves resembling the genus *Bauhinia* L. from Cenozoic sediments of India. These are *Bauhinia kachchhensis* (Lakhanpal & Guleria, 1982) from the Miocene of Kachchh; *Bauhinia siwalika* from the late Tertiary of West Champaran District of Bihar (Lakhanpal & Awasthi, 1984) and Paleocene deposits of Meghalaya (Ambwani, 1991); *Bauhinia* sp. cf. *B. purpurea* (Bande & Srivastava, 1990) from Palamau District of Bihar, *Bauhinia nepalensis* (Awasthi & Prasad, 1990) from Siwalik sediments of Surai Khola, western Nepal, *Bauhinia ramthiensis* (Antal & Awasthi, 1993) from Siwalik of Darjeeling District, West Bengal; *Bauhinia kasaulica* (Arya & Awasthi, 1994) *Bauhinia krishnanunni* (Mathur *et al.*, 1996) from Kausali Formation, Himachal Pradesh and *Bauhinia* sp. (Mathur *et al.*, 1996) from Dagsai Formation of Himachal Pradesh.

On comparison it has been found that the present fossil is entirely different fro earlier known fossil leaves of the genus *Bauhinia* in being the presence of greater number (13-14) of primary veins. It also differs in the nature of secondary and tertiary veins. Therefor, the present fossil leaf is being described as a new species *Bauhinia palaeomonandra.*

PLATE 19

(Scale bar = 1 cm)

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1. *Saraca palaeoindica* n. sp.–Fossil leaflet showing narrow elliptic shape, acute base and eucamptodromous venation pattern. Specimen No. 41125 (Holotype).
2. *Saraca indica* L.–A modern leaflet showing similar shape, acute base and eucamptodromous venation pattern.
3. *Saraca palaeoindica* n. sp.–A part of fossil leaflet magnified to show details of tertiary veins.
4. *Saraca indica* L.–A part of modern leaflet magnified to show similar details of tertiary veins.
5. *Eugenia nepalensis* n. sp.–Fossil leaf showing shape, size and especially brochidodromous venation pattern. Specimen No. 41132 (Holotype).
6. *Eugenia diospyrifolia* Wall.–Modern leaf showing similar shape, size and venation pattern.
7. *Eugenia nepalensis* n. sp–A part of fossil leaf magnified to show details of tertiary veins.
8. *Eugenia diospyrifolia* Wall.–A part of modern leaf magnified to show similar details of tertiary veins.

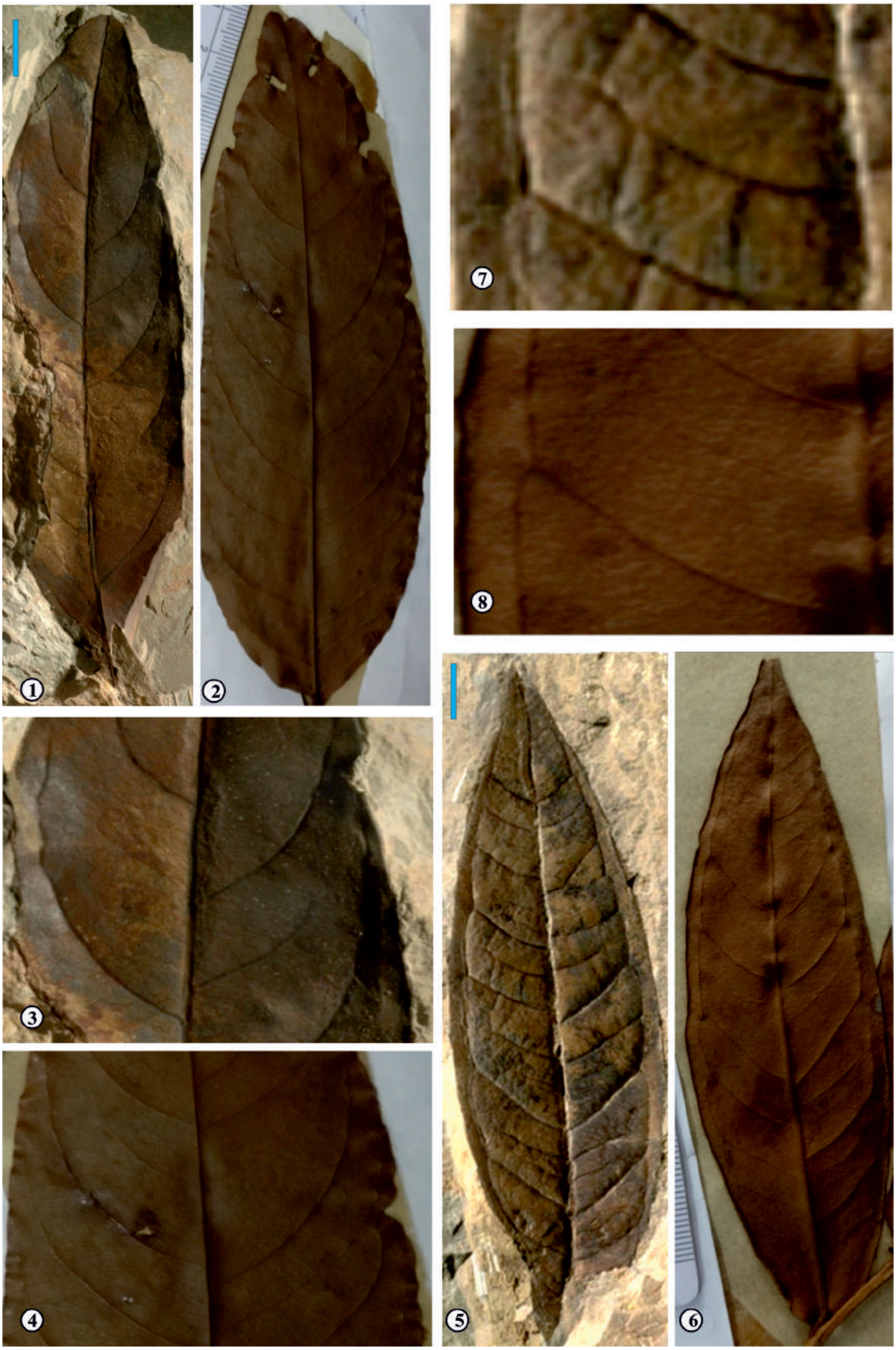

PLATE 19

The genus *Bauhinia* L. comprises 32 species distributed in the Tropics of both Hemispheres. *Bauhinia monandra* Kurz is a tree, distributed in Myanmar, Australia, Carribean, southern USA and Pacific Island (Ridley, 1967; Brandis, 1971; Gamble, 1972; Mabberley, 1997).

Genus—BUTEA Roxb. Ex Willd.

Butea nepalensis n. sp.

(Pl. 21.1, 2, 4)

Material—Three specimens.

Description—Fruits laterally concavo–convex, oblong pods, preserved size 6.2–15.0 x 3.1–3.2 cm; apex rounded; margin entire, thick surface, striations distinct, straight, horizontal, parallel to each other, running across the width of the fruit, finer striation present in between two prominent horizontal striations. One specimen showing 9–10 thick striations; while another shows only 3 striations. Impressions of 11–12 seeds are seen on fruit surface.

Holotype—BSIP Museum Specimen No. 41118.

Locality—Profile 5A (27º54'50.6" N: 82º31'00.4" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Etymology—Named after the country of Nepal where the fossil site is located.

Affinities—Morphological features of the present fossil fruits such as kidney–like oblong shaped, pods 11.7 cm long x 4.1 cm wide showing rounded apex and base, horizontal striations running across the fruit along with fine striation in between them and distinct seed impressions on pod collectively indicate similarity with the modern fruits of *Butea parviflora* DC. of the family Fabaceae (C.N.H. Herbarium Sheet No. 49302; Pl. 21.3, 5).

Two fossil fruits, *Buteocarpon oligocenica* and *B. awasthi* resembling the genus *Butea* Roxb. ex Willd. have been known from the Oligocene sediments of Trap Colliery of Makum Coalfield, Assam (Srivastava & Mehrotra, 2010). These fruits are fragmentary and poorly preserved which possess entirely different striations (veins) on their surface. Further they do not have seed impressions as found in the siwalik fossil fruits. Thus, the fossil fruits of Arjun Khola area, western Nepal are named as a new species, *Butea nepalensis*.

The genus *Butea* Roxb. ex Willd. comprises of 3 species distributed in Indo–Malaysian region. *Butea parviflora* DC. is a large climber found in the mixed deciduous and dry evergreen forests. This species has a wide geographic range from India, Bangladesh, Nepal, Bhutan and China (Yunnan), through much of south–east Asia (Brandis, 1971; Gamble, 1972; Mabberley, 1997).

Genus—CASSIA L.

Cassia arjunkholaensis n. sp.

(Pl. 16.5, 7, 9)

Material—Single specimen.

Description—Leaflet bilaterally symmetrical, widely ovate; preserved size 7.9 x 4.2 cm; apex slightly broken; base obtuse; margins entire; texture chartaceous; venation pinnate; eucamptodromous; primary vein (1º) single, almost straight, prominent, stout; secondary veins (2º) 17–18 pairs visible, closely placed, 0.3 to 0.5 cm apart, opposite to sub–opposite, seemingly unbranched almost uniformly curving upwards; angle of divergence wide to moderately acute about (50º–70º); tertiary veins (3º) fine, angle of origin usually RR, percurrent, straight to sinuous, branched, predominantly alternate and close, oblique in relation to mid vein.

Holotype—BSIP Museum Specimen No. 41121.

Locality—Profile 7 (27º55'25.7" N: 82º30'57.9" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Etymology—Named after the fossil locality, Arjun Khola, from where the fossil was collected.

Affinities—In having widely ovate symmetrical shape, obtuse base, eucamptodromous venation, opposite to sub–opposite secondary veins showing moderately acute angle of divergence and later uniformly curving upwards; RR, percurrent, straight to sinuous, predominantly alternate and close tertiary veins, the present fossil leaflet resembles the modern leaflet of *Cassia fistula* L. (C.N.H. Herbarium Sheet No. 134932; Pl. 16.6, 8) of family Fabaceae.

PLATE 20

(Scale bar = 1 cm)

⟶

1, 2. *Buchanania raptiensis* n. sp.–Fossil leaves showing oblong shape, wide acute base and craspedodromous venation pattern. Specimen Nos. 41115 (Holotype) and 41116.

3. *Buchanania lancifolia* Roxb.–Modern leaf showing similar shape, size nature of base and venation pattern.

4. *Buchanania raptiensis* n. sp.–A part of fossil leaf in Fig. 1, magnified to show acute apex.

5. *Buchanania lancifolia* Roxb.–A part of modern leaf magnified to show similar type of apex.

6. *Buchanania raptiensis* n. sp.–A part of fossil leaf in Fig. 1, magnified to show details of venation pattern.

7. *Buchanania lancifolia* Roxb.–A part of modern leaf magnified to show similar details of venation pattern.

PLATE 20

Fossil leaflet resembling the genus *Cassia* L. have been reported under two generic names, viz. *Cassia* L. and *Cassiophyllum* Geyler (1887) from India as well as abroad. *Cassiophyllum* consists of two species, *Cassiophyllum* sp. (Geyler, 1887) and *C. berenices* (Ung.) Krausel (in Givulescu, 1968). Contrastingly, several species of *Cassia* L. have been reported from different parts of the world such as Nepal, Australia, Bolivia, Czechoslovakia, Germany, Greenland, Indonesia, Italy, Japan, New Zealand, Switzerland, U.S.A. and U.S.S.R. and India (see Prasad, 1990b, 2008).

So far, 7 fossil leaflets have been reported from the Neogene sediments of India and Nepal. They are listed below along with their Locality, Age and Characters differentiating them from the present leaflet in Table 3.

After a detailed comparison with all above species, it was observed that the present fossil leaflet is quite different from the previously described ones (see Table 3) and therefore, it is instituted under a new species *Cassia arjunkholaensis*.

Cassia L. includes about 380 species of herbs, shrubs and trees distributed in both Tropical and warm Temperate regions of the World. About 12 species are found in India (Brandis, 1971). *Cassia fistula* L. is a widespread middle sized Indian tree. It is also found to grow in deciduous forests of Myanmar, Ceylon, Transudes hills of Peshawar (Gamble, 1972; Mabberley, 1997).

Genus—CYNOMETRA L.

Cynometra siwalika Awasthi & Prasad, 1990

(Pl. 15.5, 6, 9, 11)

Material—Two specimens.

Description—Leaflets asymmetrical, elliptical; preserved size 2.9–5.2 x 1.3–2.0 cm; apex acutely bifid; base acute; texture coriaceous; venation pinnate; eucamptodromous to brochidodromous; primary vein (1º) single, straight, prominent; secondary veins (2º) 9 pairs visible, 0.2 to 0.3 cm apart, opposite to alternate, angle of divergence narrowly acute (about 40º–50º), veins branched, uniformly curving upwards, intersecondary veins narrowly acute, simple, frequent; tertiary veins (3º) fine, angle of origin AO–RR type, percurrent to sometimes ramified, predominantly alternate and close, oblique in relation to mid vein.

Figured Specimen—BSIP Museum Specimen No. 1122–41123.

Table 3—Fossil species of *Cassia* L. from India and Nepal.

Fossil species	Locality/ Period	Characters
Cassia miokachchhensis Lakhanpal & Guleria, 1982	Khari Series, Kachchh, western India.	Small size (3.5 x 2.6 cm), fewer secondary veins.
Cassia nepalensis Prasad, 1990b	Lower Siwalik, Koilabas, Nepal.	Small size (4.8 x 2.1 cm), narrowly ovate, lesser secondary veins (8–9 pairs).
Cassia antique Awasthi & Lakhanpal, 1990	Upper Siwalik of Bhikhnathoree, West Champaran District, Bihar.	Small size (4.0 x 2.0 cm), elliptic, lesser secondaries (11 pairs), angle of divergence about (45°–55°).
Cassia miosiamea Prasad, 1994a	Middle Siwalik, Koilabas, Nepal.	Small size (3.5 x 1.5 cm), narrow elliptical, lesser secondary veins (8–9 pairs).
Cassia neosophora Prasad, 1994a	Lower Siwalik, Koilabas, Nepal.	Small size (3.8 x 1.0 cm), lanceolate, craspedodromous venation, 9–10 pairs of secondary veins.
Cassia siwalica Prasad, 1994b	Lower Siwalik, Kathgodam area, Uttarakhand.	Small size (2.6 x 1.7 cm), obovate, secondary veins 9–10 pairs.
Cassia praesophora Agarwal, 2002	Miocene, Neyveli Lignite deposit, Mine 1, Tamil Nadu.	Smaller size (45 x 13 mm), lanceolate, craspedodromous venation, lesser secondary veins (9–10 pairs).

PLATE 21

(Scale bar = 1 cm)

⟶

1, 2, 4. *Butea nepalensis* n. sp.–Fossil fruits showing kidney–like shape, rounded apex and base Fig. 1 (Holotype) showing surface striations. Specimen Nos. 41118 (Holotype) and 41119–41120.

3. *Butea parvifolia* DC.–Modern fruit showing similar shape and nature of apex and base.

5. *Butea parvifolia* DC.–A part of modern fruit showing similar type of striations.

PLATE 21

Locality—Profiles 5A (27º54'50.6" N: 82º31'00.4" E), 5C (27º55'03.5" N: 82º31'11.8" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Affinities—Diagnostic features of the present fossil leaflets such as narrowly elliptical asymmetrical shape, apically notched, eucamptodromous venation, narrowly acute angle of divergence of secondary veins, presence of frequent intersecondary veins; AO–RR, percurrent, ramified tertiary veins suggest resemblance with modern leaflets of *Cynometra ramiflora* L. of the family Fabaceae (C.N.H. Herbarium Sheet No. 10191; Pl. 15.7, 10, 12).

Three fossil species showing affinity with the genus *Cynometra* L. have been reported from the Siwalik sediments of India and Nepal. They are *Cynometra siwalika* (Awasthi & Prasad, 1990) from Lower Siwalik sediments of Surai Khola area, western Nepal and Tanakpur area Uttarakhand, India (Shashi *et al.,* 2006); *Cynometra tertiara* (Antal & Awasthi, 1993) from Lower–Middle Siwalik sediments of Oodlabari, Darjeeling District, West Bengal and *Cynometra palaeoeripa* from Lower Siwalik sediments of Koilabas Nala section near Imlibasa, Koilabas, western Nepal (Prasad *et al.,* 1999) and Gola River bed, near Jamrani, Kathgodam, Nainital District Uttarakhand (Prasad *et al.,* 2004).

A comparison of the present fossil leaflets with *Cynometra siwalika* Awasthi and Prasad (1990) showed similarity in size, shape and venation pattern especially in the orientation of secondary veins which formed loops before the margins. Because of these similarities the present fossil leaflets are described under the same species, *Cynometra siwalika*.

The genus *Cynometra* L. comprises of about 70 Tropical species. *Cynometra ramiflora* L. is an evergreen tree, found to grow in Tenasserim, Andaman, Coast of Konkan, Kanara, Sri Lanka, Malaya Archipelago, Sundarbans and other coastal forests (Ridley, 1967; Brandis, 1971; Mabberley, 1997).

Genus—MILLETTIA Wight & Arn.

Millettia arjunkholaensis n. sp.

(Pl. 16.1, 3)

Material—Single specimen.

Description—Leaflet seemingly bilaterally symmetrical, widely elliptical; preserved size 5.8 x 4.9 cm; apex and base unpreserved; margins entire; texture chartaceous; venation pinnate; eucamptodromous; primary vein (1º) single, straight, prominent, stout; secondary veins (2º) 4–5 pairs visible, 1.0 to 2.5 cm apart, opposite, seemingly unbranched, angle of divergence narrowly acute (45º–55º), markedly curving upwards towards the apex; tertiary veins (3º) angle of origin RR type, percurrent, forked, almost straight, oblique in middle and basal regions, at right angle, in apical region, predominantly alternate, close to distant.

Holotype—BSIP Museum Specimen No. 41124.

Locality—Profile 12 (27º56'06.1" N: 82º29'32.2" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Lower Churia Group, Middle Miocene.

Etymology—Named after the fossil locality 'Arjun Khola'.

Affinities—Diagnostic features of the present fossil leaflet such as bilateral symmetry, widely elliptical shape, entire margins, eucamptodromous venation with opposite secondary veins markedly curving upward towards apex; RR, percurrent tertiary veins right angled in relation to mid vein indicate similarity with the modern leaflets of *Millettia eriantha* Benth. (C.N.H. Herbarium Sheet No. 112801; Pl. 16.2, 4) of the family Fabaceae.

About 37 fossil leaflets resembling the genus *Millettia* Wight and Arn. have been reported from the Cenozoic sediments of India and abroad. They are listed in Table 4 along with their age and collection site. The table also indicates characters of the species which differ from the present leaflet.

A detailed study of all the species is listed in Table 4. The present fossil leaflet is quite different from them and is described as a new species *Millettia arjunkholaensis.*

The genus *Millettia* Wight and Arn. comprises of about 260 species distributed in the tropics of the old World, Eastern Peninsula Africa, Asia and Australia. *Millettia eriantha* Benth. is a woody climber, almost glabrous found growing in Singapore, Bukit Mandai, Malacca, Penang (Ridley, 1967; Brandis, 1971; Gamble, 1972; Mabberley, 1997).

Genus—SARACA L

Saraca palaeoindica n. sp.

(Pl. 19.1, 3)

Material—Single specimen.

PLATE 22

(Scale bar = 1 cm)

⟶

1–3. *Combretum siwalicum* n. sp.–Fossil leaves showing shape, size and venation pattern. Specimen Nos. 41128 (Holotype) and 41129–41130.

4. *Combretum roxburghii* Sprengel–Modern leaf showing similar shape, size and venation pattern.

5. *Combretum siwalicum* n. sp.–A part of fossil leaf in Fig. 1, magnified to show details of venation pattern.

6. *Combretum roxburghii* Sprengel–A part of modern leaf in Fig. 4, magnified to show similar venation pattern.

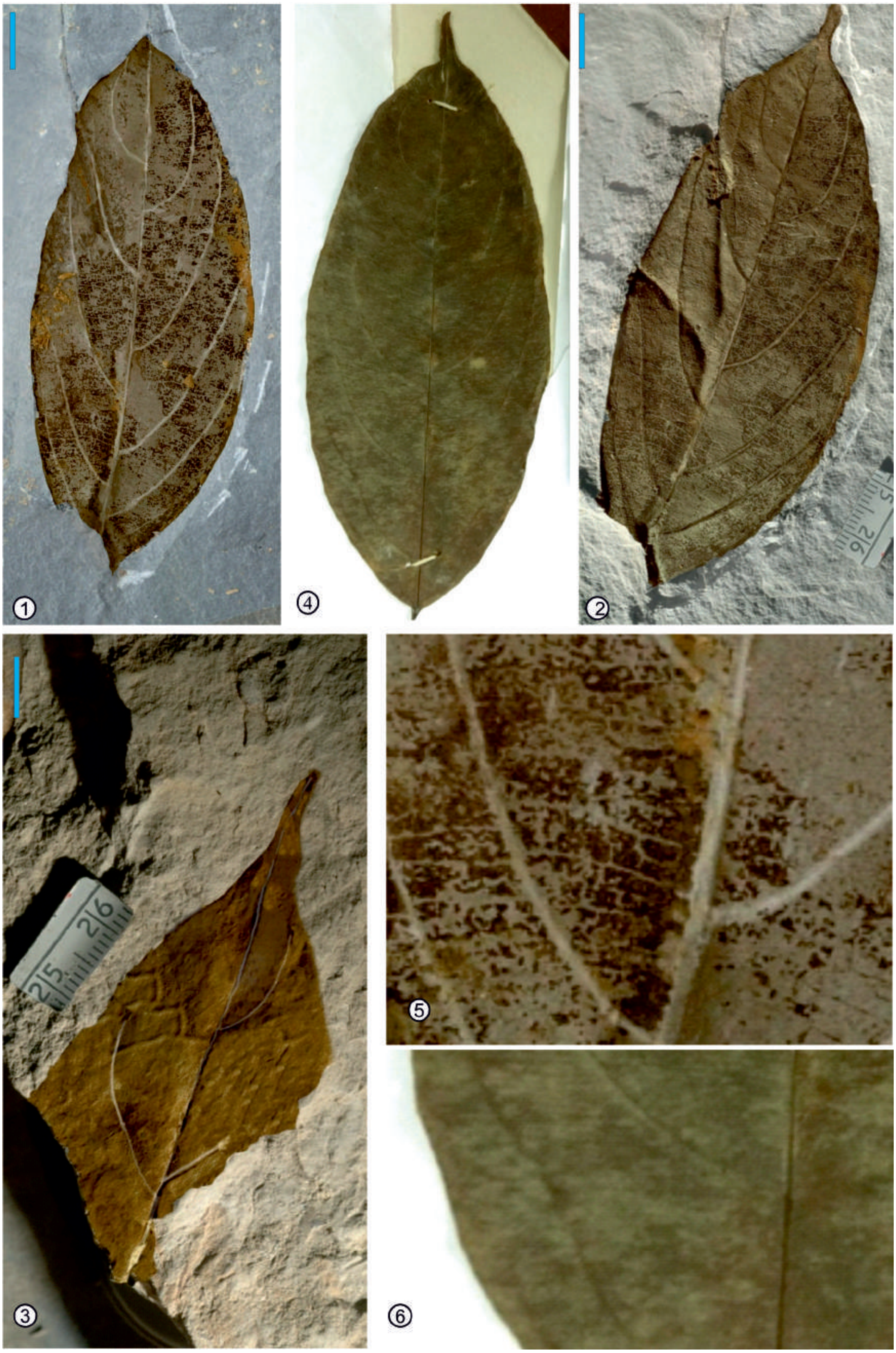

PLATE 22

Table 4—Showing characters of fossil species of *Millettia* from Tertiary sediments of India and abroad.

Fossil species	Locality/ Period	Characters
M. auriculata Bande & Srivastava, 1990	Late Cenozoic of Mahuadanr, Jharkhand	Ovate shape, secondaries upturned gradually diminishing near margins and connecting superadjacent secondaries by a series of crossveins.
M. asymmetrica Lakhanpal & Guleria, 1982	Miocene of Kachchh, western India	Small size (3.9 x 2.7 cm), ovate shape.
M. bilaspurensis Prasad, 2006	Siwalik of Bilaspur, Himachal Pradesh, India	Large size (13.6 x 2.7 cm), narrowly oblong shape, numerous (18 pairs), closely placed secondaries.
M. churiensis Prasad & Awasthi, 1996; Agarwal, 2002	Siwalik of Surai Khola, Nepal; Miocene of Neyveli Lignite, south India	Small size (4.2 x 1.2 cm), lanceolate shape, acuminate apex, higher number of secondaries (about 8 pairs).
M. imlibasensis Prasad *et al.,* 1999	Siwalik of Koilabas, Nepal	Small size (4.3 x 1.6 cm), narrowly elliptical shape, obtuse base, angle of divergence 60º.
Millettia impressa Menzel, 1920	Tertiary of West Africa	Unaccompanied by description and photograph.
M. kathgodamensis Prasad *et al*., 2004, 2017a	Siwalik of Kathgodam, Uttarakhand, India	Oblique base, tertiaries forming orthogonal meshes, oblique to right angled in relation to midvein.
M. koilabasensis Prasad 1990b; Prasad & Tripathi, 2000; Prasad & Pandey, 2008	Siwalik of Koilabas, Nepal; Siwalik of Bhutan; Siwalik of Surai Khola, Nepal	Narrowly obovate shape, higher number of secondaries (8 pairs), AR–RO angle of origin of tertiary veins.
M. miocenica Lakhanpal & Guleria, 1982	Miocene of Kachchh, western India	Small size (5.6 x 3.2 cm), oblong shape.
M. miobrandisiana Prasad, 1994a	Siwalik of Koilabas, Nepal	Small size (2.3 x 1.1 cm), brochidodromous venation, angle of divergence of secondaries acute to right angle.
Millettia mioinermis Prasad *et al.,* 2017b	Siwalik of Tanakpur, Uttarakhand, India	Obovate shape, attenuate base, angle of origin of tertiaries AO.
M. notoensis Ishida, 1970	Middle Miocene of central Japan	Ovate shape.
M. oodlabariensis Antal & Prasad, 1996a	Siwalik of Darjeeling District West Bengal, India	Large size (14.3 x 3.5 cm), elliptical to lanceolate, texture coriaceous, rarely brochidodromous venation.
M. ovatus Tripathi *et al.,* 2002	Siwalik of Koilabas, near Jarwa	Small size (3.5 x 2.5 cm), ovate shape.

PLATE 23

(Scale bar = 1 cm)

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1. *Lagerstroemia patelii* Lakhanpal & Guleria–Fossil leaf showing shape, size and venation pattern. Specimen No. 41133.
2. *Lagerstroemia speciosa* (L.) Pers.–Modern leaf showing similar shape, size and venation pattern.
3. *Lagerstroemia patelii* Lakhanpal & Guleria–A part of fossil leaf magnified to show details of tertiary veins.
4. *Lagerstroemia speciosa* (L.) Pers.–A part of modern leaf magnified to show similar details of tertiary veins.
5. *Lagerstroemia patelii* Lakhanpal & Guleria–A part of fossil leaf magnified to show obtuse base.
6. *Lagerstroemia speciosa* (L.) Pers.–A part of modern leaf magnified to show similar details of base.

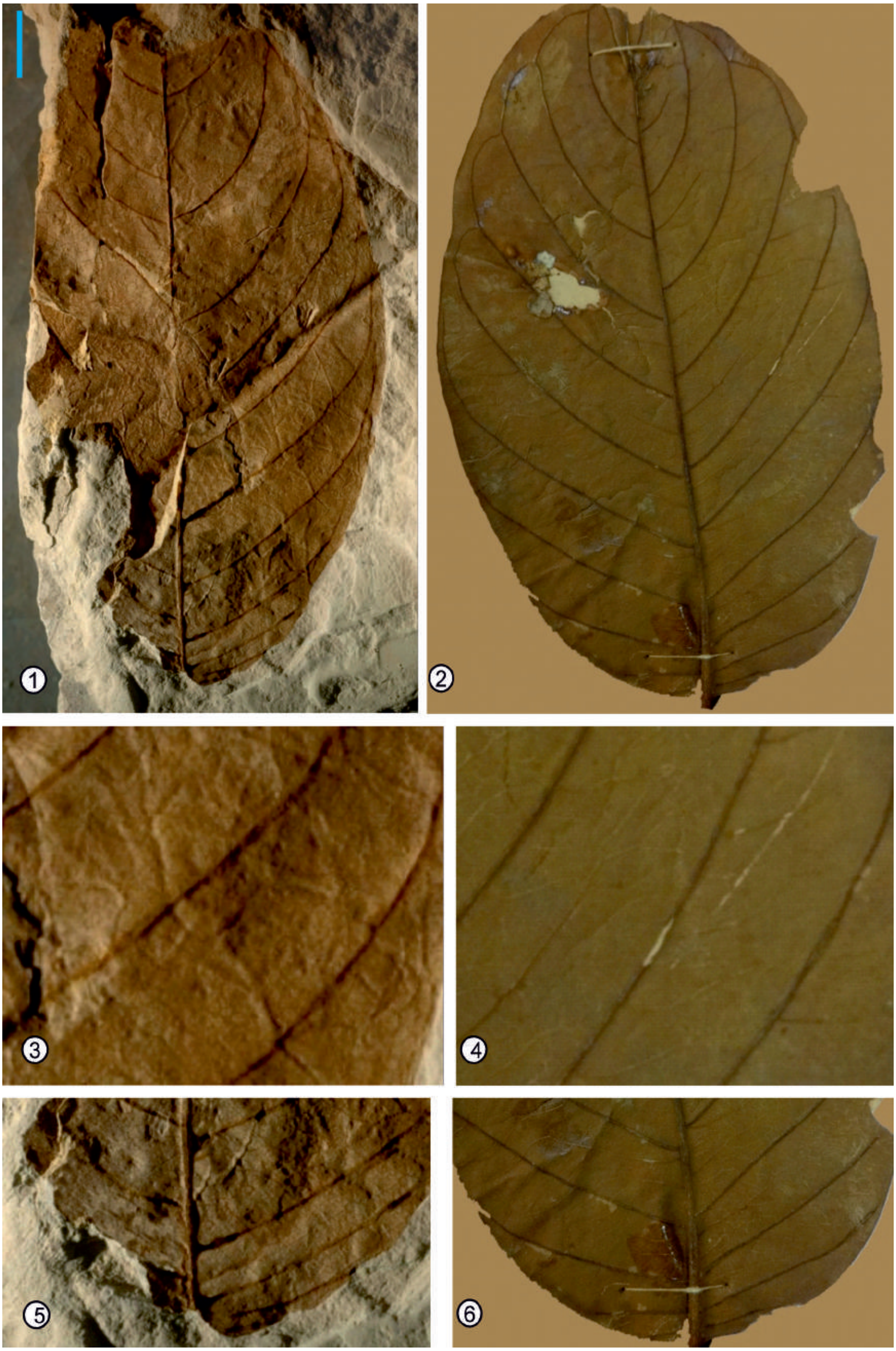

PLATE 23

M. palaeocubithii Awasthi & Prasad, 1990	Siwalik of Surai Khola, Nepal	Oblanceolate shape, almost same number of secondaries (4 pair).
M. palaeopachycarpa Agarwal, 2002	Miocene of Neyveli Lignite, south India	Small size (5.0 x 2.1 cm), lanceolate shape, more number of secondaries (about 6 pairs).
M. palaeomanii Dwivedi *et al.,* 2006b	Siwalik of Koilabas, Nepal	Small size (3.2 x 1.5 cm), widely ovate shape, texture coriaceous.
M. palaeoracemosa Awasthi & Prasad, 1990; Prasad 1994c	Siwalik of Surai Khola, Nepal; Siwalik of Kathgodam, Uttarakhand, India	Widely obovate shape, texture coriaceous, rarely AO angle of origin of tertiary veins.
M. purniyagiriensis Shashi *et al*., 2006	Siwalik of Tanakpur, Uttarakhand, India	Secondary veins 7–8 pairs, angle of origin of tertiaries AR–RR.
M. prakashii, Shashi *et al.,* 2008	Siwalik of Tanakpur, Uttarakhand, India	Large size (10 x 3.8 cm), higher number of secondaries (7–8 pairs), angle of origin of tertiaries usually AR.
M. singhii Mathur *et al*., 1996	Kasauli Formation, H.P., India	Small size (4.0 x 1.5 cm), large number of secondaries (about 7 pairs).
M. siwalica Prasad, 1990a, 1994a; Prasad *et al*., 2017b	Siwalik of Koilabas, Nepal; Siwalik of Kathgodam, Uttarakhand, India	Small size (3.1 x 2.0 cm), texture coriaceous, AO angle of origin of tertiary veins.
Millettia sp. Mathur *et al.,* 1996	Kasauli Formation, H.P., India	Small size (2.2 x 0.8 cm), large number of secondaries (about 6 pairs).
Millettia sp. Huzioka & Takahasi, 1970	Eocene of SW Honshu, Japan	Lanceolate asymmetrical shape, base obtuse.
Millettia cf. *extensa* Khan *et al*., 2011)	Siwalik of Papumpare, Arunachal Pradesh	Larger size, obovate shape, angle of divergence of secondary veins widely acute.
M. miosericea Prasad *et al.,* 2015	Middle Siwalik, Darjeeling District, West Bengal, India	Large size (7.8 x 3.2 cm), elliptical shape, secondary veins numerous 10–11 pairs, alternate to sub–opposite.
M. sevokensis Prasad *et al.,* 2015	Middle Siwalik, Darjeeling District, West Bengal, India	Large size (6.5–10.0 x 5.9–6.5 cm), asymmetrical, narrow elliptical, angle of divergence of secondaries acute to right angled.
M. miocineria Prasad *et al.,* 2016	Lower Siwalik of Arjun Khola, western Nepal	Size 7.2 x 3.2 cm, elliptical, with 7 pairs of secondary veins.

Description—Leaflet bilaterally symmetrical, narrowly elliptical; preserved size 11.5 x 3.0 cm; apex acute; base acute; margins entire; texture chartaceous; venation pinnate, eucamptodromous; primary vein (1º) single, prominent, stout; secondary veins (2º) 6–7 pairs visible, 2.1 to 2.5 cm apart, opposite to alternate, unbranched, angle of divergence moderately acute (about 50º–60º); tertiary veins (3º) fine, angle of origin RR type, percurrent straight to sinuous, branched, predominantly alternate and close, oblique in relation to mid vein.

Holotype—BSIP Museum Specimen No. 41125.

Locality—Profile 5A (27º54'50.6" N: 82º31'00.4" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

PLATE 24

(Scale bar = 1 cm)

→

1, 2. *Artocarpus arjunkholaensis* n. sp.–Fossil leaves showing elliptic shape, large size and eucamptodromous to brochidodromous venation pattern. Specimen Nos. 41142 (Holotype) and 41143.

3. *Artocarpus rigidus* Blume–Modern leaf showing similar shape, size and venation pattern.

4. *Artocarpus arjunkholaensis* n. sp.–A part of fossil leaf magnified to show details of tertiary veins.

5. *Artocarpus rigidus* Blume–A part of modern leaf magnified to show similar details of tertiary veins.

PLATE 24

Horizon and Age—Middle Churia Group, Upper Miocene.

Etymology—Named after adding the prefix 'palaeo' to the name of a modern comparable species, *S. indica.*

Affinities—The morphological features of the present fossil leaf such as bilateral symmetry, narrowly elliptical shape, entire margins, eucamptodromous venation, unbranched, secondary veins showing moderately acute angle of divergence, RR angle of origin, percurrent, alternate tertiary veins, oblique in relation to mid vein, indicate affinity with the leaves of modern *Saraca indica* L. (C.N.H. Herbarium Sheet No.138360; Pl. 19.2, 4) of the family Fabaceae.

So far there is no record of any fossil leaf resembling the genus *Saraca* L. from the Siwalik sediments. Therefore, the present fossil leaf is the first record of the species in the Siwalik sediments of Arjun Khola area, western Nepal and is hence, described as a new species *Saraca palaeoindica*.

The genus *Saraca* L. consists about 14 species distributed in Indo–Malaysian regions. *Saraca indica* L. is an evergreen small tree, found to grow in evergreen forests of Sri Lanka, Malaya, Myanmar, Tenasserim, Arakan, Western Peninsula, Northern Circar, Konkan and Kanara (Brandis, 1971; Gamble, 1972; Mabberley, 1997).

Genus—SINDORA Miq.

Sindora eosiamensis n. sp.

(Pl. 17.1, 3)

Material—Single specimen.

Description—Leaflet seemingly bilaterally symmetrical, narrowly elliptical; preserved size 4.3 x 1.3 cm; apex and base acute, margins entire; texture chartaceous; venation pinnate, eucamptodromous to brochidodromous; primary vein (1º) single, prominent, stout; secondary veins (2º) 11–12 pairs visible, 0.2–0.5 cm apart, opposite, unbranched, angle of divergence widely acute (70º–80º), unbranched, secondary veins curving upwards to join adjacent supersecondaries; tertiary veins (3º) poorly preserved, angle of origin AO, percurrent, predominantly alternate and close, oblique in relation to mid vein.

Holotype—BSIP Museum Specimen No. 41126.

Locality—Profile 3 (27º54'24.0" N: 82º30'52.7" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Lower Churia Group, Middle Miocene.

Etymology—Named after adding the prefix 'eo' to the name of a modern comparable species, *S. siamensis.*

Affinities—Morphological features of the present fossil leaflet such as bilateral symmetry, narrowly elliptical shape, entire margins, eucamptodromous to brochidodromous venation, with opposite, unbranched secondary veins showing widely acute angle of divergence and AO, percurrent, oblique tertiary veins show closest similarity with the modern leaflets of *Sindora siamensis* Teijsm. ex Miq. (C.N.H. Herbarium Sheet No. 138360; Pl. 17.2, 4) of the family Fabaceae.

Up to date, there is only one record of a fossil leaflet resembling the genus *Sindora* under the form species, *S. eovelutinicus* (Ambwani, 1991), from Cherrapunji, West Khasi Hills, Meghalaya. Besides this, a number of fossil woods have also been reported from Mio–Pliocene sediments of different parts of India and abroad (Awasthi, 1977b; Lalitha & Prakash, 1980; Prakash, 1981; Prakash *et al*., 1988; Lemoigne *et al*., 1974). The earlier reported fossil leaflets differ from Arjun Khola fossil in being widely elliptical in shape and showing right angled divergence of secondary veins. They also show craspedodromous venation pattern as compared to eucamptodromous type of venation pattern in the present fossil. On account of above mentioned dissimilarities the present fossil leaf is described as a new species, *Sindora eosiamensis.*

The genus *Sindora* Miq. comprises of about 20 species distributed in south–east Asian regions. The comparable species, *Sindora siamensis* Teijsm. ex Miq. is a large evergreen tree found to grow in open semi–deciduous forests of Cambodia, Laos, Malaysia, Thailand and Vietnam (Brandis, 1971).

Genus—SINDORA Miq.

Sindora leguminocarpoides n. sp.

(Pl. 17.5)

Material—Single specimen.

PLATE 25
(Scale bar = 1 cm)

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1. *Ficus preglobosa* n. sp.–Fossil leaf showing widely elliptic shape, obtuse base and brochidodromous venation pattern. Specimen No. 41144 (Holotype).
2. *Ficus globosa* Blume–Modern leaf showing similar shape, nature of base and venation pattern.
3. *Ficus preglobosa* n. sp.–A part of fossil leaf magnified to show details of secondary veins that are curved upwards to join super adjacent secondaries forming a loop.
4. *Ficus globosa* Blume–A part of modern leaf magnified to show similar details of secondary veins.
5. *Cordia siwalica* n. sp.–Fossil leaf showing widely ovate shape, rounded base and eucamptodromous venation pattern. Specimen No. 41138 (Holotype).
6. *Cordia sebestena* L.–Modern leaf showing similar shape, base and venation pattern.

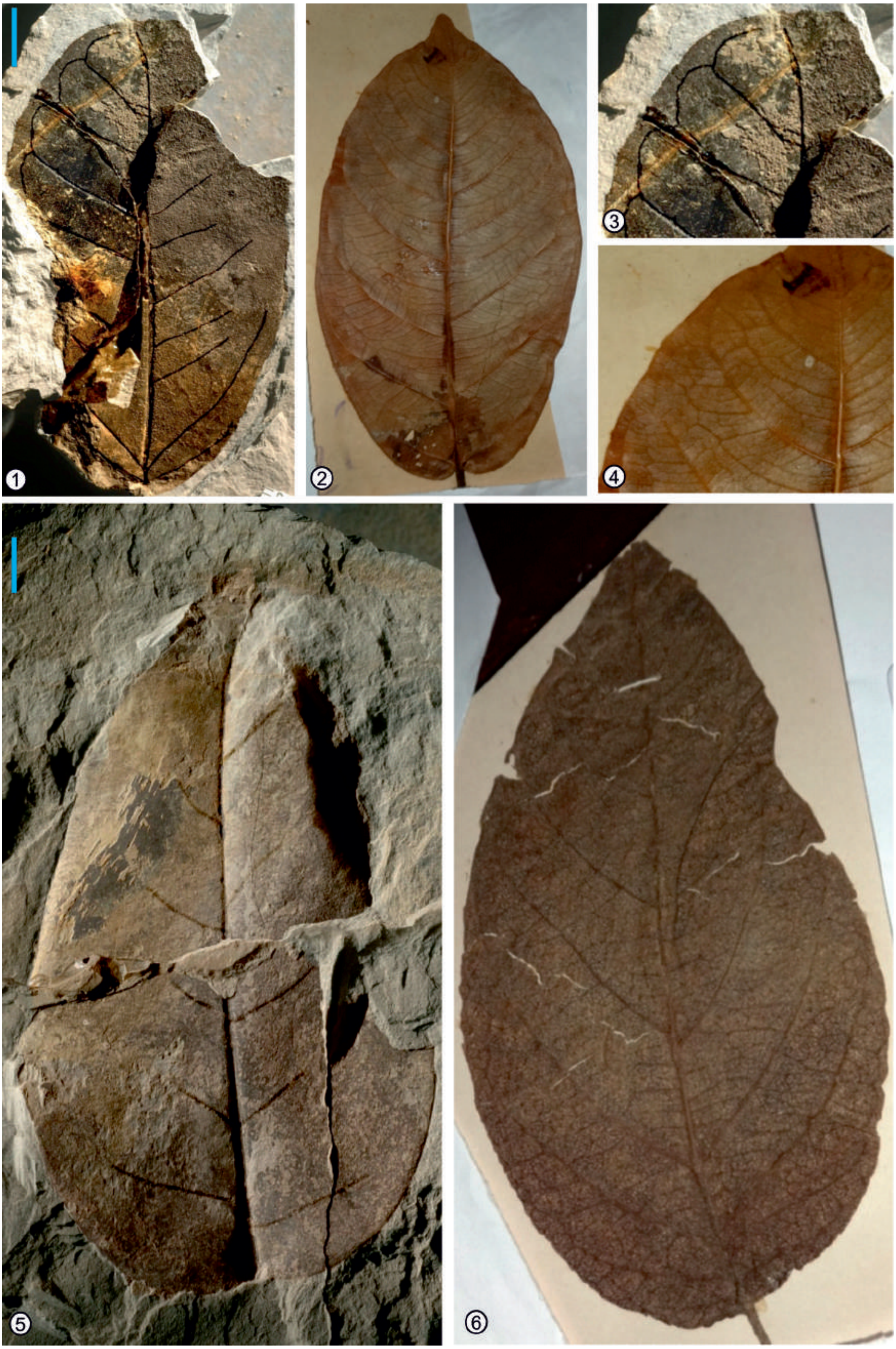

PLATE 25

Description—Fruit size 5.6 x 5.2 cm; ovoid in shape, flattened, outer surface spiny, faint striations running across the width of the fruit visible. Outer wall of the fruit slightly thick.

Holotype—BSIP Museum Specimen No. 41127.

Locality—Profile 12 (27º56'06.1" N: 82º29'32.2" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Lower Churia Group, Middle Miocene.

Etymology—Named after adding suffix 'carpoides' to the name legume, a pod closely resembling the presently described fossil fruit.

Affinities—Morphological characters of the present fossil fruit including shape and size suggest a close similarity with the extant fruits of *Sindora siamensis* Teijsm. ex Miq. (C.N.H. Herbarium Sheet No. 38609; Pl. 17.5) of family Fabaceae. The fruits of *Sindora velutina* Baker and *S. wallichii* Benth. also resemble the present fossil fruit.

So far, there is no record of fossil fruit resembling the genus *Sindora* Miq., The present fossil leaf and fruit are first records from the Siwalik sediments of Arjun Khola area, western Nepal, therefore, the new fruit is described as a new species *Sindora leguminocarpoides*.

Order—MYRTALES

Family—COMBRETACEAE

Genus—COMBRETUM Loefl.

Combretum siwalicum n. sp.

(Pl. 22.1, 2, 3, 5)

Material—Three specimens.

Description—Leaves simple, bilaterally symmetrical, elliptical; preserved size 6.1–11.3 x 2.7–4.5 cm; apex acute to acuminate; base obtuse; margins entire; texture chartaceous; venation pinnate; eucamptodromous; primary vein (1º) single, prominent, stout; secondary veins (2º) 6 pairs visible, angle of divergence moderately acute (50º–65º), 0.9 to 1.2 cm apart, alternate, unbranched, uniformly curving upwards and running a long distance before joining super adjacent secondaries; tertiary veins (3º) angle of origin RR type, percurrent, almost straight, forked, alternate to opposite and close, oblique to right angled in relation to mid vein; quaternary veins (4º) fine, branched with RR angle of origin, forming orthogonal to polygonal meshes, right angled in relation to mid vein.

Holotype—BSIP Museum Specimen No. 41128.

Locality—Profile 5A (27º54'50.6" N: 82º31'00.4" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Etymology—Named after 'Siwalik' Formation which yielded the fossil.

Affinities—Morphological features of the present fossil leaves such as bilateral symmetry, elliptical shape; entire margins; eucamptodromous venations; secondary veins alternate, unbranched, uniformly curving upwards and running a long distance before joining the super adjacent secondaries, angle of divergence moderate, tertiaries with RR angle of origin, percurrent, forked oblique in relation to mid vein, quaternary veins with RR angle of origin, branched forming rectangular to polygonal meshes indicating similarity with modern leaves of *Combretum roxburghii* Sprengel (C.N.H. Herbarium Sheet No. 12869; Pl. 22.4, 6) of the family Combretaceae.

So far, there are five records of fossil leaves of the genus, *Combretum* Loefl. from the Cenozoic sediments 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), *C. decandrum* Jacq. from Late Tertiary of Mahuadanr, Jharkhand, *C. sahnii* from several sites in Lower–Middle Siwalik of Darjeeling District, West Bengal (Antal & Awasthi, 1993), from Lower Siwalik of Koilabas area, Nepal (Prasad, 1994a), Eocene sediments of Vastan Lignite, western India (Singh *et al*., 2015) and Siwalik of Papumpare District, Arunachal Pradesh (Khan *et al*., 2011) and *C. miocenicum* from Lower Siwalik of Bhutan (Prasad & Tripathi, 2000). A comparison of above mentioned fossil leaves with the present leaves did not reveal a close similarity with any of the above as the latter varied mainly in showing an acute to acuminate type of leaf apex and larger number of secondary veins. Therefore, *Combretum siwalicum* was instituted to include the new leaves.

PLATE 26

(Scale bar = 1 cm)

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1, 2. *Cinnamomum raptiensis* n. sp.–Fossil leaves showing shape, size and venation pattern. Specimen No. 41139 (Holotype).

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

4. *Cinnamomum mollissimum* Hook. f.–Another modern leaf showing similarity with the fossil (Fig 2).

5. *Cinnamomum raptiensis* n. sp.–A part of fossil leaf in Fig. 1, magnified to show details of acute base and Acrodromous, supra basal perfect type of venation pattern.

6. *Cinnamomum mollissimum* Hook. f.–A part of modern leaf magnified to show similar details as fossils.

7. *Cinnamomum raptiensis* n. sp.–A part of fossil leaf in Fig. 2, magnified to show cross veins that are looking like tertiary veins arising at right angles from all three primaries.

8. *Cinnamomum mollissimum* Hook. f.–A part of modern leaf magnified to show similar details of cross veins.

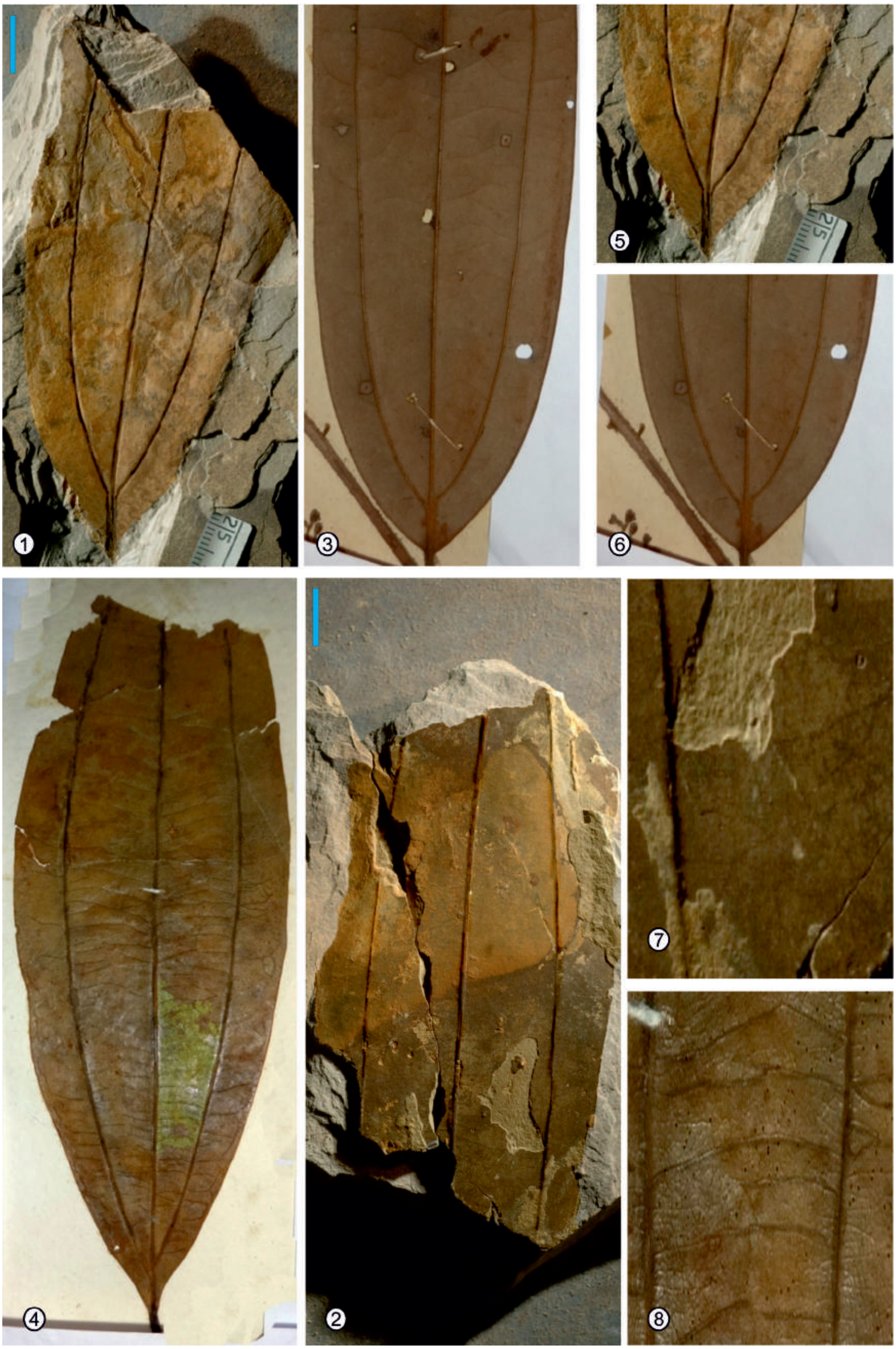

PLATE 26

The genus *Combretum* Loefl. includes about 260 species distributed in Tropical and sub–Tropical regions of the old World (Mabberley, 1997). *Combretum roxburghii* Sprengel is a small tree distributed in Bangladesh, India, Laos, Myanmar, Nepal, Sri Lanka, Thailand and Vietnam.

Genus—TERMINALIA L.

Terminalia arjunkholaensis n. sp.

(Pl. 17.7)

Material—Single specimen.

Description—Fruit drupe like; elliptical to ovoid shape, preserved size 4.1 x 2.3 cm; coriaceous with prominent central longitudinal axis showing two ridges on either side; ridges of almost equal size showing numerous horizontally running parallel striations from apex downward.

Holotype—BSIP Museum Specimen No. 41131.

Locality—Profile 6 (27º55'24.5" N: 82º31'1.3" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Etymology—Named after the fossil locality 'Arjun Khola' from where the fossil was collected.

Affinities—Morphological features of the present fossil fruit such as elliptical to oval shape, presence of ridges (wings) with horizontal striations running from central axis to fruit margins indicate similarity with modern fruits of *Terminalia tomentosa* Wight & Arn. (Syn. *Terminalia alata* = *T. crenulata* = *T. coriacea* = *T. macrocarpa*; C.N.H. Herbarium Sheet No. 163786; Pl. 17.8) of the family Combretaceae.

There is no previous record of fossil fruit resembling the genus *Terminalia* L. from the Siwaliks. Therefore, report of present fossil fruit in the Siwalik sediments of Arjun Khola area, western Nepal is the first record and hence it is described as a new species, *Terminalia arjunkholaensis.*

Fossil leaves resembling the genus *Terminalia* Linn. have been reported under three generic names, viz. *Terminalia* Linn., *Terminaliophyllum* Velenovsky and *Terminaliophyllum* Geyler from Tertiary–Cretaceous sediments of India and abroad.

The genus *Terminalia* L. comprises of 150 species (Mabberley 1997) distributed in Tropical regions of the world. *Terminalia tomentosa* Wight & Arn. a large deciduous tree, perhaps the most widely distributed of all important Indian forest trees and found in sub–Himalayan tract and lower Himalayas from the Ravi eastwards ascending to 4,000 ft. The Combretaceous taxa are mainly distributed throughout the tropics of South America, Africa, Australia, China and South–east Asia. There are global records of Combretaceous fossils represented by woods, leaves, flowers, fruits and pollen from Middle Cretaceous onwards. The genus *Terminalia* has a cosmopolitan distribution and show maximum diversity in South–East Asia. The earliest record of *Terminalia* (*Terminaliophyllum rectinervis* Velenovsky, 1889) goes back to Upper Cretaceous of Bohemia. From the fossil record, it is obvious that *Terminalia* has continued from the Late Cretaceous to the present and was more widely spread during the Tertiary Period than now. It also extends downwards occurring in dry rocky hill side forests of the peninsula (Prasad *et al.,* 2013b).

Family—MYRTACEAE

Genus—EUGENIA L.

Eugenia nepalensis n. sp

(Pl. 19.5, 7)

Material—Single specimen.

Description—Leaf simple, bilaterally symmetrical, narrowly elliptical; preserved size of leaf 12.9 x 4.0 cm; apex attenuate; base seems to be acute; margins entire; texture chartaceous; venation pinnate, brochidodromous; primary vein (1º) single, straight, prominent, stout; secondary veins (2º) more than 8–9 pairs visible with moderately acute angle of divergence (about 60º), veins 0.7 to 1.2 cm apart, opposite to sub–opposite, uniformly curving upwards to join super adjacent secondaries and forming inter–marginal vein all along the margins; unbranched, intersecondary veins frequently present, 1–2 veins in between two secondary veins; tertiary veins (3º) angle of origin RR type, percurrent, branched, almost straight, predominantly alternate, close to distant, oblique in relation to midvein.

PLATE 27

(Scale bar = 1 cm)

⟶

1–3. *Diospyros embryopterisites* Varma–Fossil leaves showing shape, size and venation pattern. Specimen Nos. 41135–41137.

4. *Diospyros embryopteris* Pers.–Modern leaf showing similar shape, size and venation pattern.

5. *Diospyros embryopterisites* Varma–A part of fossil leaf in Fig. 2, magnified to show details of tertiary veins.

6. *Diospyros embryopteris* Pers.–A part of modern leaf magnified to show similar details of tertiary veins.

7–9. *Filicium koilabasensis* Prasad–Fossil leaves showing shape, size and venation pattern. Specimen Nos. 41105–41107.

10. *Filicium decipiens* (Wight & Arn.) Thwaites–Modern leaves showing similar shape, size and venation pattern.

11. *Filicium koilabasensis* Prasad–A part of fossil leaf (Fig.7) magnified to show details of venation pattern.

12. *Filicium decipiens* (Wight & Arn.) Thwaites–A part of modern leaf magnified to show similar details of venation pattern.

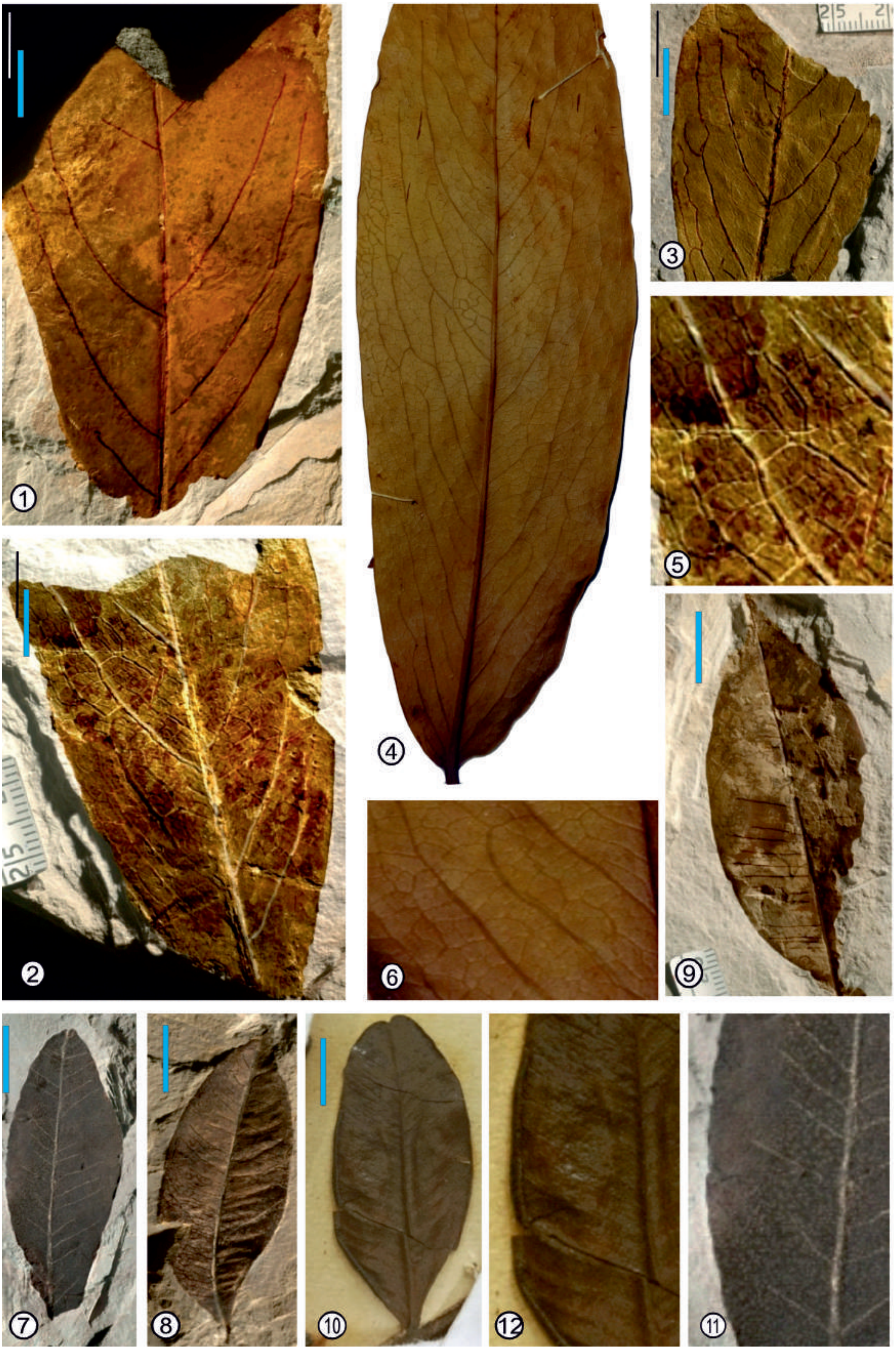

PLATE 27

Holotype—BSIP Museum Specimen No. 41132.

Locality—Profile 5A (27º54'50.6" N: 82º31'00.4" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Etymology—Named after the country of 'Nepal' where fossil site is located.

Affinities—Characteristic features of the present fossil leaf such as bilateral symmetry, narrowly elliptical shape, attenuated apex, brochidodromous venation pattern, opposite to sub–opposite secondaries showing moderately acute angle of divergence and later joining super adjacent secondaries to form intermarginal veins, presence of frequent intersecondary veins, RR, percurrent, almost straight tertiaries indicate closest resemblance with the modern leaves of *Eugenia diospyrifolia* Wall. (C.N.H. Herbarium Sheet No. 167869; Pl. 19.6, 8) of the family Myrtaceae.

So far, only two fossils leaves resembling the genus *Eugenia* L. have been reported from the Cenozoic sediments of the Indian subcontinent. *Eugenia lamhiensis* (Prasad *et al.,* 2016) from Middle Siwalik of Arjun Khola area, western Nepal and *Eugenia* sp. cf *E. americana* Makoy ex E. Morren from Middle Eocene of south–western Kachchh, Gujarat (Bajpai & Singh, 1987). A comparison of the present fossil leaf with previously reported ones revealed that the species *E. lamhiensis,* described from the same locality differed from the present leaf in having smaller size and more number (22 pairs) of secondary veins. The other fossil leaf, *Eugenia* sp. cf *E. americana* is also small sized (9.5 x 1.0 cm) but falcate in shape, instead of being narrowly elliptical as the presently described fossil. Thus, the new fossil leaf is described as a new species, *Eugenia nepalensis* n. sp.

Genus *Eugenia* L. comprises of about 550 species distributed in America, Australia, eastern New Guinea, eastern Bengal, North–east and South India. *Eugenia diospyrifolia* Wall. is a middle sized tree distributed in Upper Myanmar near streams and Khasi and Garo Hills (Gamble, 1972).

Family—LYTHRACEAE

Genus—LAGERSTROEMIA L.

Lagerstroemia patelii Lakhanpal & Guleria, 1981

(Pl. 23.1, 3, 5)

Material—Single specimen.

Description—Leaf simple, bilaterally symmetrical, widely elliptical; preserved size 9.5 x 5.5 cm; apex unpreserved; base obtuse; margins entire; texture chartaceous; venation pinnate; eucamptodromous; primary vein (1º) single, straight, prominent, stout; secondary veins (2º) 9–10 pairs visible, opposite to rarely sub–opposite, unbranched, 0.3 to 2.0 cm apart, angle of divergence moderately to widely acute (60º–70º) curving upwards to join super adjacent secondaries at an obtuse angle; moderate to widely acute; tertiary veins (3º) angle of origin AO type, fine, percurrent, straight to sinuous, branched, predominantly alternate and close, oblique to right angled in relation to mid vein.

Figured Specimen—BSIP Museum Specimen No. 41132.

Locality—Profile 5C (27º55'03.5" N: 82º31'11.4" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Affinities—Characteristic features of the present fossil leaf such as bilateral symmetry, widely elliptical shape, entire margins, eucamptodromous venation, opposite to sub–opposite, unbranched secondary veins curving upwards to join super adjacent secondaries at obtuse angle, AO percurrent, straight to sinuous tertiary veins collectively suggest similarity with modern leaves of *Lagerstroemia speciosa* (L.) Pers. of the family Lythraceae (C.N.H. Herbarium Sheet No. 610799; Pl. 23.2, 4, 6).

Several fossil leaves resembling the genus *Lagerstroemia* L. have been described under the generic name *Lagerstroemia* L. These are *Lagerstroemia patelii* from Lower Eocene of Lignite Mine at Panandhro, Kachchh, Gujarat (Lakhanpal & Guleria, 1981), Lower Siwalik of Kathgodam, Uttarakhand (Prasad, 1994b) and Lower–Middle Siwalik of Darjeeling District, West Bengal (Antal & Awasthi, 1993); *L. neyveliensis* from Neyveli Lignite Mine–1, South Arcot District, Tamil Nadu (Agarwal, 2002); *L. jamraniensis* (Prasad *et al.,* 2004) and *L. himalayaensis* (Srivastava *et al.,* 2015) from Lower Siwalik of Kathgodam, Nainital District, Uttarakhand; *L. siwalika* from Lower Siwalik of Koilabas, western Nepal (Prasad, 1994a) and Neyveli Lignite Mine–1, South Arcot District, Tamil Nadu (Agarwal, 2002); *L. mioparvifolia* and *L. eomicrocarpa* (Dwivedi *et al*., 2006b) from Siwalik sediments of Koilabas area, western Nepal; *L. imamurae* Tanai and Uemura (1991) from Oligocene of Honshu, Japan. Besides the above, three more fossil leaves, viz. *L. parviflora* Roxb., *L. macrocarpa* Wall. ex Kurz and *L. lanceolata* Wall. showing

PLATE 28

(Scale bar = 1 cm)

⟶

1. *Randia premacrophylla* n. sp. –Fossil leaf showing narrow oblong shape, large size and venation pattern. Specimen No. 41134 (Holotype).
2. *Randia macrophylla* Hook. f. –Modern leaf showing similar shape, size and venation pattern.
3. *Randia premacrophylla* n. sp. –A part of fossil leaf magnified to show details of tertiary veins.
4. *Randia macrophylla* Hook. f. –A part of modern leaf magnified to show similar details of tertiary veins.

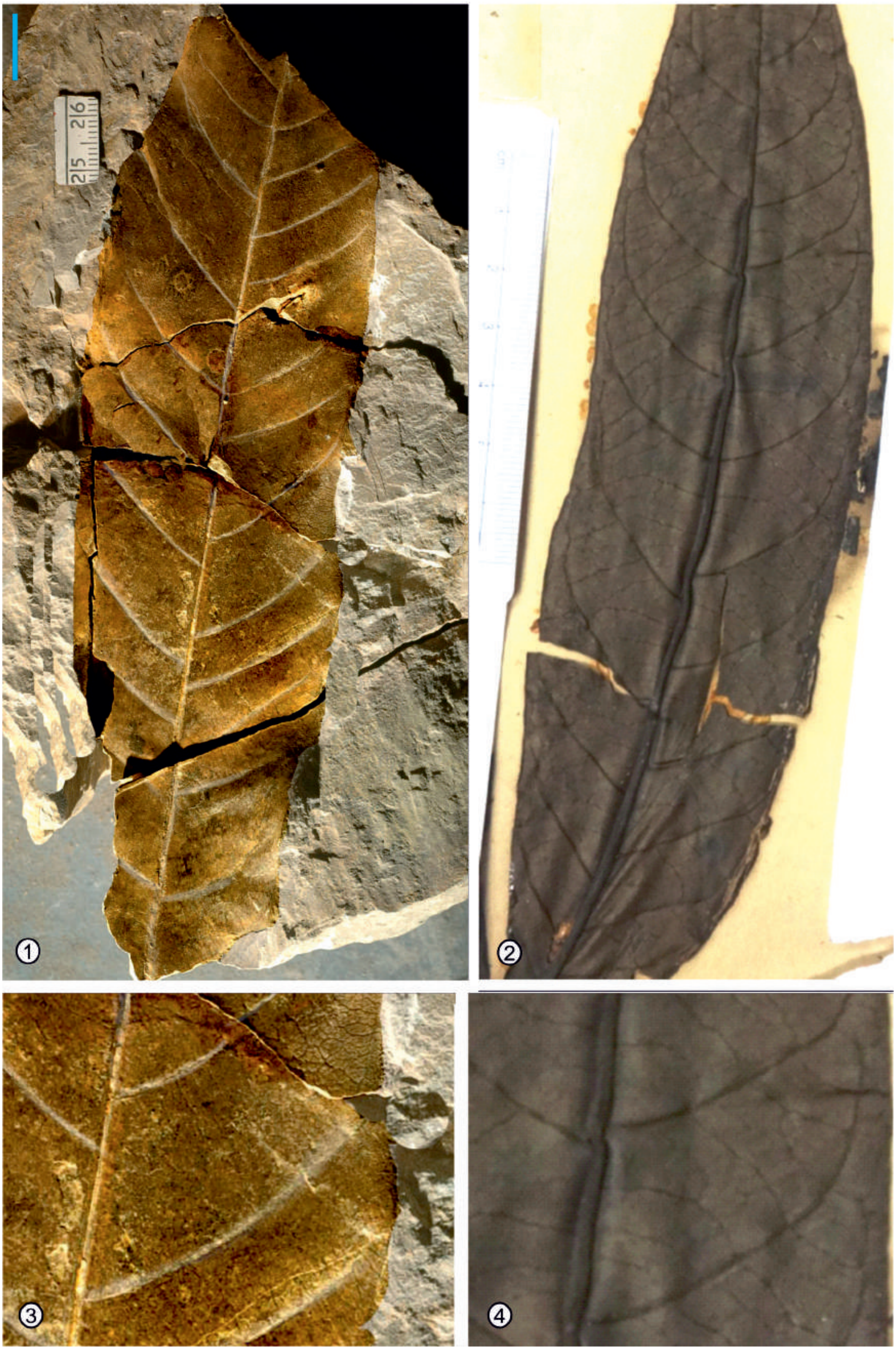

PLATE 28

affinity with the extant species, have been reported from Late Cenozoic sediments of Mahuadanr Valley, Jharkhand (Singh & Prasad, 2009a, b, c, d). A comparison of the present fossil leaf with all above known fossil species indicated closest similarity with *Lagerstroemia patelii* (Antal & Awasthi, 1993) especially in shape, size, venation pattern and upward curvature of secondary veins.

The genus *Lagerstroemia* L. includes about 53 species of trees and shrubs, distributed in the Indo–Malayan region, Tropical Africa, Asia, Polynesia and Pacific region. The modern comparable species, *Lagerstroemia speciosa* (L.) Pers. is a large tree growing in evergreen forests of Assam, Chittagong, lower Myanmar chiefly near river banks, foot hills of the Western Ghats ascending to 2000 ft, Sri Lanka and Malaya Peninsula (Brandis, 1971; Mabberley, 1997).

Order—GENTIANALES

Family—RUBIACEAE

Genus—RANDIA L.

Randia premacrophylla n. sp.

(Pl. 28.1, 3)

Material—Single specimen.

Description—Leaf simple, bilaterally symmetrical, narrowly oblong; preserved size 15.7 x 4.5 cm; apex and base not preserved; margins entire; texture chartaceous, petiole not preserved; venation pinnate, craspedodromous to eucamptodromous; primary vein (1º) single, straight, prominent, stout; secondary veins (2º) 10 pairs visible, alternate, unbranched, 0.9–1.7 cm apart, angle of divergence narrowly acute (about 40º–60º), uniformly curving upwards and sometimes joining super adjacent secondary veins; tertiary veins (3º) poorly preserved, angle of origin RR, percurrent, sometimes branched, almost straight, oblique in relation to mid vein, predominantly alternate and close,

Holotype—BSIP Museum Specimen No. 41134.

Locality—Profile 5A (27º54'50.6" N: 82º31'00.4" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Etymology—Named after adding prefix 'pre' to the name of modern comparable species, *Randia macrophylla.*

Affinities—Characteristic features of the present fossil leaf like bilateral symmetry, narrowly oblong shape, craspedodromous venation, alternate arrangement of secondary veins showing narrowly acute angle of divergence, RR, percurrent, predominantly alternate and close tertiary veins suggest resemblance with the modern leaves of *Randia macrophylla* Hook.f. (C.N.H. Herbarium Sheet No. 205959; Pl. 28.2, 4) of the family Rubiaceae.

Up to date, there are seven records of fossil leaves of *Randia* L. from India and abroad. These are *R. prodroma* Ung. from the Miocene of Sarmat, Germany (Solomon, 1934); *R. gossferiana* Kschun. from the Tertiary of Kamerum, Gebietes, Germany (Menzel, 1920); *R. mohavensis* from the Miocene of Kinnick, North America (Axelrod, 1950); *R. miowallichii* from Koilabas, Nepal (Prasad, 1990a) and Lower–Middle Siwalik of Ramthi River near Oodlabari, Darjeeling District, West Bengal (Antal & Awasthi, 1993); *R. palaeofasciculata* from Lower Siwalik of Bankas, Surai Khola area, Nepal; *R. siwalica* from Middle Siwalik of Surai Khola area, Nepal (Prasad & Awasthi, 1996); and *R. lishensis* from Middle Siwalik, Oodlabari area, Darjeeling District, West Bengal, India (Prasad *et al.,* 2015). A comparison of the present leaf with all above species showed that the present fossil leaf was entirely different from them in having very large size and showing narrowly acute angle of divergence of secondaries. Therefore, the new fossil leaf is described as a new species *Randia premacrophylla.*

Randia L. is a large genus consisting of about 250 species represented by shrubs and trees distributed throughout the tropical and sub–tropical regions of the world. About a dozen species occur in Indian regions. *Randia macrophylla* Hook.f. is an erect shrub distributed in Singapore, Malacca, Penang, Johar Gunong Pulai, Selangar, Kwala Lumpur, Sungii, Sumatra, (Hooker, 1882; Pearson & Brown, 1932; Ridley, 1967; Purkayastha, 1982).

Order—ERICALES

Family—EBENACEAE

Genus—DIOSPYROS L.

Diospyros embryopterisites Varma, 1968

PLATE 29

(Scale bar = 1 cm)

1, 2. *Persea masotkhoaensis* n. sp.–Fossil leaves showing shape, size and venation pattern. Specimen Nos. 41141a (Holotype) and 41142b.

3, 4. *Persea glaucescens* (Nees) D.G. Long–A modern leaf showing similar shape, size and venation pattern.

5. *Persea masotkhoaensis* n. sp.–A part of fossil leaf in Fig. 2, magnified to show details of tertiary veins.

6. *Persea glaucescens* (Nees) D.G. Long–A part of modern leaf magnified to show similar details of tertiary veins.

7. *Persea masotkhoaensis* n. sp.–A part of fossil leaf in Fig. 1, magnified to show details of alternate pattern of secondary veins and acute base

8. *Persea glaucescens* (Nees) D.G. Long–A part of modern leaf magnified to show similar details of secondary veins and base.

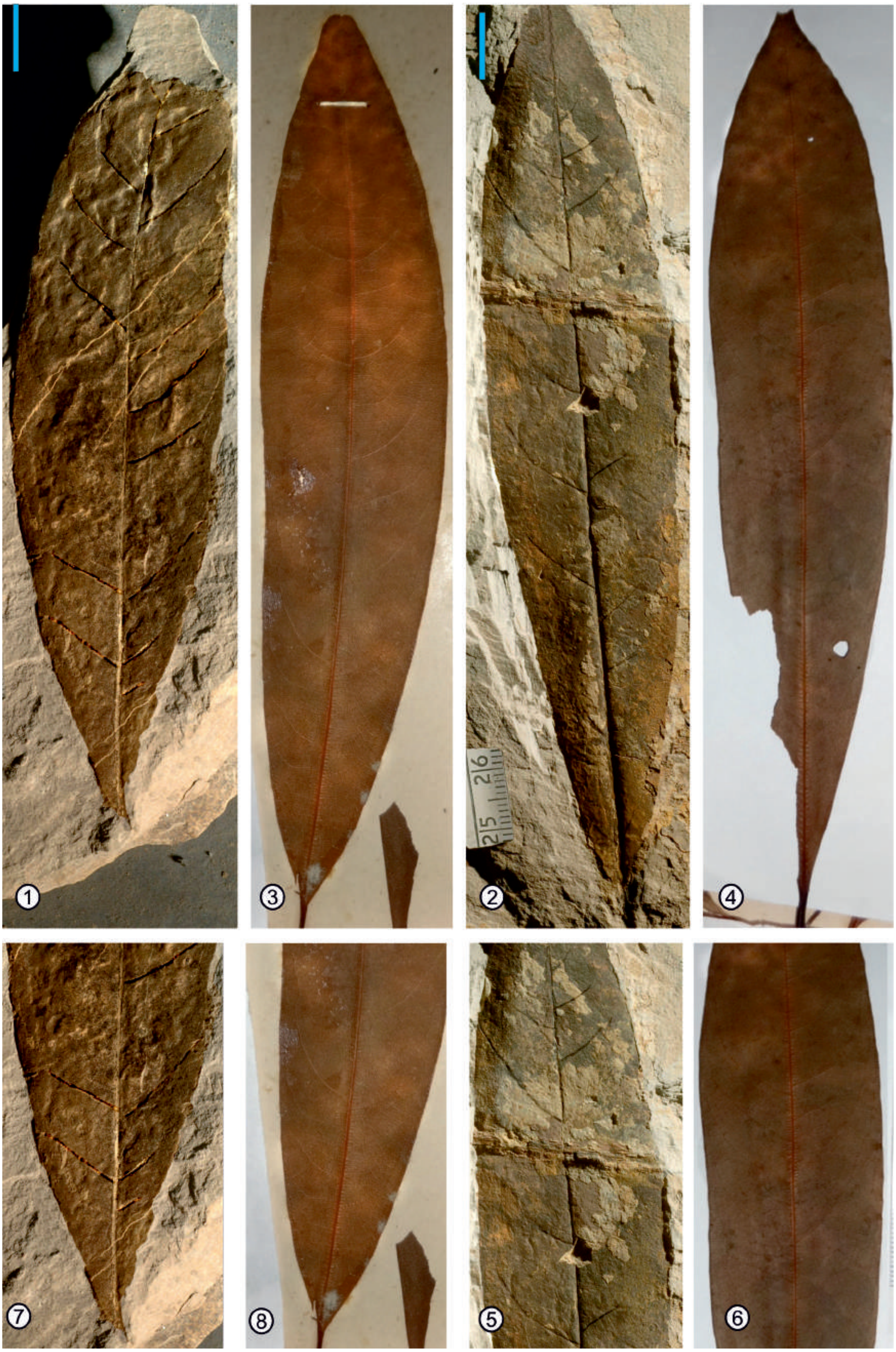

PLATE 29

(Pl. 27.1, 2, 3, 5)

Material—Three specimens.

Description—Leaves simple, seemingly elliptical; preserved size 5.3–6.1 x 3.7–5.0 cm; apex unpreserved; base slightly damaged; margins entire; texture chartaceous, petiole not preserved; venation pinnate, eucamptodromous; primary vein (1º) single, moderately thick, prominent, stout; secondary veins (2º) 4–5 pairs visible, 1.2 to 2.5 cm apart, unbranched showing narrowly acute angle of divergence (about 40º–55º), uniformly curving upwards and running for a long distance; intersecondary veins simple, frequently 2–3 veins in between two secondaries running parallel to secondary veins; tertiary veins (3º) fine, angle of origin usually RR type, percurrent, branched, opposite to alternate, predominantly alternate and close, oblique in relation to midvein.

Figured Specimen—BSIP Museum Specimen No. 41135–41137.

Locality—Profile 5A (27º54'50.6" N: 82º31'00.4" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Affinities—Characteristic features of the present fossil leaves such as elliptical shape, eucamptodromous venation, narrowly acute angle of divergence of secondary veins running upward for a long distance; presence of intersecondary veins and RR, percurrent, branched tertiary veins indicate close resemblance with modern leaves of *Diospyros embryopteris* Pers. of the family Ebenaceae (C.N.H. Herbarium Sheet No. 282095; Pl. 27.4, 6).

Fossil leaves resembling the genus *Diospyros* have been described under two generic names, i.e. *Diospyros* L. and *Diospyrophyllum* Velenovsky. The latter consists of only one species, *Diospyrophyllum provectum* (Velenovsky, 1889) described from the Upper Cretaceous of Bohemia. The former taxon, *Diospyros* L. contains about 70 species reported from different parts of the World. About fifteen species reported from the Tertiary sediments of the Indian subcontinent are listed in Table 5.

A comparison of the presently described fossil leaves with all the species listed in Table 5 showed close resemblance with *Diospyros embryopterisites,* Varma (1968) in their size and venation pattern. Therefore, the leaves have been assigned to the same species.

The genus *Diospyros* L. was cosmopolitan in distribution during the geological past. The fossil leaves have been reported from various countries such as Africa, Bohemia, Canada, Europe, England, Greece, Greenland, Japan, Panama, Switzerland and U.S.A. From its fossil record it is evident that the earliest record of *Diospyros* L. goes back to the Upper Cretaceous of Bohemia (Velenovsky, 1884). Thus, it is obvious that the genus *Diospyros* exists from the Upper Cretaceous to the present day and had wide distribution during the Tertiary Period.

The genus consists about 186 species distributed in the Tropics, rarely sub–Temperate regions. *Diospyros embryopteris* Pers. is an evergreen middle sized tree, distributed in forests of sub–Himalayan Tract from the Jamuna to Tista, Central India, common in northern Circars on the west side, Tenasserim, Sri Lanka, Malaya Archipelago (Brandis, 1971; Mabberley, 1997).

Order—BORAGINALES

Family—BORAGINACEAE

Genus—CORDIA L.

Cordia siwalica n. sp.

(Pl. 25.5)

Material—Single specimen.

Description—Leaf simple, bilaterally symmetrical, widely ovate; preserved size 9.3 x 6.0 cm; apex seemingly acute; base rounded; margins entire; texture chartaceous, petiole not preserved; venation pinnate, eucamptodromous; primary vein (1º) single, moderately thick, prominent, stout, curved in apical part; secondary veins (2º) 6–7 pairs visible, 0.5 to 1.5 cm apart, unbranched, opposite to alternate, angle of divergence moderately acute to right angled (about 50º–66º), lowest pair of secondaries right angled, uniformly curving upwards; tertiary veins (3º) poorly preserved, angle of origin usually RR type, percurrent, branched, straight to sinuous, opposite to alternate, close, oblique in relation to midvein.

Holotype—BSIP Museum Specimen No. 41138.

Locality—Profile 3 (27º54'24.0" N: 82º30' 52.7" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Lower Churia Group, Middle Miocene.

Etymology—Named after the Siwalik (Churia) Formation.

Affinities—Morphological features of the present fossil leaves such as bilateral symmetry, widely ovate shape, rounded base, eucamptodromous venation pattern, opposite to alternate, acute to right angle of divergence of secondary veins, usually RR and percurrent tertiaries showed closest similarity with the modern leaves of *Cordia sebestena* L. (C.N.H. Herbarium Sheet No. 3951; Pl. 25.6) of the family Boraginaceae.

There is no previous record of fossil leaves resembling the genus *Cordia* L. from the Siwalik sediments of India and Nepal. This is the first report of a *Cordia* L. like leaf from the Arjun Khola area of western Nepal and hence, it has been described as a new species, *Cordia siwalica* n. sp.

Table 5—Showing locality, age and characters distinguishing present fossil leaf from earlier reported species of *Diospyros* L. of the Indian subcontinent.

Fossil species	Fossil Locality/ Period	Characters
Diospyros embryopterisites (Varma, 1968)	Middle Siwalik of Haridwar, Uttarakhand	Almost similar in shape and size.
D. miocenicus (Prasad & Awasthi, 1996)	Lower Siwalik of Surai Khola, western Nepal	Large size (7.0 x 2.2 cm), narrowly oblong, more secondaries (13 pairs) showing greater angle of divergence and few intersecondary veins.
D. miokaki (Prasad & Awasthi, 1996)	Lower Siwalik of Surai Khola, western Nepal	Large size (8.0 x 5.1 cm), secondaries more (6–7 pairs).
D. kathgodamense (Prasad, 1994c)	Lower Siwalik of Kathgodam, Uttarakhand	Large size (6.0 x 2.0 cm), narrowly elliptical, secondaries more (10 pairs).
D. palaeoebenum (Prasad, 1994b)	Lower Siwalik of Kathgodam, Uttarakhand	Large size (7.7 x 4.0 cm), narrowly ovate, secondaries more (about 8 pairs) and greater angle of divergence.
D. tulsipurensis (Prasad *et al.,* 1997a)	Lower Siwalik of Seria Naka, (Indo–Nepal border) Gonda District, Uttar Pradesh	Large size (8.4 x 3.8 cm), more secondaries (about 9 pairs), angle of divergence acute to right angled.
D. koilabasensis (Prasad, 1990a)	Lower Siwalik of Koilabas, western Nepal	Small size (3.5 x 5.0 cm), lanceolate to ovate, secondaries more (about 6 pairs).
D. pretoposia (Prasad, 1990a)	Lower Siwalik of Koilabas, western Nepal	Narrowly oblong, secondaries many (about 12 pairs), distantly placed, one half of secondaries running long distance along the margin.
D. darwajaensis (Prasad *et al*., 1999)	Lower Siwalik of Koilabas, western Nepal	Narrowly oblanceolate, secondaries more (7–8 pairs), distantly placed, angle of divergence moderately acute.
D. nainitalensis (Prasad *et al*., 2004)	Lower Siwalik of Gola River near Jamrani, Kathgodam, Uttarakhand	Small size (4.3 x 2.2 cm), narrowly oblong, moderately acute angle of divergence of secondary veins.
D. palaeoeriantha (Prasad *et al*., 2004)	Lower Siwalik of Gola River near Jamrani, Kathgodam, Uttarakhand	Small size (4.9 x 1.5 cm), narrowly elliptical, secondaries distantly placed (0.4–0.8 cm).
D. purniyagiriensis (Shashi *et al*., 2008)	Lower Siwalik of Tanakpur area, Uttarakhand	Narrowly elliptical, lower pairs of secondaries more acute than above, veins distantly placed, joining super adjacent secondaries at acute angle.
D. borogensis (Mathur *et al*., 1996)	Kasauli Formation, Himachal Pradesh	Small size (3.3 x 1.6 cm), narrowly ovate, base obtuse secondary veins more (6 pairs).
D. palaeoargentia (Prasad *et al*., 2015)	Siwalik of Darjeeling District, West Bengal	Secondary veins numerous (22 pairs), closely placed.
D. masotkholaensis (Prasad *et al.,* 2016)	Lower Siwalik, Arjun Khola area, western Nepal	Large size (16.8 x 4.0 cm); lanceolate to oblong, apex attenuate, secondary veins (16 pairs), angle of divergence moderately acute (about 55º–60º).

Genus *Cordia* L. comprises of about 320 species distributed in the tropical countries of both hemispheres. *Cordia sebestena* L. is a tree distributed in tropical America. It ranges from southern Florida in the United States and the Bahamas southwards throughout Central America (Brandis, 1971; Mabberley, 1997).

Order—LAURALES

Family—LAURACEAE

Genus—CINNAMOMUM Schaeff.

Cinnamomum raptiensis n. sp.

(Pl. 26.1, 2, 5, 7)

Material—Two specimens.

Description—Leaves simple, bilaterally symmetrical; preserved size 8.9–9.6 x 3.7–5.1 cm; apex broken; base acute; margins entire; texture chartaceous, petiole not preserved; venation acrodromous, supra basal, perfect; primary veins (1º) three, one mid primary and two lateral primaries, moderately thick, prominent, stout; secondary veins (2º) arising from both mid and lateral primaries, lateral primaries giving off secondaries towards the margins and mid primary vein giving off veins joining lateral primaries, secondary veins close to distantly placed, cross veins looking like tertiaries arising from the all three primaries at right angle and reaching either lateral primary or the margins, predominantly opposite and almost close, right angled in relation to primary vein.

Holotype—BSIP Museum Specimen No. 41139.

Locality—Profile 3 (27º54'24.0" N: 82º30'52.7" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Lower Churia Group, Middle Miocene.

Etymology—Named after the Rapti River flowing near the fossil locality.

Affinities—Characteristic features of the present fossil leaves such as bilateral symmetry, acute base, acrodromous, supra–basal perfect venation, three primary veins, nature of secondary veins being distantly placed and sometimes branched looking like tertiary veins are commonly in seen modern leaves of *Cinnamomum* Schaeffer of the family Lauraceae. A comparison of all available extant species (about 30 species) of the taxon with the present fossil leaves suggests that the extant species C. *mollissimum* Hook. f. (C.N.H. Herbarium Sheet No. 780; Pl. 26.3, 4, 6, 8) is closest to it.

A number of fossil leaves resembling the genus *Cinnamomum* Schaeffer have been reported from India and aboard under four generic names, i.e. *Cinnamomum* Schaeff., *Cinnamomiphyllum* Nathorst, *Cinnamomoides* Seward and *Cinnamomophyllum* Krausel & Weyland. So far, seven fossil leaves are known from the Siwalik sediments of India and Nepal and one leaf from Eocene of Kachchh, western India. Pathak (1969) reported for the first time a fossil leaf resembling *Cinnamomum tamala* from the Middle Siwalik of Mahanadi River Section, West Bengal, India. *Cinnamomum* sp. has been described from Lower–Middle Siwalik of Oodlabari area, West Bengal, India (Antal & Awasthi, 1993), *C. mioinuctum* (Prasad, 1990a) and *C. nepalensis* (Prasad & Pandey, 2008) from the Siwalik sediments of Koilabas and Surai Khola, Nepal respectively. *C. palaeotamala* from Upper Siwalik sediments of Bhikhnathoree, Bihar, India (Lakhanpal & Awasthi, 1984). *C. miotavoyanum* (Shashi *et al.,* 2008) from the Lower Siwalik sediments of Tanakpur area, Uttarakhand, *C. eokachchhensis* (Lakhanpal & Guleria, 1981) from Eocene of Kachchh, western India and *C. corvinusianum* (Prasad *et al.,* 2016) from Lower Siwalik of Arjun Khola area western Nepal.

In comparing the present fossil leaves with leaves of all previously reported above mentioned fossil species, it was found that the new leaves varied from them in shape, size and in having supra basal veins and perfect acrodromous venation. Therefore, a new species *C. raptiensis* was instituted to include all leaves of *C. raptiensis* type.

The genus *Cinnamomum* Schaeff. consists about 140 species distributed in Tropical and sub–Tropical eastern Asia, Australia, Pacific, Indo–Malaya, China and Polynesia. *Cinnamomum mollissimum* Hook. f. is distributed in Perak, Goping (Kunstler), Thaipang, Penang (Ridley, 1967; Brandis,1971; Mabberley, 1997).

Genus—PERSEA Miller

Persea masotkholaensis n. sp.

(Pl. 29.1, 2, 5, 7)

Material—Two specimens.

Description—Leaves simple, bilaterally symmetrical, narrow elliptical; preserved size 15.0–15.5 x 3.1–4.1 cm; apex tapering, tip unpreserved; base acute; margins entire; texture coriaceous, petiole not preserved; venation pinnate, eucamptodromous; primary vein (1º) single, straight, prominent, moderately thick towards base, thinning towards apex; secondary veins (2º) 9–10 pairs visible, alternate to sub–opposite, 0.7 to 1.8 cm apart, unbranched, angle of divergence narrowly to widely acute (about 40º–70º), veins uniformly curving upwards and joining super adjacent secondary veins, intersecondary veins simple, poorly preserved; tertiary veins (3º) poorly preserved, angle of origin RR, percurrent, close and oblique in relation to midvein.

Holotype—–BSIP Museum Specimen No. 41141.

Locality—Profile 3 (27º54'24.0" N: 82º30'52.7" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Lower Churia Group, Middle Miocene.

Etymology—Named after a small village 'Masot Khola' near the collection site

Affinities—The narrowly oblong, bilaterally symmetrical, acute based fossil leaves showing eucamptodromous venation pattern, narrowly to moderately acute angle of divergence of secondary veins, presence of simple intersecondary veins and RR, percurrent tertiaries resemble very closely the modern leaves of *Persea glaucescens* (Nees) D.G. Long (C.N.H. Herbarium Sheet No. 22422; Pl. 29.3, 4, 6, 8) of the family Lauraceae.

So far, four fossil leaves resembling the genus *Persea* Miller are known from the Miocene sediments of the Indian sub–continent. These are *Persea* spp. from the Siwalik sediments of Tanakpur area, Uttarakhand (Lakhanpal & Guleria, 1978), *Persea sibdasi* (Mathur *et al.,* 1996) from Kasauli Formation, Himachal Pradesh and *Persea lakhanpalii* (Mathur *et al.,* 1996) from Dagshai Formation, Himachal Pradesh and *Persea siwalika* (Prasad *et al.,* 2016) from Lower Siwalik sediments of Arjun Khola area, western Nepal.

Out of these, the species *P. sibdasi* Mathur *et al.,* differs from the present fossil leaves in being bilaterally asymmetrical having smaller size (3.1 x 1.0 cm) and obtuse base. Similarly *P. lakhanpalii* Mathur *et al.,* is also smaller sized (3.5 x 1.2 cm) and differ in showing brochidodromous type of venation pattern instead of eucamptodromous venation as in the present fossil.

Other species *Persea* spp. Lakhanpal & Guleria and *Persea siwalika* Prasad *et al.,* also differ from the present leaves in having obovate to elliptical shape with inequilateral base in the former, narrowly elliptical shape and moderately acute angle of divergence of secondary veins in the latter. Compared to them the present leaves are narrowly oblong with a wide angle of divergence of secondary veins. In view of this, the present fossil leaves are not being described under any of the above species but are assigned to a new species *Persea masotkholaensis* n. sp.

The genus *Persea* Miller comprises of about 200 species distributed in Tropical Australia and America. *Persea glaucescens* (Nees) D.G. Long is a medium to large sized tree, distributed in mountain valleys or slopes, open or dense forests of India, Nepal, Bangladesh, Bhutan and Myanmar.

Order—ROSALES

Family—MORACEAE

Genus—ARTOCARPUS Forster & Forster

Artocarpus arjunkholaensis n. sp.

(Pl. 24.1, 2, 4)

Material—Two specimens.

Description—Leaves simple, bilaterally symmetrical, elliptical; preserved size 8.5–16.1 x 6.7–8.6 cm; apex unpreserved; base obtuse; margins entire; texture chartaceous, petiole not preserved; venation pinnate, eucamptodromous to brochidodromous; primary vein (1º) single, straight, prominent, stout, thicker towards basal region; secondary veins (2º) 8–13 pairs visible, alternate to opposite, 0.7 to 2.0 cm apart, unbranched, angle of divergence acute to right angled (about 50º–85º), basal pairs of secondaries arising nearly at right angles, later curving upwards before reaching the margins, in apical region pairs of secondaries join super adjacent veins at an acute angle forming a loop; tertiary veins (3º) angle of origin RR type, percurrent, straight to sometimes sinuous, branched, predominantly alternate and close, oblique to nearly right angled in relation to midvein.

Holotype—BSIP Museum Specimen No. 41142.

Locality—Profile 5A (27º54'50.6" N: 82º31'00.4" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Middle Churia Group, Upper Miocene.

Etymology—Named after the fossil locality Arjun Khola from where the fossils were collected.

Affinities—Characteristic features of the present fossil leaves like bilateral symmetry, elliptical shape, eucamptodromous to brochidodromous venation, alternate to opposite secondary veins, markedly curving upwards and joining super adjacent secondaries forming a loop near the margins; RR, percurrent, straight to sinuous, oblique to nearly right angled in relation to mid vein tertiaries, undoubtedly indicate a close resemblance with modern leaves of *Artocarpus rigidus* Blume (C.N.H. Herbarium Sheet No. 430933; Pl. 24.3, 5) of the family Moraceae.

Up to date only one fossil species *Artocarpus nepalensis* Prasad and Awasthi (1996) resembling the genus *Artocarpus* Forster & Forster has been reported from Middle Siwalik sediments of Surai Khola area (Prasad & Awasthi, 1996) and Koilabas area, western Nepal (Prasad & Dwivedi, 2007). A comparison of the present fossil leaves with the above known species revealed conspicuous difference between the two. While the present leaves are larger, elliptical in shape showing larger number (8–13) of secondary veins with acute to right angle of divergence, the earlier reported species *A. nepalensis* is smaller, obovate showing fewer number (7 pairs) of secondary veins. On account of these differences the present leaves are described as new species *Artocarpus arjunkholaensis*.

The genus *Artocarpus* Forster & Forster consists of about 50 species distributed in Indo–Malaysia, India, Islands of the Pacific Ocean. *Artocarpus rigidus* Blume with similar type of leaves as the present fossil is a tree distributed in hill forests of Tenasserim, Malaya Peninsula, Singapore, Myanmar, Thailand, Indo–China, Sumatra, Java, Borneo (Ridley, 1967; Brandis, 1971; Gamble, 1972; Mabberley, 1997).

Genus—FICUS L.

Ficus preglobosa n. sp.

(Pl. 25.1, 3)

Material—Single specimen.

Description—Leaf simple, bilaterally symmetrical, widely elliptical; preserved size 8.5 x 5.3 cm; apex partially unpreserved; base obtuse; margins entire; texture chartaceous, petiole not preserved; venation pinnate, brochidodromous; primary vein (1º) single, almost straight, prominent; secondary veins (2º) 9 pairs visible, 0.3 to 1.7 cm apart, unbranched, angle of divergence narrowly acute, uniformly curving upward and joining super adjacent secondaries and forming a loop, inter secondary veins simple or complex, basal pair of secondaries arising upwards and running a long distance; tertiary veins (3º) fine with angle of origin AO–RR, percurrent sometimes joining to form composite intersecondary veins.

Holotype—BSIP Museum Specimen No. 41144.

Locality—Profile 3 (27º54'24.0" N: 82º30'52.7" E), Arjun Khola–Ghorai Road section, Arjun Khola area, Deokhuri District, Rapti Anchal, western Nepal.

Horizon and Age—Lower Churia Group, Middle Miocene.

Etymology—Named after adding prefix “pre” to the name of an extant species *F. globosa* Blume.

Affinities—Morphological features such as bilateral symmetry, widely elliptical shape, eucamptodromous to brochidodromous venation pattern, secondary veins uniformly curving upwards and joining super adjacent secondaries forming a loop, presence of simple or complex inter secondary veins, basal pair of secondaries arising acutely and running upwards for a long distance, AO–RR, percurrent arrangement of tertiaries in the present fossil leaf show resemblance with the modern leaves of *Ficus globosa* Blume (C.N.H. Herbarium Sheet No. 124718; Pl. 25.2, 4) of the family Moraceae.

So far, about 33 species of fossil leaves resembling *Ficus* L. are reported from the Cenozoic sediments of India and Nepal. They are listed in Table 6. A comparison of the present fossil leaf with species listed in Table 6 showed difference in shape, size and venation pattern especially the basal pair of secondaries running to far a long distance. Therefore, the new leaf is described as new species *Ficus preglobosa.*

The genus *Ficus* L. consists of about 750 species distributed in India and tropics of both hemispheres especially Indo–Malaya to Australia, Africa and America. *Ficus globosa* Blume is a large climber distributed in Tenasserim (Brandis, 1971).

The fossils of Arjun Khola assemblage are dominated by leaf–form taxa exhibiting entire margins and a variety of venation patterns like eucamptodromous, craspedodromous, brochidodromous and acrodromous types. Amongst the above mentioned, eucamptodromous type was found to be the commonest as it is present in a large number of fossil leaves. In eucamptodromous type, the secondaries are upturned, gradually diminishing apically inside the margin and connected to superadjacent secondaries by a series of cross veins, without forming prominent marginal loops. This type of venation is seen in leaves of taxa belonging to diverse dicotyledonous families like Dilleniaceae (*Dillenia*), Fabaceae (*Saraca, Cassia*), Ebenaceae (*Diospyros*), Burseraceae (*Commiphora*), Lythraceae (*Lagerstroemia*), Vitaceae (*Cayratia*), etc. Most of these taxa also show entire leaf margins but for *Dillenia* L. where leaf margin is non–entire.

Compared to the above venation pattern, the other three venation patterns craspedodromous, brochidodromous

Table 6—List of *Ficus* L. species recorded from different localities/horizons of India and Nepal.

Fossil Species	Locality /Horizon	References
F. cunia	Karewa beds, Kashmir	Puri, 1947
	Dharamsala beds, Himachal Pradesh	Gupta & Jiwan, 1972
F. nemoralis	Karewa beds, Kashmir	Puri, 1948
F. precunia	Siwalik beds, Jawalamukhi, Himachal Pradesh;	Lakhanpal, 1968
	Siwalik sediments, Koilabas, western Nepal	Prasad, 1990a
Ficus arnottiana	Quaternary beds, Maharashtra	Mahajan & Mahabale, 1973
F. glomerata	Quaternary beds, Maharashtra	Mahajan & Mahabale, 1973
F. caricites	Mewar State	Trivedi, 1980
F. religiosities	Mewar State	Trivedi, 1980
F. kachchhensis	Eocene of Kachcch	Lakhanpal & Guleria, 1981

F. khariensis	Miocene of Kachchh	Lakhanpal & Guleria, 1982
F. champaerensis	Siwalik beds, Bhikhnathoree	Lakhanpal & Awasthi, 1984
F. foveolata	Late Tertiary deposits of Palamau District, Bihar	Bande & Srivastava, 1990
F. glaberrima	Late Tertiary deposits of Palamau District, Bihar	Bande & Srivastava, 1990
F. nepalensis	Siwalik of Koilabas, western Nepal	Prasad, 1990a
F. retusoides	Siwalik sediments, Koilabas, western Nepal	Prasad, 1990a;
	Siwalik sediments, West Bengal	Antal & Awasthi, 1993
	Neyveli Lignite, south India	Agarwal, 2002
F. tomentosa	Late Tertiary deposits of Palamau District, Bihar	Bande & Srivastava, 1990
F. cherrapunjiensis	Paleocene, Cherrapunji, Meghalaya	Ambwani, 1991
Ficus sp. cf *F. tomentosa* Roxb.	Dagshai Formation, Himachal Pradesh	Mishra & Mathur, 1992
F. oodlabariensis	Siwalik, West Bengal	Antal & Awasthi, 1993
F. raptiensis	Siwalik sediments, Surai Khola, western Nepal	Prasad & Awasthi, 1996
F. barogensis	Kasauli Formation, Barog, Himachal Pradesh	Mathur *et al.*, 1996
F. barogensis	Dagshai Formation and Dharamsala Formation, Himachal Pradesh	Mathur *et al.,* 1996
F. kasaulica	Kasauli Formation, Barog, Himachal Pradesh	Mathur *et al.*, 1996
F. kumarhattiensis	Dagshai Formation, Himachal Pradesh	Mathur *et al.,* 1996
Ficus sp.	Dagshai Formation, Solan District, Himachal Pradesh	Mathur *et al.,* 1996
F. prereligiosa	Mar Formation (Neogene), Bikaner District, Rajasthan	Mathur & Mathur, 1998
Ficus sp.	Mar Formation (Neogene), Bikaner District, Rajasthan	Mathur & Mathur, 1998
F. miocenica	Siwalik sediments, western Nepal	Konomatsu & Awasthi, 1999
F. benjamina	Quaternary beds of Sirmur District, Himachal Pradesh;	Prasad *et al.*, 2002
	Siwalik sediments of Himachal Pradesh	Prasad, 2006
F. eumysorensis	Siwalik sediments near Jarva, Uttar Pradesh	Tripathi *et al.*, 2002
F. precurticeps	Neyveli Lignite, South India	Agarwal, 2002
F. rumphii	Late Tertiary beds of Mahuadanr Valley, Jharkhand	Singh & Prasad, 2008
F. microcarpa	Late Tertiary beds of Mahuadanr Valley, Jharkhand	Singh & Prasad, 2008
F. curticeps	Late Tertiary beds of Mahuadanr Valley, Jharkhand	Singh & Prasad, 2008
F. palaeoracemosa	Kasauli Formation, Himachal Pradesh	Srivastava *et al.,* 2011

and acrodromous types are less frequently observed in the foliar fossils of Arjun Khola assemblage. Some 9 form taxa, exhibited craspedodromous venation pattern while about 8 showed the brochidodromous type. Acrodromous type of venation was observed in only three fossil taxa of the present study. They include two species of *Grewia* L. (Tiliaceae), *Bauhinia* L. (Fabaceae) and *Cinnamomum* Schaeff. (Lauraceae). In acrodromous venation pattern two or more primary veins are strongly developed and secondary veins run in convergent arches toward the leaf apex. Arches are not recovered at base.

Craspedodromous and brochidodromous type of venation patterns in leaves of Arjun Khola assemblage are relatively more common than the acrodromous type. In the former, secondary veins terminate at the margin while in the latter secondary veins are joined together in a series of prominent arches. Fossil leaf of the monocot taxon *Clinogyne* (Marantaceae), exhibits craspedodromous type of venation pattern, together with some dicot taxa, like *Calophyllum* L. (Calophyllaceae), *Shorea* Roxb. ex C.F. Gaertn., *Dipterocarpus* Gaertn. (Dipterocarpaceae), etc. Brochidodromous type of venation pattern, where secondary veins are joined together in a series of prominent arches is seen in specimen identified to show close resemblance with extant *Anaxagorea* A. St.–Hil. (Annonaceae), *Ficus* L. (Moraceae), etc.

Strangely, some fossil leaves like those *Artocarpus arjunkholaensis* and *Cynometra siwalika* were observed to show venation patterns ranging from eucamptodromous to brochidodromous types while the taxon *Arytera (Ratonia) miolittoralis* showed a reverse pattern like venation ranging from brochidodromous to eucamptodromous type. Similarly, taxa, like *Randia macrophylla* and *Euphoria churiaensis* showed venation patterns ranging from craspedodromous to eucamptodromous types.

Several leaf form taxa out of those described herein, showed medium to large sized leaves with entire margins. Among them largest leaf surface was observed in the taxon *Ryparia arjunkholaensis* n. sp. (193 sq. cm.) whereas entire leaves of taxa *Artocarpus arjunkholaensis* n. sp. and *Mitrephora mioreticulata* n. sp. exhibited 138 sq. cm and 111 sq. cm. leaf areas respectively. The assemblage also yielded some leaves of very small size like those of *Tinospora siwalika* n. sp. (4 sq. cm.), *Sindora eosiamensis* n. sp. (6 sq. cm.), *Euphoria churiaensis* n. sp. (9 sq. cm.), *Cynometra siwalika* Awasthi and Prasad, 1990 (10 sq. cm.) and *Commiphora precaudata* (14 sq. cm.). Middle sized leaves, with leaf areas ranging between 30–50 sq. cm. seemed to dominate the scene, with form genera like *Hydnocarpus mioalpinus* Prasad, 2006 showing surface area of 30 sq. cm. and form taxa *Eugenia nepalensis* n. sp. and *Combretum siwalicum* n. sp. exhibiting areas of 51 sq. cm. each and *Arytera (Ratonia) nepalensis* n. sp. showing 53 sq. cm. Exceeding surface areas of mentioned above are the leaves of *Buchanania raptiensis* n. sp. and *Dipterocarpus palaeoindicus* n. sp. showing 76 and 75 sq. cms. respectively. All the above mentioned taxa exhibited entire margins, though a few like *Dillenia palaeoindica* Prasad and Prakash, 1984 and *Grewia palaeodisperma* n. sp. exhibit non–entire margins.

DISCUSSION AND CONCLUSION

Study of plant megafossils preserved in the Siwalik sediments of the Arjun Khola area in western Nepal has added considerably to the present knowledge of fossil flora of the Siwalik of Nepal. It revealed the presence of 43 genera and 47 species belonging to 23 dicotyledonous families and a single genus to the monocotyledons of angiosperms (Tables 7, 8; Fig. 6). The families represented are Marantaceae (monocot), Fabaceae, Sapindaceae, Dipterocarpaceae, Achariaceae (Flacourtiaceae), Combretaceae, Lauraceae, Moraceae, etc. Plant fossils of the Arjun Khola assemblage are chiefly foliar remains of dicotyledonous families of the angiosperms. The assemblage has also yielded three fruit impressions of which two are assignable to *Sindora* Miq. and *Butea* Roxb. ex Willd. of the Fabaceae and one to a species of *Terminalia* L. of the Combretaceae. Diagnostic features, of most fossil leaves are so well preserved that they look very similar to those of living plants and tracing their nearest relatives in the modern day vegetation was no problem. A majority of fossil leaves of the assemblage resembled leaves of extant taxa, exhibiting a woody habit while quite a few leaf fossils like *Anaxagorea* A. St.–Hil., *Uvaria* L., *Randia* L., etc. appeared to have belonged to plants exhibiting shrubby habit. Herbaceous genera are almost unknown in the present assemblage except for the single monocot genus *Clinogyne* Salisb. of the family Marantaceae (Kress *et al.*, 2003).

Out of the identified specimens, a large majority resembled foliage of contemporary taxa, presently distributed in the Tropical evergreen forests of different geographical regions of the world and recovery of similar looking fossil elements from the Arjun Khola area, indicated existence of similar forest types in and around the area at the time of Siwalik sedimentation. Contrastingly, the present day vegetation in and around the area is quite different from the past as they include elements that generally constitute plants of dry deciduous forests. At present, distribution of comparable extant taxa is around the south–east Asian regions (Myanmar, Malaya, Thailand), suggesting large scale migration of the past floral elements towards south and south eastwards in search of favourable conditions for luxuriant growth (Table 8; Fig. 7).

Out of the 34 new form taxa described in the present paper, quite a number of them are first reports from the Cenozoic of India and Nepal like–*Anaxagorea* A. St.–Hil. (Annonaceae), *Anisoptera* Korth. (Dipterocarpaceae), *Erythrochiton* Nees & Mart. (Rutaceae), *Sindora* Miq. (Fabaceae), *Cordia* L. (Burseraceae), *Butea* Roxb. ex Willd. (Fabaceae) and *Terminalia* L. (Combretaceae). Some of the

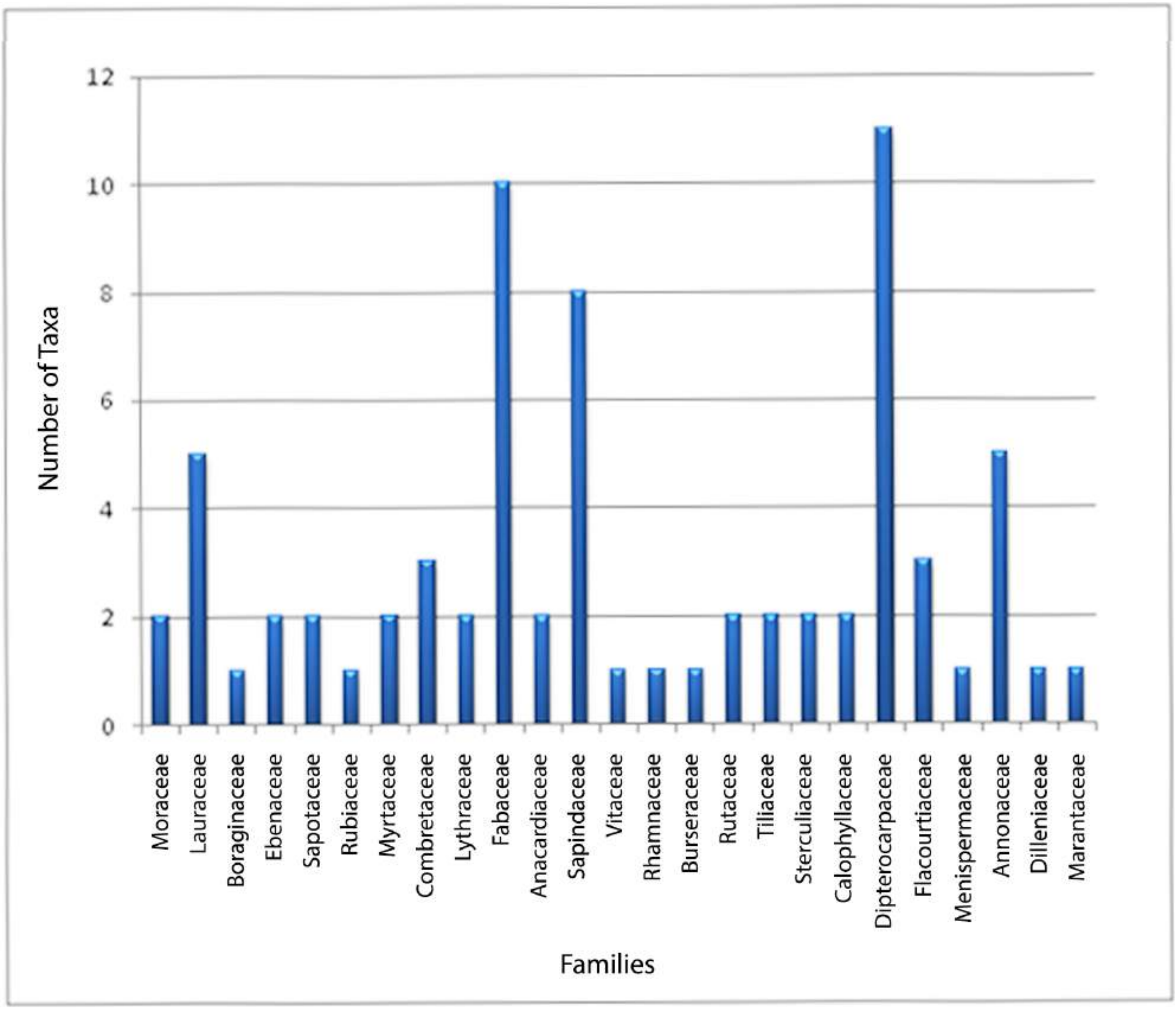

Fig. 6–Diagram indicating the frequency of angiospermous fossil taxa recovered so far from the Siwalik foreland basin of Arjun Khola area, western Nepal.

mentioned taxa were not recorded earlier, from Paleocene–Eocene sediments in Nepal as well as India, suggesting a late entry of such taxa into the Indian subcontinent, probably prior to the Miocene, only after development of land connections that allowed free movement of elements from regions where they were flourishing to regions showing poor distribution.

While examining the fossils of Arjun Khola site, it was observed that a good number of leaf and fruit impressions, closely resembled living taxa of the present day vegetation and many of these fossils could be undoubtedly assigned to various modern day families. Amongst these families, Fabaceae exhibited the largest number of fossils (eight) with six leaf and two fruit form genera. Five leaf form genera out of the six are represented by a new species each but for the taxon *Cynometra* L., which is represented by the previously reported species *C. siwalika* (Awasthi & Prasad, 1990). Out of the two fruit form genera assigned to family Fabaceae, one, closely resembled the modern day *Butea* Roxb. ex Willd. and the other to *Sindora* Miq. Both are represented by a new species each, viz. *Butea nepalensis* and *Sindora leguminocarpoides* respectively.

The other dicot family in the assemblage, showing a little lesser representation of fossil form genera than Fabaceae, is family Sapindaceae. Five leaf form genera are assigned to it. Out of the five, *Filicium* Thwaites and *Harpullia* Roxb. were previously reported from other Siwaliks sites, the former by Prasad (1994e) and the latter by Prasad and Awasthi (1996). Species of the remaining 3 genera *Arytera* (*Ratonia*) Blume, *Euphoria* Comm. ex Juss. and *Sapindus* L. are new to the area. While *Euphoria* and *Sapindus* are represented by single species each, *E. churiaensis* and *S. palaeomukorossi,* the form

Table 7—A systematic list of fossil taxa described from Siwalik sediments of India, Nepal and Bhutan (after Prasad, 2008, 2013; Prasad & Gautam, 2016; Prasad *et al.,* 2016) (Abbr:–L= Lower, M= Middle, U= Upper; AP = Arunachal Pradesh, UK = Uttarakhand, UP = Uttar Pradesh, HP = Himachal Pradesh, WB = West Bengal)

Fossil taxa	Locality	Horizon	References
PTERIDOPHYTES			
Thelypteridaceae			
Cyclosorus eoprolifera	Kathgodam, UK	L Siwalik	Prasad *et al.*, 2004
MONOCOTYLEDONS			
Marantaceae			
Alpinia siwalica	Kathgodam, UK	L Siwalik	Prasad *et al.*, 2004, 2017b
	Tanakpur, UK		
Clinogyne ovatus	Surai Khola, Nepal	M Siwalik	Awasthi & Prasad, 1990,
	Darjeeling District, WB	L Siwalik	Antal & Prasad,1995
	Kathgodam, UK	L Siwalik	Prasad *et al.*, 2004
	Arjun Khola, Nepal		–
Donax ovatus	Tanakpur, U K	L Siwalik	Prasad *et al.,* 2017b
Arecaceae			
Amesoneuron siwalica	Ranital, HP	L Siwalik	Prasad, 2006
Amesoneuron miocenica	Mandi District, HP	M Siwalik	Prasad *et al.*, 2013b
Caryota siwalica	Surai Khola, Nepal	M Siwalik	Awasthi & Prasad, 1990
Palmoxylon wadiai	Tawi River, Jammu	U Siwalik	Sahni, 1931
	Kalagarh, UK	L Siwalik	Prasad, 1987
Smilacaceae			
Smilax sp	Balugoloa, HP	L Siwalik	Lakhanpal & Dayal, 1966
Poaceae			
Bambusa siwalica	Ranital, HP	L Siwalik	Lakhanpal *et al.,* 1987
	Surai Khola, Nepal	L Siwalik	Awasthi & Prasad, 1990
	Darjeeling District, WB	L–M Siwalik	Antal & Awasthi, 1993
	Kameng District, AP	U Siwalik	Khan *et al.*, 2011
DICOTYLEDONS			
Dilleniaceae			
Dillenia palaeoindica	Koilabas, Nepal	L Siwalik	Prasad & Prakash, 1984
	Darjeeling District, WB	L–M Siwalik	Antal & Awasthi, 1993
	Arjun Khola, Nepal	M Siwalik	–
Xanthophyllaceae			
Xanthophyllum mioflavescens	Darjeeling District, WB	L Siwalik	Antal & Prasad, 1996a
Xanthophyllum mioglaucum	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017b
Annonaceae			
Anona koilabasensis	Koilabas, Nepal	L Siwalik	Prasad *et al.,* 1999
Artabotrys nahanii	Sirmur District, HP	L Siwalik	Prasad, 2012
A. siwalicus	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
Anaxagorea mioluzonensis n. sp.	Arjun Khola, Nepal	M Siwalik	–
Cananga tertiara	Kathgodam, UK	L Siwalik	Prasad, 1994c
	Darjeeling District, WB	L Siwalik	Prasad *et al.,* 2009
Dendrokingstonia palaeonervosa	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017b
Ellipeia miocenica	Tanakpur, UK	L Siwalik	Shashi *et al.,* 2008

Fissistigma siwalika	Balugoloa, HP	L Siwalik	Lakhanpal, 1969
F. mioelegans	Koilabas, Nepal	L Siwalik	Prasad *et al.,* 1999
F. senii	Jawalamukhi, HP	L Siwalik	Lakhanpal, 1969
	Seria Naka, UP	L Siwalik	Prasad *et al.,* 1997a
	Bilaspur, HP	L Siwalik	Prasad, 2006
	Sirmur District, HP	L Siwalik	Prasad, 2012
	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
Meiogyne sevokensis	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
Meiogyne purniyagiriensis	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017b
Miliusa siwalica	Koilabas, Nepal	L Siwalik	Prasad *et al.,* 1999
Miliusa (Saccopetalum) pretomentosa	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017b
Mitrephora siwalika	Darjeeling District, WB	L Siwalik	Antal & Awasthi, 1993
M. miocenica	Seria Naka, UP	L Siwalik	Prasad *et al.,* 1997a
M. mioreticulata n. sp.	Arjun Khola, Nepal	M Siwalik	–
Melodorum arjunkholaensis	Arjun Khola, Nepal	M Siwalik	Prasad *et al.,* 2016
Pseuduvaria mioreticulata	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
Polyalthioxylon indicum	Kalagarh, UK	L Siwalik	Prakash, 1978
Polyalthia palaeosimianum	Surai Khola, Nepal	L Siwalik	Awasthi & Prasad, 1990
	Darjeeling District,WB	L Siwalik	Antal & Prasad, 1996c
Saccopetalum pretomentosum	Kathgodam, UK	L Siwalik	Prasad *et al.*, 2004
Uvaria siwalika	Kathgodam, UK	L Siwalik	Prasad, 1994c
U. siwalica	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
U. nepalensis	Arjun Khola, Nepal	M Siwalik	Prasad *et al.,* 2016
U. miolucida n. sp.	Arjun Khola, Nepal	M Siwalik	–
Capparidaceae			
Capparis palaeomicrantha	Kathgodam, UK	L Siwalik	Prasad *et al.,* 2004
Polygalaceae			
Securidaca miocenica	Koilabas, Nepal	L Siwalik	Prasad *et al.*, 1999
S. precorymbosa	Tanakpur UK	L Siwalik	Prasad *et al.*, 2017b
Bixaceae			
Bixa kathgodamensis	Kathgodam, UK	L Siwalik	Prasad *et al.*, 2004
Menispermaceae			
Cocculus miotrilobus	Surai Khola, Nepal	L Siwalik	Prasad & Pandey, 2008
Tinospora siwalika n. sp.	Arjun Khola, Nepal	M Siwalik	–
Achariaceae (Flacourtiaceae)			
Alsodeia palaeozeylanica	Darjeeling District, WB	L–M Siwalik	Antal & Awasthi, 1993
A. palaeoracemosa	Darjeeling District, WB	L–M Siwalik	Antal & Awasthi, 1993
Flacourtia nepalensis	Surai Khola, Nepal	L Siwalik	Awasthi & Prasad, 1990
F. tertiara	Darjeeling District, WB	L–M Siwalik	Antal & Prasad, 1997
	Surai Khola, Nepal	L Siwalik	Prasad & Awasthi, 1996
F. seriaensis	Seria Naka, UP	L Siwalik	Prasad *et al.,* 1997a

Gynocardia mioodorata	Kathgodam, UK	L Siwalik	Prasad, 1994c
	Koilabas, Nepal	L Siwalik	Prasad *et al.*, 1999
	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017a
G. butwalensis	Butwal, Nepal	L Siwalik	Konomatsu & Awasthi, 1999
	Mandi District, HP	M Siwalik	Prasad *et al.,* 2013b
	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
Hydnocarpus palaeokurzii	Kathgodam, UK	L Siwalik	Prasad 1994c
	Darjeeling District, WB	L Siwalik	Antal & Prasad, 1997
H. chorkholaensis	Surai Khola, Nepal	L Siwalik	Prasad & Awasthi, 1996
H. siwalicus	Surai Khola, Nepal	L Siwalik	Prasad & Awasthi, 1996
H. mioalpinus	Ranibag, HP	L Siwalik	Prasad, 2006
	Arjun Khola, Nepal	M Siwalik	–
H. ghishiensis	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
H. lamhiensis	Arjun Khola, Nepal	M Siwalik	Prasad *et al.,* 2016
Ryparia (Ryparosa) prekunstelri	Koilabas, Nepal	L Siwalik	Prasad, 1990a
Ryparia arjunkholaensis n. sp.	Arjun Khola, Nepal	M Siwalik	–
Xylosma nepalensis	Surai Khola, Nepal	Siwalik	Prasad & Pandey, 2008
Clusiaceae			
Calophyllum suraikholaensis	Surai Khola, Nepal	L Siwalik	Awasthi & Prasad, 1990
	Darjeeling District, WB	M Siwalik	Antal & Awasthi, 1993
	Kathgodam, UK	L Siwalik	Prasad *et al.*, 2004
	Kameng District, AP	U Siwalik	Khan *et al.*, 2011
	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017b
	Arjun Khola, Nepal	M Siwalik	–
Calophyllum mioelatum n. sp.	Arjun Khola, Nepal	M Siwalik	–
Cratoxylon bilaspurensis	Bilaspur, HP	L Siwalik	Prasad, 2006
Garcinia corvinusiana	Surai Khola, Nepal	L Siwalik	Prasad & Awasthi, 1996
G. eocambogia	Kathgodam, UK	L Siwalik	Prasad, 1994c
	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
Mesua tertiara	Koilabas, Nepal	L Siwalik	Prasad, 1990a;
	Kathgodam, UK	L Siwalik	Prasad, 1994c
	Surai Khola, Nepal	L Siwalik	Prasad & Pandey, 2008
	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017a
Dipterocarpaceae			
Anisoptera palaeoscaphulla n. sp.	Arjun Khola, Nepal	M Siwalik	–
A. miocurtisii	Bilaspur, HP	L Siwalik	Prasad, 2006
Anisopteroxylon jawalamukhii	Jawalamukhi, HP	M Siwalik	Ghosh & Ghosh, 1958
A. kalagarhensis	Kalagarh, UK	L Siwalik	Prakash, 1978
	Kalagarh, UK	L Siwalik	Yadav, 1989
Dipterocarpus arcotense	Kalagarh, UK	L Siwalik	Prasad, 1994b
D. nalagarhense	Nalagarh, HP	L Siwalik	Prakash, 1975
D. premacrocarpum	Nalagarh, HP	L Siwalik	Prakash, 1975
D. parabaudii	Kalagarh, UK	L Siwalik	Prakash, 1978
D. nungarhensis	Kalagarh, UK	L Siwalik	Trivedi & Ahuja, 1980

D. surangeii	Kalagarh, UK	L Siwalik	Prakash, 1981
D. siwalicus	Jawalamukhi, HP	L Siwalik	Lakhanpal & Guleria, 1987
	Kathgodam, UK	L Siwalik	Prasad, 1994c
D. siwalicus	Balugoloa, HP	L Siwalik	Lakhanpal & Guleria, 1987
	Kathgodam UK	L Siwalik	Prasad, 1994c
	Koilabas, Nepal	L Siwalik	Prasad, 1990b
	Surai Khola, Nepal	L Siwalik	Awasthi & Prasad, 1990
	Kameng District, AP	U Siwalik	Khan *et al.,* 2011
	Darjeeling District, WB	M Siwalik	Antal & Prasad, 1996b
D. kalagarhensis	Kalagarh, UK	L Siwalik	Yadav, 1989
D. koilabasensis	Koilabas, Nepal	L Siwalik	Prasad *et al.*, 1999
	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017a
Dipterocarpus miogracilis	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017a
Dipterocarpus palaeoindicus n. sp.	Arjun Khola, Nepal	M Siwalik	–
Dipterocarpus churiensis (Fruit)	Arjun Khola, Nepal	L Siwalik	Prasad & Gautam, 2016
Dipterocarpoxylon spp	Mohand, UK	M Siwalik	Rawat, 1964
Dipterocarpoxylon siwalicus	Nalagarh, HP	L Siwalik	Prakash, 1975
	Masot Khola, Nepal	M Siwalik	Prasad & Gautam, 2016
Shorea siwalicus	Kalagarh, UK	L Siwalik	Prasad & Prakash, 1988
S. siwalika	Darjeeling District, WB	M Siwalik	Antal and Awasthi, 1993
S. bengalensis	Darjeeling District, WB	M Siwalik	Antal & Awasthi, 1993
Shorea miocenica	Darjeeling District, WB	L Siwalik	Antal & Prasad, 1996b
S. neoassamica	Darjeeling District, WB	L–M Siwalik	Antal & Prasad, 1997
S. eutrapigifolia	Koilabas, Nepal	L Siwalik	Prasad *et al.*, 1999
S. miocenica	Kathgodam, UK	L Siwalik	Prasad *et al.*, 2004
S. palaeostellata	Surai Khola, Nepal	L Siwalik	Prasad & Pandey, 2008
Shoreoxylon ornatum	Kalagarh, UK	L Siwalik	Trivedi & Ahuja, 1979
Shoreoxylon evidens	Siang District, AP	M Siwalik	Mehrotra *et al.,* 1999
Hopenium prenutansoides	Kalagarh, UK	L Siwalik	Prasad & Prakash, 1988
Hopea pondicherriense	Kalagarh, UK	L Siwalik	Prasad & Prakash, 1988
H. mioglabra	Koilabas, Nepal	L Siwalik	Prasad, 1994e
H. kalagarhensis	Kalagarh, UK	L Siwalik	Prasad, 1994b
	Hamirpur, HP	L Siwalik	Prasad, 2010
H. kathgodamensis	Kathgodam, UK	L Siwalik	Prasad, 1994c
	Tanakpur UK	L Siwalik	Prasad *et al.,* 2017b
H. Siwalika	Darjeeling District, WB	L–M Siwalik	Antal & Awasthi, 1993
Isoptera siwalica	Koilabas, Nepal	L Siwalik	Prasad *et al.,* 1999
	Arjun Khola, Nepal	M Siwalik	–
Vaterioxylon kalagarhensis	Kalagarh, UK	L Siwalik	Trivedi & Misra, 1980
V. miocenicum	Kalagarh, UK	L Siwalik	Trivedi & Misra, 1980
Vatica nepalensis	Surai Khola, Nepal	M Siwalik	Prasad & Pandey, 2008
V. siwalica	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015

V. prenitida	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
Ancistrocladaceae			
Ancistrocladus suraikholaensis	Surai Khola, Nepal	L Siwalik	Prasad & Pandey, 2008
Malvaceae			
Urena palaeolobata	Bhikhnathoree, Bihar	M Pliocene	Awasthi & Lakhanpal, 1990
Bombacaceae			
Bombax palaeomalabaricum	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
Pachira palaeomalabarica	Kathgodam, UK	L Siwalik	Prasad *et al.*, 2004
Sterculiaceae			
Pterospermum palaeoheynianum	Darjeeling District, WB	L–M Siwalik	Antal & Awasthi, 1993
Pterospermum mioacerifolium	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2009
P. siwalicum	Darjeeling District, WB	L Siwalik	Antal & Prasad, 1996a
Sterculioxylon kalagarhense	Kalagarh, UK	L Siwalik	Trivedi & Ahuja, 1978a
Sterculinium foetidense	Kalagarh, UK	L Siwalik	Prasad, 1994b
Sterculia kathgodamense	Kathgodam, UK	L Siwalik	Prasad, 1994c
S. kathgodamensis	Arjun Khola, Nepal	M Siwalik	Prasad & Khare, 2004
S. premontana	Surai Khola, Nepal	M Siwalik	Prasad & Pandey, 2008
S. miocolorata	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
S. siwalica	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
S. mioparviflora	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
Malpighiaceae			
Ochna siwalika	Surai Khola, Nepal	M Siwalik	Prasad & Pandey, 2008
Stigmaphyllon chorkholaensis	Surai Khola, Nepal	L Siwalik	Prasad & Pandey, 2008
Tiliaceae			
Grewia ghishia	Darjeeling District, WB	L–M Siwalik	Antal & Awasthi, 1993
Grewia nepalensis n. sp.	Arjun Khola, Nepal	L Siwalik	–
Grewia tistaensis	Darjeeling District, WB	L Siwalik	Antal & Prasad, 1998
Grewia mallotophylla	Arung Khola, Nepal Tanakpur, UK	M Siwalik L Siwalik	Konomatsu & Awasthi, 1999 Prasad *et al.,* 2017a
Grewia kathgodamensis	Kathgodam, UK	L Siwalik	Prasad *et al.,* 2004
Grewia tanakpurensis	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017a
Grewia palaeodisperma n. sp.	Arjun Khola, Nepal	M Siwalik	–
Grewia miopaniculata	Arjun Khola, Nepal	L Siwalik	Prasad *et al.,* 2016
Burseraceae			
Bursera preserrata	Darjeeling District, WB	L–M Siwalik	Antal & Awasthi, 1993
B. serratoides (fruit)	Darjeeling District, WB	L–M Siwalik	Antal & Awasthi, 1993
Burseroxylon preserratum	Kalagarh, UK	L Siwalik	Prasad, 1994b
Canarium cf bengalense	Kameng District, AP	U Siwalik	Khan *et al.,* 2011
Commiphora precaudata	Tanakpur, UK Arjun Khola, Nepal	L Siwalik M Siwalik	Shashi *et al.,* 2008 –
Meliaceae			
Aglaia nahanensis	Nalagarh, HP	L Siwalik	Yadav, 1989

A. nepalensis	Koilabas, Nepal	L Siwalik	Prasad *et al.,* 1999
A. siwalika	Kathgodam, UK	L Siwalik	Prasad, 1994c
Chukrasia miocenica	Kathgodam, UK Surai Khola, Nepal	L Siwalik M Siwalik	Prasad, 1994c, Prasad & Awasthi, 1996
Chisocheton suraikholaensis	Surai Khola, Nepal	L Siwalik	Prasad & Pandey, 2008
Dysoxydendron kalagarhensis	Kalagarh, UK	M Siwalik	Trivedi & Misra, 1979
Dysoxylum mioklanderi	Kathgodam, UK	L Siwalik	Prasad, 1994d
D. raptiensis	Surai Khola, Nepal Kameng District, AP	L Siwalik U Siwalik	Prasad & Awasthi, 1996 Khan *et al.,* 2011
Toona siwalica	Bhikhnathoree, Bihar	M Pliocene	Awasthi & Lakhanpal, 1990
Toona siwalica	Kathgodam, UK Surai Khola, Nepal	L Siwalik L Siwalik	Prasad, 1994c Prasad & Pandey, 2008
Trichilia siwalica	Bilaspur, HP	L Siwalik	Prasad, 2006
Dichapetalaceae			
Dichapetalum siwalicum	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2013a
Stemonuraceae			
Gomphandra palaeocoriacea	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017b
Ctenolophonaceae			
Ctenolophon chorkholaensis	Surai Khola, Nepal	M Siwalik	Prasad & Pandey, 2008
Rutaceae			
Acronychia siwalica	Kathgodam, UK	L Siwalik	Prasad, 1994c
Aphanomixis bhikhnathoriensis	Bhikhnathoree, Bihar	M Pliocene	Awasthi & Lakhanpal, 1990
Atlantia miocenica	Koilabas, Nepal	L Siwalik	Prasad, 1994e
A. siwalica	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017b
Chloroxylon palaeoswietenianum	Koilabas, Nepal	L Siwalik	Prasad, 1990a
Clausena miocenica	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017b
Erythrochiton masotkholaensis n. sp.	Arjun Khola, Nepal	M Siwalik	–
Evodia koilabasensis	Koilabas, Nepal	L Siwalik	Prasad, 1994e
Geijera siwalika	Kathgodam, UK	L Siwalik	Prasad, 1994d
Murraya khariense	Koilabas, Nepal	L Siwalik	Prasad, 1994e
M. khariensis	Surai Khola, Nepal	L Siwalik	Prasad & Awasthi, 1996
Toddalia miocenica	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
T. purniyagiriensis	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017b
Zanthoxylon siwalicum	Surai Khola, Nepal Arjun Khola, Nepal	L Siwalik L Siwalik	Prasad & Awasthi, 1996 –
Zygophyllaceae			
Balanites siwalica	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017b
Simaroubaceae			
Brucea darwajensis	Koilabas, Nepal	L Siwalik	Prasad *et al.,* 1999
Polygalaceae			
Securidaca miocenica	Seria Naka, UP	L Siwalik	Prasad *et al.*, 1997a

Sapindaceae			
Arytera (Ratonia DC.) nepalensis n. sp.	Arjun Khola, Nepal	M Siwalik	–
Euphoria longanoides (fruit)	Darjeeling District, WB	L–M Siwalik	Antal & Awasthi, 1993
E. nepalensis	Koilabas, Nepal	L Siwalik	Prasad, 1994e
E. siwalica	Kathgodam, UK	L Siwalik	Prasad, 1994c
	Surai Khola, Nepal	M Siwalik	Prasad & Pandey, 2008
E. churiaensis n. sp.	Arjun Khola, Nepal	L Siwalik	–
Euphorioxylon deccanense	Siang District, AP	M Siwalik	Mehrotra *et al.,* 1999
E. indicum	Kalagarh, UK	L Siwalik	Prasad, 1994b
Lepisanthes tanakpurensis	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017b
Nephelium palaeoglabrum	Seria Naka, UP	L Siwalik	Prasad *et al.,* 1997a
	Koilabas, Nepal	L Siwalik	Prasad *et al.,* 1999
	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017a
Otophora miocenica	Koilabas, Nepal	L Siwalik	Prasad, 1994e
Paranephelium seriaensis	Koilabas, Nepal	L Siwalik	Prasad & Dwivedi, 2008
	Darjeeling District, WB	L Siwalik	Prasad *et al.,* 2009
P. miocenicum	Darjeeling District, WB	L Siwalik	Prasad *et al.,* 2013c
	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
Sapindus eotrifoliatus	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017b
S. arjunkholaensis	Arjun Khola, Nepal	M Siwalik	–
Vitaceae			
Vitis siwalicus	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
Cayratia palaeojaponica n. sp.	Arjun Khola, Nepal	M Siwalik	–
Rhamnaceae			
Berchemia balugoloensis	Balugoloa, HP	L Siwalik	Lakhanpal, 1967
	Arjun Khola, Nepal	L Siwalik	–
B. siwalika	Kameng District, AP	U Siwalik	Khan *et al.,* 2011
Rhamnus siwalicus	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
Ventilago tistaensis	Darjeeling District, WB	L Siwalik	Antal & Prasad, 1997
V. ovatus	Mandi District, HP	M Siwalik	Prasad *et al.,* 2013b
V. miocalyculata	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017b
Zizyphus miocenicus	Kathgodam, UK	L Siwalik	Prasad, 1994c
	Koilabas, Nepal	L Siwalik	Prasad, 1994e
Z. kathgodamensis	Kathgodam, UK	L Siwalik	Prasad, 1994c
Z. cf *Zrugosa*	Haridwar, UK	M Siwalik	Prasad, 1994a
Z. Siwalicus	Balugoloa, HP	L Siwalik	Lakhanpal, 1965, 1967
Z. indicus	Siang District, AP	U Siwalik	Singh & Prakash, 1980
Z. champarensis	Bhikhnathoree, Bihar	M Pliocene	Lakhanpal & Awasthi, 1984
Z. palaeoapetala	Darjeeling District, WB	L Siwalik	Antal & Prasad, 1997
Sabiaceae			
Meliosma eopinnata	Bilaspur, HP	L Siwalik	Prasad, 2006

Sabia eopaniculata	Koilabas, Nepal	L Siwalik	Dwivedi *et al.*, 2006a
	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
	Tanakpur, UK	L Siwalik	Prasad *et al.*, 2017b
Anacardiaceae			
Bouea premacrophylla	Darjeeling District, WB	L–M Siwalik	Antal & Awasthi, 1993
	Koilabas, Nepal	L Siwalik	Dwivedi *et al.,* 2006a
B. koilabasensis	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017b
	Surai Khola, Nepal	L Siwalik	Awasthi & Prasad, 1996
	Koilabas, Nepal	L Siwalik	Prasad, 1994e
Buchanania palaeosessilifolia	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
B. raptiensis n. sp.	Arjun Khola, Nepal	M Siwalik	–
Dracontomelumoxylon mangiferumoides	Nalagarh, HP	L Siwalik	Prakash, 1978
	Kalagarh, UK	L Siwalik	Prakash, 1981
Dracontomelum seriaense	Seria Naka, UP	L Siwalik	Prasad *et al.*, 1997
D. cf *mangiferum*	Kameng District, AP	U Siwalik	Khan *et al.,* 2011
Drimycarpus siwalicus	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017b
Glutoxylon kalagarhensis	Kalagarh, UK	L Siwalik	Trivedi & Ahuja, 1978b
Glutoxylon burmense	Siang District, AP	M Siwalik	Mehrotra *et al.*, 1999
Gluta siwalika	Surai Khola, Nepal	M Siwalik	Awasthi & Prasad, 1990
	Arjun Khola, Nepal	L Siwalik	Prasad *et al.,* 2013a
Holarrhena nainitalensis	Kathgodam, UK	L Siwalik	Prasad *et al.,* 2004
Mangifera someshwarica	Bhikhnathoree, Bihar	M Pliocene	Lakhanpal & Awasthi, 1984
	Seria Naka, UP	L Siwalik	Prasad *et al.*, 1997a
	Surai Khola, Nepal	M Siwalik	Awasthi & Prasad, 1990
	Koilabas, Nepal	L Siwalik	Prasad, 1994e
	Koilabas, Nepal	L Siwalik	Dwivedi *et al.,* 2006a
	Kameng District, AP	U Siwalik	Khan *et al.,* 2011
Mangifera suraikholaensis	Surai Khola, Nepal	M Siwalik	Prasad & Pandey, 2008
Nothopegia eutravancorica	Darjeeling District, WB	L–M Siwalik	Antal & Awasthi, 1993
Swintonia palaeoschwenckii	Surai Khola, Nepal	L Siwalik	Prasad & Awasthi, 1996;
	Koilabas, Nepal	L Siwalik	Prasad *et al.,* 1999
S. miocenica	Darjeeling District, WB	L Siwalik	Antal & Prasad, 1996a
Tapiria chorkholaensis	Koilabas, Nepal	L Siwalik	Dwivedi *et al.,* 2006a
Connaraceae			
Rourea palaeorugosa	Surai Khola, Nepal	M Siwalik	Prasad & Pandey, 2008
Cnestis purniyagiriensis	Tanakpur, UK	L Siwalik	Prasad *et al.*, 2017b
Fabaceae			
Acacia eosericata	Kathgodam, UK	L Siwalik	Prasad, 1994a
A. miocatechuoides	Kameng District, AP	Siwalik	Khan *et al.,* 2014b
Acrocarpus siwalicus	Nalagarh, HP	L Siwalik	Yadav, 1989
Adenantheroxylon pavoninium	Nalagarh, HP	L Siwalik	Yadav, 1989
Albizinium eolebekkianum	Nalagarh, HP	L Siwalik	Prakash, 1975
A. arunachalensis	Siang District, AP	M Siwalik	Mehrotra *et al.,*1999

Albizia nepalensis	Surai Khola, Nepal	L Siwalik	Awasthi & Prasad, 1990
Albizia palaeolebbek	Darjeeling District, WB Tanakpur, UK	L–M Siwalik L Siwalik	Antal & Awasthi, 1993 Prasad *et al.,* 2017a
Albizia cf *A. gamblei*	Haridwar, UK	M Siwalik	Prasad, 1994a
A. siwalica	Koilabas, Nepal Kathgodam, UK Surai Khola, Nepal	M Siwalik L Siwalik L Siwalik	Prasad, 1994e; Prasad, 1994c; Prasad & Awasthi, 1996
A. microfolia	Surai Khola, Nepal	L Siwalik	Prasad & Awasthi, 1996
Bauhinia palaeomonandra n. sp.	Arjun Khola, Nepal	L Siwalik	–
Butea nepalensis n. sp. (Fruit)	Arjun Khola, Nepal	M Siwalik	–
Bauhinioxylon indicum	Mohand, UK	L Siwalik	Rawat, 1964
Bauhinium palaeomalabaricum	Kalagarh, UK Darjeeling District, WB	L Siwalik M Siwalik	Prakash & Prasad, 1984; Antal *et al.*, 1996
Bauhinia siwalika	Bhikhnathoree, Bihar	M Pliocene	Lakhanpal & Awasthi, 1984
B. ramthiensis	Darjeeling District, WB	L–M Siwalik	Antal & Awasthi, 1993
B. purniyagiriensis	Tanakpur, UK	M Siwalik	Prasad *et al.,* 2017b
Caesalpinia borooahii	Kalagarh, UK	L Siwalik	Prakash, 1978
Caesalpinia purniyagiriensis	Tanakpur, UK Sirmur District, HP	L Siwalik L Siwalik	Shashi *et al.,* 2008 Prasad, 2012
Cassinium prefistulai	Nalagarh, HP	L Siwalik	Prakash, 1975
Cassinium borooahii	Kalagarh, UK	L Siwalik	Prakash, 1978
Cassia arjunkholaensis n. sp.	Arjun Khola, Nepal	M Siwalik	–
Cassia cf *C. fistula*	Haridwar, UK	M Pliocene	Prasad, 1994a
C. nepalensis	Koilabas, Nepal	L Siwalik	Prasad, 1990a
C. siwalica	Kathgodam, UK	L Siwalik	Prasad, 1994c
C. antique	Bhikhnathoree, Bihar	M Pliocene	Awasthi & Lakhanpal, 1990
C. neosophora	Koilabas, Nepal	L Siwalik	Prasad, 1994e
C. miosiamea	Koilabas, Nepal	M Siwalik	Prasad, 1994e
Canavalia siwalika	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017a
Cynometroxylon holdeni	Kalagarh, UK	L Siwalik	Trivedi & Ahuja, 1978c
Cynometra siwalika	Surai Khola, Nepal Koilabas, Nepal Mandi District, HP Arjun Khola, Nepal	L Siwalik L Siwalik M Siwalik M Siwalik	Awasthi & Prasad, 1990 Dwivedi *et al.*, 2006b Prasad *et al.,* 2013b –
C. tertiara	Darjeeling District, WB	L–M Siwalik	Antal & Awasthi, 1993
C. palaeoeripa	Koilabas, Nepal Kathgodam, UK Surai Khola, Nepal Koilabas, Nepal Darjeeling District, WB	L Siwalik L Siwalik M Siwalik L Siwalik M Siwalik	Prasad *et al.*, 1999 Prasad *et al.,* 2004 Prasad & Pandey, 2008 Dwivedi *et al.*, 2006b Prasad *et al.,* 2015
Dalbergia prelatifolia	Balugoloa, HP	L Siwalik	Lakhanpal & Dayal, 1966
D. siwalica	Bhikhnathoree, Bihar	M Pliocene	Awasthi & Lakhanpal, 1990
D. miosericea	Koilabas, Nepal	L Siwalik	Prasad, 1994e

D. sissoo (fruit)	Haridwar, UK	L Siwalik	Prasad, 1994a
D. miovolubilis	Seria Naka, UP	L Siwalik	Prasad *et al.,* 1997a
	Koilabas, Nepal	L Siwalik	Prasad *et al.,* 1999
D. eocultrata	Koilabas, Nepal	L Siwalik	Prasad *et al.,* 1999
D. cf rimosa	Kameng District, AP	U Siwalik	Khan *et al.,* 2011
D. cf *D. sissoo*	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017a
Dalbergia sp.	Darjeeling District, WB	L Siwalik	Khan & Bera, 2014a
D. prelatifolia fruit	Darjeeling District, WB	L Siwalik	Khan & Bera, 2014a
Dalbergia tanakpurensis	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017b
Dialiumoxylon palaeoindicum	Kalagarh, UK	L Siwalik	Prasad, 1994b
Dialium palaeoindicum	Kathgodam, UK	L Siwalik	Prasad, 1994c
Derris champarensis	Bhikhnathoree, Bihar	M Pliocene	Awasthi & Lakhanpal, 1990
D. mioscandens	Tanakpur, UK	L Siwalik	Prasad *et al.*, 2017b
Entada palaeoscandens	Surai Khola, Nepal	L Siwalik	Awasthi & Prasad, 1990;
	Darjeeling District, WB	L–M Siwalik	Antal & Awasthi, 1993;
	Koilabas, Nepal	L Siwalik	Prasad, 1994e
Humboldtia miocenica	Tanakpur, UK	L Siwalik	Prasad, 1990b
Hopeoxylon eosiamensis	Kalagarh, UK	L Siwalik	Prakash, 1981
H. speciosum	Siang District, AP	M Siwalik	Mehrotra *et al.*, 1999
Indigofera prepulchella	Siang District, AP	M Siwalik	Mehrotra *et al.,* 1999
Koompassioxylon elegans	Nalagarh, HP	L Siwalik	Yadav, 1989
Koompassia suraikholaensis	Surai Khola, Nepal	L Siwalik	Prasad & Awasthi, 1996
Leguminocarpon siwalicum	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017a
Mastertia neoassamica	Kameng District, AP	L Siwalik	Khan & Bera, 2014a
Millettioxylon pongamiensis	Nalagarh, HP	L Siwalik	Prakash, 1975
M. indicum	Kalagarh, UK	L Siwalik	Prasad, 1994b
Millettia mioinermis	Koilabas, Nepal	L Siwalik	Prasad, 1990a
M. palaeoracemosa	Surai Khola, Nepal	L Siwalik	Awasthi & Prasad, 1990
	Kathgodam, UK	L Siwalik	Prasad 1994c
M. palaeocubithii	Surai Khola, Nepal	M Siwalik	Awasthi & Prasad, 1990
M. koilabasensis	Koilabas, Nepal	L Siwalik	Prasad, 1990b;
	Laxmi River section, Bhutan	L Siwalik	Prasad & Tripathi, 2000
	Surai Khola, Nepal	L Siwalik	Prasad & Pandey, 2008
M. siwalica	Kathgodam, UK	L Siwalik	Prasad, 1994c
	Kameng District, AP	U Siwalik	Khan *et al.,* 2011
	Koilabas, Nepal	L Siwalik	Prasad, 1990a
	Tanakpur, UK	L Siwalik	Prasad *et al.*, 2017b
M. miobrandisiana	Koilabas, Nepal	L Siwalik	Prasad,1994e
M. churiaensis	Surai Khola, Nepal	L Siwalik	Prasad & Awasthi, 1996
M. oodlabariensis	Darjeeling District, WB	L–M Siwalik	Antal & Prasad, 1996a

M. imlibasensis	Koilabas, Nepal	L Siwalik	Prasad *et al.,* 1999
M. ovatus	Koilabas, Nepal near jarwa	L Siwalik	Tripathi *et al.,* 2002
M. palaeomanii	Koilabas, Nepal	L Siwalik	Dwivedi *et al.,* 2006b
M. bilaspurensis	Bilaspur, HP Mandi District, HP Tanakpur, UK	L Siwalik M Siwalik L Siwalik	Prasad, 2006 Prasad *et al.,* 2013b Prasad *et al.,* 2017a
M. purniyagiriensis	Tanakpur, UK Darjeeling District, WB	L Siwalik M Siwalik	Shashi *et al.,* 2006 Prasad *et al.,* 2015
M. palaeomanii	Koilabas, Nepal	L Siwalik	Dwivedi *et al.,* 2006b
M. prakashii	Tanakpur, UK Darjeeling District, WB	L Siwalik M Siwalik	Shashi *et al.,* 2008 Prasad *et al.,* 2015
M. cf extensa	Kameng District, AP	U Siwalik	Khan *et al.,* 2011
M. miocinerea	Arjun Khola, Nepal	L Siwalik	Prasad *et al.,* 2016
M. kathgodamensis	Kathgodam, UK	L Siwalik	Prasad *et al.,* 2004
M. miosericea	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
M. sevokensis	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
Marjunkholaensis n. sp.	Arjun Khola, Nepal	L Siwalik	–
Mucuna miogigantea	Surai Khola, Nepal	L Siwalik	Prasad & Pandey, 2008
Ormosioxylon bengalensis	Nalagarh, HP	L Siwalik	Prasad, 1989
Ormosia robustoides	Koilabas, Nepal Tanakpur, UK Kathgodam, UK	L Siwalik L Siwalik L Siwalik	Prasad,1990b Prasad *et al.,* 2017a Prasad *et al.*, 2004
Pahudioxylon indicum	Nalagarh, HP	L Siwalik	Prakash, 1979
P. bankurensis Prakash & Bande (= *C. siwalicus*) *C. indicum*	Siang District, AP Nalagarh, HP	M Siwalik L Siwalik	Mehrotra *et al.,* 1999 Prakash, 1975
Pongamia siwalika	Bhikhnathoree, Bihar Darjeeling District, WB Kameng District, AP	M Pliocene L–M Siwalik U Siwalik	Awasthi & Lakhanpal, 1990; Antal & Awasthi, 1993 Khan *et al.,* 2011
P. cf *P. glabra*	Haridwar, UK	M Siwalik	Prasad, 1994a
P. kathgodamensis	Kathgodam, UK Surai Khola, Nepal Koilabas, Nepal Kameng District, AP	L Siwalik L Siwalik L Siwalik U Siwalik	Prasad, 1994d; Prasad & Awasthi, 1996 Prasad *et al.,* 1999 Khan & Bera, 2014a
Pongamia arjunkholaensis	Arjun Khola, Nepal	M Siwalik	Prasad, 2013
P.terocarpus ovatus	Bhikhnathoree, Bihar	M Pliocene	Awasthi & Lakhanpal, 1990
P. dalbergiocarpoides	Surai Khola, Nepal	L Siwalik	Prasad & Awasthi, 1996
Papillinoid sp (leaf)	Jawalamukhi, HP	L Siwalik	Mathur, 1978
Samanea siwalika	Kathgodam, UK	L Siwalik	Prasad, 1994c;
Saraca palaeoindica n. sp.	Arjun Khola, Nepal	M Siwalik	–
Sindora eosiamensis n. sp.	Arjun Khola, Nepal	L Siwalik	–

Sleguminocarpoides n. sp.	Arjun Khola, Nepal	L Siwalik	–
Spatholobus siwalicus	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
Wagatea miospicata	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017b
Xylia siwalika	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017a
Rosaceae			
Parinari kathgodamens	Kathgodam, UK	L Siwalik	Prasad, 1994c
Combretaceae			
Anogeissus eosericea	Koilabas, Nepal	L Siwalik	Prasad & Prakash, 1984
Calycopteris floribundoides	Koilabas, Nepal	L Siwalik	Prasad, 1990a
Combretum sahnii	Darjeeling District, WB Koilabas, Nepal Kameng District, AP Arjun Khola, Nepal	L–M Siwalik L Siwalik U Siwalik M Siwalik	Antal & Awasthi, 1993 Prasad, 1994e Khan *et al.,* 2011 Prasad *et al.,* 2016
C. purniyagiriense	Tanakpur, UK	L Siwalik	Prasad *et al.*, 2017b
C. siwalicum n. sp.	Arjun Khola, Nepal	M Siwalik	–
Terminalioxylon palaeomanii	Kalagarh, UK	L Siwalik	Prakash, 1981
T. siwalicus	Kalagarh, UK	L Siwalik	Prasad, 1989
T. belericum	Siang District, AP	M Siwalik	Mehrotra *et al.,* 1999
Terminalia Koilabasensis	Koilabas, Nepal	Siwalik	Prasad, 1990a
T. siwalica	Koilabas, Nepal	L Siwalik	Prasad, 1990a
T. panandhroensis	Surai Khola, Nepal Koilabas, Nepal	L Siwalik L Siwalik	Awasthi & Prasad, 1990; Prasad, 1994e
T. palaeochebula	Surai Khola, Nepal	L Siwalik	Awasthi & Prasad, 1990
T. balugoloaensis	Balugoloa, HP	L Siwalik	Lakhanpal & Awasthi, 1992
T. miobelerica	Kathgodam, UK	L Siwalik	Prasad, 1994c
T. himachalensis	Mandi District, HP	M Siwalik	Prasad e*t al.,* 2013b
T. bhairauvensis	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017b
T. arjunkholaensis n. sp.(Fruit)	Arjun Khola, Nepal	M Siwalik	–
Melastomataceae			
Medinilla siwalica	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017b
Anisophylleaceae			
Anisophyllea siwalica	Surai Khola, Nepal Koilabas, Nepal	L Siwalik L Siwalik	Prasad & Awasthi, 1996 Prasad *et al.*, 1999
Myrtaceae			
Eugenia lamhiensis	Arjun Khola, Nepal	M Siwalik	Prasad *et al.,* 2016
Eugenia nepalensis n. sp.	Arjun Khola, Nepal	M Siwalik	–
Syzygium palaeobracteatum	Bhikhnathoree, Bihar	M Pliocene	Awasthi & Lakhanpal, 1990
S. palaeocuminii	Surai Khola, Nepal Darjeeling District, WB	L Siwalik M Siwalik	Prasad & Awasthi, 1996 Antal & Prasad, 1997
S. miooccidentalis	Koilabas, Nepal	L Siwalik	Prasad *et al.,* 1999
Syzygium miocenicum	Koilabas, Nepal	L Siwalik	Prasad *et al.,* 1999

Lecythidaceae			
Careyoxylon pondicherriense	Nalagarh, HP	L Siwalik	Prakash, 1979
Lythraceae			
Duabangoxylon indicum	Kalagarh, UK	L Siwalik	Awasthi & Prasad, 1987
	Hamirpur, HP	M Siwalik	Prasad, 2010
Duabanga siwalica	Surai Khola, Nepal	L Siwalik	Prasad & Pandey, 2008
Lagerstroemia siwalika	Kathgodam, UK	L–M Siwalik	Prasad, 1994c;
	Koilabas, Nepal	L Siwalik	Prasad, 1994e
L. patelii	Darjeeling District, WB	L–M Siwalik	Antal & Awasthi, 1993
	Kathgodam, UK	M Siwalik	Prasad, 1994a
	Arjun Khola, Nepal	L Siwalik	–
Lagerstroemia sp.	Balugoloa, HP	L Siwalik	Lakhanpal & Dayal, 1966
L. jamraniensis	Kathgodam,UK	L Siwalik	Prasad *et al.,* 2004
L. mioparviflora	Koilabas, Nepal	L Siwalik	Dwivedi *et al.,* 2006b
L. eomicrocarpa	Koilabas, Nepal	L Siwalik	Dwivedi *et al.,* 2006b
L. siwalica	Sirmur District, HP	L Siwalik	Prasad, 2012
L. corvinusii	Arjun Khola, Nepal	M Siwalik	Prasad, 2013
L. himalayaensis	Kathgodam, UK	L Siwalik	Srivastava *et al.,* 2015
L. prakashii	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017b
Woodfordia neofruiticosa	Koilabas, Nepal	L Siwalik	Prasad, 1994e
Caprifoliaceae			
Lonicera mioquinquecularis	Koilabas, Nepal	L Siwalik	Prasad, 1994e
Rubiaceae			
Anthocephalus siwalicus	Surai Khola, Nepal	L Siwalik	Prasad & Awasthi, 1996
Gardenia palaeoturgida	Bhikhnathoree, Bihar	M Pliocene	Lakhanpal & Awasthi, 1984
G. nainitalensis	Kathgodam, UK	L Siwalik	Prasad, 1994c
G. precoronaria	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
Ixora purniyagiriensis	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017b
Morinda palaeotinctoria	Kathgodam, UK	L Siwalik	Prasad, 1994c
M. siwalika	Koilabas, Nepal	L Siwalik	Prasad, 1994e
Randia miowallichii	Koilabas, Nepal;	L Siwalik	Prasad, 1990a;
	Darjeeling District, WB	L–M Siwalik	Antal & Awasthi, 1993
R. siwalica	Surai Khola, Nepal	L Siwalik	Prasad & Awasthi, 1996
R. palaeofasciculata	Surai Khola, Nepal	M Siwalik	Prasad & Awasthi, 1996
R. lishensis	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
R. tanakpurensis	Tanakpur, UK	L Siwalik	Prasad *et al.*, 2017b
R. premicrophylla n. sp.	Arjun Khola, Nepal	M Siwalik	–
Compositae			
Vernonia palaeoarborea	Darjeeling District, WB	L–M Siwalik	Antal & Awasthi, 1993
Myrsinaceae			
Ardisia antique	Bhikhnathoree, Bihar	M Pliocene	Awasthi & Lakhanpal, 1990
A. palaeosimplicifolia	Kathgodam, UK	L Siwalik	Prasad, 1994c

Myrsine cf *M. capitellata*	Haridwar, UK	M Siwalik	Prasad, 1994a
Myrsine precapitellata	Surai Khola, Nepal	M Siwalik	Prasad & Pandey, 2008
Sapotaceae			
Chrysophylloxylon pondicherriense	Arjun Khola, Nepal	M Siwalik	Prasad, 2007
Chrysophyllum churiensis	Arjun Khola, Nepal	L Siwalik	Prasad, 2007
C. bhairauvensis	Tanakpur, UK	L Siwalik	Prasad *et al.*, 2017b
Mimusops mioelengi	Koilabas, Nepal	L Siwalik	Prasad *et al.*, 2013a
Palaquium palaeogrande	Tanakpur, UK	L Siwalik	Prasad *et al.*, 2017b
Sarcosperma mioarboreum	Kathgodam, UK	L Siwalik	Prasad *et al.*, 2004
Ebenaceae			
Ebenoxylon miocenicum	Kalagarh, UK	L Siwalik	Prakash, 1978
	Darjeeling District, WB	M Siwalik	Antal *et al.*,1996
E. siwalicus	Kalagarh, UK	M Siwalik	Prakash, 1981
E. palaecandoleana	Kalagarh, UK	L Siwalik	Prasad, 1994b
E. kalagarhensis	Kalagarh, UK	L Siwalik	Prasad, 1989
Diospyros embryopterisites	Haridwar, UK	M Siwalik	Varma, 1968
	Arjun Khola, Nepal	M Siwalik	–
D. pretoposia	Koilabas, Nepal	L Siwalik	Prasad, 1990a
	Arjun Khola, Nepal	M Siwalik	Prasad & Khare, 2004
D. miokaki	Surai Khola, Nepal	L Siwalik	Awasthi & Prasad, 1990
D. koilabasensis	Koilabas, Nepal	L Siwalik	Prasad, 1990a
	Darjeeling District, WB	L–M Siwalik	Antal & Awasthi, 1993
D. kathgodamensis	Kathgodam, Nepal	L Siwalik	Prasad, 1994c
D. palaeoebenum	Kathgodam, UK	L Siwalik	Prasad, 1994d
	Tanakpur, UK	L Siwalik	Shashi *et al.,* 2008
D. miocenicus	Surai Khola, Nepal	L Siwalik	Prasad & Awasthi, 1996
D. tulsipurensis	Seria Naka, UP	L Siwalik	Prasad *et al.*, 1997a
D. darwajensis	Koilabas, Nepal	L Siwalik	Prasad *et al.,* 1999
D. nainitalensis	Kathgodam, UK	L Siwalik	Prasad *et al.*, 2004
D. palaeoeriantha	Kathgodam, UK	L Siwalik	Prasad *et al.*, 2004
D. purniyagiriensis	Tanakpur, UK	L Siwalik	Shashi *et al.,* 2008
D. palaeoargentia	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
D. masotkholaensis	Arjun Khola, Nepal	L Siwalik	Prasad *et al.,* 2016
Oleaceae			
Chionanthus siwalicus	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
Apocynaceae			
Alstonia mioscholaris	Darjeeling District, WB	L–M Siwalik	Antal & Awasthi, 1993
Carissa koilabasensis	Koilabas, Nepal	L Siwalik	Prasad, 1994e
Chonemorpha miocenica	Surai Khola, Nepal	L Siwalik	Prasad & Awasthi, 1996
	Kameng District, AP	U Siwalik	Khan *et al.,* 2011
	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
Cerbera miocenica	Darjeeling District, WB	M Siwalik	Prasad *et al.,* 2015
Tabernaemontana precoronaria	Koilabas, Nepal	L Siwalik	Prasad, 1990a

Wrightia siwalica	Kathgodam, UK	L Siwalik	Prasad, 1994c
W. palaeotinctoria	Surai Khola, Nepal	L Siwalik	Prasad & Awasthi, 1996
Olacaceae			
Anacolosa mioluzoniensis	Koilabas, Nepal	L Siwalik	Prasad, 1994e
Olax bankasii	Surai Khola, Nepal	L Siwalik	Prasad & Pandey, 2008
Loganiaceae			
Gaertnera siwalica	Koilabas, Nepal	L Siwalik	Prasad, 1990a
Boraginaceae			
Boraginocarpus lakhanpalii	Chandigarh, Punjab	U Siwalik	Mathur, 1974
Cordia siwalica n. sp.	Arjun Khola, Nepal	L Siwalik	–
Convolvulaceae			
Ipomoea eriocarpoides	Bhikhnathoree, Bihar	M Pliocene	Awasthi & Lakhanpal, 1990
Solanaceae			
Datura miocenica	Koilabas, Nepal	L Siwalik	Prasad, 1990a
Verbenaceae			
Vitex prenegundo	Koilabas, Nepal	L Siwalik	Prasad, 1990a
V. pubescens	Koilabas, Nepal	L Siwalik	Prasad, 1990a
Callicarpa siwalika	Darjeeling District, WB	L–M Siwalik	Antal & Awasthi, 1993
Protiaceae			
Helicia oerrectica	Koilabas, Nepal	L Siwalik	Prasad *et al.,* 1999
Myristicaceae			
Knema cf *K. glaucescens*	Kameng District, AP	U Siwalik	Khan *et al.,* 2011
Myristica palaeoglomerata	Surai Khola, Nepal	L Siwalik	Awasthi & Prasad, 1990
Myristica siwalica	Tanakpur, UK	L Siwalik	Prasad *et al.*, 2017b
Lauraceae			
Actinodaphne palaeoangustifolia	Darjeeling District, WB Tanakpur, UK Surai Khola, Nepal Arjun Khola, Nepal	L–M Siwalik L Siwalik L Siwalik M Siwalik	Antal & Awasthi, 1993 Prasad *et al.,* 2017a Prasad & Pandey, 2008 Prasad, 2013
Actinodaphne cf A. obovate	Kameng District, AP	U Siwalik	Khan *et al.,* 2011
Cinnamomum tamala	Darjeeling District, WB	M Siwalik	Pathak, 1969
C. palaeotamala	Bhikhnathoree, Bihar	M Pliocene	Lakhanpal & Awasthi, 1984
C. mioinuctum	Koilabas, Nepal	L Siwalik	Prasad, 1990a
Cinnamomum sp.	Darjeeling District, WB	L–M Siwalik	Antal & Awasthi, 1993
C. miotavoyanum	Tanakpur, UK	L Siwalik	Shashi *et al.,* 2008
C. nepalensis	Tanakpur, UK	L Siwalik	Shashi *et al.,* 2008
C. palaeobejolghota	Kameng District, AP	Siwalik	Khan & Bera, 2014b
C. corvinusianum	Arjun Khola, Nepal	L Siwalik	Prasad *et al.,* 2016
C. palaeotamala	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017b
C. raptiensis n. sp.	Arjun Khola, Nepal	L Siwalik	–
Laurinoxylon siwalicus	Kalagarh, UK	L Siwalik	Prasad, 1990c
Litsea prenitida	Bhikhnathoree, Bihar	M Pliocene	Lakhanpal & Awasthi, 1984
L. cf *L. salicifolia*	Kameng District, AP	U Siwalik	Khan *et al.,* 2014a

Lindera cf *L. pulcherrima*	Kameng District, AP	U Siwalik	Khan *et al.,* 2014a
L. neobifaria	Kameng District, AP	U Siwalik	Khan *et al.*, 2014a
L. polyantha	Darjeeling District, WB	M Siwalik	Pathak,1969
L. bhatiai	Kangra, HP	U Siwalik	Mathur, 1978
Machilus villosa	Darjeeling District, WB	M Siwalik	Pathak, 1969
M. miocenica	Kathgodam, UK	L Siwalik	Prasad, 1994d
	Surai Khola, Nepal	L Siwalik	Prasad & Pandey, 2008
M. miovillosus	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017a
Persea masotkholaensis n. sp.	Arjun Khola, Nepal	L Siwalik	–
P. siwalika	Arjun Khola, Nepal	L Siwalik	Prasad *et al.,* 2016
P. preglaucescens	Kameng District, AP	U Siwalik	Khan & Bera, 2014b
P. mioparviflora	Kameng District, AP	U Siwalik	Khan & Bera, 2014b
P. punyagiriensis	Tanakpur, UK	L Siwalik	Lakhanpal & Guleria, 1978
Phoebe champarensis	Bhikhnathoree, Bihar	M Pliocene	Awasthi & Lakhanpal, 1990
Euphorbiaceae			
Antedesma siwalika	Koilabas, Nepal	L Siwalik	Prasad *et al.,* 1999
Baccaurea miocenica	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017b
Bridelia stipularis	Darjeeling District, WB	M Siwalik	Pathak, 1969
B. verrucosa	Darjeeling District, WB	L Siwalik	Pathak, 1969
B. mioretusa	Surai Khola, Nepal	M Siwalik	Prasad & Pandey, 2008
B. siwalika	Surai Khola, Nepal	M Siwalik	Prasad & Pandey, 2008
B. hanumanchattiensis	Tanakpur UK	M Siwalik	Prasad *et al.,* 2017b
Breynia prerhamnoides	Surai Khola, Nepal	L Siwalik	Prasad & Awasthi, 1996
Cleistanthus suraikholaensis	Surai Khola, Nepal	L Siwalik	Prasad & Awasthi, 1996
Croton cf *C. teglis*	Haridwar, UK		Varma, 1968
C. cf *C. caudatus*	Kameng District, AP	U Siwalik	Khan *et al.,* 2011
Exoecaria palaeocrenulata	Surai Khola, Nepal	L Siwalik	Awasthi & Prasad, 1990
Glochidion miocenica	Kathgodam, UK	L Siwalik	Prasad, 1994c
G. (=*Phyllanthus*) *palaeohirsutum*	Darjeeling District, WB	L Siwalik	Antal & Prasad, 1996a
Homonoia cf *H. riparia*	Haridwar, UK	M Siwalik	Prasad, 1994a
H. mioriparia	Darjeeling District, WB	L Siwalik	Antal & Prasad, 1997
	Kathgodam, UK	L Siwalik	Prasad *et al.*, 2004
H. philippinensis	Darjeeling District, WB	M Siwalik	Pathak, 1969
Macaranga siwalika	Darjeeling District, WB	L–M Siwalik	Antal & Awasthi, 1993
M. cf *M. denticulate*	Kameng District, AP	U Siwalik	Khan *et al.,* 2011
Mallotus sp.	Jawalamukhi, HP	M Siwalik	Mathur, 1978
M. kalimpongensis	Darjeeling District, WB	L–M Siwalik	Antal & Awasthi, 1993
	Surai Khola, Nepal	M Siwalik	Prasad *et al.,* 2008
	Darjeeling District, WB	M Siwalik	Pathak, 1969
	Tanakpur, UK	L Siwalik	Prasad *et al.,* 2017b
M. venkatachalai	Kathgodam, UK	L Siwalik	Prasad, 1994c

M. prejaponicus	Tanakpur, UK	L Siwalik	Prasad *et al.*, 2017b
Phyllanthus palaeoreticulatus	Surai Khola, Nepal	L Siwalik	Prasad & Awasthi, 1996
P. siwalica	Kathgodam, UK	L Siwalik	Prasad, 1994d
P. mioreticulatus	Koilabas, Nepal Kathgodam, UK	L Siwalik L Siwalik	Prasad *et al.,* 1999 Prasad *et al.*, 2004
P. koilabasensis	Koilabas, Nepal	L Siwalik	Prasad *et al.,* 1999
Moraceae			
Artocarpoxylon deccanensis	Kalagarh, UK	L Siwalik	Prasad, 1994b
Artocarpus nepalensis	Surai Khola, Nepal	L Siwalik	Prasad & Awasthi, 1996
Artocarpus arjunkholaensis n. sp.	Arjun Khola, Nepal	M Siwalik	–
Ficus precunia	Balugoloa, HP Koilabas, Nepal Kathgodam, UK Darjeeling District, WB	L Siwalik L Siwalik L Siwalik M Siwalik	Lakhanpal, 1968 Prasad, 1990a Prasad *et al.*, 2004 Prasad *et al.,* 2015
F. cunia	Bilaspur District, HP	Tertiary	Gupta & Jiwan, 1972
F. champarense	Bhikhnathoree, Bihar	M Pliocene	Lakhanpal & Awasthi, 1984
F. retusoides	Koilabas, Nepal Darjeeling District, WB	L Siwalik L–M Siwalik	Prasad, 1990a; Antal & Awasthi, 1993
F. oodlabariensis	Darjeeling District, WB Bilaspur, HP Kathgodam, UK	L–M Siwalik L Siwalik L Siwalik	Antal & Awasthi, 1993 Prasad, 2006 Prasad *et al.*, 2004
F. raptiensis	Surai Khola, Nepal	L Siwalik	Prasad & Awasthi, 1996
F. nepalensis	Koilabas, Nepal	L Siwalik	Prasad, 1990a
Ficoxylon kalagarhensis	Kalagarh, UK	L Siwalik	Prasad, 1994b
F. raptiensis	Surai Khola, Nepal	–	Prasad & Awasthi, 1996
F. miocenica	western Nepal	–	Konomatsu & Awasthi, 1999
F. eumysorensis	Near Jarwa, UP	–	Tripathi *et al.,* 2002
F. benjamina	Bilaspur, HP	–	Prasad, 2006
Ficus preglobosa n. sp.	Arjun Khola, Nepal	M Siwalik	–
Urticaceae			
Sarcochlamys miopulcherrima	Tanakpur, UK	L Siwalik	Prasad *et al.*, 2017b
Ericaceae			
Rhododendron lepidotum	Darjeeling District, WB	M Siwalik	Pathak, 1969
Fagaceae			
Castanopsis tribuloides	Darjeeling District, WB	M Siwalik	Pathak, 1969
Incertae sedis			
Dicotylophyllum spp1–4	Nahan beds, HP	L Siwalik	Dayal & Chaudhuri, 1967
Dryoxylon nahanai	Nalagarh, HP	L Siwalik	Prakash, 1975
Dicotylophyllum dioscoreoides	Siang District, AP	U Siwalik	Singh & Prakash, 1980
Phyllites sp. cf *Phyllites ramrupensis*	NEFA, AP	Tertiary	Chaudhury *et al.,* 1970

Table 8—Present day distribution and forest types of modern day taxa comparable to fossils species recovered from the Siwalik sediments of Arjun Khola area, Nepal.

Fossil Taxa	Modern equivalent taxa	Forest Type	Plant type	Distribution
MONOCOTYLEDONS				
Marantaceae				
Clinogyne ovatus Awasthi & Prasad, 1990	*Clinogyne dichotoma* (Roxb) Salisb.	Mixed deciduous	Herb	North–east India, Sub–Himalaya tract, Myanmar, Malaysia
DICOTYLEDONS				
Dilleniaceae				
Dillenia palaeoindica Prasad & Prakash, 1984	*Dillenia indica* L.	Mixed deciduous	Tree	North–east India, Nepal, Myanmar, Konkan, Kanara, Malabar, Sri Lanka, Malaya Peninsula
Annonaceae				
Anaxagorea mioluzonensis n. sp.	*Anaxagorea luzonensis* A. Gray	Evergreen	Shrub	Andaman, Malacca, Myanmar, Philippines, Malaya Archipelago
Melodorum arjunkholaensis Prasad *et al.,* 2016	*Melodorum fulgens* Hook F. & Thomson	Evergreen	Small tree	Africa, South East Asia, Australia, Malaya
Mitrephora siwalika Antal & Awasthi, 1993	*Mitrephora maingayi* Hook F. & Thomson	Evergreen	Tree	India, Tenasserim, Malaya Peninsula, Java, Myanmar,
Mitrephora mioreticulata n. sp.	*Mitrephora reticulata* (Blume) Hook F. & Thomson	Evergreen	Small tree	North–east India, South East Asia, Malaya, Peninsula, Tenasserim, Myanmar, Chittagong
Uvaria nepalensis Prasad *et al.,* 2016	*Uvaria calamistrata* Hance	Evergreen	Climbing shrub	China, Southern China, East Asia, Vietnam
Menispermaceae				
Tinospora siwalika n. sp.	*Tinospora cordifolia* (Willd) Miers.	Mixed deciduous	Climbing shrub	Southern India, Kumaon to Assam, Myanmar, Bihar, Konkan to Sri Lanka
Achariaceae				
Hydnocarpus mioalpinus Prasad, 2006	*Hydnocarpus alpinus* Wight	Evergreen	Large Tree	Eastern side of Nilgiris, Western Ghats, Sri Lanka
Hydnocarpus lamhiensis Prasad *et al.,* 2016	*Hydnocarpus macrocarpa* Bedd.	Mixed deciduous	Large tree	Travancore Ghats, India, Myanmar
Ryparia arjunkholaensis n. sp.	*Ryparia (Ryparosa) caesia* Blume ex Baill	Evergreen	Small tree	India, Andaman and Nicobar Islands, Malaya Peninsula, Indonesia, New Guinea
Dipterocarpaceae				
Anisoptera palaeoscaphula n. sp.	*Anisoptera scaphula* (Roxb.) Pierre	Evergreen	Tall tree	Bangladesh, Malaya, Myanmar, Thailand, and Vietnam, South east Australia

Shorea siwalika Antal & Awasthi, 1993	*Shorea assamica* Dyer	Evergreen	Large tree	North–east India
Dipterocarpus churiensis Prasad & Gautam, 2016	*Dipterocarpus bourdillonii* Br.	Evergreen	Tree	South India
Diptercarpoxylon siwalicus Prakash 1975	*Dipterocarpus indicus* Bedd.	Evergreen	Tree	North east India, Andaman, Myanmar, Malaya
Dipterocarpus suraikholaensis Prasad & Pandey, 2008	*Dipterocarpus alatus* Roxb.	Evergreen		North east India, Myanmar, Malaya Peninsula
Dipterocarpus miocenicus Prasad & Gautam, 2016	*Dipterocarpus bourdillonii* Br.	Evergreen	Tree	South India
Dipterocarpus koilabasensis Prasad *et al.*, 1999	*Dipterocarpus turbinatus* Gaertner	Evergreen	Tree	North–east India, Myanmar, Andaman, some species Malaya Peninsula
Dipterocarpus nepalensis Prasad & Gautam, 2016	*Dipterocarpus indicus* Bedd.	Evergreen	Lofty tree	South India
Dipterocarpus palaeoindicus n. sp.	*Dipterocarpus indicus* Bedd.	Evergreen	Lofty tree	South India
Isoptera siwalica Prasad *et al.,* 1999	*Isoptera boreneensis* Scheffex Burck	Evergreen	Large tree	Borneo, Myanmar, Java, Sumatra, Malaya Peninsula
Hopea masotkholaensis Prasad *et al.,* 2016	*Hopea belangeran* Korth	Evergreen	Tree	Borneo, Malaysia
Calophyllaceae				
Calophyllum mioelatum n. sp.	*Calophyllum elatum* Bedd.	Evergreen	Large tree	Western Ghats, North Kanara to Travancore, Sri Lanka
Calophyllum suraikholaensis Prasad *et al.,* 2016	*Calophyllum polyanthum* Wallich ex Choisy	Evergreen	Tree	Tenasserim, Andaman and Nicobar Island, Malaya Peninsula, Sri Lanka
Sterculiaceae				
Sterculia arjunkholaensis n. sp.	*Sterculia hamiltonii* (Kuntze) Adelb.	Evergreen to moist deciduous	Shrub	North–east India, South–east Asia, Myanmar
Sterculia kathgodamensis Prasad, 1994a	*Sterculia coccinea* Jack.	Evergreen	Tree	Eastern Himalayas Sikkim, Bhutan and Myanmar
Tiliaceae				
Grewia palaeodisperma n. sp.	*Grewia disperma* Rottler ex Spreng	Evergreen	Small tree	North–east India, South India, Tropical Africa, Malaya, Australia
Grewia nepalensis n. sp.	*Grewia salvifolia* Heyne ex Roth.	Mixed deciduous	Small tree	North–west India, Deccan
Rutaceae				
Erythrochiton masotkholaensis n. sp.	*Erythrochiton brasiliensis* Nees & Mart	Evergreen	Small Shrub	America, East Bolivia, Peru, South Brazil
Zanthoxylum siwalicum Prasad & Awasthi*,* 1996	*Zanthpxylum hamiltonium* Wall.	Mixed deciduous	Small tree	North–East India, Myanmar, Sikkim, Assam, Upper Myanmar

Burseraceae				
Commiphora precaudata Shashi *et al.,* 2007	*Commiphora caudata* (Wight & Arn.) Engl.	Mixed deciduous	Tree	South India, Sri Lanka
Rhamnaceae				
Berchemia balugoloensis Lakhanpal, 1967	*Berchemia floribunda* (Wall.) Brongn.	Evergreen to moist deciduous	Climbing shrub	Sub–Himalayan zone and Myanmar
Vitaceae				
Cayratia palaeojaponica n. sp.	*Cayratia japonica* (Thunb.) Gagnep	Evergreen	Climber	North–east India, Chittagong, Malacca
Sapindaceae				
Arytera (Ratonia DC.*) nepalensis* n. sp.	*Arytera (Ratonia* DC.*) littoralis* Blume	Evergreen	Small tree	Tenasserim, Malaya/ Archipelago
Arytera (*Ratonia* DC.) *miolittoralis* n. sp.	*Arytera (Ratonia* DC.*) littoralis* Tejsmand Binn	Evergreen to moist deciduous	Tree	South–east Asia, North–east India
Euphoria churiaensis n. sp.	*Euphoria cinerea* (Turcz.) Radlk.	Evergreen	Large tree	South India, Myanmar
Filicium koilabasensis Prasad, 1994e	*Filicium decipiense* (Wight & Arn.) Thwaites	Evergreen	Medium sized tree	Western Ghats, Nilgiri, southwards, Sri Lanka, Tropical Africa
Harpullia siwalica Prasad & Awasthi, 1996	*Harpullia arborea* (Blanco) Radlk.	Evergreen	Tree	Indo–Malaysia, Australia, South India
Sapindus arjunkholaensis Prasad *et al.,* 2016	*Sapindus emarginatus* Vahl.	Mixed deciduous	Large tree	Throughout India, Myanmar, Aravali Hills
Sapindus palaeomukorossi n. sp.	*Sapindus mukorossi* Gaertner	Evergreen to moist deciduous	Tree	North–west and east India, Central Japan
Otonephelium nepalensis Prasad *et al.,* 2016	*Ontonephelium stipulaceum* Radlk.	Evergreen	Tree	Malabar, Andaman, Western Ghats, South and Central Sahyadris
Anacardiaceae				
Gluta siwalika Awasthi &Prasad, 1990	*Gluta renghas* Linn.	Evergreen	Tree	Madagascar, India, Myanmar, Thailand, Indo–China, Malaysia
Buchanania raptiensis n. sp.	*Buchnania lancifolia* Roxb.	Evergreen to moist deciduous	Tree	Chittagong, Arracan, Myanmar, Andaman
Fabaceae				
Bauhinia palaeomonandra n. sp.	*Bauhinia monandra* Kurz	Evergreen	Tree	Myanmar, Australia, Christmas land, Caribbean, Southern USA
Butea nepalensis n. sp.	*Butea parviflora* DC.	Mixed deciduous	Large climber	India, Bangladesh, Nepal, Bhutan, China (Yunnan), through much of South East Asia
Cassia arjunkholaensis n. sp.	*Cassia fistula* L.	Mixed Deciduous	Middle sized tree	Myanmar, Sri Lanka, Peshawar

Cynometra siwalika Awasthi & Prasad, 1990	*Cynometra ramiflora* L.	Evergreen	Tree	South India, Andaman, Sri Lanka, Malaya Archipelago, Sundarbans
Millettia arjunkholaensis n. sp.	*Millettia eriantha* Benth.	Evergreen	Climber	South east Asia
Saraca palaeoindica n. sp.	*Saraca indica* L.	Evergreen	Small tree	South India, South east Asia
Millettia miocinerea Prasad *et al.,* 2016	*Millettia cinerea* Benth.	Evergreen	Climber	North–east India Himalaya, West China
Sindora eosiamensis n. sp.	*Sindora siamensis* Teijsmex Miq.	Evergreen	Large tree	Cambodia, Laos, Malaysia, Thailand, Vietnam
Sindora leguminocarpoides n. sp.	*Sindora siamensis* Teijsmex Miq.	Evergreen	Large tree	Cambodia, Laos, Malaysia, Thailand, Vietnam
Pongamia arjunkholaensis Prasad, 2013	*Pongamia glabra* Vent.	Evergreen to moist deciduous	Moderate tree	Andaman, Sri Lanka, Myanmar, Malaya, South China, Fiji Island, Tropical Australia
Lythraceae				
Lagerstroemia corvinusii Prasad, 2013	*Lagerstroemia flosreginae* Retz.	Mixed deciduous	Tree	North east India, Chhota Nagpur, South India Myanmar, Sri Lanka
Lagerstroemia patelii Lakhanpal & Guleria, 1981	*Lagerstroemia speciosa* (L.) Pers.	Evergreen	Large tree	North–east India, Lower Myanmar Western Ghats, Sri Lanka, Malaya
Combretaceae				
Combretum siwalicum n. sp.	*Combretum roxburghii* Sprengel	Mixed deciduous	Tree	Bangladesh, India, Laos, Myanmar, Nepal, Sri Lanka, Thailand, Vietnam
Combretum sahnii Antal & Awasthi, 1993	*Combretum decandrum* Jacq.	Mixed deciduous	Large climbing shrub	Sub–Himalayan tract Myanmar, Central Provinces
Terminalia arjunkholaensis n. sp.	*Teminalia tomentosa* Wight & Arn.	Mixed deciduous	Large tree	Sub–Himalayan tract, both peninsulas
Myrtaceae				
Eugenia nepalensis n. sp.	*Eugenia diospyrifolia* Wall.	Evergreen	Middle sized Tree	Upper Myanmar, Khasi and Garo Hills
Eugenia lamhiensis Prasad *et al.,* 2016	*Eugenia jambolana* Lam.	Evergreen	Tree	India, Bangladesh, Pakistan, Nepal, Sri Lanka, Malaysia, Philippines, Indonesia
Rubiaceae				
Randia premacrophylla n. sp.	*Randia macrophylla* Hook. f.	Evergreen	Shrub	South east Asia
Sapotaceae				
Crysophyllum churiensis Prasad, 2007	*Crysophyllum roxburgii* G. Don	Evergreen	Tree	North east India, Western Ghats, Sri Lanka
Crysophylloxylon pondicherriense Awasthi, 1977a	*Crysophyllum roxburgii* G. Don	Evergreen	Tree	North east India, Western Ghats, Sri Lanka

Ebenaceae				
Diospyros embryopterisites Varma, 1968	*Diospyros embryopteris* Pers.	Evergreen to moist deciduous	Middle sized tree	Sub–Himalayan Tract South India, Sri Lanka, Malaya Archipelago
Diospyros masotkholaensis Prasad *et al.,* 2016	*Diospyros oleifolia* (Wallex) Kurz	Evergreen	Medium sized tree	South India, Myanmar, Java
Diospyros pretoposia Prasad, 1990	*Diospyros toposia* Buch–Ham.	Evergreen	Medium sized tree	Khasi Hills, Cachar, Chittagong, Tinnevelli hills Sri Lanka
Boraginaceae				
Cordia siwalica n. sp.	*Cordia sebestena* L.	Evergreen	Tree	Tropical America, Southern Florida, Central America
Lauraceae				
Cinnamomum raptiensis n. sp.	*Cinnamomum mollissimum* Hook. f.	Evergreen	Tree	Perak, Goping (Kunstler), Thaipang, Penang
Cinnamomum corvinusianum Prasad *et al.,* 2016	*Cinnamomum culitlawn* L.	Evergreen	Moderate size tree	China, Malaya
Persea masotkholaensis n. sp.	*Persea glaucescens* (Nees) D.G. Long	Evergreen	Tree	Tropical Australia, America
Persea siwalika Prasad *et al.,* 2016	*Persea glaucescens* (Nees) D.G. Long		Large tree	Bangladesh, Bhutan, India, Myanmar, Nepal
Actinodaphne palaeoangustifolia Antal & Awasthi, 1993	*Actinodaphne angustifolia* Nees	Evergreen	Large tree	North–east India, Myanmar
Moraceae				
Artocarpus arjunkholaensis n. sp.	*Artocarpus rigidus* Blume	Evergreen to moist deciduous	Tree	South India, South east Asia
Ficus preglobosa n. sp.	*Ficus globosa* Blume	Evergreen	Large climber	Tenasserim

genus *Arytera* (*Ratonia*) is represented by two species, viz. *A. nepalensis* and *A. miolittoralis*.

Besides the above, family Dipterocarpaceae is also well represented in the assemblage. Four leaves, viz. *Shorea* Roxb. ex C.F. Gaertn., *Isoptera* Scheff. ex Burck, *Dipterocarpus* Gaertner and *Anisoptera* Korth. are assigned to it. The species of *Shorea, S. siwalika, I. siwalica* of *Isoptera* and *D. koilabasensis* of *Dipterocarpus* are not new records but were reported earlier from the Siwaliks (Antal & Awasthi, 1993; Prasad *et al.,* 1999) but species of *Anisoptera, A. palaeoscaphula* and a species of *Dipterocarpus, D. palaeoindicus* are new records from the area.

The family Annonaceae is also well represented in the assemblage by three leaf form genera, viz. *Anaxagorea* A. St.–Hil., *Mitrephora* Hook. f. & Thomson and *Uvaria* L. Each of the above is represented by a single species, new to the Siwaliks.

Apart from the above, some dicot families like Achariaceae (Flacourtiaceae), Lauraceae and Moraceae are represented by two form genera each. While species of the two form genera *Artocarpus* Forster & Forster and *Ficus* L. of Moraceae are new records, Achariaceae represented by the form genus *Ryparia* Blume also exhibits a new species *R. arjunkholaensis*. Family Lauraceae represented by *Cinnamomum* Schaeff. and *Persea* Miller show a new species each *C. raptiensis* and *P. masotkhoaensis* respectively. The remaining families of dicots described in the text are represented by a single leaf form genus each. Each genus consisting of a single, new or already reported species except for the family Tiliaceae with form genus *Grewia* L. represented by two new species, *Grewia palaeodisperma* and *G. nepalensis.*

Assuming the fact, that elements recovered from the Arjun Khola beds comprise remains of a past flora existing in the Siwalik hill region during the Miocene–Pliocene times

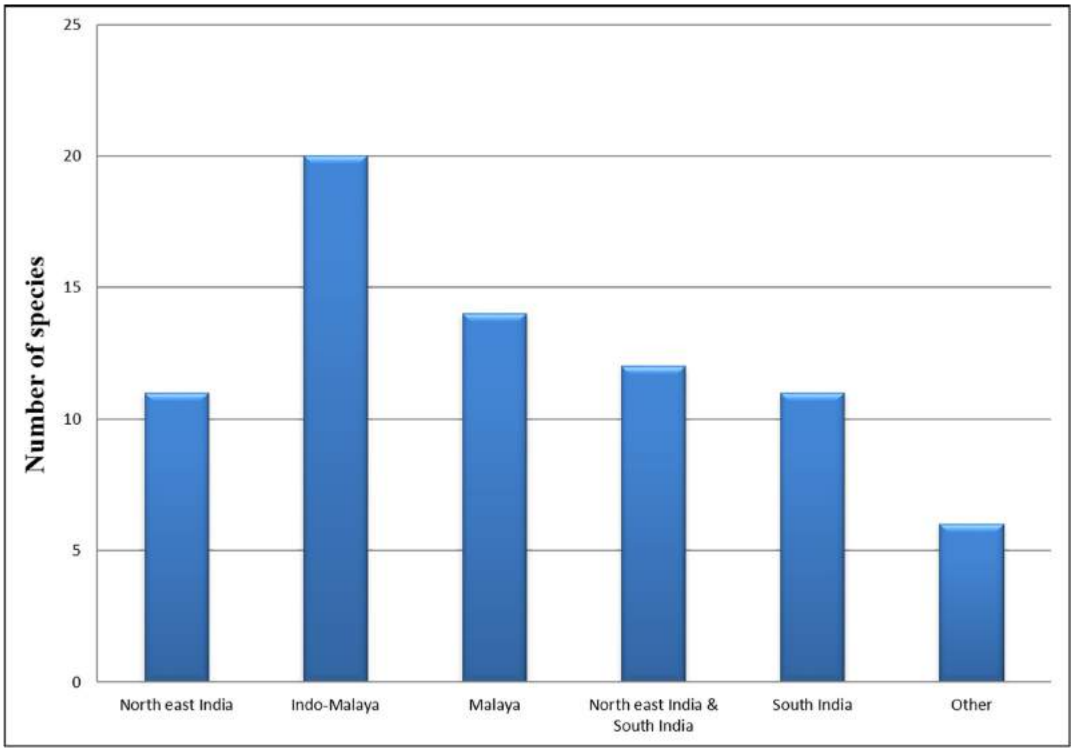

Fig. 7–Present day distribution of comparable extant taxa of Arjun Khola fossil assemblage.

of Neogene and on applying the extant, exotic and extinct categories to the fossil components (as is practiced for constituents of modern day flora of a region) it was observed that quite a number of fossils had their comparable living counterparts still persisting in and around the region (Table 8). Such components could be categorized under extant group of the flora. Similarly, other fossil taxa, with no comparable living equivalents, in or near the locality presently, but growing elsewhere, in other regions of Nepal and India are considered as exotic taxa while fossil taxa with no living counterparts in Nepal and India but otherwise, flourishing in other regions of the world, are considered as extinct taxa. Thus, after setting aside the few fossil taxa enlisted under extant category, it was found that a handsome majority of the assemblage was comprised of exotic taxa, exhibiting a widespread distribution pattern in the Miocene but becoming restricted with the passage of time, gradually decreasing in numbers and finally disappearing from the region entirely on account of changed climatic conditions. Likewise, under the extinct taxa category are placed those elements, that had reached the Arjun Khola area in the Himalayan foot–hills from other sub–continents, either by dispersal mechanism or through existing land connections but which subsequently failing to adapt themselves to existing environmental conditions, disappeared from the region for ever.

Extant species of plants comparable to the Churia fossils, are presently distributed in the tropical evergreen to semi–evergreen forests of Western Ghats, northeast India, Andaman and Nicobar Islands, Myanmar and Malayan regions, but a few of them, still continue to occur in the sub–Himalayan tract, mostly in the valleys and along the river banks.

Earlier reports and present findings (Table 8) indicated that the whole assemblage appeared to represent a vegetation specially dominated by woody trees (59), a small number of shrubs (5), a few woody climbers (9) and an almost negligible number of herbs (Lakhanpal, 1967; Varma, 1968; Awasthi, 1977a, b; Prasad & Prakash, 1984; Awasthi & Prasad, 1990; Prasad, 1994a, b, 2006, 2007, 2013; Antal & Awasthi, 1993; Antal & Prasad, 1996a, b, c; Shashi *et al.*, 2006; Prasad & Pandey, 2008; Prasad & Gautam, 2016; Prasad *et al.,* 1999, 2016).

Palaeoclimatic implications

Palaeoclimate determination through the study of plant fossils is an important contribution of palaeobotanical studies. The Cenozoic fossil plants are believed to be reliable indicators of past climate, as many of them are identified with modern day plants that exist in forests of varied phytogeographical regions of the world. Knowledge of climatic conditions, prevailing in these regions in the present times, is believed to indicate the climate probably prevailing at fossil site region during sedimentation. In the case of Siwalik fossils too, determination of palaeoenvironmental condition, prevailing in the area during Miocene epoch, was similarly determined.

Table 9—Physiognomic characters of fossil leaves recovered up to date from Arjun Khola area, western Nepal.

	PHYSIOGNOMIC CHARACTERS						
Fossil Taxa	**Average leaf size** sq. cm.	**Leaf margin** Entire (E) Non–entire (N)	**Nature of petiole** Normal (N) indistinct (–)	**Leaf texture** Chartaceous (CH) Coriaceous (CO)	**Leaf base shape** Acute(A) Obtuse (O) Cuneate (C) Attenuate (AT) Cordate (CR) Indistinct (–)	**Leaf organization** Compound (C) Simple (S)	**Venation pattern** Close (C) Distant (D) Indistinct (–)
Clinogyne ovatus Awasthi & Prasad	29.12	E	–	CH	O	S	–
Dillenia palaeoindica Prasad & Prakash	25.16	N	–	CH	–	S	C
Anaxagorea mioluzonensis n. sp.	331.36	E	–	CH	A	S	D
Melodorum arjunkholaensis Prasad *et al*	41.08	E	N	CH	A	S	C
Mitrephora siwalika Antal & Awasthi	35.28	E	N	CH	A	S	C
Mitrephora mioreticulata n. sp.	110.78	E	–	CH	A	S	C,D
Uvaria nepalensis Prasad *et al*	13.89	E	–	CH	A	S	C,D
Uvaria miolucida n. sp.	49.17	E	–	CH	–	S	C
Tinospora siwalika n. sp.	4.08	E	–	CH	CR	S	C
Hydnocarpus lamhiensis Prasad *et al*	77.29	E	N	CH	OA	S	C,D
Hydnocarpus mioalpinus Prasad	29.75	E	–	CO	O	S	C
Ryparia arjunkholaensis n. sp.	193.05	E	–	CH	–	S	D
Calophyllum mioelatum n. sp.	37.68	E	–	CO	–	S	–
Calophyllum suraikholaensis Prasad *et al*	68.80	E	N	CO	A	S	–
Anisoptera palaeoscaphula n. sp.	72.20	E	–	CH	O	S	C
Shorea siwalika Antal & Awasthi	27.76	E	–	CH	O	S	C
Dipterocarpus koilabasensis Prasad *et al*	28.80	E	–	CH	O	S	C
Dipterocarpus palaeoindicus n. sp.	75.36	E	–	CH	–	S	C

Isoptera siwalica Prasad *et al*	28.86	E	–	CH	O	S	C
Hopea masotkhoaensis Prasad *et al*	38.22	E	–	CH	A	S	C
Grewia palaeodisperma n. sp.	24.39	N	–	CH	O	S	C
Grewia nepalensis n. sp.	53.20	E	–	CO	O	S	C
Grewia miopaniculata Prasad *et al*	13.23	E	–	CH	O	S	D
Sterculia arjunkholaensis n. sp.	48.96	E	–	CH	–	S	C,D
Sterculia kathgodamensis Prasad	58.75	E	–	CO	A	–	C
Erythrochiton masotkholaensis n. sp.	48.00	E	–	CH	AT	S	D
Zanthoxylum siwalicum Prasad & Awasthi	18.60	E	–	CO	A	S	C,D
Commiphora precaudata Shashi *et al*	13.50	E	–	CH	O	S	C
Berchemia balugoloensis Lakhanpal	20.16	E	–	CH	A	S	C
Cayratia palaeojaponica n. sp.	21.70	E	–	CH	A,AT	C	D
Arytera (*Ratonia*) *nepalensis* n. sp.	52.50	E	–	CH	O	S	C
Arytera (*Ratonia*) *miolittoralis* n. sp.	21.79	E	–	CH	–	S	C
Euphoria churiaensis n. sp.	8.52	E	N	CH	A	S	C
Filicium koilabensis Prasad	14.26	E	N	CH	A	S	C
Harpullia siwalica Prasad & Awasthi	22.40	E	–	CH	A	S	C
Sapindus palaeomukorossi n. sp.	22.55	E	–	CH	O	S	C
Otonephelium nepalensis Prasad *et al*	51.50	E	–	CH	AT,A	S	C,D
Sapindus arjunkholaensis Prasad *et al*	20.46	E	–	CH	O	S	C
Buchanania raptiensis n. sp.	75.50	E	–	CH	A	S	C,D
Gluta siwalika Awasthi & Prasad	65.00	E	–	CO	A	C	C
Bauhinia palaeomonandra n. sp.	55.25	E	–	CH	CR	C	D
Cassia arjunkholaensis n. sp.	33.18	E	–	CH	O	C	C
Cynometra siwalika Awasthi & Prasad	10.40	E	–	CO	A	C	C

Millettia arjunkholaensis n. sp.	28.42	E	–	CH	–	C	C,D
Millettia miocinerea Prasad *et al*	23.04	E	–	CH	A	C	C,D
Saraca palaeoindica n. sp.	34.50	E	–	CH	A	C	C
Sindora eosiamensis n. sp.	5.59	E	–	CH	A	C	C
Pongamia arjunkholaensis Prasad	15.90	E	–	CH	–	C	C
Combretum siwalicum n. sp.	91.88	E	–	CH	–	S	C
Combretum sahnii Awasthi	45.15	E	–	CH	–	S	C,D
Eugenia nepalensis n. sp.	51.60	E	–	CH		S	C,D
Eugenia lamhiensis Prasad *et al*	25.60	E	–	CH	A	S	D
Lagerstroemia patelii Lakhanpal & Guleria	52.25	E	–	CH	O	S	C
Lagerstroemia corvinusii Prasad	44.00	E	–	CO	–	S	C
Randia premacrophylla n sp	70.65	E	–	CH	–	S	C
Diospyros embryopterisites Varma	19.61	E	–	CH	A	S	C
Diospyros masotkhoaensis Prasad *et al*	67.20	E	–	CO	A	S	–
Diospyros pretoposia Prasad	95.40	E	–	CO	A	–	C
Cordia siwalica n. sp.	55.80	E	–	CH	O	S	C
Cinnamomum raptiensis n. sp.	48.96	E	–	CH	–	S	C
Cinnamomum corvinusianum Prasad *et al*	30.68	E	–	CH	A	S	C
Persea masotkhoaensis n. sp.	63.55	E	–	CO	AT	S	C
Persea siwalika Prasad *et al*	9.70	E	–	CH	A	S	C,D
Actinodaphne palaeoangustifolia Antal & Awasthi	22.75	E	–	CH	C	S	C
Artocarpus arjunkholaensis n. sp.	138.46	E	–	CH	O	S	C
Ficus preglobosa n. sp.	45.05	E	–	CH	O	S	C

In addition to the above mentioned method, determination of palaeoclimate is also possible on the basis of plant megafossils. It is generally conducted by two approaches:–

(i) The **Co–existence Approach**, i.e. by comparison of fossil leaf–impressions with leaves of similar looking extant plants. (ii) The **Foliar Physiognomic Approach**, i.e. structural features of leaf–impressions, like shape, size, apex, base, margin, vein density, etc. indicating environmental conditions around the area.

(i) The Co–existence Approach (CoA) developed by Mosbrugger and Utescher (1997) and subsequently enhanced by Utescher *et al.* (2014), is based on the concept that fossil plant taxa (particularly that of the tertiary flora), have similar climatic requirements as their Nearest Living Relatives (NLR). The analysis consists of three broad steps: (1) the nearest living relative (NLR), is determined for individual fossil taxon (2) the modern distribution area is compiled for individual NLR (3) range of climate parameters Mean Annual Temperature and Mean Annual Precipitation (MAT, MAP), are determined for the distribution area(s) and lastly, (4) for each climate parameter analyzed, the climatic ranges under which maximum number of NLRs of individual fossil flora can co–exist (Coexistence Interval), is determined. Then, if coexistence interval of two comparable modern species of the fossils, i.e. *Clinogyne dichotoma* (Roxb.) Salisb. and *Artocarpus rigidus* Blume is about 18º–34ºC and 21º–32°C respectively, it means that the comparable fossil species *Clinogyne ovatus* and *Artocarpus arjunkholaensis* n. sp., were presumably also surviving under a Mean Annual Temperature (MAT) between 18°–34°C and 21°–32°C respectively. Indicating thereby, both species probably coexisted when Mean Annual Temperature (MAT) Co–existence interval was between 18°C and 34°C. Likewise, Co–existence intervals or MAT of 33 similar looking living relatives (NLR) of fossils of Arjun Khola assemblage were obtained from internet and through data from Indian Meteorological Department. The MAT value estimated by above method indicated MAT (Mean Annual Temperature) in the Himalayan foot hills of Arjun Khola area was 22–28°C during Miocene (Middle and Upper) whereas the present day MAT of Arjun Khola area (based on data of Department of Hydrology and Meteorology, Nepal) in the Himalayan foot hill zone is 23°C. (Fig. 8a).

In a similar way, Coexistence intervals of Mean Annual Precipitation (MAP), of comparable extant species were obtained from Indian Meteorological Department through internet which showed the MAP value for extant species ranging between 2200–3200 mm. It is therefore presumed, that somewhat similar conditions of precipitation prevailed around the Arjun Khola area in the past (Fig. 8b).

(ii) Foliar Physiognomic method is independent of systematic relationship of species therefore, errors in interpretation of palaeoclimate are minimized, compared to above Co–existence approach. This approach utilizes physiognomic features such as leaf shape, size, texture, margin, drip tips, apex and base, venation density, petiole and leaf organization of the fossil leaves for interpreting the palaeoclimate (Table 9). A cursory glance over the fossil leaves recovered from Arjun Khola area, revealed dominance of entire margined leaves that indicated a warm Ttropical climate for the region. Even leaf size, is considered to be a reliable indicator of terrestrial palaeoclimate as there is a strong relation between the Mean Annual Precipitation (MAP) and average leaf area.

Study of physiognomic characters of leaf–impressions, collected from the Siwalik sediments of western Nepal, also threw light on climatic conditions prevailing in the area at the time of deposition of the plant debris containing sediments. As a majority of fossil leaves in the assemblage, showed entire margins, apparent greater venation density, large to medium size with drip tips (Table 9) they collectively indicated a tropical to sub–tropical climate in the middle Miocene–Pliocene epoch all along the Himalayan foot–hills.

Out of all the leaf features mentioned above, the best indicator of climate appears to be the leaf margin analysis (LMA), viz. entire versus non–entire. According to Bailey and Sinnott (1916), woody plants of tropical lowlands generally possessed entire margins, while leaves of trees growing in temperate regions possessed non–entire margins. Even, Wolf (1969) concluded that Tropical rainforests had the highest percentage of entire margined species. However, this percentage decreased with decreasing temperature either due to increasing altitude or with increasing latitude. Dicot families, like Annonaceae, Lauraceae, Ebenaceae, Clusiaceae, Sapotaceae, Dipterocarpaceae and Apocynaceae with typical entire margined leaves, are practically absent from mesophytic cool Temperate regions. On the contrary, non–entire margined leaves of families Betulaceae, Platanaceae, etc. are absent from lowland tropical areas. However, determination of climate becomes difficult, in case where leaves are both, i.e. entire, as well as non–entire margined, as observed in leaves of families Malvaceae, Rosaceae, Ulmaceae, Fagaceae, Tiliaceae, Flacourtiaceae (Achariaceae), Anacardiaceae and Fabaceae.

Since trees of most of the leaf form genera represented in the Siwalik flora, of the area are no longer present in the region today but distributed in the Tropical evergreen and moist deciduous forests of northeast India, Bangladesh, Myanmar and Malaya (Table 8; Fig. 7), it is surmised that a Tropical warm and humid climate prevailed in the Arjun Khola area at the time of deposition, instead of the relatively dry climate prevailing now–a–days. This alteration of climate since the deposition of the Siwalik sediments resulted in the extinction of several members of families, like Dipterocarpaceae, Fabaceae, Anacardiaceae, etc. which could not tolerate the climatic changes since the Middle Miocene within this region and disappeared.

Even habit and habitat of modern day equivalent taxa, indicated a warm and humid climate with plenty of rainfall in the Arjun Khola area during Middle Miocene–Pliocene epoch, quite different to the relatively dry climate in the area at the present.

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

Phytogeographical Implications

In the orogenic movement of Himalayas, middle Miocene Period has been considered as most important. During this period, several significant changes occurred in physiography, environment and floral characteristics resulting

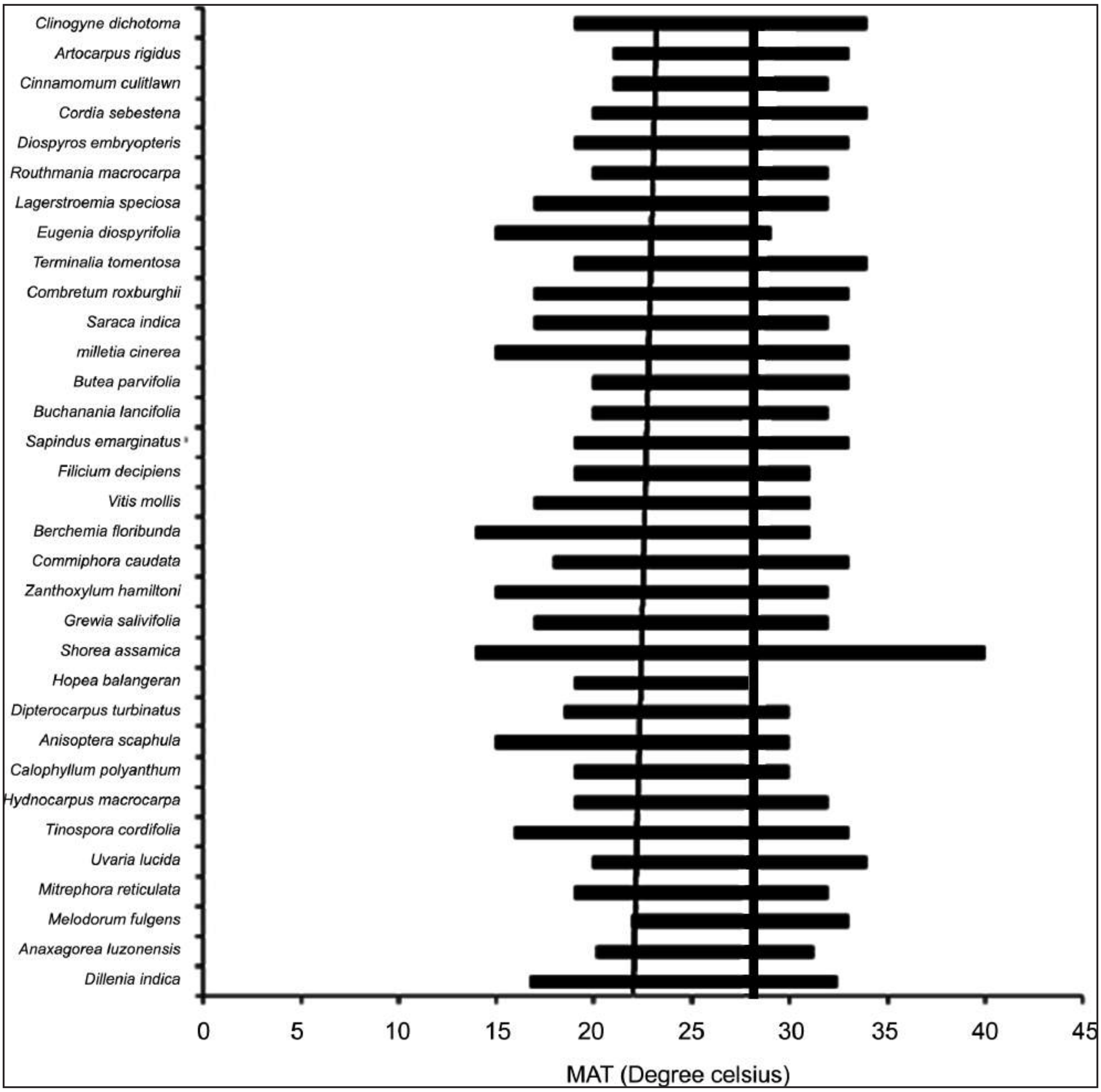

Fig. 8a–Showing the co-existence intervals of climatic parameter Mean Annual Temperature (MAT) of modern relatives of fossil species recorded from Arjun Khola area, western Nepal. The vertical line indicates the common range of MAT and ▬ indicates the intervals of co-existence (after Prasad, 2008, 2013; Prasad & Gautam, 2016, Prasad *et al.*, 2016).

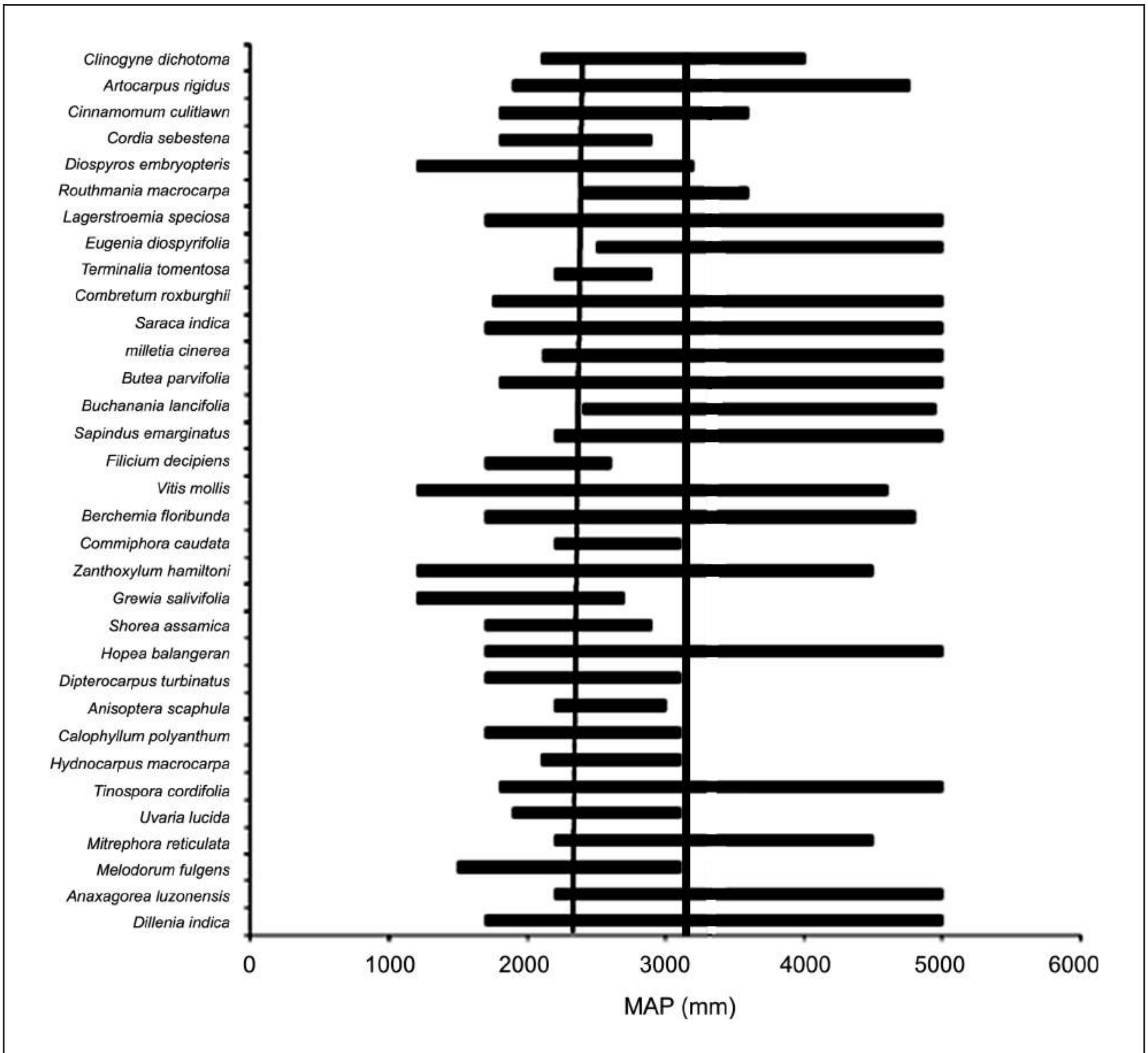

Fig. 8b–Showing the co-existence intervals of climatic parameter Mean Annual Precipitation (MAP) of modern relatives of recorded fossil species from Arjun Khola area, western Nepal. The vertical line indicating the common range of MAP and ▬ indicate the intervals of co-existence (after Prasad, 2008, 2013; Prasad & Gautam, 2016, Prasad *et al.*, 2016).

in the gradual perishing of older life forms which could not accommodate themselves to the new environment and were replaced by new plants or animals that came into existence and flourished.

Geological events in the region resulting in the establishment of land connection between India and south–east Asia through Myanmar also strongly influenced the phytogeography of the region during the Siwalik period (Smith & Briden, 1979). A number of plants migrated from south–east Asia to India via Myanmar and vice–versa. Consequently, many taxa, especially members of Dipterocarpaceae and Fabaceae, existing in south–east Asia in the Palaeogene appeared on the Indian subcontinent and Nepal in the Neogene.

Phytogeographical data suggests that taxa flourishing in the Himalayan foot–hills during Siwalik period have migrated elsewhere in modern times possibly south and south eastwards in search of favourable conditions for luxuriant growth.

The present day distribution of modern equivalents of the 43 taxa recovered from the Siwaliks of Arjun Khola, showed quite a number of these, like *Anisoptera*, *Dipterocarpus*, *Euphoria, Bauhinia*, *Cassia*, etc. occurred both in Nepal and Malaya. They indubitably indicated a fair exchange of floral elements, between the two sub–continents after land connections were established during the Mio–Pliocene Period. On the other hand, other taxa like *Shorea* Roxb. ex C.F Gaertn., *Sterculia* L., *Hydnocarpus* Gaertn. and *Millettia* Wight & Arn. suggested migration of taxa from Malaya to Nepal during the Neogene. They flourished around the Arjun Khola area during the deposition of Siwalik sediments and disappeared later, on the advent of unfavourable environmental conditions. Besides these, a few taxa are also found growing in the tropical regions of Africa, China, Sri Lanka, etc. in the present times.

A perusal of earlier literature on records of fossil remains, reported so far from all the Siwalik hill localities of Nepal and India, showed dominance of fabaceous taxa at all the sites (Prakash & Tripathi 1992; Prasad, 1994a–d; Prasad, *et al.,* 1997, 1999, 2004; Antal & Awasthi 1993; Prasad & Awasthi 1996; Antal & Prasad, 1995, 1996a–c, 1997; Antal *et al.,* 1996). Dominance of the fabaceous taxa was also observed in the present study. The mentioned taxa were not recorded earlier from Paleocene–Eocene sediments in Nepal as well as India, suggesting a late entry of such taxa into the Indian subcontinent, probably prior to the Miocene, only after development of land connections that allowed free movement of elements from regions where they were flourishing to regions showing poor distribution. In the case of the fabaceous taxa *Millettia* Wight & Arn., which was not authentically reported from the Paleogene Period of Indian subcontinent till the end of Oligocene or early Miocene, but recorded from middle Miocene suggested late entry of the taxa into the Indian sub–continent after the establishment of land connections with south–east Asian region (Smith & Briden, 1979; Smith *et al.,* 1994). Perhaps, this was the appropriate time for south–east Asian elements to enter into the Indian subcontinent, through its northeast corner during early Miocene (Agarwal *et al.,* 2006). Later on, these taxa became abundant and were growing luxuriantly during the Neogene throughout India (Guleria, 1992; Prasad, 2008). Another cause of luxuriant growth and richness of family Fabaceae at the end of Oligocene was global warming which was at its peak in the middle Miocene (Zachos *et al.,* 2001; Punyasena *et al.,* 2008). Phylogenetic evidence suggests that the family Fabaceae evolved in tropical/sub–tropical regions along the Tethys seaway during Paleogene Period (Schrine *et al.,* 2005). Other fabaceous taxa were also authentically not recorded from the Paleogene sub–period of India, Nepal and Bhutan, which indicated that the Asian elements might have entered later, in the Indian subcontinent during Miocene Period, only after the establishment of land connections with south–east Asia.

The dipterocarps too had encountered a similar situation. Both the families Fabaceae and Dipterocarpaceae were poorly represented or totally absent from the Siwalik region in the Paleogene and had migrated to the region in the Neogene only after establishment of land connections. Phytogeographically, Dipterocarpaceae is regarded as an important family as its fossil record suggests that it originated during the early Middle Oligocene (Merrill, 1923; Muller, 1970), in western Malaysia (Lakhanpal, 1974). *Dipterocarpus* Gaertner, a significant genus of the Neogene flora of India is not authentically recorded from sediments older than Miocene and is no longer extant now–a–days, all along the Himalayan foot hills where they were growing in abundance during Mio–Pliocene times. Presently, the genus *Dipterocarpus* consists of about 80 species out of which, more than 50 species occur in western Malaysia (Desch, 1957). From western Malaysia the dipterocarps spread eastward to Philippines and northwards through Myanmar to India. Their existence in the Himalayan foot hills of Nepal during Miocene times indicated the existence of evergreen forests flourishing under warm humid conditions. The finding of dipterocarp fossils in the Siwalik sediments of Himalayan foot hills of Nepal also suggested their migration from South–east Asian regions during early Miocene but later becoming extinct due to unfavourable condition prevailing in the region as a result of the uplift of Himalayas. Presently, dipterocarps such as *Dipterocarpus, Anisoptera, Isoptera, Shorea,* etc. do not grow in the Siwalik region (Himalayan foot hills) because of change in vegetation pattern from evergreen to mixed deciduous forests with reduced precipitation. Instead, they are found growing luxuriantly in the evergreen forests of southern and north–eastern parts of India and south–east Asian region. Occurrence of fossil woods of Malaysian dipterocarps in other Himalayan foot–hill beds, indicated the possibility of dipterocarps having a wider distribution pattern in the Mio–Pliocene Period but gradually decreasing, perhaps, due to change in climatic conditions. Alternatively, possibility of their migration from Malaysia at the time of earlier land connections and subsequent extinction cannot also be ruled out.

In the case of family Sapindaceae, the taxon *Arytera* (*Ratonia*) Blume is new to the Tertiary flora of India and Nepal (Prasad, 2010). However, in evaluating evolutionary history of Sapindaceae, Harrington (2008) opined that the family originated during the Pliocene–Miocene, rather than in the Paleocene. In India the oldest record of Sapindaceae (fossil wood) is from the late Cretaceous of Deccan Intertrappean beds (Dayal, 1965; Mehrotra, 1987). The family is primarily tropical or sub–tropical in distribution, showing centre of diversity in the south Asian regions, with some forms extending into the temperate regions of Asia and North America (Klassen, 1999).

The family Annonaceae represented by three taxa, viz. *Anaxagorea* A. St.–Hil., *Mitrephora* Hook. f. & Thomson and *Uvaria* L. in the assemblage, is considered to be a pantropical family occurring mainly in rainforests, with few occurrences in the temperate regions (Richardson *et al.,* 2004).

In the case of family Combretaceae too, represented by *Combretum* L. and *Terminalia* L. in the Arjun Khola Assemblage it was observed that the family occurred throughout the tropical and sub–tropical regions with limited spread into warm temperate zones. The oldest confirmed remains of Combretaceae (*Terminalia*) are from the late Cretaceous of Portugal (Friis *et al.,* 1992; Stace, 2007). In India, fossils of Combretaceae have been reported from the late Cretaceous and Paleocene to Eocene deposits of western India (Mahabale & Deshpande, 1965; Prakash & Dayal, 1968; Singh *et al.,* 2010, 2011; Mehrotra, 2000a; Sahni *et al.,* 2006).

Besides the above, family Lythraceae represented in the assemblage by leaves of *Lagerstroemia* L., is also known to occur in the Mio–Pliocene of different localities of India and Nepal (Prasad, 2008). This family of the order Myrtales is comprised mainly of woody plants that have worldwide distribution mostly in tropical to the sub–tropical region, (Dahlgren & Thorne, 1984). They occur primarily in the moist to wet habitats including mangroves, rainforests and marshes. The family has an extensive fossil record that includes both extant and extinct genera (Tiffney, 1981). In India, the oldest records of *Lagerstroemia* are from the late Cretaceous (Intertrappean beds) from where both leaves and silicified fruits (Mehrotra *et al.,* 2007) were recorded.

Out of the two taxa of family Achariaceae (Flacourtiaceae) identified in the assemblage, *Hydnocarpus* is an Indo–Malaysian genus according to Mabberley (1997). Fossil record suggests that it was common in India during the Mio–Pliocene times (Prasad, 2008).

Leaves of *Diospyros* L., another constituent of the Arjun Khola plant assemblage, is one of the most common genera of the family Ebenaceae. It is native to the tropical and sub–tropical regions and shows greatest diversity of species in the Indo–Malayan region.

The Arjun Khola Assemblage is also comprised of two taxa attributed to the Lauraceae, viz. *Cinnamomum* Schaeff. and *Persea* Miller. Lauraceous fossils are common in Cretaceous and Tertiary sediments of both the Northern and Southern Hemispheres (Hills, 1986; Drinnan *et al.,* 1990; Carpenter & Pole, 1995; Eklund & Kvacek, 1998; Herendeen *et al.,* 1999). Several fossil woods showing resemblance with the family Lauraceae are known from Neogene sediments of India. They have generally been reported under the form genus *Laurioxylon* Felix (Lakhanpal *et al.,* 1981; Awasthi & Jafar, 1990; Prasad, 1990c; Tiwari & Mehrotra, 2000). Fossil leaves resembling *Cinnamomum* (Lakhanpal & Guleria, 1981; Lakhanpal & Awasthi, 1984; Prasad, 1990b; Antal & Awasthi, 1993; Konomatsu & Awasthi, 1999; Prasad, 2008; Shashi *et al.,* 2008) and *Persea* (Lakhanpal & Guleria, 1978) are also recorded from both Neogene and Paleogene sediments of the Indian subcontinent.

Members of family Lauraceae mostly showing arboreal habit are presently distributed throughout Tropical evergreen and moist deciduous forests of north–east India, Myanmar, Malaya and adjoining areas (Hooker, 1879, 1894; Champian & Seth, 1968; Gamble, 1972). Occurrence of lauraceous fossil leaves in the study area, predicted prevalence of a warm and humid climate in and around the fossil locality at the time of deposition, in contrast to present day relatively dry climate.

A fleeting glance over the literature on fossils described so far from all the Siwalik sites of Nepal and India, indicated the presence of innumerable common elements at various sites. They include *Calophyllum* L.*, Grewia* L.*, Zizyphus* Mill.*, Bauhinia* L.*, Cinnamomum* Schaeff.*, Clinogyne* Salisb. (Awasthi, 1992; Awasthi & Prasad, 1990; Prasad & Awasthi, 1996; Antal & Awasthi, 1993; Konomatsu & Awasthi, 1996). This could be possible, only when physical conditions controlling the distribution pattern of plants remained nearly equable throughout the Himalayan frontal zone during the sedimentation of the Arjun Khola rocks. Excessive humid condition seems to have prevailed all along, owing to several water bodies, such as lakes, swamps and rivers occupying vast areas in the region, favouring maximum development and proliferation of evergreen mesophytic low–land and tropical vegetation. Further, the climatic conditions became so conducive that the tropical evergreen families migrated to the Indian subcontinent (Awasthi, 1992; Guleria, 1992).

In the megafloral assemblage of Arjun Khola, more than twelve taxa are common to India and the Malayan region. These are *Dillenia* L. (Dilleniaceae), *Acharia* Thunb. (Achariaceae/ Flacourtiaceae), *Diospyros* L. (Ebenaceae), *Euphoria* Comm. ex Juss.*, Arytera* (*Ratonia*) Blume (Sapindaceae), *Cassia* L.*, Cynometra* L. (Fabaceae), *Anaxagorea* A. St.–Hil.*, Uvaria* L. (Annonaceae), *Cinnamomum* Schaeff. (Lauraceae), *Ficus* L.*, Artocarpus* Forster & Forster (Moraceae). Occurrence of such forms in the Arjun Khola area indicated a good exchange of taxa between the Indian and the Malayan Peninsulas. Again, contrary to above, quite a number of taxa like *Mitrephora* Hook.f. & Thomson (Annonaceae), *Ryparia* Blume (Achariaceae) and *Terminalia* L. (Combretaceae), believed to have been restricted to the Malayan region alone, were found to be present in the presently studied assemblage too.

However, considering the wide extent of Siwalik (Churia) sediments and the huge amount of plant material entombed therein, the authors feel the number of taxa recognized so far is a very small fraction of the vast Siwalik flora lying embedded within the rocks. Therefore, identification and documentation of more and more taxa, from different localities and areas of known stratigraphic sequences is necessary for precise reconstruction of the floristic and climatic conditions prevailing throughout the Siwalik succession.

Another importance of the extensive study of the plant fossils of the Siwalik (Churia) Group was to assess the magnitude of diversification and proliferation of tropical angiosperms in the northern part of peninsular and the extra peninsular regions of the Indian subcontinent with the advent of African and Malaysian elements.

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