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# SOME PLANT MEGAFOSSILS FROM THE SUB-HIMALAYAN ZONE (MIDDLE MIOCENE) OF WESTERN NEPAL

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## ABSTRACT

A systematic study on leaf impressions collected from the middle Miocene sediments of the Sub-Himalayan zone exposed near the Seria Naka and Koilabas, western Nepal, revealed the existence of nine more taxa during the middle Miocene. These taxa belong to the genera *Donax* (Marantaceae), *Uvaria* (Anonaceae), *Flacourtia* (Flacourtiaceae), *Qualea* (Polygalaceae), *Shorea* (Dipterocarpaceae), *Iodes* (Icacinaceae), *Ochna* (Ochnaceae) and *Paranephelium* and *Arytera* (Sapinadaceae). The genera like *Qualea, Iodes* and *Arytera* are new to the Tertiary sediments of Indian subcontinent. The present-day distribution of comparable extant taxa indicates existence of an evergreen to moist deciduous forest under tropical, warm humid climate in and around the study areas in the sub-Himalayan zone of western Nepal, as compared to the mixed deciduous forests there at present day.

**Keywords:** Plant megafossils, Sub-Himalayan zone, Churia Group, Middle Miocene, Palaeoclimate, western Nepal

## INTRODUCTION

The Sub-Himalayan zone is also called the Siwalik (Churia) zone and is delimited on the south by Main Frontal Thrust (MFT) and on the north by the Main Boundary Thrust (MBT). It consists basically of fluvial deposits of the Neogene age (23-1.6 Ma). This zone extends all along the Himalaya towards south, forming a hill range with a width of 8-50 km. The Sub-Himalayan zone is very rich in both plant and animal fossils. Seria Naka and Koilabas lie on the southern flank of the Sub-Himalayan zone in the Rapti Anchal of western Nepal (Fig.1). Earlier investigations on the megafossils from the Churia sediments of the Koilabas and Seria Naka area indicate the occurrence of a variety of taxa belonging to dicotyledonous families of angiosperm (Prasad *et al.*, 1999, 1997; Prasad, 1994a).

A rich collection of leaf impressions recently collected from the Lower Siwalik sediments exposed in the Seria nala and Koilabas nala section, western Nepal. The recent morphotaxonomical study has revealed the presence of nine more taxa viz., *Donax kasauliensis* Srivastava & Guleria, *Uvaria siwalica* Prasad, *Flacourtia koilabasensis,* sp. nov. *Qualea siwalica* sp. nov. *Shorea palaeocurtisii* sp. nov. *Iodes koilabasensis* sp nov. *Ochna miowallichii* sp.nov., *Paranephelium seriensis* sp. nov. and *Arytera seriensis* sp. nov. which have been described and discussed in the present communication.

## GEOLOGICAL BACKGROUND OF THE AREAS

The Himalaya is a young mountain system representing a broad, continuous arc along the northern fringes of the Indian subcontinent, from the bend of the Indus River in the northwest to Brahmaputra River in the east. The most important episode in the mountain building process during middle Miocene is the formation of a long and narrow depression on the northern border of India. This depression became the site of deposition of massive alluvial sediments derived from the existing mountain. These deposits constitute the Siwalik Group. The term 'Siwalik' was introduced by Cautley (1832) to designate the Sub-Himalayan hill ranges occurring between the Ganga and Yamuna rivers, which yielded memorable vertebrate fossils around Haridwar. Falconer (1835) also adopted this term to designate the nearly continuous Series of Tertiary sediments stretching from Punjab to Irrawadi, bounded by a major thrust, the Main Boundary Fault (MBF) in the north and the Indo-Gangetic alluvium in the south. It is generally 10-12 km wide with a steep scarp towards south and a gentle slope in the north..

The Siwalik Group represents clastic sediments of the nature of fresh water molasses. They accumulated under four different environments, viz., Lacustrine, Channel and flood plains, Outwash plain and Piedmont. They range in age from middle Miocene to middle Pleistocene and are underlain by the Lower Tertiary-Upper (Muree/Dharmsala) sediments.

Lithologically, the Siwalik Group represents a great thickness of detrital rocks, such as coarsely bedded sandstones, clays and conglomerates, 5000-5500 m in thickness. Since their discovery in 1832, the Siwalik vertebrates have presented a fascinating picture of mammalian evolution during the late Tertiary and early Quaternary of the India. A century and half ago, the study that began with the pioneering work of Cautley (1832), Falconer (1835), Baker and Durand (1836) continued up to the present day (Lydekker, 1876; Wyne 1877; Blanford, 1879; Medlicott 1879; Middlemiss, 1890; Pilgrim, 1913; Colbert, 1935, 1942; Wadia, 1928, 1968; Gill, 1951; Sahni and Mathur, 1964; Sahni and Khan, 1964; Tripathi, 1968 and Corvinus,1990).

In Nepal, the sediments equivalent of the Siwalik Group are known as the Churia Group of the Churia Hills. They are extensions of the Himalayan foot-hills (Siwalik Hills) of India. The Churia hills are distributed along the southern front of the Nepal Himalaya constituting a narrow belt of 800 km bounded by Main Boundary Thrust (MBT) to the north and Frontal Churia Thrust (FCT) to the south (Fig. 2). The Churia Group has been classified into two formations (Bordet, 1961; Gleinnie and Ziegler, 1964): (i) Lower Churia Formation (Sandstones Facies) and (ii) Upper Churia Formation (Conglomerate Facies). Chaudhuri (1983) suggested a three-fold lithostratigraphical classification of the Churia Group. The Lower Churia with an

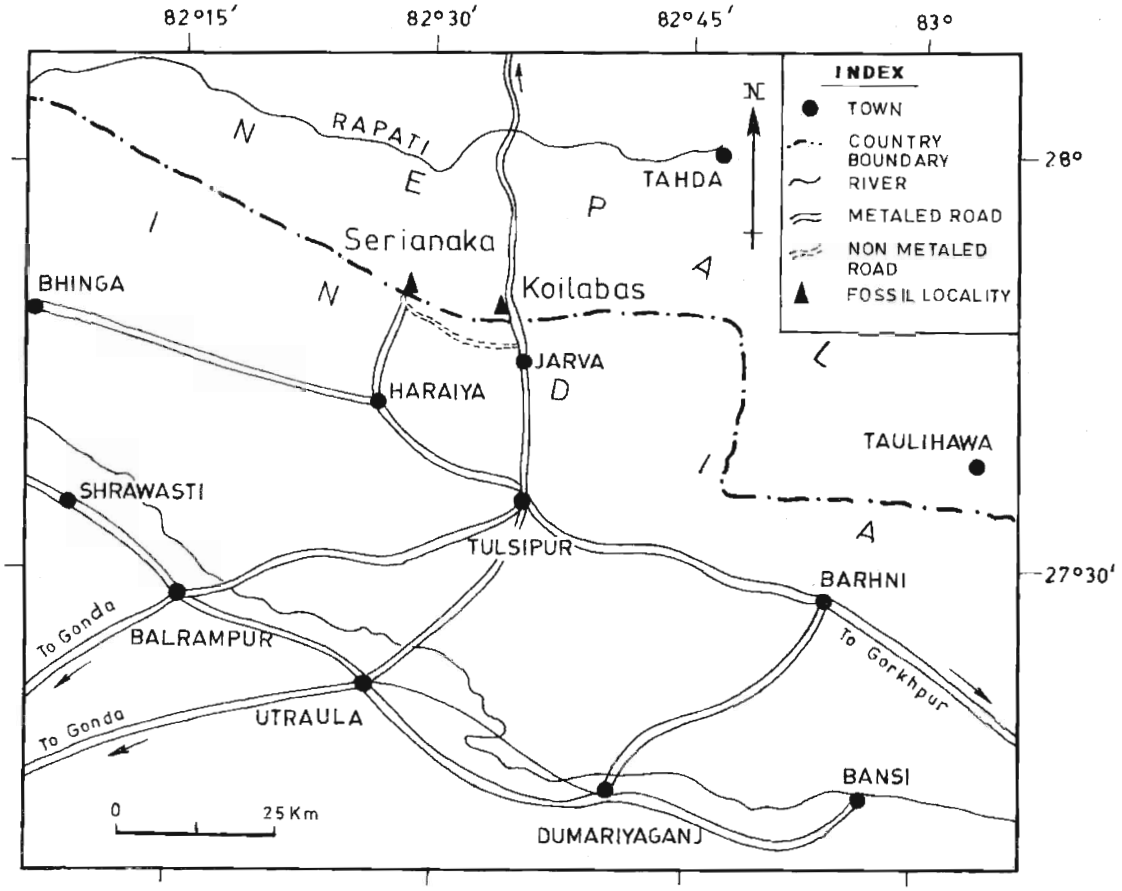



Fig. 1. Map showing location of fossil localities.

average thickness of about 1800 m is characterized by an alternate sequence of sandstones and clays. The Middle Churia is about 2000 m thick succession dominantly of arenaceous rocks with intercalation of clay beds. The Upper Churia consists of up to 2.5 km thick succession and is characterized by fine grained, poorly indurated sandy clays in the lower part and border conglomerate in the upper part of the succession. In the study area, Koilabas and Seria Naka, the Lower Churia is well exposed in both sides of the Koilabas and Seria nala coming down from the hills. In the Koilabas nala, this formation is exposed from Koilabas village to Darwaja and consists of fine-grained sandstones, calcareous thin limestones and variegated clays. Beyond Darwaja up to Chorkholi onwards, the rocks are supposed to represent the Middle Churia which is predominantly arenaceous in nature (Sharma, 1980).

## MATERIAL AND METHOD

The fossil localities in the Koilabas area lie at Indo-Nepal border in western Nepal and are easily approachable by road both from India and Nepal side. The sections belonging to the Lower Churia containing leaf-impressions are well exposed on both sides of Koilabas Nala and Seria Nala (Figure-3,4). The leaf-impressions occur in both grey as well as brown calcareous shales but they are more common and well preserved in the grey shale. More than 50 specimens of leaf-impressions were collected and have been studied in detail with the help of either hand lens or low power microscope under reflected light. In order to identify the leaf-impressions, the herbarium sheets of a number of extant taxa were examined at the Central National Herbarium, Sibpur, Howrah, West Bengal. For description of the leaf impressions, the terminology given by Hickey (1973) and Dilcher (1974) has been followed.

The photographs of the leaf-impressions were taken on 35mm B/W film by Yashica SLR Camera. The photographs of the comparable modern leaves showing similar features were also taken at the same magnification and put along with the fossil leaves for close comparison. All the specimens and their photo-negatives are preserved at the Botany Department, M.L.K. Post Graduate College, Balrampur, Uttar Pradesh.

## SYSTEMATIC DESCRIPTION

**Liliopsida**

*Family* **Marantaceae** Petersen

*Genus* ***Donax*** Lour.

*Donax kasauliensis* Srivastava & Guleria, 2002

(Pl.I, figs. 1,2)

*Material*: one well-preserved and almost complete leaf impression.

*Description* : Leaf simple, symmetrical, oblong to elliptical; preserved size 12 X 3.9 cm; apex broken; base slightly broken, seemingly obtuse; margin entire; texture chartaceous, petiole not seen; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, almost straight, thick in the basal region and thinning towards apex; secondary veins (2°) numerous, fine, arising very closely from the primary vein and run almost parallel towards apex at greater length, about 12 secondaries are prominent and arise from primary vein almost at equal

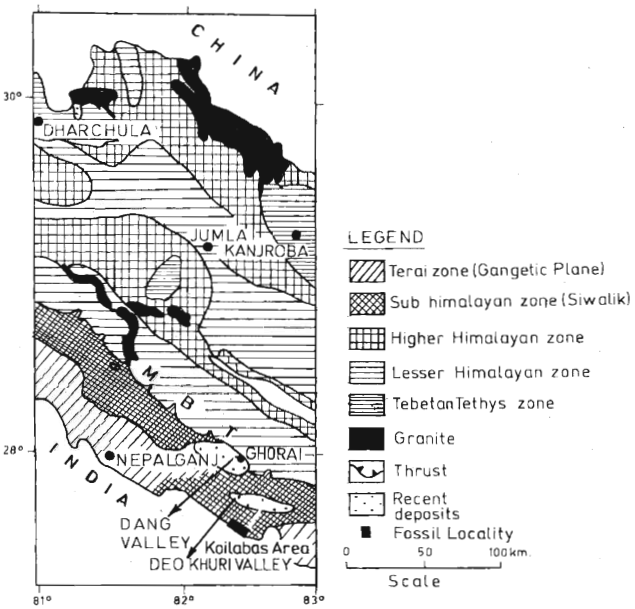



Fig. 2. A part of geological map of Nepal Himalaya showing Siwalik outcrops in the study area (Modified after Upreti and Yoshida, 2005 and Kizaki, 1994).

distance, angle of divergence narrow, acute (40° - 45°), unbranched; tertiary veins (3°) are not seen.

*Specimen No*: K- 4 (Pl.I figs 1).

*Locality*: Imlibasa, Koilabas Nala, western Nepal

*Modern affinity*: The most important features of the fossil leaf such as oblong to elliptical shape, entire margin, eucamptodromous venation and few prominent and numerous, fine very closely placed secondaries indicate that these leaves belong to the genus *Donax* Lour. of the family Marantaceae. The present fossil leaf has been compared with available three modern species of *Clinogyne* salisb. (now *Donax*) viz., *Clinogyne dichotoma* Salisb., *C. grandis* Benth. and *C. virgata* Benth. and *C. cannaeformis* Lour. Of these, the leaves of *Clinogyne grandis* Benth differ from the fossil in the comparatively distantly placed and prominent secondaries. Further, in *C. dichotoma* Salisb. and *C. virgata* Benth. the leaves are similar in size but differ in the course of secondaries arising from primary vein at less angle. Thus, the leaf of *Donax cannaeformis* (*C. cannaeformis*) of the family Marantaceae closely resemble the present fossil leaf in shape, size and venation pattern (Pl. I, fig. 3).

*Fossil records and comparison*: The fossil leaves resembling the genus *Clinogyne* ( now *Donax,* Mabberely, 1997) have been described earlier under the form species *C. Ovatus* Awasthi & Prasad, 1990 from the Siwalik sediments of Surai Khola area, Nepal and *Clinogyne* cf. *C. ovatus* from Kasauli Formation, Himachal Pradesh (Arya & Awasthi, 1995). These leave have been compared with the extant species *C. grandis* and therefore differ from the present fossils. *Clionogyne ovatus* Awasthi & Prasad possesses asymmetrical shape as compared to the symmetrical shape of present fossil. Moreover, the angle of divergence of secondaries in the former is comparatively less. Antal and Prasad (1995) described another fossil leaf showing affinity with *Clinogyne dichotoma* from the Siwalik sediments of the Oodlabari area in Darjeeling District, West Bengal. This fossil leaf differs in the nature and course of secondary veins which arise at a less angle (20°-30°) as compared to 40°-45° in the present fossil. Recently, Srivastava and Guleria (2002) described a fossil leaf resembling *Donax cannaeformis* Lour. from the Kasauli Formation, Himanchal Pradesh under a form species *D. kasauliensis*. On comparison, it has been found that both the present fossil and *D. kasauliensis* exhibit similar morphological characters. In view of this similarity, the present fossil in described as *D. kasauliensis*.

*Present-day distribution*: The genus *Donax* Lour. consists of 20 species which are mostly distributed in tropical Africa (Willis, 1973). The extant species *Donax cannaeformis* Lour., with which fossil shows closest affinity is a large shrub that grows throughout the Indo-Malayan region.

**Magnoliopsida**

*Family* **Anonaceae** Juss.

*Genus* ***Uvaria*** Linn.

*Uvaria siwalica* Prasad, 1994b

( Pl.II, figs. 1, 2)

*Material*: This has a part of well-preserved leaf.

*Description*: Leaf simple, symmetrical elliptic; preserved size 8 X 5.5 cm; apex broken; base broken; margin entire; texture thick chartaceous; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, straight; secondary veins (2°) 11 pairs visible, 0.5-1.0 cm apart, angle of divergence moderate acute (50°—60°), alternate to sub-opposite, thick, branched, uniformly curving up; intersecondary veins rare, simple; tertiary veins (3°) fine, angle of origin RR, percurrent, mostly alternate, straight, oblique in relation primary vein,

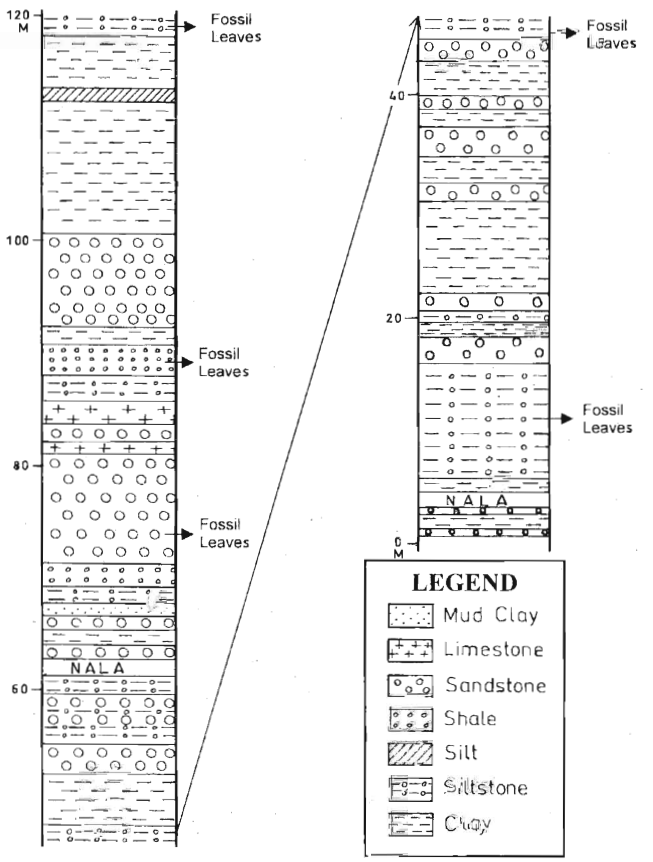



Fig. 3. Lithocolumn of a part of the Koilabas nala section indicating the fossiliferous beds from where fossil leaves were collected.

predominantly alternate and close.

*Specimen No*: H-18 ( Pl. II, figs. 1).

*Locality*: Koilabas Nala, western Nepal.

*Modern affinity*: The characteristic features of this fossil leaf, such as entire margin, eucamptodromous type of venation, presence of inter-secondary veins, course of secondary veins and RR, percurrent, almost straight tertiary veins, indicate its resemblance with the modern leaves of *Uvaria hamiltonii* Hook. f. Th. of the family Anonaceae.(C.N.H. Herbarium Sheet no. 9441: Pl.I, fig. 6; Pl. II, fig. 3).

*Fossil record and comparison*: Prasad (1994b) has described a fossil leaf showing affinity with *Uvaria hamiltoni* Hook.f. Th. under the form species, *Uvaria siwalica* from the Lower Siwalik sediments of Kathgodam, Nainital District, Uttrakhand. On comparison with Prasad's specimen it has been found that both the fossil leaves have similar venation pattern, specially the course and orientation of secondary and tertiary veins. The present fossil leaf is therefore included under *Uvaria siwalica* Prasad.

*Present-day distribution*: The genus *Uvaria* Linn. comprises 110 species distributed mainly in Tropical Asia; a few species also occur in Africa. About 16 species grow in the Indian region. *Uvaria hamiltonii* Hook. f. Th., with which the fossil specimen shows closest resemblance is a large shrub, distributed in evergreen to moist deciduous forests of the Sub-Himalayan tract, Assam, Sikkim, Chhota Nagpur, Bangladesh, Andman Islands and Myanmar. (Hooker, 1872; Gamble, 1972).

*Family* **Flacourtiaceae** DC

*Genus* ***Flacourtia*** Commers

*Flacourtia koilabasensis* n. sp.

(Pl.I, fig. 4)

*Material*: This is represented by a single, incomplete specimen.

*Description*: Leaf simple, symmetrical, narrow elliptic; preserved lamina length 8.5 cm, maximum width 3.5 cm.; apex broken, seemingly acute; base broken; margin entire; texture thick chartaceous; venation pinnate, eucamptodromous; primary vein (1°) single, moderate, almost straight, prominent; secondary veins (2°), 4 pairs visible, with moderate angle of divergence (45°-60°), arising uniformly, sparsely arranged up to 4.6 cm apart, moderate, deeply curved upwards, taking a long course towards apex to reach the margin, unbranched; tertiary veins (3°) very fine, angle of origin R R percurrent, straight, branched, nearly at right angles to primary vein, predominantly alternate and close.

*Holotype* : Specimen No. H-206 (Pl.I, fig. 4).

*Locality*: Koilabas nala, western Nepal.

*Derivation of name*: After the name of the fossil locality, Koilabas.

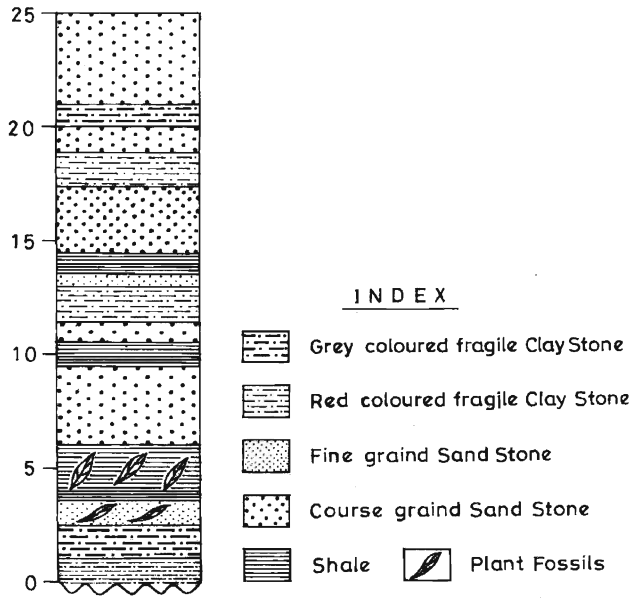



Fig. 4. Lithocolumn of a part of Seria nala section showing the fossiliferous beds from where fossil leaves were collected.

*Modern affinity*: The fossil leaf is characterized by narrow elliptical shape, entire margin, eucamptodromous venation, sparsely arranged, few secondary veins which are deeply curved and take a large distance towards apex, and RR, fine, percurrent tertiary veins. These features undoubtedly indicate that the present fossil leaf closely resembles the extant leaves of *Flacourtia montana* Grahm. of the family Flacourtiaceae (C.N.H.Herbarium Sheet no.7765; Pl. I, fig. 5).

*Fossil records and comparison*: So far, two fossil leaves have been known from the Siwalik sediments of Surai Khola, Nepal (Awasthi and Prasad, 1990; Prasad and Awasthi, 1996). These are *Flacourtia nepalensis* Awasthi and Prasad and *Flacourtia tertiara* Prasad and Awasthi. These two leaves have been compared with the present fossil leaf and found that they are different in having serrated margin as compared to the entire margin in the present fossil. On account of its distinctiveness, this fossil specimen has been described as a new species *Flacourtia koilabasensis*.

*Present-day distribution*: The genus *Flacourtia* Commers consists of fifteen species distributed in tropical Africa and Asia. The modern comparable species *Flacourtia montana* Graham. is presently distributed in the Sub-Himalayan tract from Nepal to Myanmar, Konkan, north and south Kangra. (Brandis, 1971).

*Family* **Polygalaceae** Juss.

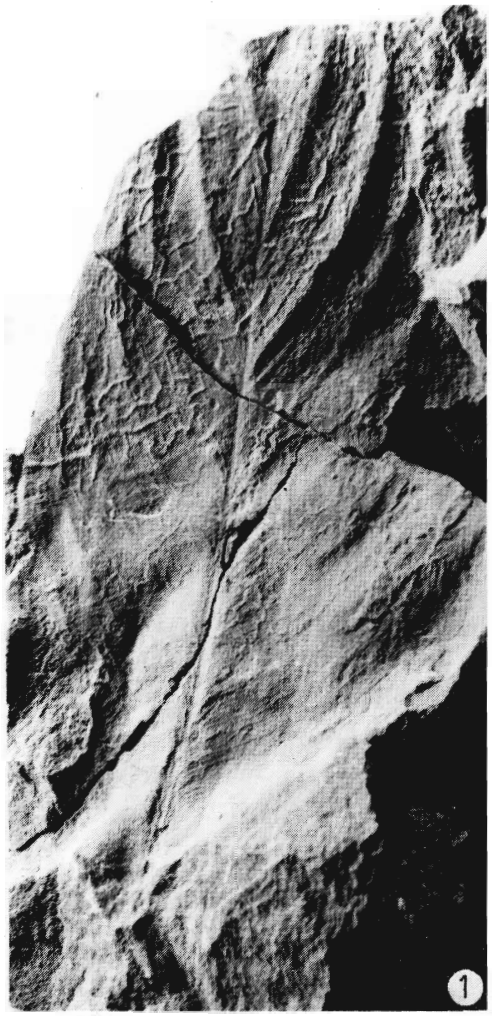
*Genus* ***Qualea*** Aubl.

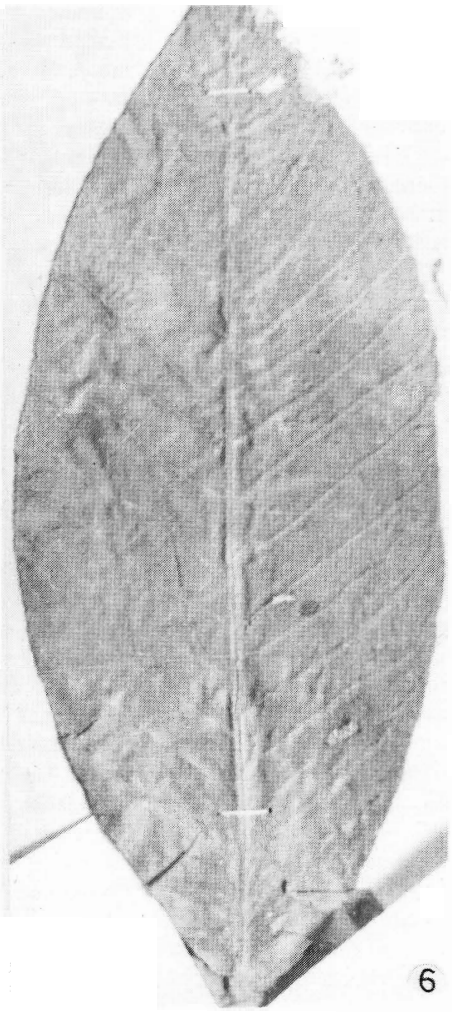
## EXPLANATION OF PLATE I

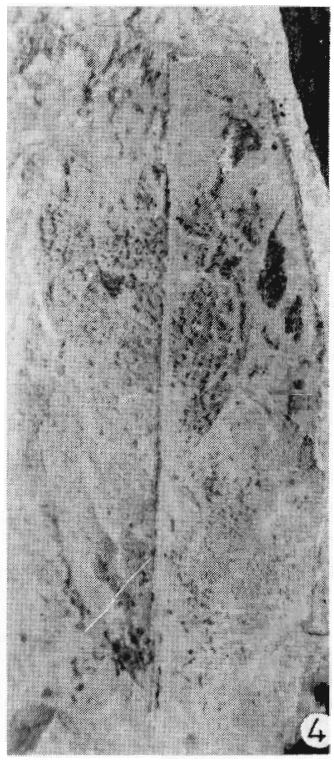
(All figures are of natural size unless otherwise mentioned)

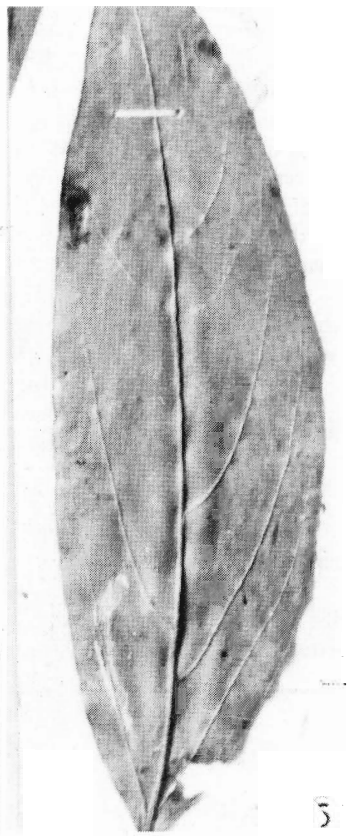
1. ***Donax kasauliensis*** Srivastava & Guleria Fossil leaf showing shape, size and venation pattern, Specimen no. K-4.
2. ***Donax kasauliensis*** Srivastava & Guleria A. part of fossil leaf showing details of venation x2, Specimen no. K-4.
3. ***Donax cannaeformis***. Lour A part of modern leaf showing similar details of venation x2, F.R.I. Herbarium sheet no. 311.
4. ***Flacourtia koilabasensis*** n. sp. Fossil leaf showing shape, size and venation pattern, Specimen no. H-206 (Holotype).
5. ***Flacourtia montana*** Grahm. Modern leaf showing similarity in shape, size and venation pattern, C.N.H. Herbarium sheet no.7765.
6. ***Uvaria hamiltonii*** Hook. f. Thoms. Modern leaf showing resemblance in shape, size and venation pattern with fossil leaf (Pl. II, fig. 1), C.N.H. herbarium sheet no.9414.

**Plate I**

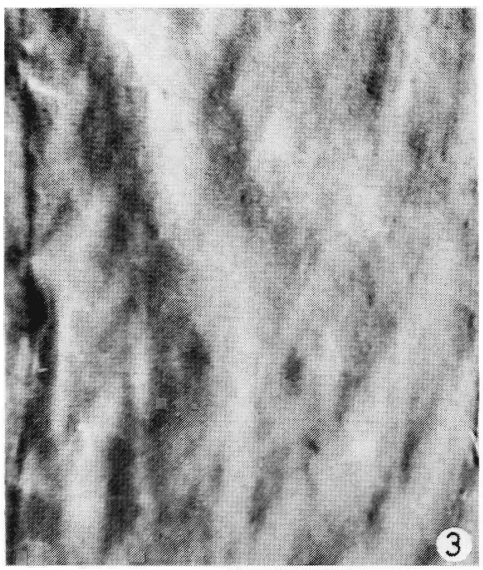







PRASAD AND DWIVEDI

*Qualea siwalica* n. sp.
(Pl. II, figs. 4, 6; Pl. IV, fig. 7; Pl. III, fig.11)

*Material*: There are two well-preserved specimens, of which one is with counterpart and incomplete.

*Description*: Leaves simple symmetrical, narrow oblong to elliptical, preserved size 7x3.5 cm, 5x3.1 cm., 6x3.5 cm., apex slightly broken, seemingly acute; base broken; petiole not preserved; margin entire; texture chartaceous; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, straight; secondary veins (2°), 5-6 pairs visible, angle of divergence moderate (50°-60°), nearly uniform, alternate to sub-opposite, moderately thick, uniformly curving up towards margin; veins present, 2-3 inter secondary veins present in between two secondaries; tertiary veins (3°) fine, angle of origin, RR percurrent, branched, predominantly alternate, oblique in relation to primary vein, close to distant; quaternary veins (4°) fine, randomly oriented forming polygonal meshes.

*Holotype*: Specimen No. K-211(Pl. II figs 40).

*Paratype*: Specimen No 211A, 211B.

*Locality*: Koilabas Nala, western Nepal.

*Derivation of name*: From the Siwalik Group of rocks.

*Modern affinity*: Narrow oblong to elliptical shape, entire margin, eucamptodromous venation, nature and arrangement of secondary veins, presence of prominent inter secondary vein and RR, percurrent and somewhat distantly placed, tertiary veins directly indicate its resemblance with the modern leaves of *Qualea densiflora* Warm. of the family Polygalaceae (C.N.H. Herbarium Sheet no 3714; Pl.II figs 5,7).

*Fossil records and comparison*: Although two fossil leaves belonging to the family Polygalaceae are known from the Churia sediments of Nepal (Prasad *et al.*, 1997,1999). As far as the authors are aware, there is no record of the fossil leaf resembling the genus *Qualea* Aubl. of this family. These fossil leaves form its first record from the Churia sediments of the Koilabas area and is being described as a *Qualea siwalica* n. sp.

*Present day distribution*: *Qualea densiflora* Warm with which the new species resembles closely is distributed in the evergreen forests of tropical America.

*Family* **Dipterocarpceae** Bl.
*Genus* ***Shorea*** Roxb.
*Shorea palaeocurtisii* n. sp.
(Pl. III, figs 1, 3)

*Material*: There is a single, complete specimen of leaf impression which is devoid of cuticles.

*Description*: Leaf simple, symmetrical, narrow elliptical; size 5.0 x 1.6 cm; apex acute; base widely acute; margin entire; texture thick, chartaceous; petiole 0.2 mm, normal; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, straight; secondary veins (2°) 10 pairs closely placed, 0.4-0.8 cm apart, angle of divergence 60°, acute moderate, arise straightly, uniformly curved up, alternate to subopposite, unbranched; tertiary veins (3°) fine, poorly preserved, angle of origin usually RR, percurrent, almost, straight, oblique in relation to midvein, predominantly alternate and close.

*Holotype*: Specimen No. K-250 (Pl. III, figs. 1).

*Locality*: Koilabas Nala, western Nepal.

*Derivation of name*: By adding prefix 'palaeo' to the modern comparable species.

*Modern affinity*: The diagnostic features of the present fossil leaf, such as small elliptical shape, acute apex and base, entire margin, normal petiole eucamptodromous venation, closely placed secondaries arising straightly at acute angle and RR, suggest that this fossil leaf shows its closest similarity with the leaves of *Shorea curtisii* Dyer of the family Dipterocarpaceae (C.N.H. Herbarium Sheet no. 554513; Pl. III, fig.2).

*Fossil records and comparison*: Fossil leaves resembling the genus *Shorea* Roxb. have been described from the Tertiary sediments of India and abroad, e.g. *Dipterocarpophyllum blumii* and *D. gerativense* from the Tertiary of Egypt (Seward, 1935), *Shorea guiso* and *S. polyspermum* from the Pliocence of Philippines (Merrill,1923). Later on, six more fossil leaves have been reported from the Siwalik (Churia) sediments of India and Nepal. These are *Shorea siwalika* Antal and Awasthi , *Shoera neoassamia* Prasad, *Shorea eutrapizifolia* Prasad *et al.*, *Shorea miocenica* Konomatsu and Awasthi, *Shorea robusta* Gaertn. f. Bande and Srivastava and *Shorea palaeostellata* Prasad and Pandey (Antal and Awasthi, 1993; Prasad,1994b; Antal and Prasad, 1996; Prasad *et al.*, 1999, 2004; Konomatsu and Awasthi, 1999; Bande and Srivastava, 1990 and Prasad and Pandey, 2007). The present fossil leaf has been compared with all the above known species. It diffes from them in being smaller in size and having no inter-secondary veins. The course of secondary and tertiary veins is also different from them. In view of these differences, the present specimen is described as a new species.

*Present-day distribution*: The genus *Shorea* Roxb. contains about 360 species distributed from Sri Lanka to South China, western Malaysia and Malacca. Of the 12 species, five are known from in Sri Lanka, three are found in Myanmar, two in south India, one in Assam and one in the well known Sal forest in northern and central India. *Shorea curtisii* Dyer, with which the present fossil shows closest resemblance, is distributed in the forests of the Malayan region (Hooker, 1872.).

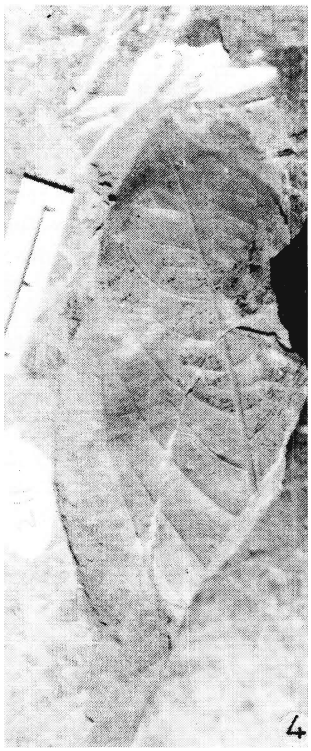
*Family* **Icacinaceae** Juss.
*Genus* ***Iodes*** Blume

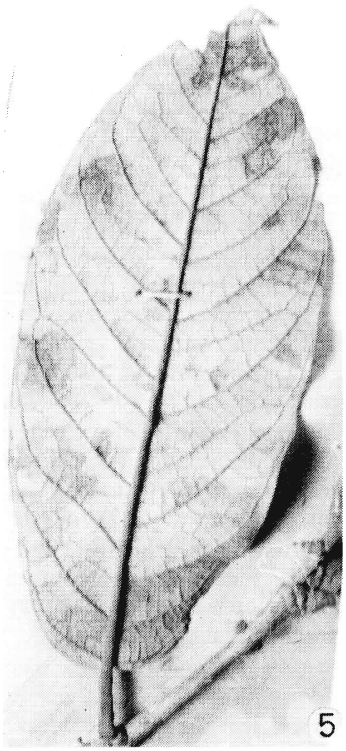
## EXPLANATION OF PLATE II

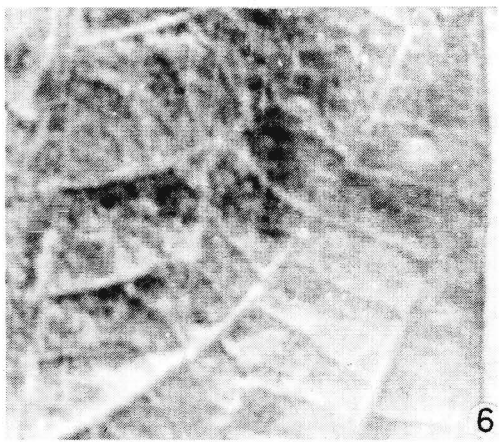
(All figures are of natural size unless otherwise mentioned)

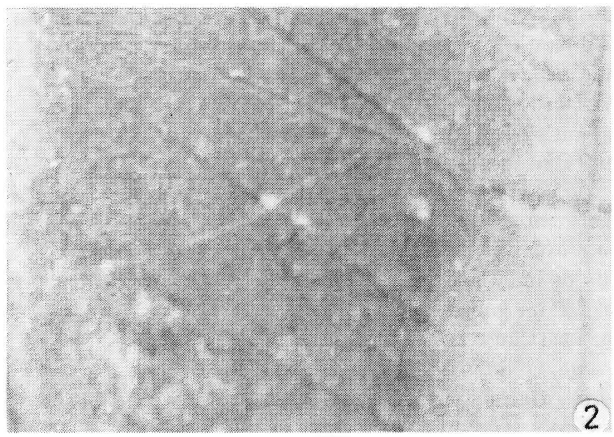
1. ***Uvaria siwalica*** Prasad Fossil leaf showing shape, size and venation pattern, Specimen no. H-18.
2. ***Uvaria siwalica*** Prasad A. part of fossil leaf showing details of venation x 2.5, Specimen no. H-18.
3. ***Uvaria hamiltonii*** Hook. f. Thoms. A part of modern leaf magnified to show similar details of venation pattern x 2.5, C.N.H. herbarium sheet no.9441.
4. ***Qualea siwalica*** n. sp. Fossil leaf showing shape, size and venation pattern, Specimen no. K-211 (Holotype).
5. ***Qualea densiflora*** Warm. Modern leaf showing similar shape, size and venation pattern, C.N.H. herbarium sheet no.3714.
6. ***Qualea siwalica*** n. sp. A part of fossil leaf magnified to show details of venation x 2, Specimen no. K-211.
7. ***Qualea densiflora*** Warm. A part of modern leaf magnified to show similar details of venation x 2, C.N.H. herbarium sheet no.3714.

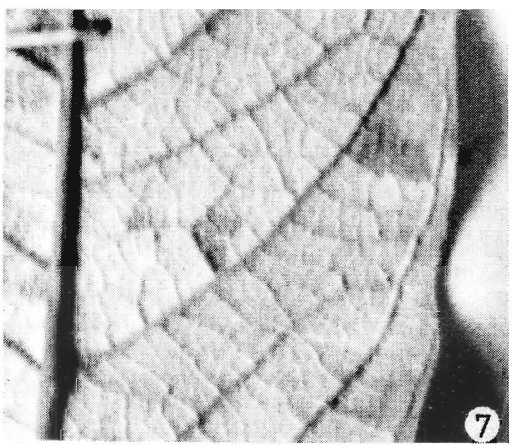
**Plate II**





PRASAD AND DWIVEDI

*Iodes koilabasensis* n. sp.
(Pl. III, figs. 4, 6)

*Material*: This species is represented by a single well preserved almost complete leaf impression which is devoid of cuticles.

*Description*: Leaf simple, slightly asymmetrical, lamina on one side of midrib is narrow than the other side, elliptic; 4.9x 2.5 cm long; apex obtuse; base wide acute, or nearly obtuse; petiole preserved, 0.2cm visible, normal; margin entire; texture, chartaceous; venation pinnate, eucamptodromous; primary vein (1°) single, stout, slightly curved; secondary veins (2°) 3 pairs visible 0.3 to 2.4 cm apart with angle of divergence moderate (40°-60°), deeply curving upward taking a long course towards apex to reach at margin, unbranched; inter secondary veins present composite; tertiary vein (3°) fine, angle of origin RR, percurrent, almost straight, branched, oblique in relation to mid vein, predominantly alternate and close; quaternary veins (4°) very fine, randomly oriented forming polygonal meshes.

*Holotype*: Specimen No.- K-207 (Pl. III, figs 4).

*Locality*: Koilabas Nala, western Nepal,

*Derivation of name*: After the name of the fossil locality.

*Modern affinity*: The most characteristic features of the present fossil leaf are asymmetrical elliptial shape, nearly obtuse apex and base, entire margin, eucamptodromous type of venation, spacely arranged secondary veins, presence of composite inter-secondary veins and RR, per-current, tertiary veins. A critical examination of the herbarium sheets at Central National Herbarium, Howrah suggests that these features are found commonly in the leaves of *Iodes ovalis* Blume of the family Olacaceae (C. N. H. Herbarium Sheet no. 83948; Pl. III, figs 5, 7)

*Fossil records and comparison*: So far, there is no record of the fossil leaf of the genus *Iodes* Blume from the Tertiary sediments of India and Nepal. This is the first record of the fossil leaf of thi genus from Churia sediments of Koilabas and described here as new species, *Iodes koilabasensis.*

*Present day distribution*: The extant taxon *Iodes ovalis* (syn.I. *tomentella* Kurz) Blume with which fossil shows closest affinity is a large tree found in the evergreen forests of Assam, Khasi hills, Chittagong, Myanmar and Malaya peninsula (Brandis,1971.).

*Family* **Ochnaceae** DC
*Genus* ***Ochna*** Schreber

*Ochna miowallichii* n. sp.
(Pl. III, figs. 8, 10; Pl. IV, fig. 1.)

*Material*: There are three complete leaf impressions.

*Description*: Leaves simple, almost symmetrical, narrow elliptic; size 13.5 x 3.5 cm, 8.5 x 3.1, and 10.8x 2.3 cm; apex acute; base wide acute; margin entire; texture coriaceous; petiole preserved; 0.8cm long normal; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, straight to slightly curved; secondary veins (2°) about 14 pairs visible, poorly preserved less than 0.5cm to 1.4 cm apart, angle of divergence acute (45°-55°), uniformly curved up, seemingly unbranched; inter-secondary veins present; simple, frequent, 1-3 intersecondary veins are found in between two secondaries.

*Holotype*: Specimen No. K 101 (Pl. IV, fig.1 )

*Paratype*: Specimen No. K 105 and K135

*Locality*: Darwaja, Koilabas, western Nepal

*Derivation of name*: By adding an affix 'mio' in the name of extant species, *O. wallichii.*

*Modern affinity*: The diagnostic features of the present fossil leaves, e.g. narrow to very narrow elliptical shape, acute apex and base, normal, 0.8 cm long petiole, eucamptodromous type of venation, presence of 1-3 intersecondary veins in between two secondary veins and somewhat closely placed secondary veins, collectively indicate that the present fossil shows closest affinity with the leaves of *Ochna wallichii* King of the family *Ochnaceae* (C.N.H. Herbarium Sheet no. 88, 77225; Pl. III fig. 9; Pl.IV, fig.2).

*Fossil records and comparison*: Prasad and Pandey (2006) described a fossil leaf *Ochna siwalika* showing resemblance with the modern leaves of *Ochna integrifolia* Presl. from the Siwalik sediments of Surai Khola, western Nepal. On comparison of the present fossil leaves with the described fossil, it is been seen that *Ochna siwalika* is marked by absence of inters econdary veins. Howerver, the present fossil leaves possess 1-3 intersecondary veins in between two secondaries. This difference from the known species allows to describe the present fossil leaves as a new species.

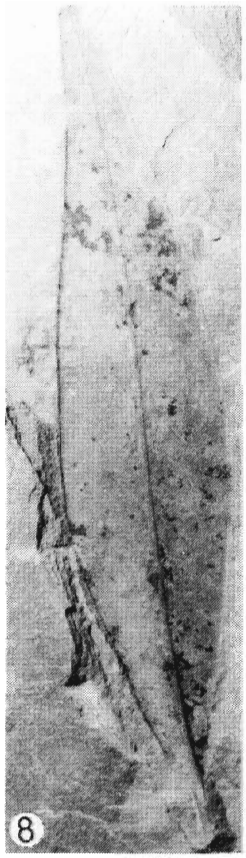
*Present day distribution*: The genus *Ochna* Schreber consists of 86 species distributed in the tropical regions of Africa and Asia. *Ochna wallichii* ( Syn. *O. andmanica* Kurz.) with which the fossil leaf shows closest affinity, is a tree which grows in the evergreen forests of N.E. India, Andamans, Myanmar and Malaya Peninsula ( Brandis, 1971).

## EXPLANATION OF PLATE III

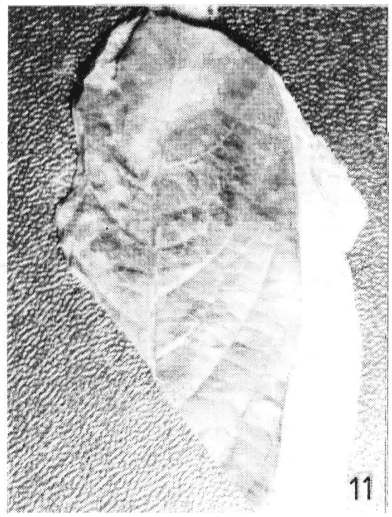
(All figures are of natural size unless otherwise mentioned)

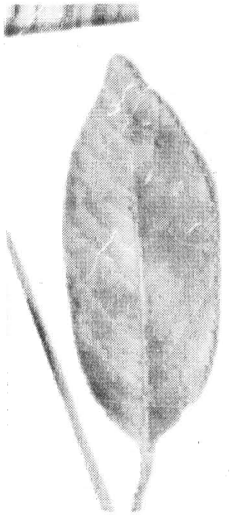
1. ***Shorea palaeocurtisii*** n. sp. Fossil leaf showing shape, size and venation pattern, Specimen no. K-250 (Holotype).
2. ***Shorea curtisii*** Dyer Modern, leaf showing similar shape, size and venation pattern, C.N.H. herbarium sheet no.554513.
3. ***Shorea palaeocurtisii*** n. sp. A part of fossil leaf magnified to show details of venation pattern. x 2.25, Specimen no. K-250 (Holotype).
4. ***Iodes koilabasensis*** n. sp. Fossil leaf showing shape, size and venation pattern. Specimen no. K-207 (Holotype).
5. ***Iodes ovalis*** Blume, Modern leaf showing similar shape, size and venation pattern, C.N.H. herbarium sheet no.83948.
6. ***Iodes koilabasensis*** n. sp. A part of fossil leaf magnified to show details of venation pattern. x 2, Specimen no. K-207 (Holotype).
7. ***Iodes ovalis*** Blume A part of modern leaf magnified to show similar details of venation pattern. x 2, C.N.H. herbarium sheet no.83948.
8. ***Ochna miowallichii*** n. sp. An other fossil leaf showing variation in shape and size, Specimen no. K-105 (Paratype).
9. ***Ochna Wallichii*** King, Modern leaf showing similar shape and size, C.N.H. herbarium sheet no.77225.
10. ***Ochna miowallichii*** n. sp. Apical part of a fossil leaf showing attenuate type of apex, Specimen no. K-135 (Paratype).
11. ***Qualea siwalica*** n. sp. An other fossil leaf showing variation in size, Specimen no. K-211A (Paratype).

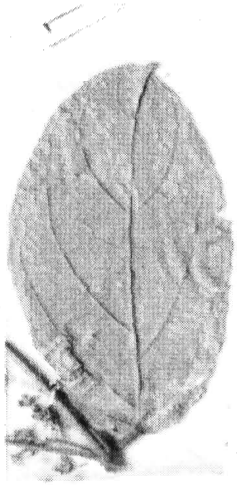
**Plate II**

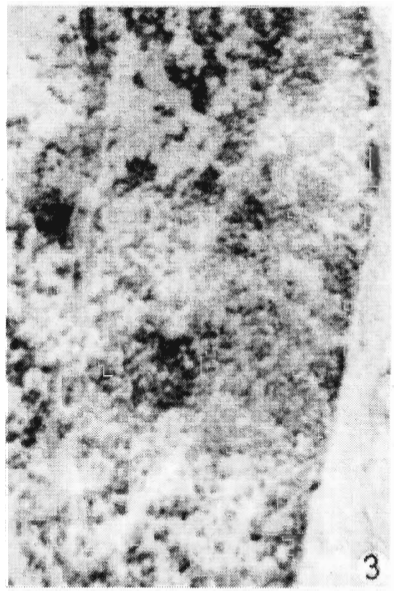





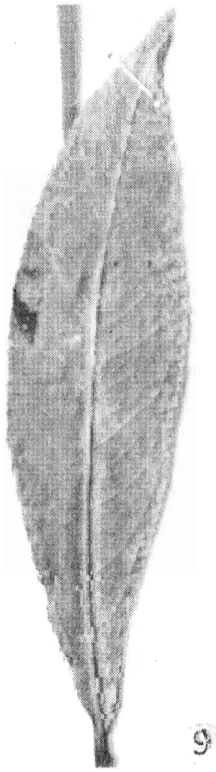


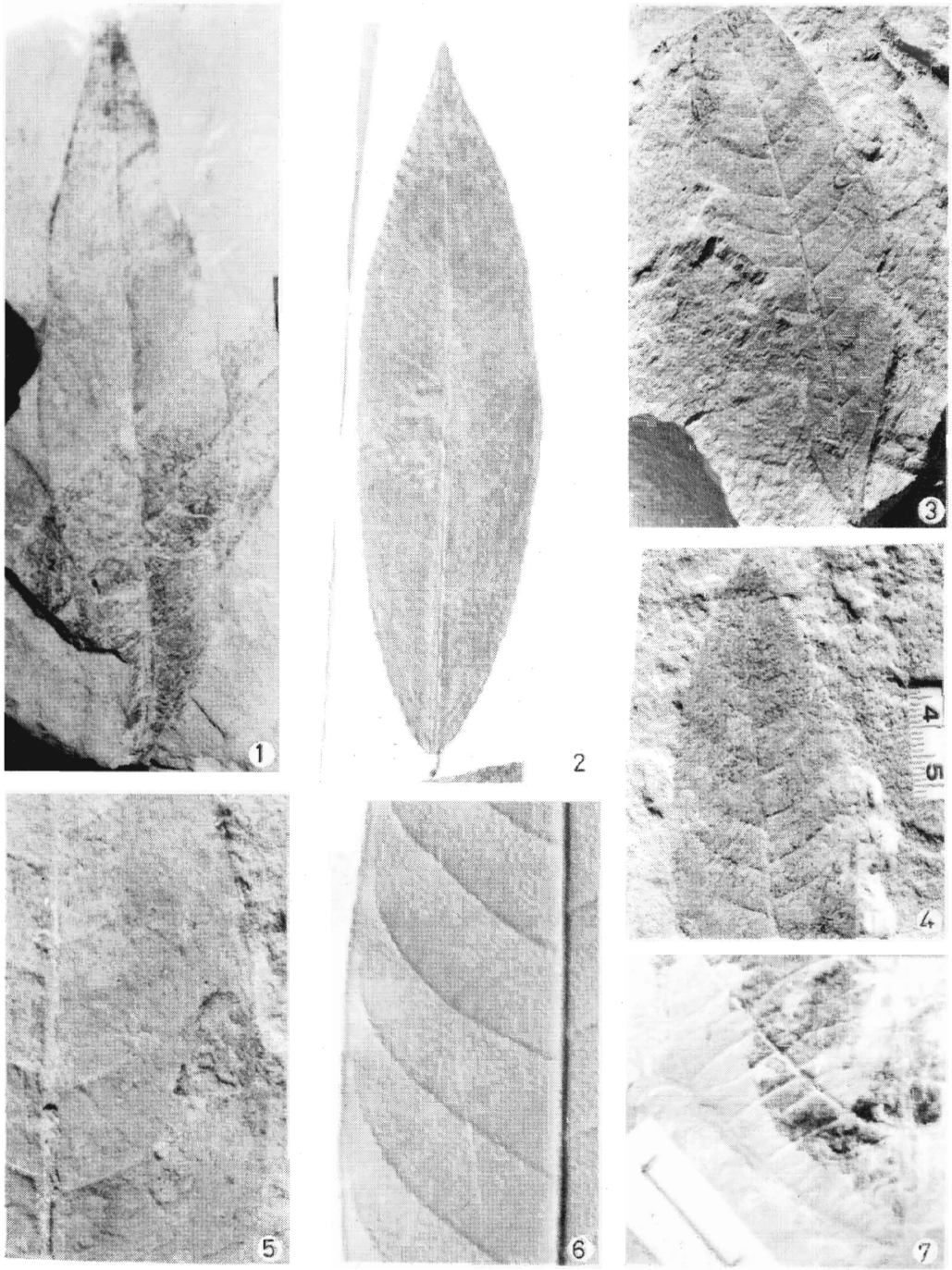











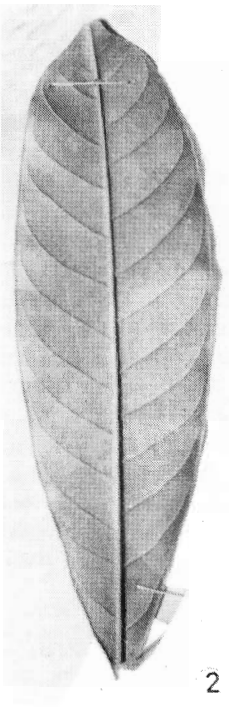

PRASAD AND DWIVEDI

## EXPLANATION OF PLATE IV

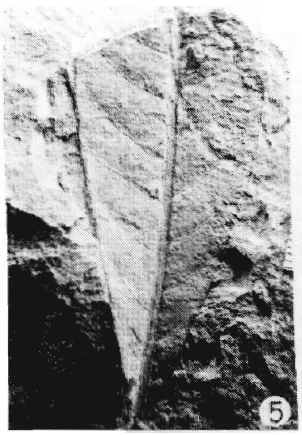
(All figures are of natural size unless otherwise mentioned)

1. ***Ochna miowallichii*** n. sp. Fossil leaf showing shape, size and venation pattern, Specimen no. K-101 (Holotype).
2. ***Ochna wallichii*** King, Modern leaf showing similar shape, size and venation pattern, C.N.H. herbarium sheet no.88.
3. ***Paranephelium seriaensis*** n. sp. Fossil leaf showing shape, size and venation pattern, Specimen no. K-66 (Paratype).
4. ***Paranephelium seriaensis*** n. sp. An other fossil leaf showing nature of apex, Specimen no. K-67 (Paratype).
5. ***Paranephelium seriaensis*** n. sp. A part of fossil leaf (Pl. IV, fig. 3) magnified to show details of venation pattern.x2.5, Specimen no. K-65 (Holotype).
6. ***Paranephelium xestophyllum*** (Miq.) King, A part of modern leaf magnified to show similar details of venation x. 2.5, C.N.H. herbarium sheet no.15392.
7. ***Qualea siwalica*** n. sp. A portion of another fossil leaf showing details of venation x.1.5, Specimen no. K-211B (Paratype).

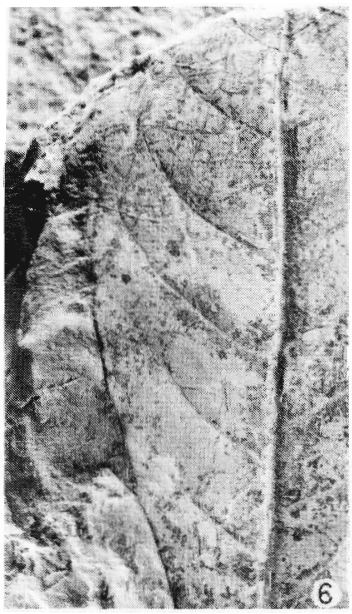
**Plate V**

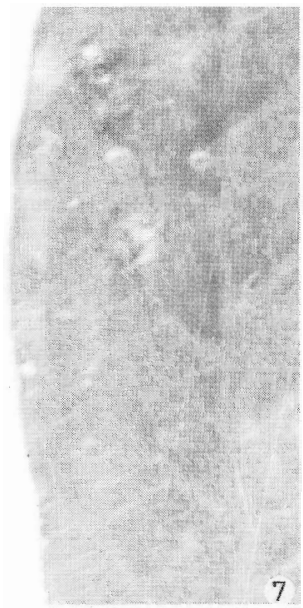












PRASAD AND DWIVEDI

## EXPLANATION OF PLATE IV

(All figures are of natural size unless otherwise mentioned)

1. ***Paranephelium seriaensis*** n. sp. Fossil leaf showing shape, size and venation pattern, Specimen no. K-65 (Holotype).
2. ***Paranephelium xestophyllum*** (Miq.) King ,Modern leaf showing similar shape, size and venation pattern, C.N.H. herbarium sheet no.15392.

3,5. ***Arytera seriaensis*** n. sp. Fossil leaves showing shape, size and venation pattern, Specimen no. K-13 (Holotype), K-27(Paratype).

4. ***Arytera (Ratonia) oshaneiana*** Bedd. Modern leaf showing similar shape, size and venation pattern, C.N.H. herbarium sheet no.19157.
6. ***Arytera seriaensis*** n. sp. A part of fossil leaf (Fig. 3) magnified to show details of venation x. 1.75, Specimen no. K-13 (Holotype).
7. ***Arytera (Ratonia) oshaneiana*** Bedd. A part of Modern leaf magnified to show similar details of venation x 1.75, C.N.H. herbarium sheet no.19157.

*Family* **Sapindaceae** Juss.
*Genus* ***Paranephelium*** Miq.
*Paranephelium seriaensis* n. sp.
(Pl.IV, figs 3,4,5; Pl. V, fig.1)

*Material*: There are three leaf impressions, one with its counter part.

*Description*: Leaves simple, almost symmetrical, elliptical; preserved size 9 x 3 cm; apex acute; base acute; margin entire; texture thick chartaceous; petiole preserved, 0.3 cm long, normal; venation pinnate, eucamptodromous; primary vein ($1^0$) single, prominent, stout, straight; secondary veins ($2^0$), about 12 pairs visible, alternate to subopposite, unbranched, 0.5 to 1.2 cm apart, angle of divergence ($55^0$- $60^0$), moderate acute, uniformly curved up; tertiary veins ($3^0$) fine, angle of origin usually RR, precurrent, almost straight, branched, oblique in relation to mid vein, predominantly alternate, close.

*Holotype*: Specimen No. K 65 ( Pl.V, fig. 1).

*Paratype*: Specimen No. K 66, K 67.

*Locality*: Seria Naka, western Nepal.

*Derivation of name*: After the name of fossil locality, Seria Naka.

*Modern affinity*: The characteristic features of the present fossil leaves are almost symmetrical, elliptic shape, acute base and apex, eucamptodromous venation, uniform curving of secondary veins, and RR, percurrent tertiary veins. These features are commonly found in the leaves of *Mischocarpus pentapetalus* Roxb., *Arytera oshaneiana* Radik. and *Paranephlium xestophyllum* (Miq.) King of the family Sapindaceae. On examination of the herbarium sheets of above taxa, it has been concluded that the present fossil leaf shows close affinity with the leaves of *Paranephelium xestophyllum* (Miq.) King. (C.N.H Herbarium Sheet no. 15392, Pl. IV,fig 6; Pl.V,fig. 2) in shape, size and venation pattern.

*Fossil records and comparison*: There is no fossil record of the genus *Paranephelium* from the Tertiary sediments of India and Nepal. This leaf form is its first record from the Churia sediments of western Nepal and is described herewith as *Paranephelium seriaensis* n. sp.

*Present-day distribution*: *Paranephelium xestophyllum* (Miq.) King is a small evergreen tree distributed mainly in Sumatra, Upper Myanmar and Thailand (Brandis, 1971).

*Genus* ***Arytera*** Blume
*Arytera seriaensis* n. sp.
(Pl.V, figs. 3,5, 6)

*Material*: There are two leaf impressions which are broken on apical portion.

*Description*: Leaf simple, slightly asymmetrical, obovate; preserved size 8 x 3.4 and 5.4 x 2.6 cm; apex broken; base nearly cuneate; margin entire; texture thick charataceous; petiole about 1.0 cm long; venation pinnate, eucamptodromous; primary vein (1°) single, stout, slightly curved; secondary veins ($2^0$) about 8 pairs visible, 0.4 to 1.0 cm apart, alternate to subopposite, unbranched, angle of divergence acute ($50^0$ – $60^0$), moderate, uniformly curved up; intersecondary veins present, simple, rare; tertiary veins ($3^0$) fine, angle of origin AO- RR, percurrent, branched, oblique in relation to mid veins, alternate to opposite and close.

*Holotype*: Specimen No. K- 13 (Pl.V, figs 3).

*Paratype*: Specimen No K- 27.

*Locality*: Seria Naka , western Nepal.

*Derivation of name*: After the name of the fossil locality, Seria Naka.

*Modern affinity*: The diagnostic features of the present fossil leaves (slightly asymmetrical obovate shape, acute apex, cuneate base, eucamptodromous type of venation, alternate to opposite secondaries arising from primary vein at acute angle, presence of inter-secondary veins and RR, percurrent tertiary veins) collectively suggest that the fossil leaves show closest affinity with the extant leaves of *Arytera (Ratonia) oshaneiana* Bedd. of the family Sapindanceae in shape, size and venation pattern (C.N.H. Herbarium Sheet no. 19157, Pl.V, figs 4,7).

*Fossil records and comparison*: As far as authors are aware there is no record of fossil leaves resembling the genus *Arytera (Ratonia)* Blume from the Tertiary sediments of India and Nepal. It is therfore described as a new species.

*Present day distribution*: *Arytera oshanieana* Bedd. with which the fossil forms show closest affinity is a large tree that is presently found in Australia.

## DISCUSSION

The present systematic study on the fossil leaf impressions collected from the Churia Group of the Koilabas area (Imblibasa, Darwaja, Koilabas nala and Seria Naka) in western Nepal reveals the presence of nine more angiospermous taxa in the sub-Himalayan zone during the middle Miocene times. They belong to nine genera of eight families (One monocot and 7 Dicot families). The genera such as *Qualea, lodes* and *Arytera* are new to the Tertiary sediments of the Indian subcontinent. The modern comparable species suggest that a tropical, mesophytic, evergreen forest was flourishing in and around the study areas during deposition (Table 1). On the contrary, the mixed deciduous forests grow now-a-days there. The present-day distribution of the comparable species indicates that they occur mostly in the evergreen and sometimes evergreen to moist deciduous forests of North East India, Andamans, Myanmar, Malayan peninsula, etc (Table-1). It may therefore be surmised that a warm and humid climate prevailed in Koilabas and the nearby area at the time of sedimentation, in contrast to the relatively present-day dry climate. Most of the species, except *Donax cannaeformis* and *Flacourtia montana*, do not grow in the sub-Himalayan zone of this region. This indicates a change in climate after the deposition of sediments. These changes in climate since middle Miocene may be due to uplift of the Himalaya and disappearance of the Tethys sea which progressively changed from a marine through estuarine to fresh water environment (Mukherjee, 1984).

The analysis of the physiognomic features of the recorded fossil leaf assemblage has also been carried out in order to infer the climate of the area. In the present assemblage, all the taxa possess medium-sized leaves with entire margin and higher venation density. The extended leaf tip (Drip tip), an important physiognomic feature, has been found only in *Ochna miowallichii* and *Shorea palaeocurtisii*. These features collectively indicate prevalence of tropical climate during the sedimentation.

## ACKNOWLEDGEMENTS

We are grateful to the authorities of Birbal Sahni Institute of Palaeobotany, Lucknow for providing necessary facilities during the progress of this work. We are also grateful to the authorities of the Central National Herbarium, Sibpur, Howrah, West Bengal for providing facilities during the consultation of

**Table 1: Present-day distribution and forest types of modern comparable taxa of fossils recovered from the Churia sediments of Koilabas area, western Nepal.**

| Fossil taxa | Modern equivalent taxa | Forest Type | Present day Distribution |
|---|---|---|---|
| **Marantacere** | | | |
| *Donax kasauliensis* Srivastava & Gulcria | *D. cannaeformis* Lour. | Evergreen to moist deciduous | Indo-Malayan regions |
| **Anonaceae** | | | |
| *Uvaria siwalica* Prasad | *U. hamiltonii* H. f. Th. | Evergreen to moist deciduous | North East India, Andaman, Myanmar |
| **Flacourtiaceae** | | | |
| *Flacourtia koilabasensis* sp. nov. | *F. montana* Grahm. | Evergreen to moist deciduous | North East India, Myanmar, South India |
| **Polygalaceae** | | | |
| *Qualea siwalica* sp. nov. | *Q. densiflora* Warm. | Evergreen | Tropical America |
| **Dipterocarpaceae** | | | |
| *Shorea palaeocurtisii* sp. nov. | *S. curtisii* Dyer | Evergreen | Malaysia |
| **Icacinaceae** | | | |
| *Iodes koilabasensis* sp. nov. | *I. ovalis* Kurz | Evergreen | North east India, Malaysia, Myanmar, |
| **Ochnaceae** | | | |
| *Ochna miowallichii* sp. nov. | *O. wallichii* King | Evergreen | North East India, Andamans Myanmar, Malaysia |
| **Sapindaceae** | | | |
| *Paranephelium seriaensis* sp. nov. | *P. xestophyllum* (Miq.) King. | Evergreen | Malaysia, Myanmar |
| *Arytera seriaensis* sp. nov. | *A. oshaneiana* Radik. | Evergreen | Australia |

Herbarium for the identification of the fossils.

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