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# Study on plant fossils from the Siwalik sediments of Far Western Nepal

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Study on the plant megafossils comprising well preserved leaves from the Siwalik sediments of Bardiya and Surkhet area in the Himalayan foot-hills of Far Western Nepal has been done. The leaf-impressions described here represent the first collection from the Siwalik sediments of Babai and Surkhet valleys. The leaves show closest affinity with six extant taxa belonging to the families Poaceae, Dipterocarpaceae, Ampelidaceae, Myrsinaceae and Ebenaceae. The present day distribution of their modern equivalent taxa indicates a phytogeographical link between Nepal and the south east Asian countries during the Siwalik Period. The physiognomic characters of the fossil leaves and the habit and habitat of the extant comparable taxa suggest that a warm humid climate with plenty of rainfall prevailed in this region during the deposition of Siwalik sediments.

**Key-words**—Plant megafossils, Angiosperms, Leaf-impressions, Siwalik, Far Western Nepal.

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## साराँश

### सुदूर पश्चिमी नेपाल के शिवालिक अवसादों से प्राप्त अश्मित पौधों का अध्ययन

महेश प्रसाद एवं यू.एम.एस. प्रधान

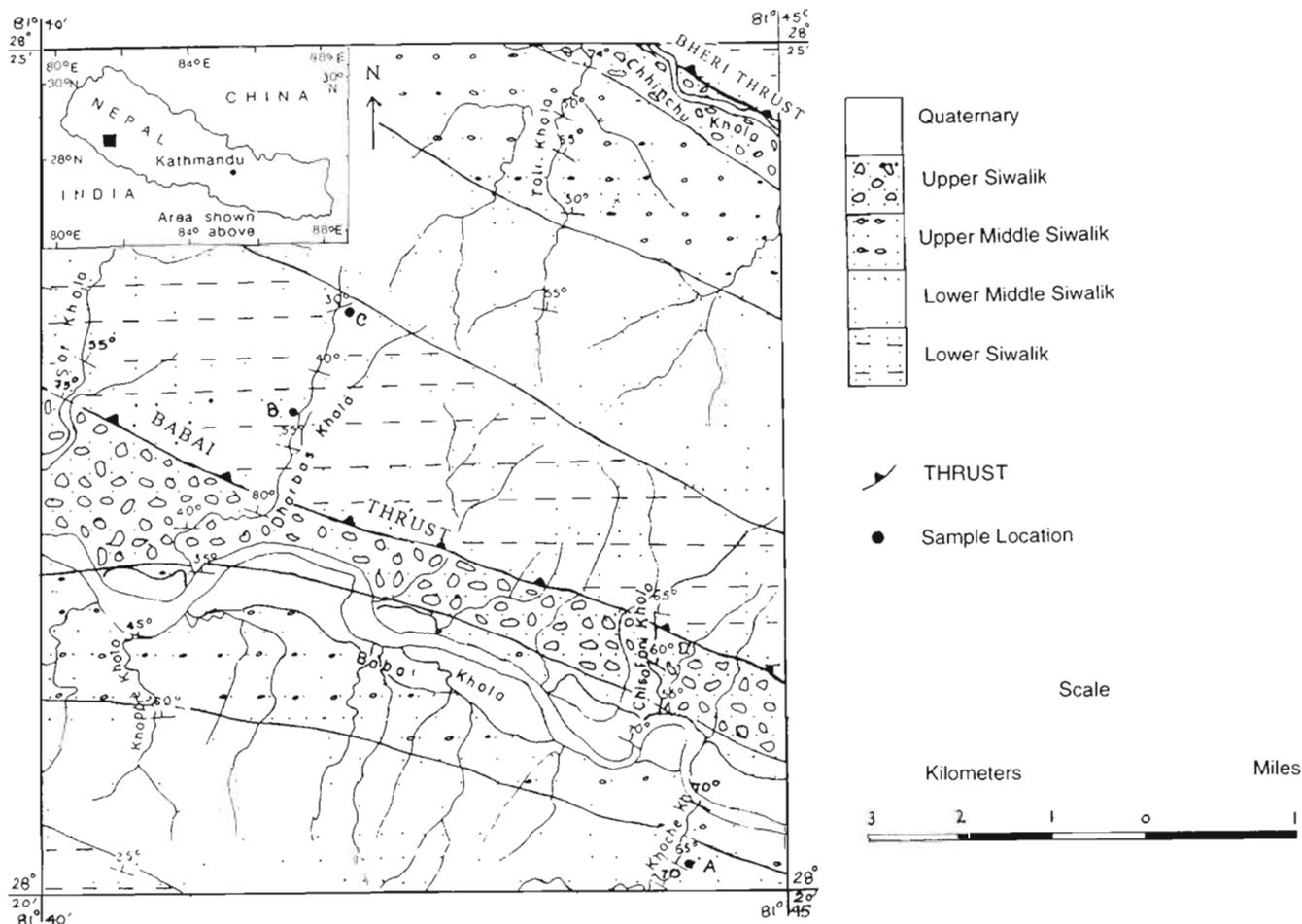
इस शोध-पत्र में सुदूर पश्चिमी नेपाल के शिवालिक अवसादों से प्राप्त गुरु पादपाश्र्मों का अध्ययन किया गया है। अश्मित पत्तियों के रूप में ये गुरुपादपाश्र्म बर्बाई और सुरखेत घाटियों से पहली बार वर्णित किये गये हैं। ये अश्मित पत्तियाँ पोएसी, डिप्टेरोकार्पेसी, एम्पेलिडेसी, मिर्सिनेसी एवं एबीनेसी नामक कुलों से सजातीयता व्यक्त करती हैं। इनके वर्तमान समतुल्य वर्गकों के वितरण से प्रदर्शित होता है कि शिवालिक अवसादन के समय नेपाल और दक्षिण पूर्व एशिया के बीच पादप भौगोलिक सम्बन्ध था। प्राप्त पत्तियों के आकारिकीय लक्षणों से व्यक्त होता है कि इन अवसादों के समय नम और उष्ण जलवायु विद्यमान थी।

THE Siwalik Hills of Nepal are commonly known as Churia Hills. The Department of Mines and Geology (Pradhan & Karki; 1977), Nepal has also adopted the general classification of Siwalik Group, i.e., Lower, Middle and Upper Siwaliks. Middle Siwalik has been further subdivided into Lower and Upper Middle Siwalik based on the increasing grain size of sandstones in the lower part and in the presence of extraformational clast of pebbles in the Upper Middle Siwalik.

The Lower Siwalik rocks are characterised by fine grained sandstone with interbedded red coloured mudstone, shale, siltstone and occasional marl. The Lower Middle Siwalik comprises medium, fine to medium grained sandstone with interbeds of mudstone, shale and siltstone. The samples of leaf-impressions were collected from

the Siwalik sediments of Babai Valley and Surkhet Valley of Far Western Nepal. In Babai Valley, well preserved leaf-impressions are found in purple and grey shales of the Lower-Middle Siwalik. Similarly, in Surkhet Valley, the leaf specimens are found in grey shales of Lower Siwalik and Lower Middle Siwalik sediments of Jhupra Khola.

The Siwalik sediments of both India and Nepal are very rich in plant megafossils including fossil woods, leaf-impressions, fruits, flowers and seeds (Antal & Awasthi, 1993; Antal & Prasad, 1996a, 1996b, 1996c; 1997; Awasthi & Lakhnupal, 1990; Awasthi & Prasad, 1990; Prasad, 1987, 1990a, 1990b, 1993, 1994a, 1994b, 1994c; Prasad & Awasthi, 1996; Prasad & Prakash, 1984; Prasad *et al.*, 1997a, b). The Chinese Petroleum Investigation Team (1973) has also worked on



Text-figure 1—Geological map of Babai Valley around Kanche Khola and Dharbas Khola, Bardiya District, Far Western Nepal.

some leaf imprints and microfossils from the Lower and Middle Siwalik sediments of central and western Nepal. They described fossil leaves belonging to modern *Ternstroemia* sp. and *Paramignya* sp. besides few spores of Pteridophyta and pollen of Angiosperms and Gymnosperms from the Lower Siwalik beds, exposed at Chinchu Khola of Surkhet District, Far Western Nepal.

Prasad, Pradhan and Shyam (1997) systematically studied the petrified woods collected from Kamala River Valley of eastern Nepal and reported a fossil wood of *Duabanga*.

Study on the plant fossils collected from the Siwalik sediments of Babai and Surkhet regions,

Far Western Nepal reveals the presence of a variety of leaf-impressions showing close resemblance with the modern genera *Bambusa*, *Dipterocarpus*, *Hopea*, *Leea*, *Ardisia* and *Diospyros* which are discussed and described in the present paper.

MATERIAL AND METHOD

Seven specimens of well preserved leaf-impressions described and discussed in the present paper were recovered from the Siwalik sediments, exposed in Babai Valley (Figure 1) and Surkhet Valley of far western Nepal (Figure 2). The specimens are devoid of cuticle and preserved on purple and grey coloured shales. The herbarium sheets of a number of extant genera and species of

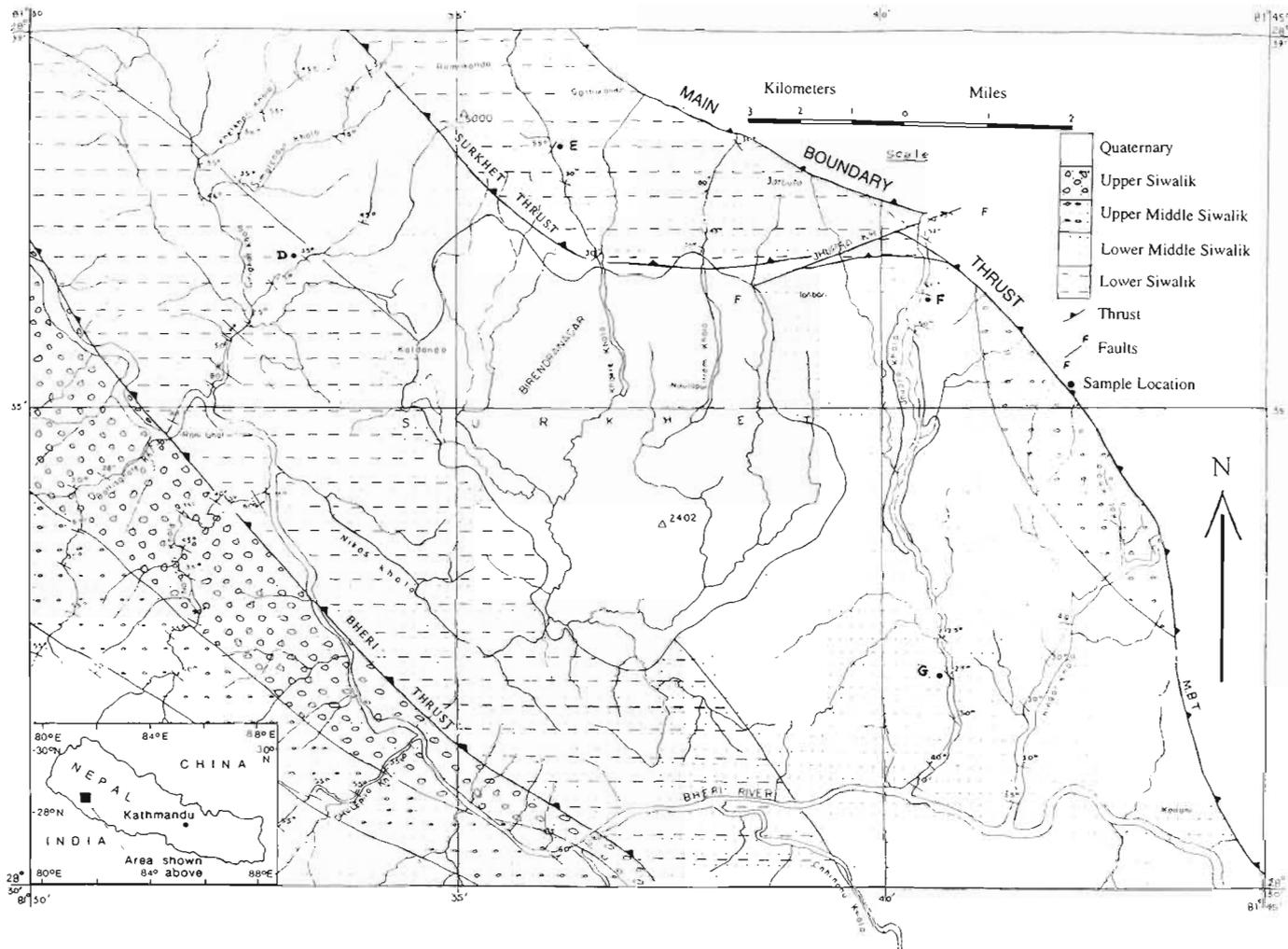
PLATE 1

1, 2. *Bambusa siwalica* Awasthi & Prasad—Fossil leaves in natural size

showing lanceolate shape with parallelodromous type of venation pattern.



PLATE 1



Text-figure 2—Geological map of Surkhet Valley, Far Western Nepal.

angiospermous families were consulted at the Herbaria of the National Botanical Research Institute, Lucknow and Forest Research Institute, Dehradun in order to identify the leaf impressions. The type specimens are preserved in the Museum of Department of Mines and Geology, Kathmandu, Nepal.

## SYSTEMATIC DESCRIPTION

Family—Poaceae

Genus—*Bambusa* Schreber

*Bambusa siwalica* Awasthi & Prasad 1990

Pl 1, figs 1, 2

1990 *Bambusa siwalica* (Awasthi & Prasad), p. 300, pl. 1, fig. 1.

## PLATE 2

1. *Dipterocarpus siwalicus* (Lakhanpal & Guleria) Prasad—Fossil leaves in natural size showing acute apex, slightly undulated margin and eucamptodromous type of venation.
2. *Hopea mioparviflora* sp. nov.—Fossil leaves in natural size showing lanceolate shape with acute apex and base and eucamptodromous venation (Holotype).
3. *Leea nepalensis* sp. nov.—Fossil leaves in natural size showing narrow oblanceolate shape, slightly cordate base and non-entire margin (Holotype).
4. *Ardisia palaeosimplicifolia* Prasad—Fossil leaves in natural size showing only apical part with attenuate apex and eucamptodromous type of venation with marked curvature in secondaries near margin.
5. *Diospyros palaeobennum* Prasad—Fossil leaves in natural size showing narrow ovate shape with slightly undulated entire margin and brochidodromous venation.

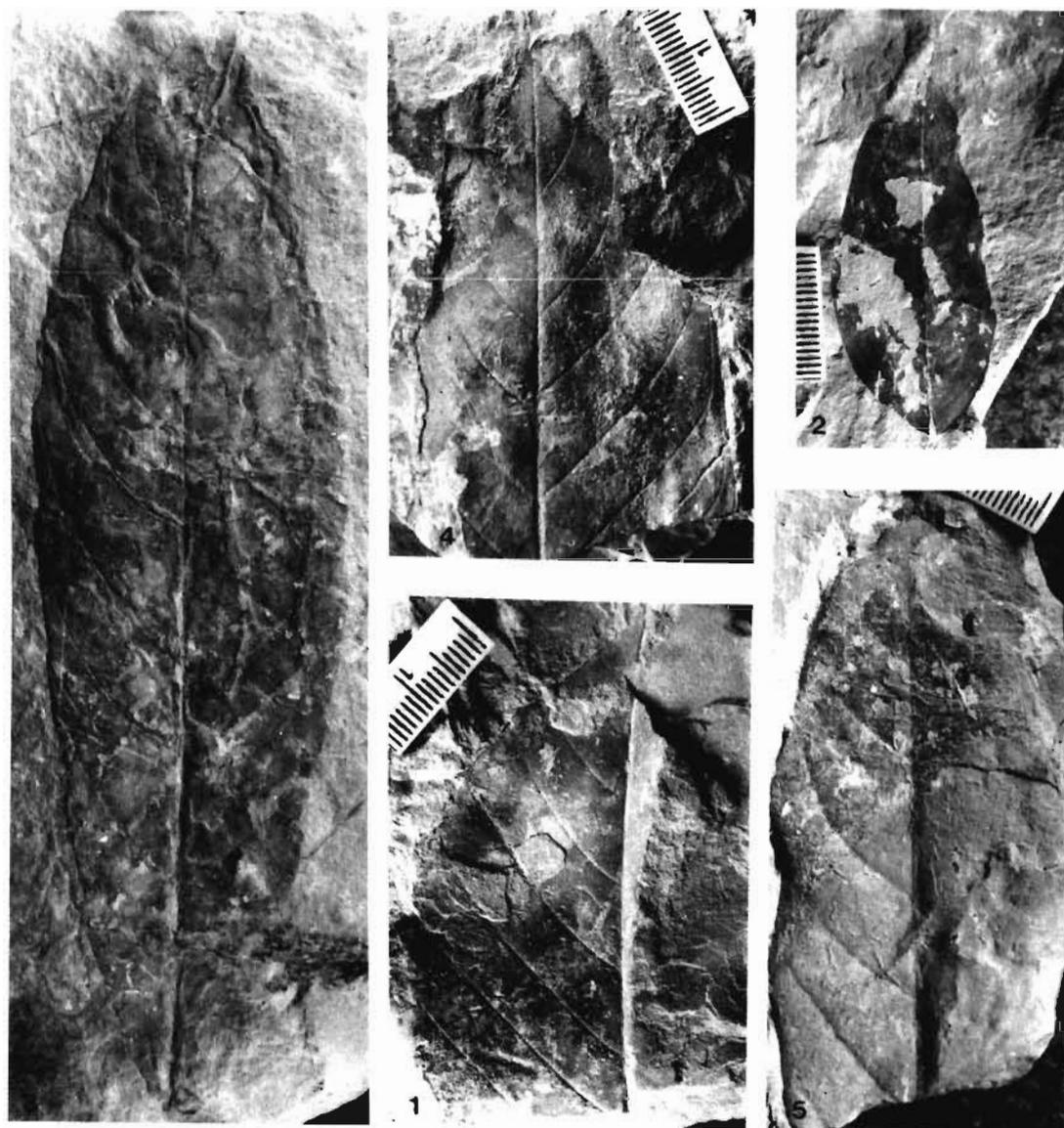


PLATE 2

1994b *Bambusa siwalica* (Awasthi & Prasad)  
Prasad, p. 55, pl. 1, fig. 1.

*Material*—This species is based on four leaf-impressions collected from both Babai and Surkhet Valleys.

*Description*—Leaves simple, symmetrical, lanceolate, preserved size 4.2 x 2.8, 12.5 x 4.0 cm, 16.0 x 3.5, 8.0 x 3.5 cm; apex and base missing; margin entire; texture thick chartaceous; venation parallelodromous, more than 15 pairs of veins running parallel to their adjacent veins, sometimes mid-vein prominent.

*Affinities*—The most characteristic features of the fossil leaves such as lanceolate shape, parallelodromous venation and entire margin indicate their resemblance with those of *Bambusa* Schreber, *Dendrocalamus*, *Oxytenanthera* Munro, *Teinostachyum* Munro; *Thyrsostachya* Gamble and *Cephalostachyum* of the family Poaceae. A detail examination of the modern leaves of above genera reveals that the leaves of *Bambusa arundinacia*, *Dendrocalamus hamiltonii* (F.R.I. Herbarium Sheet no. 49458), *Oxytenanthera thwaitesii* (F.R.I. Herbarium Sheet no. 2053) show resemblance with the fossil leaves. However, *B. tulda* Roxb. (F.R.I. Herbarium Sheet no. 79916) shows closest affinity with the fossil leaves.

Two fossil leaves resembling that of *Bambusa* are known from the Siwalik sediments under the form species *Bambusa siwalica* Awasthi & Prasad. Of them, one is from the Siwalik sediments of Surai Khola, western Nepal (Awasthi & Prasad, 1990) and other is from Siwalik sediments of Kathgodam, Nainital District, Uttar Pradesh, India (Prasad, 1994b). On comparison of these fossil leaves with those of present fossils it has been observed that there is no marked difference between them. Therefore, the present fossil leaves have been kept under the same species *Bambusa siwalica* Awasthi & Prasad.

The modern comparable taxa *Bambusa tulda* Roxb. is a gregarious, densely tufted culm, about 6-24 m high occurring in evergreen forests of Bengal, Assam, Chittagong and Myanmar. It is

common on flat ground and along streams (Brandis, 1971).

Family—Dipterocarpaceae

Genus—*Dipterocarpus* Gaertn.f.

*Dipterocarpus siwalicus* (Lakhanpal & Guleria)

Prasad 1990b

Pl. 2, fig. 1

1987 *Dipterocarpus siwalicus* (Lakhanpal & Guleria), p. 258, figs 1, 2A-C.

1990b *Dipterocarpus siwalicus* (Lakhanpal & Guleria) Prasad, p. 299, pl. 1, figs 1, 3.

1994b *Dipterocarpus siwalicus* (Lakhanpal & Guleria) Prasad, p. 63, pl. 4, fig. 1.

1996b *Dipterocarpus siwalicus* (Lakhanpal & Guleria) Antal & Prasad, p. 74, pl. 1, figs 1, 2.

*Material*—This species consists of a single specimen collected from Surkhet Valley.

*Description*—Leaf fragmentary, apical part preserved, seemingly elliptical; preserved size 6.5 x 4.5 cm; apex acute, slightly curved; base missing; margin entire, slightly undulated; texture chartaceous; venation pinnate, eucamptodromous; primary vein (1<sup>o</sup>) single, prominent, stout, almost straight; secondary veins (2<sup>o</sup>) 9-10 pairs visible with acute angle of divergence, moderate (50<sup>o</sup>-60<sup>o</sup>), upper more acute than lower, secondaries on one side of midrib not clear, uniformly curved up and run almost parallel to each other, moderately thick, unbranched; tertiary veins (3<sup>o</sup>) fine with angle of origin AR-RO, percurrent, simple, sometimes branched, seemingly straight, oblique in relation to mid-vein, alternate to opposite, close. Further details not visible.

*Affinities*—The shape, size and venation pattern of the fossil leaf indicate its resemblance with the modern leaves of *Dipterocarpus tuberculatus* Roxb. of the family Dipterocarpaceae. Uptil now, four fossil leaves resembling the same species are known from the Siwalik sediments of Jawalamukhi, Himachal Pradesh, India (Lakhanpal & Guleria, 1987), Koilabas, western Nepal (Prasad, 1990b), Kathgodam in Nainital

District, Uttar Pradesh, India (Prasad, 1994b) and Darjeeling District, West Bengal (Antal & Prasad, 1996b) under the form species *Dipterocarpus siwalicus*. In over all features the present fossil leaf shows close resemblance with the already known species *Dipterocarpus siwalicus* described from the Siwalik sediments of Koilabas, western Nepal and hence it has been assigned to the same species.

The modern equivalent taxa *D. tuberculatus* Roxb. with which the fossil shows closest similarity is a large deciduous tree growing in plain and low hills in Myanmar. It is also common in Cochin (India), China and Thailand (Brandis, 1971).

Genus—*Hopea* Roxb.

*Hopea mioparviflora* sp. nov.

Pl. 2, fig. 2

*Material*—This species is based on a single well preserved leaf-impression collected from Babai Valley.

*Description*—Leaf simple, symmetrical, lanceolate, size 5.3 x 2.0 cm; apex acute; base wide acute; margin entire; texture chartaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein (1°) prominent, stout, slightly curved; secondary veins (2°) 6-7 pairs visible, angle of divergence narrow acute (about 50°), uniformly curved up, 0.3 to 1.4 cm apart, alternate, seemingly branched; intersecondary veins present, simple; tertiary veins (3°) fine with angle of origin AR-RO, percurrent, rarely branched, usually oblique in relation to mid-vein, predominantly alternate and close. Further details could not be seen.

*Affinities*—The diagnostic features of the present fossil leaf such as lanceolate shape, acute apex and wide acute base, eucamptodromous type of venation, presence of intersecondary veins and narrow acute angle of divergence of secondary veins suggest its resemblance with the modern leaves of *Hopea* Roxb. of the family Dipterocarpaceae. In order to find out its closest species about 30 species of the genus *Hopea* were examined and concluded that the leaves of *Hopea parviflora* Bedd.

(F.R.I. Herbarium Sheet no. 27401) show closest affinity with the fossil leaf.

So far, two fossil leaves resembling the genus *Hopea* Roxb. are known from the Siwalik sediments. Antal and Awasthi (1993) described a fossil leaf under *Hopea siwalika* from the Siwalik sediments near Oodlabari, Darjeeling District, West Bengal, India. Later, Prasad (1994a) described another fossil leaf *Hopea mioglabra* from the Siwalik sediments of Koilabas, western Nepal. Besides, a number of fossil woods resembling the genus *Hopea* have been reported from the Tertiary sediments of India (Prasad, 1993). The present fossil was compared with both the known species. It differs from *Hopea mioglabra* Prasad in being smaller in size having different type of venation pattern. *Hopea siwalika* Antal & Awasthi is somewhat similar to the fossil but can be distinguished in the nature of base and venation pattern. In view of its close affinity with *H. parviflora* it has been described as *Hopea mioparviflora* sp. nov.

*Hopea parviflora* Bedd. with which the fossil shows close affinity is a large tree growing in the evergreen forests of Western Ghats, South Canara, Malabar Hills, Travancore and Tinnevely (Brandis, 1971).

Family—Ampelidaceae

Genus—*Leea* Royen ex. Linn.

*Leea nepalensis* sp. nov.

Pl. 2, fig. 3

*Material*—This species is based on a complete well preserved leaf-impression collected from Babai Valley.

*Description*—Leaf simple, almost symmetrical, narrow lanceolate, size 14.5 x 3.7 cm; apex acute to acuminate, slightly curved; base seemingly cordate, oblique; margin non-entire, dentate, more pronounced in upper part; texture coriaceous; petiole not preserved; venation pinnate, simple craspedodromous to eucamptodromous; primary vein (1°) single, stout, slightly curved in apical part; secondary veins (2°) 13 pairs visible, 0.3 to 1.7 cm apart, basal pairs of secondary veins closely placed,

uniformly curved up; angle of divergence about 60°, moderate acute, seemingly unbranched; tertiary veins (3°) fine with angle of origin usually RR, percurrent, sometimes branched, oblique in relation to mid-vein, alternate to opposite and close. Further details could not be seen.

*Affinities*—In general shape, size and venation pattern the present fossil leaf shows resemblance with the modern leaf/leaflets of *Xylosma longifolium*, *Scolopia spinosa* of the family Flacourtiaceae, *Sterculia densifolia* of Sterculiaceae, *Schima noronhae* and *S. crenulata* of family Ternstroemiaceae, and *Leea parallela* Wall, *L. sambucina* and *L. robusta* of the family Ampelidaceae. A critical examination of the Herbarium sheets of these taxa indicates that the leaves of *Xylosma longifolia* slightly differ in having closely serrated margin and *Sterculia densifolia* have almost entire margin. *Scolopia spinosa* can be differentiated in having very faint secondaries. Similarly, the leaves of *Schima noronhae* and *S. crenulata* are comparatively wide than the fossil and moreover in *S. crenulata* the margins are crenulate. Out of three modern species of *Leea*, the leaflets of *L. parallela* Wall (F.R.I. Herbarium Sheet nos 71817, 2355) show closest similarity in shape, size and venation pattern with the present fossil.

As far as the authors are aware there is no record of the fossil leaflets resembling the genus *Leea* from the Tertiary sediments of Indian subcontinent. Although, two fossil woods are known under the form genus *Leeoxylon* Prakash & Dayal from the Deccan Intertrappean beds of India (Prakash & Dayal, 1964; Trivedi & Panchabhai, 1978). Awasthi and Panjwani (1984) also reported the same fossil wood from Mio-Pliocene beds of Kerala, south India. Thus the present fossil leaflet is being reported for the first time from the Siwalik sediments of Nepal as a new species *Leea nepalensis*.

The modern taxa *Leea parallela* Wall. with which the fossil shows closest resemblance is a tall shrub growing in the evergreen forests of Assam, Myanmar and Malaya (Hooker, 1972; Desch, 1957).

#### Family—Myrsinaceae

##### Genus—*Ardisia* Sw.

*Ardisia palaeosimplicifolia* Prasad 1994b

Pl. 2, fig. 4

1994b *Ardisia palaeosimplicifolia* Prasad, p. 80, pl. 6, fig. 8; pl. 10, fig. 1.

*Material*—This species consists of a single specimen collected from Surkhet Valley.

*Description*—Leaf simple, symmetrical, shape not clear, preserved size 7.3 x 5.4 cm; apex attenuate; base not preserved; margin entire; texture thick chartaceous; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) 6-7 pairs visible, 1.2-1.8 cm apart, angle of divergence about 55°, moderate acute, curved near the margin, alternate to opposite, sometimes branched; intersecondary veins present, simple, rare; tertiary veins (3°) fine with angle of origin usually RR, percurrent, straight to sinuous, branched, oblique in relation to mid-vein, predominantly alternate and close.

*Affinities*—The important morphological features of the present fossil such as attenuate apex, entire margin, eucamptodromous venation, presence of intersecondary veins and the curvature of secondary veins near the margin strongly indicate its close affinity with the extant leaves of *Ardisia simplicifolia* Walp. (F.R.I. Herbarium Sheet no. 2941) of the family Myrsinaceae.

The fossil leaves resembling the genus *Ardisia* Sw. are known from the Siwalik sediments of India. Awasthi and Lakhnupal (1990) described a fossil leaf as *Ardisia antiqua* from the Siwalik sediments of Bhikhnathoree, Bihar. Later, Prasad (1994b) reported a fossil leaf under the form species *Ardisia palaeosimplicifolia* from the Siwalik of Kathgodam, Uttar Pradesh, India. The later fossil species shows close resemblance with the present fossil leaf in shape, size and venation pattern. Therefore, this fossil leaf has also been described under the same species *Ardisia palaeosimplicifolia* Prasad. Besides, a fossil wood

showing resemblance with the genus *Ardisia* has been recorded under *Ardisioxylon indicum* from the Deccan Intertrappean Series of Nawargaon, Wardha District, Maharashtra, India (Shete & Kulkarni, 1982).

The extant taxon *Ardisia simplicifolia* Walp. with which the fossil shows close resemblance is a medium sized tree occurring in evergreen to moist deciduous forests of Tennasserim, Bengal and Assam.

Family—Ebenaceae

Genus—*Diospyros* Linn.

*Diospyros palaeoebenium* Prasad 1994c

Pl. 2, fig. 5

1994c *Diospyros palaeoebenium* Prasad, p.123, fig. 3A.

*Material*—This species is based on a single well preserved leaf-impression collected from Surkhet Valley.

*Description*—Leaf simple, symmetrical, narrow ovate to elliptic, size 8.0 x 4.0 cm; apex slightly broken, seemingly acute; base broken; margin entire, slightly undulated; texture thick chartaceous; petiole not preserved; venation pinnate, brochidodromous; primary vein (1<sup>o</sup>) single, prominent, stout, almost straight; secondary veins (2<sup>o</sup>) 7-8 pairs visible, 1.0-1.8 cm apart, angle of divergence (60°-65°) moderate acute, usually alternate, uniformly curved up, branched; intersecondary veins present, simple; tertiary veins (3<sup>o</sup>) fine, angle of origin usually RR, percurrent, straight to sinuous, sometimes branched, oblique in relation to mid-vein, near the margin nearly right angle to mid-vein, predominantly alternate, close to distant.

*Affinities*—Symmetrical, narrow ovate to elliptic shape, acute apex, entire and slightly undulated margin, brochidodromous venation, presence of intersecondary veins and percurrent tertiaries are the diagnostic features of the present fossil, which are commonly seen in the modern leaves of *Diospyros* Linn. of the family Ebenaceae. A critical study of about 50 species of *Diospyros*

Linn. indicates that the present fossil shows resemblance with the modern leaves of *Diospyros ebenum* Kurz. (Central National Herbarium, Howrah, Sheet no. 563862).

The fossil leaves resembling *Diospyros* Linn. have been described under two generic names, i.e., *Diospyros* Linn. and *Diospyrophyllum* Velenovsky, the later consisting of only one species *Diospyrophyllum provectum* Velenovsky 1889 from the Upper Cretaceous of Bohemia. However, *Diospyros* Linn. includes about 70 species reported from different parts of the world (La Motte, 1952; Prasad, 1987, 1994c). Out of these, 5 fossil species of *Diospyros* Linn. are described from the Himalayan foot-hills. They are *Diospyros koilabasensis* Prasad from the Siwalik sediments of Koilabas, western Nepal (Prasad, 1990a) and Oodlabari, Darjeeling District, West Bengal, India (Antal & Awasthi, 1993), *Diospyros pretoposia* Prasad 1990a from the Siwalik sediments of Koilabas, western Nepal, *D. miokaki* Hu & Channey from Siwalik sediments of Surai Khola, Dang Valley, western Nepal (Awasthi & Prasad, 1990), *Diospyros kathgodamense* Prasad 1994b and *D. palaeoebenium* Prasad 1994c from the Siwaliks of Kathgodam, Nainital District, U.P., India. The present fossil leaf has been compared with all the available known fossil leaves and concluded that fossil leaf—*Diospyros palaeoebenium* Prasad described from the Siwalik hills of Kathgodam shows closest affinity with the present fossil and therefore it is being described under the same species.

The genus *Diospyros* 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* 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 modern taxon *Diospyros ebenum* Kurz. with which the present fossil shows closest affinity is a large tree widely distributed in the forest of Deccan and Carnatic chiefly in dry evergreen forest of Cedded District, specially Kurnool and Cuddapah. It is also found in the dry region of Sri Lanka chiefly in northern Provinces and Malaya (Brandis, 1971; Hooker, 1882).

#### DISCUSSION

The study on plant megafossils collected from the Siwalik sediments exposed in Babai and Surkhet Valleys in Far Western Nepal has added considerably to the present knowledge of fossil flora of Nepal Siwalik Basin. The fossil assemblage recovered from the area consists of 6 species belonging to 5 dicotyledonous families of angiosperms. They are mostly woody and a shrub. Most of the modern comparable taxa are presently distributed in the tropical evergreen forests of different geographical regions. This indicates that such type of forest was flourishing around the area during the deposition of these Siwalik sediments, in contrary to the present dry mixed deciduous forest. The present day distribution of the extant taxa indicates that all of them except *Hopea parviflora* is found to grow in south east Asian region (Myanmar, Malaya, Thailand). Thus the data suggest that these taxa which were flourishing in the Himalayan foot-hills in the area during Siwalik period have migrated towards south and south eastwards where they found favourable conditions for their luxuriant growth. The habit and habitat of the modern equivalent taxa infer a warm and humid climate with plenty of rainfall around Bardiya and Surkhet regions during Middle Miocene-Pliocene Epoch in contrast to the relatively present day dry climate in the area.

The study of physiognomic characters of the leaf-impressions collected from the Siwalik sediments of far western Nepal throws light on climatic condition prevailing during deposition. The fossil assemblage comprises mostly entire margined species with somewhat greater venation

density. The fossil leaves are of medium size with drip tips in *Dipterocarpus siwalicus*, *Hopea mioparviflora*, *Leea nepalensis* and *Ardisia palaeosimplicifolia*. These physiognomic characters also collectively indicate the prevalence of tropical humid climate during Middle Miocene-Pliocene Epoch all along the Himalayan foot-hills.

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