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Systematic study of the leaf impressions from the Churia Formation of Koilabas area, Nepal and their significance

MAHESH PRASAD[1] AND H.D. DWIVEDI[2]

[1]*Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.*
[2]*Department of Botany, M.L.K. Post Graduate College, Balrampur, U.P., India.*

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ABSTRACT

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Detailed study of the leaf impressions collected from the Churia sediments of Koilabas area, western Nepal reveals the occurrence of eight taxa, viz. *Berchemia nepalenisis* sp. nov. (Rhamnaceae), *Canthium siwalicum* sp. nov., *Nauclea seriensis* sp. nov. and *Randia miouncaria* sp. nov. (Rubiaceae), *Alyxia koilabasensis* sp. nov. and *Alstonia nepalensis* sp. nov. (Apocynaceae), *Antidesma miocenica* sp. nov. (Euphorbiaceae) and *Artocarpus nepalensis* Prasad and Awasthi (Moraceae). The habit and habitat of the modern equivalent of leaf impressions indicate existence of evergreen forest thriving under warm humid climate in the Koilabas area during the Middle Miocene as compared to mixed deciduous forests growing at present under reduced precipitation.

Key-words—Leaf impressions, Churia Formation, Middle Miocene, Palaeoclimate, Koilabas, western Nepal.

नेपाल के कोइलाबास क्षेत्र के चुरिया शैलसमूह से प्राप्त पत्ती-छापों का अध्ययन एवं इनकी सार्थकता

महेश प्रसाद एवं एच.डी. द्विवेदी

सारांश

पश्चिमी नेपाल के कोइलाबास क्षेत्र के शिवालिक अवसादों से संग्रहीत पत्ती-छापों के विस्तृत अध्ययन से आठ वर्गकों अर्थात् *बर्चेमिया नेपालेन्सिस* नवप्रजाति (रहाम्नेसी), *कैंथीयम शिवालिकम* नवप्रजाति, *नौक्लेआ सेरीएन्सिस* नवप्रजाति एवं *रेंडिया माओनकेरिआ* नवप्रजाति (रुबिएसी), *एलीक्सिआ कोइलाबासेन्सिस* नवप्रजाति एवं *एल्सटोनिआ नेपालेन्सिस* नवप्रजाति (एपोसाइनेसी), *एंटीडेस्मा मायोसिनिका* नवप्रजाति (यूफोर्बिएसी) एवं *ऑर्टोकार्पस नेपालेन्सिस* प्रसाद व अवस्थी (मोरेसी) की प्राप्ति व्यक्त करते हैं। कोइलाबास क्षेत्र में मध्य मध्यनूतन के दौरान समानीत अवक्षेपण के अंतर्गत वर्तमान में बढ़ रहे मिश्रित पतझड़ी वनों की तुलना में जीवाश्मों की आधुनिक तुलनीय पौधों की प्रकृति एवं आवास कोष्ण आर्द्र जलवायु के अंतर्गत फलते-फूलते सदाहरित वन की विद्यमानता इंगित करते हैं।

संकेत-शब्द—पत्ती छापें, चुरिया शैलसमूह, मध्य-मध्यनूतन, पुराजलवायु, कोइलाबास, पश्चिमी नेपाल।

INTRODUCTION

THE Churia Formation is delimited on the south by the Main Frontal Thurst (MFT) and on the north by the Main Boundary Thrust (MBT). It consists basically of fluvial deposits of the Neogene age (23 to 1.6 m.y.) extending all along the Himalaya forming the southern most hills range with width of 8-50 km. The general dip of the beds of Siwalik has northward trend with varying angle and the overall strike is east-west.

Churia (Siwalik) represents clastic sediments of the nature of fresh water molasses which accumulated in a long narrow fore deep formed to the south of the rising Himalaya during the Middle Miocene. The Siwalik sediment is very rich in plant fossils including woods, leaves, fruits and flowers (Awasthi, 1992; Prasad *et al.*, 1999, 2004; Konomatsu & Awasthi, 1999). A number of plant megafossils specially leaf impressions are recorded from the Siwalik sediments of Nepal (Awasthi & Prasad, 1990; Prasad, 1990a, b; Prasad & Awasthi, 1996, Prasad & Pradhan, 1998, Prasad *et al.* 1999). Recently variety of leaf impressions was collected from the Lower Churia Formation of Koilabas area, western Nepal (Fig. 1). Investigation reveals some new taxa belonging to the families Rhamnaceae, Rubiaceae, Apocynaceae, Euphorbiaceae, and Moraceae.

GEOLOGY OF THE STUDY AREA

The Siwalik sediments of Nepal Himalaya is often called Churia Formation which lies south of the Main Boundary Thrust (Fig. 2). This is thin in Narayangarh and thickens in Nawalpur due to development of valley and again it is thin in Butwal and thickens maximum to Dang area where two valleys – Dang and Rapti valleys developed. The detailed lithology and stratigraphy of the Churia Group of Nepal have been given by Auden (1935), Lehner (1943), Hagen (1959), Bordet (1961), Gleinnie and Zeigler (1964), Ohta and Akiba (1973), Sharma (1977, 1980), Kumar and Gupta (1981), Chaudhuri (1983), West (1984), Tokuoka *et al.* (1986, 1988), Corvinus (1990), Appel *et al.* (1991) and Quade *et al.* (1995).

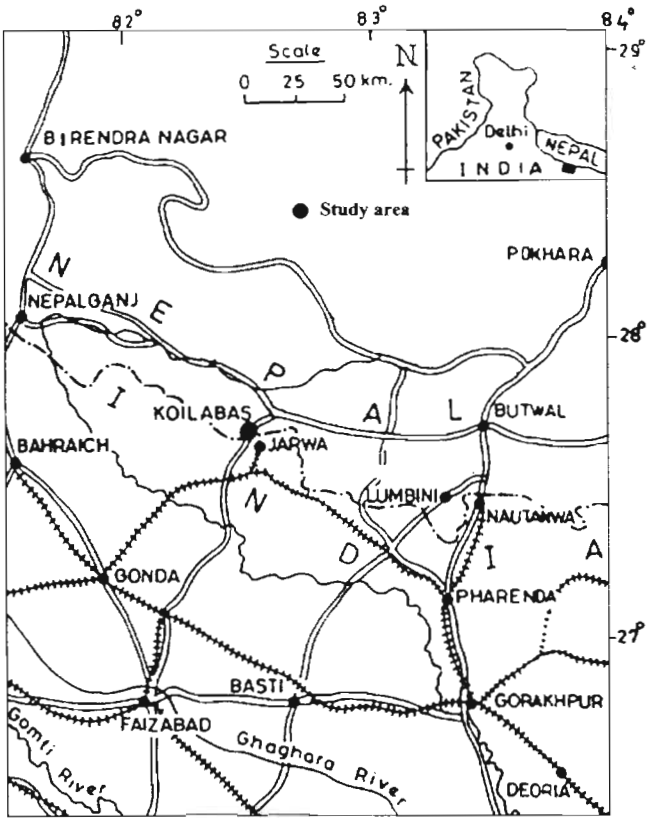


Fig. 1—Map showing the location of study areas.

Hagen (1959) classified the Churia Group into two formations : (i) Lower Churia Formation (Sandstone Facies), and (ii) Upper Churia Formation (Conglomerate Facies). However, a three fold lithostratigraphical classification of the Churia Group in the western Nepal Himalaya has been suggested by Chaudhuri (1983). The Lower Churia Formation with an average thickness of about 1800 m is composed of fine grained green chlorite, biotite, muscovite well bedded indurate sandstones and siltstones. The sandstone is interbedded with green nodular withering clay and siltstone and yellow micaceous clay. Sometimes friable white to yellow medium grained arkosic, pebbly sandstones interbedded with green to brown fine grained sandstones are seen in the upper part of the formation. The rock generally shows simple current bedding. The Upper Churia Formation consisting mainly of boulder pebble bed and loose micaceous sandstone is exposed in south of Lower

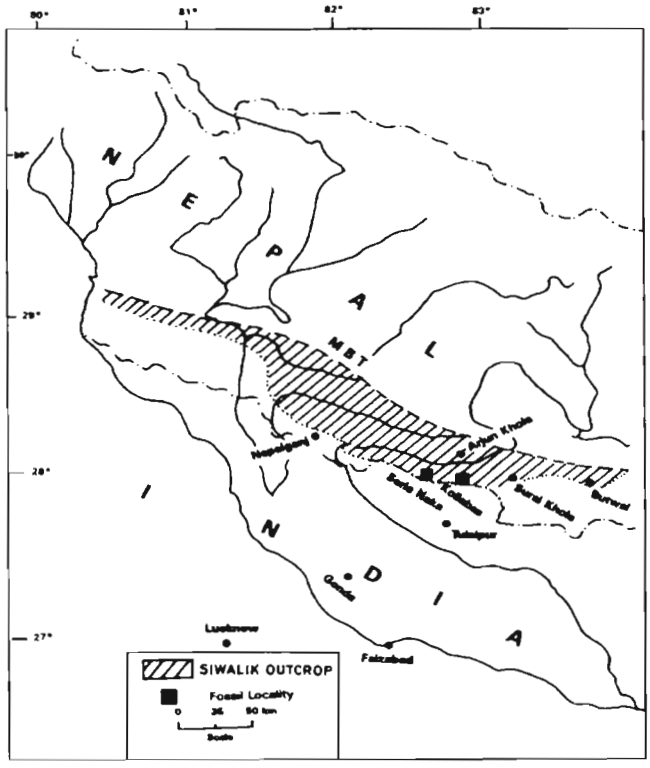


Fig. 2—Map showing outcrop of Churia Formation in Koilabas and Serianaka, western Nepal.

Churia Formation around Dang, Trijuga and east of Dharan. They are graded and cyclic in nature. The bottom part is composed of boulder beds. The boulders are rounded consisting mainly of quartzite cemented with clay.

The fossil locality, Koilabas (27°42': 82°20') is situated in the Dang Section of Churia Hills in western Nepal (Fig. 1). In this area, the Lower Churia Formation is observed from Koilabas to Darwaja containing fine grained sandstone beds with variegated clay and some pebbles (Fig. 3). From Darwaja to Masot Khola, the Rocks of Upper Churia Formation extend. Above the Upper Churia Formation again lies the Lower Churia Formation in Garudbir Pass which is found thrusted (Sharma, 1977). According to Chaudhuri's of three fold division of Churia (Siwalik), this area from Koilabas to Darwaja falls in Lower Churia (Siwalik) Formation and beyond Darwaja to Chorkholi onward the rocks are supposed to be belonging to Middle Churia (Siwalik) Formation which is predominantly arenaceous in nature.

The fossil locality, Serianaka is situated about 10 km west of town Koilabas at Indo-Nepal Border. The sediments of Lower Churia Formation are well exposed in this area on both sides of Seria nala.

MATERIAL AND METHOD

The leaf impressions collected from the Lower Siwalik sediment (Lower Churia Formation) exposed near Koilabas and Serianaka Village, western Nepal (Figs 1-2) are well preserved mostly on grey and purple shale and they are devoid of cuticles. They have been studied with the help of low power microscope. Herbarium sheets of a number of extant taxa mostly belonging to tropical families were examined at the herbarium of Central National Herbarium, Sibpur, Howrah, West Bengal for identification of the fossil impressions. The terminology given by Hickey (1973) and Dilcher (1974) has been used for the description. The photographs of the leaves of modern taxa showing close similarity with the fossil leaves have been provided in the plate. All the figured specimens and negatives are kept in the Department of Botany, M.L.K. Post Graduate College, Balrampur, Uttar Pradesh.

Family—RUBIACEAE

Genus—CANTHIUM Lamarck

Canthium siwalicum sp. nov.

(Pl. 1.5, 7)

Material—This species is based on a single, well preserved and slightly incomplete specimen of leaf impression.

Diagnosis—Leaf slightly asymmetrical, narrow elliptic; size 4.1 x 1.9 cm; apex acute; margin entire; venation eucamptodromous to brochidodromous; primary vein prominent, slightly curved; secondary veins 3-4 pairs, up to 1.5 cm apart with angle of divergence acute (40°-50°), deeply curving upwards; tertiary veins with angle of origin RR, rarely branched, percurrent, right angle in relation to midvein, alternate and close.

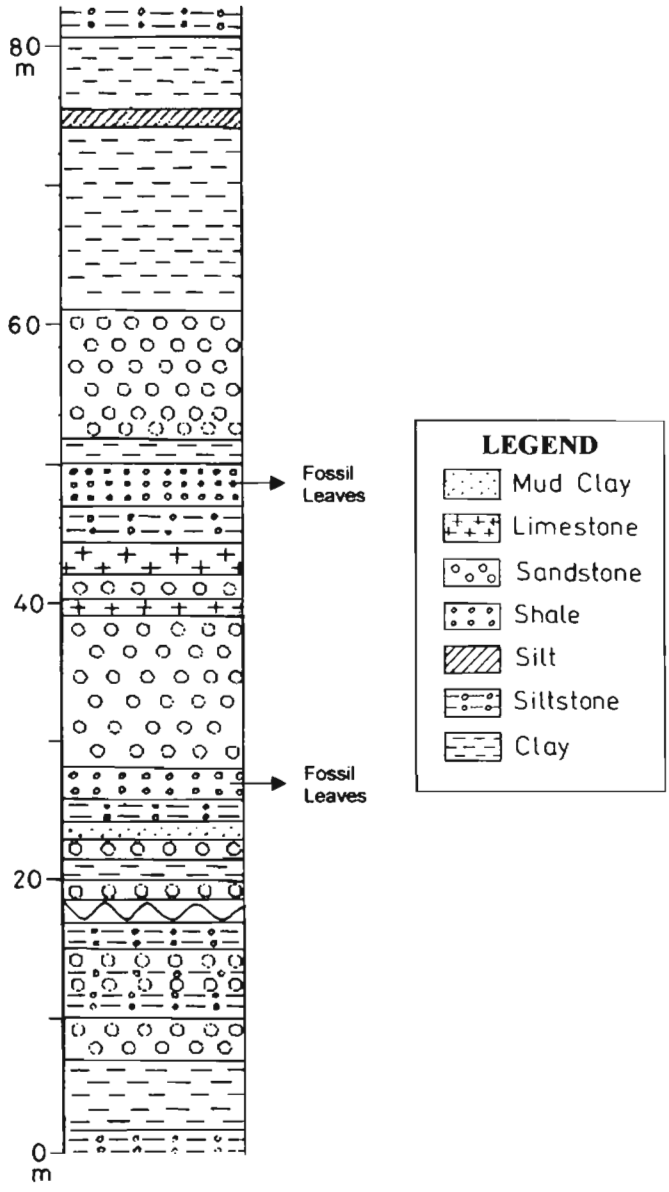


Fig. 3—Lithocolumn of a part of Koilabas nala section indicating the fossiliferous beds from where fossil leaves were collected.

Description—Leaf simple, slightly asymmetrical, narrow elliptic; preserved size 4.1 x 1.9 cm; base broken; apex acute; margin entire; texture thin chartaceous; petiole not preserved, venation pinnate, eucamptodromous to brochidodromous; primary vein (1°) single, prominent, moderate, slightly curved; secondary veins (2°) 3-4 pairs visible, up to 1.5 cm apart with angle of divergence acute (40° -50°), arising uniformly, moderate, deeply curving upwards taking a long course towards apex to reach at margin, unbranched; tertiary veins (3°) fine, angle of origin RR, sometimes branched, percurrent, right angle in relation to midvein, predominantly alternate and close.

Holotype—Specimen No. K-232.

Locality—Koilabas Nala, western Nepal.

Horizon and age—Lower Churia Formation; Middle Miocene.

Etymology—After the name of Siwalik sediments.

Modern affinity—The diagnostic features of the present fossil leaf such as slightly asymmetrical, narrow elliptic shape, acute apex, entire margin, eucamptodromous to brochidodromous type of venation, distantly arranged few secondaries running upward for a long distance, RR, percurrent tertiaries which are right angle in relation to midvein collectively suggest its affinity with the modern leaves of *Canthium didymum* Roxburgh of the family Rubiaceae (C.N.H. Herbarium Sheet No. 11483, Pl. 1.6; Pl. 2.7).

Fossil records and comparison—So far, there is no record of any fossil leaf showing resemblance with the genus *Canthium* Lamarck. This fossil leaf forms its first fossil record from the Siwalik sediments of Koilabas area, western Nepal and is described here as *Canthium siwalicum* sp. nov.

Present day distribution—The genus *Canthium* Lamarck comprises about 70 species distributed in the tropics of old world. *Canthium didymum* Roxburgh with which fossil shows closest affinity is a small evergreen tree found to grow in Western Ghat, Nilgiris, Orissa, Sikkim, Upper Myanmar, Khasi and Jayantia hills, Sri Lanka and Malaya peninsula (Brandis, 1971).

Genus—**NAUCLEA** Linnaeus

Nauclea seriaensis sp. nov.

(Pl. 1.1, 3)

Material—There is a single specimen of leaf impression with slightly broken apex.

Diagnosis—Leaf slightly asymmetrical, elliptic; preserved size 8.6 x 5.3 cm; base obtuse; margin entire; venation eucamptodromous; primary vein prominent, slightly curved; secondary veins about 6 pairs 0.9 to

Fossil taxa	Modern equivalent taxa	Forest types	Present day distribution
Berchemia nepalensis sp. nov.	*B. hamosa* Brongniart	Mixed deciduous	Nepal, Western peninsula
Canthium siwalicum sp. nov.	*C. dydimum* Roxburgh	Evergreen	India, Myanmar
Randia miouncaria sp. nov.	*R. uncaria* Elmer	Evergreen	Philippines
Nauclea seriaensis sp. nov.	*N. subdita* (Miquel) Merril	Evergreen	Malaya
Alyxia koilabasensis sp. nov.	*A. fasciculata* Bentham	Evergreen	North east India
Alstonia nepalensis sp. nov.	*A. angustifolia* Wallich	Evergreen	Malacca, Myanmar
Antidesma miocenica sp. nov.	*A. veluntinosum* Blume	Evergreen	Myanmar, Malaya
Artocarpus nepalensis Prasad & Awasthi	*A. integrifolia* Linnaeus f.	Evergreen	N.E. India, Myanmar, Western Ghats

Fig. 4—Present day distribution of the modern equivalent taxa of the fossils recovered from the Koilabas area, western Nepal.

2.2 cm apart, angle of divergence acute (40°-50°), alternate to subopposite, uniformly curved up, unbranched; tertiary veins with angle of origin RR, percurrent, branched, predominantly alternate and close.

Description—Leaf simple, slightly asymmetrical at basal part, elliptic; preserved size 8.6 x 5.3 cm; apex broken; base obtuse; margin entire; texture thick chartaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, , stout, slightly curved; secondary veins (2°) poorly preserved, about 6 pairs visible, 0.9 to 2.2 cm apart, angle of divergence acute (40°-50°), upper secondaries more acute than lower, alternate to subopposite, uniformly curved up, unbranched; tertiary veins (3°) fine, poorly preserved, angle of origin RR, percurrent, branched, oblique in relation to midvein, predominantly alternate and close. Further details could not be seen.

Holotype—Specimen No. S-23.

Locality—Seria Naka, western Nepal.

Horizon and age—Lower Churia Formation; Middle Miocene.

Etymology—After the name of fossil locality, Seria Naka from where the fossil was collected.

Modern affinities—The characteristic features of the present fossil leaf are slightly asymmetrical elliptic shape, obtuse base, entire margin, eucamptodromous venation, acute angle of divergence of secondary veins which run straightly toward margin and RR, percurrent tertiary veins. These features collectively suggest that the present fossil resembles closely with the modern leaves of *Nauclea subdita* (Miquel) Merril of the family Rubiaceae (C.N.H. Herbarium Sheet No. 197791; Pl. 1.2, 4).

Fossil records and comparison—There is no record of fossil leaf resembling the genus *Nauclea* Linnaeus. This is the first record of fossil leaf of *Nauclea* Linnaeus from the Tertiary sediments of Nepal. Therefore, it has been discribed as *Nauclea seriaensis* sp. nov.

Present day distribution—The genus *Nauclea* Linn. consists of about 12 species of trees and shrubs distributed in tropical regions (Mabberley, 1997) *Nauclea subdita* (Miquel) Merril with which fossil shows close resemblance is distributed in Malayan region (Desch, 1957).

Genus—RANDIA Linnaeus

Randia miouncaria sp. nov.

(Pl. 2.1, 3)

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

Diagnosis—Leaf oblanceolate; preserved size 11 x 4.5 cm; base cuneate; margin entire; venation eucamptodromous; primary vein prominent, straight; secondary veins 5 pairs visible, 0.8 to 2.4 cm apart, angle of divergence moderate acute (50°-60°), uniformly curving upwards, sub-opposite to alternate, unbranched; tertiary veins with angle of origin usually RR, rarely AO, percurrent, alternate and close to distant.

Description—Leaf simple, symmetrical, oblanceolate; preserved length 11 cm; maximum width 4.5 cm; apex broken; base cuneate; margin entire; texture, chartaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, straight; secondary veins (2°) 5 pairs visible, 0.8 to 2.4 cm apart, angle of divergence moderate acute (50°-60°), moderate in thickness, uniformly curving upwards, sub-opposite to alternate, unbranched; tertiary veins (3°) fine, with angle of origin usually RR rarely AO, percurrent, almost straight oblique in relation to midvein, predominantly alternate and close to distant, Further details not preserved.

Holotype—Specimen No. S-14a.

Locality—Seria Naka, western Nepal.

Horizon and age—Lower Churia Formation; Middle Miocene.

Etymology—By adding prefix 'mio' to the name of modern comparable species *Randia uncaria* Elmer.

Modern affinity—The most important features of the present fossil leaf such as oblanceolate shape, cuneate base, entire margin, eucamptodromous venation, moderate angle of divergence of secondary veins and usually RR, percurrent, slightly spacely arranged tertiary veins undoubtedly indicate affinity of the fossil leaf with modern leaves of *Randia uncaria* Elmer of the family Rubiaceae (C.N.H. Herbarium Sheet No. 7001; Pl. 2.2, 4).

Fossil records and comparison—Seven species of fossil leaves showing affinity with the genus *Randia* Linnaeus are known from India and abroad. These are *Randia prodroma* Unger from the Miocene of Germany (Salomon-Calvi, 1934), *R. gossferiana* Kschun from the Tertiary of Kamerun, Germany (Menzel, 1920), *R. mohavensis* Axelrod (1950) from the Miocene of North America, *R. miowallichii* Prasad (1990a) from the Siwalik sediments of Koilabas, Nepal and from Oodlabari, Darjeeling District, West Bengal (Antal & Awasthi, 1993) and *R. siwalica* Prasad & Awasthi and *R. palaeofasciculata* Prasad & Awasthi from Siwalik sediments of Suraikhola, western Nepal (Prasad & Awasthi 1996). None of these species show similarity with the present fossil. The present specimen is characterized by its larger size (11.0 x 4.5 cm) as compared to *R. palaeofasciculata* Prasad & Awasthi (3.4 x 1.4 cm). The fossil leaf, *R. siwalica* Prasad & Awasthi can be differentiated in being its very large size (18.5 x 5.8 cm) with narrow elliptic shape. However, *R. miowallichii* Prasad is almost same in size but possesses about 10 pairs of closely placed secondary veins in comprison to only 5 pairs of widely spaced secondary vein in the present fossil. Moreover, the type of venation in *R. miowallichii* Prasad is craspedodromous as compared to eucamptodromous type of venation in the present fossil. Similarly the fossil leaves known from abroad mainly differ in the nature and orientation of secondary and tertiary veins. In being different from already known species the present fossil leaf has been described as *Randia miouncaria* sp. nov.

Present day distribution—The genus *Randia* Linnaeus comprises about 250 species distributed throughout the tropical to subtropical regions of the world. The extant taxon *Randia uncaria* Elmer with which fossil resembles closely is distributed in the tropical regions of Philippines.

PLATE 1 →

(All figures are of natural size unless otherwise mentioned)

1. *Nauclea seriaensis* sp. nov. - Fossil leaf showing shape, size and venation pattern.
2. *Nauclea subdita* (Miq.) Merr. - Modern leaf showing similar shape, size and venation pattern.
3. *Nauclea seriaensis* sp. nov. - A part of fossil leaf magnified to show details of venation. x 2.
4. *Nauclea subdita* (Miq.) Merr. - A part of modern leaf magnified to show similar details of venation. x 2.
5. *Canthium siwalicum* sp. nov.- Fossil leaf showing shape, size and venation pattern.
6. *Canthium didymum* Roxb. - Modern leaf showing similar shape, size and venation pattern.
7. *Canthium siwalicum* sp. nov.- A part of fossil leaf magnified to show details of venation. x 3.

PLATE 1

Family—RHAMNACEAE

Genus—BERCHEMIA Necker

Berchemia nepalensis sp. nov.

(Pl. 2.5, 6)

Material—This species consists of a single well preserved and almost complete leaf impression.

Diagnosis—Leaf narrow elliptic; preserved size 7.8 x 2.1 cm; apex acute; margin entire; venation eucamptodromous; primary vein curved at the apex; secondary veins about 9 pairs visible, 0.6 -1.0 cm apart, angle of divergence acute (45°-55°), unbranched; inter secondary veins present, tertiary veins with angle of origin usually RR, oblique in relation to midvein, altemate and close.

Description—Leaf simple, almost symmetrical, narrow elliptic; preserved size 7.8 x 2.1 cm; apex acute; base broken; margin entire; texture chartaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, slightly curved at the apex; secondary veins (2°) about 9 pairs visible, 0.6-1.0 cm apart, alternate to subopposite, angle of divergence acute (45°-55°), lower secondary deeply curving upwards taking a long course towards apex to reach at margin, unbranched; inter secondary veins present, simple, rare; tertiary veins (3°) fine, angle of origin usually RR, straight to sinuous, oblique in relation to midvein, predominantly alternate, close; quaternary veins very fine, randomly oriented forming polygonal meshes.

Holotype—Specimen No. S-60.

Locality—Seria Naka, western Nepal.

Horizon and age—Lower Churia Formation; Middle Miocene.

Etymology—After Nepal to which fossil locality Seria Naka belongs.

Modern affinity—Almost symmetrical, narrow elliptic shape, acute apex, entire margin, eucamptodromous venation, acute angle of secondary veins which are taking a long course towards apex to reach margin, RR, percurrent, straight to sinuous tertiary veins of the fossil leaf collectively indicate the affinity of the fossil leaf with the extant leaves of *Berchemia hamosa* Brongniart of the family Rhamnaceae (C.N.H. Herbarium Sheet No. 88832).

Fossil records and comparison—Two fossil record of the genus *Berchemia* Necker are known from the Siwalik sediments. These are *Berchemia bolugoloensis* from Siwalik sediments of Jawalamukhi, Himachal Pradesh (Lakhanpal, 1967) and *Berchemia siwalica* from the Siwalik sediments of Jarva, Uttar Pradesh, India (Tripathi *et al.*, 2002). Both the leaves differ from present fossil mainly in different nature of secondary veins which arise closely than the present fossil leaf. Further, in both the known fossil the secondary veins are slightly curved and join the margin while in case of present fossil the lower few pairs of secondary veins are deeply curving up and taking a long course before joining the margin. Being different, the present fossil leaf is described as *Berchemia nepalensis* sp. nov.

Present day distribution—The genus *Berchemia* Necker consists of about 11 species distributed in Eastern Asia, tropical Africa and tropical regions of North America. *Berchemia hamosa* Brongniart, with

PLATE 2 →

(All figures are of natural size unless otherwise mentioned)

1. *Randia miouncaria* sp. nov. - Fossil leaf showing shape, size and venation pattern.
2. *Randia uncaria* Elmer - Modern leaf showing similar shape, size and venation pattern.
3. *Randia miouncaria* sp. nov. - A part of fossil leaf magnified to show details of venation. x 2.5.
4. *Randia uncaria* Elmer - A part of modern leaf magnified to show similar details of venation. x 2.
5. *Berchemia nepalensis* sp. nov.- Fossil leaf showing shape, size and venation pattern.
6. *Berchemia nepalensis* sp. nov.- A part of fossil leaf magnified to show details of venation. x 2.5.
7. *Canthium didymum* Roxb. - A part of modern leaf magnified to show similar details of venation as the fossil (Pl. 1.5). x 2.

PLATE 2

which fossil resembles closely is a large shrub found to grow in India and Nepal (Hooker, 1872).

Family—APOCYNACEAE

Genus—ALYXIA Brown

Alyxia koilabasensis sp. nov.

(Pl. 3.6, 8)

Material—There is only one specimen of leaf impression which is well preserved and incomplete .

Diagnosis—Leaf elliptic, preserved size 2.6 x 1.6 cm; base acute; margin entire; venation eucamptodromous; primary vein prominent, slightly curved; secondary veins about 16 pairs visible, very closely placed, angle of divergence wide acute (70°-80°), tertiary veins fine with angle of origin usually RR, percurrent, alternate and close.

Description—Leaf simple seemingly elliptic, symmetrical; preserved size 2.6 x 1.6 cm; apex broken; base acute; margin entire; texture thin chartaceous; petiole not preserved, venation pinnate, eucamptodromous; primary vein (1°) single, prominent, moderate, unbranched, slightly curved; secondary veins (2°) about 16 pairs visible, very closely placed, 1-2 mm apart, angle of divergence wide acute (70°-80°), arising uniformly, moderate; tertiary veins (3°) fine, angle of origin usually RR, percurrent, oblique to nearly parallel in relation to mid vein, predominantly alternate, close; quaternary veins (4°) still fine, randomly oriented forming polygonal meshes, Further details not preserved.

Holotype—Specimen No. K-223.

Locality—Koilabas Nala, western Nepal.

Horizon and age—Lower Churia Formation; Middle Miocene.

Etymology—After the name of fossil locality, Koilabas.

Modern affinities—The shape size and venation pattern, mainly orientation of secondary veins which are fine and arising very closely at wide acute angle, indicate that the fossil leaf shows closest affinity with the modern leaves of *Alyxia fasciculata* Bentham of the family Apocynaceae (C.N.H. Herbarium Sheet No. 289185 ; Pl. 3.7, 9).

Fossil records and comparison—There is no fossil record of the genus *Alyxia* Brown and hence it is described here as a new species, *Alyxia koilabasensis.*

Present day distribution—The genus *Alyxia* Brown comprises about 30 species distributed in tropical Asia, Malaya, Australia and Polynesia. The extant taxon *A. fasciculata* Bentham with which fossil resembles closely is a woody shrub found in Khasi hills, Churra and Desilva (Hooker, 1882).

Family—APOCYNACEAE

Genus—ALSTONIA R. Brown

Alstonia nepalensis sp. nov.

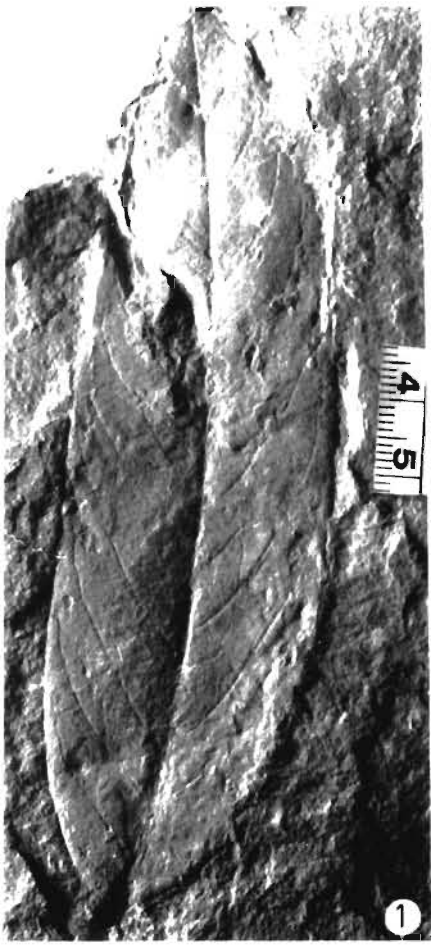
(Pl. 3.4; Pl. 4.5)

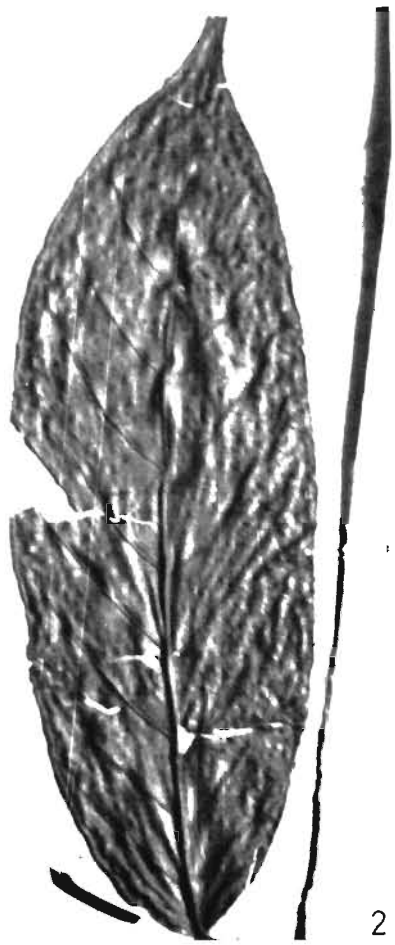
Material—This species is based on a single, well preserved and almost complete specimen of leaf impression.

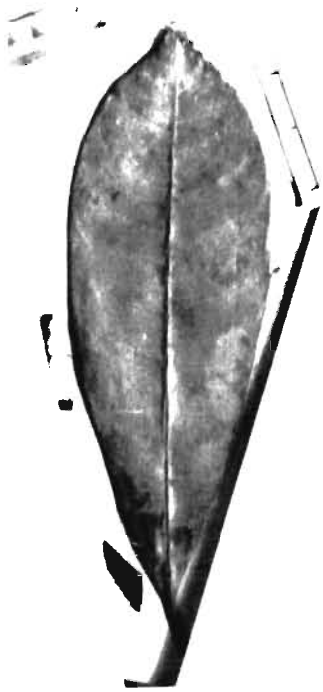
PLATE 3 →

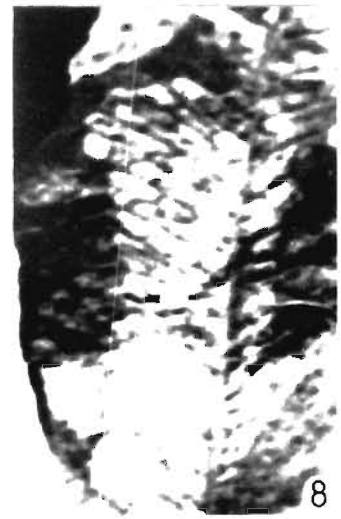
(All figures are of natural size unless otherwise mentioned)

1. *Antidesma miocenica* sp. nov.- Fossil leaf showing shape, size and venation pattern.
2. *Antidesma veluntinosum* Blume - Modern leaf showing similar shape, size and venation pattern.
3. *Antidesma miocenica* sp. nov.- An other fossil leaf showing variation in shape and size.
4. *Alstonia nepalensis* sp. nov.- Fossil leaf showing shape, size and venation pattern.
5. *Alstonia angustifolia* Wall. - Modern leaf showing similar shape, size and venation pattern.
6. *Alyxia koilabasensis* sp. nov.- Fossil leaf showing shape, size and venation pattern.
7. *Alyxia fasciculata* Benth. - Modern leaf showing similar shape, size and venation pattern.
8. *Alyxia koilabasensis* sp. nov.- A part of fossil leaf magnified to show details of venation. x 2.5.
9. *Alyxia fasciculata* Benth. - A part of modern leaf magnified to show similar details of venation. x 2.5.









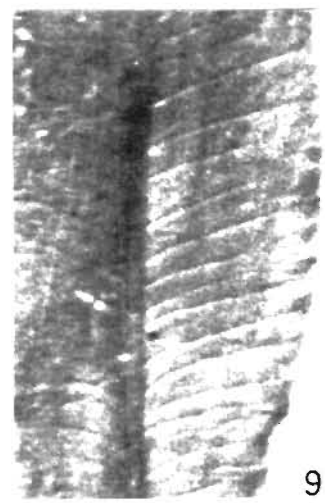


PLATE 3

Diagnosis—Leaf oblanceolate; size 7 x 2.5 cm; base cuneate; margin entire; petiole distinct; venation craspedodromous to eucamptodromous; primary veins prominent; secondary veins about 13 pairs visible, 0.4-0.9 cm apart with angle of divergence acute (60°), inter secondary veins present; tertiary veins with angle of origin RR, percurrent; alternate and close,

Description—Leaf simple, symmetrical, oblanceolate; preserved length 7 cm, maximum width 2.5 cm; apex broken; base cuneate, slightly curved; margin entire; texture coriaceous; petiole distinct, 0.3 cm long, curved; venation pinnate, simple craspedodromous to eucamptodromous; primary vein (1°) single, prominent, stout, almost straight; secondary veins (2°) about 13 pairs visible, 0.4-0.9 cm apart with angle of divergence moderate acute (60°), running almost parallel to each other, moderate, slightly curved up, unbranched, inter secondary veins present, poorly preserved, frequent, simple; tertiary veins (3°) fine with angle of origin RR, percurrent, almost oblique in relation to midvein, predominantly alternate and close, Further details not preserved.

Holotype—Specimen No. S-13.

Locality—Seria Naka, western Nepal.

Horizon and age—Lower Churia Formation; Middle Miocene.

Etymology—After Nepal to which the fossil locality, Seria Naka, belongs.

Modern affinity—The diagnostic features of the present fossil leaf such as oblanceolate shape, cuneate, slightly curved base, entire margin, acute angle of divergence of secondary veins which run almost parallel to each other, some times curved and joined to their superadjacent secondary; RR, percurrent tertiaries and presence of inter secondary veins indicate that the fossil leaf belongs to the genus *Alstonia* R. Brown of the family Apocynaceae. A critical examination reveals that the leaves of extant *Alstonia angustifolia* Wallich show closest affinity with the present fossil specimen (C.N.H. Herbarium Sheet No. 289879, Pl. 3.5; Pl. 4.6).

Fossil records and comparison—So far, two fossil leaves showing resemblance with the genus *Alstonia* R. Brown are known from the Tertiary sediments of India. First of all Bande and Srivastava (1990) described fossil leaf of *Alstonia scholaris* Brown from the Upper Tertiary sediments of Mahuadanr Valley, Palamau District, Bihar. Secondly Antal and Awasthi (1993) reported another fossil leaf, *Alstonia mioscholaris* resembling the same species from the Siwalik sediments of Oodlabari, Darjeeling District, West Bengal. Both the above known fossil leaf resembles *Alstonia scholaris* Brown while the present fossil leaf resembles closely with the extant species *Alstonia angustifolia,* Wall. and differ from them in being possessing few secondary veins which are distantly arranged. Moreover, the intramarginal veins occurring in the above known fossil leaves are absent in the present fossil. Thus, the present fossil is different from them and hence described as a new species, *Alstonia nepalensis.*

Present day distribution—The genus *Alstonia* R. Brown. comprises about 50 species distributed in the Indo-Malayan region. Only four species are found in India and Nepal. *Alstonia angustifolia* Wallich with which fossil resembles closely is a large tree found to occur in Malaya peninsula (Ridley, 1923; Desch, 1957).

Family—EUPHORBIACEAE

Genus—ANTIDESMA Linnaeus

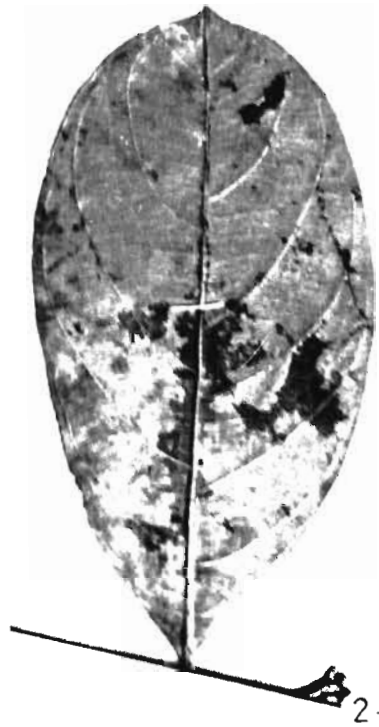
Antidesma miocenica sp. nov.

(Pl. 3.1, 3; Pl. 4.4)

PLATE 4 ⟶

(All figures are of natural size unless otherwise mentioned)

1. *Artocarpus nepalensis* Prasad & Awasthi- Fossil leaf showing shape, size and venation pattern.
2. *Artocarpus integrifolia* Linn f.- Modern leaf showing similar shape, size and venation pattern.
3. *Artocarpus nepalensis* Prasad & Awasthi- A part of fossil leaf magnified to show details of venation. x 2.25.
4. *Antidesma miocenica* sp. nov.- A part of fossil leaf (Pl. 3.1) magnified to show details of venation. x 2.25.
5. *Alstonia nepalensis* sp. nov.- A part of fossil leaf magnified to show details of venation. x 2.
6. *Alstonia angustifolia* Wall. - A part of modern leaf magnified to show similar details of venation. x 2.



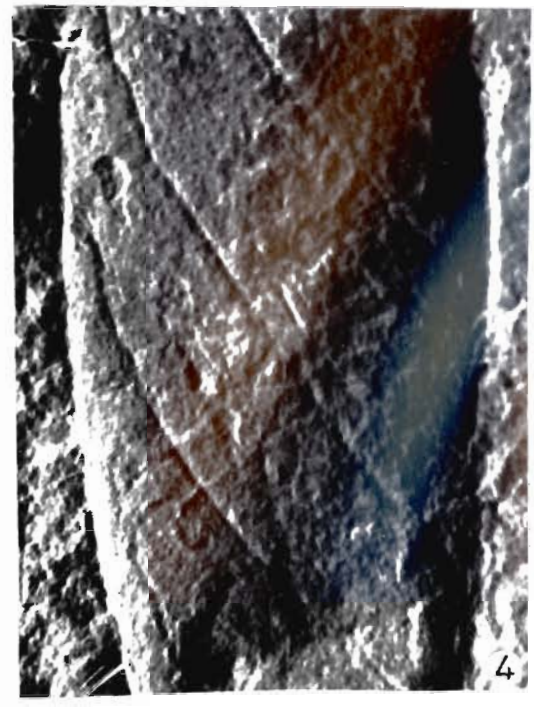


PLATE 4

Material—The species is based on two well preserved specimens of leaf impression.

Diagnosis—Leaf narrow elliptic; maximum size 10.5 x 4.2 cm; apex acute; base obtuse; margin entire; venation eucamptodromous; primary vein prominent, slightly curved; secondary veins 12 pairs, 0.7-1.3 cm apart, unbranched, angle of divergence wide acute (50°-60°), inter secondary veins present, tertiary veins with angle of origin RR, percurrent, alternate and close

Description—Leaf simple, almost symmetrical, narrow elliptic, preserved size 10.5 x 3.2 , 10.2 x 4.2 cm; apex slightly broken, seemingly acute; base obtuse; margin entire; texture thin chartaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein (1°) single, prominent, stout, slightly curved; secondary veins (2°) about 12 pairs, 0.7-1.3 cm apart, alternate to subopposite, unbranched, angle of divergence acute (50°-60°), moderate, uniformly curved up; running upward for a short distance; inter secondary veins present, simple rare; tertiary veins (3°) fine, angle of origin RR, percurrent, straight, branched, oblique in relation to midvein, predominantly alternate and close; Further details could not be seen.

Holotype—Specimen No. K-42.

Paratype—Specimen No. K-44.

Locality—Imlibasa, Koilabas, western Nepal.

Horizon and age—Lower Churia Formation; Middle Miocene.

Etymology—After the Miocene, the age of the sediments from which samples are collected.

Modern affinity—The most important features of the present fossil leaves are elliptic shape, acute apex and base, entire margin, eucamptodromous venation, alternate to subopposite secondary veins arising at wide acute angle and running upward for a short distance, RR, percurrent tertiaries and presence of inter secondary veins. These features collectively suggest the affinity of the present fossil leaf with that of modern *Antidesma veluntinosum* Blume of the family Euphorbiaceae (C.N.H. Herbarium Sheet No. 407945; Pl. 3.2).

Fossil records and comparison—A fossil leaf has been recordrd from Siwalik sediments of Koilabas Nala Section as *Antidesma siwalica* (Prasad *et al.*, 1999). This taxa has been compared with the extant species *A. cuspidatum* Muel. Arg. and *A. montanum* Blume. The present fossils resemble closely to the extant species *A. veluntinosum* Blume and are quite different in being narrow elliptic shape with smaller size. Moreover, the curvature of secondary veins in *A. siwalica* Prasad *et al.* is more pronounced near the margin. Therefore, these have been described as *Antidesma miocenica* sp. nov.

Present day distribution—The genus *Antidesma* Linnaeus is represented by 170 species distributed in tropical to sub-tropical regions especially in Asia. The extant species, *A. veluntinosum* Blume with which fossils show affinity is an evergreen tree found in Tenasserim, Malaya peninsula and Archipelago and Myanmar (Brandis, 1971).

FAMILY—MORACEAE

Genus—ARTOCARPUS Jackson R. & Forster

Artocarpus nepalensis Prasad & Awasthi, 1996

(Pl. 4.1, 3)

Material—There is a single specimen which is almost complete with satisfactory preservation.

Description—Leaf simple, symmetrical, wide obovate; preserved size 11.5 x 4.5 cm; apex seemingly acuminate; base acute; margin entire; texture coriaceous; petiole not preserved; venation eucamptodromous; primary veins (1°) single, prominent, slightly curved, stout; secondary veins (2°) about 7 pairs, 0.6 to 2.1 cm apart, angle of divergence (60°-75°), wide acute, lower pairs of secondary arise more acute, unbranched uniformly curved up; inter secondary veins present, simple; tertiary veins (3°) fine, poorly preserved, angle of origin mostly RR rarely AO, percurrent, sometimes branched straight to sinuous, oblique in relation to midvein, predominantly alternate and close .

Specimen—Specimen No. S-14.

Locality—Seria Naka, western Nepal.

Horizon and age—Lower Churia Formation; Middle Miocene.

Modern affinity—The diagnostic features of the present fossil leaf such as its obovate shape, acuminate apex and acute base, eucamptodromous type of venation; wide acute angle of secondary veins and RR, percurrent, straight to sinuous tertiary veins undoubtedly indicates that the fossil resembles closely to the leaves of *Artocarpus integrifolia* Linnaeus f. of the family Moraceae (C.N.H. Herbarium Sheet No. 27108; Pl. 4.2).

Fossil records and comparison—So far, three fossil leaves resembling the genus *Artocarpus* Jackson R. & Forst. are known from the Tertiary sediments of India and Nepal. They are *Artocarpus murrecus* from the Murree sediments, Jammu (Sharma & Gupta, 1972), *Artocarpus garoensis* from the Tura Formation (Upper Palaeocene) of Garo Hills, Meghalaya (Bhattacharya, 1983) and *Artocarpus nepalensis* from the Siwalik sediments of Surai Khola sequence, western Nepal (Prasad & Awasthi, 1996). All these above fossil leaves have been compared with the present fossil and it was found that the leaf, *Artocarpus nepalensis* Prasad & Awasthi shows closest similarity with the present fossil in shape, size and venation pattern. Therefore, it has been described under the same species *Artocarpus nepalensis* Prasad & Awasthi.

Present day distribution—The extant taxon *Artocarpus integrifolia* Linnaeus f. with which fossil shows affinity is a large evergreen tree distributed in the dense forest along the Western Ghats. It is also cultivated in India, Myanmar and Pakistan (Brandis, 1971).

CONCLUSIONS

Study of the leaf impressions collected from Siwalik sediments (Lower Churia Formation) of Koilabas area, western Nepal revealed the presence of eight taxa, out of which seven are new showing close affinities with those of *Berchemia hamosa* Brongniart of family Rhamnaceae, *Canthium dydimum* Roxburgh, *Randia uncaria* Elmer, and *Nauclea subdita* (Miquel) Merril of family Rubiaceae, *Alyxia fasciculata* Bentham and *Alstonia angustifolia* Wallich of family Apocynaceae, *Antidesma veluntinosum* Blume of family Euphorbiaceae and *Artocarpus integrifolia* Linnaeus f. of the family Moraceae. The analysis of the present day distribution of the above equivalent taxa indicates that all of them (except *Berchemia hamosa* Brongniart) are now a days flourishing luxuriantly in the evergreen forests of north east India, Myanmar and Malayan regions (Fig. 4). This indicates that such evergreen taxa existed in and around the Koilabas area during Middle Miocene times. However, they became extinct from the region due to changes in environmental conditions most probably due to uplift of the Himalaya. In Early Pleistocene the uplift of Himalaya and associated mountains was responsible for the floristic change all along the Himalayan foot hills because the rising mountains became effective barriers to floral migration and also to monsoon clouds and wind current, causing the prevalence of dry condition. As a result, the pre Pliocene summer high rainfall changed into low rainfall area providing the environment suitable for tropical mixed deciduous flora to invade the region.

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