PalArch's Journal of Archaeology of Egypt / Egyptology

"Leaf-Impression and Palaeoscientific Study of Siwalik-belt of Koilabas in Western Nepal: Part-1"

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Neetu Chandra, Pateshwari Prasad Tripathi, Leaf-Impression and Palaeoscientific Study of Siwalik-belt of Koilabas in Western Nepal: Part-1, -- Palarch's Journal Of Archaeology Of Egypt/Egyptology 18(4). ISSN 1567-214x

Keywords: Leaf-impression, palaeoscience, Siwalik-belt of Koilabas and Western Nepal.

ABSTRACT

The present study comprises of well-preserved leaf-impression of eleven species of angiosperm. These leaf-impressions were searched from Siwalik belt of Koilabas in Western Nepal. We have found that above eleven species belonging to eleven genera and eight family of dicotyledon. Based on above study alongwith already known data, the palaeoecology and phytogeography of area shows Miocene-Pleistocene age in the Himalayan foot hills. Above study also signify the physiogenomic characters of fossil's leaves with climate.

Introduction:

Paleoscience play an important role to understand the pre-existing lives on universe and tell the environmental conditions of that time and what happened which makes them fossils. Are environmental conditions for these fossil species at that time making them fossils? Are they failing to survive due to competition among fitted species of that time? Are individual activities making them fossils? Paleobotany plays a big role to know pre-existing plants of various families from phytoplankton to giant plants including bacteria, fungi, bryophytes, pteridophytes, gymnosperms and angiosperms. As we known that The Great Himalayan and its periphery were, are and will be a rich source of fossils from beginning to till date. This motivates us to go Siwalik belt of Koilabas of the country Nepal (Fig.1a and 1b). Here, we got a lot of leaf-impression among the various groups of fossils. Paleoclimate, paleoecology, phytogeography and physiogenomic study of Siwalik belt of Koilabas are also described here. The kingdom of Nepal is a landlocked country physiographically sandwiched between China in the north and India in the south (Fig.1c). Nearly two third of the country, in the northern part, is hilly and one

-third is Terai plain of the south which constitute the northern edge of Indo-Gangetic plain. Nepal is middle strip of Himalaya consisting of high hill and plain area which can physically be divided into following six zones viz., (i) Terai plain, (ii) Midlands, (iii) Churia Hills, (iv) Higher Himalayan Zone, (v) Mahabatat Hills, and (vi) Inner Himalayan Valley. The area of present study known as Dang area constitutes both Terai plain and Churia Hills. The fossiliferous localities, in Dang area Koilabas (27°42′: 82°20′) and Seria Naka (27° 44′: 82° 05′) lies on the Indo-Nepal border near district balrampur (Uttar Pradesh). It is bounded by Churia Hills towards north and Terai plain towards south. This is easily approachable by road from both Nepal and India (Fig.2a). Churia Hills rise abruptly to about 1300m above the sea level immediately to the north of the town Koilabas. The hills are merged with Mahabharat range at many places except in area where valleys are developed. These are Rapti valley, Hetaura Valley, Surkhet Valley and Dang Valley which just north of the Koilabas. Most of the valleys are highly fertile and similar in nature as that of Terai plain of south. The hills are composed of sedimentary rocks of Miocene-Pleistocene age which contain sand, shale and pebble beds. There is a small seasonal Nala, Koilabas Nala also known as Dang Nala which coming down from the hills is generally dry during summer or non-rainy season.

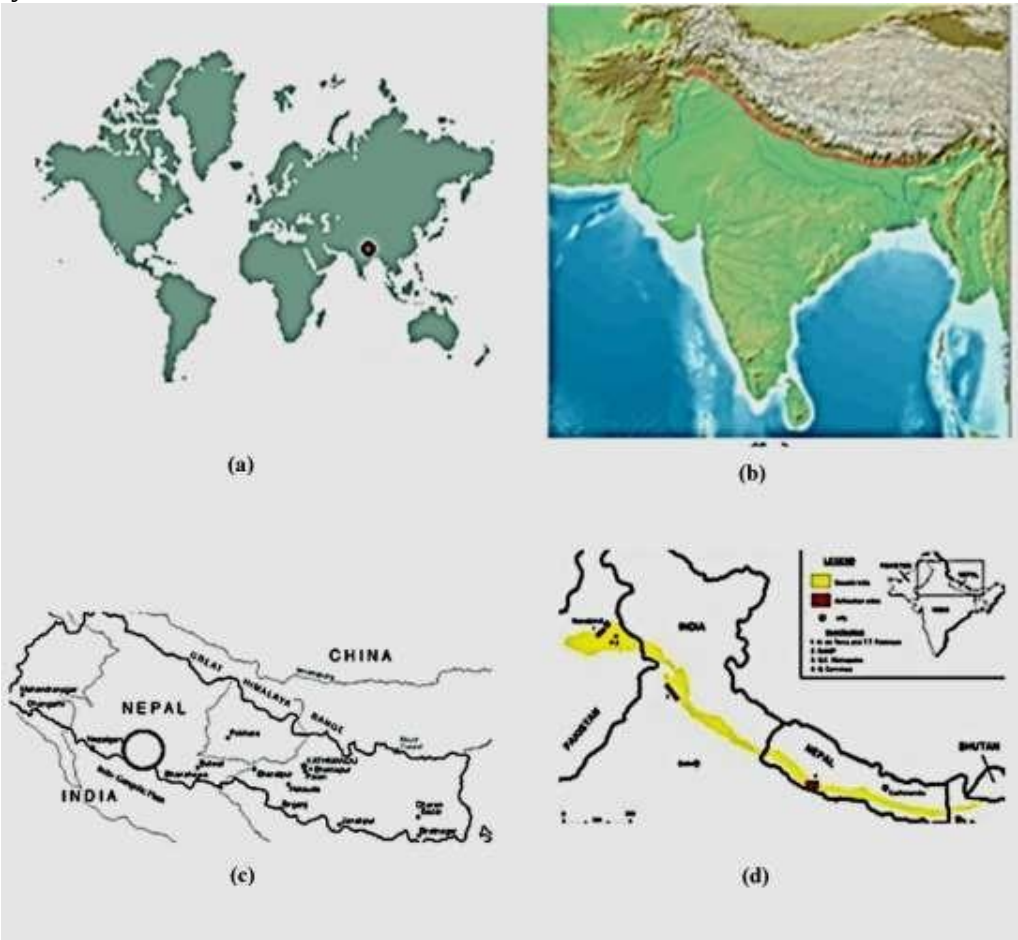
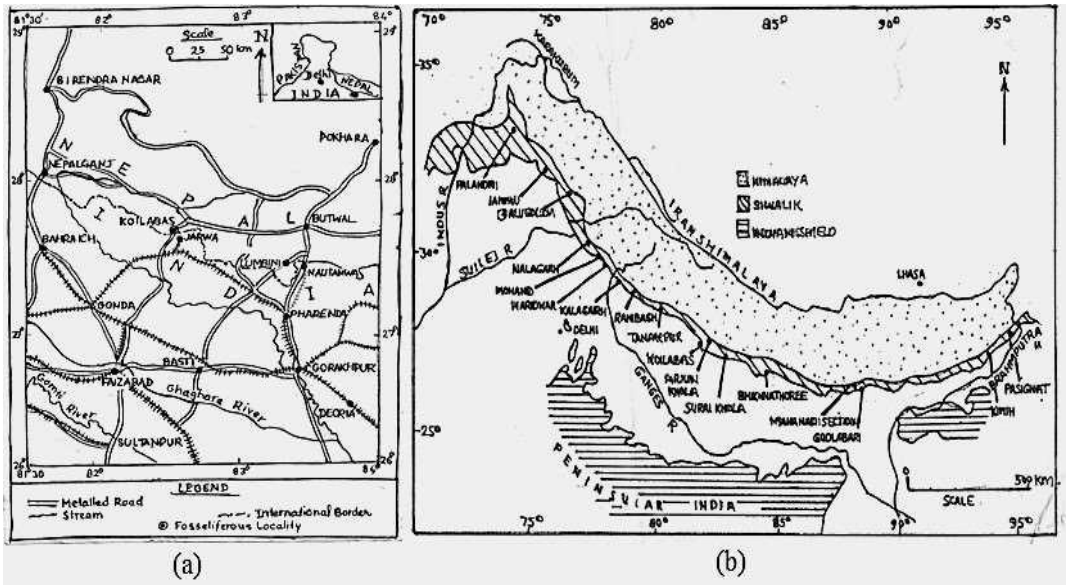


Figure-1: (a) Red spot showing Koilabas in world map, (b and c) Map showing Nepal sandwiched between China in the north and India in the south, and (d) Yellow coloured area showing Sivalik hills.



(a) (b)

Figure-2: (a) Road-map showing location of Koilabas at Indo-Nepal Border. (b) Map showing areas of palaeobotanical study in Sivalik formation.

1.1 General Geology of the Siwalik Hills: The term „Siwalik Hills" was introduced by Cautley in 1832 to designate the sub-Himalayan hill ranges occurring between Ganga and Yamuna rivers, which yielded the memorable vertebrate fossils around Haridwar [1]. Falconer (1835) also adopted this term to designate the nearly continuous series of Tertiary formation stretching from Punjab down to Irrawadi [2]. They have an outcrop pattern more or less bounded by a major thrust, the Main Boundary Fault (MBF) in the north and IndoGangetic alluvium on the south. They are generally 10-12 km wide with a step scrap towards south and a gentle slope on the north Siwalik outcrops Kalka Himachal Pradesh are 16-30 km. wide but widen considerably to attain a width of 90 km. in the Nalagarh-Pathankot section due to the Main Boundary Thrust (MBT) receding to the northeast. The Siwalik formation ranges in age from Middle Miocene to Middle Pleistocene and is underlain by the Lower Tertiary upper Muree/ Dharmsala sediments on the basis of lithology and palaeontological data it has been subdivided into lower, middle and upper shiwalik. Lithologically the Siwaliks represent a great thickness of detrital rocks, such as coarsely bedded sandstones, sand rock, clays and conglomerates measuring between 5000-5500m in thickness.

1.2. Geology of the Area: The area of present study falls in Dang section of Western Nepal Himalaya. The Siwalik formation in Nepal Himalaya is often called Churia Group which lies south of the Main Boundary thrust (MBT). This group 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 Siwalik (Churia) group of Nepal have been studied time to time by various researchers [3-16]. The Churia Group has often been classified into two formations: (i) Lower Churia Formation (Sandstone Facies) and (ii) Upper Churia Formations (Conglomerate Facies) [5-7]. However, a three-fold lithostratigraphical

classification of the formation in the Western Nepal Himalaya has been suggested by Chaudhuri [11]. The Lower Churia formation with an average thickness of about 1800m is composed of the fine grained green chlorite, biotite, muscovite calcareous well bedded indurated sandstones and silts stones. 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 gross composition of sandstone is 80% quartz, 10%, muscovite, 5%, biotitic and black tourmaline and black minerals 5%. 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 formation in Dang area, Trijuga area and east 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. In this area, the lower Churia formation is observed from Koilabas to Darwaja containing fine grained sandstone beds with variegated clay and some pebbles from Darwaja to Masot Khola the rocks are of upper formation. Above the Upper formation again lays the Lower formation in Garudhir pass [9]. According to Chaudhuri‟s classification of three fold division of Churia (Siwalik) Hills [11], this area from Koilabas to Darwaja falls in Lower Churia (Siwalik) formation and beyond Darwaja to Chor Khola onward the rocks are supposed to be belonging to Middle Churia (Siwalik) formation which is predominantly arenaceous in nature.

Material and Method:

The fossil locality Koilabas (27° 42´: 80° 20´) and Seria Naka (27° 44´: 82° 05´) lies at Indo-Nepal border in Western Nepal. It is easily approachable by road from both India and Nepal side. It is a famous and an important business centre at the Border of both countries (Fig.2a). The sections belonging to the lower Siwalik beds containing excellently preserved leaf-impressions as well exposed on both the sides of Koilabas Nala (also known Dang Nala). The leaf impressions are found on both grey as well as brown calcareous shales but they are more common and well preserved in the grey shale. A rich collection of well-preserved leaf impressions were collected and have been described here. The leaf-impressions are devoid of cuticles. They were studied morphologically with the help of either hand lens or low power of microscope under reflected light. In order to identify the leaf-impressions, a number of herbarium sheets of extant taxa were examined at the herbaria of National Botanical Research Institute (Lucknow), Forest Research Institute (Dehradun) and Central National Herbarium (Sibpur, Howarh West Bengal). For the description of leaf impressions, the terminology given by Hickey and Dilcher has been followed [17, 18]. The photographs of leaf impressions showing various morphological characters were taken on cut film on Pan-phot camera. In almost all the cases the leaf impressions have been found resembling the modern leaves closely. The photographs of the comparable modern leaves showing similar features were also taken at the same magnification and put along with those of the fossil leaves for close comparison. The entire specimen and their photo-negatives are preserved at the botany department, M.L.K Post Graduate College, Balrampur-271201, Uttar Pradesh.

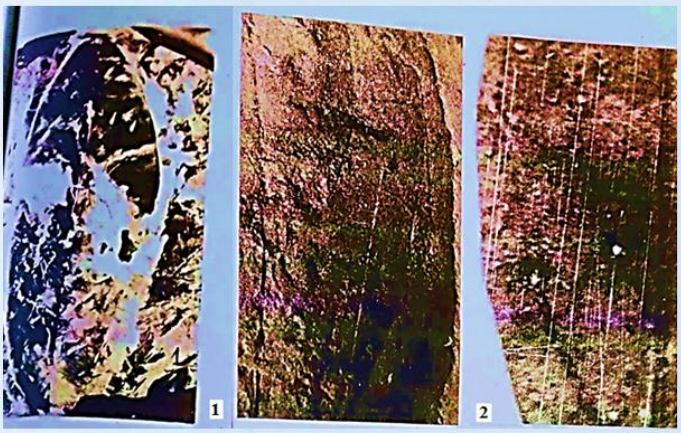
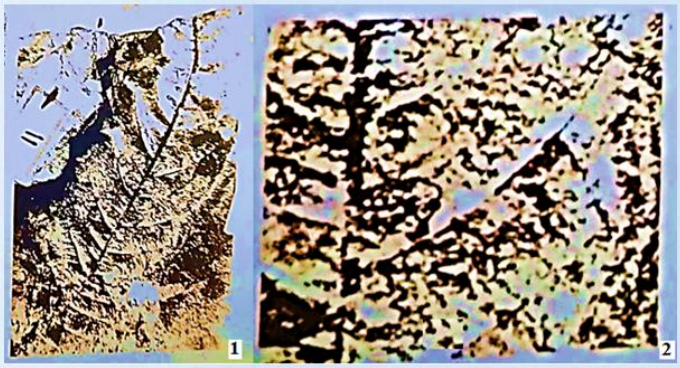


PLATE-1



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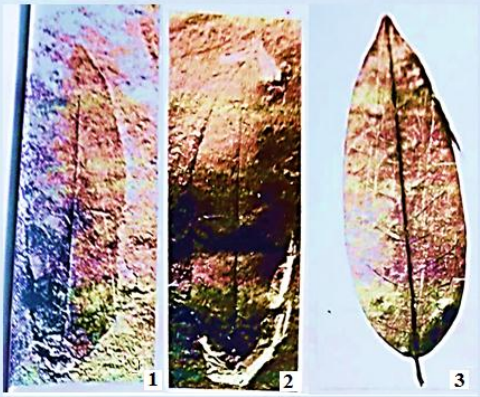
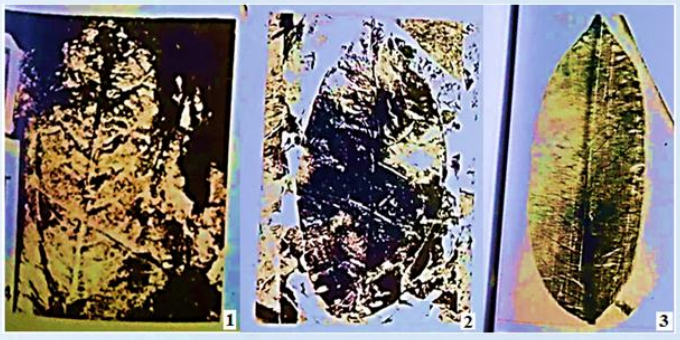


PLATE-3



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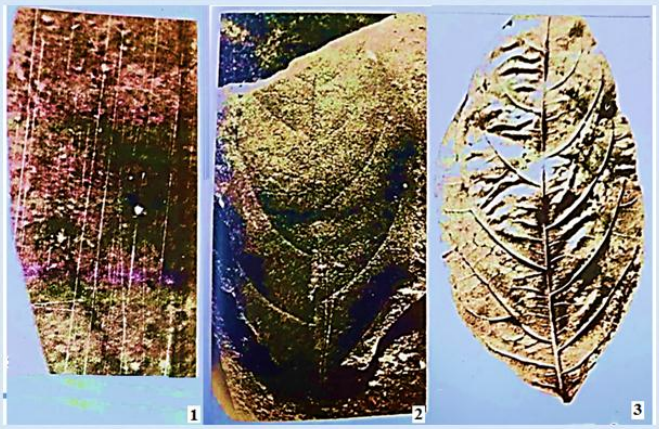

PLATE-5

PLATE-6

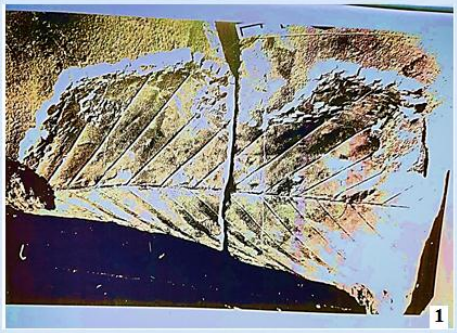

PLATE-7

PLATE-8

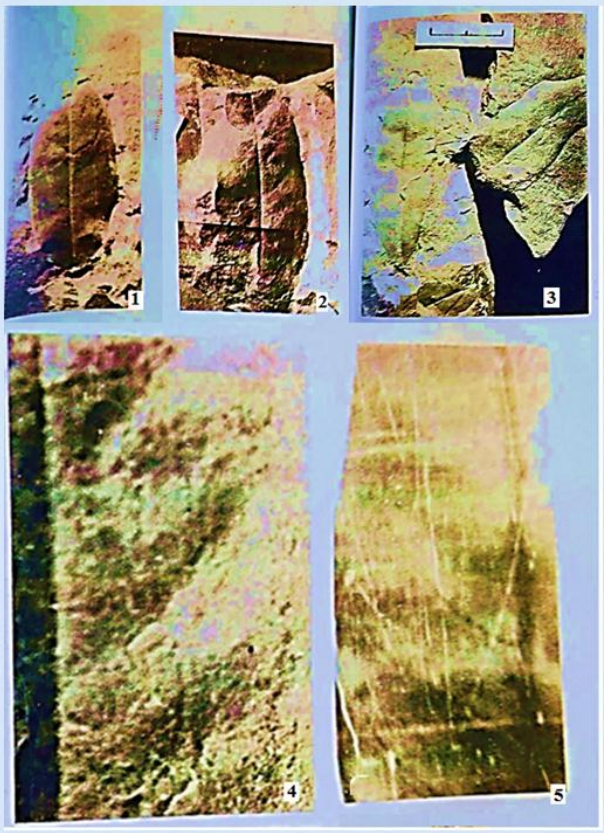

PLATE-9

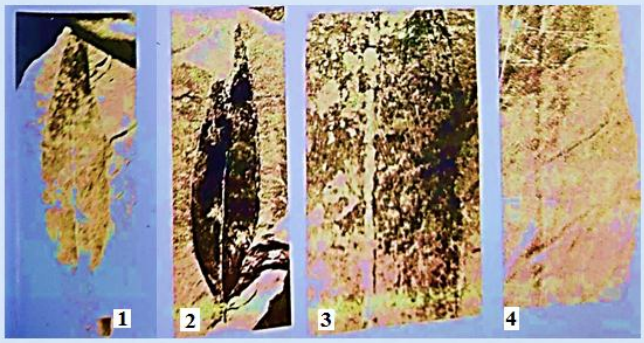

PLATE-10

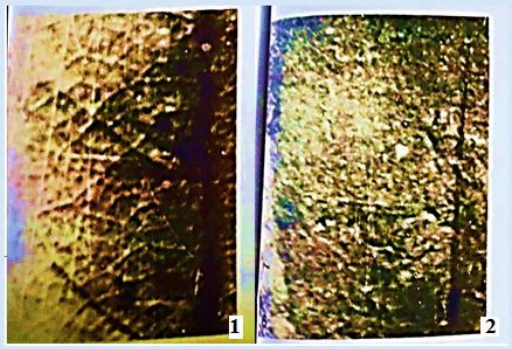

PLATE-11

Results and Discussion

The systematic descriptions of each fossil specimen (Plate-1 to Plate-11) are described as below:

1. First specimen (Plate-1): Family – Annonaceae
Genus – *Miliusa* Leschen. Ex. A. Dc.
Miliusa siwalica [19]

Material:	The present species is based on a well preserved incomplete specimen with its counterpart who is devoid of cuticle and almost well preserved.
Description:	Leaf simple, symmetrical, elliptic preserved sized 9.5 × 4.5 cm., apex broken, base indistinct, margin entire texture coriaceous, petiole not preserved, venation pinnate, eucamptodromous, primary vein (1°) single, prominent, stout, slightly curved, thicker at the basal region, secondary veins (2°) 3 pairs visible, 0.8 to 3.5 cm apart, curved up and run upward to a greater length and joined at their superadjacent secondaries, angle of divergence about (40°), narrow acute, alternate, seemingly unbranched, tertiary veins (3°) fine, pairly preserved, angle of origin AO-RR, percurrent, seemingly unbranched oblique to right angle in relation to midvein, predominantly alternate, close to distant, further details could not be seen.
Holotype:	Specimen no. P. P. M. L. K. 005
Locality:	Dang Nala section, Western Nepal
Horizon & Age:	Lower Siwalik, Middle Miocene
Etymology:	From the Siwalik formation
Modern Affinity:	The most characteristic features of the present fossil leaf such as symmetrical, elliptic shape, entire margin, eucamptodromous venation, the nature of secondary veins which arise narrow acutely and run upwards to a greater length and percurrent somewhat distantly placed tertiary veins indicate that the present fossil leaf shows close resemblance with the modern leaves of the genus *Miliusa Leschen* ex A. Dc. of the family Annonaceae. In order to findout the specific affinity, the herbarium sheets of all the available species of this genus were critically examined and concluded that the leaves of *Miliusa thoretii* Finet and Gagnep (C. N. Herbarium Sheet no 14317) show closest affinity with the fossil leaf in shape size and venation pattern.
Fossil records and comparison:	Prasad et al., in 1999 described a fossil leaf impression from the same locality as *Miliusa siwalika* which on comparison is very similar to the present fossil leaf. Therefore, this specimen is recorded from the same locality [19].
Present day distribution:	*Miliusa Leschen* ex A. Dc. consists of about 40 species distributed mostly in Indo-Malayan region and Australia. Out of which, 7 species are found to grow in India mainly in Sikkim, Khasi Hills, Travancore, Mysore, Kanara and Konkan [20, 21].

2. Second specimen (Plate-2): Genus – *Anona* Linn
Anona tertiarum sp. nov.

Material:	It consists of a well preserved specimen which is devoid of cuticles.
Description:	Leaves simple, symmetrical, narrow elliptic, preserved size 5.0 × 2.2 cm and 10.5 × 4.0 cm, apex slightly broken base obtuse normal, margin entire, texture chartaceous, petiole indistinct, venation pinnate, eucamptodromous, primary vein (1°) single, prominent, stout, curved in apical portion, uniform in thickness, secondary veins (2°) about 14 pairs visible, 8 to 2.0 cm apart curved up and joined to their superadjacent secondaries, angle of divergence mainly

right angle to acute (85° to 55°) usually alternate sometimes opposite, rarely branched, intersecondary veins present simple, abundant tertiary veins (3°) fine, abundant, angle of origin usually RR percurrent, straight to sinuous sometimes branched oblique in relation to midvein predominantly, alternate, close to nearly distant.

Holotype: Specimen no. P. P. M. L. K. 006

Locality: Dang Nala section, Koilabas, Western Nepal.

Horizon & Age: Lower Siwalik, Middle Miocene

Etymology: From the type Tertiary locality of Koilabas.

Modern Affinity: The diagnostic features of the present fossil leaf is symmetrical, narrow, elliptic, obtuse base, entire margin, eucamptodromous venation, abundant simple inter secondary veins, right angle to acute angle of divergence of secondary veins, percurrent sometimes sinuous and close to nearly distant tertiary veins. These features collectively indicate that the fossil leaf belongs to the family Annonaceae. After a critical examination of the herbarium sheets of a number of genera of this family it was found that the leaves of the genus *Anona* Linn, show nearest affinity with the fossil leaf. Although the modern leaves of a few species of *Mitrephora* (Bl.) Hook, F. and Thomas and *Polyalthia* Bl. also show resemblance in having inter secondaries as well as in nature of secondary veins, but they differ in the course of tertiary veins.

A comparative study of all the available species of the genus *Anona* Linn. was done and concluded that the leaves of *Anona reticulata* L. (C. N. Herbarium sheet no 13522) show closest affinity with the fossil leaf in which the intersecondaries are frequent and tertiaries are straight to sinuous.

Fossil records and comparison: As far as the author is aware there is no record of fossil leaves of the genus *Anona* Linn. from Tertiary sediments of India, and abroad. The present leaf impression form the first Fossil records and hence is being described as a new species, *Anona tertiarum* sp. nov.

Present day distribution: The genus *Anona* Linn. consists of about 120 species distributed in tropical regions. Only four introduced fruit species are found to grow in India [20]. The modern comparable taxon *Anona reticulata* Linn is a medium sized evergreen tree distributed in naturalized way in Bengal and elsewhere, especially in tropical America [22].

3. Third specimen (Plate-3): Genus – *Fissistigma* Griff
Fissistigma nepalensis sp. nov.

Material: The species is based on a single leaf-impression which is almost complete and devoid of cuticles.

Description: Leaf simple, almost symmetrical, narrow elliptic, preserved size 7.5 × 2.2 cm and 7.0 × 2.0 cm. apex acute, base obtuse, margin entire, textures thick chartaceous, venation pinnate, eucamptodromous primary vein (1°) single, prominent stout, almost straight secondary veins (2°) about 12 pairs visible, 0.4 to 0.9 cm apart, alternate to sub-opposite, angle of divergence about 60°, acute, moderate uniformly curved up, seemingly unbranched intersecondary veins present simple rare, tertiary veins (3°) fine, poorly preserved, angle of origin usually RR, percurrent straight to sinuous, branched oblique in relation to midvein, predominantly alternate and close.

Holotype: Specimen no. P. P. M. L. K. 007

Locality: Dang Nala section near Koilabas village, Western Nepal

Horizon & Age: Lower Siwalik, Middle Miocene

Etymology: From Siwalik beds of Nepal.

Modern Affinity: The most important characters exhibited by the present fossil leaf such as narrow elliptic shape, acute apex, obtuse base, entire margin, eucamptodromous venation, moderate acute angle of divergence of secondary veins, presence of inter secondary veins, and percurrent straight to sinuous tertiary veins indicate its resemblance with the modern leaf of the genus *Fissistigma* Griff. of the family Annonaceae. After a detailed comparison of the present fossil leaf with all the available species of this genus it was concluded that the fossil come closer to *Fissistigma korthatlaii* Mig, *F. manubreatum* Hook. F. and *F. elegans* Hook, F. Th. further, a critical examination of the herbarium sheets of these species suggests that the leaves of *F. manubreatum* Hook, F. Th. shows closest affinity with the fossil (C.N Herbarium sheet no 13815, p1.6 fig. 5,7). The leaves of other two species can be differentiated in having more number of secondary veins, more over their course and arrangement also differ from fossil.

Fossil records and comparison: So far, three fossils leave resembling the genus *Fissistigma* Griff. have been described from the Siwalik sediments of India and Nepal. Lakhanpal (1969) described a fossil leaf as *Fissistigma senii* from the Siwalik sediments of Jawalamukhi, Himachal Pradesh. Some species have also been reported by Prasad *et al.,* (1997) from the Siwalik sediments of Seria Naka at Indo-Nepal Border in Balrampur district of Uttar Pradesh. Both these leaf-impression have been compared with the extant *Fissistigma wallichii* (Hook, F. and Th.) Merill and have been found different from the present fossil leaf in nature of secondary veins which arise more acutely and run upward to a little distance. In 1992, Lakhanpal and Awasthi reported a fossil leaf under *Fissistigma siwalika* from the Siwalik sediments of Jawalamukhi, Himachal Pradesh, India. This fossil is large in size (14.5 × 5.3) having oblanceolate shape and rounded apex. So it is also different from the present fossil. As the present fossil is entirely different from already known species, they have been described as a new species, *Fissistigma nepalensis* sp. nov.

Present day distribution: The genus *Fissistigma* Griff contains about 60 species distributed in tropical Africa, China, and northeast Australia and in Indo-Malayan region (Willis, 1973). *F. manubreatum* Hook, F. and Th. with which the fossil show closest resemblance is a large climber widely distributed in Malaya peninsula, Malacca and Penang [23].

4. Fourth specimen (Plate-4):

Family- Polygalaceae
Genus – *Securidaca* Linn.
Securidaca miocenica [19]

Material: This species is based on single specimen. The specimen is somewhat poorly preserved but almost complete and devoid of cuticles.

Description: Leaves simple, slightly, asymmetrical elliptic, preserved size 6.5 × 3.2 cm and 7.5 × 3.1 cm apex acute to seemingly acuminate, base obtuse, slightly enequilateral, margin entire, texture thick chartaceous, petiole broken, venation pinnate, eucamptodromous, primary veins (1°) single, prominent, stout, slightly, curved, secondary vein (2°) 9-10 pairs, 0.6 to 1.2 cm apart, uniformly curved up, angle of divergence 50°-60°, moderately acute, sometimes branched, alternate to opposite intersecondary veins present frequent simple, tertiary veins (3°) very fine, angle of origin usually AO, percurrent, almost straight, sometimes branched oblique in relation to midvein, predominantly alternate to close.

Holotype: Specimen no. P. P. M. L. K. 008

Locality:	Koilabas Nala near Darwaja, Koilabas, Western Nepal
Horizon & Age:	Lower Siwalik, Middle Miocene
Etymology:	From Siwalik beds of Nepal.
Modern Affinity:	The elliptic shape, acute to acuminate apex, obtuse base entire margin, moderate acute angle of divergence of secondary veins, presence of frequent intersecondary veins and percurrent tertiaries are the diagnostic features of the present fossil leaf Besides, the present fossil leaf is also characterized by slightly unequal base as well as lamina on either side of midrib. These features collectively indicate that the present fossil leaf shows closest resemblance with the modern leaves of *Securidaca inappendiculata* Hask (C.N. Herbarium sheet no 36383, P1-1, fig. 8) of the family Polygalaceae.
Fossil records and comparison:	Three fossil leaves resembling the extant taxa *Securidaca inappendiculata* have been described so far under *Securidaca miocenica* from the Siwalik sediments of Seria Naka at Indo-Nepal Border in Balrampur district of Utter Pradesh (Prasad *et al.,* 1998). The present fossil leaf also comes closest with the above known fossil leaves and hence they are described and recorded under the same species *Securidaca miocenica* [24].
Present day distribution:	The genus *Securidaca* Linn comprises 80 species distributed all over tropics exclusively Australia. Only one species is found in India (Willis, 1973). The modern comparable taxon *Securidaca inappendiculata* Hask is a large woody climber growing in the moist deciduous forest of Eastern Bengal, Aracan and Tenasserium. It is also found in the Kochin Hills near Myithyina and Java [21, 22].

5. Fifth specimen (Plate-5): Family- Flacourtiaceae
Genus – *Gynocardia* R. Br.
Gynocardia mio-odorata sp. nov.

Material:	The present species is based on single well preserved leaf impressions. The leaf impression is devoid of cuticles.
Description:	Leaves simple, symmetrical, elliptic, preserved size 9.0 × 4.0 cm and 9.0 × 5.0 cm, apex slightly broken, seemingly acute, base acute, margin entire, texture chartaceous, petiole not preserved, venation pinnate, eucamptodromous to nearly brochidodromous, primary vein (1°), single, prominent, stout, almost straight, secondary veins (2°) six pairs visible, 0.7 to 3 cm apart, uniformly curved up and joined to their superadjacent secondary, sometimes forming loop in the apical portion, angle of divergence about 60°, moderate acute, alternate to subopposite, seemingly unbranched tertiary veins (3°) still fine, angle of origin RR, percurrent, the tertiaries arise from midrib looking like a intersecondary veins but they join the secondary veins arising below them, sometimes branched, oblique to right angle in relation to midvein predominantly alternate and close to distant. Further details could not be seen.
Holotype:	Specimen no. P. P. M. L. K. 009
Locality:	Dang Nala section, Koilabas, Western Nepal
Horizon & Age:	Lower Siwalik, Middle Miocene.
Etymology:	From the extant species *G. odorata* Plus prefix ‘Mio’ for its Miocene age.
Modern Affinity:	The present fossil leaf is characterised by symmetrical elliptic shape, acute apex and, base, entire margin, eucamptodromous to brochidodromus venation, moderate acute angle of divergence of secondary veins, RR, close to distant having oblique to right angle in relation to midvein percurrent tertiaries. The nature of tertiary vein arising from midrib giving an appearance of intersecondary vein is also an important distinguishing character. After a

detailed study of the herbarium sheets of different families it was found that the above these features are found in the modern leaves of *Gynocardia odorata* R. Br. of the family Flacourtiaceae (C.N. Herbarium sheet nos. 33497, 33499, P12, fig. 5).

Fossil records and comparison: So far, there is no record of fossil leaf of the genus *Gynocardia* R. Br. from the Tertiary sediments of India and abroad. Thus present fossil leaf form the first record from the Siwalik sediments of Nepal and have been described here as *Gynocardia mio-odorata* sp. nov.

Present day distribution: The genus *Gynocardia* R. Br. consists of only one species *G. odorata* R. Br. with which the present fossil show close resemblance. It is moderate sized evergreen tree distributed in northern and Eastern Bengal and Assam, Chittagong and Myanmar. Its wood is used in Chittagong for planking and for posts and the pulp of the fruit in Sikkim to poison the fishes [21].

6. Sixth specimen (Plate-6): Family – Clusiaceae
Genus – *Garcinia* Linn
Garcinia nepalensis sp. nov.

Material: The present species consists of single specimen which is almost complete devoid of cuticles.

Description: Leaf simple, almost symmetrical, narrow elliptic, preserved size 7.8 × 2.5 cm, apex slightly, broken, seemingly acute, base acute, margin entire, texture coriaceous petiole preserved small, 0.3 cm visible, normal venation pinnate, eucamptodromous, primary vein (1°) single, prominent stout, almost straight, secondary vein (2°) more than 20 pairs visible, closely, placed less than 0.5 cm apart, angle of divergence about 55°, acute, moderate, almost uniformly, curved up, alternate to opposite, sometimes branched, intersecondary veins present, simple frequent, 2-3 intersecondary in between two secondary veins, tertiary veins (3°) fine abundant, poorly preserved, angle of origin AO, percurrent, almost, straight, branched, oblique in relation to midvein, alternate to opposite and close. Further details could not be seen.

Holotype: Specimen no. P. P. M. L. K. 010

Locality: Dang Nala Seetion near Darwaja, Koilabas, Western Nepal.

Horizon & Age: Lower Siwalik, Middle Miocene.

Etymology: From country name to which fossil locality belongs.

Modern Affinity: The diagnostic features of the present fossil leaf such as narrow elliptic shape, acute base and apex, entire margin, closely placed secondaries and presence of intersecondary veins collectively suggest its resemblance with the family Clusiaceae. These features are not found common in the genera, *Kayea* Wall. *Calophyllum* Linn and *Garcinia* Linn of this family after a critical examination of the herbarium sheets of there genera and the present fossils it was found that the leaves of *Calophyllum* Linn, differ in the angle of secondary veins which is almost right angle the genus *Kayea* Wall can be differentiated in being larger size with more angle of divergence of secondary veins. The only genus *Garcinia* Linn. comes closest resemblance with the present fossil. Further, in order to find out the nearest resembling a number of herbarium sheets of all the available species (about 20) were studied in detail and concluded that the leaves of *Garcinia cowa* Roxb. resembles the present fossil leaf in shape, size and venation pattern (C.N. Herbarium sheet no 46192, Pl, fig.).

Fossil records and comparison: The resembling the genus *Garcinia* Linn, known so far, are *Garcinia borooahii* Lakhnpal and *Garcinia* sp. Lakhanpal and Bose from Eocene of

Barmer sandstones, Kapurdi, Barmer District, Rajasthan [25, 26]. *G. neyveliensis* Agarwal from Neyveli lignite (Miocene), South India and *G. palaeoluzoneinsis* from the Oligocene of Makum coalfield, Assam, India [27]. Besides, *G. eucambogia* from Siwalik sediments of Kathgodam Uttar Pradesh [28], *G. kasaulica* Arya and Awasthi from the Kasauli beds, Himachal Pradesh and *G. corvinusiana* Prasad and Awasthi from Siwalik sediments of Surai Khola, Western Nepal, are also recorded [29, 30]. The present fossil leaf has been compared with all the above known species and found that is different either in having wide elliptic shape or in the nature and arrangement of secondary veins. In being different with all the known species present fossil leaf is described as a new species *G. nepalensis.* The leaf cuticles of the genus *Garcinia* Linn have also been recorded from lignite beds (Miocene) of Ratnagiri District, Maharastra and its fossil woods are known from Deccan Intertrappean beds of Shahpura, Madhya Pradesh, India [31, 32].

Present day distribution: The genus *Garcinia* Linn. consists of about 400 species of trees and shrubs distributed in the tropical regions of Asia and South Africa [20]. Of which 36 species are found in India. *Garcinia cowa* Roxb, with which fossils shows closest resemblance, is a tall evergreen tree found in the evergreen forests of Eastern Bengal, Assam, Chittagong, Myanmmar and the Andaman Island [21].

7. Seventh specimen (Plate-7): Family – Dipterocarpaceae
Genus – *Dipterocarpus* Gaertn
Dipterocarpus nepalensis sp. nov.

Material: The present species is based on a single well preserved leaf impression which is devoid of cuticles.

Description: Leaf simple, symmetrical, narrow elliptic, preserved size 21.0 × 11.0 cm apex, broken, base obtuse, margin entire, texture coriaceous, petiole not preserved, venation pinnate, craspedodromous to eucamptodromous, primary vein (1°) single prominent, stout, almost straight, secondary veins (2°) about 16 pairs visible 0.5 to 1.7 cm apart, lower most pair arise closely and the rest are almost at same distance, curved up almost straightly before joining the margin or their super adjacent secondaries, angle of divergence about 55°, acute, moderate, alternate to opposite seemingly unbranched, tertiary veins (3°) fine abundant, angle of origin usually RR, percurrent, straight, sometimes branched oblique in relation to midvein predominantly alternate and close.

Holotype: Specimen no. P. P. M. L. K. 011

Locality: Koilabas Nala Section near Darwaja, Koilabas, Western Nepal.

Horizon & Age: Lower Siwalik, Middle Miocene.

Etymology: After the country Nepal the specimens were collected.

Modern Affinity: The large size of the leaf having narrow elliptic shape, obtuse base, entire margin coriaceous texture, crapedo to eucamptodromous type of venation course of secondary veins which run straightly upwards with moderate acute angle of divergence and percurrent, straight tertiary veins altogether undoubtedly indicate its resemblance with the modern Leaves of the genus *Dipterocarpus* Gaertn of the family Dipterocarpaceae. The herbarium sheets of all the available species of this genus (about 22) have been critically examined in order to findout the nearest specific affinity. After a detailed comparison it was found that most of the species could not be differentiated from each other easily on the basis of leaf size, shape and venation pattern. However, amongst the available 22 modern species, *Dipterocarpus turbinatus*

Gaertn, F. (C. N. Herbarium sheet no. 50480) shows closest similarity with the present fossil leaf in all morphological characters.

Fossil records and comparison: A number of fossils leave showing close similarity with the genus *Dipterocarpus* Gaertn. have been described from the tertiary of both India and abroad. They are *Dipterocarpus antiquus* Heer and *D. atavinus* Heer from the Tertiary of Sumatra [33], *D. labuanus* Geyler, *D. nordenspoioldi* Geyler and *Dipterocarpus* sp. from the Tertiary of Labuan [34], *Phyllites dipterocarpoides* Crie, 1888 from the Pliocene of Java, *D. siwalicus* from the Siwalik sediments of Jawalamukhi, Himachal Pradesh [35]. This species has also been described from the Siwalik sediments of Koilabas, western Nepal [36], from Surai Kola, Western Nepal [37] and foot hills of the Himalaya, India [28]. On comparing the present fossil with the above already known species, it has been observed that it does not show similarity with any of them. The present fossil leaf differs from most of them being larger in size. The course of secondaries is also not common in any of the above specimens. This has therefore been described as a new species *Dipterocarpus nepalensis.*

Present day distribution: The genus *Diptercarpus* Gaertn contains about 76 species distributed in India and Western Malaysia [20]. Out of which, 17 species are Indian and 5 are endemic in Ceylon. Two are found in South India and rest in Eastern Bengal Myanmar and Andaman Island. The extant species *Dipterocarpus turbinatus* Gaertn, F. with which the fossil shows closest affinity is a large evergreen tree occurring in the forest of Cachar and Chittagong Hills. It is also common in the tropical forest throughout Myanmar [21].

8. Eighth specimen (Plate-8): Genus – *Isoptera Scheff.* Ex. Burck
Isoptera nepalensis sp. nov.

Material: This consists of only well preserved specimen, which is complete and devoid of cuticles.

Description: Leaf simple, symmetrical narrow elliptic, preserved size 9.2 × 3.3 cm, apex slightly broken, seemingly acute, base obtuse, slightly in equilateral, margin entire, texture thick, chartaceous, petiole not preserved, venation pinnate eucamptodromous, primary vein (1°) single, prominent, stout, thicker towards basal region, straight, secondary, veins (2°) about 10 pairs visible, 0.5 to 1.8 cm apart, angle of divergence 60°-65°, acute moderate, alternate, uniformly curved up curving more pronounced near the margin, run upward to a little distance joining to the superadjacent secondaries, unbranched, tertiary veins (3°) moderate in thickness, not so abundant, angle of origin RR, percurrent, mostly straight sometimes sinuous, rarely branched, oblique in relation to midvein prominently alternate and close to nearly distant. Further details are not clearly seen.

Holotype: Specimen no. P. P. M. L. K. 012

Locality: Koilabas Nala section near Imlibasa, Koilabas, Western Nepal.

Horizon & Age: Lower Siwalik, Middle Miocene.

Etymology: After the Siwalik formation of the country Nepal.

Modern Affinity: The most important features of the present fossil leaf are narrow elliptic shape, acute apex obtuse inequilateral base, eucamptodromous venation straightly running upward secondary veins whose curvature is pronounced near the margin percurrent and close to distant tertiary veins. These features collectively indicate that the fossil leaf belongs to the genus *Isoptera* Scheff. ex Burk of the family Dipterocarpaceae. In the genus *Isoptera* Scheff ex Burk only two species were available for consultation in the C. N. Herbarium,

Sibpur, West Bengal. However, after a detailed comparison of fossil leaf with the extant leaves of this genus it was found that the leaves of *Isoptera borneoensis* shows closest affinity with the fossil (C. N. Herbarium sheet no. 52123, Pl-3, Fig. 6)

Fossil records and comparison: So for there is no record of fossil leaves of *Isoptera* Scheff. Ex Burk from the Tertiary sediments of any part of the world. Therefore it has been described as *Isoptera nepalensis* sp. nov. The specific epithet indicates its occurrence in the Siwalik sediments of Nepal.

Present day distribution: The genus *Isoptera* Scheff. ex. Burk contains only three species found to grow in tropical forests of western Malaysia [20]. *Isoptera borneoensis* with which the fossil specimen shows closest affinity, is an evergreen tree distributed in the forest of Myanmar, Java and Sumatra.

9. Ninth specimen (Plate-9): Genus – *Shorea* Roxb.
Shorea neplensis sp. nov.

Material: This species is based on leaf impression which is devoid of cuticle.

Description: Leaf simple, symmetrical, elliptic to narrow elliptic, preserved size 4.4 × 2.3 cm 5 × 2.2 cm and 5.5 × 2.0 cm, apex seemingly acute, base acute to obtuse, margin entire, texture coriaceous, petiole not preserved, venation pinnate, eucampto-dromous, primary vein (1°) single, prominent, stout, almost straight, secondary vein (2°) about 8 pairs visible, 0.4 to 0.8 cm apart, angle of divergence about 60°, acute moderate, uniformly curved up usually alternate, seemingly, unbranched, intersecondary veins present, simple, tertiary veins (3°) fine, poorly preserved, angle of origin usually RR, percurrent, almost straight, sometimes branched oblique in relation to midvein, predominantly alternate and close. Further details could not be seen.

Holotype: Specimen no. P. P. M. L. K. 013

Locality: Koilabas Nala section just before Imlibasa, Koilabas, Western Nepal.

Horizon & Age: Lower Siwalik, Middle Mocene.

Etymology: From the locality Nepal.

Modern Affinity: The characteristic features of the fossil leaves such as elliptic to narrow elliptic shape, acute apex, acute to obtuse base, entire margin, eucamptodromous venation, moderately acute angle of divergence of secondary veins, presence of intersecondary veins and R. R. percurrent tertiaries indicate that these are closest to the extant *Shorea trapizifolia* (Thw.). Ashton of the family Dipterocarpaceae (C.N. Herbarium sheet no. 29).

Fossil records and comparison: Seven fossils leave resembling the genus *Shorea* Roxb. have been described from the tertiary sediments of India and abroad. Seward (1935) reported two leaves under the form genus *Dipterocarpophyllum*, *D. blumii* and *D. gerativense* from the Tertiary of Egypt showing resemblance with the extant genus *Shorea* Roxb [38]. Merrill (1923) described two fossil leaves, viz, *Shorea guiso* and *S. polyspermum* form the Pliocene of Philippines [39]. Recently, three more fossil leaves have been reported from the Siwalik sediments of India. There are *Shorea siwalika* from the Siwalik sediments of Ramthi River, Darjeeing District, West Bengal [40], *Shorea neoassamica* from the Siwalik sediments of Kathgodam [28] and *Shorea miocenica* from Ghish River near oodlabari, Darjeeling District, West Bengal [41]. The present fossil leaf has been compared with all the above known species and found that these are different from them in being smaller in size having intersecondary veins. The course of secondary and tertiary veins is also different from them. Thus in being different the present specimen has been

described under a new specific name *Shorea nepalensis* sp. nov.

Present day distribution: The genus *Shorea* Roxb. contains about 180 species distributed from Ceylon to South China, Western Malaysia and Moluccas. Out of 12 species in which five are endemic in Ceylon, three are found in Myanmar, two in south India, one in Assam and one in well-known Sal forest in northern and central India. *Shorea trapizifolia* (Thw.) Ashton with which the present fossil shows closest resemblance is an evergreen tree found to occur in Ceylon [42].

10. Tenth specimen (Plate-10): Family – Simaraubaceae
Genus – *Brucea* J. F. Mill
Brucea darwajensis sp. nov.

Material: The present species is based on two leaf impressions which are almost complete and devoid of cuticles.

Description: Leaves simple, slightly asymmetrical at basal portion, narrow elliptic, preserved size 5.4 × 1.3 cm and 5.8 × 1.3 cm, apex attenuate, base acute in equilateral, margin entire, texture coriaceous, petiole preserved in one specimen 0.4 cm long, normal, venation pinnate, eucamptodromous, primary vein (1°) single, prominent, stout, almost, straight, Secondary veins (2°) about 10 pairs visible, less than 0.5 cm apart, angle of divergence about 65°, acute, moderate, uniformly curved up, alternate to opposite, seemingly unbranched, tertiary veins (3°) fine poorly preserved, angle of origin usually RR, percurrent, straight, oblique in relation to midvein, alternate to opposite and close further details could not be seen.

Holotype: Specimen no. P. P. M. L. K. 017

Locality: Koilabas Nala section near Darwaja, Koilabas, Western Nepal.

Horizon & Age: Lower Siwalik, Middle Miocene.

Etymology: After Darwaja, a place in Koilabas Nala from where fossils were collected.

Modern Affinity: The main diagnostic features of the fossil leaf such as narrow elliptic shape, alternate apex, inequilateral acute base, coriaceous texture, eucamptodromous venation and the course of secondary and tertiary veins strongly suggest that the fossil leaves show their affinity with the leaves of extant genus *Brucea* J. F. Mill of the family Simaroubaceae. A lot of herbarium sheets of all the available species of the genus *Brucea* J. F. Mill, were examined and it was found that the leaves of *Brucea* mollis Wall show closest affinity with the present fossil leaves (C.N. Herbarium Sheet nos. 77233 and 77234, Pl. 5 figs. 10, 12).

Fossil records and comparison: There is no any Fossil records of the genus *Brucea* J. F. Mill from the tertiary sediments of India and abroad. The present fossils show their first occurrence in the Siwalik sediments of Nepal and therefore have been assigned as *Brucea darwajensis* sp. nov.

Present day distribution: The genus *Brucea* J. F. Mill contains about 10 palaeotropical species. Out of which only two species are found in India and Myanmar. *Brucea mollis* Wall, with which the fossils show closest affinity, is an evergreen shrub growing in north east Himalaya and sylhet ascending to about 6,000 ft. It is also common in Kochin Hills, Karan Hills and Tennasserim in Myanmar [21].

11. Eleventh specimen (Plate-11): Family – Sapindaceae
Genus – *Nephelium* Linn.
Nephelium palaeoglabrum [24]

Material: This species is based on single, well preserved leaf impressions.

Description:	Simple, symmetrical, narrow obovate to elliptic, preserved size 8.2 × 5.0 cm, apex broken, base acute, equilateral, margin entire, texture chartaceous, venation pinnate, eucamptodromous, primary vein (1°) single, prominent, stout, almost, straight, secondary veins (2°) about 7 pairs visible, 0.7 to 1.5 cm apart, angle of divergence about 60°, moderate acute, uniformly curved up and joined superadjacent vein, seemingly unbranched usually alternate, rarely sub opposite, tertiary veins (3°) fine, angle of origin RR, sometimes nearly right angle predominantly alternate and close.
Holotype:	Specimen no. P. P. M. L. K. 016
Locality:	Near Darwaja in Koilabas Nala, Koilabas, Western Nepal.
Horizon & Age:	Lower Siwalik, Middle Miocene.
Etymology:	After Darwaja, a place in Koilabas Nala from where fossils were collected.
Modern Affinity:	In overall morphological features the present fossil leaf resembles closely with the extant leaves of *Nephelium glabarum* Noronh of the family Sapindaceae (C.N. Herbarium sheet no 95476).
Fossil records and comparison:	Four fossil leaves resembling the genus *Nephelium* have been described from the Tertiary sediments of India and abroad. These are *Nephelium jovis* from the Tertiary of Europe [34], *N. verberrtrianum* from the Tertiary of Bornea and *N. oligocenicum* from the Oligocene of Makum coalfield, Assam and India [43] and *N. palaeoglabrum* from the Siwalik sediments of Seria Naka near Tulsipur, U.P. [24], on comparison of present fossil leaf with those of above mentioned species. It has been found that the species described form Seria Naka in *N. palaeoglabrum* shows closest resemblance with present fossil in almost all the morphological features.
Present day distribution:	The extant *Nephelium glabrum* Noronh. is an evergreen tree found to grow in Malayan archipelago [22a].

Conclusions:

We have found that above eleven species belonging to eleven genera and eight family of dicotyledon. Based on above study alongwith already known data, the palaeoecology and phytogeography of area shows Miocene-Pleistocene age in the Himalayan foot hills. Above study also signify the physiogenomic characters of fossil‟s leaves with climate.

Acknowledgements

I am thankful to the authorities of the Birbal Sahni Institute of Palaeobotany, Lucknow and Forest Research Institute Dehradun for providing the permission and facilities to consult their herbarium. I am also thankful to the authorities of Central National Herbarium, Sibpur, Howrah for permission to consult their herbaria.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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