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Leaf-Impression and Palaeoscientific Study of Siwalik-belt of Koilabas in Western Nepal: Part-2

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ABSTRACT

In this work, we present well-preserved leaf-impression of fourteen species of angiosperm. These leaf-impressions were also searched from Siwalik belt of Koilabas in Western Nepal. The study shows that above fourteen species belonging to twelve genera and seven family of dicotyledon. Above study alongwith already known data reflect palaeoecology and phytogeography of area which shows Miocene-Pleistocene age in the Himalayan foot hills. These studies further signify the physiogenomic characters of fossil's leaves with climate.

Introduction:

In our previous communication, we have presented well-preserved leaf-impression of eleven species of angiosperm. This reflected Miocene-Pleistocene age in the Himalayan foot hills. This boosts us to go back to the Siwalik-belt of Koilabas to search out more and more fossils and to explore the richness of the Great Himalayan and their periphery for a rich source of fossils from beginning to till date. Here, we got a lot of leaf-impression among the various groups of fossils. 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]. The detailed lithology and stratigraphy of the Siwalik (Churia) group of Nepal have been studied time to time by various researchers [3-16]. 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:

A rich collection of well-preserved leaf impressions were collected on both the sides of Koilabas Nala also known Dang Nala and are described here. The leaf-impressions are devoid of cuticles. They were studied morphologically with the help of hand lens and 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.

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 – *Meliaceae*
Genus – *Aglaia* Lour.
Aglaia nepalensis sp. nov.

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

Description: Leaf simple, symmetrical, narrow elliptic, preserved size 7.5 × 3.0 cm, apex broken, base indistinct, margin entire, texture thick, chartaceous, venation pinnate, eucamptodromous, primary vein (1°) single, prominent, stout, almost straight, secondary veins (2°) about 11 pairs visible, 0.3 to 1.0 cm apart, usually alternate rarely sub opposite, angle of divergence 70° - 80° wide acute to nearly right angle, uniformly curved up, curvature is more pronounced near the margin before joining superadijacent secondary, unbranched, intersecondary rarely present, simple, tertiary veins (3°) fine, poorly preserved, angle of origin usually RR, percurrent, straight to curved convex, rarely branched oblique in relation to midvein, predominantly alternate and close, further details could not be seen.

Holotype: Specimen no. P. P. M. L. K. 018

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

Horizon & Age: Lower Siwalik, Middle Miocene.

Etymology: After the name of country to which fossil locality belongs.

Modern Affinity: Medium size of leaf with narrow elliptic shape, eucamptodromous venation, wide acute angle of divergence of secondary veins, basal 1-2 pairs of secondary arise nearly at right angle, RR, percurrent, straight to curved tertiary veins are the important features of the present fossil. These features indicate that the fossil belong to the modern leaves of the genus *Aglaia* Lour of the family Meliaccae. A critical examination of the herbarium sheets of a number of species of this genus suggests that the leaves of *Aglaia euryphylla* Koord and Valeton (C.N. Herbarium Sheet no. 80785) nearest affinity with the fossil leaf.

Fossil records and comparison: As far as the author is aware there is no record of fossil leaves resembling the genus *Aglaia* Lour although, a fossil wood resembling this genus has been described as *Aglaioxylon mandalensis* from the Deccan Intertrappean beds of Parapani, Mandla District of Madhya Pradesh [19]. The present fossil forms the first occurrence of the fossil leaves of this genus in the Siwalik sediments of Koilabas, Western Nepal and has been assigned as *Aglaia nepalensis* sp. nov.

Present day distribution: The genus *Aglaia* Lour Consists of 200-300 species found in China, Indo Malaya, Australia and Pacific. Of them, 23 species are distributed in India, Myanmar and Sri Lanka. *Aglaia euryphylla* Koord and Valeton, with which the fossil leaf resembles closely, is an evergreen tree found to grow mainly in Java.

2. Second specimen (Plate-2): Family – Anacardiaceae
Genus – *Swintonia* Griff.
Swintonia palaeoschwenckii [20]

Material: This is based on a Single incomplete leaf-impression which is devoid of cuticle.

Description: Leaf simple, symmetrical, seemingly narrow elliptic, preserved size 4.5 × 3.0 cm, apex broken, indistinct on one side of midrib, margin entire, texture thick chartaceous petiole preserved, 0.6 cm long, normal, venation pinnate, eucamptodromous, primary vein (1°) single, prominent, stout, almost straight, secondary veins (2°) only 6 pairs visible, 0.3 to 1.2 cm apart, lowest two pairs closely placed, alternate, angle of divergence 60° to 80°, wide acute to right angle, lowest pain arises mainly at right angle, uniformly curved up and joined to their superadjacent secondaries without any pronounced curvature, unbranched intersecondary veins present but poorly preserved, tertiary veins (3°) fine, poorly preserved, angle of origin usually RR, percurrent, straight to curved sometime branched oblique in relation to midvein, predominantly alternate and close.

Holotype: Specimen no. P. P. M. L. K. 019

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

Horizon & Age: Lower Siwalik, Middle Miocene.

Modern Affinity: Symmetrical elliptic shape, obtuse base, entire margin veins, closely placed with more angle of divergence of lowest pairs of secondaries presence of intersecondary veins and RR, percurrent closely placed tertiary veins strongly indicate the present fossil shows closest affinity with the extant leaves of *Swintoria schwenckii* Teysm of the family Anacardiaceae (C.N. Herbarium sheet no. 37034, Pl.7, fig. 2).

Fossil records and So far, three fossil leaves resembling the genus *Swintonia* Griff. have been

comparison: described from the Siwalik sediments of India and Nepal. Awasthi and Prasad described a fossil leaf resembling extant *Swintonia floribunda* Griff. under the form species *S. miocenica* from Siwalik sediments of Surai Khola, Western Nepal [21]. Later, Antal and Prasad and Prasad and Awasthi described another fossil leaf separately under *Swintonia palaeoschwenckii* from the Siwaliks sediments of West Bengal, India, and Surai Khola, Western Nepal, respectively [22, 23]. The present fossil leaf has been compared with above already known Siwalik fossils and found that *S. palaeoschwenckii* Prasad and Awasthi described from Surai Khola, Western Nepal shows closest similarity with the present fossil and thus it has been described under the same species.

Present day distribution: The genus *Swintonia* Griff is represented by 15 species are found to occur in the tropical evergreen forests of Tennasserim, Andaman Islands, Bangladesh and Myanmar. *Swintonia schwenckii* with which the fossil leaf shows closest affinity is a tall tree found to grow in the evergreen forests of Chittagong and Myanmar along rivers. In the Chittagang forests this is one of the most conspicuous trees especially along the banks of the Karnaful River. It is also found in Malayan region [24, 25].

3. Third specimen (Plate-3): Family – Fabaceae
Genus – *Pongamia* Vent.
Pongamia kathgodamensis [26]

Material: It consists of a single fruit impression.

Description: Fruit flattened, oblong with discussed points, much thickened on suture, size 2.3 × 1.1 cm, wings absent.

Holotype: Specimen no. P. P. M. L. K. 020

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

Horizon & Age: Lower Siwalik, Middle Miocene.

Modern Affinity: In all morphological features the present fossil fruit shows closest affinity with the extant fruit of *Pongamia glabra* Vent of the family Fabaceae (C.N. Herbarium sheet no. 15650, Pl, 7, fig. 4).

Fossil records and comparison: The genus *Pongamia* is well known in the Fossil records by the occurrence of its petrified woods, fossil leaves, and fruit impressions from the Tertiary sediments of India and abroad. A number of fossil woods have been described from tertiary sediments of India under form genus *Millettioxylon* [27]. So far three fossil leaflets have been recorded from the Siwalik sediments of Haridwar, Uttar Pradesh [26], Bhikhnathoree, Bihar and West Bengal respectively [31, 23]. The fossil fruits resembling *Pongamia glabra* Vent are also known from the Siwalik sediments of Kathgodam under the form species *Pongamia kathgodamensis* [29]. Prasad and Awasthi (1996) also described another fossil fruit of the same species from the Siwalik sediment of Surai Khola, Western Nepal and assigned it to *Pongamia kathgodmensis* [20]. The present fossil fruit has been compared with all the above known fruits and found that it is very similar to them and hence has been described under the same species.

Present day distribution: The genus *Pongamia* Vent consists of single species *P. glabra* vent. with which the fossil shows its close resemblance. It is large tree found common near the banks of stream and water sources in both peninsula in the out forests and sub Himalayan tracts. It is also common in tidal and beach forests of India, Srilanka, Malaya, Archipelago expending to the Coast, South China, Fiji Islands and Tropical Australia [25].

1 2

PLATE-1

PLATE-2

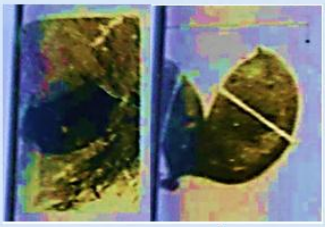

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PLATE-3

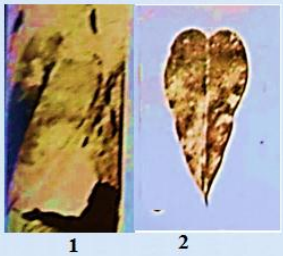

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PLATE-4

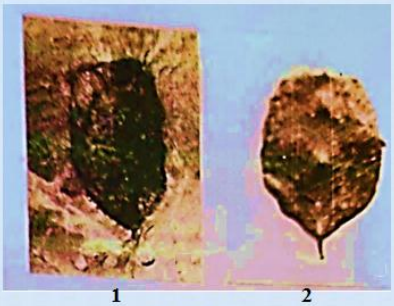

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PLATE-5

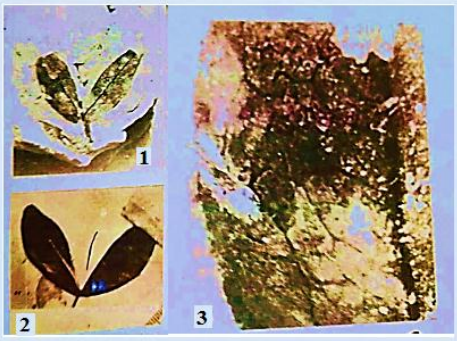

PLATE-6

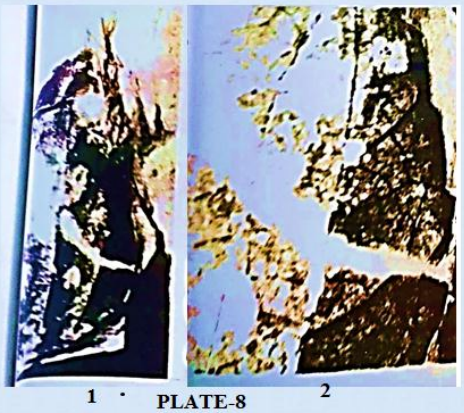

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PLATE-8

PLATE-7

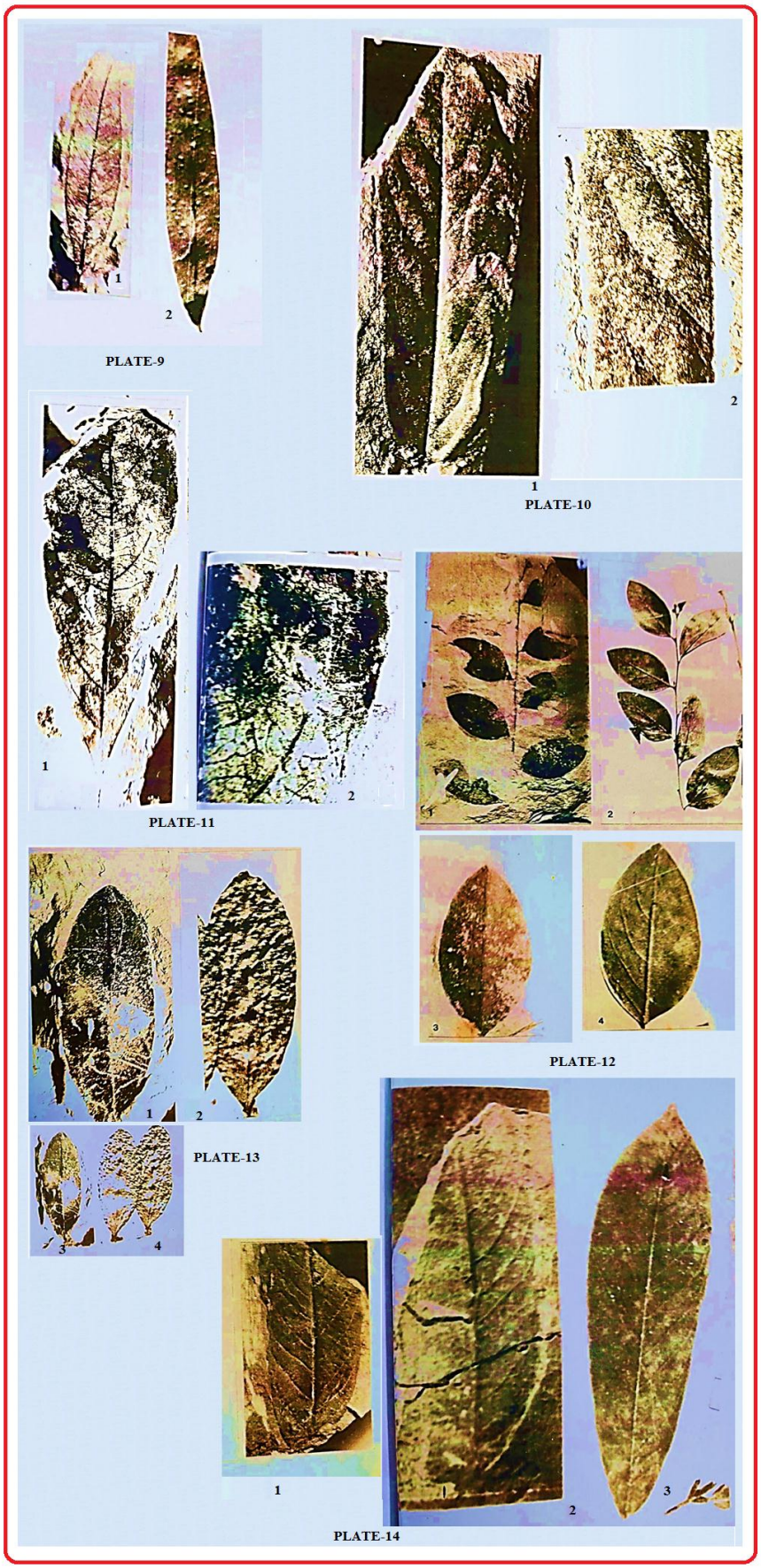
1
2
PLATE-9
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PLATE-10
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PLATE-11
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PLATE-12
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PLATE-13
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PLATE-14

4. Fourth specimen (Plate-4): Genus – *Dalbergia* Linn. F.
Dalbergia eocultrata sp. nov.

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

Description: Leaflet asymmetrical due to unequal lamina on either side of midrib, narrow elliptic, preserved size 4.0 × 1.7 cm, apex notched (emarginated), base acute, slightly enequilateral margin entire, texture chartaceous, petiole not preserved venation pinnate, eucamptodromous, primary vein (1°) single, prominent, stout, almost straight, secondary veins (2°) 1-8 pairs visible, 3.0 to 0.7 cm apart, alternate to opposite, angle of divergence about 50°-60° acute, moderate, uniformly curved up and join their superadjacent secondary, lowest pair closely placed, seemingly unbranched, intersecondary veins present, simple, tertiary veins (3.°) fine poorly preserved, angle of origin usually AO, percurrent and join inter secondary veins oblique in relation to midvein, predominantly alternate and close.

Holotype: Specimen no. P. P. M. L. K. 021

Locality: Koilabas Nala, Near Darwaja, Koilabas, Western Nepal.

Horizon & Age: Lower Siwalik, Middle Miocene.

Etymology: From the extant species *D. cultrata* plus the prefix 'eo'

Modern Affinity: The diagnostic features of the present fossil leaflet such as asymmetrical elliptic shape, emarginate apex, acute base, entire margin charataceous texture, eucamptodromous venation closely placed secondary veins with moderate angle of divergence presence of intersecondary veins and percurrent tertiaries strongly suggest its resemblance with the extant leaves of *Dalbergia cultrata* Linn. of the family Fabaceae (C.N. Herbarium sheet no. 130595).

Fossil records and comparison: The fossil leaflets resembling the genus *Dalbergia* Linn. F. have been known from different parts of the world under the genera *Dalbergia* Linn. and *Dalbergia* Berry. So far, about 50 species of India and abroad [26-45]. Besides, there is one more leaflet resembling that of *Dalbergia* described under the form genus *Phylites* by Tanai (1972) from the Tertiary of Japan [46]. These species have been reported from Africa, Australia, France, Germany, Greenland, Japan Sumatra, USA, West Indies and India. Besides, two fossil fruits resembling *Dalbergia sisso* have also been described from the tertiary sediments. First of all, Lakhanpal and Dayal (1966) described it from the Siwalik sediments of Balugoloa Himachal Pradesh [47]. Later Awasthi and Mehrotra (1995) reported other fossil fruit under *Leguminocarpon dalbirgioides* from the Oligocene of Makum Coalfield, Assam, India [48]. Thus, from its Fossil records it is clear that the genus *Dalbergia* Linn. F. was cosmopolitan in distribution during the geological past. Four fossil leaflets resembling *Dalbergia* Linn. F. have been described from the Siwalik Sediments of India and Nepal. They are *Dalbergia miosericea* [49]; *D. siwalika* [27]; from the Siwalik sediments of Koilabas, Western Nepal, Dalbergia cf. *D. sissoo* [26]; from the Siwalik sediments of Haridwar, Uttar Pradesh, *D. miovolubites* [45] from the Siwalik of Seria Naka at Indo-Nepal Border, U.P. and *Dalbergia* sp. [44] from the Siwalik sediments of Bhikhnathoree, Bihar. The present fossil leaflet was compared with the available known species of *Dalbergia* Linn. F. and found that none of them shows similarity with the present fossil. Although the fossil leaflet described as *Dalbergia miosericea* Prasad somewhat shows resemblance in the nature of apex but differs in course of secondary veins having obtuse base instead of acute base in the present fossil. Thus in being different this fossil leaftet is

assigned to a new species *Dalbergia eocultrata.*

Present day distribution: The genus *Dalbergia* Linn. F. consists of about 300 species of tropical to subtropical region of the world [24, 50]. About 36 species are reported to occur in India [51]. *Dalbergia cultrata* Linn. with which the fossil shows closest resemblance is a moderate sized deciduous tree common in all deciduous forests specially the upper mixed savannah and Eng forests throughout Myanmar, the Shah Hills, South wards.

5. Fifth specimen (Plate-5): Genus – *Dalbergia* Linn. F.
Dalbergia miovolubilis [45]

Material: This species is represented by only one specimen which is almost complete and devoid of cuticle.

Description: Leaflet, almost symmetrical, elliptic, preserved size 1.6 × 0.9 cm, apex broken, base nearly obtuse, slightly, inequilateral, margin entire, texture thick chartaceous, petiole preserved, 0.2 visible, normal, venation pinnate, eucamptodromous, primary vein (1°) single, not so prominent weak, secondary veins (2°) more than 12 pairs visible, closely placed, alternate to opposite, angle of divergence 55°, acute, moderate, uniformly curved up, branching not clear, intersecondary veins present, tertiary veins (3°) fine, poorly preserved, angle of origin RR-AO, percurrent, sometimes branched oblique in relation to midvein alternate to opposite and close. Further details could be seen.

Holotype: Specimen no. P. P. M. L. K. 022

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

Horizon & Age: Lower Siwalik, Middle Miocene.

Modern Affinity: The most important distinguishing features of the present fossil leaflet such as a small size, nearly obtuse base, entire margin, small petiole, eucamptodromous venation closely placed secondary veins arising at moderate acute angle from the midvein, presence of intersecondary veins and percurrent tertiaries collectively indicate that the fossil leaflet shows closest affinity with the extant leaflet of *Dalbergra volubilis* Roxb. of the family Fabaceae (C. N. Herbarium sheet no. 130772).

Fossil records and comparison: So far, about 42 species of *Dalbergia* Linn. F. are known from the Tertiary sediments of India and abroad [45]. The present fossil leaf was compared with all the available species and concluded that the fossil leaflet described from the Siwalik sediments of Seria Naka (Balrampur District) at Indo-Nepal Border shows closest affinity in shape and venation pattern and hence has been described under the same species. This fossil leaflet was also compared with the extant taxa *D. volubilis* Roxb. but it is larger in size with somewhat distantly placed secondaries. I would like to mention that these variations here in the morphological features may be due to different ecological condition of the regions.

Present day distribution: The extant taxa *D. volubilis* Roxb. with which the fossil shows closest affinity is a large climbing shrub growing in central and eastern Himalaya from the Kumaon to Sikkim, Bihar, central Provinces, Chhota Nagpur, South and West India and Myanmar [51].

6. Sixth specimen (Plate-6): Genus – *Cynometra* Linn.
Cynometra palaeoiripa sp. nov.

Material: This species is based on one well preserved and complete leaflets attached

with a small twig.

Description: leaflets asymmetrical, elliptic 2.1 × 1.0 cm and 2.5 × 1.0 cm, apex slightly broken, seemingly wide acute, base wide acute, margin entire, texture chartaceous, petiole very small, indistinct, venation pinnate eucamptodromous to brochidodromous, primary vein (1°) single, prominent, stout almost straight, secondary veins (2°) about 8 pairs, 0.2 to 0.5 cm apart, alternate to subopposite, angle of divergence about 60°, acute, moderate, uniformly curved up, and joined to their super adjacent secondary sometimes forming loop, rarely branched, intersecondary veins present, simple, frequent, tertiary veins (3°) fine, angle of origin RR-AO, percurrent, straight to sinuous, branched, oblique in relation to midvein, predominantly alternate, close, further details not clearly seen.

Holotype: Specimen no. P. P. M. L. K. 023

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

Horizon & Age: Lower Siwalik, Middle Miocene

Etymology: From the extant species *Cynometra iripa* suffix 'palaeo'

Modern Affinity: The most characteristic features of the present fossil leaflets are asymmetrical elliptic shape, wide acute apex and base, entire margin, texture chartaceous eucamptodromous to brochidodromous venation, closely placed secondary veins arising at moderate angle of divergence, presence of intersecondary veins and percurrent straight to sinuous tertiary veins. These features are found common in the extant leaflets of the genus *Cynometra* Linn. of the family Fabaceae. In order to find out its specific affinity the Herbarium sheets of about 12 species of this genus have been critically examined and concluded that the extant leaflets of *Cynometra iripa* Kotel (C. N. Herbarium sheet nos. 138727, 138745, Pl. 7, fig. 10) closely match in shape, size and venation pattern.

Fossil records and comparison: First of all, Awasthi and Prasad (1990) described the fossil leaflets resembling the genus *Cynometra* Linn. from the Lower Siwalik sediments of Suraikhola, Western Nepal under *C. siwalika* [21]. Later, Antal and Awasthi (1993) reported another species *C. tertiara* from the Lower Middle Siwalik of Odlabari, Darjeeling District, West Bengal [23]. Both these already Known fossil leaflets were compared with the present fossil leaflet and found that the present fossil is entirely different especially in being smaller in size. The course of secondary veins too, is also different from them. In view of this the present fossil leaflet has been described as a new species *Cynometra palaeoiripa.* The specific epithet indicates its resemblance with extant *C. iripa* Kotel.

Present day distribution: The genus *Cynometra* Linn. consists of about 60 tropical species of which five are found to occur in the Indian region. The extant taxa *C. iripa* with which the fossil shows resemblance, is distributed in Indo-Malayan region.

7. Seventh specimen (Plate-7): Genus – *Millettia* W. & A.
Millettia imlibasensis sp. nov.

Material: This species is based on a single well preserved, almost complete leaflet impression, which is devoid of cuticle.

Description: Leaflet symmetrical, narrow elliptic, preserved size 4.3 × 1.6 cm apex wide acute, base obtuse, margin entire texture chartaceous, petiole not preserved, venation pinnate, eucamptodromous, primary vein (1°) single prominent, stout, almost, straight thicker towards basal half region, secondary veins (2°) about 10 pairs, 0.3 to 0.6 cm apart alternate to subopposite, angle of

divergence about 60° acute, moderate, uniformly curved up and joining to the superadjacent secondary unbranched, intersecondary veins present, simple, tertiary veins (3°) fine, angle of origin usually RR, percurrent, straight to sometime sinuous, oblique in relation to midvein, predominantly alternate and close. Further details could not be seen.

Holotype: Specimen no. P. P. M. L. K. 024

Locality: Dang Nala, section near village Imlibasa, Koilabas, Western Nepal

Horizon & Age: Lower Siwalik, Middle Miocene

Etymology: After a place, Imlibasa, in Koilabas Nala from where the fossil was collected.

Modern Affinity: The most characteristics features of the present fossil leaflet are symmetrical narrow elliptic shape, wide acute apex, obtuse base, entire margin, chartaceous texture, eucamptodromous venation, moderate acute angle of divergence of secondary veins, presence of intersecondary veins and RR, percurrent, straight to sinuous tertiary veins. These features are found common in the genus *Millettia* W & A of the family Fabaceae. A critical observation of a number of herbarium sheets of more than 30 species of *Millettia* W. & A. indicates that the present fossil is very similar to the extant leaflets of *Millettia brandisiana* Kurz. (C.N. Herbarium sheet no. 112443, Pl. 7, fig. 12, 14).

Fossil records and comparison: So far, 12 fossil leaflets showing resemblance to that of *Millettia* W. & A. have been recorded from all over the world. They are *M. impressa* (Harms) from the Tertiary of West-Africa, *M. notoensis* Ishida (1970) from the Middle Miocene of Central Japan. *Millettia* sp. from the late Eocene of South Hensha, Japan [54], *M. asymmetrica* and *M. miocenica* from the Miocene of Kachchh, Western India, *M. koilabasensis* [49b], *M. siwalica* Prasad and *Millettia miobrandisiana* from the Lower Siwalik sediments of Koilabas, western Nepal [20], *M. palaeoracemosa* [21], *M. churiensis* [20] from the Siwalik sediments of Surai Khola, Western Nepal, *M. palaeoracemosa* Awasthi & Prasad from Siwalik sediments of Kathgodam, Uttar Pradesh[28] and *M. oodlabariensis*[22] from the Lower Siwaliks of Darjeeling District West Bengal. After comparative study it is observed that the earlier known species are distinguishable from the present fossil in possessing narrow elliptic shape with different course of secondary and tertiary veins. In being different from all the known species a new specific name *M. imlibasensis* is proposed for the new fossil.

Present day distribution: The genus *Millettia* W & A consists of 80 species of trees shrubs and woody climbers distributed in the tropical regions of Africa, Asia and Australia [24]. About 30 species are reported to occur in the Indian region, half of which are trees and other half are large climbing shrubs and are mostly distributed in West-Bengal and Myanmar *M. brandisiana* Kurz. With which the fossil resembles closely is a large tree distributed in the forests of Pegriyama and Myanmar [25].

8. Eighth specimen (Plate-8): Family – Anisophylleaceae
Genus – *Anisophyllea* R. Br.
Anisophyllea siwalika [20]

Material: This consists of only one specimen which well preserved and almost complete.

Description: Leaf simple, symmetrical, narrow ovate to elliptic, preserved size 6.3 × 3.0 cm apex acute, base obtuse, slightly indistinct, margin slightly entire, texture thick, chartaceous, venation acrodromous, basal, perfect, primary veins (1°)

three, one midvein and two lateral, one on each side of the midvein, prominent stout, unbranched midvein straight, lateral primary veins, slightly curving while approaching towards apex, secondary veins (2°) numerous arising acutely from lateral midveins and run upwards and join thin superadjacent veins and making appearance of intramarginal vein, tertiary veins (3°) fine, angle of origin RR, percurrent, usually straight, sometimes curved to sinuous, rarely branched, oblique to right angle in relation to midvein, predominantly alternate and close, quaternary veins (4°) still fine with RR origin, forming triangular to polygonal meshes.

Holotype: Specimen no. P. P. M. L. K. 025

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

Horizon & Age: Lower Siwalik, Middle Miocene.

Modern Affinity: The diagnostic features of the present fossil leaf are narrow ovate to elliptic shape, acute apex, obtuse base, non-entire margin, acrodromous venation, acute angle of divergence of secondary veins arising from lateral midvein and making an appearance of intramarginal vein and RR, percurrent, straight to sinuous tertiary veins. These features collectively indicate its near resemblance to those of *Anisophyllea* of the family Anisophylleaceae.

Fossil records and comparison: In Fossil records the genus *Anisophyllea* R. Br. is known by the occurrence of its fossil leaves *Anisophyllea siwalica* from the Siwalik sediments of Surai Khola, Western Nepal [20]. These fossil leaves were compared with the present fossil leaf and found that both are almost similar in shape, size and venation pattern showing no marked difference in between them. Hence, the present fossil leaf is described under the same species *Anisophyllea siwalika* by Prasad and Awasthi [20].

Present day distribution: The genus *Anisophyllea* R. Br. consist about 30 species distributed in the tropical regions of South Africa, Asia and South America *Anisophyllea apetala* Scort with which the fossil shows near resemblance is an evergreen tree found to grow in the Malayan regions [52].

9. Ninth specimen (Plate-9): Family – Myrtaceae
Genus – *Syzygium* Gaertn
Syzygium miooccicentalis sp. nov.

Material: This species is based on a single well preserved complete leaf- impression devoid of cuticles.

Description: Leaf simple, symmetrical, very narrow elliptic, preserved size 7.2 × 1.5 cm apex slightly broken, seemingly alternate, base acute, margin entire, texture chartaceous, petiole preserved, 0.4 cm long, normal, venation eucamptodromous, primary vein (1°) single, secondary veins (2°) about 17 pairs visible, usually less than 0.6 cm apart, alternate to opposite, angle of divergence about 55°, acute, moderate, rarely branched uniformly curved up and jointed to then superadjacent forming intramarginal veins all along the margin intersecondary veins present frequent, 1-4 intersecondary in between two secondary veins, tertiary veins (3°) fine, angle of origin RR-AO, percurrent, straight, branched, oblique in relation to midvein, predominantly alternate and close.

Holotype: Specimen no. P. P. M. L. K. 026

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

Horizon & Age: Lower Siwalik, Middle Miocene.

Etymology: From extant taxa *Syzygium occidentalis* plus prefix ‘Mio’

Modern Affinity: The important distinguishing features of the fossil leaf are very narrow elliptic

shape, acute base, entire margin, eucamptodromous venation, presence of intersecondary and intramarginal veins and RR-AO, percurrent, tertiary veins. These morphological features suggest that the present fossil leaf shows its affinity with the leaves of extant genus *Syzygium* Gaertn of the family Myrtaceae. A critical examination of the modern leaves of about 50 species of the genus was done and found that the modern leaf of *S. occidentalis* Bourd (*Eugenia occidentals*) closely resembles the present fossil leaf (C.N. Herbarium sheet no. 66156, Pl, 8, fig. 4).

Fossil records and comparison: So far, six species of *Syzygium* Gaertn. based on fossil leaves have been reported from the Tertiary sediments of India and abroad. They are *Syzyggium floribundoides* Engelhardt [53] from the Middle Miocene of West Germany, *S. chaneyi* [54] from the Eocene of Japan, *S. miocenicum* [54] from the Siwalik beds of Koilabas, Western Nepal, *S. palaeobracteatum* [31] from the Siwalik of Bhikhnathoree, Bihar, and *S. palaeocumini* [20] from the Siwalik sediments of Surai Khola, Western Nepal and from the Siwaliks of Darjeeling District, West Bengal [56]. On comparing the present fossil with the above already known species it is found that none of them is similar to the present fossil and hence it is being described as a new species *S. miooccicentalis*.

Present day distribution: The genus *Syzgium* Gaertn consists to about 5000 species of trees, shrubs and rarely climbers. They are palaeotropical distribution (Willis, 1973). There are 79 species in India of which about 76 species are indigenous which thrive in moist localities along the banks or in the beds of streams. It occurs in wet evergreen, semi evergreen, moist deciduous, littoral and swamp, dry evergreen and dry deciduous. Forests of tropical India *S. occidentalis* with which the fossil specimen shows closest affinity is found in the Indian region.

10. Tenth specimen (Plate-10): Family – Ebenaceae
Genus – *Diospyros* Linn.
Diospyros darwajensis sp. nov.

Material: This consists of a well preserved almost complete leaf impression which is devoid of cuticle.

Description: Leaf simple, symmetrical, narrow oblancealate, preserved size 13.2 × 4.2, apex broken, base obtuse, margin entire, texture coriaceous, petiole not preserved, venation pinnate, eucamptodromous to brochidodromous primary vein (1°) single, prominent, stout, almost straight, secondary veins (2°) 7-8 pairs visible, 0.5 to 2.0 cm apart, lowest pair closely placed, usually alternate, rarely sub-opposite, angle of divergence about 50°, acute, moderate, uniformly curved up and join to their superadjacent secondary at obtuse angle, sometime join before meeting the margin and giving the appearance of brochidodromous type of venation pattern, seemingly unbranched, intersecondary veins rarely seen, tertiary veins (3°) fine, angle of origin RR, percurrent straight to sinuous, branched, oblique in relation to midvein, predominantly alternate close, quaternary veins (4°) still fine with RR, angle of origin, branched forming orthogonal to polygonal meshes.

Holotype: Specimen no. P. P. M. L. K. 027

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

Horizon & Age: Lower Siwalik, Middle Miocene.

Etymology: After a place Darwaja in Koilabas Dang Nala from where the fossil was collected.

Modern Affinity: The most characteristic features of the present fossil leaf like narrow oblanceolate shape, obtuse base, entire margin coriaceous texture,

eucamptodromous to brochidodromous venation, course and nature of secondary vein, rare occurrence of intersecondary veins, RR, percurrent, straight to sinuous tertiary veins undoubtly indicate its resemblance with the leaves of *Diospyros* Linn of the family Ebenaceae. In order to findout its nearest modern equivalent, about 55 species of *Diospyros* Linn. were examined critically and found that the present fossil leaf shows closest affinity with the leaves of extant *Diospyros dasyphyllea* Kurz. (F.R-I Herbarum sheet no. 39889).

Fossil records and comparison: The fossil leaves showing close resemblance with those of *Diospyros* have been described under two genetic names, i.e. *Diospyros* Linn. and *Diospyrophyllum* Velenovsky, the later consists of only one species *Diospyrophyllum provectum* Velenovsky (1889) from the upper cretaceous of Bohemia. However, *Diospyros* Linn. contains about 70 species reported from different parts of world, viz. Africa, Bohemia, Canada, Europe, England, Greek, Greenland, Japan, Panama, Switzerland and U.S.A. [33-46]. Thus it is obvious that this genus was cosmopolitan in distribution during the geological part. From the geological distribution of fossil Diospyros it is evident that its earliest record goes back to the upper cretaceous [57]. So far seven species have been reported from the Siwalik sediments of India and abroad. They are *Diospyros embryopterisites* from the Middle Siwalik of Hardwar, Uttar Pradesh, India [58]. *D. miocenica* from the lower Siwalik sediments of Surai Khola, Western Nepal [29, 21], *D. kathgodamensis* and *D. palaeoebenum* from the lower Siwalik of Kathgogodam, Uttar Pradesh, India [28, 29]. *D. pretoposia* and *D. koilabasensis* from the Lower Siwalik sediments of Koilabas, Western Nepal [49a]. The later species has also been reported from the Lower-Middle Siwalik of Darjeeling District, West Bengal, India, *D. tulsipurensis* from the Lower Siwaliks of Seria Naka, at Indo-Nepal Border, in Balrampur District of Uttar Pradesh, India [45]. The present fossil leaf was compared with all the above available species and found entirely different from them in the course and nature of secondary and tertiary veins. Therefore, it has been described under a new species *Diospyros dorwajensis.*

Present day distribution: The genus *Diospyros* Linn. consists about 500 species of trees or rarely shrubs distributed in tropical and mild temperate regions of the world, a few in south Africa and North America [50]. About 55 species are found in the Indian region *D. dasyphyllea* Kurz., with which the fossil resembles closely, is an evergreen tree of Martaban Hills.

11. Eleventh specimen (Plate-11): Family – Portiaceae
Genus – *Helicia* Lour
Helicia eoerrectica sp. nov.

Material: This species is represented by a well preserved almost complete, leaf impression. It is devoid of cuticle.

Description: Leaf simple, symmetrical, oblanceolate, preserved size 11.5 × 4.0 cm apex broken, base cuneate, margin entire, texture chartaceous, petiole preserved 0.8 cm long, normal, venation pinnate eucamptodromous, primary veins (1°) single prominent, stout, almost straight, secondary veins (2°) 5-6 pairs visible, 1.3 to 2.8 cm apart, usually alternate, seemingly unbranched, angle of divergence about 60° acute, moderate, lowest pair of secondary arising more acutely, curved up and run upwards to a little distance and join to their superadjacent secondary, intersecondary veins present, simple, frequent, tertiary veins (3°) fine, angle of origin RR, percurrent straight to sinuous,

branched, oblique in relation to midvein right angle near the margin, predominantly, alternate and close, quaternary vein (4°) still fine, angle of origin RR, forked, forming orthogonal to polygonal meshes.

Holotype: Specimen no. P. P. M. L. K. 028

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

Horizon & Age: Lower Siwalik, Middle Miocene.

Etymology: From extant taxa *H. erretica* Plus prefix 'eo'

Modern Affinity: The most important distinguishing features of the fossil leaf such as oblanceolate shape, cuneate base, entire margin, chartaceous texture, eucamptodromous venation, distantly placed secondaries with moderate angle of divergence running upward to a little distance, presence of intersecondary veins and RR, percurrent, straight to sinuous, tertiary veins strongly suggest that the present fossil leaf shows closest affinity with the modern leaves of *Helicia erretica* Hook. F. of the family Proteaceae (C.N. Herbarium sheet no. 13457).

Fossil records and comparison: As far as the author is aware there is no Fossil record of the genus *Helicia* Lour. form the Indian subcontinent. Therefore the present fossil leaf form its first record from the Siwalik of Koilabas, Western Nepal and its has been assigned as *Helecia eoerretica* sp. nov.

Present day distribution: The genus *Helicia* Lour. Consists of about 90 species distribute in Europe, south-east Asia, Indo-Malaya and Eastern Australia of these, only 8 species are found to occur in the Indian region *H. erretica* Hook. F. with which fossil resembles closely is a small evergreen tree found is the forests of Sikkim and Shan Hills of Martaban. It is common in Darjeeling forests chiefly in open ground [51].

12. Twelfth specimen (Plate-12): Family – Euphorbiaceae
Genus – Phyllanthus Linn.
Phyllanthus mioreticulatus sp. nov.

Material: This species is represented by seven leaflets attached on a twig devoid of cuticles.

Description: Leaflets symmetrical, elliptic average size 2.5 × 1.3 cm, apex wide acute, base wide acute to obtuse, margin entire, texture thick charataceous, petiole small, 0.2 to 0.3 cm long, venation pinnate, eucamptodromous, primary vein (1°) single, prominent, stout, almost straight, secondary veins (2°) 5-6 pairs less than 0.5 cm apart, alternate to opposite, unbranched, angle of divergence about 55°, acute moderate, uniformly curved up and join to their superadjacent secondary, intersecondary veins occasionally seen, tertiary veins (3°) poorly preserved, fine, angle of origin RR, percurrent straight, oblique in relation to midvein, predominantly alternate and close.

Holotype: Specimen no. P. P. M. L. K. 029

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

Horizon & Age: Lower Siwalik, Middle Miocene.

Etymology: Extant taxa *Phyllanthus reticulatus* plus prefix 'mio'

Modern Affinity: The diagnostic features of the present fossil leaf such as small size, elliptic shape, wide acute apex and base, entire margin, eucamptodromous venation, closely placed secondary arising at moderate angle of divergence, rare inter secondary veins and RR, percurrent, straight tertiary veins undoubtedly indicate there resemblance with the genus *Phyllanthus* Linn of the family Euphorbiaceae. In order to find out the nearest resembling species a number of Herbarium sheet of about 55 species were critically examined and concluded

that the present fossil shows affinity with the extant leaflets of *Phyllanthus reticulatus* Poir in shape, size and venation pattern (C.N. Herbarium sheet no. 13875).

Fossil records and comparison: Four fossil leaves are known so far showing close resemblance to those of *Phyllanltus* (=*Glochidion*) from the Siwalik sediments of India and Nepal of them, three are from India and one is form Nepal. They are *Glochidion siwalica* from the Lower Siwalik sediments Kathgodam, Uttar Pradesh, India [28]. *Glochidion palaeohisutum* Antal & Prasad (1996a) from the Lower Siwaliks of Oodlabari West Bengal, India, *Phyllanthus siwalica* from the lower Siwalik of Kathgodam. Uttar Pradesh, India [29] and *Phyllantus palaeoreticulatus* [20] from the Lower Siwalik sediments of Surai Khola, Western Nepal. A comparative study of both the above known fossil leaves as well as present fossil specimen indicate that the present fossil differ in being smaller size and having different course and arrangement of secondary veins. The fossil leaf described under *Phyllanthus palaeoreticulatus* and comparable with the same extant species differs in nature of apex and having more secondary veins as compared to the present fossil. Thus, in being different, the present fossil is assigned to new species *P. mioreticulatus.*

Present day distribution: The genus *Phyllanthus* Linn. contains about 600 species distributed in tropical to subtropical regions of the world exclusively Eurasia and North Asia. It is a genus comprising the plants varying in sizes, many of them more or less shruby *Phyllanthus reticulatus* Poir with which fossil shows closest affinity is a struggling shrub distributed throughout the greater part of India, Myanmar and Srilanka. In the drier region it is commonly found in ravines and along streams [51].

13. Thirteenth specimen (Plate-13): Family - Euphorbiaceae
Genus: *Phyllanthus*
Phyllanthus koilabasensis sp. nov.

Material: This species is based on a single complete leaf – impression which is devoid of cuticle.

Description: Leaflet symmetrical, preserved size 4.8 × 1.7 cm, narrow, elliptic, apex obtuse, base acute, margin entire, texture coriaceous petiolule preserved, small, 0.2 long, venation pinnate, eucamptodromous, primary vein (1°) single, prominent, stout, almost straight, secondary reins (2°) about 78 pairs visible, 0.3 to 0.7 apart, alternate to subopposite, seemingly unbranched, angle of divergence about 60°, acute moderate, uniformly curved up and join to their super adjacent secondary inter secondary veins present, simple, frequent, tertiary veins (3°) fine, poorly preserved, angle of origin RR-AO, percurrent, straight to sinuous, branched, oblique in relation to midvein, predominantly alternate and close. Further details could not be seen.

Holotype: Specimen no. P. P. M. L. K. 030

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

Horizon & Age: Lower Siwalik, Middle Miocene.

Etymology: After the fossil locality Koilabas from where the fossil was collected.

Modern Affinity: The important distinguishing features of the present fossil are narrow elliptic shape, obtuse apex, acute base, entire margin, small petiolule, eucamptodronous venation, somewhat closely placed secondaries with moderate acute angle of divergence, presence of intersecodnary veins and percurrent tertiary. These features are found common among the species of the genus phyllanthus Linn. of the family Euphorbiaceae. After a critical

examination of those species it has been concluded that the extant taxa *Phyllanthus collumnaris* Muell. Arg. Shows closest affinity with the present fossil in all morphological features (C.N. Herbarium sheet no. 401998. Pl.9, fig. 6, Pl. 10, fig. 4).

Fossil records and comparison: So far five fossil leaflets resembling the genus *Phyllanthus* Linn. are known from the Siwalik sediments of India and Nepal. These are mentioned earlier in the previous species. The present fossil has been compared to those of all already known fossils and found that it is different from them either in shape or in the nature of secondary and tertiary veins. Thus in being different it is assigned to a new species *Phyllanthus koilabasensis*.

Present day distribution: The modern comparable taxa *Phyllanthus collumnaris* is a small deciduous tree of mixed forests in Myanmar. It is common all along the rivers [51].

14. Fourteenth specimen (Plate-14): Genus – *Antedesma* Linn
Antedesma siwalica sp. nov.

Material: This species is represented by single well preserved almost complete leaf-impression.

Description: Leaf simple, symmetrical, narrow elliptic, preserved size 11.5 × 3.6 cm and 7.2 × 3.5 cm, apex broken, base wide acute, margin entire, texture thick, chartaceous petiole not preserved, venation pinnate, eucamptodromous venation, primary vein (1°) single prominent, stout, slightly curved, secondary veins (2°) about 10 pairs visible, 0.5 to 1.5 cm apart, alternate to subopposite seemingly unbranched angle of divergence. 55° to 60°, acute moderate, uniformly curved up and run upward to join the super adjacent secondary veins, curvature more pronounced near the margin, intersecondary veins present, tertiary veins (3°) fine, angle of origin, RR, percurrent usually straight, branched oblique in relation to midvein, predominantly alternate and close.

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

Locality: Dang Nala, Section near Darwaja, Koilabas, Wester Nepal.

Horizon & Age: Lower Siwalik, Middle Miocene.

Etymology: Lower Siwalik Formation.

Modern Affinity: Narrow elliptic shape, wide acute base, entire margin, eucamptodromous venation, specific course of secondary veins, presence of intersecondary veins and RR, percurrent tertiary veins undoubtly indicate that the present fossils resemble closely to the extant leaves of *Antedesma montanum* Bl. and *A. cuspidatum* Mull. Arg (C.N. Herbarium sheet no. 408750, Pi. 10, fig. 2).

Fossil records and comparison: As far as author is aware there is no record of fossil leaves resembling the genus *Antedesma* Linn. from the Tertiary sediments of India and abroad. The present fossil leaves from its first occurrence in the Siwalik sediments of Koilabas, Nepal and therefore they have been described under a new species *Antedesma siwalica*.

Present day distribution: The genus *Antedesma* Linn. consists of about 170 species distributed in tropical to subtropical regions especially in Asia. About 23 species are found to occur in India. The extant *A. montanum* Bl. is a small tree distributed in the Malayan region [59].

Conclusions:

We have found that above fourteen species belonging to twelve genera and seven 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, further signify the physiogenomic characters of fossil's leaves with climate.

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Conflicts of Interest

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

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