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First Record of Fossil *Parthenocissus* (Vitaceae) Leaf from Siwalik Sediments of Sarkaghat, Himachal Pradesh, India and its Biogeographic Implications

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ABSTRACT

A non- entire fossil leaf, *Parthenocissus miocenica* n. sp. is reported for the first time from the Upper Miocene sediments of Sarkaghat area in the Himalayan foot hills of Himachal Pradesh, India. It shows close resemblance with an extinet taxon, *Parthenocissus semicordata* (Wall.) Planch. of the family Vitaceae. This is one of the biogeographically important taxa which is native to Himalaya and presently distributed in tropical and subtropical regions of N.W. India, Nepal to central China and western Malaysia. The present recovered fossil along with other known fossils from Sarkaghat area suggest a tropical humid climate in the area during Miocene epoch.

Key words: *Fossil leaf, Parthenocissus (Vitaceae), Siwalik (Upper Miocene), Sarkaghat, Himachal Pradesh, Palaeoclimate, Biogeographic distribution.*

Introduction

The Siwalik is considered to be the most significant in geological history of India because some major geological events took place during this period. The major upheaval of the Himalaya has taken place during the Middle Miocene and continued until the close of Pleistocene which changed the physiography and provided ample opportunity for rapid spread and diversification of angiospermous plants in India. The Siwalik sediments provide an excellent opportunity to study the plant megafossils entombed in the alluvial sediments. The studies of plant megafossils carried out by several workers (Awasthi, 1992; Prasad, 2008) to contribute significantly to understanding of plant diversity and climate changes through the ages in Indian subcontinents. Most of the paleaobotanical work has been carried out during the last three decades from the different localities mainly in the central sector of Siwaliks (Prasad, 2008). However, from the western Siwalik sector (Himachal Pradesh) the palaeobotanical work has been done mainly from the Siwalik of the Nalagarh area, Jawalamukhi and Ranital area and Bilashpur area (Prasad, 2006, 2008; Lakhanpal and Awasthi, 1992). So far, only seven fossil taxa belonging to the families, Flacourtiaceae, Fabaceae, Rhamnaceae, combretaceae and Arecaceae are reported from Siwalik of Sarkaghat area, Himachal Pradesh (Prasad *et al.*, 2013). In view of the meagre record of plant fossils from the Siwalik sediments of Himachal Pradesh, we visited again the fossil locality, Sarkaghat and collected a variety of fossil leaves from the Upper Miocene sediments of Sarkaghat in Mandi District, Himachal Pradesh.

Only few fossil leaves were identified with the extant species and one of the biogeographically important fossil leaf, *Parthenocissus miocenica* n. sp. has been described and discussed here in detail.

Geology of the Study Area

The Siwalik belt exposed between the northerly dipping Himalayan Frontal Thrust (HFT) in the south and Main Boundary thrust (MBT) in the north contains post collisonal fluvial mollase sediments by erosion of the rising Himalaya ranging in age from 18.3 Ma (Johnson *et al*, 1985) to 0.22 Ma (Ranga Rao, *et al*., 1979). The Sarkaghat Anticline is exposed in the north east part of Kangra reentrant of the Himachal Pradesh sub- Himalayan zone along the northerly dipping Main Boundary Fault. The fossil locality (N 31° 44' 26" E 76° 43'33") lies along the National Highway 70 very near to Sarkaghat area of Mandi District, Himachal Pradesh (Fig. 1). More than 60 specimens of leaf impressions were collected from middle Siwalik beds exposed in a road cutting section (31° 44.265':76 °.43.339') about 7Km from Sarkaghat town on the left side of main road which leads to Dharampur and easily approachable through vehicle. About 8 km from the leaf fossil site is the Nalad Khad section (lat 31°46'N, log 76°43'E) from where few fossil woods were also collected. This section has been magnetostratigraphically studied and dated by earlier workers, Brozovic and Burbank (2000). The Nalad Khad section is located at, on the western limb of the Sarkaghat anticline, and in the Jawalamukhi thrust sheet. It is characterized by mainly thick units of fine to coarse, dark grey indurate, multistoried sandstones with red, yellow and brown pedogenic mudstones (Fig. 2).

The Sarkaghat anticline is exposed in the north-

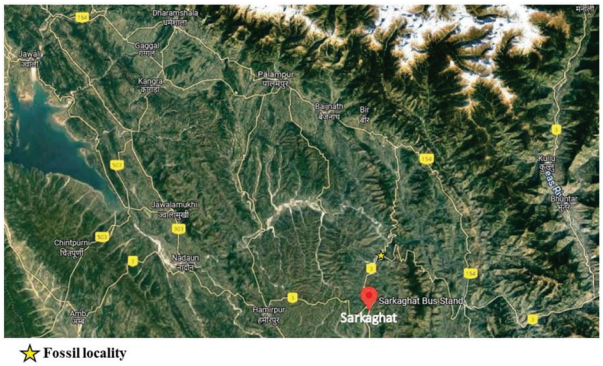

Fig. 1. Google map showing location of the study area, Sarkaghat in Mandi district, Himanchal Pradesh, India

Fig. 2. A Siwalik section exposed in Sarkaghat area from where fossil leaf, *Parthenocissus miocenica* n.sp. is collected from shale bed.

east part of the Kangra reentrant of the Himachal Sub-Himalaya along the northerly dipping Main Boundary Fault (MBF) between the NNW-SSE trending Awah Devi - Lamba Graon syncline in south and Main Boundary Fault (MBF) in north. It is a regional structure in the Paleogene-Siwalik belt around west Sarkaghat. Based on litho-association, grain size, compactness and internal geometry of beds, five mappable lithostratigraphic units of the Siwalik Group have been classified viz. Nahan Formation of the Lower Siwalik Subgroup, Dewal and Mohargarh formations of the Middle Siwalik Subgroup and Pinjor and Kalar formations of the Upper Siwalik Subgroup within the MBF related Sarkaghat Anticline structure (Kumar *et al.,* 2017).

The Nahan Formation (i.e. Chinji Formation) consists of fine grained, compact, grey white, occasionally flaggy sandstone with minor brick red mudstone/claystone along the core portion of the anticline. It shows gradational contact with the underlying Kasauli Formation of the Sirmur Group. The Dewal Formation (i.e. Nagri Formation) of the Middle Siwalik Subgroup comprises medium grained, grey to buff-brown and less compact sandstone and brick red to purple siltstone and friable red-brown to variegated color, nodular claystone/ mudstone with or without intra-formational conglomerate (IFC) lenses. Overlying the Dewal Formation with gradational contact, the Mohargarh Formation (i.e. Dhok Pathan Formation) comprises rather friable, massive, multistoreyed, medium to coarse grained, greenish-grey micaceous sandstone having polygonal cracks/fractures, pebbly conglomerate horizons and occasionally grey/ khaki mudstone bands. Having pebbly conglomerate bands, this litho-assemblage of the Mohargarh Formation differ from litho-pack of the Mohargarh Formation

exposed in other parts of the Siwalik belt, probably due to proximal part of the Siwalik belt

The Mohargarh Formation show local erosional unconformity with the overlying coarse rudaceous sediments of the Pinjor Formation around Baddu, Laungni and Duhgni areas. The Pinjor Formation comprises alternate sequence of coarse to gritty sandstone and polymictic, pebbly conglomerate almost in equal proportion along with minor grey to reddish brown siltstone/mudstone. This lithostratigraphic unit is well exposed around Kharot, Riyur, and Khera area. The successive lithostratigraphic unit the Kalar Formation (i.e. Boulder Conglomerate Formation) of the Upper Siwalik Subgroup conformably overlies the Pinjor Formation and well exposed around Marhi, Tihra, Kamlagarh and Dolan areas up to MBF in the northeast. This unit is well exposed along the footwall vicinity of the SE segment of the MBF around Sarkaghat area. It comprises polymodal and polymictic bouldery conglomerate sequence along with sandy to muddy matrix and coarse sandstone/mudstone lenses. The clast size increases in younging direction towards MBF (up to >2 m diameter boulders). The clasts are composed of different colored quartzite, sandstone, granite/gneiss, mud stone, and limestone, slate and basic rocks in descending order of abundance in Sarkaghat Anticline area. Almost all the formations contain burnt wood/charcoal pocket and thin carbonized layers. The pole plot of bedding data also indicates that the Sarkaghat anticline structure is a gentle, asymmetrical, inclined fold having northwesterly plunge (average 28° towards 333°) with steeper northern limb. The geometry and kinematics of the MBF, upright Sarkaghat anticline, joints and cum minor secondary faults of the area suggest the NE-SW trending, subhorizontal maximum tectonic compression axis of the terminal phase of Himalayan tectonics to form the MBF related Sarkaghat Anticline in the area. (Kumar *et al*., 2017).

Materials and Methods

Three leaf impressions showing close resemblance with the genus, *Parthenocissus* Planch. were collected from Middle Siwalik (Upper Miocene) sediments exposed in a road cutting section (31°44'15.70"N:76° 43' 20.19") near a well known town, Sarkaghat which falls in Mandi District of Himachal Pradesh **(Fig. 1).** The fossil locality is situated on the left side of main road which leads to Dharampur and easily accessible through vehicle and the leaf impressions were devoid of cuticle and preserved on usually grey shales. The fossil leaves have been studied morphologically with the help of either hand lens or low power microscope under reflected light. The herbarium sheets of several extant families and genera were examined at Central National Herbarium, Shibpur, Howrah, West Bengal in order to identify these leaf impressions. For the description of leaf impressions, the terminology given by Hickey (1973) and Dilcher (1974) has been followed. The photograph of the leaf of the modern comparable taxa has been provided to show similarity with the fossil leaves.

SYSTEMATIC PALAEOBOTANY OF FOSSIL LEAVES

Kingdom: Plantae
Clade: Angiosperm
Order: Vitales
Family: Vitaceae
Sub family: Vitoidae
Genus: *Parthenocissus* Planch.
Parthenocissus miocenica n. sp.
(Figs. 3a,c,d,e)

Diagnosis

Leaves asymmetrical, ovate to lanceolate; apex acute; base wide acute; oblique; margin non-entire, petiole about 2.0 cm long, normal; venation pinnate, simple craspedodromous to nearly eucamptodromous; primary vein not prominent, stout, almost straight; secondary veins 7-8 pairs visible, 0.6-1.2 cm apart, angle of divergence 55-70°, acute, lower pair of secondary vein arises with more angle of divergence tertiary veins fine, angle of origin usually RR, rarely AO, percurrent, oblique in relation to midvein, predominantly alternate and close.

Description

Leaves asymmetrical, ovate to lanceolate; preserved size 7.4x3.0 cm, 6.8x3.4cm, and 7.7x2.6cm; apex sharply acute; base wide acute, oblique; margin non-entire, dentation irregular; texture chartaceous; petiole preserved in two specimens, about 2.0cm long, normal; venation pinnate, simple craspedodromous to nearly eucamptodromous; primary vein (1°)

single, not prominent, stout, almost straight; secondary veins (2º) poorly preserved,7-8 pairs visible, 0.6-1.2 cm apart, uniformly curved up, angle of divergence 55-70º, acute, lower pair of secondary vein arises with more angle of divergence, usually alternate, seemingly unbranched; intersecondary veins present, simple; tertiary veins (3º) poorly preserved, still fine, angle of origin usually RR, rarely AO, percurrent, sometimes branched, straight to sinuous, oblique in relation to midvein, predominantly alternate and close.

Holotype: Specimen no. MLK/S/201.

Paratype: MLK/S/202,203.

Type locality: Sarkaghat, Mandi District, Himachal Pradesh, India.

Horizon & Age: Middle Siwalik; Upper Miocene.

Etymology: The specific epithet is named after Miocene age of the section from where fossils are collected.

Affinity

The diagnostic features of the present fossil leaves such as asymmetrical, ovate to lanceolate shape, acute apex, wide acute base, non-entire margin, craspedodromous to eucamptodromous venation, narrow to wide angle of divergence of secondary veins, RR, rarely AO, percurrent, straight to sinuous tertiaries with oblique angle in relation to midvein collectively suggest its resemblance with the extant leaves of *Parthenocissus semicordata* (Wall.) Planch., *P. nilgiriensis* Planch., *Cayratia trifolia* Linn., *C. japonica* (Thunb.) Gagnep. *Vitis bracteolata* Wall, *V. oxyphylla* A. Rich. and *V. dubia* M.A. Lawson of the family Vitaceae, *Urtica parviflora* of the family Urticaceae, *Pittospermum pentandrum* (Blco.) Nees and *P. brachysephalum* Kurz of the family Pittospermaceae. Critical examination of the herbarium sheets of all the above extant species revealed that the leaves of *Pittospermum pentandrum* (Blco) Nees (C.N.H. Herbarium sheets no. 6752) and *P. brachysephalum* Kurz (C.N.H. Herbarium sheets no. 34477) show affinity with the present fossil leaves in shape, size and venation pattern but differ mainly in the nature of apex The apex in these extant species is bluntly acute and sometimes nearly acuminate instead of sharply acute apex in Sarkaghat fossil leaves. *Urtica parviflora* Roxb. differs from present fossils in being presence of fine and small serration as compared to thick dentate type of serration. The leaves of *Cayratia trifolia* Linn., *C. japonica* (Thunb.) Gagnep. possess irregular serration, the upper part of the lamina is prominently serrated as compared to the basal region. The leaves of above mentioned species of the genus *Vitis* Linn. show similarity with the present fossils in the nature of margin and its serration but differ entirely in shape, size and venation pattern. The extant species of both the species of *Parthenocissus, P. semicordata* (Wall.) Planch. and *P. nilgiriensis* Planch. are so similar which can not be easily separated each other. The comparative study of the herbarium sheets of both species suggests that the leaves of *Parthenocissus semicordata* (Wall.) Planch. (C.N.H. Herbarium sheet no. 91044; Figs. 3b, f) show closest resemblance with the present fossils in shape, size, venation pattern, nature of apex and non- entire margin.

Fossil Records and Comparison

As far as authors aware there is no record of fossil leaf resembling the genus *Parthenocissus* Planch. of the family Vitaceae from the Tertiary sediments of India and abroad. The present fossils have been reported for the first time from Siwalik sediments of Sarkaghat area of Himachal Pradesh, India and described herewith as a new form species, *Parthenocissus miocenica*. However, a fossil leaf, *Cayratia palaeojaponica* Prasad *et al*., 2019 of the family Vitaceae is reported from the Middle Churia Group (Upper Miocene) sediments of Arjun Khola area, western Nepal. Fossil leaf, *Cayratia palaeojaponica* Prasad *et al.* has been compared and found that it differs mainly from the present fossils in the nature of non-entire margin which is weakly serrated with small teeth as compared to doubly serrated with larger teeth. In the fossil record the genus, *Parthenocissus* Planch. is well known by occurrence of its fossil seeds in Tertiary sediments of Asia, Europe and North America (Fig. 4). These are *Parthenocissus boveyana* Chandler 1957 from Oligocene of Bovey Tracey Lignite, England, Europe, *P. monasteriensis* (Ried and Chandler) Scott from early Eocene of Paris Basin, France, Europe (Blanc-Lauvel, 1986), *P. eoquinquefolia* Tiffiney & Barghoorm,1976 from the Miocene of North America, *P. angustisulcata* Scott and *P. clarnensis* Manchester from early Middle Eocene Claro Formation, North America (Manchester, 1994), *P. hordwellensis* Chandler, 1957 from Late Eocene of England, Europe, *P. britanica* (Heer) Chandler, 1957 from Oligocene of Bovey Tracey Lignite, England, Europe, *P. obovata* Nikitin, 2006 from Late Oligocene/ early Miocene of Siberia, Russia. *P. longsdorfii* Mai, 2006 from Middle

Miocene Germany, Europe and *Parthenocissus* sp. Dorofeev, 1963 from Late Oligocene/ early Miocene of Siberia, Russia.

Results and Discussion

The morphological study on plant megafossils collected from Middle Siwalik sediments of Sarkaghat area, Himachal Pradesh, India revealed the presence of a new form species, *Parthenocissus semicordta* (Wall.) Planch. of the family Vitaceae in the Siwalik flora of Indian subcontinents. The genus *Parthenocissus* Planch. is consists of about 12 species of tendril climbing plants distributed in Himalaya, eastern India and North America. *P. semicordata* (Wall.) Planch. with which fossil leaves show closest affinity is a deciduous climbing shrub having about 18 m long stem distributed in N.W. Himalaya, India, Nepal to central china and western Malaysia. In India it is mainly found to grow in Himachal Pradesh, Uttar Pradesh, West Bengal, Sikkim, Meghalaya and Nagaland. On the basis of the present day distribution of extant comparable taxon, *P. semicordata* (Wall.) Planch. it can be surmised that there was a prevalence of a tropical warm humid climate during Miocene Period which is suitable for a deciduous forest in the Sarkaghat and nearby area of Himachal Pradesh, India.

Family Vitaceae (Grape family) comprises 14 genera with about 978 species distributed mostly in tropical and subtropical region of Africa and South Africa (Shetty and Singh, 2000). They are usually climbing shrubs or small trees having compound or simple deeply lobed/ non-entire leaves. A good amount of taxa are succulent mainly belonging to the genus *Cissus* Linn. In India 10 genera and 82 species of this family are found mostly in tropical or subtropical evergreen forests. A few taxa like *Cissus subramaniam* Shetty and Singh and *Tetrastigma andmanica* (King) Suess. are endemic to Tamilnadu, South India and Andaman and Nicobar respectively (Fatma, 2016).

Parthenocissus Planch. is a well-known and large genus in the family Vitaceae and has a disjunctive distribution in Asia and North America (Fig. 4). Their members are found in both tropical and temperate regions. Two major clades of this genus are recognizable corresponding to their distribution in Asia and North America (Nie *et al.*, 2010). The fossil evidence and palaeoclimate data suggest that the members of the genus *Parthenocissus* Planch. have derived from the Eocene boreotropical elements. Its current Asia North American disjunction is dated as early Miocene. The biogeographic complexity of the Northern hemisphere has been attributed to widely covered boreotropical flora with subsequent dynamics of contraction and expansion between tropical and temperate regions The boreotropical theory postulate the presence of an extensive frost free and

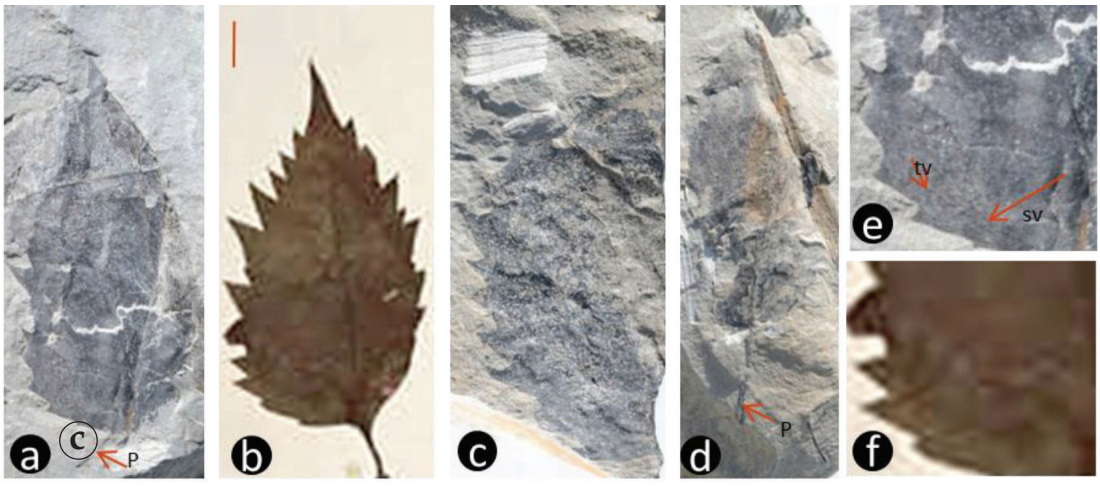

Fig. 3 (a-c). *Parthenocissus miocenica* n sp. – Fossil leaves showing shape size and venation and dentations pattern in the margin (Specimen no. MLK/S/201 (Holortype); MLK/202 (Paratype). **(b)** *Parthenocissus semicordata* (Wall.). Planch. - Modern leaf showing similarity with the fossil leaves in shape, size and venation as well as dentations pattern (C.N.H. Herbarium sheet no. 91044). **(d)** An other fossil leaf (*P. miocenica* n.sp.) showing nature of people (indicate by arrow; specimen no, MLK/S 203). **(e)** A part of fossil leaf (Fig. 2a) magnified to show that details of venation pattern (Long arrow indicated secondary vein and small arrow tertiary vein). **(f)** A part of modern leaf (Fig. 2b) magnified to show similarity with the fossil in both venation and dentations pattern. (Scale 1 cm)/

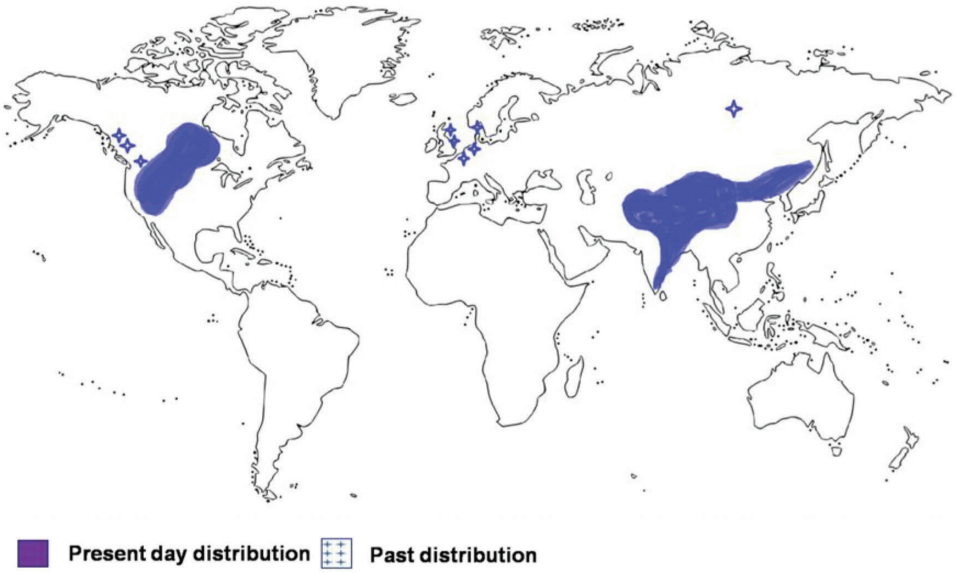

Fig. 4. Showing present and past distribution of the genus *Parthenocissus* (Vitaceae)

humid belt reaching the mid altitude throughout the northern hemisphere during the early Eocene (Nie *et al.*, 2010). Wolf, (1979) has used this theory to explore the origin and diversification of plants in northern hemisphere. This hypothesis also helps to explain the distribution of many angiospermous families like, Annonaceae, Fabaceae, Vitaceae, Magnoliaceae because most temperate region in the northern hemisphere has once covered by boreotropical forest in their geologic past.

Conclusion

The palaeobotanical study on plant megafossils from Siwalik sediments (Upper Miocene) of Sarkaghat area, Himachal Pradesh, India revealed the presence of a new form species, *Parthenocissus semicordta* (Wall.) Planch. of the family Vitaceae

The present day distribution of the extinct comparable taxon, *P. semicordata* (Wall.) Planch. suggests that there was a prevalence of a tropical warm humid climate during Miocene Period which is suitable for a deciduous forest in the Sarkaghat and nearby area of Himachal Pradesh, India.

The fossil record and the known palaeoclimate data suggest that the species of the genus *Parthenocissus* Planch. have derived from the Eocene boreotropical elements.

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Disclosure Statement

Conflict of Interest

Authors declare no conflict of interest.

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