

# Leaf impressions of *Terminalia* (Combretaceae) and *Daphnogene* (Lauraceae) from the Middle Siwalik of the Chatara-Barahakshetra area, eastern Nepal

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## ABSTRACT

Leaves of *Terminalia* (Combretaceae) and *Daphnogene* (Lauraceae) are described from the lower member of Lower Siwalik of Chatara-Barahakshetra area, eastern Nepal. The habit, habitat and present day distribution of the comparable extant taxa indicates the existence of tropical to sub-tropical evergreen to semi evergreen forest with humid climate in the area during the deposition of the Siwalik sediments.

**Key Words:** Fossils, *Terminalia*, *Daphnogene*, Middle Siwalik, Late Miocene, eastern Nepal.

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## INTRODUCTION

The Siwalik foreland basin accumulated a huge pile of molasse sediments since the middle Miocene to early Pleistocene between the Lesser Himalaya in the north and the Indo-Gangetic Plain in the south (Gansser 1964; Valdiya 2002). These fluvial succession consists of coarsening upward sequences as a whole but individual beds are fining upward on a scales of one to tens of meters (Nakayama and Ulak 1999). The Siwalik Group is also termed as the Churia Group in Nepal (Tokuoka and Yoshida 1984). The group is divided into two belts namely northern and southern belts, which are separated by the Central Churia Thrust (CCT of Tokuoka et al. 1986) and CCT is correlated to the Sit Khola Thrust (ST) of Dhital et al. (1995). During the early stage of the Siwalik research in Nepal, the three fold classification system (Lower, Middle, and Upper Siwalik) was commonly adapted (Auden 1935; Lombard 1958; Hagen 1969; Ithihara et al. 1972; Yoshida and Arita 1982; Kafle and Einfalt 1992; Schelling 1992; Ulak 2002, 2004, 2009). Several geologists provided local classification on the Siwalik Group on the basis of grain size and lithological characters (Tokuoka et al. 1986, 1988, 1990; Corvinus and Nanda 1994; Sah et al. 1994; Dhital et al. 1995; Ulak and Nakayama 1998; Sah et al. 2000a, 2000b, 2000c; Corvinus and Rimal 2001; Joshi and Dwivedi 2003; Sigdel et al. 2011; Adhikari and Sakai 2017). The fluvial sediments of the Siwalik yielded plant and animal fossils (West et al. 1978, 1991; West and Muthe 1981; Muthe et al. 1983; Awasthi and Prasad 1990; Sarkar 1990; Prasad 1990,

1994c; Konomatsu 1997; Prasad et al. 1997, 1999; Prasad and Pradhan 1998; Konomatsu and Awasthi 1999; Sah et al. 2000a; Hoorn et al. 2000; Corvinus and Rimal 2001; Prasad and Khare 2004; Prasad and Pandey 2008; Paudyal 2012, 2013a, 2013b). In the present communication, we report two plant megafossils recorded from the lower member of Middle Siwalik of Chatara-Barahakshetra area, eastern Nepal (Fig. 1). In the Chatara-Barahakshetra area a detailed plant megafossils study is still lacking. Therefore, this research is mainly focused on the identification of plant impressions recovered from this area.

## GEOLOGY OF THE STUDY AREA

The structure and sedimentary facies of the Siwalik in Chatara-Barahakshetra area were studied by several authors (Bashyal 1980; Dhital 1992, 2015; Dhakal 2001; Ulak 2004). On the basis of lithostratigraphy, the Siwalik Group in Chatara-Barahakshetra area can be divided from bottom to top as the Lower Siwalik (Lower and Upper Members) and the Middle Siwalik (Lower and Upper Members). The Upper Siwalik is missing from the study area. The Siwalik rock is separated by the Main Boundary Thrust (MBT) from the Lesser Himalayan Precambrian dolomitic sequences and the Gondwana sequences in the north (Bashyal 1980; Dhital 1992, 2015) and by the Himalayan Frontal Thrust (HFT) from the Indo-Gangetic Plain in the south (Fig. 2).

## Lower Siwalik

The Lower Siwalik is represented by very fine to medium grained sandstone interbedded with variegated mudstone and

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siltstone. The mudstone, siltstone, and sandstone are calcareous in nature. On the basis of thickness of sandstone and mudstone, grain size, composition, texture, it can be further subdivided into the lower and upper members.

**Lower member of Lower Siwalik**

It consists of variegated mudstone with dominance of bioturbation alternating with the dark grey, bluish grey, purple siltstone and very fine to fine grained light grey, greenish grey to dark grey sandstone. However, at some places medium grained dark grey sandstone is also found.

**Upper member of Lower Siwalik**

It consists of fine to coarse grained, light grey to dark grey sandstone alternating dark grey, greenish grey, bluish grey, violet siltstone and variegated to dark grey mudstone. The sandstone rarely shows 'salt and pepper' appearances but sandstone bed is more than mudstone beds. The contact between the upper member of Lower Siwalik and the lower member of Middle Siwalik is transitional.

**Middle Siwalik**

The Middle Siwalik is represented by fine to very coarse grained sandstone, pebbly sandstone interbedded with mudstone and siltstone. The calcareous cement is profusely present in mudstone, siltstone and sandstone. It is further

subdivided into lower and upper members, on the basis of thickness of mudstone and sandstone, composition, grain size and texture etc.

**Lower member of Middle Siwalik**

It consists of medium to coarse grained, 'salt and pepper' and fine grained, dark grey sandstone interbedded with greenish grey, dark grey siltstone and dark grey mudstone. The mud clasts are found in siltstone and sandstone beds. The size of the clast is up to 1 cm in diameter.

**Upper member of Middle Siwalik**

It consists of coarse to very coarse grained, 'salt and pepper' grey sandstone, pebbly sandstone. The pebbly sandstone contains clast of quartzite, gneiss, and limestone and clast size is up to 2 cm. The thickness of the sandstone beds may reach up to 30 meters. Sedimentary structures such as cross laminations, ripple marks, flute casts and convolute beddings are common in sandstone beds. Fine grained, bluish grey, dark grey, light grey, sandstones are frequently found interbedded with greenish grey, bluish grey, dark grey, black siltstone and dark grey mudstone. The plant leaf bearing horizon is found in the lower member of Middle Siwalik, Chatara-Barahakshetra road section, Satra Number and its lithological details and geological route map are shown in Figs. 3 and 4.

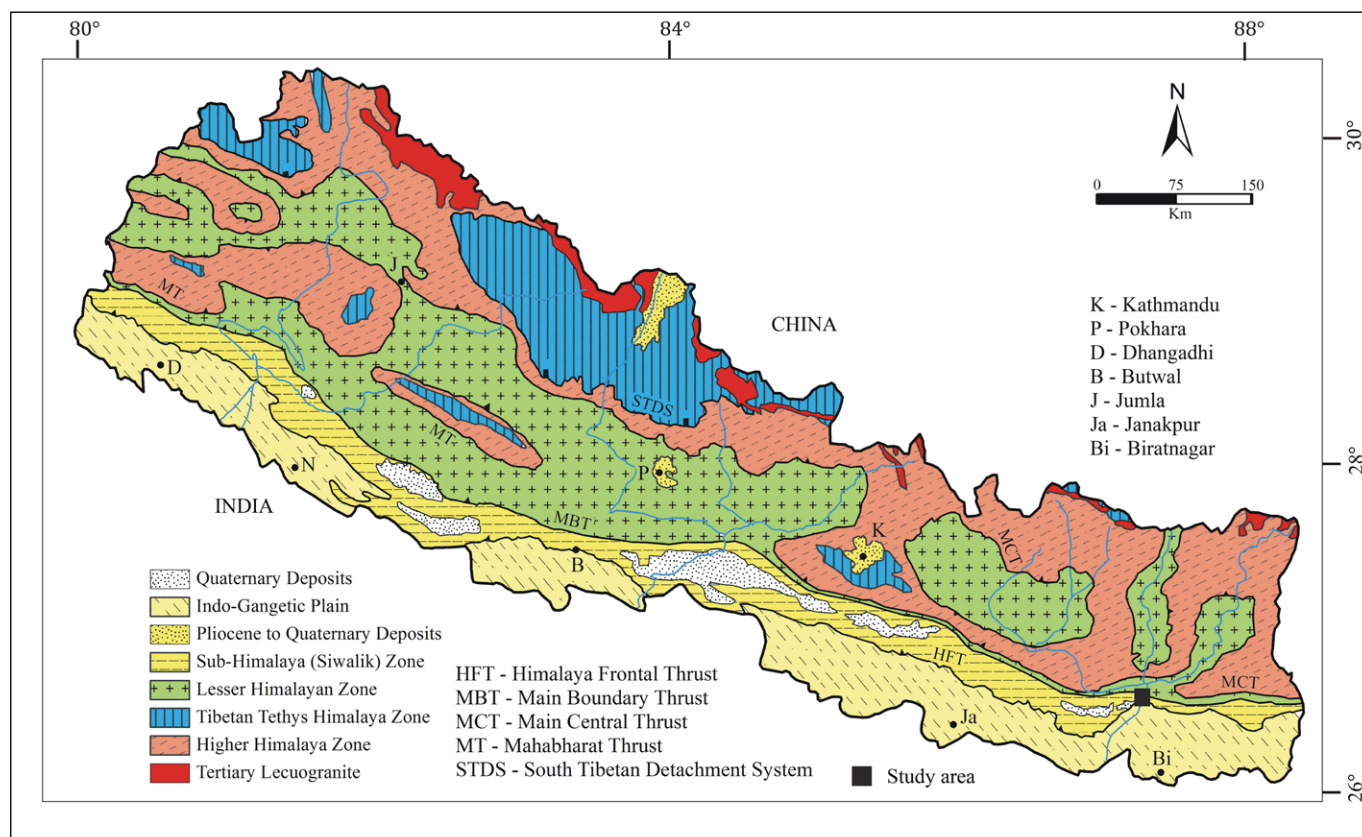


Fig. 1: Distribution of the Siwalik sediments in Nepal (modified after Martin et al. 2005). Black square indicates study area.

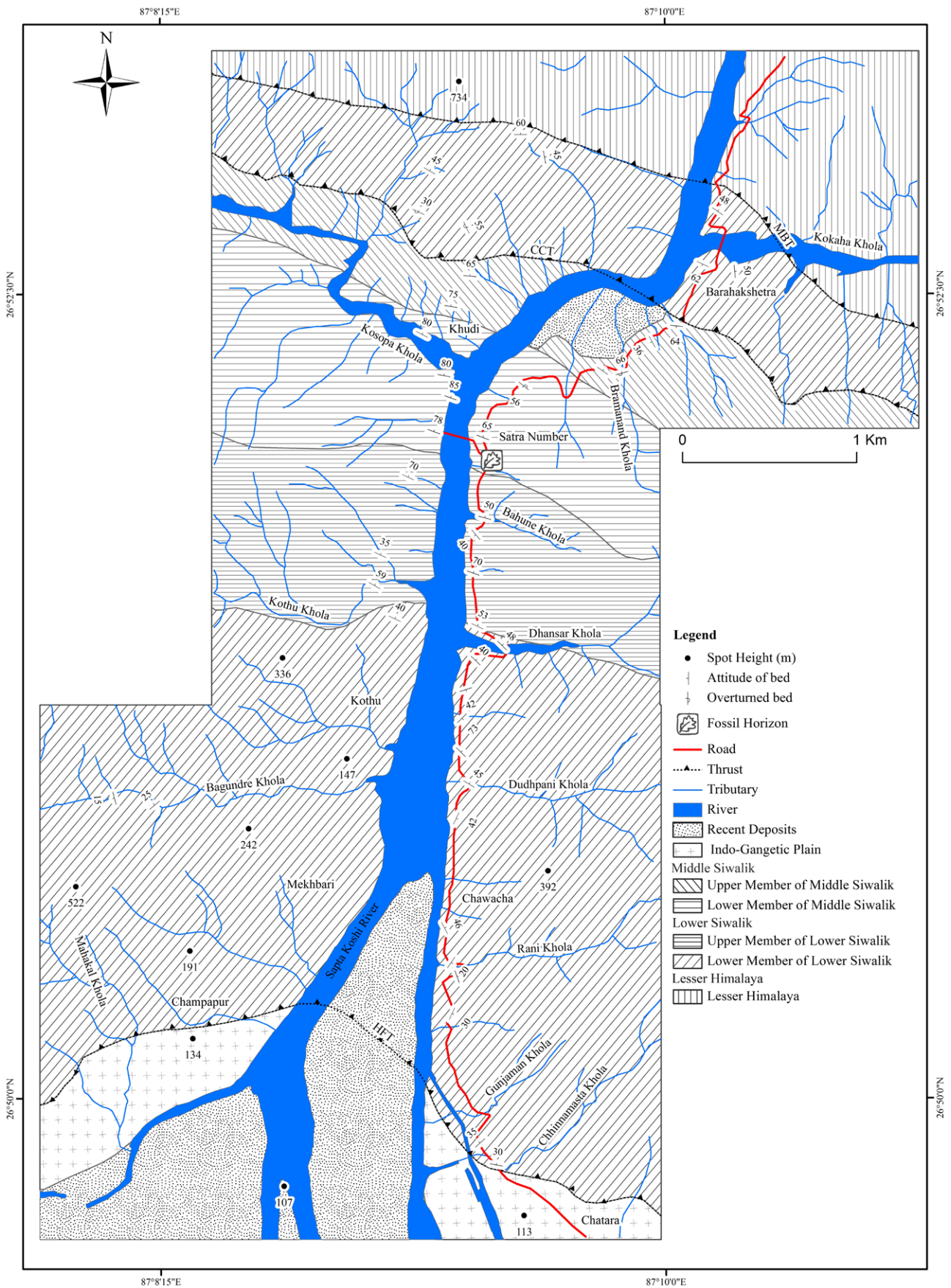


Fig. 2: Geological map of study area showing the fossil locality (Adhikri 2017).

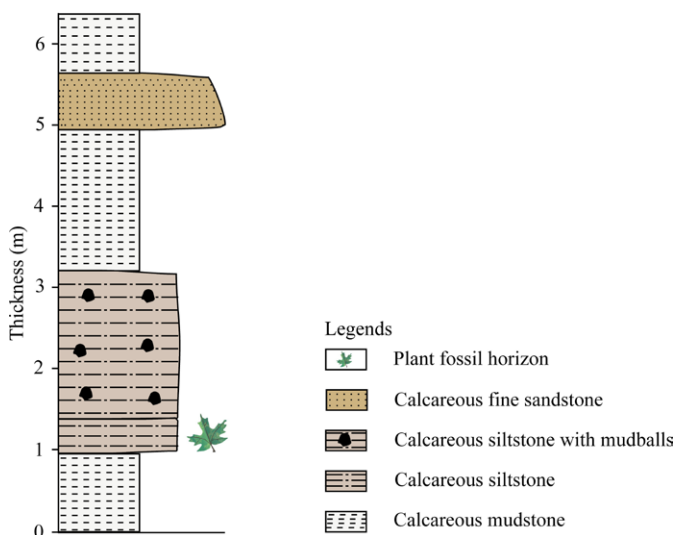


Fig. 3: Lithological details of the fossil horizon at the Chatara-Barahakshetra road section, Satra Number.

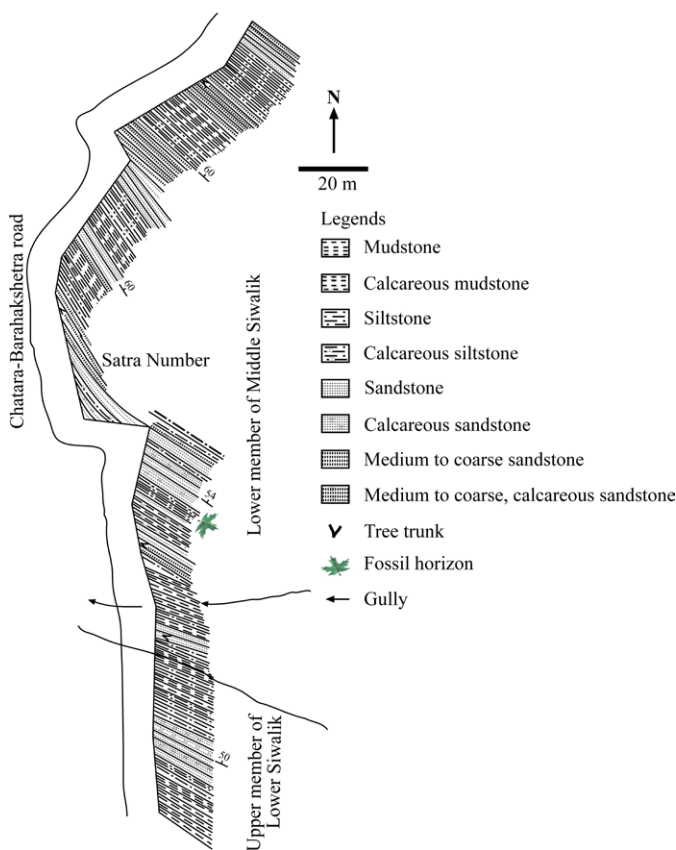


Fig. 4: Geological route map along the Chatara-Barahakshetra road section showing the fossil horizon.

## MATERIAL AND METHODS

Material for present study was collected by one of us (PA) from the Siwalik sediment of the Chatara-Barahakshetra area, eastern Nepal. The specimens were cleared with the help of chisel and hammer and photographed under the natural low angled light using a Canon digital camera SX110. For

describing the fossil leaves, terminology proposed by Dilcher (1974), and Ellis et al. (2009) was followed. The specimens were compared and identified in the herbarium of Central National Herbarium (CNH), Howrah, India. All the specimens are stored at the Central Department of Geology Museum (CDGM), Tribhuvan University, Kirtipur, Kathmandu, Nepal.

## RESULTS

### (1). Systematics

Order: Myrtales

Family: Combretaceae

Genus: *Terminalia* L.

Species: *Terminalia* sp.

Figures: Plate I (Fig. a)

Number of specimens examined: One

Figured specimen no.: 17N10a

Locality: Chatara-Barahakshetra road section, Satra Number (26°52'00"N, 87°09'23"E).

Stratigraphic horizon: Lower member of Middle Siwalik.

Age: Late Miocene.

### Description

Leaf incomplete, narrow elliptic, seemingly symmetrical, preserved lamina length 8.56 cm, maximum width 4.9 cm; apex and base broken; margin entire; texture chartaceous; venation pinnate, eucamptodromous; primary vein thickness stout, straight; secondary vein about eight pairs visible, simple, alternate and opposite, 0.8-1.9 cm apart, angle of divergence moderate acute (57°-64°), more or less uniform, moderately thick, abruptly curved up near the margin; intersecondary veins not observed; tertiary veins percurrent and recurved, angle of origin RA; marginal venation pattern fimbriate; further details not observed.

### Affinities

The characteristics features of fossil leaf such as elliptic shape, symmetrical lamina, entire margin, pinnate, eucamptodromous venation, angle of divergence of secondary vein moderate acute, alternate and opposite, percurrent and recurved tertiary veins suggest its affinities with *Terminalia* (Plate I, Fig. b) of the family of the Combretaceae. Several herbarium specimens of the modern genus were studied in detail but due to incompleteness of the fossil it is difficult to identify it up to the specific level.

### Fossil records and comparison

Several fossil leaves of *Terminalia* have been described from the Cenozoic sediments of Nepal and India by Lakhanpal (1970); Lakhanpal and Guleria (1981); Awasthi (1982); Tripathi and Tiwari (1983); Bande and Prakash (1984); Awasthi and Prasad (1990); Bande and Srivastava (1990); Prasad (1990, 1994a, 1994b, 1994c); Ambwani (1992); Lakhanpal and Awasthi (1992); Awasthi and Mehrotra (1995); Antal and Prasad (1998); Singh and Prasad (2007). Similarly several fossil wood of the genus *Terminalioxylon* have been

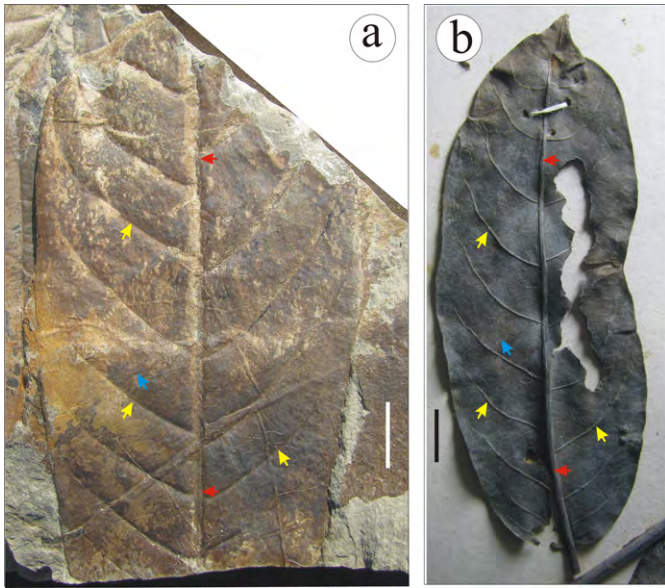


Plate I: a. Fossil leaf *Terminalia* sp. showing shape, size, and venation pattern such as primary vein (red arrow), secondary vein (yellow arrow) and tertiary vein (blue arrow) b. A modern leaf *Terminalia paniculata* showing similar shape, size, and venation pattern (CNH herbarium sheet No. 554928) as in fossil such as primary vein (red arrow), secondary vein (yellow arrows) and tertiary vein (blue arrow). Scale bar = 1 cm.

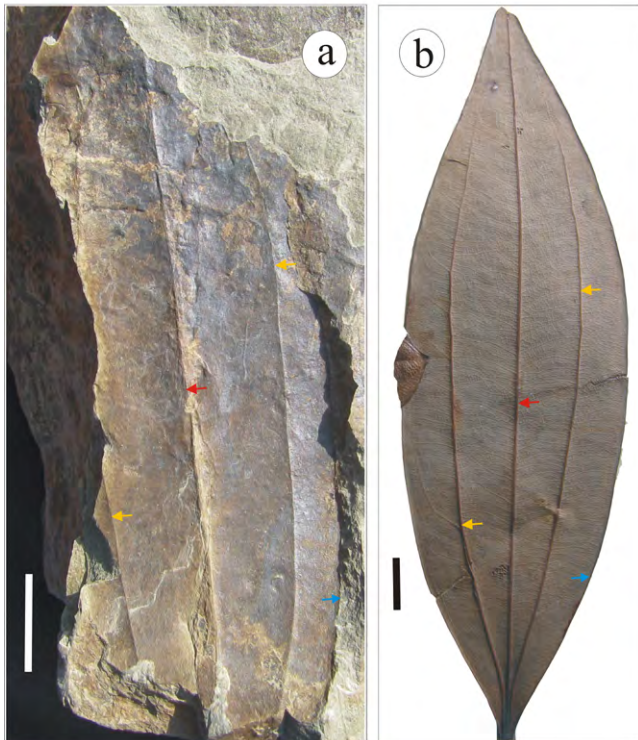


Plate II: a. Fossil leaf *Daphnogene makumensis* showing shape, size, and venation pattern such as primary vein (red arrow), lateral primary vein (yellow arrow) and entire margin (blue arrow) b. A modern leaf of *Cinnamomum tamala* showing similar shape, size, and venation pattern (CNH herbarium sheet No. 383551) as in fossil such as primary vein (red arrow), lateral primary vein (yellow arrows) and entire margin (blue arrow). Scale bar = 1 cm.

described from the Cenozoic sediment of India (Mahabale and Deshpande 1965; Ramauryum 1966; Prakash 1966; Guleria 1983; Shukla et al. 2013). A fossil fruit of *Terminalia* has also been described from the Eocene of India by Singh et al. (2010) while pollen of *Terminalia* has been recorded from the Siwalik sediments of Nepal by Paudyal (2012).

## (2). Systematics

Order: Laurales

Family: Lauraceae

Genus: *Daphnogene* Unger

Species: *D. makumensis* Mehrotra, Dilcher, and Lott

Figures: Plate II (Fig. a)

Number of specimens examined: One

Figured specimen nos.: 17N15b

Locality: Chatara-Barahakshetra road section, Satra Number (26°52'00"N, 87°09'23"E).

Stratigraphic horizon: Lower member of Middle Siwalik.

Age: Late Miocene.

## Description

Leaf incomplete, narrow elliptic, preserved lamina length 7.8 cm, maximum width 2.6 cm; apex and base broken; margin entire; texture chartaceous; venation acrodromous; mid vein moderately thick, markedly curved, one pair of lateral veins probably arising from the base of the lamina and running parallel to the midvein with equal distance from the margin and midvein, thin; further details not preserved.

## Affinities

The characteristics features of the fossil leaf such as narrow elliptic shape, entire margin, acrodromous venation, lateral veins equidistance to mid vein and running convergently at distal portion suggest its affinities with *Cinnamomum* Schaeffer, *Cryptocarya* R. Brown, *Lindera* Thunb., and *Neocinnamomum* H. Liou of the family Lauraceae. As the fossil leaf is incomplete, it is difficult to identify it up to the generic level. It has been suggested that the fossils leaves which are incomplete with the features such as acrodromous venation, lateral vein parallel and equidistance to midvein and running convergently at distal portion can be placed in *Daphnogene*. After making detailed comparison with them, the fossil specimen shows resemblance with the leaf *Cinnamomum tamala* Buch.- Ham. (Plate II, Fig. b).

## Fossil record and comparison

Leaves of the genus *Cinnamomum* are also known from the Siwalik sediments of Nepal and India (Lakhanpal and Awasthi 1984; Prasad 1990; Antal and Awasthi 1993; Shashi et al. 2007; Prasad and Pandey 2008, Khan and Bera 2014). *Cinnamomum* sp. is known from the middle Miocene of the Kerala Coast, India (Awasthi and Srivastava 1992). *Daphnogene makumensis* Mehrotra, Dilcher, and Lott is described from the Oligocene sediments of Assam, India (Mehrotra et al. 2009). The present fossil shows maximum similarity with *Daphnogene*

*makumensis* Mehrotra, Dilcher, and Lott and therefore, the present fossil has been placed into the same species. The fossil woods of *Cinnamomum* have been assigned to *Laurinoxylon* from the Miocene to Pliocene sediments of India (Prakash and Tripathi 1974; Bande and Prakash 1980; Lakhanpal et al. 1981; Awasthi and Ahuja 1982).

## DISCUSSION AND CONCLUSION

The genus *Terminalia* Linn. comprises about 150 species, which are large trees distributed widely in the tropics of Africa, America, and Asia, extending to South Africa, Australia, and Pacific Islands (Shu 2007). In Nepal Himalaya, five species are known to exist at the range of 200-1400 m amsl. (Press et al. 2000). Similarly, *Cinnamomum tamala* Bauch.- Ham. is an evergreen tree growing up to 20 m in height. It is distributed throughout the sub-tropical region of west Yunnan, Nepal, India, Bhutan etc. at 1100-2000 m (Gui 2008). The habit, habitat and the present day distribution of the comparable extant taxa indicate the existence of tropical to sub-tropical evergreen to semi evergreen forest with humid climate. Thus, it may be concluded that probably a humid climate prevailed in Chatara-Barahakshetra area at the time of deposition in contrast to present day relatively dry climate.

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