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Antidesma miocenica sp. nov. and *Cyclosorus eoproliferus* leaves from Middle Siwalik (Late Miocene) exposed near Sarkaghat, Mandi district, Himachal Pradesh, India

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ABSTRACT

Tiwari S., Mishra R.K., Singh S.K. & Prasad M. 2022. *Antidesma miocenica* sp. nov. and *Cyclosorus eoproliferus* leaves from Middle Siwalik (Late Miocene) exposed near Sarkaghat, Mandi district, Himachal Pradesh, India. Geophytology 50(1&2): 135–142.

Fossil leaf impression comparable with extant taxon *Antidesma moritzii* (belonging to angiosperm family *Phyllanthaceae*) has been described as a new species, *Antidesma miocenica* sp. nov., from Middle Siwalik exposed near Sarkaghat in Mandi District, Himachal Pradesh. In addition, *Cyclosorus proliferus* (belonging to pteridophytic family *Thelypteridaceae*) has also been reported, for the first time, from the same area. Both the species are presently distributed in the tropical evergreen forests of south-east Asian region. The presence of these taxa in the western Siwalik sector suggests that tropical humid climate with high precipitation prevailed in the area during Late Miocene. The occurrence of *Cyclosorus,* constituent fern species of moist tropical vegetation, is indicative of high precipitation and humidity that prevailed in the area throughout the year.

Keywords: Fossil leaves, angiosperm, *Antidesma miocenica* sp. nov., pteridophyta, morphotaxonomy, climate, phytogeography, Middle Siwalik (Late Miocene), Sarkaghat, Himachal Pradesh, India.

INTRODUCTION

The Sub-Himalayan zone of Indian subcontinent consists of Neogene deposits known as the Siwalik Group. It extends from Potwar Plateau in the north-west to Brahmaputra in the north-east covering a distance of about 2400 km in length and 20–25 km in width (Ranga Rao et al. 1979). 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 took place during the Middle Miocene and continued until the culmination 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 plant megafossils comprising petrified and carbonized woods and leaves, fruits and seed impressions. The studies on

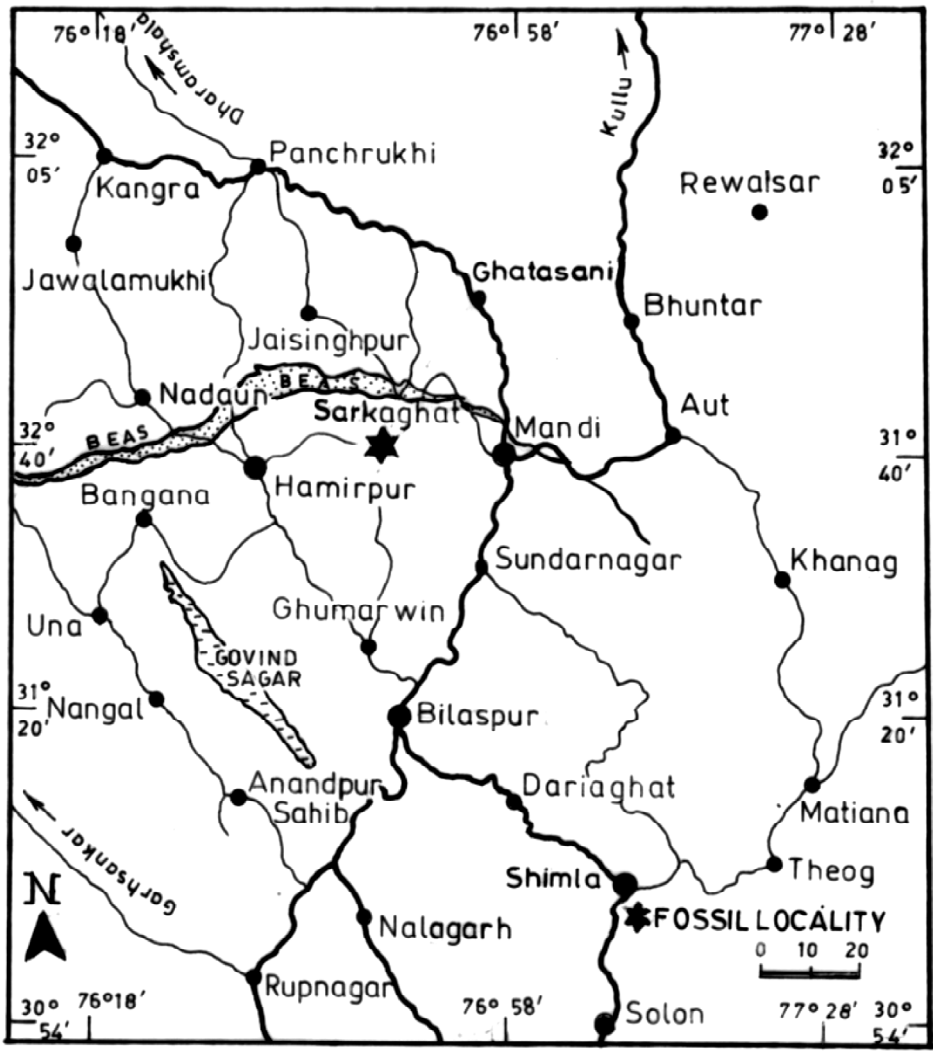

Figure 1. Map showing location of the study area, Sarkaghat, in Mandi district, Himachal Pradesh, India.

plant megafossils of Siwalik were carried out by several workers (Awasthi 1992, Prasad 2008 and references therein). Most of the palaeobotanical work has been done during the last two and a half decades from the different localities mainly in central sector of the Siwalik (Prasad 2008). However, in the western Siwalik sector, little palaeobotanical work has been carried out from the Siwalik of the Nalagarh (Prakash 1975, 1979, Yadav 1989) Jawalamukhi and Ranital (Ghosh & Ghosh 1958, Lakhanpal 1967, 1968, 1969, Lakhanpal & Dayal 1966, Lakhanpal & Awasthi 1992) and Bilaspur (Prasad 2006). In view of the previous meagre work on the western Siwalik sector of Himachal Pradesh, authors surveyed different fossil localities and collected large number of fossil leaf impressions for the first time from the Middle Siwalik sediments of Sarkaghat in Mandi District, Himachal Pradesh (Figure 1). Two more leaf impressions comparable to the extant taxon, *Antidesma* L. (*Phyllanthaceae*) and *Cyclosorus* Link (*Thelypteridaceae*) are described in the present communication.

GEOLOGICAL SET-UP OF THE AREA

The Siwalik are freshwater deposits representing a continuous sedimentation and fossil record of the last ~18 million years. They form nearly 6000 m of an

Figure 2. Middle Siwalik section on Sarkaghat-Dharampur Road from where fossil specimens were collected for present study.

extensive Neogene-Quaternary apron of freshwater sediments, which are exposed along the proximal margin of the Himalayan Foreland Basin, between Potwar Plateau in the west and Brahamputra Valley in the east. Pilgrim (1913) was the first to provide three fold classifications of Siwalik as Lower, Middle and Upper Siwalik and suggested 7 faunal zones as Kamlial, Chinji, Nagri, Dhok Pathan, Tatrot, Pinjor and Boulder Conglomerate (Figure 2). It is interesting to note that these deposits represent one of the best continuous terrestrial Neogene fossil records, which are significant for understanding of the Eurasian terrestrial environments and palaeoclimates. The fossil locality Sarkaghat lies along the National Highway 70 in Mandi District, Himachal Pradesh (Figure 1). The fossil leaf bearing bed is a part of Middle Siwalik Sarkaghat anticline. It is characterized mainly by thick units of fine to coarse, dark grey indurate, multistoried sandstones with red, yellow and brown pedogenic mudstones (Figure 2).

MATERIAL AND METHODS

The leaf impressions were collected from Middle Siwalik beds exposed in a road cutting section (31°44'15.70"N, 76°43'20.19"E) near Sarkaghat, Mandi, Himachal Pradesh. The fossil locality situated on the left side of main road leading to Dharampur is easily accessible. The leaf impressions were devoid of cuticle and preserved on usually grey shales (Figure 3). The morphological features of the fossil leaves have been examined with the help of either hand lens or low power microscope under reflected light. In order to identify leaf impressions, the herbarium sheets of several extant families and genera were examined at Central National Herbarium, Shibpur, Howrah, West Bengal. For the description of leaf impressions, the terminology given by Hickey (1973) and Dilcher (1974) has been followed. The photographs of the leaves of the extant comparable taxa have been provided to show similarity with the fossil leaves.

DESCRIPTION OF FOSSIL LEAVES

Phylum: *Tracheophyta* Sinnott ex Caval.-Sm.

Class: *Magnoliopsida* Brongn.

Order: *Malpighiales* Juss. ex Bercht. & J. Presl

Family: *Phyllanthaceae* Martinov

Genus: *Antidesma* L.

Antidesma miocenica S. Tiwari, R.K. Mishra, S.K. Singh & Mah. Prasad **sp. nov.**

Figures 3a, c

Material: One well preserved leaf impression.

Diagnosis: Leaf symmetrical, narrow elliptic; size 11.3 × 4.2 cm; margins entire; venation eucamptodromous; secondary veins (2°) 5-6 pairs visible, alternate to opposite, about 1.4 to 2.8 cm apart, unbranched, angle of divergence about 50°, intersecondary veins present, tertiary veins (3°) angle of origin RR type, percurrent, straight to sinuous, branched, predominantly alternate, usually oblique in relation to midvein, right angle near the margin and nearly distant.

Description: Leaf simple, symmetrical, narrow elliptic. preserved size 11.3 × 4.2 cm; base and apex not preserved; margin entire; texture thick chartaceous, petiole not preserved; venation pinnate, eucamptodromous; primary vein (1°) single, straight, prominent, stout; secondary veins (2°) 5-6 pairs visible, alternate to opposite, about 1.4 to 2.8 cm apart, unbranched, angle of divergence about 50°, curving upwards and join super adjacent secondary veins at obtuse angle; intersecondary veins present, simple rare; tertiary veins (3°) angle of origin RR type, percurrent, straight to sometimes sinuous, branched, predominantly alternate, usually oblique in relation to midvein some time right angle near the margin and nearly distant.

Holotype: Specimen No. MLK/S/309.

Locality: Road cutting section about 7 km from Sarkaghat town on the left side of main road leading to Dharampur, Mandi District, Himachal Pradesh.

Horizon and Age: Middle Siwalik; Late Miocene.

Etymology: The specific epithet is after Miocene age of rocks from where fossil leaf was collected.

Affinities: Symmetrical, narrow elliptic shape, entire margin, eucamptodromous venation, distantly arranged secondary veins having acute angle of divergence, presence of intersecondary veins and RR, percurrent and distantly placed tertiary veins undoubtedly indicate that the present fossil leaf resembles closely to the leaves of *Antidesma moritzii* Muell. Arg. (C.N.H. Herbarium sheet nos. 408781, 407828, Figures 3b, d) of the family *Phyllanthaceae*.

Fossil record and comparison: So far, only one fossil leaf resembling the genus *Antidesma* L. is recorded from the Lower Siwalik sediments of Koilabas, western Nepal. This fossil leaf shows its resemblance with the extant leaf of *A. montanum* Blume and described as *Antidesma siwalica* (Prasad et al. 1999). It differs entirely from the present fossil leaf in presence of more than 10 secondary veins and are comparatively closely placed. In view of this the Sarkaghat fossil leaf has been described as a new species, *Antidesma miocenica* S. Tiwari et al. sp. nov.

Antidesma L. consists of about 170 species distributed in tropical to subtropical regions especially in Asia. The greatest diversity occurs in Southeast Asia. About 23 species are found to occur in India. The extant comparable species, *A. moritzii* Muell. Arg. is a large evergreen tree distributed in Sumatra, Java, Borneo, and Philippines Islands (Hooker 1894).

Phylum: *Tracheophyta* Sinnott ex Cavalier-Smith

Class: *Polypodiopsida* Cronq., Takht. & W. Zimm.

Order: *Polypodiales* Link

Family: *Thelypteridaceae* Ching ex Pic. Serm.

Genus: *Cyclosorus* Link

Cyclosorus eoproliferus (Mah. Prasad) Mah. Prasad et al. 2004

Figures 3e, g

Material: Two well preserved frond impressions.

Description: Fronds 6.5 × 1.4 cm and 5.0 × 1.4 cm in size; sessile; oblong to lanceolate; apex seemingly attenuate; base slightly broken, seemingly obtuse;

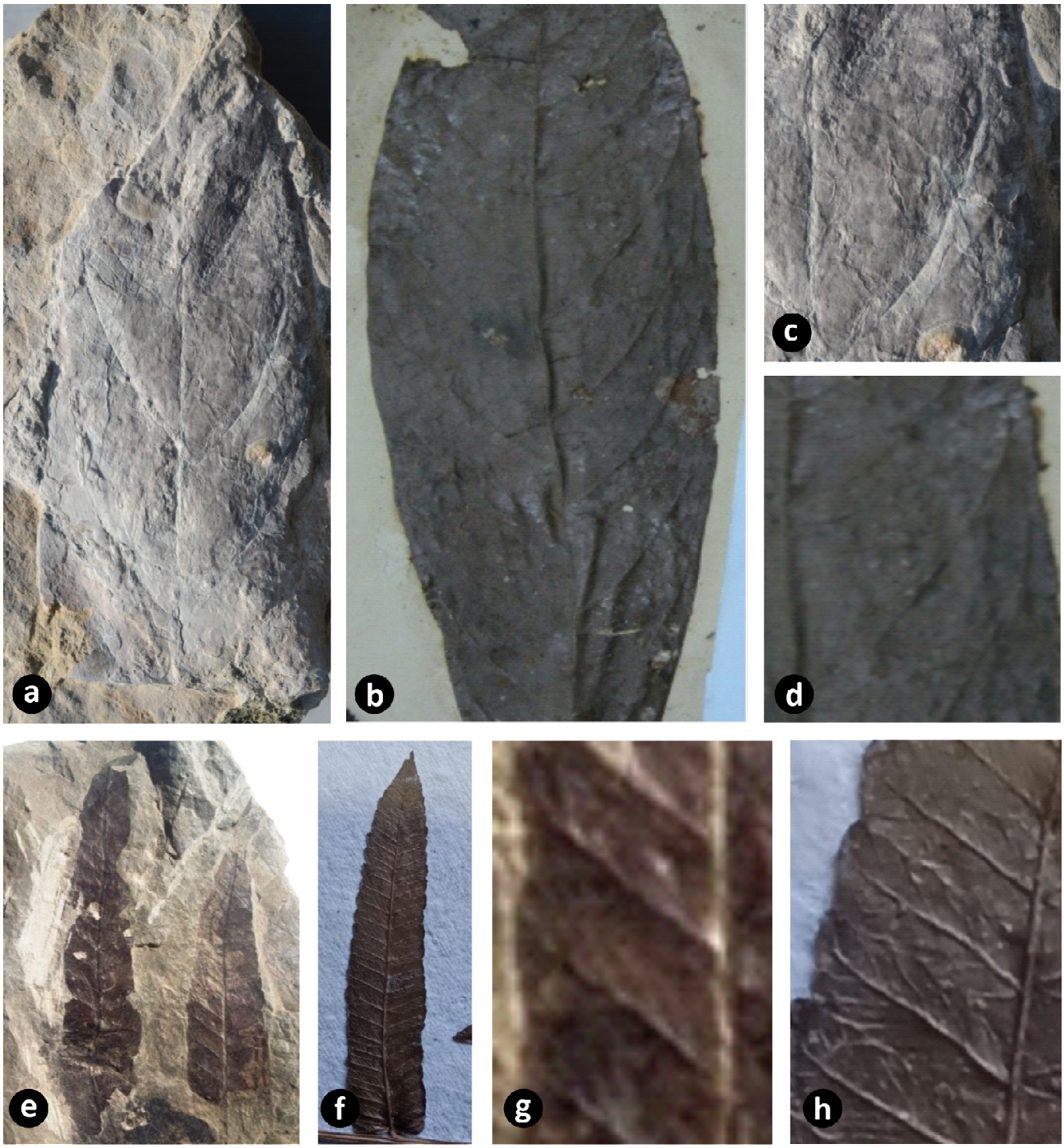

Figure 3. a–d. ***Antidesma miocenica*** S. Tiwari, R.K. Mishra, S.K. Singh & Mah. Prasad **sp. nov.**
a. Fossil leaf in natural size showing shape, size and venation pattern; Holotype specimen no. MLK/S/309. **b.** Modern leaf, *Antidesma moritzii* Muell. Arg. showing similarity with the fossil leaf. **c.** A part of fossil leaf magnified to show the details of venation pattern . **d.** A part of modern comparable leaf magnified to show the similar details of venation as the fossil.
e–h. ***Cyclosorus eoproliferus*** (Mah. Prasad) Mah. Prasad et al. 2004.
e. Fossil fronds in natural size showing shape size and venation pattern, specimen no. MLK/S 310. **f.** Modern frond, *Cyclosorus proliferus* Persl. showing similarity with the fossil fronds. **g.** A part of fossil frond magnified to show details of venation pattern. **h.** A part of modern comparable frond magnified to show the similar details of venation as the fossil.

margin smooth to crenulate; texture coriaceous; about 22 pairs of pinnules visible; 7-9 veinules in each pinna arising at acute angle, about 50 º -55 º.

Specimen: Specimen No. MLK/S/310.

Locality: Road cutting section about 7 km from Sarkaghat town on the left side of main road leading to Dharampur, Mandi District, Himachal Pradesh.

Horizon and Age: Middle Siwalik; Late Miocene.

Affinities: The diagnostic features of the present frond such as oblong to lanceolate shape, attenuate apex and number and nature of pinnules show that it resembles with the modern fronds of *Cyclosorus proliferus* (Retz.) Tardieu (National Botanical Research Institute, Lucknow Herbarium sheet nos. P 1144, P 1149; Figures 3f, h) of the family *Thelypteridaceae*.

Fossil records and comparison: A frond showing close similarity with extant *Goniopteris prolifera* (Retz.) C. Presl was described as *Goniopteris eoprolifera* Mah. Prasad for the first time from the Lower Siwalik sediments of Kathgodam area in Nainital District, Uttarakhand (Prasad 1991, 1994). Later, Prasad et al. (2004) described another frond as *Cyclosorus eoproliferus* from Gola River beds, near Kathgodam, Nainital, Uttarakhand showing affinity with the same taxon (as the genus *Goniopteris* is merged with a broad genus, *Cyclosorus* Link (Mabberley 1997). Prasad and Pandey (2008) also reported same form species, *Cyclosorus eoproliferus* Prasad from the Middle Siwalik sediments of Surai Khola area, western Nepal. Comparative study of present fossil frond with the above mentioned fossil fronds indicated that the Sarkaghat fossil fronds show their closest similarity with the fossil frond, *Cyclosorus eoproliferus* described from the Surai Khola area, western Nepal. Therefore, these fronds have been described under the same species.

Cyclosorus Link comprises about 600 species which grow throughout tropical regions. It is widely distributed from Africa, through mainland Asia to New Guinea, Australia and New Caledonia. *Cyclosorus proliferus* (Retz.) Tardieu, with which fossil fronds show closest resemblance, is distributed in evergreen forests of Bengal and Nilgiri usually in moist shady places or along streams.

DISCUSSION AND CONCLUSION

Study of plant fossils from Middle Siwalik sediments of Sarkaghat and nearby area revealed the occurrence of two new fossil leaves showing affinity with extant taxon, *Antidesma moritzii* Muell. Arg. of angiospermous family, *Phyllanthaceae* and *Cyclosorus proliferus* (Retz.) Tardieu of a pteridophytic family, *Thelypteridaceae* respectively. *Antidesma. moritzii* Muell. Arg. is a large evergreen tree distributed in Sumatra, Java, Borneo and Philippines Islands. *Cyclosorus proliferus* (Retz.) Tardieu is distributed in evergreen forests of Bengal and Nilgiri. The forest type and present day distribution of above extant comparable taxa suggest that the Sarkaghat area enjoyed tropical humid climate during Late Miocene. The presence of a fern *Cyclosorus* Link in the Siwalik sediments of Sarkaghat area further suggests existence of high humidity and rain fall in the study area during the Middle Siwalik sedimentation.

Antidesma L. is a genus in the family *Phyllanthaceae* of the order *Malpighiales*. It comprises trees and shrubs and is most diverse in South-east Asia where it is commonly found in understory of the tropical forests as well as in open stands. Earlier a fossil leaf, *Antidesma siwalica* from Miocene sediments of Nepal was described by Prasad et al. (1999). Besides, the fossil leaves of few other members of the family *Phyllanthaceae* like, *Baccauria, Bischofia, Breynia, Bridelia, Cleitanthus, Glochidion* and *Phyllanthus* are recorded from Miocene sediments (Siwalik) of India and Nepal (Prasad 2008). The fossil leaves of the genus *Bridelia* (*B. oligocenica* and *B. makumensis*) are further recorded from Oligocene sediments of Assam, India (Awasthi & Mehrotra 1995, Srivastava & Mehrotra 2014). Kapgate et al. (2017) reported a fossil fruit, *Phyllanthocarpon singpurensis* of the family *Phyllanthaceae* from Deccan Intertrappean sediments (Late Cretaceous) of central India. This fruit confirms the presence of *Phyllanthaceae* in India since 66 million years well prior to tectonic fusion of Indian plate with Eurasia.

Cyclosorus Link is a genus of fern in the family *Thelypteridaceae* comprising about 600 species

widespread in tropics and subtropics of Old World to New Caledonia, New Guinea and Australia. Several fossils known from the Eocene of South China (Naugolnykh et al. 2016) and the Quaternary of Australia. Most of the fossils in the family *Thelypteridaceae* have a relatively close relationship to *Christella* in having similar morphological characters. (Collinson 2002). Stockey et al. (2006) reported a fossil fern, *Speirseopteris orbiculata* from the Palaeocene of Paskapoo Formation in Canada. *Abacopteris stiriacum* was reported from the Eocene of Germany and later on assigned to *Cyclosorus stiriacus* (Collinson 2001). Naugolnykh et al. (2016) reported a fossil species, *Cyclosorus scutum* from the Eocene of the Changchang Formation on Hainan Island, South China. Pole (1992) reported *Cyclosorus tertiario-zeelandicus* Oliver from the early Miocene of New Zealand. Sanín et al. (2016) reported a fossil fern of *Thelypteris* from the late Miocene of Colombia. Some fossil fern fronds have been described as *Cyclosorus eoproliferus* from Middle-Late Miocene sediments of India and Nepal (Prasad 1991, Prasad et al. 2004, Prasad & Pandey 2008, Mehrotra et al. 2011). Robledo et al. (2015) described the first fern fossil *Thelypteridaceae* in the neotropics, as *Thelypteris interrupta* (Willd.) Iwatsuki from the late Miocene of Argentina. The above fossil records suggest that some taxa including the genus *Cyclosorus* of family *Thelypteridaceae* originated most probably during Eocene or prior to it. Moreover, the abundant fossil records of *Thelypteridaceae* during the Miocene in India and other countries might be owing to the diversification of this family under relatively humid and warm periods at that time (Collinson 2002).

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