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Monocotyledon fossil leaf from the Early Cretaceous of India

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ABSTRACT

Reports of the angiosperm macrofossils from the Early Cretaceous sediments of India are relatively poor, with only one report from the Krishna-Godavari Basin. The present study documents a monocotyledon leaf fossil from the Barremian-Aptian (Early Cretaceous) of Gangapur Formation, Pranhita-Godavari Basin, India. The present fossil leaf placed under a new genus *Sahniophyllum* and it is characterised by the ribbon shaped leaves, with parallel venation, arranged in rosette form suggests its probable affinity with Hydrocharitaceae. The taphocoenosis demonstrates its autochthonous preservation and aquatic habitat.

Keywords: Angiosperm, Early Cretaceous, Gangapur Formation, India, Monocot, *Sahniophyllumindica* gen. et sp. nov.

Introduction

The early origin and evolution of the Angiosperms is Darwin's abominable mystery (Friedman 2009). However, it is well established that the flowering plants became a part of the global ecosystem by the Early Cretaceous (Hughes 1994; Bell *et al*. 2010; Friis *et al*. 2011). Currently, the angiosperms are the major group of land plants with more than 300.000 species and share 89.4 % among embryophytes (Cronquist 1981; Crepet 2000). Modern monocots are composed of 81 families and about 60.000 species. Their origin and rapid explosion is still under debate (Doyle 2006; 2012 and references therein) but they became the significant components of the ecosystem from the Cretaceous (Friis *et al*. 2011).They changed the face of earth ecosystem and provided the structural definition for most terrestrial ecosystems (Crepet 2000; Graham 2011). The diversification of this group also assisted in the explosion of the ferns (Schneider *et al*. 2004) and co-evolution of the insects (Grimaldi & Engel 2005).

The angiosperms mega fossils from the Early Cretaceous sediments were well documented from the various parts of the globe (Hickey & Doyle 1977; Hill 1994; Sun *et al*. 1998; Taylor *et al*. 2009; Friis *et al*. 2011). However, the mega fossils of angiosperms from the Early Cretaceous sedimentary basins of India were poorly known (Chinnappa *et al*. 2020b). The previous reports of the fossils described under the angiosperms (Sahni 1932; Sharma 1997; Banerji 2000) were later proved to be Bennettitaleans (Bose & Sah 1954; Srivastava & Krassilov 2012). The lack of early angiosperm remains from the Early Cretaceous sedimentary basins of India hinders understanding of their early evolutionary history locally and globally. In India, the existing knowledge of angiosperm history is based on the fossils from the upper part of the Cretaceous when this group diversified (Crane *et al*. 2000; Soltis & Soltis 2004; Crepet 2007; Friis *et al*. 2011).

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The present study describes a monocotyledon mega fossil from the Barremian-Aptian of Gangapur Formation, Pranhita-Godavari (PG) Basin, East Coast of India.

Materials and methods

Geological setting

The Pranhita-Godavari Basin is one of the largest Gondwana basins of India. It contains an almost complete succession of Gondwana rocks. The sediment in the basin deposited from the Late Carboniferous/Early Permian to Cretaceous, is ca 3000 m thick (Biswas 2003). Sedimentation in the Gangapur area took place during the Early Cretaceous after renewed rift activity (Biswas 2003). The Gangapur Formation is 100-250 m thick, and the Chikyala Formation is ca 275 m (Lakshminarayana 1996). The Gangapur Formation is sandwiched between the lower Kota Formation which is of Jurassic age and is well known for its mammalian fossils (Parmar *et al.* 2013) and upper Deccan traps. The Formation is characterized by coarse ferruginous sandstone with many pebble bands succeeded by an alternating sequence of sandstones and mudstones or silty mudstone with abundant fossil plant material. Sedimentological and heavy mineral studies indicated that formation was deposited under freshwater conditions (Ramamohanarao *et al.* 2003). The Gangapur Formation is dated as Barremian-Aptian in age based on palaeobotanical evidence (Chinnappa *et al.* 2020a and references therein).

Data collection and analysis

Sahniophyllum indica gen. et sp. nov. was collected from the mudstone sequences of Gangapur Formation, Pranhita-Godavari Basin exposed on the banks of ButarmalNala (19° 27' N; 79° 13' E) about 13 km West North West of the Asifabad (19° 21' N-79° 17' E) Adilabad District, Telangana State, India (Figs. 1, 2). This taxon is fairly preserved as an impression with most morphological details on pinkish-gray colored mudstone. Counterparts of the impression were collected and studied. On the same slab, our taxon co-occurs with the fragments of *Elatocladus* and unknown seed impression. We follow the Angiosperm Phylogeny Group (APG III 2009) to classify the fossil. The fossil specimens with id number BSIP 40427 and 40428 were hosted in a repository of Birbal Sahni Institute of Palaeosciences, India.

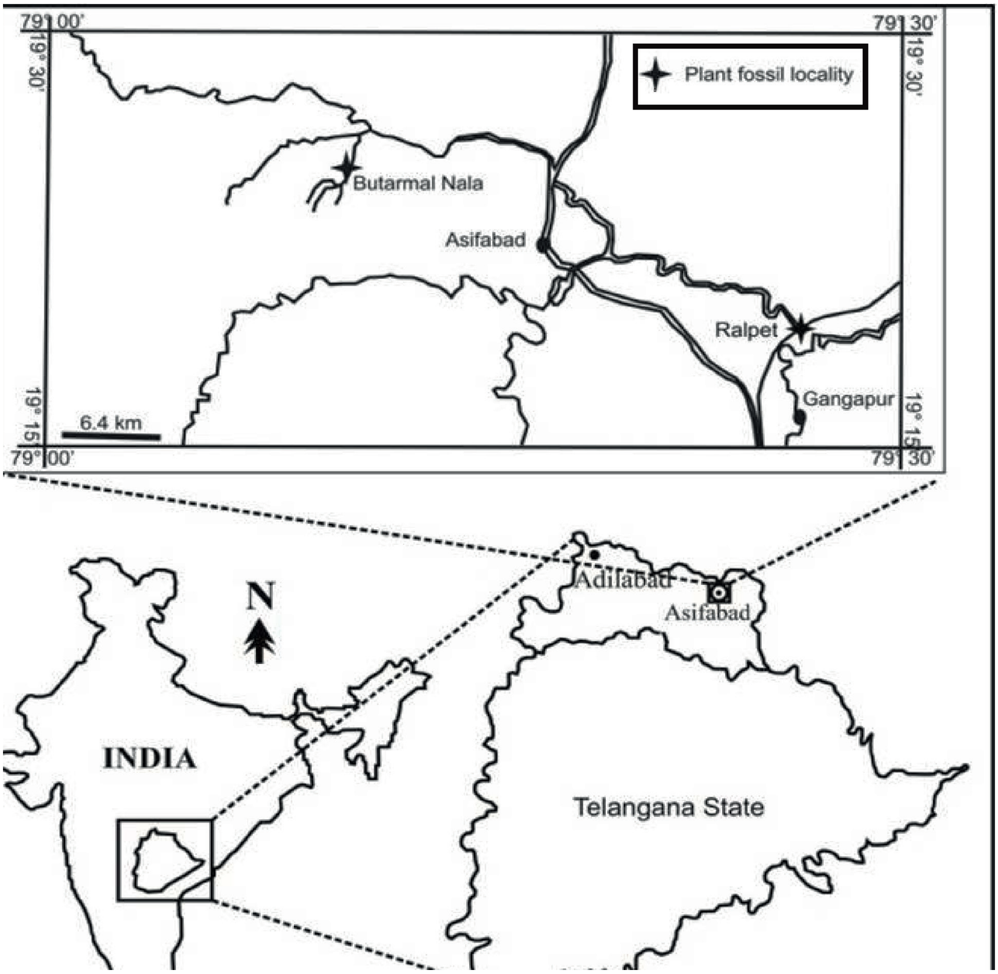

Figure 1. Map showing the studied area and the place where plant fossil was found.

Figure 2. Photo showing the plant fossil.

Attempts to find pollen and cuticles by macerating small pieces of the same slab failed. Fossils were studied with an Olympus SZH 10 stereo dissecting microscope and photographed with a Canon SX 150 IS digital camera using either polarized light or low angle lighting to reveal surface details.

Results

Systematic palaeontology

Family Hydrocharitaceae Juss.

Genus ***Sahniophyllum*** Chinnappa & Rajanikanth gen. nov.

Generic diagnosis. The fossil consists of a cluster of five leaves arranged in a rosette form on short corm-like shoot. The leaf is sessile and ribbon/strap shaped. Margin is entire. Leaf width is mostly constant up to the upper part, 7–8 mm and maximum available length is 110 mm (may exceed up to 200-300 mm). Venation is parallel, five to six primary veins with hierarchical veins in between and all veins converge towards the leaf apex.

Etymology: *Sahnio* is given in honor of the renowned palaeobotanist Birbal Sahni; *Phyllum* for leaves.

Sahniophyllum indica Chinnappa & Rajanikanth sp. nov.

Figures 2, 3, 4

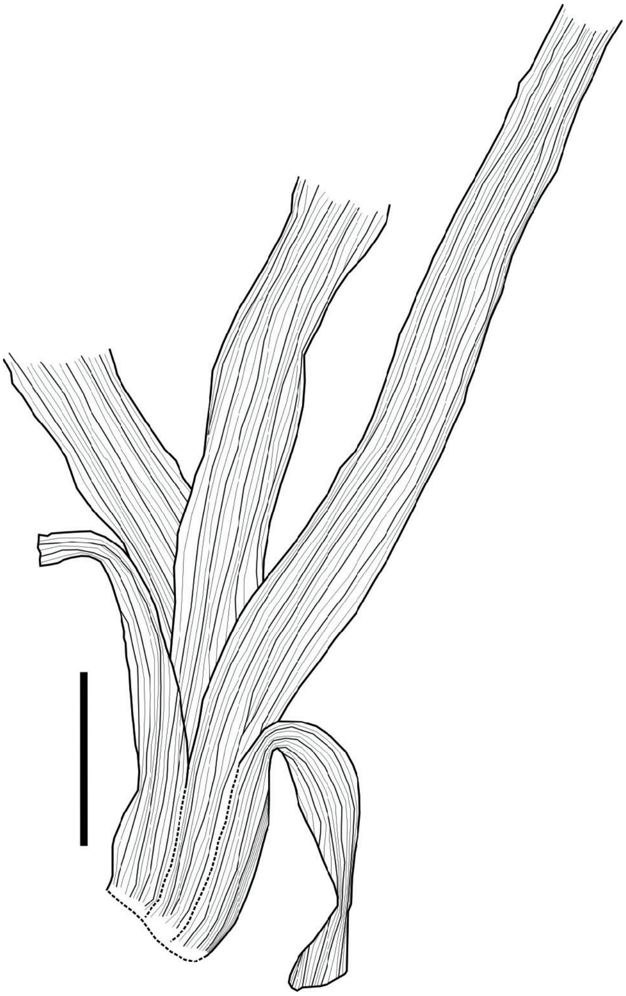

Figure 3. Illustration with the reconstruction of the plant fossil.

Etymology: *indica* is given after India from the country where it is known.

Type material. BSIP 40427

Referred specimens. BSIP 40427, 40428

Specific diagnosis. The specific diagnosis is the same as for the generic diagnosis due to the limited material available currently.

Geographic occurrence. On the banks of Butarmal Nala 13 km North West of the Asifabad, Adilabad District, Telangana State, India

Stratigraphic occurrence. Barremian-Aptian, Gangapur Formation, Pranhita-Godavari Basin.

Description. A vegetative plant body preserved most of the details of herbaceous pattern with possible dimorphic shoot consisting of horizontal stolons and vertical short corm, up on which rosette leaves are born (Figs. 2, 3 and also see Fig. 4 for a reconstruction). Five leaves of entire margin are present on the short corm like shoot, 7-8 mm wide, 110 mm long (maximum available). Base and apex of the leaf are unknown. Venation is parallel and five to six primary veins converge from leaf base to apex. Second order veins visible as finer longitudinal strands between the denser primary veins. Cross veins not observed. No reproductive features are known.

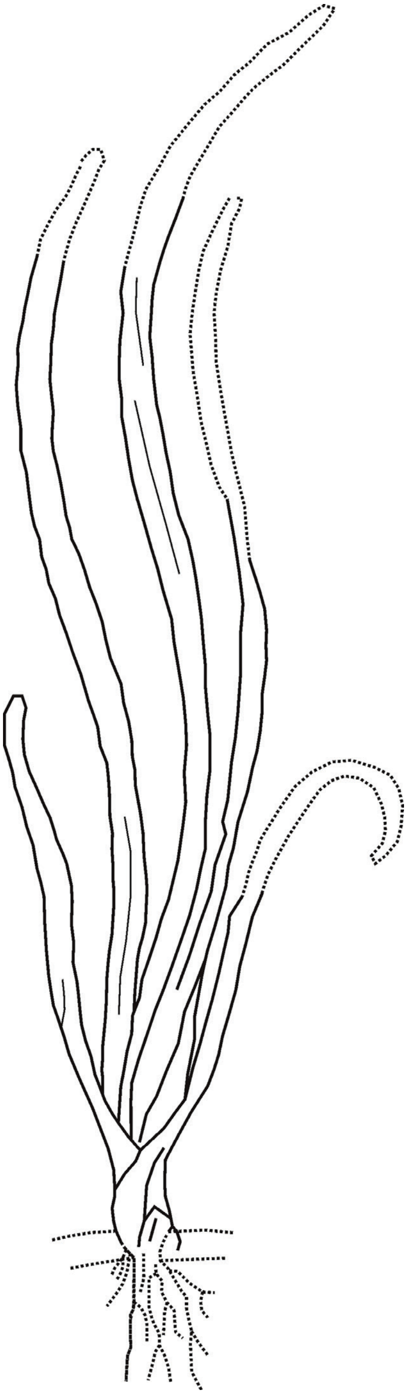

Figure 4. Illustration with the reconstruction of the plant fossil.

Remarks. The evidence allows us to hypothesize that leaves are sessile, not obviously distichous and leaf apex is bluntly obtuse. Even though the maximum available leaf size is 110 mm, it is likely longer ranging up 200 mm due base and apex are not preserved.

Comparison. The fossil plant described herein resembles various Hydrocharitaceae in its habit (Fig. 4) especially with the extant *Vallisneria*. Hydrocharitaceae (Alismatales) is a fully-aquatic monocot family, consisting of 18 genera and approximately 120 species (Les *et al*. 2006). Several genera of the Hydrocharitaceae (*e.g.*, *Ottelia, Blyxa*) show similar habit, varying slightly in the arrangement of leaves, venation and habitat. So far, leaves of a single specimen of the fossil *Vallisneria* (*V. janecekii* Bogner & Kvaček) from the Early Miocene of the Most Basin (North Bohemia), Czech Republic, are documented (Bogner & Kvaček 2009). The leaves of *S. indica* gen. et sp. nov. are very similar to *V. janecekii* in many characters, like leaf size, entire margin and venation (for instance, the absence of transverse veins). However, in *V. janecekii*the development of stolon is well established. Because of the greatest similarity of *S. indica* gen.et sp. nov., with extant genera of the Hydrocharitaceae, our taxon might be an extinct form of the lineage of this extant family.

Discussion

Evolutionary significance of the Sahniophyllum indicagen. et sp. nov.

The early fossil history of monocots is a subject of dispute (Doyle 1973; Gandolfo *et al*. 2000; Friis *et al*.2004; 2010; 2011; Hofmann & Zetter 2010) and their report from the Early Cretaceous is uncertain (Gandolfo *et al*. 1998, 2000). However, recent studies establish their existence during the Early Cretaceous (Coiffard *et al*. 2019; Liu *et al*. 2020). Molecular phylogeny studies (Bremer 2000; Janssen & Bremer 2004; Kato *et al*. 2003; Chen *et al*. 2012) suggested the presence of Alismatales during the Early Cretaceous. The present study also supports the evolution of Monocots early in the Cretaceous and their rapid diversification in the Late Cretaceous.

Molecular diverging date derived from sequences of chloroplast protein coding genes and nuclear rRNA genes14 and mitochondrial protein coding genes (Laroche *et al*. 1995) suggest the Jurassic (~200 Mya) to be the most likely time for the early divergence between monocots and dicots. Recent multi-gene analysis by Hedges *et al*. (2006) also supports the Jurassic age yet slightly younger than the previous studies (~130-150 Mya). Molecular phylogeny studies of Bremer (2000), Wikström *et al*. (2001), Janssen & Bremer (2004) clearly demonstrated that much of the monocot diversification took place before 100 Mya during the Early Cretaceous. These studies indicate, with few exceptions, that most family stem lineages were present by the end of the Cretaceous, however, reliable fossils related to any taxonomic rank of the monocots are largely unknown earlier than the late Cretaceous (Gandolfo 1998; Friis *et al*. 2011). The under-representation of the monocots in the fossil record can be attributable to their physiological properties (Herendeen & Crane 1995). This created a large gap between the molecular and palaeobotanical evidence. In this sense, molecular phylogeny studies (Bremer 2000; Janssen & Bremer 2004; Kato *et al*. 2003; Chen *et al*. 2012) suggested the presence of Alismatales during the Early Cretaceous, and our specimen provides the evidence and helps to bridge this gap.

The divergence time for Hydrocharitaceae is still subject of dispute; two competing ages have resulted in molecular phylogeny. The age estimates for the Hydrocharitaceae by Jansen & Bremer (2004) and Chen *et al*. (2012) are 75-88 Mya and 54.7-72.6 Ma respectively (*i.e.*, Palaeocene-Late Cretaceous). However, Kato *et al*. (2003) dated the Hydrocharitaceae as 119±11 Ma (*i.e.*, latest Early Cretaceous). The report of *Sahniophyllum indica* gen. et sp. nov., of possible Hydrocharitaceae affinity, alert to revisit dating of the family with a great concern. This record represents the first unequivocal presence of Alismatales during the Early Cretaceous and it should be considered as a forerunner in Hydrocharitaceae members. So, little is known about the Early Cretaceous monocot fossil record, therefore, each fossil that can be placed in this clade provides new and important information to improve the lineage of this group in the angiosperm evolution.

Ecological aspects

Taphonomy has played a major role in understanding fossil preservation and their subsequent interpretations (Behrensmeyer *et al*. 1992). The whole plant body is rarely recovered (Sun *et al*. 2011; Liu *et al*. 2020) and such type of plant preservation is common in not or minimum transported deposits. *Sahniophyllum indica* gen. et sp. nov. is preserved almost complete thereby indicating minimum transportation before it is buried. The incompleteness of our fossil material was caused by sampling conditions. The available evidence of *Sahniophyllum indica* gen. et sp. nov. demonstrate that the plant was probably a submerged small herb of 200-300 mm height, with dimorphic shoot and might be growing in a standing water body. Leaves were usually born on reduced corm like short shoot (Fig. 4). Eventually at maturity the plant got detached from runners/stolons along with the corm like short shoot and buried without much transportation. Intact leaves of *S. indica* gen. et sp. nov., reinforced *in situ* autochthonous preservation (Ferguson 1985; Behrensmeyer *et al*. 1992). Ecologically, the early angiosperms were considered herbs with aquatic habitat preferences (Taylor & Hickey 1992; Sun *et al*. 2002).

Conclusion

The present finding of *Sahniophyllum* gen. nov. represents a first angiosperm macro fossil record from India that can be definitely assigned to the Monocots. The characteristic features of the leaves suggest a probable affinity to the family Hydrocharitaceae. Given its nature of leaves and mode of preservation, the plant would have grown in the shallow parts of the water body.

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