APPENDICES

Published Papers 2
FOSSIL WOOD RESEMBLING *Sindora* Miq.
FROM THE NEOGENE OF WEST BENGAL, INDIA

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ABSTRACT

The paper describes a fossil wood of Fabaceae, *Hopeoxylon assamkum* Lalltha and Prakash from the Tertiary deposits of Burdwan District, West Bengal. Xylotomical features of the fossil wood closely resemble the wood anatomy of extant genus *Sindora* Miq. This is the first record of the occurrence of *Sindora* from the Tertiary of West Bengal. Distribution of *Sindora* in different parts of India during Tertiary is also discussed.

INTRODUCTION

Petrified wood remains resembling *Sindora* Miq. (Fabaceae) are known from different Neogene strata of Peninsular India viz., Cuddalore Sandstones of South India (Awasthi, 1977), Tipam Sandstones of Assam (Lalltha and Prakash, 1980), Arunachal Pradesh (Awasthi and Mehrotra, 1997), Lower Siwalik of Uttar Pradesh (Prakash, 1981) and Bihar (Prakash et al., 1988). The present fossil wood resembling *Sindora* is reported from a Neogene exposure at Aduria forest (23°29' N and 87°32' E) Burdwan district, West Bengal (Fig.1) for the first time. It adds significantly to the already known rich fossil flora of West Bengal (Ghosh, 1943; Deb and Ghosh, 1974; Ghosh and Roy, 1978, 1979a-e, 1980a-d, 1981a-b, 1982; Roy and Ghosh, 1979a-b, 1980, 1981a-b, 1982; Ray and Mukhopadhyay, 1996; Srivastava and Prakash, 1984; Bande and Prakash, 1980; Bande and Srivastava, 1988; Acharya and Roy, 1989; Bara and Banerjee, 1990, 1997, 2001; Antal et al., 1996).

MATERIALS AND METHOD

The decorticated wood measures about 1.12 m in length and 40 cm in diameter. The wood was sectioned along transverse, tangential longitudinal and radial longitudinal planes by a rock cutting machine followed by a grinding machine. It was then polished on glass slab with different grades of carborandum powder till the sections revealed cellular details. Finally, the sections were mounted in Canada balsam and studied under compound microscope.

The slides (PPL/ CU/A-1/1-4) are kept in the repository of Palaeobotany and Palaeopollenology Laboratory, Department of Botany, University of Calcutta.

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FOSSIL WOOD RESEMBLING Sindora Miq

Systematic Description

Family: Fabaceae (= Leguminosae)
Sub-family: Caesalpinioidae
Genus: Hopeoxylon Navale emend. Awasthi, 1977
Synonym: Copaiferoxylon Muller-Stoll & Medel 1967
Sindoroxylon Lemoligne et al., 1974
Detarioxyion Boureau & Louvet, 1976
Species: Hopeoxylon assamicum Lalitha & Prakash, 1980
(Plate: 1A-E)

Wood diffuse porous. Growth rings distinct, delimited by layers of parenchyma enclosing gum canals (Plate: 1A-B). Vessels medium to large, solitary or in radial multiples of 2-4, 2-3/mm²; tyloses absent but dark brown gummy substances present. Vessels thick walled, wall 8-12 µm thick, round to oval in cross section, tangential diameter 140-208 µm and radial diameter 174-248 µm; vessel members 204-700 µm in length with slightly truncated to oblique ends; perforations simple, intervessel pit pairs round to oval or horizontally elongated bordered alternate.
to subopposite, 8-10 μm in diameter with linear apertures.

Parenchyma paratracheal and apotracheal; apotracheal parenchyma in concentric bands enclosing gum canals; paratracheal parenchyma vasicentric to aliform and sometimes confluent. Individual parenchyma 12-15 μm in diameter, sometimes crystalliferous parenchyma strands present adjacent to xylem rays.

Xylem rays fine to broad, 1-6 seriate (mostly 3-4 seriate), 4-38 cells high, 208-1072 μm in length, 5-10/mm; ray tissue weakly heterogenous consisting of procumbent cells with 1-2 marginal rows of upright cells at one or both ends (Plate 1E).

Fibres aligned in distinct radial rows, semilibriform, moderately thick walled, nonseptate, polygonal in cross section, 290-620 μm in length and 10-14 μm in diameter.

Gum canals vertical in concentric rings, circular to oval, 112-300 μm in diameter, associated with apotracheal bands of parenchyma.

Specimen no.: PPL/CU/A-1, Slide nos. 1-4
Locality: Aduria Forest, Burdwan District, West Bengal, India.
Horizon: Tropam Series
Age: Miocene

DISCUSSION
The present fossil wood shows vertical gum canals in concentric rows similar to most of the species of Copaifera Linn., Detarium Juss. and Sindora Miq. of Fabaceae. Some resemblances of the fossil wood with Eperua Aubl., Hardwickia Roxb., and Kingiodendron Harms of Fabaceae are also noticed. Eperua, a South American genus differs from the present fossil wood and modern Copaifera, Sindora, and Detarium in having strong heterogenous ray tissue. Hardwickia, usually does not have gum canals. Besides, many apotracheal lines of parenchyma in Hardwickia differ from the fossil wood. Kingiodendron differs from it in having scattered gum canals.

Modern woods of Copaifera, Detarium and Sindora of Fabaceae are xylotomically so identical that it is difficult to separate them. So fossil woods resembling to any one of these genera are now placed in the genus Hopeoxyion Navale emend. Awasthi (1977). Earlier the genus Copaiferoxylon was instituted to include the woods with concentric rows of gum canals resembling Copaifera (Chiarugi, 1933). Lemoigne et al. (1974) proposed the genus Sindoroxylon for the fossil wood resembling Sindora. The fossil wood having similarities with modern Detarium wood has been instituted as Detarioxylon by Boureau and Louvet.
(1975). As the genus *Hopeoxylon* Navale emend. Awasthi (1977) has the priority, *Copaiferoxylon*, *Sindoroxyylon* and *Detarioxyylon* should be considered as the synonyms of *Hopeoxylon* (Awasthi, 1977).

So far, nine species of *Hopeoxylon* are known from different parts of the world among which five are known from India. These are *H. migiurtinum* (Chiarugi) [syn. *Copaiferoxylon migiurtinum* (Chiarugi, 1933) Muller-Stoll and Madel, 1967] from the Miocene of Somaliland, *H. sindoroides* (Kramer) [syn. *Copaiferoxylon sindoroides* Kramer, 1974] from the Tertiary of Ethiopia, *H. libycum* (Boureau & Louvet). [Syn. *Detarioxyylon libycum* Boureau & Louvet, 1975] from the Palaeogene of Libya; Among the Indian species *H. indicum* (Navale) Awasthi (1977) and *H. arcotense* Awasthi (1977) from the Mio-pliocene of Pondicherry, South India. *H. speciosum* (Navale) Awasthi (1977) from Pondicherry, Bihar, and Arunachal Pradesh (Awasthi and Mehrotra, 1997), *H. assamicum* Lalitha & Prakash (1980) from Upper Miocene (Tipam Sandstones) of Assam and *H. eosianensis* from Lower Siwalik of Uttar Pradesh (Prakash, 1981) are recorded. Of these, the present fossil wood appeared to be identical to *Hopeoxylon speciosum* and *Hopeoxylon assamicum* but *H. speciosum* possesses apotracheal parenchyma in fine and short lines apart from those surrounding the gum canals which are absent in *H. assamicum* and the present specimen. Therefore, the fossil wood is assigned to *H. assamicum* Lalitha & Prakash (1980).

At present, none of the three genera viz., *Copaifera*, *Detarium* and *Sindora* is found in India. The nearest comparable species to *Hopeoxylon assamicum* is suggested to be *Sindora siamensis* Teysm. ex Miq. (Lalitha & Prakash, 1980) which grows in Thailand (Ridley, 1967). Other species are restricted to Hainan, West Malaysia, Celebes and Molucca (Willis, 1973). Thus none of these extant species of *Sindora* grows in India. Occurrence of fossil wood resembling *Sindora* from exposures of Assam, Arunachal Pradesh, Bihar, West Bengal, Pondicherry and Uttar Pradesh suggests a wider distribution of the same in India particularly in the eastern, north eastern, southeastern and northern parts during Neogene times. Awasthi & Mehrotra (1997) suggested that *Sindora* along with some other Malayan and African taxa disappeared from Indian subcontinent due to decrease in the mean annual temperature and rainfall caused by rise of the Himalaya and northward movement of the Indian plate.

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FOSSIL WOOD RESEMBLING *Sindora* Miq


A Fossil Wood of Cynometra (Fabaceae) from the Plio-Pleistocene Dupi Tila Formation in Sylhet, Bangladesh

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Abstract

This paper deals with a well-preserved fossil wood of Cynometroxylon holdenii Prakash and Bande, 1980 identified in the Dupi Tila Formation (Plio-Pleistocene) in the Sylhet District, northeast Bangladesh. This find is the first record of Leguminous (Fabaceae) wood from the Tertiary sequence of Bangladesh. The wood is characterised by small to medium, uniformly distributed solitary or radial multiple vessels, vestured alternate intervessel pits, regular concentric bands of parenchyma alternating with fibre bands, 1-3 seriate heterogeneous rays. Distribution of the genus in the past and present is discussed. The wood indicates tropical, humid, littoral to swampy palaeoenvironment during the growth of the forest.

Introduction

The Plio-Pleistocene Dupi Tila Formation is very well-exposed in its type section in the Dupi Tila of Dupigaon and surrounding areas near Sharighat in the Sylhet District of northeastern Bangladesh (Reimann 1993). The Formation is divided into Lower and Upper units. The Lower unit is characterized by pebbly, coarse-grained sandstone, and the Upper unit by medium- to coarse-grained sandstone and shale containing lignite with fossil-wood fragments. The Upper unit is highly ferruginous.

Although much information on the fossil flora in central and southeast Asia, especially, in India is known, study on the occurrence of fossil wood in Bangladesh is very few. So far, only two fossil woods, viz., Glutoxylon sitakundensis Poole and Davies of Anacardiaceae from Sitakund anticline, southeastern Bangladesh (Poole and Davies 2001) and Barringtonioxylon assamicum Prakash and Tripathi (Agarwal et al. 2000) of the family Lecythidaceae from Chittagang Hill Tracts have been reported. The present article deals with a fossil wood resembling Cynometra of the family Fabaceae reported for the first time from the Dupi Tila Formation in Sylhet, northeastern Bangladesh. This study provides information regarding the climatic adaptation, ecology, vegetation and also on the floral dynamics during this period.
Material and Method

The fossil wood for present study was collected from the Dupi Tila Formation in Dupigaon near Sharighat of Sylhet, Bangladesh (Figure 1). Its preservation is satisfactory. For the systematic study, the sample was sectioned along transverse (T.S.), tangential-longitudinal (T.L.S.) and radial-longitudinal (R.L.S.) planes. It was then grinded and polished with carborundum powder using a motor driven grinder and finally, mounted in Canada balsam. All specimens and slides were preserved in the depository of Palaeobotany–Palaeopalynology Laboratory, Department of Botany, University of Calcutta, India.

Figure 1. Sample location map of Dupi Gaon and surrounding areas, Sylhet District.
A fossil wood of *Cynometra* from Dupi Tila

Systematic Description

**Family:** Fabaceae  
**Genus:** *Cynometroxylon* Chowdhury and Ghosh, 1946  
**Species:** *Cynometroxylon holdenii* Prakash and Bande, 1980  
(Figure 2, Nos. 1-6)  
**Locality:** Dupi Tila near Dupigaon, Sylhet District, Bangladesh  
**Co-ordinates:** lat 25°06' N. long 92°08' E.  
**Stratigraphic horizon:** Dupi Tila Formation (Lower Unit), Plio-Pleistocene.  
**Specimen No. BD 4.**

This description is based on a 36 cm long and 23 cm diameter sample of fossil wood. It has several narrow longitudinal furrows. Most probably, this represents the main branch or trunk of the plant as it bears the broken bases of branches that have sharp and angular edges. No pith, bark, phloem or outer cortex is preserved. The wood is silicified. It is white to reddish-brown with isolated staining at places, this might have resulted either from the original organic material or this could be due to permineralization. It shows inconspicuous growth rings and branches.

The wood is diffuse porous. Vessels are small to medium, solitary or in radial multiples of 2-3, uniformly distributed (6-12/mm²). Radial diameter (r.d.) and tangential diameter (t.d.) of vessels range from 45 to 120 μm and 70 to 200 μm, respectively. Length of vessels varies from 150 to 450 μm. Perforations are simple. Intervessel pits alternate and are vestured and small in diameter (4-5 μm). Abundant parenchyma are arranged in regular concentric bands alternating with fibre bands of almost same width, undulating, sometimes surrounding the vessels; often bands dichotomizing and joining the adjacent ones. The bands are 4-8 cells wide, cells are circular and 15-30 μm in diameter. Non-storied xylem rays are 1-3 seriate (mostly 2), 8-12/mm, 200-550 μm long, 15-30 μm in diameter having 8-40 cells per ray. Ray tissues are heterogeneous, upright cells, forming 1-2 marginal rows having length of 24-60 μm and tangential height of 15-25 μm. Procumbent cells are 45-70 μm in length and 15-30 μm in tangential height. Fibres are thick-walled, 6-10 μm in diameter; aseptate, and lack pits.

Discussions

1. Systematic Affinity and Distribution

   The anatomical features of the present fossil wood *i.e.*, diffuse porous wood with solitary vessels or in radial multiples of 2-3, vestured intervessel pits, regular concentric bands of parenchyma, 1-3 seriate heterogeneous rays, suggest
Figure 2. Nos 1-6 *Cynometroxylon holdenii*. No. 1. T. S. through wood showing bands of parenchyma x 30. No. 2. Enlarged part of No. 1 showing pattern of axial parenchyma x 60. Nos. 3 & 4. T. L. S. through the wood showing organization of rays and fibres. x 60. No. 5. R. L. S. through the wood showing ray histology and intervessel pits. x 60. and No. 6. Same with ray histology x 60.
that it belongs to the genus *Cynometra* of Fabaceae. It closely resembles the extant woods of *Cynometra polyandra* Roxb. and *C. ramiflora* Linn. of Fabaceae (Pearson and Brown 1932, Ramesh Rao et al. 1972), which are xylotomically inseparable from each other.

Chowdhury and Ghosh (1939) included all the fossil woods of *Cynometra* under the generic name *Cynometroxylon*. There are six species of *Cynometroxylon* known so far from different parts of the world. *Cynometroxylon holdenii* (Gupta) Prakash and Bande, 1980 [= *C. indicum* Chowdhury and Ghosh, 1946] is reported from the Neogene sediments of India (Guleria 1984), *C. tertiarum* Awasthi and Mehrotra, 1997 from the Neogene of Arunachal Pradesh, *C. pareinaequefolium* Prakash, 1979 from the Tertiary of Thailand, *C. alexandri* C.H. Wright, *C. sessiliflora* Harms and *C. zairensis* from the Cenozoic of Zaire, Africa (Bande et al. 1987). As the fossil resembles *Cynometroxylon holdenii* Prakash and Bande in all its characters and attributes, it is assigned to the same species. Earlier, the species was recorded from the Neogene strata of West Bengal (Ghosh and Roy 1982; Bera and Banerjee, 2001), Kerala coast (Awasthi and Ahuja 1982), Kutch (Guleria 1984), Assam (Prakash and Tripathi 1976), Arunachal Pradesh (Prakash and Awasthi 1971, Mehrotra et al. 1999), Himachal Pradesh (Prakash 1975), Uttar Pradesh (Prakash 1978) and Tripura (Awasthi et al. 1994). In addition to the earlier reports from other parts of the world, the occurrence of *Cynometra* in the Dupi Tila Formation (Plio-Pleistocene) in Bangladesh suggests that the genus was distributed in southeast Asia, especially, in India, Bangladesh, Thailand and adjoining landmasses during Neogene-Pleistocene time (Figure 3).

Figure 3. Global distribution of *Cynometra* through geologic time.
2. Ecology

During the Tertiary Period, the Indian lithospheric plate remained between the paleolatitudes 15°S and 24°N. During Late Miocene to Pliocene in particular, the Bengal Basin was approximately within the paleolatitude of 20-22°N (Dewey et al. 1989), which is almost similar to its present position (21-24°N). The palaeoclimate during Late Tertiary was tropical to subtropical, warm and humid, which became more arid during the Pliocene due to the close up of the Tethys sea and accompanying upliftment of the Himalayas. This brought a change in the relatively uniform nature of vegetation in India and Malaysia (Bande and Prakash 1986, Guleria 1991). During Neogene a rich tropical to subtropical vegetation existed representing dicotyledonous angiosperms like, Anacardiaceae, Burseraceae, Sapindaceae, Fabaceae, Lauraceae, Dipterocarpaceae, Ebenaceae, Simaroubaceae, Sapotaceae (Bande and Prakash 1986, Singh and Singh 1987, Singh and Tripathi 1990, Prasad 1993, Prasad and Awashti 1996 and Mehrotra et al. 1999).

The sharp and angular edges of the fossil wood and absence of pit or boring in it suggest only short distance transportation. From its occurrence within the channel sandstone facies it may be presumed that the plant material entered into the river channel as driftwood and subsequently became water logged and finally buried within the channel deposit. It was eventually silicified, silica being introduced into the wood through clay diagenesis, and then preserved in the sediments (Leo and Barghoom 1976).

The flora was derived locally from the growing vegetation under a prevailing subtropical to tropical warm humid climatic condition. The host rock of the fossil wood, i.e., the reddish-brownish colour of the sandstone supports this type conclusion. As the Dupi Tila channels originated from the emerging areas nearby, it may be presumed that this trunk or branch was derived from nearby vegetation/forest on the natural levee or from uplifted areas.

At present the genus *Cynometra* Linn. has 60 species distributed throughout the tropics in the Indo-Malayan region, Philippines, Australia, Pacific islands, Mexico, Brazil and Africa (Figure 4). As mentioned earlier, two species are comparable with the studied fossil wood, i.e. *C. ramiflora* and *C. polyandra*. *C. ramiflora*, a large evergreen tree grows in tropical, littoral and swampy forests of Sunderbans, South India, Myanmar and Sri Lanka. Another large tree, viz., *C. polyandra*, also thrives in tropical evergreen forests of Cachar, Garo, Lushai and Khasi Hills in northeastern India and Sylhet-Chittagong region of Bangladesh (Ramesh Rao et al. 1972).

From the fossil records of *Cynometra* it appears that the distribution of this genus was restricted to southeast Asia and Africa during Neogene-Pleistocene time (Figure 3). Later, it became widespread possibly through an east-west
A fossil wood of *Cynometra* from Dupi Tila migration and developed a common element of the modern tropical swampy forests of the world (Figure 4).

![Figure 4. Present-day global distribution of *Cynometra.*](image)

**Conclusion**

Study on a fossil wood from the Dupi Tila Formation in the Dupigaon area of Sylhet district, Bangladesh shows a close resemblance to *Cynometroxylon holdenii* Prakash and Bande, 1980. It also shows similarity with the extant woods of *Cynometra polyandra*, Roxb and *C. ramiflora* Linn. The wood is silicified and mostly white with reddish-brown patches at places, which might have resulted either from the original organic material or due to permineralization. The plant is arboreal in habit and grows in swamp, coastal plain, interchannel depression as well as hilly evergreen forest. This find is the first record of leguminous (Fabaceae) wood from the Tertiary of Bangladesh. Occurrence of such wood from the Plio-Pleistocene alluvial fan / fluvial sequence of Bengal Basin is not surprising as the flora was distributed abundantly in India, Mayanmer and surrounding areas during ancient and modern times.

**References**


A fossil wood of *Cynometra* from Dupi Tila


