

Fossil woods from the late Miocene-Pliocene sediments of Arunachal Pradesh

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ABSTRACT

Four fossil woods, namely *Glutoxylon burmense* (Holden) Chowdhury, *Bauhinia miocenica* Mehrotra et al., *Brachystegioxylon lakhanpalii* sp. nov. and *Cassinium prefiistulai* Prakash are described from the late Miocene-Pliocene sediments of Kimin River beds, Arunachal Pradesh. They belong to *Gluta* of the Anacardiaceae and *Bauhinia*, *Brachystegia* and *Cassia* of the Fabaceae. Their presence indicates tropical warm and humid climate in the region during the depositional period. *Brachystegia* is of special interest as it is an African element.

Key-words: Fossil wood, Anacardiaceae, Fabaceae, Palaeoclimate, Arunachal Pradesh.

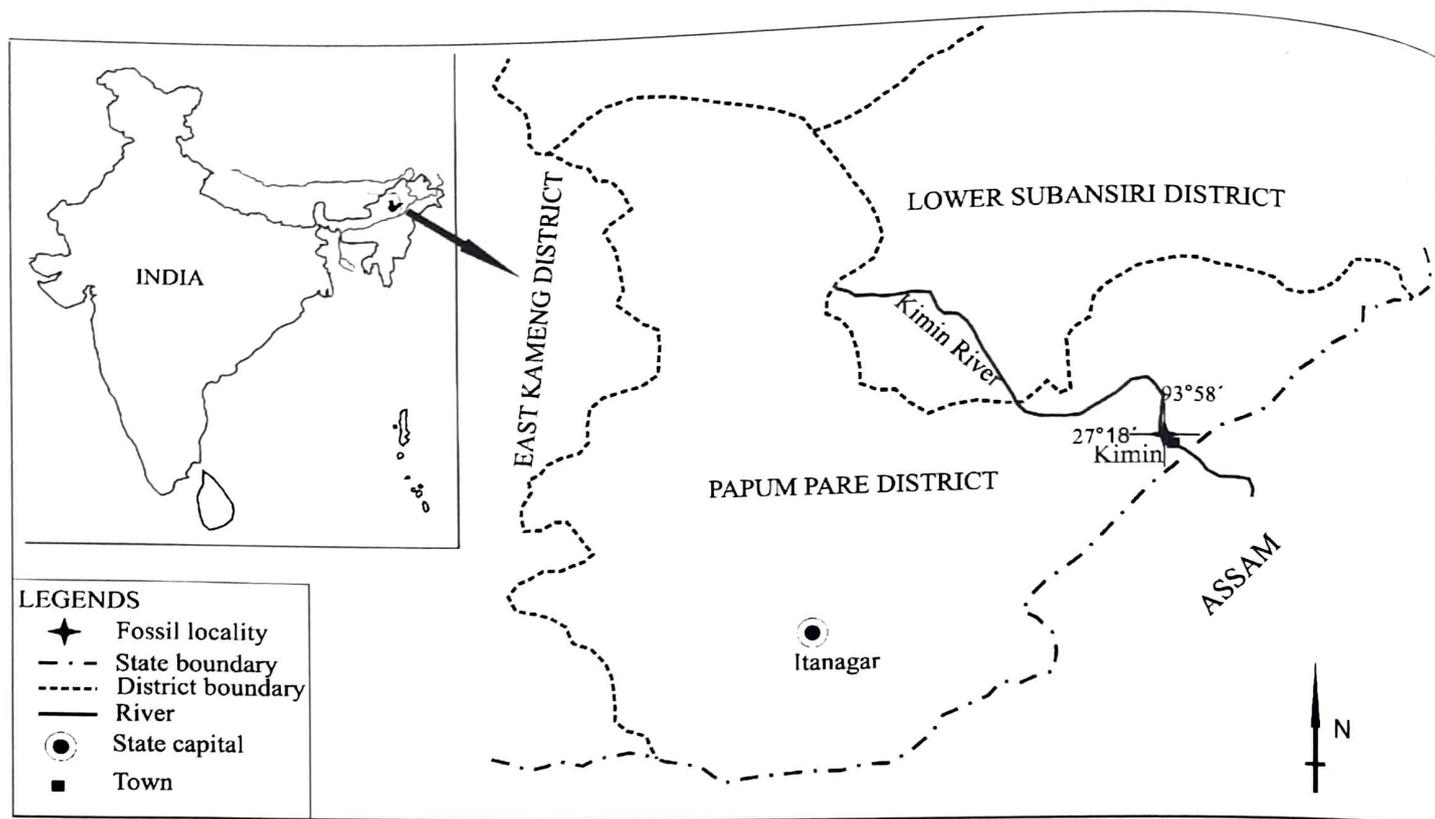
INTRODUCTION

Arunachal Pradesh located in the northeastern part of India borders Assam and Nagaland in the south, Bhutan in the west, Myanmar in the east and China in the north. Karunakaran and Ranga Rao (1979) classified the Tertiary sediments of Arunachal Pradesh into three formations viz., Dafla, Subansiri and Kimin. However, Dutta and Singh (1979) considered them equivalent to the Siwalik sediments. Mehrotra et al. (1999) described numerous fossil woods from these sediments and considered them equivalent to the Namsang Formation of Assam (late Miocene–Pliocene in age). Most of these woods were described from the Siang District, Arunachal Pradesh. In the last decade, a number of fossil leaves have also been described from the West Kameng, East Kameng and Papum Pare districts of Arunachal Pradesh (Joshi & Mehrotra 2007, Bera et al. 2014, Khan & Bera 2014, Khan et al. 2015). Although, Kimin (of the Papum Pare District)-Ziro (of the Lower Subansiri District) road section is

very rich in fossil woods, the only fossil described from this locality is *Cassinium borooahii* (Prakash) Prakash (Mehrotra et al. 1999). Keeping this in mind, a field trip was undertaken and one of us (S. K. B.) recovered a good collection of woods near Kimin (27°18' N; 93°58' E) (Text Figure 1). Four of them are described in the present communication.

MATERIAL AND METHODS

The fossil woods collected from the river beds are petrified and blackish-brown in colour. Their preservation is satisfactory to reveal anatomical details. The slides were prepared by standard method of cutting, grinding and polishing using carborundum powder of various grades and mounted in canada balsam. The slides are housed in the museum of the Birbal Sahni Institute of Palaeosciences, Lucknow. The anatomical terms used in describing these woods follow Wheeler et al. (1986) and International Association of Wood Anatomists (1989).



Text Figure 1. Map showing the fossil locality (not to scale).

SYSTEMATIC DESCRIPTION

Family : Anacardiaceae

Genus : *Glutoxylon* (Chowdhury) Prakash & Tripathi 1976

Glutoxylon burmense (Holden) Chowdhury 1952

(Pl. 1, figs. a–d)

Description: Wood diffuse porous (Pl. 1, fig. a). Growth rings not observed. Vessels medium to large, tangential diameter range 133–277 μm , mostly solitary, round to oval, evenly distributed, 1–3 per sq mm; tyloses frequently present (Pl. 1, fig. a); perforation plates simple; intervessel pits not seen due to profuse tyloses. Axial parenchyma paratracheal and apotracheal; paratracheal scanty, apotracheal in the form of thin (2 to 3 celled) continuous bands at irregular intervals (Pl. 1, fig. a). Rays 10–12 per mm and of two types simple and fusiform (Pl. 1, figs. b, c); simple rays uniseriate, made up of procumbent cells, 43–50 μm in width and 3–18 cells or 125–451 μm in height; fusiform rays 4 to 5 seriate containing gum canal in the centre, made up

of procumbent cells with 1 or 2 rows of upright cells at the margins, 135–143 μm in width and 16–20 cells or 413–489 μm in height; procumbent cells 28–42 μm in tangential height and 69–95 μm in radial length; upright cells 65–75 μm in tangential height and 44–57 μm in radial length (Pl. 1, fig. d). Fibres moderately thick walled and non septate. Axial canals radial, 83–95 μm in tangential diameter (Pl. 1, figs. b, c).

Figured specimen: Specimen no. BSIP 41050.

Locality: Near Kimin, Papum Pare District, Arunachal Pradesh.

Horizon: Namsang Formation (= Upper Siwalik).

Age: Late Miocene to Pliocene.

Remarks: The important anatomical features of the fossil such as diffuse porous wood, heavily tylosed vessels, simple perforation plates, apotracheal bands of axial parenchyma at irregular intervals, uniseriate and fusiform rays having axial canal, and non septate fibres indicate its close affinities with *Gluta* Linn. of the Anacardiaceae. As it is difficult to differentiate various



Plate 1

Glutoxylon burmense (Holden) Chowdhury: a. Cross section (CS) of the fossil wood showing shape, size and distribution of vessels and parenchyma. b. Tangential longitudinal section (TLS) showing axial canal in a fusiform ray. c. TLS in low power showing predominantly uniseriate rays. d. Radial longitudinal section (RLS) showing heterocellular rays.

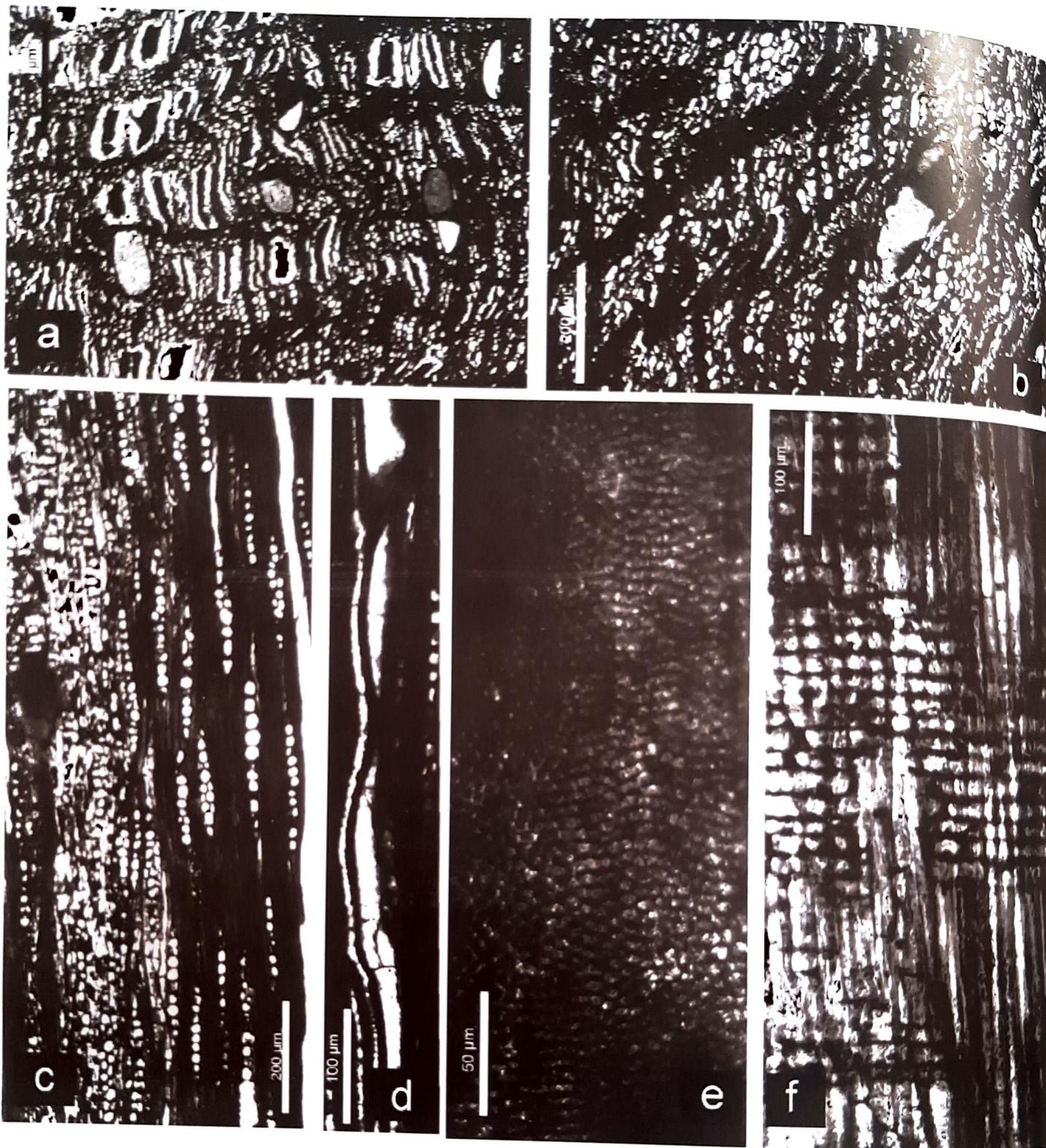


Plate 2

Bauhinia miocenica Mehrotra et al.: a. CS of the fossil wood showing shape, size and distribution of vessels and parenchyma. b. CS enlarged to show alternating parenchyma and fibre bands. c. TLS showing irregularly storied uniseriate rays. d. Showing storied vessel elements. e. Intervessel pits showing lenticular apertures. f. RLS showing weakly heterocellular rays.

species of the genus xylotomically, no further attempt was made for comparison at the specific level.

Chowdhury (1934, 1936) instituted the genus *Glutoxylon* for the fossil woods resembling *Gluta* from the Tertiary of Assam. So far five species of

Glutoxylon, namely *G. burmense* (Holden) Chowdhury (1952), *G. cuddalorese* Awasthi (1966), *G. kalagarhense* Trivedi & Ahuja (1978), *G. cacharensis* (Prakash & Tripathi) Guleria and *G. garbetansis* (Roy & Ghosh) Guleria (1984) are known

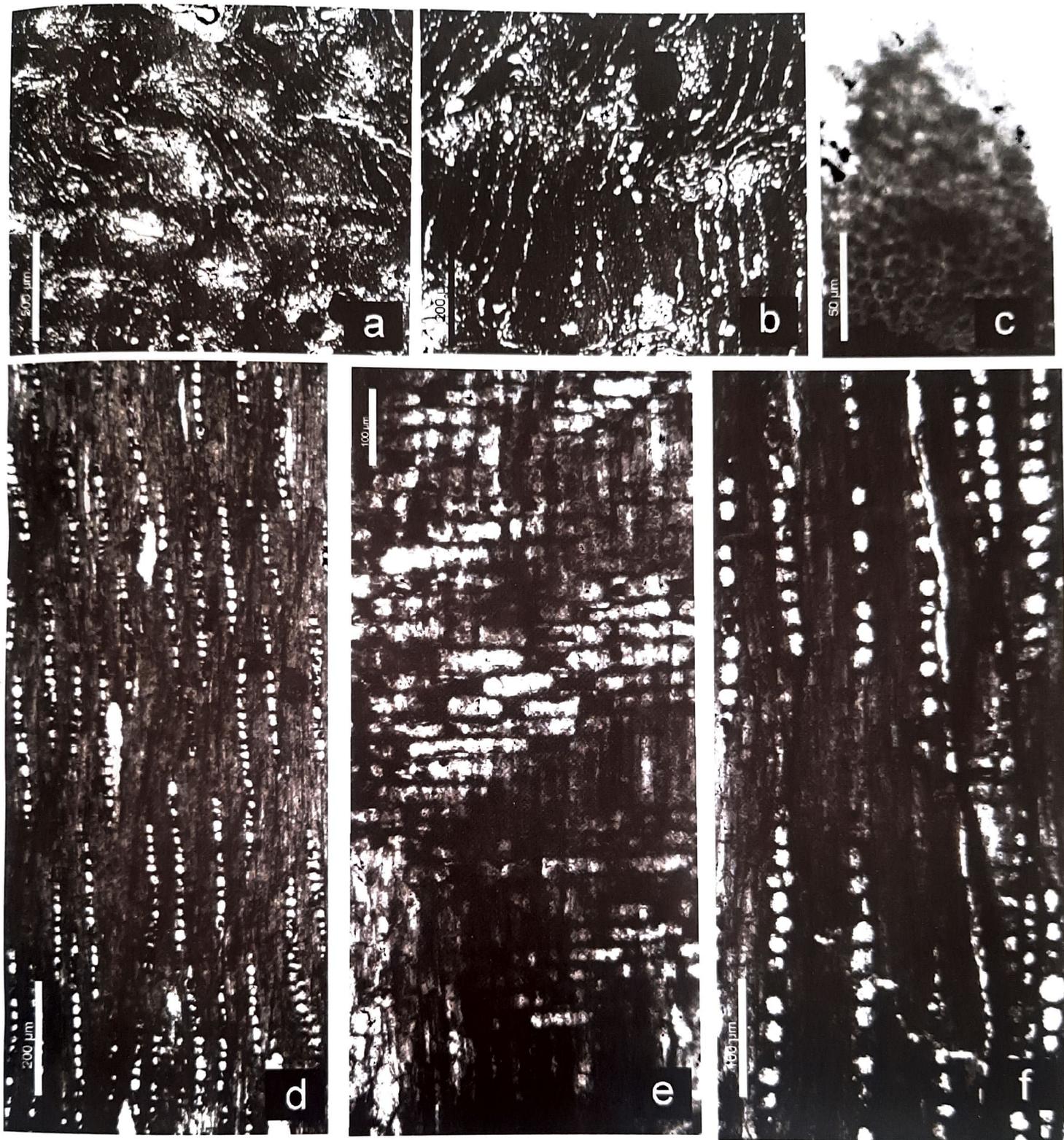


Plate 3

Brachystegioxylon lakhanpalii sp. nov.: a. CS of the fossil wood showing shape, size and distribution of vessels and terminal parenchyma. b. CS in high power showing aliform to confluent parenchyma. c. Vestured intervessel pits. d. TLS in low power showing irregularly storied uniseriate rays. e. RLS showing homocellular rays. f. TLS enlarged showing storied rays.

from various Tertiary exposures of India. As the present fossil is found very similar to *G. burmense* (Holden) Chowdhury, it has been placed under the same.

Gluta is a genus of small to very large trees and consists of about 30 species distributed in Madagascar, India, Myanmar, Thailand, Laos, Cambodia, Vietnam, China and throughout Malaysia (Ghosh and

Purkayastha 1963, Hou 1978). In the Indian Subcontinent, it is found in the coastal or evergreen forests.

Family : Fabaceae

Genus : *Bauhinia* L.

***Bauhinia miocenica* Mehrotra et al. 2011**

(Pl. 2, figs. a–f)

Description: Wood diffuse porous (Pl. 2, fig. a). Growth rings absent. Vessels small to medium, 91–162 μm in tangential diameter, solitary and in radial pairs, round to oval, occasionally elongated, evenly distributed, 6–10 per sq mm, filled with brownish gummy deposits (Pl. 2, figs. a, b); vessel members truncate, storied, 140–613 μm in height (Pl. 2, fig. d); perforation plates simple; intervessel pits bordered, alternate, about 5–8 μm in diameter, circular to oval with lenticular apertures (Pl. 2, fig. e). Axial parenchyma banded, bands regular, continuous, alternating with fibre bands, broader than fibres, up to 6 celled thick (Pl. 2, figs. a, b); cells 9–15 μm in width and 48–103 μm in length. Rays 8–15 per mm, exclusively uniseriate, rarely biseriate, irregularly storied (Pl. 2, fig. c), made up of mainly procumbent cells, 18–32 μm in width and 4–15 cells or 64–234 μm in height; ray tissue weakly heterogeneous (Pl. 2, fig. f); ray cells crystalliferous; procumbent cells 41–66 μm in radial length and 13–22 μm in tangential height; upright cells about 20 μm in radial length and 34 μm in tangential height. Fibres angular in cross section, moderately thick walled, non-septate, 8–10 μm in diameter. Ripple marks present due to storied vessel elements and rays (Pl. 2, figs. c, d).

Figured specimen: Specimen no. BSIP 41051.

Locality: Near Kimin, Papum Pare District, Arunachal Pradesh.

Horizon: Namsang Formation
(= Upper Siwalik).

Age: Late Miocene to Pliocene.

Remarks: The noteworthy features of the fossil, namely diffuse porous wood, simple perforation plates, continuous thick bands of axial parenchyma alternating with fibre bands, exclusively uniseriate rays, presence of ripple marks and non-septate fibres indicate its

affinities with *Bauhinia* Linn. of the Fabaceae (Pearson & Brown 1932, Metcalfe & Chalk 1950, Kribs 1959, Ramesh Rao et al. 1972, Ilic 1991, Gupta 2007). The fossil wood has been compared with the Indian species and shows near resemblance with *B. foveolata* Dalzell, *B. malabarica* Roxburgh, *B. purpurea* Linn. and *B. racemosa* Lamarck in having storied elements (Ramesh Rao et al. 1972). The fossil shows maximum resemblance with *B. malabarica* in possessing parenchyma bands wider than fibres and tangential diameter of vessels <230 μm (Pearson & Brown 1932).

Trivedi and Panjwani (1986) established the genus *Bauhinium* for the fossil wood of *Bauhinia*, whereas Awasthi and Prakash (1987) kept their fossil directly under the modern genus. The fossil woods resembling *Bauhinia* are: *Bauhinium miocenicum* (Trivedi & Panjwani 1986) and *B. palaeomalabaricum* (Prakash & Prasad 1984) from the Siwalik sediments of Uttar Pradesh, *Bauhinia deomalica* (Awasthi & Prakash 1987) from the Namsang beds of Deomali, Arunachal Pradesh and Tipam Group of Udaipur, Tripura (Mehrotra et al. 2006), *B. tertiara* (Awasthi & Mehrotra 1990) and *B. miocenica* (Mehrotra et al. 2011) from the Tipam Group of Naginimora, Nagaland and Dhemaji, Assam respectively. After detailed comparison with all of them it has been found that the fossil shows near resemblance with *Bauhinia miocenica* (Mehrotra et al. 2011). *Bauhinium miocenicum* is different due to the presence of broader rays (1–3 seriate), whereas *B. palaeomalabaricum* can be distinguished in having longer rays (up to 32 cells). *Bauhinia deomalica* and *B. tertiara* differ in possessing aliform to confluent and thinner bands of parenchyma. As our fossil shows maximum resemblance with *Bauhinia miocenica*, it has been placed under the same.

Bauhinia comprises about 300 species distributed throughout the tropics of the world and about 30 of its species are found in India and Myanmar. *B. malabarica*, the modern comparable form of the fossil, is a small to moderate-sized tree distributed in the moist deciduous forests of India (Ramesh Rao et al. 1972, Mabberley 1997).

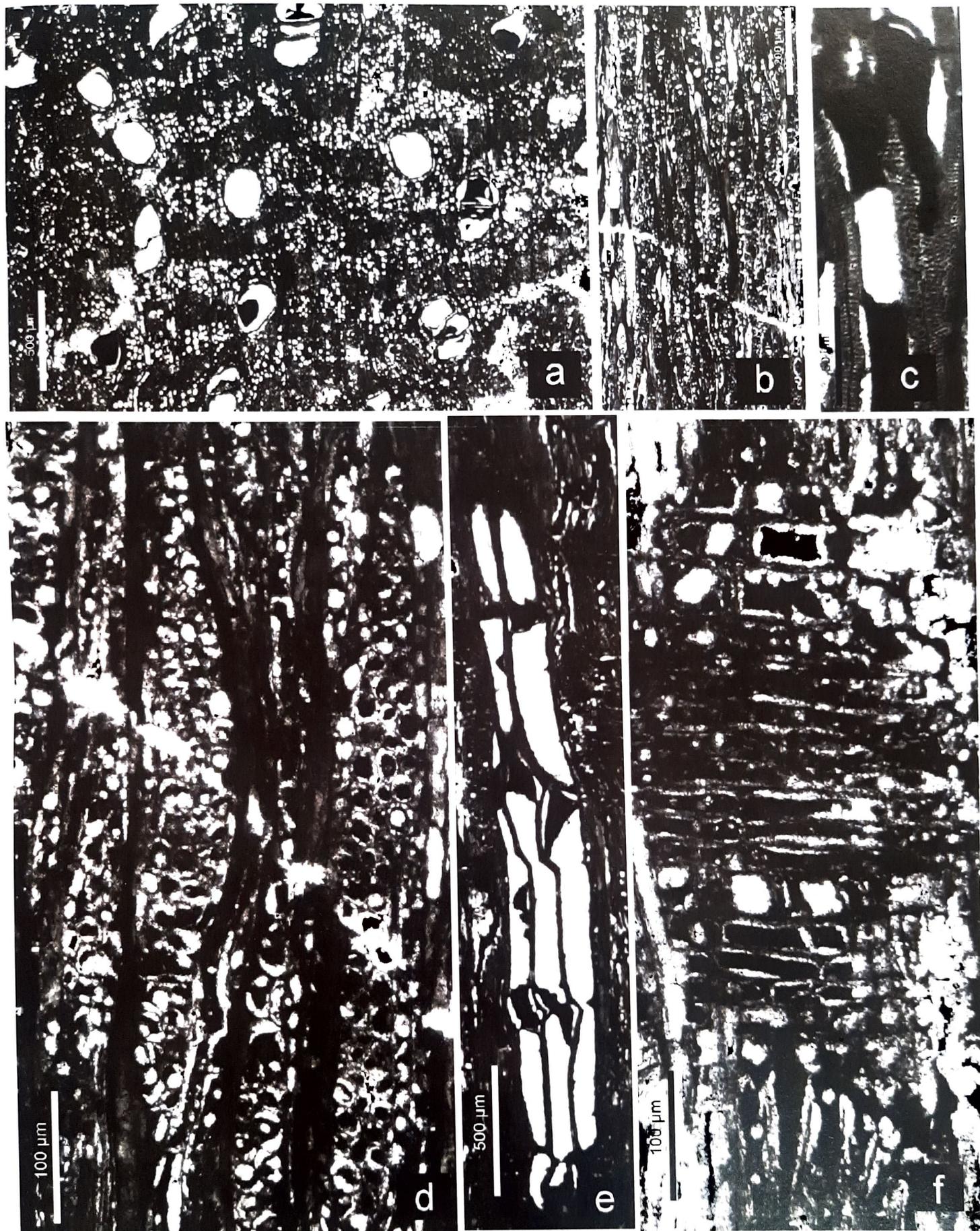


Plate 4

Cassinium prefistulai Prakash: a. CS of the fossil wood showing shape, size and distribution of vessels and parenchyma. b. TLS in low power showing distribution of rays. c. Vestured intervessel pits. d. TLS in high power showing structure of rays. e. Stored vessel elements. f. RLS showing crystalliferous heterocellular rays.

Genus : *Brachystegioxylon* Lakhanpal & Prakash 1970

***Brachystegioxylon lakhanpalii*, Mehrotra et al., sp. nov.**

Pl. 3, figs. a–f

Description: Wood diffuse porous. Growth rings present, delimited by terminal parenchyma (Pl. 3, fig. a). Vessels medium to large, 121–204 μm in tangential diameter, round to oval in shape, solitary and in radial multiples of 2–3, plugged with brownish gummy material (Pl. 3, figs. a, b), evenly distributed, about 10–12 per sq mm; vessel members 142–380 μm in length, with truncate ends; perforations simple; intervessel pits bordered, alternate, about 6–9 μm in diameter, vested (Pl. 3, fig. c). Axial parenchyma paratracheal, vasicentric (Pl. 3, figs. a, b) and aliform to aliform-confluent joining adjacent vessels; cells 20–30 μm in width and 40–80 μm in length. Rays 13–16 per mm, predominantly uniseriate (Pl. 3, figs. d, f), biseriation present due to paired cells, consisting of procumbent cells (Pl. 3, fig. e), 15–36 μm in width and 6–19 cells or 111–345 μm in height, storied at places (Pl. 3, figs. d, f); ray cells 19–26 μm in tangential height and 43–62 μm in radial length (Pl. 3, fig. e); crystals not seen. Fibres thick walled, non septate, 10–14 μm in diameter.

Figured specimen: Specimen no. BSIP 41052.

Locality: Near Kimin, Papum Pare District, Arunachal Pradesh.

Horizon: Namsang Formation (= Upper Siwalik).

Age: Late Miocene to Pliocene.

Remarks: The characteristic features of this fossil wood are: distinct growth rings, diffuse-porous wood, medium to large vessels, simple perforations, vested intervessel pits, marginal and vasicentric to aliform-confluent axial parenchyma, exclusively uniseriate homocellular rays and non septate fibres. These features show affinities of the fossil with woods of *Terminalia* L. of the Combretaceae and *Brachystegia* Benth. of the Fabaceae. Woods of *Terminalia* generally possess crystals in parenchyma and ray cells. Some species of *Terminalia* do not have crystals but they usually have wider rays or lesser parenchyma (Shukla et al. 2013).

The fossil resembles *Brachystegia*, especially with *B. eurycoma* Harms. (Kribs 1959, Miles 1978, Ilic 1991).

Lakhanpal and Prakash (1970) instituted the genus *Brachystegioxylon* for the fossil woods showing affinities with *Brachystegia*. To date, three species of this genus, namely *Brachystegioxylon premicrophyllum* Lakhanpal & Prakash (1970), *B. welkitii* (Lemoigne & Beauchamp) Lemoigne (1978) and *B. kaedense* (Delteil-Desneux & Flicoteaux) Lemoigne (1978) are known from various Cenozoic deposits of Africa. The first two species differ from our fossil in having non storied rays, while the third one is distinct due to the presence of scalariform perforation plates. As our fossil is different from the known species, a new species *Brachystegioxylon lakhanpalii* Mehrotra et al., sp. nov. has been instituted. The specific name is after Dr. Lakhanpal who instituted the genus.

Brachystegia Benth. is a tree native to tropical Africa. It is found in the forests of central and southern Africa. *B. eurycoma*, the modern comparable species, occurs along stream-banks at elevations ranging from 500–1,150 m in southern Nigeria and western Cameroon, possibly also in Gabon. A few years back, Shukla et al. (2013) described *Brachystegia* from the Plio- Pleistocene sediments of Kutch (Gujarat) and Jaisalmer (Rajasthan). The present discovery not only confirms its presence in India, but also indicates its wide distribution from west to east.

Genus : *Cassinium* Prakash 1975

***Cassinium prefistulai* Prakash 1975**

(Pl. 4, figs. a–f)

Description: Wood diffuse porous (Pl. 4, fig. a). Growth rings not seen. Vessels medium to large, 111–231 μm in tangential diameter, solitary and in radial multiples of 2–4, evenly distributed, 5–9 per sq mm (Pl. 4, fig. a), filled with gum deposits; vessel members truncate, storied, 325–632 μm in height (Pl. 4, fig. e); perforations simple; intervessel pits bordered, alternate, 5–8 μm in diameter, round to oval, vested (Pl. 4, fig. c). Axial parenchyma in the form of anastomosing bands enclosing the vessels, each > 4 cells wide, sometimes aliform-confluent also (Pl. 4, fig. a); cells 20–24 μm in diameter and 45–83 μm in height. Rays 8–12 per mm,

1–5 (mostly 2–4) seriate, mostly made up of procumbent cells with 1 or 2 rows of upright cells at the margins, 38–80 μm in width and 17–33 cells or 294–594 μm in height (Pl. 4, figs. b, d); ray cells crystalliferous; ray tissue weakly heterogeneous; procumbent cells 19–26 μm in tangential height and 60–86 μm in radial length, upright cells 25–41 μm in tangential height and 27–29 μm in radial length (Pl. 4, fig. f). Fibres angular in cross section, thick walled and non septate.

Figured specimen: Specimen no. BSIP 41053.

Locality: Near Kimin, Papum Pare District, Arunachal Pradesh.

Horizon: Namsang Formation (= Upper Siwalik).

Age: Late Miocene to Pliocene.

Remarks: The important characters of the fossil, namely diffuse porous wood, vested intervessel pits, usually thick anastomosing banded axial parenchyma, 1–5 (mostly 2–4) seriate xylem rays and non septate fibres indicate its nearest affinities with *Cassia* Tournefort ex Linnaeus of the Fabaceae (Pearson & Brown 1932, Kribs 1959, Ilic 1991).

Prakash (1975) established the genus *Cassinium* to include fossil woods showing affinities with *Cassia*. To date, eight species of *Cassinium* are known from various Tertiary exposures of India and Myanmar. These are: *Cassinium variegatum* (Ramanujam) Prakash (1975), *C. borooahii* (Prakash) Prakash (Prakash 1975, Prakash et al. 1994), *C. cassinodosum* (Prakash) Prakash (1975), *C. cassioides* (Prakash & Awasthi) Prakash (1975), *C. prefistulai* Prakash (1975), *C. arcotense* Awasthi (1979), *C. tripuranum* Acharya & Roy (1986) and *C. ballavpureense* Ghosh & Roy (1982). Our fossil differs from *Cassinium variegatum*, *C. arcotense* and *C. ballavpureense* in having non septate fibres. The present fossil shows maximum resemblance with *C. prefistulai* as rays are narrower (mostly 2 to 3 seriate) in the remaining species. Therefore, it has been assigned to *C. prefistulai*.

Cassia is a tropical genus comprising more than 500 species of which 20 are found in the Indian region. However, out of these 20 only 10 attain tree height. *Cassia* is often found in dry deciduous forests (Ramesh Rao et al. 1972).

DISCUSSION

For fossil woods, Nearest Living Relative (NLR) is the most reliable method for the reconstruction of palaeoclimate. It envisages that very little or insignificant change has taken place in wood characters due to climate change. The NLRs of the fossil, namely *Gluta*, *Bauhinia malabarica*, *Brachystegia eurycoma* and *Cassia* indicate tropical conditions with warm and humid climate in the region during the depositional period. The study is also supported by the xylotomical characters which have been used to predict the climate. As all the fossil woods are diffuse porous in nature, they indicate tropical conditions with little seasonality (Wheeler & Baas 1993). The fossil woods lack vasicentric tracheids and possess large vessels with simple perforation plates indicating high precipitation (Wolfe & Upchurch Jr 1987). Punyasena et al. (2008) have suggested that the abundance and richness of the family Fabaceae covary with the temperature. As there is an abundance of fabaceous taxa in the Kimin material, it suggests high temperature.

Significant interchange took place between India and Africa during the late Miocene and Pliocene (~10–2.6 Ma) when land connections were established between Africa and India via the Eurasian corridor (Shukla et al. 2013). The two probable routes for the floral interchange might be: (1) Egypt–Arabia–Persia–Baluchistan–Sind–western India and (2) Ethiopia–South Arabia–Persia–Baluchistan–western India. *Brachystegia*, an African element, might have entered the Indian Subcontinent possibly through one of these routes.

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