Petrified wood remains from the Neogene of Tripura, India

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Dicotyledonous fossil woods described from the Tipam Sandstones (U. Miocene) of Tripura, India include *Terminalioxylong siwalicus* Prakash of Combretaceae, *Euphorioxylon indicum* Awasthi *et al.* of Sapindaceae, *Millettioxylon pongamiensis* Prakash and *Bauhinia tertiara* Awasthi & Mehrotra of Fabaceae, *Anisopteroxylon oblongoides* Yadav of Dipterocarpaceae and *Anacardioxylan shardai* Prakash & Tripathi of Anacardiaceae. Modern comparable forms of the fossil woods indicate the occurrence of a warm humid climate with high rate of precipitation during the growth of the Neogene forest in Tripura.

Key-words – Fossil woods, Dicotyledon, Upper Miocene, Tripura

INTRODUCTION

THE Tipam Sandstone representing the Neogene sediments of Tripura is rich in petrified dicotyledonous woods (Menon, 1975). Tipam Sandstone subgroup is divided lithologically into two distinct formations, the Lower Tipam Formation consisting of fairly bedded, fine to medium grained, sub-arkosic sandstone, while the Upper Tipam (Champanagar) Formation (U. Miocene) is characterized by coarse, poorly sorted massive, friable sub-arkosic sandstone and abundant silicified woods.

Fossil woods have earlier been recorded from Tripura. are *Glutoxylon burmense* (Ghosh & Taneja 1961); *Pahudioxylon sahnii* (Ghosh & Kazmi 1961), *Millettioxylon bengalensis, Cassinium tripuranum* (Acharya & Roy 1986) and *Cynometroxylon holdenii* (Awasthi *et al.* 1994) and *Dipterocarpoxylon bolpurense* (Mehrotra & Bhattacharya 2002).

In the present article six dicotyledonous woods are described from three new Neogene exposures of Tripura.

MATERIAL AND METHOD

The fossil woods for present study were collected by one of us (S.B.) from Baramura, Kunjaban and Yogendranagar areas of Tripura. The slides were prepared by the standard methods of cutting, grinding and polishing using different grades of carborundum powder and finally mounted in Canada Balsam. All slides are kept in the repository of Palaeobotany, Palaeopalynology Laboratory, Department of Botany, University of Calcutta.

Systematic Description

Family - Combretaceae

Genus - *Terminalioxylon* Schonfeld, 1947

Terminalioxylon siwalicus, Prakash 1978 Pl. 1; Figs. 1–4

Wood diffuse porous, growth ring inconspicuous. Vessels mostly medium to large, rarely small, usually solitary, sometimes in radial multiples of 2-4, 5-7 per sq. mm., t.d. 150-375µm, r.d. 150-220µm, length of vessels 130-640µm, tyloses absent, vessels often plugged with reddish brown gummy deposits, intervessel pits bordered, alternate, vestured, 4-10µm in diameter. Parenchyma paratracheal and apotracheal, paratracheal parenchyma vasicentric aliform, occasionally confluent joining adjacent vessels; apotracheal parenchyma sparse and diffuse, 16-32µm in diameter, 30-32µm in length. Xylem rays strictly uniseriate, 7-9 per mm, 3-15 cells high or 92-450µm in length, 15-30µm in diameter, rays heterocellular, consisting of both procumbent and upright cells; procumbent cells 80-96µm in length, 32-45 µm in breadth and upright cells 80-96µm in length, 45-65 µm in breadth. Fibres nonseptate, moderately thick-walled, 30-50µm in diameter.

Affinities: Presence of inconspicuous growth rings, uniseriate, heterocellular xylem rays, vasicentric to aliform and occasionally confluent paratracheal

parenchyma suggest the affinity of the present wood with *Terminalia* of Combretaceae.

About 37 species of this genus are known from India and abroad. The Indian species include *Terminalioxylon ghoshii* (Satyanarayan and Mahabale 1984) from East Godavari district, Andhra Pradesh; *T. tomentosum* (Mahabale & Deshpande 1965) and *T. burmense* (Guleria 1983) from Kachchh, Gujarat; *T. tertiarum* (Prakash & Tripathi 1975), *Terminalioxylon* sp. (Deb & Ghosh 1974) from West Bengal, *T. varkalaensis* (Awasthi & Ahuja 1982) from Kerala; *T. grandiporosum* (Ramanujam 1966) from South India, *T. siwalicus* (Prakash 1978) from Kalagarh, U.P., *T. chowdhurii* (Prakash & Navale 1963) from Assam and *T. coriaceum* (Prakash & Awasthi 1971) from Arunachal Pradesh.

A thorough comparison with all the known species of *Terminalioxylon* reported from India indicates some resemblance of the present fossil with *T. chowdhurii, T. coriaceum* and *T. siwalicus*. A closer resembance with *T. siwalicus* was noticed with some minor variations and therefore the present fossil is assigned to the same species.

Family - Sapindaceae

Genus - *Euphorioxylon* Awasthi *et al.* 1982
Euphorioxylon indicum Awasthi *et al.* 1982
Pl. 1, Figs. 5–9

Wood diffuse porous, growth rings not observed. Vessels small to medium, t.d. 50-170μm, r.d. 100-250μm, solitary and in radial multiples of 2-4, evenly distributed, sometimes flattened due to compression, 8-16 per sq. mm., vessel members 450-600μm in length, intervessel pits bordered, alternate, orbicular, 4-6μm in diameter. Parenchyma scanty, paratracheal, 40-60μm in length and 20-22μm in width. Rays uniseriate, 12-16 per mm, homocellular, made up of procumbent cells, rays 4-30 cells or 200-650μm in height and 10-25μm in width and fibres nonseptate, 4-12μm in diameter.

Affinities: The anatomical features of the present fossil clearly indicate its close resemblance with extant *Euphoria* and xylotomically allied genera of Sapindaceae and thus assigned it to the genus *Euphorioxylon*. So far, two species of this genus are reported from India, viz. *Euphorioxylon indicum* Awasthi *et al.*, 1982 from Cuddalore Series of Pondicherry, Kankawati Series of Kachchh, Arunachal Pradesh, Assam and Kerala (Awasthi *et al.* 1982, Awasthi & Mehrotra 1993, Prasad 1993, Prakash *et al.* 1994, Srivastava & Awasthi, 1994) and *E. deccanense* (Mehrotra 1987) from Madhya Pradesh, Neyveli Lignite deposits of Tamil Nadu and Arunachal Pradesh (Mehrotra, 1987, Agarwal, 1996 and Awasthi *et al.* 1999). The present fossil resembles *E. indicum* in having small to medium sized vessels, uniseriate and homocellular rays and hence assigned to the same species.

Family - Fabaceae

Genus - *Millettioxylon* Awasthi 1967
Millettioxylon pongamiensis Prakash 1975
Pl. 2, Figs. 3-4,6

Wood diffuse porous, growth rings present, vessels small to large, t.d. 70-180μm, r.d. 80-350μm, mostly solitary and in radial multiples of 2-3, 3-4 per sq. mm., intervessel pits vestured, alternate, 4-6μm in diameter with lenticular apertures. Parenchyma in 4-8 seriate, concentric tangential bands alternating with the fibres. Rays 1-3 seriate, 5-30 cells or 180-340μm in height, homocellular, made up of procumbent cells, 60-

PLATE 1 →

1-4. *Terminalioxylon siwalicus* Prakash
1. T.S. showing distribution of vessels and parenchyma
2. T.L.S. showing vascular rays
3. T.L.S. showing intervessel pits
4. R.L.S. showing ray histology
5-9. *Euphorioxylon indicum* Awasthi et al.
5: T.S. showing distribution of vessels, parenchyma and fibres
6: T.L.S. showing distribution and dimension of vascular rays and fibres
7: T.L.S. showing intervessel pits
8: R.L.S. showing ray histology
9. same enlarged

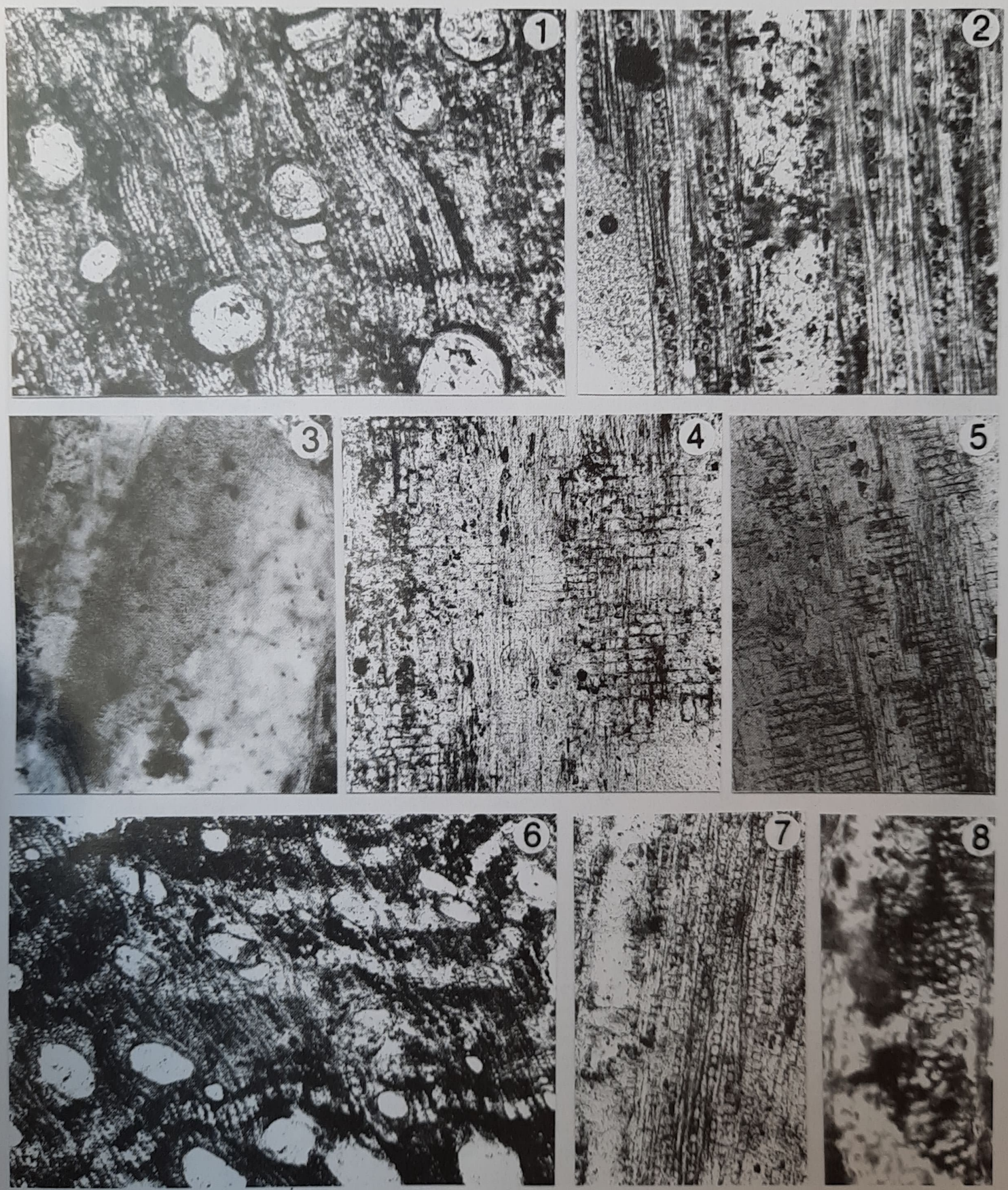

PLATE 1

80μm in radial length and 15-32μm in tangential height, 8-10 per mm. Fibres libriform, nonseptate, polygonal in cross section, 15-25μm in diameter.

Affinities: So far about six species of *Millettioxylon* are reported from different parts of India and abroad, *viz. M. indicum* from Cuddalore Series, South India (Awasthi, 1967, 1975) and Upper Tertiary of Thailand (Prakash 1979); *M. pongamiensis* from Himachal Pradesh and also from West Bengal (Prakash 1975; Bande & Prakash, 1980, Ghosh & Roy, 1981; Bera & Banerjee, 2001); *M. palaeopulchra* from Mio-Pliocene beds of Deomali (Lakhanpal *et al.* 1981); *M. bengalensis* from Midnapur, West Bengal (Ghosh & Roy 1979); *M. kalagarhensis* from Kalagarh, U.P. (Trivedi & Mishra 1980) and *M. embergeri* from Miocene of Ethiopia (Lemoigne 1978).

Presence of concentric tangential bands, 1-3 seriate homogeneous xylem rays and nonseptate fibres suggest that the present fossil wood is identical to *Millettioxylon pongamiensis*.

Family - Fabaceae

Genus - *Bauhinia* Linn.

Bauhinia tertiara Awasthi & Mehrotra 1990

Pl. 3, Figs. 5–8

Wood diffuse porous, growth rings absent. Vessels small to large, t.d. 70-170μm, r.d. 72-250μm, mostly solitary, occasionally in radial multiples of 2-4, evenly distributed, 2-10 per sq. mm., tyloses present, vessel members 100-350μm long, storied, intervessel pits bordered, alternate, circular in shape with lenticular apertures. Parenchyma paratracheal, mostly aliform to confluent, banded, joining adjacent vessels; parenchyma cells 15-45μm in width and 50-100μm in length. Rays mostly uniseriate 10-12 per mm, weakly heterocellular, rays 8-60 cells or 150-950μm in height, 16-40μm in width; procumbent cells 30-60μm in radial length and 16-30μm in tangential height, upright cells 40-48μm in tangential length and 16-20μm in radial length. Fibres nonseptate, 8-15μm in diameter.

Affinities: Presence of tylosed vessel members, predominantly uniseriate xylem rays and vasicentric, aliform to confluent parenchyma indicates the affinity of the present wood with *Bauhinia* of Fabaceae.

The fossil woods of *Bauhinia* are of common occurrence in Neogene deposits of India. They have been described as *Bauhinium miocenicum* Trivedi & Panjwani, 1986 and *B. palaeomalabaricum* Prakash & Prasad, 1984 from the Siwalik beds of Kalagarh, Uttar Pradesh and Darjeeling District, West Bengal (Antal *et al.* 1996), from Cuddalore Series (Ramanujam & Rao 1966), *Bauhinia deomalica* Awasthi & Prakash 1987 from Deomali, Arunachal Pradesh and *Bauhinia tertiara* from Tipam Sandstone, Nagaland (Awasthi & Mehrotra 1990). Comparative account of the present fossil wood with other known fossil species of *Bauhinia* suggests its closer resemblance with *Bauhinia tertiara* Awasthi & Mehrotra.

Family - Dipterocarpaceae

Genus - *Anisopteroxylon* Ghosh & Kazmi, 1958

Anisopteroxylon oblongoides Yadav 1988

Pl. 2, Figs. 1-2,5

Wood diffuse porous, growth rings absent. Vessels mostly solitary or in pairs, thick-walled, t.d. 105-190μm, r.d. 150-270μm, perforation simple, intervessel pits vestured, tyloses present. Parenchyma both paratracheal and apotracheal, paratracheal parenchyma vasicentric, apotracheal parenchyma diffuse, cells thin walled, 32-45μm in diameter and 65-125μm in length. Gum canals vertical, solitary, encircled by parenchyma cells, 90-120μm in diameter. Xylem rays broad, 1-6 seriate, 5-8

PLATE 2

1-2,5: *Anisopteroxylon oblongoides* Yadav

1. T.S. showing distribution of vessels, parenchyma and gum canals
2. T.L.S. showing vascular ray dimension and fibres
5. R.L.S. showing ray histology

3-4,6. *Millettioxylon pongamiensis* Prakash

3. T.S. showing distribution of vessels and parenchyma
4. T.L.S. showing distribution and dimension of vascular rays and fibres
6. R.L.S. showing ray histology

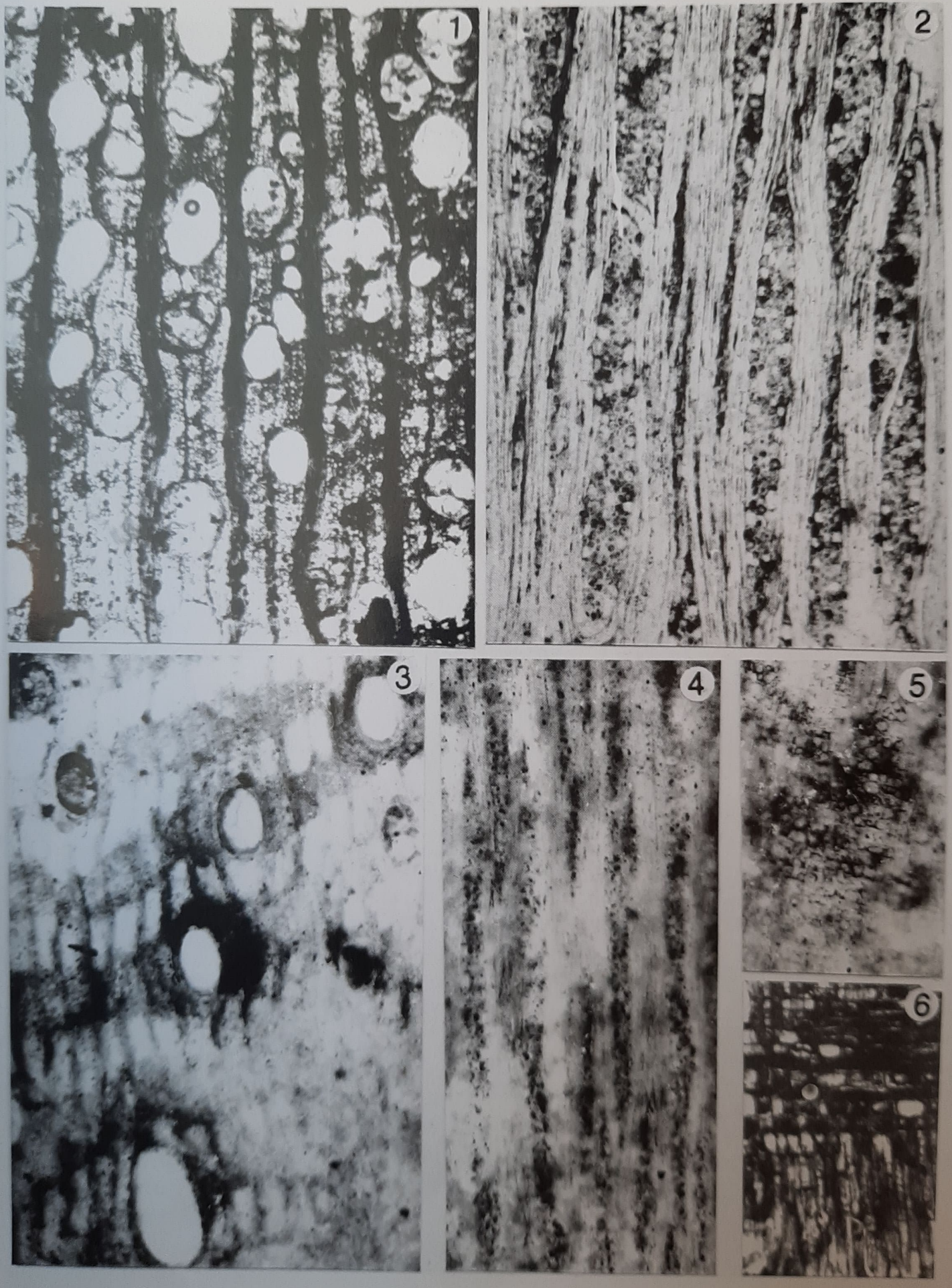

PLATE 2

per mm, 6-50 cells or 250-720μm in height, ray tissue heterocellular, composed of both upright and procumbent cells, procumbent cells 10-22μm in vertical height and 60-80μm in radial length, upright cells 45-55μm in vertical height and 12-25μm in radial length forming 1-2 marginal rows at one or both ends and also present as sheath cells along the flanks of multiseriate rays. Fibres, thick-walled 14-20μm in diameter.

Affinities: The present fossil wood shows marked resemblance with modern woods of *Anisoptera* of Dipterocarpaceae, in the nature of vessel arrangement, ray structure, type and pattern of gum canal distribution.

Different species of *Anisopteroxylon* are known from the Tertiary sediments of India and South Asia (Ghosh & Kazmi 1958; Ghosh & Ghosh 1958, Ramanujam 1960, Navale 1963; Prakash & Tripathi 1970; Prakash, 1978; Ghosh & Roy, 1980; Yadav 1988, Bera & Banerjee 2001). The fossil wood shows closest similarity with *Anisopteroxylon oblongoides* in possessing broad, fusiform xylem rays, vertical gum canals in long tangential rows and having broad xylem rays. Thus, the present fossil wood is identified as *Anisopteroxylon oblongoides* Yadav.

Family - Anacardiaceae

Genus - *Anacardioxylon* Felix, 1882

Anacardioxylon shardai Prakash & Tripathi, 1976

Pl. 3, Figs. 1-4

Wood diffuse porous, growth rings delineated by terminal parenchyma bands. Vessels mostly solitary, small to large, 2-3 per sq mm, tyloses abundant, vessels with gummy deposits, t.d. of vessels 40-220μm, r.d. 45-300μm, 200-550μm in length, intervessel pits large, alternate, bordered, 4-6μm in diameter. Rays 1-3 (mostly 2) seriate, 12-50μm in width and 1-22 cells or 45-500μm in height, ray tissue heterocellular composed of procumbent and upright cells; procumbent cells 20-35μm in tangential height and 80-105μm in radial length, upright cells 60-85μm in tangential height 15-45μm in radial length. Parenchyma paratracheal and apotracheal; paratracheal parenchyma aliform to aliform confluent, forming 1-3 cells thick sheath around the vessels, apotracheal parenchyma in 4-5 cells broad bands. Fibres septate, angular in cross section, 30-40μm in diameter.

Affinities: The characteristic anatomical features exhibited by the present fossil wood indicate its resemblance with *Anacardioxylon* of Anacardiaceae.

Many fossil woods belonging to *Anacardioxylon* are reported from India and abroad, *viz. A. spondiaeforme* Felix 1882 from Antigua, *A. magniporosum* Platen 1908 from California, *A. semecarpoides* Prakash & Dayal 1965 from Nagpur, *A. shardai* Prakash & Tripathi 1976 from the Tertiary of Assam and *A. ratnagiriense* Phadtare & Kulkarni 1984 from Maharashtra.

Comparing all known fossil species, the present fossil wood is found xylotomically similar to *Anacardioxylon shardai* having affinity with the extant *Mangifera* spp. (Prakash & Tripathi, 1976).

DISCUSSION

The occurrence of six taxa of fossil dicotyledonous woods *viz. Terminalioxylon siwalicus, Euphorioxylon indicum, Millettioxylon pongamiensis, Bauhinia tertiara, Anisopteroxylon oblongoides* and *Anacardioxylon shardai* from the Tipam Sandstone of Tripura, indicates that the members of the families like Combretaceae, Sapindaceae, Fabaceae, Dipterocarpaceae and Anacardiaceae were common elements in the Neogene forests of Tripura. The comparable extant forms of the

PLATE 3

1-4: *Anacardioxylon shardai* Prakash & Tripathi

1. T.S. showing distribution of vessels, parenchyma and fibres
2. T.L.S. showing dimension of vascular rays and fibres
3. T.L.S. showing intervessel pits
4. R.L.S. showing ray histology

5-8. *Bauhinia tertiara* Awasthi & Mehrotra

5. R.L.S. showing ray histology
6. T.S. showing distribution of vessels and parenchyma
7. T.L.S. showing distribution and dimension of vascular rays and fibres
8. T.L.S. showing intervessel pits

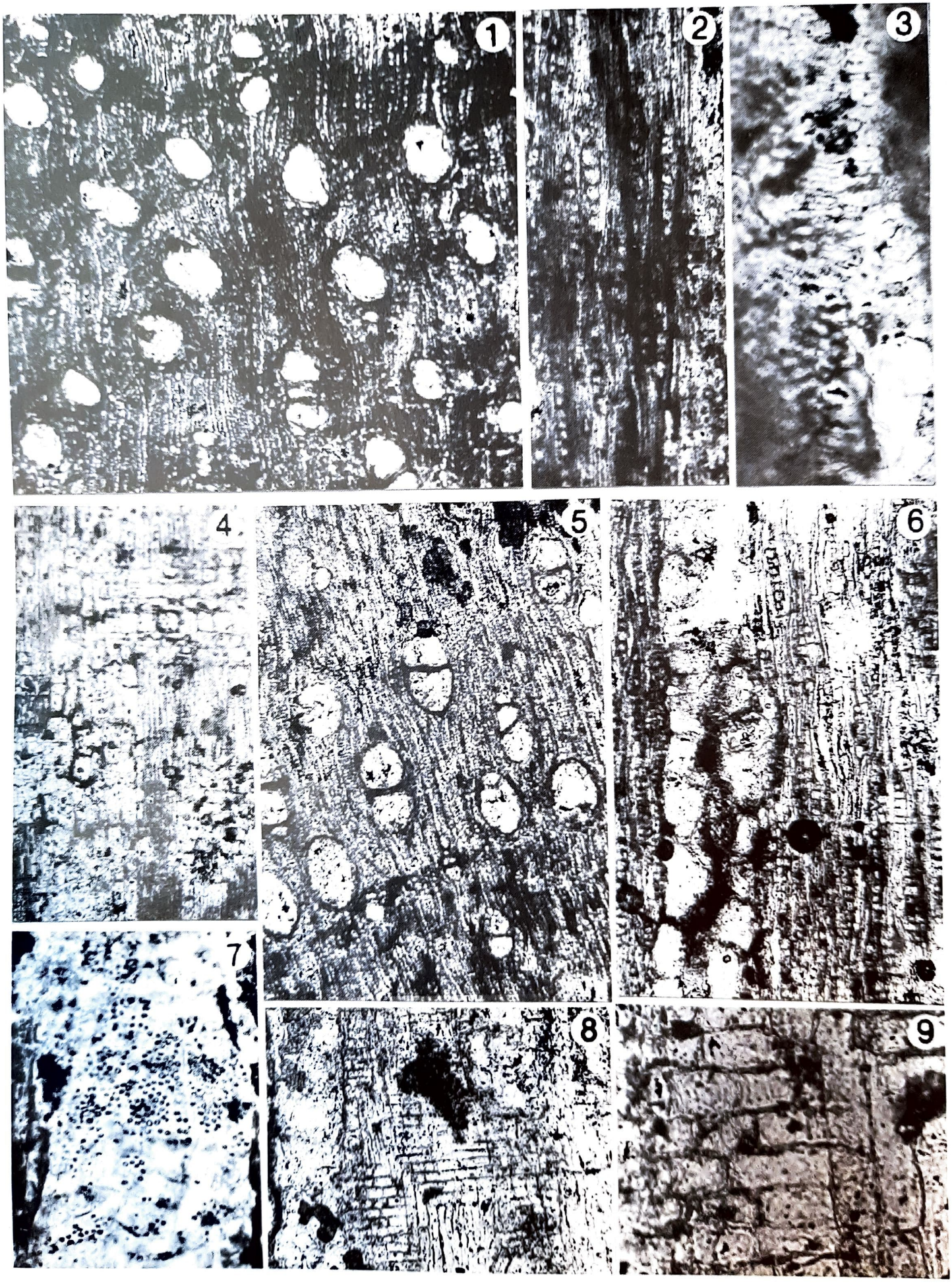

PLATE 3

described fossil woods, *viz.*, *Terminalia, Euphoria, Millettia, Bauhinia, Anisoptera* and *Mangifera* are abundantly found to grow in the rich deciduous-evergreen forest of India. At present sixteen species of *Terminalia* are found in the tropical moist- dry deciduous forests of India, Myanmar and Sri Lanka; *Euphoria* and allied genera grow in the tropical evergreen to montane subtropical forests of Western Ghats, Assam in India, South China, Myanmar, Malaysia and Sri Lanka, species of *Millettia* are the common elements in the foot hills of eastern Himalayas and Assam and throughout the greater part of India and Myanmar particularly in the tidal and beach forests, thirty two species of *Bauhinia* grow in the sub -Himalayan tract, dry forests over most of eastern, central and south India, Nepal and Myanmar; the genus *Anisoptera* consisting of about thirty species is now widely distributed in the evergreen forests from Chittagong in Bangladesh, Myanmar to New Guinea in the Pacific and *Mangifera* with forty one evergreen species confined mainly to Indo-Malayan region (Gamble 1972).

The extant taxa of the petrified wood assemblage and their present day distribution pattern clearly indicate a tropical climate suggesting prevalence of a warm, humid condition with high rate of precipitation during deposition of Neogene sediments in Tripura. Earlier, on palynological investigation of subsurface Neogene sediments of Ḃaramura-2 well and nearby exposures of Atharmura Anticline, an identical climatic condition was suggested (Salujha & Kindra 1979, 1984).

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