Some fossil woods from Tipam Sandstone of Assam and Nagaland

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The paper records four fossil woods, viz., *Koompassioxylon elegans* Kramer, *Bauhinia tertiara* sp. nov., *Bischofia palaeojavanica* Awasthi and *Laurinoxylon naginimariense* sp. nov. from the Tipam Sandstone of Assam and Nagaland. These show close resemblance with the woods of extant genera, viz., *Koompassia, Bauhinia, Bischofia* and Lauraceae, respectively. Occurrence of *Koompassia* in the Indian and southeast Asian Neogene sediments provides further evidence of a close phytogeographical link between Indian subcontinent and southeast Asia.

Key-words—Fossil woods, Fabaceae, Lauraceae, Bischofiaceae, Tipam Sandstone, Late Miocene (India).

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सारॉंश

असम एवं नागालैंड के तिपम बालुपत्थर से कुछ अश्मित काष्ठें

नीलाम्बर अवस्थी एवं राकेश चन्द्र मेहरोत्रा

असम एवं नागालैंड के तिपम बालुपत्थर से **कूम्पासिऑक्सीलान एलिगेन्स** क्रेमर, **बॉहीनिआ टर्शियेरा** नव जाति, **बिस्क्वेफ़िआ पेलियोजावानिका** अवस्थी एवं **लॉरीनॉक्सीलॉन नगीनीमारीयेन्से** नव जाति नामक चार अश्मित काष्ठों का वर्णन किया गया है। ये काष्ठें क्रमशः वर्तमान **कूम्पासिआ, बॉहीनिआ, बिस्क्वेफ़िआ** नामक प्रजातियों तथा लॉरेसी कुल से घनिष्ठ समानता प्रदर्शित करते हैं। भारतीय एवं दक्षिण-पूर्व एशिया के पश्चनूतन कालीन अवसादों में **कूम्पासिआ** की उपस्थिति से इन दो उपमहाद्वीपों के बीच पादप-भौगोलिक सम्बन्ध व्यक्त होता है।

THE Neogene sediments belonging to the Tipam Group are well-developed throughout northeast India. They generally contain plant remains in the form of silicified and semicarbonised woods associated with coarse, loose, ferruginous, mottled sandstones, sandy clays and pebbles. Detailed anatomical studies of the fossil woods carried out by several workers (Chowdhury, 1936; 1938; Chowdhury & Ghosh, 1946; Chowdhury & Tandon, 1949; Ghosh, 1956; Eyde, 1963; Prakash, 1966; Prakash & Tripathi, 1969a, b, 1970a, b, 1972, 1974, 1975, 1976, 1977; Prakash & Awasthi, 1970, 1971; Prakash & Lalitha, 1978; Lalitha & Prakash, 1980; Prakash, Bande & Lalitha, 1986) from Assam and Nagaland have revealed the presence of a number of tropical dicotyledonous genera belonging to the families Flacourtiaceae, Clusiaceae (Guttiferae), Dipterocarpaceae, Celastraceae, Sterculiaceae, Elaeocarpaceae, Fabaceae (Leguminosae), Combretaceae, Lecythidaceae, Lythraceae, Sonneratiaceae, Sapotaceae, Ebenaceae, Verbenaceae, Lauraceae, Euphorbiaceae, and Moraceae. With the intention of updating the flora of Tipam Group and for better understanding of the palaeoenvironment and phytogeography, we have further carried out detailed investigation of fossil woods from these areas. Amongst them, the fossil woods showing close resemblance with the woods of extant *Koompassia, Bauhinia, Bischofia* and a lauraceous member, are described in the present paper.

SYSTEMATIC DESCRIPTION

Family—Fabaceae (Leguminosae)

Genus—*Koompassioxylon* Kramer 1974

Koompassioxylon elegans Kramer 1974
Pl. 1, figs 1, 4, 6

Description—*Wood* diffuse-porous (Pl. 1, fig. 1). *Growth rings* not seen. *Vessels* small to large, t.d. 72-240 μm, r.d. 52-280 μm, round to oval, solitary and

in radial multiples of 2-6, rarely in tangential pairs, evenly distributed, 3-7 per sq mm (Pl. 1, fig. 1), perforations simple; vessel-members storied; intervessel pits bordered, alternate, 6-8 μm in diameter, vestured. *Parenchyma* paratracheal, aliform, confluent to confluent-banded, bands up to 5 cells thick (Pl. 1, fig. 1), strands storied. *Xylem rays* 1-3 (mostly 2) seriate, 6-8 per mm, storied (Pl 1, fig. 6); ray tissue heterogeneous; uniseriate rays 4-15 cells or 80-280 μm in height, composed wholly of procumbent cells; multiseriate rays 6-21 cells or 140-400 μm in height, mostly consisting of procumbent cells, sometimes with single row of upright or square cells at one or both the ends (Pl. 1, fig. 4). *Fibres* angular in cross section, 12-20 μm in diameter, about 560 μm in length, thick-walled, non-septate. *Ripple marks* present due to storied arrangement of vessel members, parenchyma strands and rays (Pl. 1, fig. 4).

Affinities—The above anatomical characters of fossil wood collectively indicate its close similarity with that of the Malayan *Koompassia malaccensis* and the fossil wood—*Koompassioxylon elegans* Kramer reported earlier from the Neogene of south-east Asia and Bengal (Kramer, 1974; Bande & Prakash, 1980).

Figured specimen—Museum specimen no. BSIP 36351.

Locality—Bimlapur, Dibrugarh District, Assam

Genus—*Bauhinia* Linn.

Bauhinia tertiara sp. nov.
Pl. 1, figs 3, 8; Pl. 2, figs 1-3

Single piece of well-preserved secondary wood measuring about 13 cm in length and 3 cm in width.

Description—Wood diffuse-porous (Pl. 2, fig. 1). *Growth rings* not observed. *Vessels* small to large, mostly medium in size, t.d. 72-180 μm, r.d. 72-280 μm, mostly solitary, occasionally in radial multiples of 2-4, evenly distributed, 3-11 per sq mm, oval in shape when solitary, with flat contact walls when in multiples (Pl. 2, fig. 1); tyloses present; perforations simple; vessel-members 100-380 μm long with oblique to horizontal ends, storied (Pl. 1, fig. 3), intervessel pits bordered, alternate, 4-8 μm in diameter, almost circular in shape with lenticular apertures (Pl. 1, fig. 8). *Parenchyma* vasicentric, having 3-5-celled sheath completely enclosing vessels, mostly aliform to confluent, banded, joining several adjacent vessels (Pl. 2, fig. 1); parenchyma strands storied, cells 16-48 μm in width and 48-100 μm in length. *Xylem rays* 1-2 seriate, mostly uniseriate, 9-12 per mm, usually made up of procumbent cells, storied (Pl. 2, figs 2, 3); ray tissue weakly heterogeneous, rays 16-44 μm in width and 8-60 cells or 160-960 μm in height; procumbent cells 32-60 μm in radial length and 16-32 μm in tangential height; upright cells 44-48 μm in tangential height and 16-20 μm in radial length. *Fibres* moderately thick-walled, angular in cross section, 8-16 μm in diameter and 440-600 μm in length, non-septate (Pl. 2, figs 1, 3). *Ripple marks* present due to storied arrangement of vessel-members, parenchyma strands and rays (Pl. 2, figs 2, 3)

Holotype—Museum specimen no. BSIP 36352.

Locality—Naginimara Village, Kongan Coalfield, Mon District, Nagaland.

Affinities—Presence of ripple marks due to storied arrangements of vessel-members, parenchyma strands and xylem rays, tylosed vessels, vasicentric, aliform to confluent-banded parenchyma, predominantly uniseriate xylem rays and non-septate fibres indicate its affinity with *Bauhinia* Linn. of Fabaceae (Metcalfe & Chalk, 1950; Rao *et al.*, 1972). Wood slides of five species of *Bauhinia*, viz., *B. malabarica* Roxb., *B. mirandina* Pittier, *B. purpurea* Linn., *B. racemosa* Lam. and *B. variegata* Linn. were examined for comparison of the fossil wood; the descriptions and photographs of

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PLATE 1 →

1. *Koompassioxylon elegans* Kramer 1974: Cross section showing shape, size and distribution of vessels and parenchyma pattern, × 45; Slide no. BSIP 36351-I.
2. *Koompassia malaccensis* Maing. ex Benth.: Cross section showing similar nature and distribution of vessels and parenchyma as in fossil, × 45.
3. *Bauhinia tertiara* sp. nov. Radial longitudinal section showing storied nature of vessel elements, × 100; Slide no. BSIP 36352-III.
4. *Koompassioxylon elegans* Kramer 1974: Tangential longitudinal section showing storied rays, × 45; Slide no. BSIP 36351-II.
5. *Koompassia excelsa* (Becc.) Taub.: Tangential longitudinal section showing similar storied rays, × 45.
6. *Koompassioxylon elegans* Kramer 1974: Tangential section showing details of ray cells, × 120; Slide no. BSIP 36351-II.
7. *Laurinoxylon naginimariense* sp. nov.: Radial longitudinal section showing oil cells in rays, × 120; Slide no. BSIP 36353-III.
8. *Bauhinia tertiara* sp. nov.: Intervessel pits, × 600; Slide no. BSIP 36352-III.
9. *Laurinoxylon naginimariense* sp. nov.: Intervessel pits, × 600; Slide no. BSIP 36353-II.

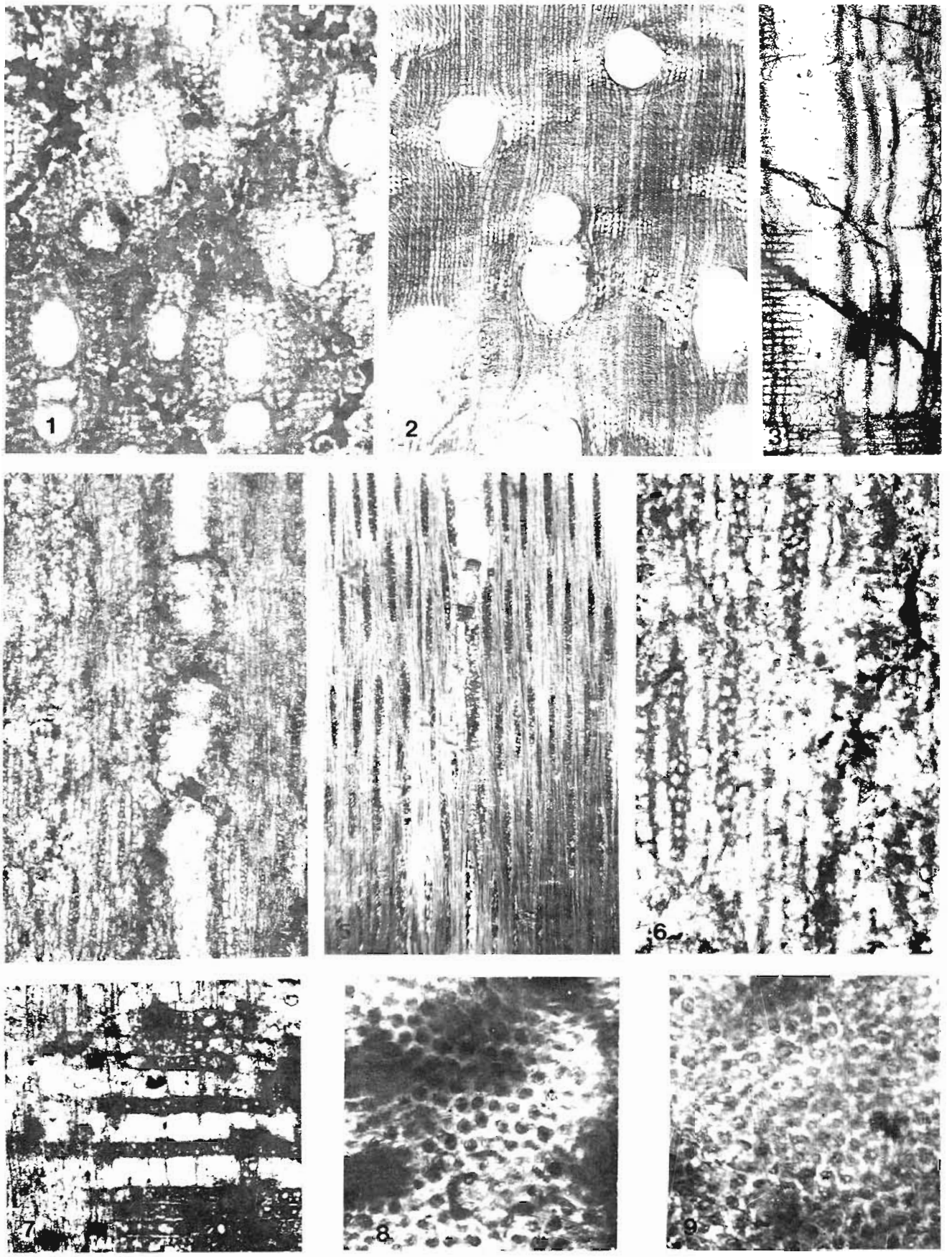

PLATE 1

two other species, *B. foveolata* Dalz. and *B. retusa* Ham. (Pearson & Brown, 1932; Rao *et al.*, 1972) were also consulted. It has been found that the present fossil wood shows closest resemblance with *B. racemosa* and differs from other species in several features. *B. purpurea* and *B. variegata* differ from the fossil in the absence of ripple marks. In *B. mirandina*, the parenchyma is relatively less (vasicentric) and the rays are broader (1-3 seriate). While in *B. foveolata, B. malabarica* and *B. retusa* the amount of parenchyma is more than in the present fossil wood.

The fossil woods of *Bauhinia* are of common occurrence in the Neogene deposits of India. They have been described as *Bauhinium miocenicum* Trivedi & Panjwani (1986) and *B. palaeomalabaricum* Prakash & Prasad (1984), both from the Siwalik beds of Kalagarh, Uttar Pradesh, cf. *Bauhinia* from the Cuddalore Series of Cauvery Basin (Ramanujam & Rao, 1966) and *Bauhinia deomalica* Awasthi & Prakash 1987 from the Namsang beds of Deomali, Arunachal Pradesh. Fossil woods cf. *Bauhinia* (Ramanujam & Rao, 1966), *Bauhinium miocenicum* and *B. palaeomalabaricum* differ from this Nagaland wood in having relatively broad and continuous parenchyma bands. Moreover, in *B. miocenicum* the xylem rays are broader. In *B. deomalica* the parenchyma is mostly banded, whereas in our fossil it is vasicentric to aliform-confluent. Therefore, the present fossil wood is assigned to *Bauhinia tertiara* sp. nov.

Family—Lauraceae

Genus—*Laurinoxylon* Felix 1883

Laurinoxylon naginimariense sp. nov.
Pl. 1, figs 7, 9; Pl. 2, figs 4-6

This species is represented by a small piece of secondary wood measuring 7 cm in length and 2.5 cm in width.

Description—*Wood* diffuse-porous (Pl. 2, fig. 4). *Growth rings* indistinct. *Vessels* usually medium to large, occasionally small, rarely very small, t.d. 80-320 μm, r.d. 40-320 μm, mostly round to oval, sometimes flattened due to compression, usually solitary, occasionally in radial multiples of 2-3 (rarely up to 5), uniformly distributed, 2-6 per sq mm (Pl. 2, fig. 4); tyloses present; perforations simple; vessel-members 240-360 μm long with oblique to horizontal ends; intervessel pits bordered, alternate, minute, less than 4 μm in diameter, circular to oval in shape with linear apertures (Pl. 1, fig. 9). *Parenchyma* vasicentric to aliform, sometimes confluent joining adjacent vessels (Pl. 2, figs 4, 6); parenchyma cells 16-32 μm in diameter and 20-120 μm in length. *Xylem rays* 1-5 (mostly 2) seriate, 8-11 per mm, usually made up of procumbent cells; uniseriate rays 12-20 μm in width and 2-10 cells or 48-220 μm in height; multiseriate rays 24-72 μm in width and 5-25 cells or 88-340 μm in height (Pl. 2, fig. 5); ray tissue heterogeneous; rays homocellular to heterocellular (Pl. 1, fig. 7), consisting of procumbent cells and oil cells at one or both the ends; ray cells 40-80 μm in radial length and 16-40 μm in tangential height. *Fibres* moderately thick-walled, angular in cross section, 8-20 μm in diameter and 200-560 μm in length. *Oil cells* associated with xylem rays either in the middle portion or at the margins of rays, also present scattered among fibres either singly or in pairs, 44-60 μm in tangenital height and 40-52 μm in radial length (Pl. 1, fig. 7; Pl. 2, figs 4-6).

Holotype—Specimen no. BSIP 36353.

Locality—Naginimara Village, Kongan Coalfield, Mon District, Nagaland.

Affinities—In having mostly solitary vessels with occasional multiples, septate fibres, heterogeneous xylem rays, paratracheal parenchyma and oil cells, the present fossil wood shows resemblance with the members of the family Lauraceae.

PLATE 2 →

1. *Bauhinia tertiara* sp. nov.: Cross section showing nature and distribution of vessels and parenchyma, × 40; Slide no. BSIP 36352-I.
2. *Bauhinia tertiara* sp. nov.: Tangential longitudinal section showing xylem rays, × 65; Slide no. BSIP 36352-II.
3. *Bauhinia tertiara* sp. nov.: Tangential longitudinal section showing ray cells and fibres, × 100; Slide no. BSIP 36352-IV.
4. *Laurinoxylon naginimariense* sp. nov.: Cross section showing nature and distribution of vessels and oil cells, × 25; Slide no. BSIP 36353-I.
5. *Laurinoxylon naginimariense* sp. nov. Tangential longitudinal section showing xylem rays, fibres and oil cells, × 80; Slide no. BSIP 36353-II.
6. *Laurinoxylon naginimariense* sp. nov.: Cross section showing paratracheal parenchyma and oil cells, × 70; Slide no BSIP 36353-I.
7. *Bischofia palaeojavanica* Awasthi 1990: Cross section showing nature and distribution of vessels, × 50; Slide no. BSIP 36354-I.
8. *Bischofia palaeojavanica* Awasthi 1990: Tangential longitudinal section showing xylem rays and septate fibres, × 90; Slide no. BSIP 36354-II.

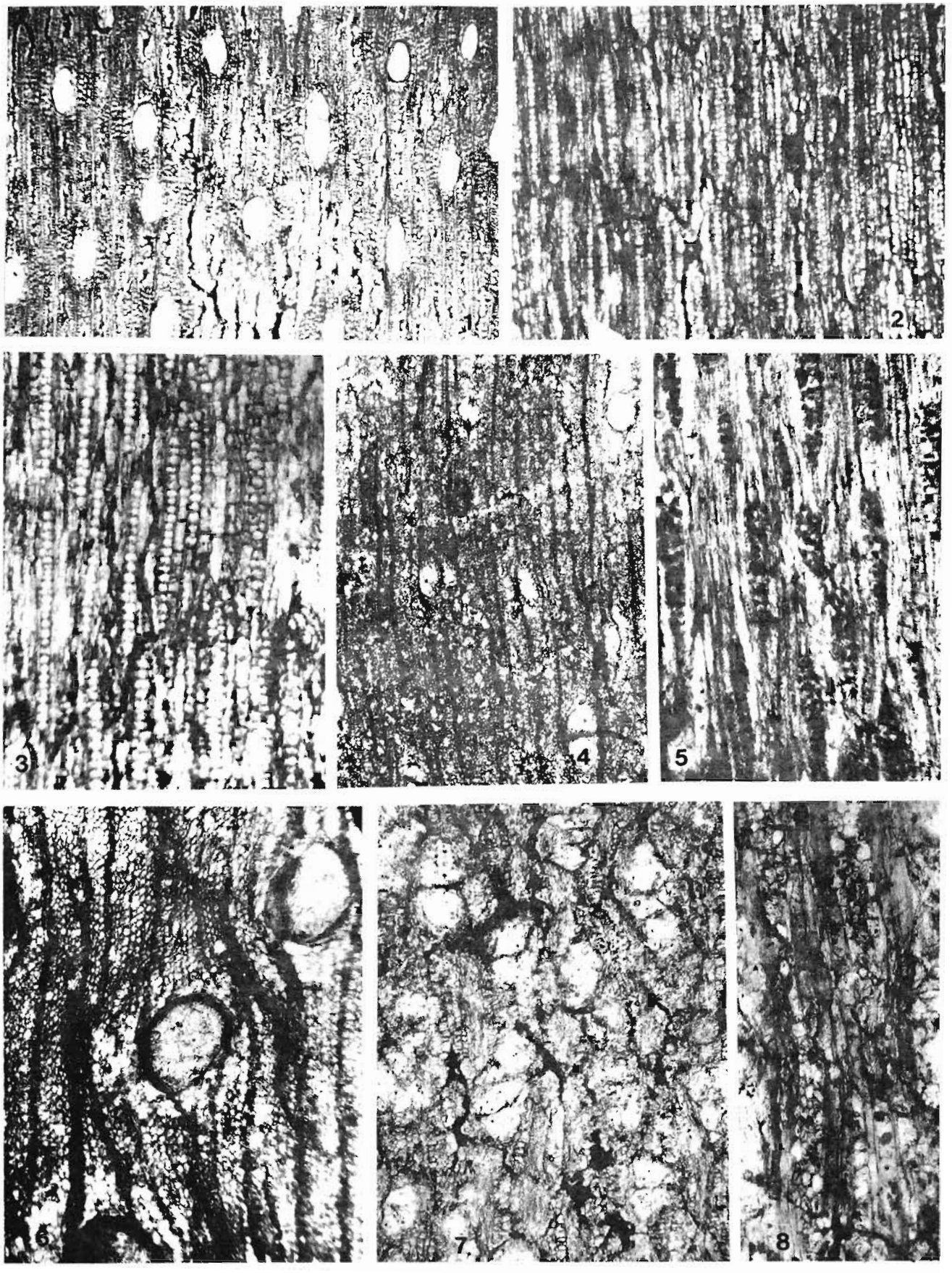

PLATE 2

The family Lauraceae is homogeneous in wood anatomy, thus on the basis of individual genus differentiation is difficult. Therefore, all the lauraceous fossil woods described so far from different parts of the world are placed under the genus *Laurinoxylon* Felix 1883. From India, four species of *Laurinoxylon* are known. They are *Laurinoxylon tertiarum* Prakash & Tripathi 1974 from Tipam Sandstone of Hailakandi, Assam; *L. namsangensis* Lakhanpal *et al.* 1981 and *L. deomaliensis* Lakhanpal *et al.* 1981 from Namsang beds of Deomali, Arunachal Pradesh and *L. varkalaensis* Awasthi & Ahuja 1982 from the Neogene of Varkala, Kerala. The important characters of these fossil woods are summarized in Table 1. *Laurinoxylon tertiarum* differs from the present

Table 1—Important anatomical characters of *Laurinoxylon* Felix known from India

FOSSIL SPECIES	GROWTH RINGS	VESSELS	PARENCHYMA	XYLEM RAYS	FIBRES	OIL CELLS
Laurinoxylon tertiarum Prakash & Tripathi 1974	Distinct	t.d. 60-152 μm, r.d. 80-200 μm, solitary and in radial multiples of 2-4; 8-10 per sq mm; tyloses present; perforations simple and scalariform	Scanty to vasicentric, forming 1-3 celled sheath, sometimes aliform, rarely confluent joining 2-3 adjacent vessels	1-3 (mostly 2) seriate, 1-24 cells in height, enlarged upright cells at the margins	Non-libriform to semi-libriform, septate	Present in xylem rays, parenchyma cells and fibres
L. namsangensis Lakhanpal *et al.* 1981	Not seen	t.d. 75-300 μm, r.d. 75-405 μm, solitary and in radial multiples of 2-5, 8-10 per sq mm; tyloses profuse; perforations simple	Scanty paratracheal, rarely forming uniseriate sheath	2 seriate (rarely 3 seriate), 5-22 cells in height, single row of marginal upright or square cells present	Thick-walled, septate	Present in xylem rays
L. deomaliensis Lakhanpal *et al.* 1981	Present	t.d. 60-120 μm, r.d. 40-320 μm, solitary and in radial multiples of 2-5, occasionally up to 8, 12-44 per sq mm; tyloses present; perforations simple	Scanty paratracheal	1-2 (mostly 2) seriate, 5-30 cells in height, single marginal row of upright or square cells present	Moderately thick-walled, septate	Abundant; scattered singly among fibres
L. varkalaensis Awasthi & Ahuja 1982	Not seen	t.d. 80-240 μm, r.d. 128-280 μm, solitary and in radial multiples of 3-4, closely placed; tyloses profuse; perforations simple	Paratracheal, 2-3 seriate sheath around vessels, sometimes aliform	1-3 (mostly 2) seriate, 12-45 cells high, 1-2 enlarged upright cells at the margins	Semi-libriform to libriform, septate	Present among fibres and at the margins of rays
L. naginimariense sp. nov.	Indistinct	t.d. 80-320 μm, r.d. 40 320 μm, solitary and in radial multiples of 2-5, 2-6 per sq mm; tyloses present; perforations simple	Vasicentric to aliform, sometimes confluent joining adjacent vessels	1-5 (mostly 2) seriate, homocellular to heterocellular, 5-25 cells in height	Moderately thick-walled, septate	Associated with xylem rays either in the middle portion or at the margins; also occuring as scattered cells among fibres

fossil in having scalariform perforation plates. In *L. namsangensis* and *L. deomaliensis* the parenchyma is less, i.e., scanty paratracheal to uniseriate vasicentric than in the present fossil specimen. The parenchyma in *L. varkalaensis* is also scanty and the rays are narrower. Moreover, in the former the tyloses are abundant completely occluding the vessels.

In view of the above differences, the present fossil wood is placed under a new species, *Laurinoxylon naginimariense*. The specific name is derived after Naginimara, the type locality of the fossil wood.

Family—*Bischofiaceae*

Genus—*Bischofia* Blume

Bischofia palaeojavanica Awasthi 1989
Pl. 2, figs 7, 8

Wood diffuse-porous (Pl. 2, fig. 16). *Growth rings* not seen. *Vessels* usually small to medium, rarely large, t.d. 68-240 μm, r.d. 52-200 μm, solitary and in radial multiples of 2-5, round to oval, evenly distributed, 6-14 per sq mm; tyloses abundant (Pl. 2, fig. 7); perforations simple; vessel-members 100-520 μm long with oblique to horizontal ends; intervessel pits bordered, alternate, large, 10-14 μm in diameter, circular to oval in shape with lenticular apertures. *Parenchyma* absent, or rarely 1-2 cells may be present associated with vessels (Pl. 2, fig. 7). *Xylem rays* 1-5 seriate, 5-8 per mm; ray tissue heterogeneous, uniseriate rays consisting of upright cells only, 24-52 μm in width and 4-9 cells or 220-720 μm in height; multiseriate rays made up of procumbent cells in the central portion and 1-6 rows of upright cells at one or both the ends, 40-140 μm in width and 7-29 (rarely 50) cells or 360-1120 (rarely 1720) μm in height (Pl. 2, fig. 8); sometimes ray to ray fusion observed. *Fibres* moderately thick-walled, angular in cross section, 20-40 μm in diameter, septate (Pl. 2, fig. 8).

Affinities—In its anatomical characters the fossil wood resembles extant *Bischofia javanica* Bl. Among known fossil woods it resembles *Bischofia palaeojavanica* described by Awasthi (1989) from the Namsang beds near Deomali, Arunachal Pradesh.

Figured Specimen—Specimen no. BSIP 36354.

Locality—Naginimara Village, Kongan Coalfield, Mon District, Nagaland.

DISCUSSION

Of the four taxa added to the Tipam flora, the genus *Koompassia* is significant from the phytogeographical point of view as it does not exist in the Indian subcontinent today. However, it is represented by four species distributed only in the Malayan Peninsula, Borneo and New Guinea (Willis, 1973). *K. malaccensis* Maing. ex Benth. is a large tree, about 30-50 m tall, though buttressed at the base, occurring throughout the lowland forest in swampy ground and also on hill sides in Malayan Peninsula and Indonesia, especially in Sumatra (Ridley, 1922; Desch, 1957). The fossil woods of *Koompassia* are also known from the Neogene of Bengal and Malayan Peninsula (Kramer, 1974; Bande & Prakash, 1980) indicating its wider distribution during that time. Like *Koompassia*, a few other elements, viz., *Dryobalanops* (Awasthi, 1971; Schweitzer, 1958), *Anisoptera* (Prakash & Tripathi, 1970b), *Gluta* (Prakash & Tripathi, 1969b; Prakash, 1973), *Swintonia* (Prakash & Tripathi, 1969a; Prakash & Bande, 1980), *Afzelia-Intsia* (Prakash, 1973; Prakash & Tripathi, 1975), *Sindora* (Lalitha & Prakash, 1980), etc., known from the Neogene sediments of India, Mynmar and Malaysia are now confined to Mynmar and Malayan region where they still grow luxuriantly in the tropical evergreen forest. None of these genera has so far been found in Indian Palaeogene sediments. Thus, it is quite evident that they had originated in the Malayan region perhaps during the Early Tertiary. After the land connections between India and Southeast Asia were established towards the close of Oligocene, several Malayan tropical elements including the two legumes, *Koompassia* and *Sindora* entered the Indian subcontinent via Mynmar, and flourished there under equable climate till the end of Pliocene. The reason for their total disappearance from the Indian subcontinent after Pliocene could be due to gradual decrease in the mean annual temperature and precipitation caused by the Himalayan orogeny and northward drifting of the Indian Plate (Smith & Briden, 1979). Being sensitive to the changing environments, several such taxa which were growing luxuriantly in the Indian subcontinent under tropical and high humid conditions failed to regenerate thereafter.

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