FOSSIL WOOD OF *SINDORA* FROM THE TERTIARY OF ASSAM WITH A CRITICAL ANALYSIS OF THE ANATOMICALLY ALLIED FORMS

C. LALITHA AND U. PRAKASH

Birbal Sahni Institute of Palaeobotany, Lucknow-226 007, India

ABSTRACT

The present paper includes in detail a petrified wood of *Sindora* from the Tipam Sandstones of Assam and critically analyses other anatomically allied forms, both living and fossil. The fossil woods resembling the modern woods of *Copaifera*, *Detarium* and *Sindora* are now placed under the genus *Hopeoxylon* Navale emend. Awasthi as the woods of these genera are anatomically so similar that it is not possible to separate them. Although none of these genera are presently found in India and the adjoining regions—Pakistan, Bangla Desh, Burma and Sri Lanka, the nearest comparable species of the present fossil, *Sindora siamensis* Teysm. ex Miq., grows in Thailand.

INTRODUCTION

Fossil woods of *Sindora* are of common occurrence in the Neogene rocks of India, although this genus is presently confined to Southeast Asia with a species found in Tropical Africa. These are known from the widely scattered regions of the subcontinent viz., the Cuddalore sandstones of South India (AWASTHI, 1977), the Siwalik beds of the Himalayan foothills and the Namsang beds of Deomali in Arunachal Pradesh (personal communication). Here, it is being described from the Tipam sandstones of Sultanicherra, about 55 km south of the town Hailakandi, District Cachar, Assam. This record of *Sindora* further adds significantly to our knowledge of an already known rich flora based on petrified angiospermous woods from this area (PRAKASH, 1972, Table 2, pp. 185-186 ; PRAKASH & TRIPATHI, 1974, 1975, 1976, 1977 ; PRAKASH & LALITHA, 1978 ; LALITHA & PRAKASH, in press).

SYSTEMATIC DESCRIPTION

Family LEGUMINOSAE
Sub-family CAESALPINOIDEAE

Genus **Hopeoxylon** Navale emend. Awasthi, 1977
Syn. *Copaiferoxylon* Müller-Stoll & Mädel, 1967
Sindoroxylon Lemoigne, Beauchamp & Samuel, 1974
Detarioxylon Boureau & Louvet, 1975

Hopeoxylon assamicum sp. nov.
Pls. 1-2, Figs. 1, 3, 7-9

MATERIAL—A single piece of mature secondary xylem measuring 30 cm in length and 12 cm in diameter. It shows satisfactory preservation.

TOPOGRAPHY—*Wood* diffuse-porous. *Growth rings* appear to be delimited by layers of wood parenchyma containing intercellular canals (Pl. 1, Fig. 1). *Vessels* visible to the naked eye, small to large, solitary and in radial multiples of 2-4, about 2-3 per sq. mm ; tyloses wanting. *Parenchyma* visible with a hand lens, paratracheal and apotracheal ; apotracheal parenchyma forming concentric bands surrounding the gum canals ; paratracheal

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parenchyma mostly vasicentric to aliform and occasionally aliform-confluent joining a number of vessels. *Xylem rays* distinct, (Pl. 2, Fig. 7), fine to broad, fusiform (Pl. 1, Fig. 3), 1-5 (mostly 3-5) seriate and 25-225 μ wide, and 4-41 cells or 165-1300 μ high, 6-9 per mm ; ray tissue weakly heterogeneous ; multiseriate rays mostly consisting only of procumbent cells, but a few of them have one or occasionally two upright cells at one or both the ends ; uniseriate rays few, heterocellular, 4-7 cells or 150-390 μ high, composed of both procumbent and upright cells. *Fibres* aligned in distinct radial rows. *Gum canals* vertical, normal, in concentric rows, embedded in parenchymatous tissue (Pl. 1, Fig. 1).

ELEMENTS—*Vessels* thick-walled, the walls 10-15 μ thick, t.d. 60-165 μ, r.d. 75-255 μ, round to oval in cross section ; vessel members 105-750 μ in length with truncate to slightly oblique ends ; perforations simple ; intervessel pit-pairs bordered, alternate to subopposite and vestured (Pl. 2, Fig. 8), 6-8 μ in diameter with linear apertures. *Parenchyma cells* 15-30 μ in diameter, crystalliferous strands present. *Ray cells* thick-walled, tangential height of procumbent cells 32-40 μ and radial length 40-48 μ ; tangential height of upright cells 40-48 μ and radial length 24-32 μ. *Fibres* non-libriform, non-septate, polygonal in cross section, 12-20 μ in diameter and 225-510 μ in length. *Gum canals* 30-280 μ in diameter and mostly oval in shape.

DISCUSSION

The most important anatomical features of the present fossil wood are vessels small to large, solitary and in radial multiples of 2-4 ; parenchyma mostly vasicentric to aliform, occasionally aliform-confluent and in concentric rows surrounding the gum canals ; xylem rays 1-5 (mostly 3-5) seriate, fusiform ; weakly heterogeneous ray tissue ; fibres non-libriform, non-septate and gum canals normal, vertical in concentric rows. Concentric rows of vertical gum canals indicate that the affinities of this fossil wood can be found among the members of the families Leguminosae, Connaraceae, Cornaceae, Dipterocarpaceae, Combretaceae, Malvaceae, Meliaceae, Simarubaceae and Sterculiaceae where similar gum canals are present in the wood. However, considering the other structural details of the present fossil, it shows close resemblance only with some members of the family Leguminosae (Caesalpinoideae) and differs from others in the following manner :

Connaraceae (*connarus martii* Schell.) : Parenchyma scanty paratracheal ; xylem rays 1-2 seriate and fibres libriform, septate.

Cornaceae (*Mastixia rostrata* BL. *M. trichotoma* BL.) : Vessels small, intervessel pit-pairs and vessel-ray pits scalariform ; parenchyma scanty paratracheal and diffuse.

Dipterocarpaceae (Shoreae-*Shorea* Roxb., *Parashorea* Kurz., *Hopea* Roxb. etc.) : Vessels solitary and often in groups ; vasicentric tracheids present ; parenchyma vasicentric, diffuse and surrounding the gum canals.

Combretaceae (*Terminalia* Linn., *Anogeissus latifolia* Wall.) : Parenchyma often confluent, sometimes aliform ; xylem rays mostly uniseriate, the ray cells containing solitary crystals ; fibres libriform, septate.

Malvaceae (*Hibiscus similis* BL.) : Parenchyma predominantly apotracheal in narrow, short bands, paratracheal parenchyma mostly confluent ; xylem rays with prominent sheath cells.

Meliaceae (*Lovoa klaineana* Pierre, *Carapa obovata* BL.) : Vessels in radial groups of 2-3, intervessel pit-pairs bordered, minute ; parenchyma often paratracheal confluent and apotracheal banded ; fibres libriform, mostly septate ; gum canals traumatic in nature.

Simarubaceae (*Ailanthus altissima* Swing., *Simaruba amara* Aubl.) : Parenchyma aliform to confluent ; fibres libriform, septate.

Sterculiaceae (*Sterculia* Linn.) : Parenchyma predominantly apotracheal ; xylem rays of two types, fine and broad, the broad rays with prominent sheath cells ; gum canals traumatic.

In the family Leguminosae similar vertical gum canals in concentric rows in addition to other minute structural features as seen in the present fossil are found in most of the species of *Copaifera* Linn., *Detarium* Juss., and *Sindora* Miq. Besides these, *Eperua* Aubl., *Hardwickia* Roxb. (*H. binata* Roxb.) and *Kingiodendron* Harms (*Kingiodendron pinnata* Harms syn. *Hardwickia pinnata* Roxb.) also show a superficial resemblance with the present fossil wood. The South American genus *Eperua* differs from the fossil in having strongly heterogeneous ray tissue (upto 4 marginal rows of upright cells) as against weakly heterogeneous ray tissue seen in *Copaifera*, *Detarium*, *Sindora* and the present fossil wood. One wood specimen of *Hardwickia pinnata* Roxb., which possesses traumatic gum canals, also resemble the fossil wood. However, this can be differentiated from the fossil in having numerous apotracheal lines of parenchyma. Normally, gum canals are not found in *Hardwickia*. Similarly *Kingiodendron pinnata* Harms (syn. *Hardwickia pinnata* Roxb.) also differs from it in having scattered gum canals.

This detailed comparison is based on the study of thin sections, descriptions and photographs of modern woods of the following available species. These are *Copaifera baumiana* Harms, *C. longsdorfii* Desf., *C. mildbraedii* Harms, *C. salikounda* Hackel, *Detarium macrocarpum* Harms, *D. microcarpum* Guill. & Perr., *D. senegalense* Gmel. syn. *Detarium heudelotianum* Baill., *Sindora beccariana* Backer ex de Wit, *S. cochinchinensis* Baill., *S. coriacea* Prain, *S. echinocalyx* Prain, *S. intermedia* Baker, *S. irpicina* de Wit, *S. klaineana* Pierre, *S. leiocarpa* Backer ex K. Heyne, *S. parvifolia* Sym., *S. siamensis* Teysm. ex Miq., *S. sumatrana* Miq., *S. supa* Merr., *S. tonkinensis* A., *S. velutina* Baker, *S. wallichii* Benth., *Eperua falcata* Aubl., *Hardwickia binata* Roxb., *Kingiodendron pinnata* (Roxb.) Harms syn. *Hardwickia pinnata* Roxb. (Moll & Janssonius, 1914, pp. 142-149, fig. 163 ; Kanehira, 1924, p. 30 ; Lecomte, 1926, pl. 19 ; Reyes, 1938, pp. 149-152, pl. 22, figs. 2-3 ; Metcalfe & Chalk, 1950, pp. 493-497, figs. 110 D, F.; Normand, 1950, pp. 119-120, pls. 37 & 42 ; Henderson, 1953, pl. 38, fig. 181 and pl. 47, fig. 234 ; Lebacq, 1955, pls. 50 & 51 ; Desch, 1957, pp. 295-297, pl. 65, fig. 2 ; Kribs, 1959, pp. 79, 81 & 100, figs. 195, 226, 406 & 424 ; Ramesh Rao & Purkayastha, 1972, pp. 79-82, pl. 74, fig. 444).

It is evident from this study that the modern woods of *Copaifera*, *Detarium* and *Sindora* are anatomically very similar and cannot be separated at the generic level (Table 1). The present fossil shows near resemblance with the modern woods of *Sindora siamensis* Teysm. ex Miq. (FRI Sl. No. F 1035) and *Detarium senegalense* Gmel. (FRI Sl. No. F 3312). *Sindora siamensis* (Pl. 1, Figs. 2, 4) shows resemblance to this fossil in almost all the anatomical details but the xylem rays are slightly narrower, 1-4 (mostly 3) seriate in the modern wood, as against 1-5 (mostly 3-5) seriate and largely fusiform in the present fossil. *Detarium senegalense* (Pl. 2, Figs. 5, 6) also resembles the fossil in vessel and parenchyma distribution, in the nature of xylem rays and the fibres and in the presence of concentric rows of vertical gum canals. However, the vessels are slightly bigger and their frequency is less in *Detarium senegalense* than in the present fossil wood.

In 1967, Müller-Stoll and Mädel instituted the organ genus *Copaiferoxylon* to include the fossil woods with concentric rows of gum canals resembling *Copaifera*, *Detarium* and *Sindora*. Lemoigne, Beauchamp and Samuel (1974) also instituted another genus *Sindoroxylon* to describe their fossil wood resembling *Sindora*. Further, Boureau and Louvet

Table-1—Anatomical features of *Copaifera*, *Detarium*, *Sindora* and other anatomically allied forms

Modern Species	Growth Rings	Vessels	Parenchyma	Xylem Rays	Fibres	Gum Canals	References
Copaifera baumiana Harms	Distinct, delimited by terminal parenchyma.	Mostly solitary occasionally in radial multiples of 2-3, small to medium sized, t.d. 60-135 μ; inter-vessel pit-pairs bordered, alternate, vestured, 4 μ in diameter.	Scanty paratracheal to vasicentric and aliform; terminal parenchyma surrounding the gum canals.	1-2 seriate ; ray tissue hetero geneous.	Non-libriform, non-septate.	Vertical, in concentric rows surrounded by apotracheal parenchyma.	BSIPw Slide No. 2700 (Small specimen near pith region).
Copaifera longsdorfii Desf.	Delimited by terminal parenchyma enclosing gum canals.	Solitary and in radial multiples of 2-5, medium sized ; intervessel pit-pairs bordered, vestured, alternate, 4-7μ in diameter.	Scanty paratracheal to vasicentric ; terminal parenchyma surrounding the gum canals.	1-3 (mostly 2-3) seriate ; ray tissue heterogeneous.	Non-libriform non-septate.	Vertical, in concentric rows.	Pinho, 1966, p. 117.
Copaifera mildbraedii Harms	Demarcated by terminal parenchyma enclosing gum canals.	Mostly solitary, sometimes in radial multiples of 2, small to medium sized, t.d. 90-180μ; intervessel pitpairs bordered, vestured, alternate, 4-6μ in diameter.	Vasicentric to aliform, occasionally confluent; terminal parenchyma surrounding the gum canals.	2-4 (mostly 3) seriate, quite long ; ray tissue heterogenous.	Non-libriform to semi-libriform, non-septate.	Vertical, in concentric rows.	Lebacq, 1957, Pl. 50; BSIPw Slide No. 1842.
Copaifera salikounda Hackel.	Delimited by terminal parenchyma surrounding the gum canals.	Mostly solitary and rarely in radial multiples of 2-3, small to medium-sized.	Vasicentric to aliform, terminal parenchyma surrounding gum canals.	2-4 seriate ; ray tissue homogeneous.	Semi-libriform, non-septate.	Vertical, in concentric rows.	Normand, 1950 p. 119, pl. 37.
Detarium senegalense Gmel. syn. *Detarium heudelotianum* Baill.	Distinct, delimited by terminal parenchyma.	Solitary and in radial rows of 2-4, medium-sized to large, t.d. 25-280μ, intervessel pitpairs bordered, alternate, vestured, 6-8μ in diameter.	Vasicentric and aliform with short wings, rarely confluent joining few vessels ; also terminal and diffuse (terminal surrounding the gum canals seen in FRI Sl. No. F 3312).	1-6 (mostly 3-5) seriate ; ray tissue weakly heterogeneous; 2-4 (mostly 2-3) seriate in Kribs, 1959.	Libriform, non-septate.	Vertical, more or less scattered and embedded in terminal parenchyma.	FRI Sl. No. F 3312 ; Kribs 1959 p. 79, fig. 406 ; Normand, 1959 p. 119, pl. 42.

Table 1—Contd.

Modern Species	Growth Rings	Vessels	Parenchyma	Xylem Rays	Fibres	Gum Canals	References
Detarium macrocarpum, Harms	Distinct, delimited by terminal parenchyma.	Mostly solitary, and also in radial rows of 2-3, small to large, t.d. 45-345μ, intervessel, pit-pairs bordered, vestured, alternate.	Vasicentric to aliform, narrowing into fine lines extending beyond several rays and running parallel to concentric rings of gum canals; short lines of apotracheal parenchyma also present besides those surrounding the rows of gum canals.	1-4(5) seriate; ray tissue weakly heterogenous.	Non-libriform to semi-libriform, non-septate.	Vertical, in concentric rows.	Boureau & Louvet, 1975, p. 33; BSIPw Slide No. 3128.
Detarium microcarpum Guill. & Perr.	Delimited by terminal parenchyma.	Mostly solitary, often in radial rows of 2-3, small to large, mostly medium sized, t.d. 25-280μ, intervessel pit—pairs bordered, vestured, alternate, medium to large.	Vasicentric to aliform; apotracheal parenchyma terminal and also bands surrounding the gum canals.	1-6(7) seriate; ray tissue homogeneous.	Semi-libriform to libriform, non-septate.	Vertical, in concentric rows.	Boureau & Louvet, 1975, p. 33.
Sindora beccariana Backer ex de Wit	Delimited by apotracheal parenchyma surrounding the gum canals.	Mostly solitary, sometimes in radial rows of 2-3, small to mostly medium-sized, t.d. 90-180μ, intervessel pit-pairs bordered, alternate, vestured, 8μ in diameter.	Vasicentric to aliform, terminal parenchyma, surrounding the gum canals.	1-2 (mostly 2) seriate; ray tissue homogeneous.	Non-libriform, non-septate.	Vertical, in concentric rows embedded in terminal parenchyma.	BSIPw Slide no. 1243.
Sindora cochinchinensis Baill.	Delimited by apotracheal parenchyma containing gum canals.	Mostly solitary, sometimes 2 or more in radial rows, small to large, t. d. 90-210μ, intervessel pit-pairs bordered, vestured, alternate to sub-opposite, 8-12μ in diameter.	Scanty paratracheal to vasicentric, sometimes aliform; apotracheal parenchyma diffuse and in concentric lines enclosing gum canals.	1-4 seriate; ray tissue heterogeneous.	Libriform to semi-libriform, non-septate.	Vertical, in concentric rows surrounded by apotracheal parenchyma.	BSIPw Slide No. No. 3036.

Sindora coriacea Prain *Sindora velutina* Baker *Sindora echinocalyx* Prain *Sindora wallichii* Benth. *Sindora parvifolia* Sym.	Delimited by narrow layers of wood parenchyma containing gum canals.	Solitary and in radial groups of 2-4, small to medium-sized, t.d. 90-180μ; intervessel pit-pairs bordered, alternate, vestured, 8μ in diameter.	Vasicentric to aliform; terminal parenchyma bands present.	Moderately fine; ray tissue weakly heterogeneous. Frequently 3, sometime 4 seriate in *S. coriacea*; 1-3 seriate in *S. velutina*; 1-4 seriseriate in *S. echinocalyx*.	Libriform to non-libriform, non-septate.	Vertical, in concentric rows.	Desch, 1957 p. 297; BSIPw Slide Nos. 1001 and 2335.
Sindora irpicina de Wit	Delimited by apotracheal parenchyma surrounding the gum canals.	Mostly solitary and in radial rows of 2-3, medium-sized 105-180 μ, in diameter; intervessel pit-pairs bordered, vestured, alternate to subopposite, 6-8μ in diameter.	Vasicentric and terminal.	1-4 (mostly 3) seriate; ray tissue almost homogeneous.	Non-libriform, non septate.	Vertical, in concentric rows.	BSIPw Slide No. 2151.
Sindora Klaineana Pierre.	Distinct, delimited by terminal parenchyma and thicker walled fibres.	Solitary and in radial groups of 2-3, medium-sized to large, t.d. 143-272μ; inter-vessel pitpairs bordered alternate, vestured, 8μm in diameter.	Vasicentric to occasionally aliform with short wings, rarely confluent.	2-3 seriate, ray tissue heterogeneous.	Libriform, non-septate.	Vertical, diffuse.	Kribs, 1959 p. 100.
Sindora leiocarpa Baker ex K. Heyne	Delimited by terminal parenchyma containing gum canals.	Mostly solitary, sometimes in radial rows of 2-3, medium to large.	Aliform to aliform confluent and terminal.	1-4 (mostly 3) seriate; ray tissue heterogeneous.	Non-libriform, non-septate.	Vertical, in concentric rows.	FRI Slide No. F 1038.
Sindora siamensis Teysm. ex Miq.	Delimited by terminal parenchyma, sometimes containing gum canals.	Mostly solitary, sometimes in radial rows of 2-3, mostly large, 195-330μ; intervessel pit-pairs bordered, alternate to subopposite, vestured, 8-12μ in diameter.	Vasicentric to aliform, occasionally aliform-confluent joining many vessels; apotracheal parenchyma terminal and in short and long bands.	1-4 (mostly 3) seriate; ray tissue heterogeneous.	Non-libriform to semi-libriform, non-septate.	Vertical, in concentric rows.	FRI Slide No. F 1035.

Table-2—Anatomical features of the species of *Hopeoxylon* Navale emend. Awasthi

Name of the fossil species	Vessels	Parenchyma	Xylem rays	Fibres	Gum Canals	Age and Locality
Hopeoxylon migiurtinum (Chiarugi) comb. nov. [syn. *Copaiferoxylon migiurtinum* (Chiarugi, 1933) Muller-Stoll & Madel, 1967].	Solitary and in radial multiples of 2-3, round, t. d. 60-120 μ, r. d. 60-100 μ ; intervessel pits 8 μ in diameter.	Paratracheal and apotracheal; paratracheal parenchyma, vasicentric ; apotracheal parenchyma diffuse and in tangential lines surrounding the gum canals.	1-5 seriate; ray tissue homogeneous.	Libriform, non-septate.	Vertical, in regular concentric rows.	Miocene, Somaliland.
Hopeoxylon sindoroides (Kramer) comb. nov. [syn. *Copaiferoxylon sindoroides* Kramer 1974].	Mostly solitary and in radial multipies of 2-3, round to oval, t. d. 70-210 μ, r. d. 100-290 μ ; intervessel pits 7×8 μ.	Paratracheal and apotracheal ; paratracheal parenchyma aliform occasionally confluent ; apotracheal parenchyma surrounding the gum canals.	2-5 (mostly 3-4) seriate ; ray tissue weakly heterogeneous.	Libriform, non-septate.	Vertical, in concentric rows.	Tertiary, West Borneo.
Hopeoxylon aethiopicum (Lemoigne, Beauchamp & Samuel) comb. nov. [syn. *Sindoroxylon aethiopicum* Lemoigne *et al.*, 1974].	Solitary and in radial multiples of 2 (rarely 3 or 4), round, 180-200 μ in diameter.	Paratracheal and apotracheal; paratracheal parenchyma vaiscentric to aliform ; apotracheal parenchyma surrounding the gum canals.	1-3 (mostly 2-3) seriate ; ray tissue heterogeneous.	Libriform, non-septate.	Vertical, in concentric rows.	Tertiary, Ethiopia.
Hopeoxylon libycum (Boureau & Louvet), comb. nov. [syn. *Detarioxylon libycum* Boureau & Louvet, 1975].	Mostly solitary and in radial multiples of 2-3, round, 25-280 μ in diameter ; intervessel pits 4-13 μ in diameter.	Paratracheal and apotracheal ; paratracheal parenchyma vasicentric to aliform; apotracheal parenchyma surrounding the gum canals.	1-6 (7) seriate (mostly 4-5 seriate) ; ray tissue homogeneous	Non-libriform, non-septate.	Vertical, in concentric rows.	Palaeogene, Libya.
Hopeoxylon indicum Navale emend. Awasthi, 1977.	Solitary and in radial rows of 2, round, t. d. 60-165 μ, r. d. 45-180 μ ; intervessel pits 8-10 μ in diameter.	Paratracheal and apotracheal ; paratracheal parenchyma vasicentric to aliform, rarely aliform-confluent apotracheal parenchyma in thin, narrow, regular to irregular lines occurring in association with the gum canals.	1-3 (mostly 2) seriate ; ray tissue weakly heterogeneous.	Thin to moderately thick-walled, non-septate.	Vertical, in concentric rows.	Mio-Pliocene near Pondicherry, South India.

Hopeoxylon speciosum (Navale) Awasthi, 1977.	Solitary and mostly in radial multiples of 2-5, round, 75-300 μ in diameter ; intervessel pits 8-10 μ in diameter.	Paratracheal and apotracheal ; paratracheal parenchyma vasicentric, aliform to aliform-confluent ; apotracheal, parenchyma in bands enclosing the gum canals and in fine, short or long tangential lines (seen in type slides).	1-6 (mostly 3-6) seriate ; ray tissue weakly heterogeneous.	Semi-libriform, non-septate.	Vertical, in concentric rows.	Mio-Pliocene near Pondicherry, South India.
Hopeoxylon arcotense Awasthi, 1977.	Solitary and in radial multiples of 2-4, circular to oval, t. d. 120-270 μ, r. d. 75-270 μ ; intervessels pits 8-12 μ in diameter.	Paratracheal and apotracheal ; paratracheal parenchyma vasicentric to aliform and aliform-confluent, confluent parenchyma narrowing into thin concentric lines, amongst which short lines of parenchyma also present (seen in type slides) apotracheal parenchyma associated with gum canals.	1-4 (mostly 3) seriate ; ray tissue weakly heterogeneous.	Semi-libriform, non-septate.	Vertical, in concentric rows.	Mio-Pliocene near Pondicherry, South India.
Hopeoxylon assamicum sp. nov.	Solitary and in radial multiples of 2-4, round to oval, t. d. 65-165 μ, r. d. 75-255 μ ; intervessel pits 6-8 μ in diameter.	Paratracheal and apotracheal ; paratracheal parenchyma mostly vasicentric to aliform, occasionally aliform-confluent ; apotracheal parenchyma surrounding the gum canals.	1-5 (mostly 3-5) seriate ; ray tissue weakly heterogeneous.	Non-libriform, non-septate.	Vertical, in concentric rows.	Upper Miocene (Tipam Sandstones), near Hailakandi, Assam.

(1975) proposed the genus *Detarioxylon* for their fossil wood resembling the genus *Detarium*. In 1977, AWASTHI revised the affinities of *Hopeoxylon indicum* Navale (1963) and showed that it belongs to *Sindora* of the family Leguminosae instead of *Hopea* of the family Dipterocarpaceae. As the modern woods of *Copaifera*, *Detarium* and *Sindora* which possess concentric rows of vertical gum canals, are anatomically so similar that it is not possible to separate them, it is advisable to assign all of them under a single generic name. As *Hopeoxylon* Navale emend. AWASTHI (1977) has the priority (Article 62, ICBN) and is a valid name, it is adopted here to designate such fossil woods of *Copaifera*, *Detarium* and *Sindora* instead of *Sindora* only as suggested by AWASTHI (1977). However, all the other names such as *Copaiferoxylon* Müller-Stoll & Mädel (1967), *Sindoroxylon* Lemoigne, Beauchamp & Samuel (1974) and *Detarioxylon* Boureau & Louvet (1975) become its synonym. Thus, the fossil woods of *Copaiferoxylon migiurtinum* (CHIARUGI, 1933) Müller-Stoll & Mädel (1967) from the Tertiary of Somaliland, *C. sindoroides* Kramer (1974) from the Tertiary of West Borneo, *Sindoroxylon aethiopicum* Lemoigne, Beauchamp & Samuel (1974) from the Tertiary (probably Miocene) of Ethiopia and *Detarioxylon libycum* Boureau & Louvet (1975) from the Palaeogene of Libya are renamed as *Hopeoxylon migiurtinum* (Chiarugi) comb. nov., *Hopeoxylon sindoroides* (Lemoigne, Beauchamp & Samuel) comb. nov., and *Hopeoxylon libycum* (Boureau & Louvet) comb. nov. respectively. Besides these, in addition to *Hopeoxylon indicum* Navale emend. Awasthi (1977) two more fossil woods resembling this complex are known from the Cuddalore Sandstones of South India. They are *Hopeoxylon speciosum* (Navale) Awasthi (1977) and *Hopeoxylon arcotense* Awasthi (1977).

In 1939, KRÄUSEL described a fossil wood as *Sterculioxylon aegyptiacum* from the Tertiary of Western Egypt and in 1949, it was again recorded from the Post Eocene of Tibesti by BOUREAU. This has been compared with the modern wood of *Sterculia*. However, from its description and photographs (KRÄUSEL, 1939, pp. 81-89, Pl. 18, figs. 3-6, Pl. 19, figs. 1-7, Pl. 20, figs. 1-3 ; Text-figs. 23, 24), the distribution of parenchyma does not seem to show any resemblance with that of *Sterculia* which has metatracheal parenchyma either predominantly in lines of one cell width or in broad bands (CHATTAWAY, 1937) as against vasicentric to aliform, occasionally aliform-confluent and apotracheal bands of parenchyma with gum canals in the fossil wood of *Sterculioxylon aegyptiacum*. BOUREAU (1949, p. 782) also pointed out a strong resemblance of his *Sterculioxylon aegyptiacum* with *Detarium senegalense* and *D. microcarpum*. In 1975, Boureau again showed a close resemblance of the fossil wood *Detarioxylon libycum* with that of *Sterculioxylon aegyptiacum*. However, he separated *Detarioxylon libycum* from *Sterculioxylon aegyptiacum* by the nature of gum canals, which according to him are normal in the former and traumatic in the latter. But this is also questionable. Although the authors strongly feel that Kräusel's *Sterculioxylon aegyptiacum* is a wood of *Copaifera-Detarium-Sindora*-complex, they do not think it proper to transfer it now to *Hopeoxylon* Navale emend. Awasthi until the type slides of this material are re-examined.

All the above species so far known differ quite distinctly from the present fossil wood (Table 2). Thus *Hopeoxylon migiurtinum* differs from the present fossil mainly in having homogeneous ray tissue. *Hopeoxylon sindoroides* can also be distinguished from this fossil wood. It possesses short xylem rays (12-15 cells or 250-320 μ in height), slightly bigger vessels, 70-290 μ in diameter, whereas the present fossil has very long xylem rays (7-41 cells or 165-1300 μ in height) and the vessels are 60-225 μ in diameter. *Hopeoxylon aethiopicum* is distinct in the absence of confluent parenchyma and in having only 1-3 (mostly 2-3) seriate xylem rays. *Hopeoxylon libycum* has 1-6 (7) seriate xylem rays with homogeneous ray tissue as against 1-5 (mostly 3-5) seriate xylem rays with weakly hetero-

geneous ray tissue in the present fossil. *Hopeoxylon indicum* has 1-3 (mostly 2) seriate xylem rays and no crystals in the parenchyma strands. *Hopeoxylon arcotense* is also distinct in having confluent parenchyma narrowing into this concentric lines, amongst which short lines of parenchyma also occur frequently, and narrow xylem rays which are 1-4 (mostly 3) seriate. Although from the description, *Hopeoxylon speciosum* appeared to be identical to the present fossil wood, but on further examination of the type material, it was found to possess apotracheal parenchyma in fine, short or long lines apart from those surrounding the gum canals (Table 2). Moreover, xylem rays are 1-5 seriate in the present fossil as against 1-6 seriate in *Hopeoxylon speciosum*. As the present fossil wood is quite distinct from all the species of *Hopeoxylon* Navale emend. Awasthi (1977), it is described here under a new species, *Hopeoxylon assamicum* sp. nov. Because some anatomical characters of *Copaifera*, *Detarium* and *Sindora* such as width of xylem rays, nature of ray tissue and parenchyma pattern are not fully covered by the amended generic diagnosis of *Hopeoxylon* Navale emend. Awasthi (1977), which now represents the wood structure of all these forms, it is being expanded here to include these anatomical characters.

The genus *Copaifera* L. consists of 25 species found in Tropical America and 5 species in Tropical Africa (Willis, 1973, p. 289), while *Detarium* Juss. is confined only to Tropical Africa with 4 species (Willis, 1973, p. 361). The genus *Sindora* Miq. consists of 21 species (Willis, 1973, p. 1069), of which only one species is found in Tropical Africa and the rest are confined to Southeast Asia, Hainan, West Malaysia, Celebes and Molucca. None of these genera are found in India proper and the adjoining regions of Pakistan, Bangla Desh, Burma and Ceylon. *Detarium senegalense* Gmel. which is also nearly comparable to the present fossil wood is a tree which grows in Upper Guinea, North Central Africa and Nile land (Oliver, 1871, p. 313). However, according to geographical locale, the nearest comparable species is *Sindora siamensis* Teysm. ex Miq. which grows in Thailand (Ridley, 1967, p. 638). Therefore, it appears that the present fossil wood most probably belongs to *Sindora* which had a wider distribution in the past during the Miocene-Pliocene period, when it was also present in the Northern, Northeastern and Southeastern parts of India.

Revised Generic Diagnosis

Hopeoxylon Navale emend. Awasthi, 1977.

Wood diffuse porous. *Growth rings* distinct, delimited by apotracheal parenchyma lines or bands containing vertical gum canals. *Vessels* large to medium-sized and small, solitary as well as in radial multiples ; perforations simple ; intervessel pit-pairs medium sized to large bordered, alternate, vestured. *Parenchyma* vasicentric, aliform to confluent and associated with concentric rings of gum canals, thin apotracheal lines or bands also present. *Xylem rays* 1-7 seriate ; ray tissue homogeneous or weakly heterogeneous, the heterocellular rays with one or occasionally two rows of marginal upright or square cells. *Fibres* non-libriform to libriform and non-septate. *Gum canals* normal, vertical, in concentric rows.

Specific Diagnosis

Hopeoxylon assamicum sp. nov.

Wood diffuse-porous. *Growth rings* appear to be delimited by layers of wood parenchyma containing gum canals. *Vessels* solitary and in radial multiples of 2-4, round to oval, t.d. 60-165 μ, r.d. 75-255 μ and 2-3 per sq. mm ; tyloses wanting ; vessel members 105-750 μ in length ; intervessel pit-pairs bordered, alternate, vestured, 6-8 μ in diameter with

linear apertures ; *Parenchyma* mostly vasicentric to aliform and occasionally aliform-confluent joining a number of vessels and in concentric bands surrounding the gum canals ; parenchyma cells 15-30 μ in diameter ; crystalliferous strands present. *Xylem rays* 1-5 (mostly 3-5) seriate, 25-225 μ wide and 4-41 cells or 165-1300 μ high, 6-9 per mm ; ray tissue weakly heterogeneous with most of the multiseriate rays consisting only of procumbent cells and a few have one or occasionally two marginal rows of upright or square cells at one or both the ends. *Fibres* polygonal, non-libriform, walls 6-8 μ thick, non-septate, 225-510 μ in length and 12-20 μ in diameter. *Gum canals* normal, vertical, in concentric rows, 30-280 μ in diameter.

Holotype—B.S.I.P. Museum No. 35398

Locality—Sultanicherra, 55 km South of Hailakandi, District Cachar, Assam.

Horizon—Tipam Sandstones ; Upper Miocene.

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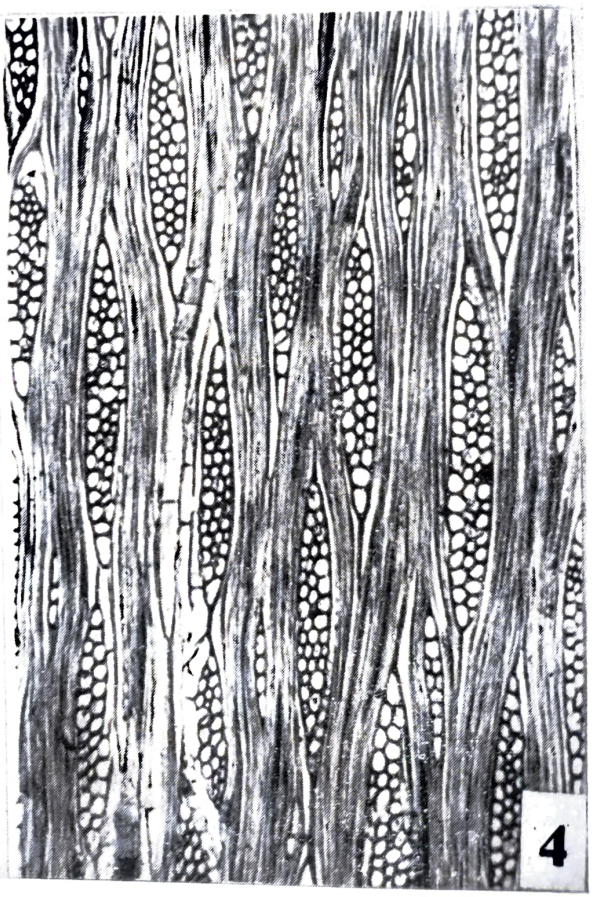
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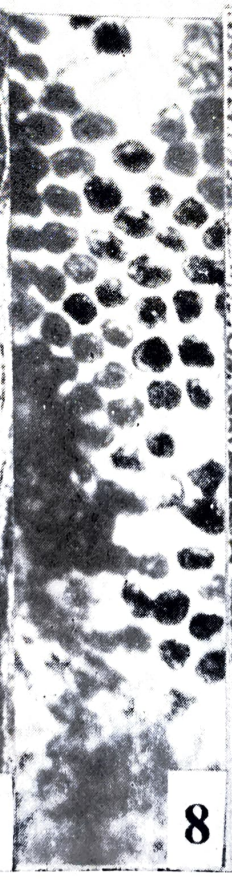
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EXPLANATION OF PLATES

PLATE 1

1. *Hopeoxylon assamicum* sp. nov.—Cross section showing vessel and parenchyma distribution and the gum canals. ×30. B.S.I.P. Museum Sl. No. 6212.

2. *Sindora siamensis* Teysm. ex Miq.—Cross section showing similar vessel and parenchyma distribution and the gum canals. ×30. FRI Sl. No. F 1035.

3. *Hopeoxylon assamicum* sp. nov.—Tangential longitudinal section showing rays. ×60. B.S.I.P. Museum Sl. No. 6213.

4. *Sindora siamensis* Teysm. ex Miq.—Tangential longitudinal section, showing somewhat similar xylem rays. ×60. FRI Sl. No. F 1035.

PLATE 2

5. *Detarium senegalense* Gmel.—Cross section showing vessel and parenchyma distribution and the gum canals. ×30 FRI Sl. No. F 3312.

6. *Detarium senegalense* Gmel.—Tangential longitudinal section showing xylem rays. ×60. FRI Sl. No. F 3312.

7. *Hopeoxylon assamicum* sp. nov.—Tangential longitudinal section showing xylem rays ×30. B.S.I.P. Museum Sl. No. 6213.

8. *Hopeoxylon assamicum* sp. nov.—Magnified intervessel pits. ×600. B.S.I.P. Sl. No. 6213.

9. *Hopeoxylon assamicum* sp. nov.—Radial longitudinal section showing heterocellular xylem rays. ×80. B.S.I.P. Museum Sl. No. 6214.