SOME MORE FOSSIL WOODS FROM THE LOWER SIWALIK SEDIMENTS OF KALAGARH, UTTAR PRADESH, INDIA

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Abstract

Three fossil dicotyledonous woods resembling those of *Ormosia robusta* (Fabaceae), *Terminalia paniculata* (Combretaceae) and *Diospyros malabarica* (Ebenaceae) are described from the Lower Siwalik sediments of Kalagarh, Uttar Pradesh and named as *Ormosioxylon bengalensis* Bande & Prakash, *Terminalioxylon siwalicus* sp. nov. and *Ebenoxylon kalagarhensis* sp. nov. respectively.

Introduction

The Siwalik sediments exposed in the foot-hills near Kalagarh (29° 30′, 78° 44′), Pauri Garhwal District, Uttar Pradesh are very rich in petrified woods. These sediments have been assigned to Lower Siwalik on the basis of lithology, heavy minerals and vertebrate fauna (Sahni & Mathur, 1964; Sahni *et al.*, 1980). A number of fossil woods have already been described from this area belonging to both monocots and dicots (Prakash, 1978, 1981; Prakash & Prasad, 1984; Prasad, 1987; Prasad & Prakash, 1987; Trivedi & Misra, 1978, 1979, 1980; Trivedi & Ahuja, 1978a, b, c, 1979, 1980; Awasthi & Prasad, 1987). In the present paper three more fossil woods have been described from Nungarh Nala, Kalagarh.

Systematic Description

Family—Leguminosae

Genus—*ORMOSIOXYLON* Bande & Prakash, 1980

Ormosioxylon bengalensis Bande & Prakash, 1980
Pl. 1, figs. 1-4

Material—The specimen consists of a single well-preserved silicified secondary wood, measuring about 12 cm in length and 9 cm in diameter.

Description—Wood diffuse-porous. *Growth rings* indistinct. *Vessels* medium to large, solitary as well as in radial multiples of 2-8 (mostly 2-4), 3-6 per sq mm, mostly empty, thick-walled, t.d. 120-290 μm, r.d. 154-340 μm (Pl. 1, fig. 1); vessel members 176-600 μm long with truncate ends; perforation simple; intervessel pits vestured, alternate, 8-12 μm in diameter, circular to oval in shape with linear to lenticular apertures (Pl. 1, fig. 4). *Parenchyma* paratracheal, aliform to predominantly aliform confluent, joining a few adjacent vessels, slightly thick-walled, cells 9-12 μm in diameter and 15-135 μm in length (Pl. 1, fig. 1). *Xylem rays* 1-4 (mostly 2-3) seriate, 16-60 μm in width and 8-30 cells or 150-575 μm in height (Pl. 1, fig. 2); ray tissue weakly heterogeneous with rays composed of mostly procumbent cells and rarely with 1-2 rows of upright cells at one or

both the ends; upright cells 18-36 μm in vertical height and 10-25 μm in radial length; procumbent cells 20-60 μm in radial length and 15-28 μm in vertical height (Pl. 1, fig. 3). *Fibres* aligned in radial rows, polygonal in cross-section, non-septate, semilibriform, slightly thick-walled, 9-18 μm in diameter and 460-700 μm in length.

Affinities—In having medium to large vessels with simple perforations and vestured intervessel pit-pairs, aliform to aliform-confluent parenchyma, 1-4 seriate, weakly heterogeneous, storied xylem rays and non-septate fibres, the present Siwalik fossil wood shows close resemblance with that of *Ormosia robusta* Wight of Fabaceae.

Comparison—Bande and Prakash (1980) instituted the genus *Ormosioxylon* for the fossil woods resembling that of *Ormosia* they described under it a fossil wood showing close resemblance with *Ormosia robusta* Wight and *O. watsonii* C.E.C. Fischer as *Ormosioxylon bengalensis* from the Tertiary of West Bengal. The present Siwalik wood possesses similar anatomical characters as exihibited by *Ormosioxylon bengalensis* Bande & Prakash, hence it is placed under the same species.

Specimen—Museum no. BSIP 36222.

Family—Combretaceae

Genus—*TERMINALIOXYLON* Schönfeld, 1947

Terminalioxylon siwalicus sp. nov.
Pl. 1, fig. 6; Pl. 2, figs. 7, 9

Material—This species is based on a small piece of petrified secondary xylem measuring about 5 cm in length and 4 cm in diameter. The preservation is fairly good.

Description—*Wood* diffuse-porous. *Growth rings* inconspicuous, occasionally delimited by thick-walled fibres and smaller vessels. *Vessels* mostly medium to large, rarely small, usually solitary, often in radial multiples of 2-4 (usually 2), 5-10 per sq mm, tyloses absent, sometime plugged with redish brown gummy deposits; t.d. 66-220 μm, r.d.80-280 μm (Pl. 2, fig. 7), vessel-members 220-590 μm in length with usually truncate ends; perforations simple; intervessel pits alternate, vestured, angular to oval in shape, 6-10 μm in diameter with linear to lenticular apertures. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma vasicentric to aliform, occasionally confluent, joining adjacent vessel; apotracheal parenchyma sparse, diffuse, scattered among the fibres (Pl. 1, fig. 5), thin-walled, 15-26 μm in diameter and 120-550 μm in length. *Xylem rays* mostly uniseriate, rarely biseriate, 15-40 μm wide and 3-20 cells or 90-950 μm in height (Pl. 2, fig. 9), ray tissue heterogeneous, rays heterocellular, consisting of both procumbent and crystalliferous upright cells; procumbent cells 15-30 μm in tangential height and 35-55 μm in radial length, upright cells 30-50 μm in vertical height and 16-28 μm in radial length (Pl. 1, fig. 6), swollen crystalliferous cells frequently present. *Fibres* aligned in radial rows between two consecutive rays, semi-libriform to libriform, moderately thick-walled, septate; pits not seen.

Affinities—Vestured intervessel pits, vasicentric to aliform and occasionally confluent parenchyma, mostly uniseriate, heterogeneous, xylem rays with crystals in some cells are the characteristic features of the present fossil woods which suggest its affinities with those of *Terminalia* and *Anogeisus*. However, it can be differentiated from the wood of *Anogeisus* in having more pronounced heterogenity in xylem rays and the presence of crystalliferous parenchyma strands. Moreover, the average height of the ray

cells is more in *Terminalia* than in *Anogeisus* (Ramesh Rao & Purkayastha, 1972, p. 177; Pearson & Brown, 1932, p. 539). In the present fossil wood also the height of rays is nearly same as in *Terminalia*. With a view to find out the modern equivalent of the present fossil wood, thin sections of a number of species of *Terminalia* Linn. were examined and found that *Terminalia paniculata* shows close similarity with the present fossil wood.

Comparison—A large number of fossil woods resembling *Terminalia* have been described from India and abroad. They are listed in Table 1 for ready reference.

From a detailed comparison with all the known species of *Terminalioxylon* it has been found that the present fossil wood is different. Most of them differ in possessing abundant parenchyma while some other differ eihter in having homogeneous rays or terminal parenchyma. A few species differ in possessing of longer rays or smaller vessels with higher frequency (Table 1). Hence, it is being named as *Terminalioxylon siwalicus* sp. nov.

The genus *Terminalia* Linn. comprises 250 species of mostly large trees, widely distributed in the tropics of the world (Willis, 1973, p. 1136). Gamble (1972) has enumerated 16 species in India. *Terminalia paniculata* Roth, with which the fossil closely resembles, is a large tree found in the dry and moist deciduous forests of Western Ghats from Konkan southwards through Kanara, Malabar and Coorg to Travancore and also on the hills in Satara, Vellore, Salem, Cuddapah, Bellary and Mudura (Pearson & Brown, 1932; Rao & Purkayastha, 1972).

SPECIFIC DIAGNOSIS

Terminalioxylon siwalicus sp. nov.

Wood diffuse-porous. *Growth rings* inconspicuous, occasionally delimited by thick-walled fibres and smaller vessels. *Vessels* mostly medium to large rarely small, t.d. 66-220 μm, r.d. 80-280 μm, usually solitary often in radial multiples of 2-4, round to oval, vessel-members 220-590 μm long with usually truncate ends, perforations simple; intervessel pit-pairs vestured, alternate, angular to oval in shape with linear to lenticular apertures. *Parenchyma vasicentric* to aliform and sometimes confluent joining adjacent vessels. *Xylem rays* mostly uniseriate, rarely biseriate, 3-29 cells or 90-850 μm in length; ray tissue heterogeneous, rays heterocellular, consisting of both upright and procumbent cells; crystals present in enlarged cells. *Fibres* semilibriform to libriform, septate.

Holotype—Museum no. BSIP 36223.

Family—Ebenaceae

Genus—*EBENOXYLON* Felix, 1882

Ebenoxylon kalagarhensis sp. nov.
Pl. 3, figs. 11, 13, 15, 16

Material—The fossil wood is a small piece of secondary wood measuring about 5 cm in length and 13 cm in diameter. The preservation is fairly good.

Description—*Wood* diffuse-porous. *Growth rings* indistinct. *Vessels* very small to medium, t.d. 45-80 μm, r.d. 65-125 μm, solitary as well as in radial multiples of 2-4 (rarely

Table 1—Showing differentiative characters of known species of *Terminalioxylon*

Fossil species	Locality	Age	Differentiative characters from *Terminalioxylon siwalicus* sp. nov.
1	2	3	4
Terminalioxylon naranjo Schonfeld (1947)	Columbia, South America	Tertiary	Homogeneous rays and nonseptate fibres
T. porosum Schönfeld, (1947)	,,	,,	Abundant parenchyma and longer rays (32-45 cells in height), non-septate fibres
T. portae Mirioni (1965)	,,	,,	Abundant parenchyma, nonseptate fibres
T. endengense Boureau (1955)	Sahara, North Africa	Eocene	Abundant parenchyma, nonseptate fibres
T. fezzenense Boureau (1958)	Calancho, North Africa	,,	Abundant parenchyma and nonseptate fibres
T. erichsensii Musa (1958)	Brazil	Tertiary	Abundant parenchyma and longer rays (32-45 cells in height)
T. welkitii Lemoigne & Beauchamp (1972)	Ethiopia	,,	Homogeneous rays
Terminalioxylon sp. Lemoigne, Beauchamp & Samuel (1974)	,,	,,	Homogeneous rays
T. doubingeri Lemoigne (1978)	,,	,,	Terminal parenchyma and nonseptate fibres
T. primigenium Madel-Angeliewa and Mulle-Stoll (1972)	Sudan	Upper Cretaceous or Eocene	Vessels with higher frequency (30/mm^2) and longer rays (up to 40 cell in height)
T. qeinitzii Madel-Angeliewa & Muller-Stoll (1973)	,,	,,	Mostly small vessels in usually multiples, vasicentric parenchyma
T. intermedium Madel-Angeliewa & Muller-Stoll (1973)	,,	,,	Smaller vessels and scanty to vasicentric parenchyma
T. edwardsii Madel-Angeliewa & Muller-Stoll (1973)	Egypt	Oligocene	Abundant parenchyma and longer rays (up to 30 cell in height)
T. pachitanensis Sukiman (1977)	Java	Miocene	Abundant parenchyma and nonseptate fibres
T. burmense Madel-Angeliewa & Muller-Stoll (1973)	Sumatra	Tertiary	Abundant parenchyma
Terminalioxylon sp. Kramer (1974)	,,	,,	Abundant parenchyma
T. martrohense Madel-Angeliewa & Muller-Stoll (1973)	Vietnam	,,	Smaller vessels arranged in radial groups of 2-7
T. tertiarum (Prakash) Kramer (1974)	,,	,,	Abundant parenchyma, homogeneous rays, terminal parenchyma
T. burmense (Madel-Angeliewa & Muller-Stoll) Kramer, 1974	,,	,,	Abundant parenchyma

Table 1—(*Contd.*)

1	2	3	4
T. coriaceum (Prakash & Awasthi) Kramer (1974)	,,	,,	Abundant parenchyma, homogeneous rays
T. tunisense Duperon-Landoueneix (1973)	Indonesia	,,	Slightly semi-ring porous, larger vessels, abundant parenchyma and non-septate fibres
T. densiporosum Kramer (1974)		,,	Vessels with higher frequency, longer rays and terminal parenchyma
T. annamense Boureau (1950)	Indochina	,,	Abundant parenchyma & nonseptate fibres
T. kratiense Serra (1966)	,,	,,	Homogeneous rays and nonseptate fibres
Terminalia tomentosum Chowdhury & Tandon (1964)	Burma	Mio-Pliocene	Abundant parenchyma, homogeneous rays and terminal parenchyma
T. felixi Ramanujam (1956)	South India	Teritary	Terminal parenchyma and nonseptate fibres
T. speciosum Ramanujam (1956)	South India	Tertiary	Abundant parenchyma, nonseptate fibres
T. sahnii Navale (1956)	,,	,,	Homogeneous rays and nonseptate fibres
T. martandrense Navale (1956)	,,	,,	Homogeneous rays
T. grandiporosum Ramanujam (1966)	,,	,,	Terminal parenchyma and nonseptate fibres
T. traumaticum Ramanujam (1966)	,,	,,	Abundant parenchyma, homogeneous rays and traumatic gum canals
T. indicum (Navale) Madel-Angeliewa & Muller-Stoll (1973)	,,	,,	Small-sized vessels with higher frequency (12-40 mm^2), terminal parenchyma
T. varkalaensis Awasthi & Ahuja (1982)	,,	,,	Scanty parenchyma, nonseptate fibres
T. chowdhurii Prakash & Navale (1963)	Assam, India	,,	Abundant parenchyma, terminal parenchyma and homogeneous rays
T. tomentosum Prakash (1966)	,,	,,	Homogeneous rays and nonseptate fibres
T. tertiarum (Prakash) Prakash & Awasthi (1970)	,,	,,	Abundant parenchyma, homogeneous rays and terminal parenchyma
T. coriaceum Prakash & Awasthi (1971)	,,	,,	Abundant parenchyma, terminal parenchyma and homogeneous rays
T. tomentosum Mahabale & Deshpande (1956)	Kachchh, India	Eocene	Homogeneous rays and nonseptate fibres
T. tertiarum (Prakash) Ghosh & Roy (1980)	West Bengal India	Tertiary	Abundant parenchyma, terminal parenchyma and homogeneous rays
T. palaeomanii Prakash (1981)	Kalagarh, India	Miocene	Scanty parenchyma

7), 5-8 per sq mm, plugged with dark contents (Pl. 3, fig. 11), vessel-members 220-360 μm in length with usually truncate to tailed ends; perforations simple; intervessel pits small to medium, 5-7 μm in diameter, bordered, alternate with linear to lenticular apertures. *Parenchyma* apotracheal, irregular, closely placed, 1-2 (mostly 1) seriate lines, about 19-25 lines per mm; paratracheal parenchyma scanty, associated with vessels (Pl. 3, fig. 11); cells thin-walled, 12-18 μm in diameter and 45-58 μm in length. *Xylem rays* fine, 1-2 mostly uniseriate, 13-37 μm in width, 4-25 cells and 90-810 μm in height (Pl. 3, fig. 13), ray tissue heterogeneous, rays composed of both upright and procumbent cells; procumbent cells 10-24 μm in tangential height, 24-60 μm in radial length; upright cells 32-64 μm in tangential height, and 16-30 μm in radial length, upright cells sometime swollen and crystalliferous (Pl. 3, fig. 15). *Fibres* aligned in radial rows, semi-libriform, moderately thick-walled, non-septate, 10-16 μm in diameter, 700-1020 μm in length.

Affinities—The fossil wood is characterized by apotracheal parenchyma occurring in 1-2 seriate, close, concentric tangential lines at regular interval and 1-2 seriate xylem rays. This type of apotracheal parenchyma and rays are seen in the modern woods of Apocynaceae, Ebenaceae, Rubiaceae and Sapotaceae (Pearson & Brown, 1932; Metcalfe & Chalk, 1950). Of these, the family Sapotaceae differs in having vasicentric tracheids which are absent in the present fossil wood. The families Apocynaceae and Rubiaceae can also be differentiated in having vestured intervessel pit-pairs, it is with the family Ebenaceae that the present fossil shows close resemblance. However, on the basis of all other characters of the fossil wood, viz., vessels very small to medium-sized, solitary as well as in radial multiples, xylem rays mostly uniseriate occasionally biseriate, heterocellular with some swollen crystalliferous upright cells the fossil wood shows closest affinity with the modern woods of *Diospyros* Linn. of this family. However, on critical examination of the thin section of about 40 species of *Diospyros* it was found that the fossil is closer to *D. malabarica* (Derr.) Kosten (Pl. 3, figs. 12, 14).

Comparison—The fossil woods showing close resemblance with that of *Diospyros* are assigned to the genus *Ebenoxylon* Felix (1882) which have already been listed by Prakash and Tripathi (1970, p. 165, table 1); Prakash (1978, p. 386) and Awasthi and Ahuja (1982, pp. 252-253, table 1). Since then two more fossil woods are known from India, viz., *Ebenoxylon deccanensis* Trivedi & Srivastava, 1982 from the Deccan Intertrappean beds of Madhya Pradesh, India and *Ebenoxylon obliquiporosum* Awasthi & Ahuja 1982 from the Neogene of Varkala in Kerala Coast, South India. All these species differ from the present fossil wood. *Ebenoxylon indicum* Ghosh & Kazmi, 1958 from the Tirap Frontier Division, Arunachal Pradesh, differs in having large vessel (t.d. 82-225 μm, r.d. 164-328 μm) and homogeneous xylem rays. *Ebenoxylon kartikcherriense* Prakash & Tripathi, 1970 from the Tipam Sandstone of Cachar is different in possessing 1-3 seriate xylem rays and slightly larger vessels (t.d. 80-180 μm and r.d. 92-240 μm). *Ebenoxylon arcotense* Awasthi (1970) from the Cuddalore Series of South India is quite distinct from the present fossil in having comparatively longer xylem rays (4-40 cells in height) without crystalliferous swollen ray cells. Moreover, the frequency of apotracheal parenchyma lines in *E. arcotense* is less than in the Siwalik fossil wood. *Ebenoxylon mohgaoense* Chitaley & Patil, 1972 from the Deccan Intertrappean beds of Mohgaonkalan also differs both in parenchyma pattern and the xylem rays. In this fossil the apotracheal parenchyma is diffuse and uniseriate, tangential line seen only at some places in between the xylem rays and the paratracheal parenchyma forms 1-2 seriate sheath around the vessel, whereas in the present fossil wood the apotracheal paren-

chyma is 1-2 seriate, closely placed, regular concentric lines and the paratracheal parenchyma is sparse. However, on the basis of the type and distribution of parenchyma *E. mohgaoense* does not appear to belong to *Diospyros* because there are no regular apotracheal parenchyma lines which is a characteristic feature of the wood of *Diospyros* and *Maba*. *Ebenoxylon miocenicum* Prakash, 1978 and *E. siwalicus* Prakash, 1981 from the Lower Siwalik beds of Kalagarh possess less frequent apotracheal parenchyma lines, i.e. 9-11 per mm. *Ebenoxylon obliquiporosum* is quite different in having vessels obliquely arranged along the radial lines. *E. deccanensis* Trivedi & Srivastava, 1982 from the Deccan Intertrappean beds of Madhya Pradesh also differs in having storied xylem rays.

Thus it is evident that the present fossil wood is quite different from all the species of *Ebenoxylon* Felix so far known, therefore it is named as *Ebenoxylon kalagarhensis* sp. nov., the specific name indicating the locality from where the fossil wood was collected.

The genus *Diospyros* Linn. consists of about 500 species of trees and shrubs and is widely distributed throughout the tropical and subtropical region of the world (Willis, 1973). About 40 species have been reported to occur in the Indian region, which grow in South India, Sri Lanka, Burma, Bangladesh and a few extending to North India (Gamble, 1972, p. 453; Purkayastha, 1982, p. 122). *Diospyros malabarica* (Derr.) Kosten, with which the fossil shows close resemblance, now grows in the Malayan region (Desch, 1957, p. 151).

SPECIFIC DIAGNOSIS

Ebenoxylon kalagarhensis sp. nov.

Wood diffuse porous. *Growth rings* indistinct. *Vessels* very small to medium-sized, round to oval solitary as well as in radial multiples of 2-4 (7), t.d. 45-80 μm, r.d. 65-125 μm, 5-8 per sq mm, plugged with dark gummy deposits; vessel-members 220-260 μm in length, usually with truncate or tailed ends; perforations simple; intervessel pit pairs small to medium, 5-7 μm in diameter, bordered, alternate, orbicular to oval in shape with linear to lenticular apertures. *Parenchyma* scanty paratracheal and 1-2 seriate, regular, very closely placed. *Xylem rays* mostly uniseriate, 4-25 cells in height; ray tissue heterogeneous with swollen crystalliferous upright cells present. *Fibres* semilibriform, non-septate.

Holotype—Museum no. BSIP 36224.

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Explanation of Plate

Plate 1

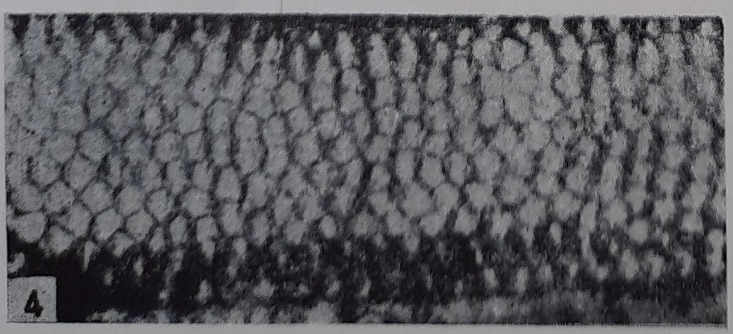
1. *Ormosioxylor bengalensis* Bande & Prakash—Cross section in low power showing shape, size and distribution of vessels and aliform to confluent parenchyma × 30. Slide no. BSIP 36222/I.
2. *Ormosioxylon bengalensis* Bande & Prakash—Tangential longitudinal section showing nature of xylem rays × 80. Slide no. BSIP 36222/II.
3. *Ormosioxylon bengalensis* Bande & Prakash—Radial longitudinal section showing weakly heterogeneous xylem rays × 80. Slide no. BSIP 36222/III.
4. *Ormosioxylon bengalensis* Bande & Prakash—Magnified intervessel pit-pairs × 450. Slide no. BSIP 36222/II.
5. *Terminalioxylon siwalicus* sp. nov.—Magnified cross section showing vasicentric, aliform-confluent paratracheal parenchyma × 80. Slide no. BSIP 36223/I.
6. *Terminalioxylon siwalicus* sp. nov.—Radial longitudinal section showing heterocellular xylem rays × 80. Slide no. BSIP 36223/III.

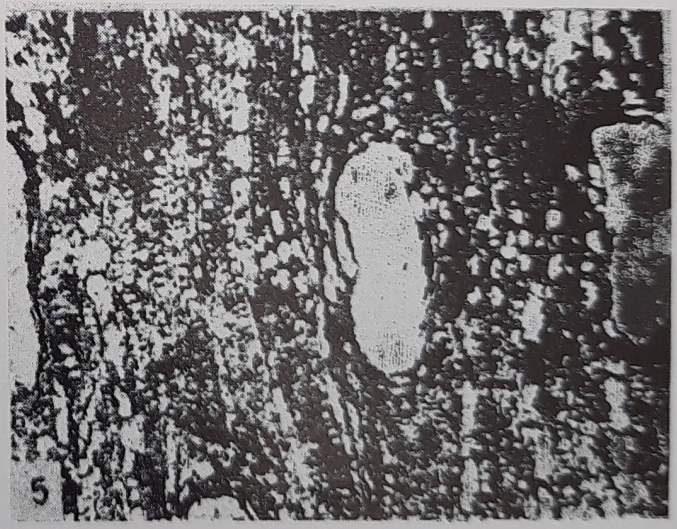
Plate 2

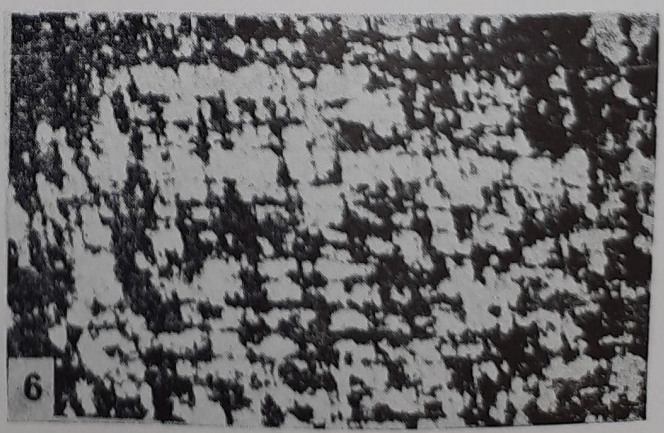
7. *Terminalioxylon siwalicus* sp. nov.—Cross section in low power showing shape, size and distribution of the vessels and parenchyma pattern. × 30. Slide no. BSIP 36223/I.
8. *Terminalia paniculata*—Cross section showing similar shape, size and distribution of the vessels and parenchyma pattern × 30.
9. *Terminalioxylon siwalicus* sp. nov.—Tangential longitudinal section shwonig structure of the xylem rays × 80. Slide no. BSIP 36223/II.
10. *Terminalia paniculata*—Tangential longitudinal section showing similar structure of the xylem rays × 90.

Plate 3

11. *Ebenoxylon kalagarhensis* sp. nov.—Cross section in low power showing shape, size and distribution of the vessels and parenchyma pattern × 30. Slide no. BSIP 36224/I.
12. *Diospyros malabarica*—Cross section in low power showing similar shape, size and distribution of the vessels and parenchyma pattern × 330.
13. *Ebenoxylon kalagarhensis* sp. nov.—Tangential longitudinal section showing structure of the xylem rays × 80. Slide no. BSIP 36224/II.
14. *Diospyros malabarica*—Tangential longitudinal section showing similar structure of the xylem rays × 80.
15. *Ebenoxylon kalagarhensis* sp. nov.—Radial longitudinal section showing heterocellular xylem rays × 80. Slide no. BSIP 36224/III.
16. *Ebenoxylon kalagarhensis* sp. nov.—Magnified intervessel pit-pairs × 600. Slide no. BSIP 36224/IV.





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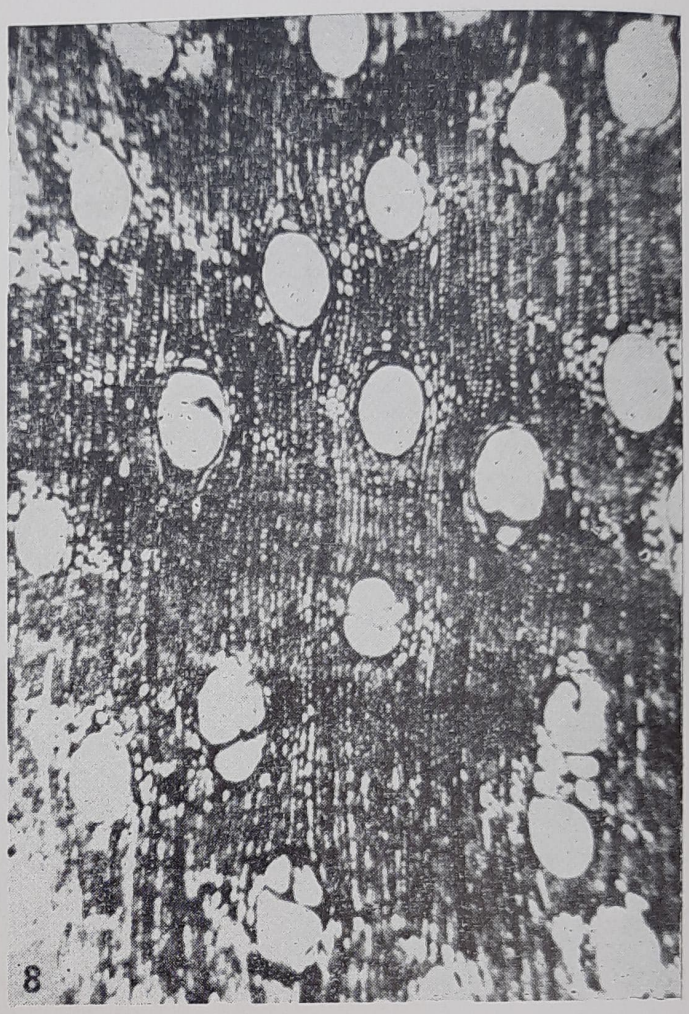
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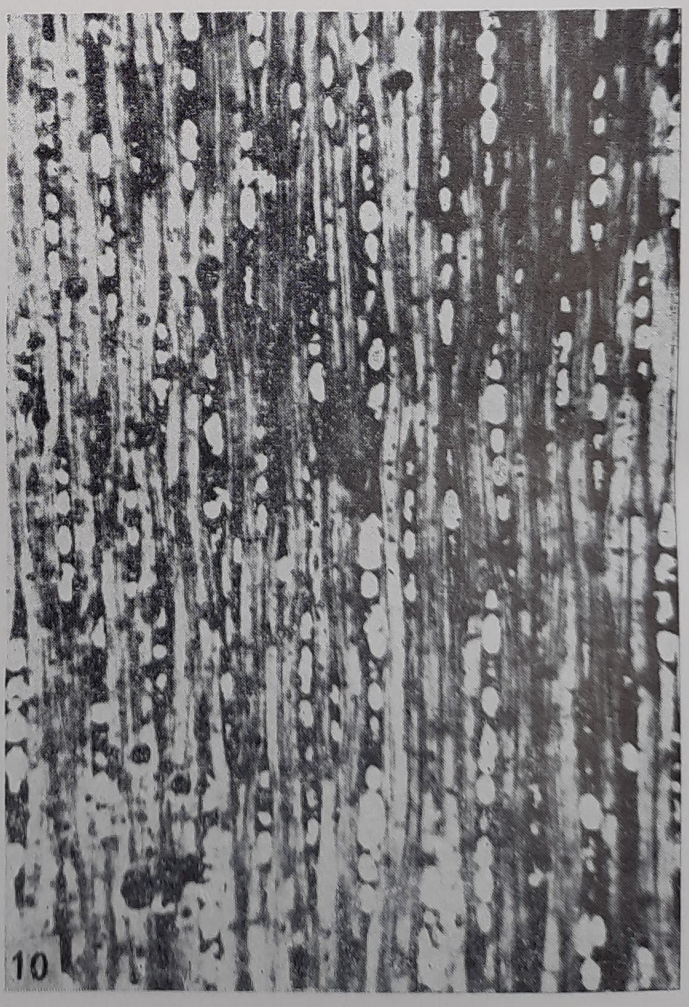
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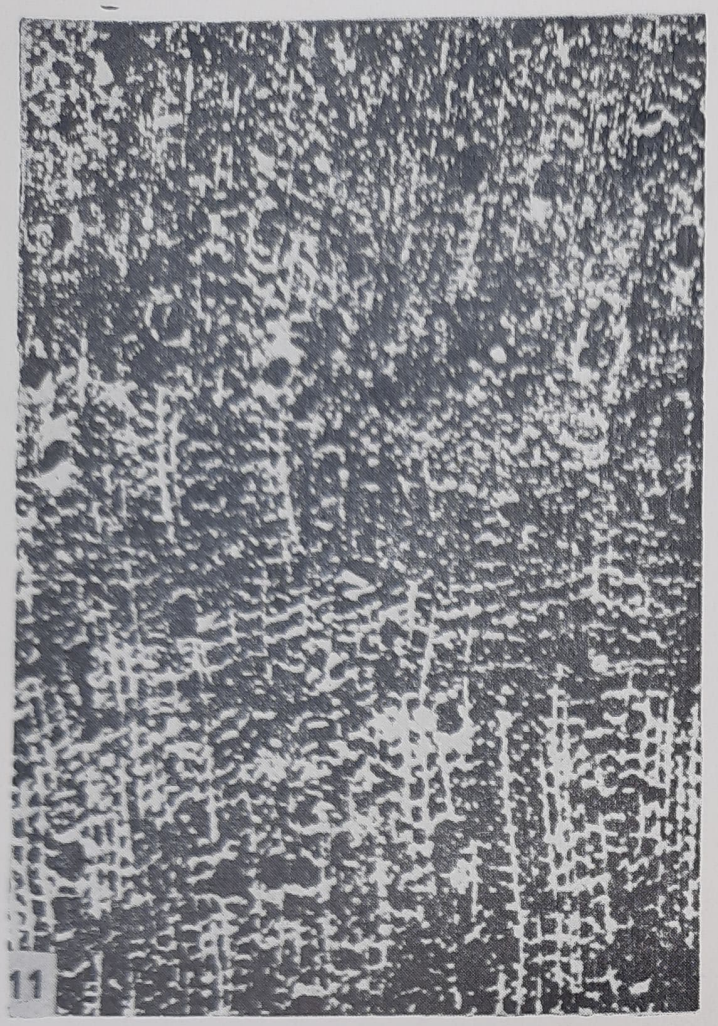
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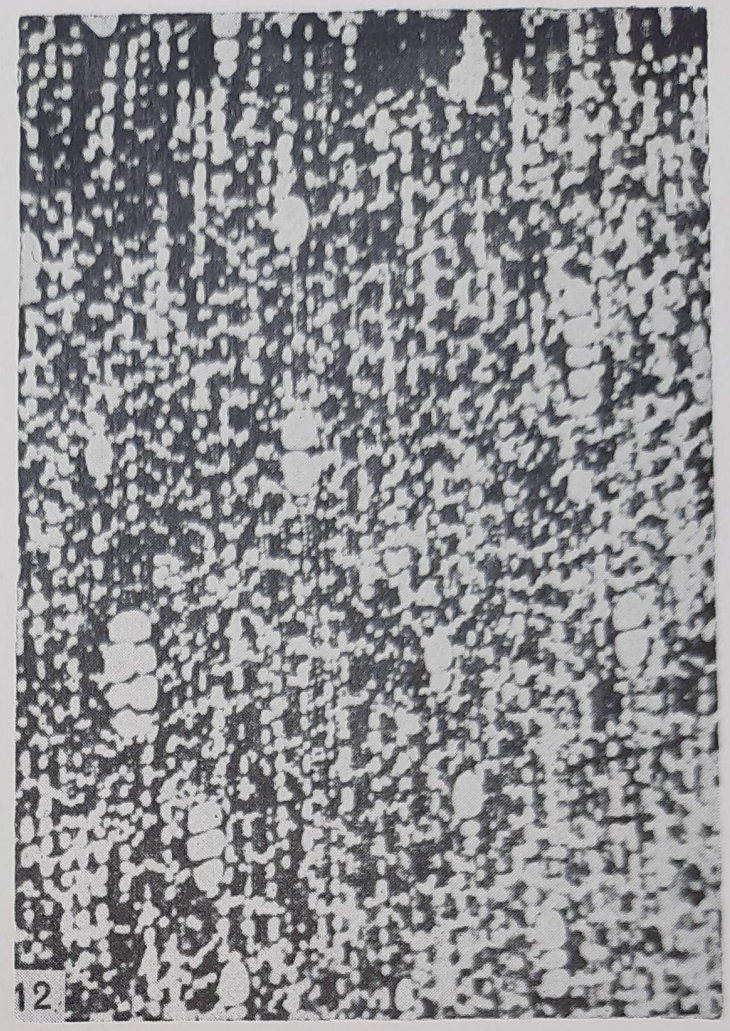
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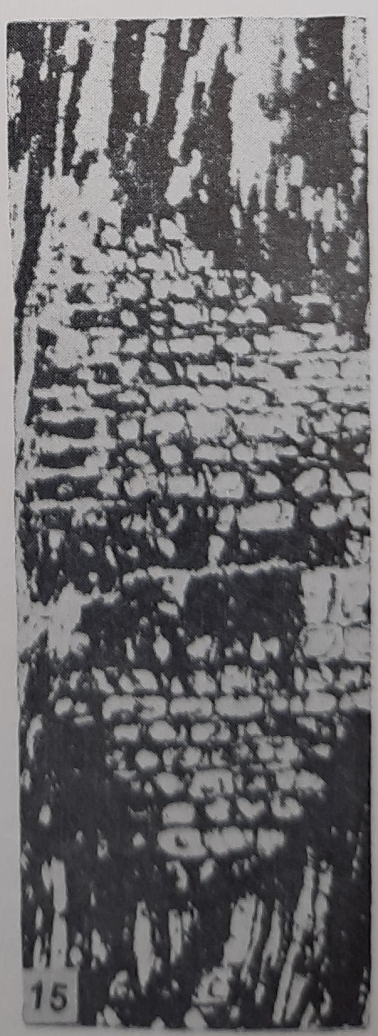
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