FOSSIL DICOTYLEDONOUS WOODS FROM THE DECCAN INTERTRAPPEAN BEDS OF MANDLA DISTRICT IN MADHYA PRADESH

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ABSTRACT

Fossil woods of *Sterculioxylon deccanensis* sp. nov., *Grewioxylon* sp. cf., *G. mahurzariense* Prakash & Dayal, *Elaeocarpoxylon mandlaensis* sp. nov. and *Atalantioxylon indicum* gen. et sp. nov. have been described here from the Deccan Intertrappean beds of Mandla District in Madhya Pradesh. These represent the extant genera *Sterculia, Grewia, Elaeocarpus-Echinocarpus* and *Atalantia-Limonia* of the families Sterculiaceae, Tiliaceae, Elaeocarpaceae and Rutaceae respectively. Of these, *Sterculia* and *Atalantia-Limonia* are new additions to the Palaeogene flora of India.

INTRODUCTION

THE present paper describes four fossil dicotyledonous woods collected from a new Intertrappean locality near the village Mohgaon (Map 1) in Mandla District of Madhya Pradesh. This Mohgaon is distinct from the well known locality of Mohgaon Kalan which is in Chhindwara District. It can best be approached from the Railway Station of Nainpur from which it is 15 km north-east.

Although fossil woods are quite abundant in the fields near the village Mohgaon, some stray pieces can also be picked up from around the villages Parsatola, Delha, Alipur, Sanha Tola and Samnapur which lie 4-10 km south-west of Mohgaon. From Samnapur two fossil woods have been described recently (Ingle, 1972, 1973). Another fossiliferous locality of this district, Parapani, has also yielded some interesting fossil woods (Bande, 1973, 1974).

SYSTEMATIC DESCRIPTION

FAMILY — STERCULIACEAE

Genus — *Sterculioxylon* Kräusel, 1939

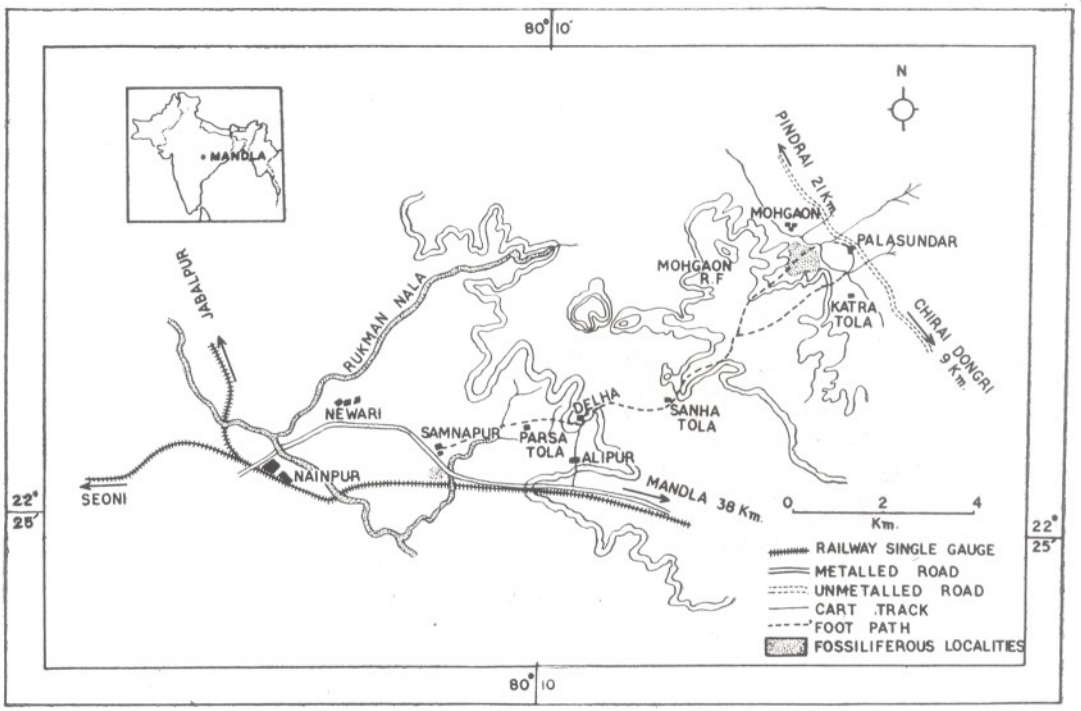
1. *Sterculioxylon deccanensis* sp. nov.

Pl. 1, figs. 1-5

The description of the present fossil is based on a piece of secondary wood measuring about 5 cm in length and 4 cm in diameter. The specimen is well-preserved to enable a detailed anatomical study.

Topography— Wood diffuse-porous. *Growth rings* absent (Pl. 1, fig. 1). *Vessels* medium to small in size, solitary and in radial multiples of 2-3-(4), rarely in clusters, evenly distributed, 12-18 per sq mm (Pl. 1, figs. 1, 2). *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma vasicentric forming 1-2 seriate sheath around the vessels; apotracheal parenchyma diffuse to diffuse-in-aggregate, usually with short uniseriate, tangential lines (Pl. 1, figs. 1, 2). *Xylem rays* of two distinct types, broad rays separated by a number of narrow rays (Pl. 1, figs. 1, 2), closely spaced, 8-10 per mm; ray tissue heterogeneous (Pl. 1, figs. 4, 5); narrow rays 1-2 (mostly 1) seriate, 25-55 μ broad and up to 60 cells or 400 μ in height composed of both procumbent and upright cells (Pl. 1, fig. 5); broad rays 3-10 cells or 100-225 μ in width and 60-120 cells or 1500-4800 μ in height, consisting of procumbent cells in the middle region flanked by the sheath cells and with uniseriate extensions of upright cells at one or both the ends (Pl. 1, figs. 4, 5). *Fibres* aligned in regular radial rows in between the consecutive xylem rays (Pl. 1, figs. 1, 2).

Elements — Vessels thick-walled, circular to oval when solitary, flattened at the places of contact when in groups, t.d. 60-120 μ, r.d. 70-180 μ; vessel members 300-450 μ in length with oblique to nearly horizontal ends; perforations simple; intervessel pit-pairs 4-6 μ in diameter, bordered, alternate, oval in shape with linear to



Map 1 — Locality map of Mohgaon and nearby areas.

lenticular apertures (Pl. 1, fig. 3). Vessel-parenchyma and vessel-ray pits could not be seen. *Parenchyma cells* thin-walled, t.d. 15-18 μ, height 120-153 μ with a tendency towards storied arrangement. *Ray cells* thin-walled, procumbent cells 15-20 μ in vertical height and 40-60 μ in radial length; upright cells 60-90 μ in vertical height and 40-60 μ in radial length. *Fibres* thick-walled, polygonal in cross section, 20-30 μ in diameter and 400-800 μ in length, non-septate; inter-fibre pits could not be seen.

Affinities — The main characters of the fossil wood, viz., the presence of diffuse to diffuse-in-aggregate parenchyma with a tendency towards storied arrangement, broad xylem rays separated by a number of narrow rays with sheath cells and thick-walled non-septate fibres, strongly suggest its affinity with the extant genus *Sterculia*. Chattaway (1932, 1937) has described two distinct types of apotracheal parenchyma in the modern species of *Sterculia*, i.e. (a) apotracheal parenchyma predominantly in lines of one cell width and (b) apotracheal parenchyma often indistinguishable from the paratracheal, predominantly in broad bands of 3 or 4 cells width. The affinities of the present fossil should be traced to those species of *Sterculia* in which apotracheal parenchyma is usually in uniseriate lines. These are *Sterculia angustifolia* Roxb., *S. caribaea* R. Br., *S. carthaginensis* Cav., *S. columbiana* Sprague, *S. crassiramea* Merril., *S. foetida* L., *S. harmanda* Pierre, *S. hypochra* Pierre, *S. javanica* R. Br., *S. macrophylla* Vent., *S. montana* Merril., *S. oblongata* R. Br., *S. ornata* Wall., *S. parviflora* Roxb., *S. philippinensis* Merril., *S. recordiana* Standl., *S. rubiginosa* Vent., *S. spangleri* R. Br., *S. tragacantha* Lind., *S. urceolata* Smith, *S. villosa* Roxb. (Chattaway, 1937, p. 358). An examination of thin sections of six species of *Sterculia* of the former group at the Forest Research Institute, Dehra Dun and a study of the published descriptions and photographs of these as well as two other species were made (Lecomte, 1926, pl. 21; Pearson & Brown, 1932, pp. 146-152, figs. 52-55; Chattaway, 1932, pl. 4, figs. 1, 2; Chattaway, 1937, pls. 29-31; Metcalfe & Chalk, 1950, pp. 243-251,

fig. 61J; Henderson, 1953, pls. 68, 69, figs. 362-364; Desch, 1957, pp. 581-583, pl. 114, fig. 2; Chowdhury & Ghosh, 1958, pp. 210-223, pls. 27, 28, figs. 160, 163, 164, 165; Brazier & Franklin, 1961, p. 79). The species studied at Dehra Dun are *Sterculia angustifolia* Roxb., *S. foetida* L., *S. ornata* Wall., *S. scaphigera* Wall., *S. urens* Roxb., and *S. villosa* Roxb. Detailed anatomical study of the above species indicates that the fossil does not show close resemblance with any particular species of *Sterculia* examined by us. However, it combines the anatomical characters of *Sterculia foetida* and *S. angustifolia*. Thus, in the size and distribution of vessels and the parenchyma pattern, the fossil wood shows similarity with *Sterculia foetida*. However, the lines of apotracheal parenchyma are more closely spaced in the living species than in the fossil. Moreover, the height of xylem rays is considerably less in *S. foetida* than in the fossil wood. In this character, the fossil is more similar to *S. angustifolia* where the rays are also of two types and the height of broad rays is about 5000 μ similar to the rays of the fossil wood. The amount of apotracheal parenchyma in this species is much more as compared to our wood from Deccan. As the fossil shows anatomical features of the modern wood of *Sterculia*, it has been placed under the organ genus *Sterculioxylon* Kräusel (1939).

Although five species of *Sterculioxylon* Kräusel are known from abroad, only one fossil species, viz., *Sterculioxylon dattai* Prakash & Tripathi (1974) has so far been recorded from the Tertiary of India. Those recorded from abroad are *Sterculioxylon aegyptiacum* (Ung.) Kräusel, 1939 from the Tertiary of Egypt and the Post-Eocene of Tibesti in Sahara (Boureau, 1949), *S. rhenanum* Müller-Stoll (1949) from the Eocene of South-West Germany, *S. freulonii* Boureau (1957) from the Post-Eocene of Libya, Sahara, *S. giarabubense* (Chiarugi) Kräusel (1939) from the Lower Oligocene to Lower Miocene of North Africa and *S. foetidense* Prakash (1973) from the Tertiary of Burma. All these are quite distinct from the present fossil wood. Thus, *Sterculioxylon aegyptiacum, S. giarabubense* and *S. freulonii* are different from our species in having vertical, traumatic secretory canals and broad bands of apotracheal parenchyma. Besides, width of the xylem rays is also less in the above three species, being 2-7 seriate in *S. aegyptiacum*, 1-5 seriate in *S. giarabubense* and 1-6 seriate in *S. freulonii*. However, the xylem rays are 1-10 cells broad and the parenchyma occurs in uniseriate tangential broken lines in the present species. *Sterculioxylon rhenanum* is also distinct from the present fossil in having broader, 1-15 seriate xylem rays and in possessing vasicentric to aliform-confluent and banded metatracheal parenchyma. The Burmese species, *S. foetidense*, although somewhat resembling the present fossil in the parenchyma pattern, differs from it in the size of vessels which is more in *S. foetidense* (t.d. 160-400 μ, r.d. 240-480 μ) than in the present specimen (t.d. 60-120 μ, r.d. 70-180 μ). Besides, the xylem rays are less broad, 1-8 seriate in *S. foetidense*. Lastly, *S. dattai* differs from the present fossil wood in having bigger vessels (t.d. 72-310 μ, r.d. 96-348 μ), more close lines of apotracheal parenchyma forming reticulum with the xylem rays, storied fibres and in the presence of traumatic, vertical gum canals. Because the present fossil wood is quite distinct from all the previously known species of *Sterculioxylon*, it is placed under a new species, *S. deccanensis*.

Family Sterculiaceae is chiefly a tropical family consisting of 60 genera and 700 species of trees, shrubs or herbs (Willis, 1973). The genus *Sterculia* Linn. consists of 300 species (Willis, 1973) distributed throughout the tropics and reaches its best development in tropical Asia (Pearson & Brown, 1932, p. 145). Twenty species are known from India (Chowdhury & Ghosh, 1958). *Sterculia foetida* with which the fossil shows some resemblance is a large tree found on the West Coast at low elevations from Konkan southwards, Ceylon, and Martaban and Upper Tenasserim in Burma. Outside the Indian region it has a wide distribution from tropical East Africa to North Australia. *S. angustifolia* is a small to medium sized tree found in Lower Burma from Martaban to Tenasserim (Chowdhury & Ghosh, 1958, pp. 212, 214).

SPECIFIC DIAGNOSIS

Sterculioxylon deccanensis sp. nov.

Wood diffuse-porous. *Growth rings* absent. *Vessels* small to medium-sized, t.d. 60-120 μ,

r.d. 70-180 μ, solitary and in radial multiples of 2-3-(4), rarely in clusters, evenly distributed, 12-18 per sq mm; vessel members 300-450 μ long with oblique to nearly horizontal ends; perforations simple; intervessel pit-pairs 4-6 μ in diameter, bordered, alternate, oval in shape with linear to lenticular apertures. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma vasicentric forming 1-2 seriate sheath around the vessels; apotracheal parenchyma diffuse to diffuse-in-aggregate forming short, usually uniseriate, tangential lines; parenchyma strands show storied tendency. *Xylem rays* 1-10 seriate, of two distinct types, broader rays separated by a number of narrow rays, 8-10 per mm; ray tissue heterogeneous; uniseriate rays quite common, made up of both procumbent and upright cells; multiseriate rays up to 10-seriate or 225 μ in width and up to 120 cells or 4800 μ in height, composed of upright and procumbent cells; sheath cells present. *Fibres* thick-walled, polygonal in cross section, 20-30 μ in diameter and 400-800 μ in length, non-septate; interfibre pits not seen.

Holotype — B.S.I.P. Museum no. 8/1505.

FAMILY — TILIACEAE

Genus — *Grewioxylon* (Schuster) Prakash & Dayal, 1965

2. *Grewioxylon* sp. cf. *Grewioxylon mahurzariense* Prakash & Dayal, 1965

Pls. 1, 2, figs. 6-8

Topography— *Wood* diffuse porous. *Growth rings* usually absent, sometimes indistinctly seen. *Vessels* small to medium-sized (Pl. 2, fig. 7), solitary and in radial rows of 2-3-(4) and rarely in small clusters of 3-4, evenly distributed, 18-25 per sq mm; tyloses absent. *Parenchyma* paratracheal, forming 1-2 seriate continuous or interrupted sheath around most of the vessels (Pl. 2, fig. 7). *Xylem rays* closely spaced, 10-15 per mm with broader rays separated by a number of narrow rays (Pl. 2, figs. 7, 8); normally 1-12 seriate becoming more broad in the region of knots; narrow rays 1-2 seriate or 30-75 μ wide and up to 30 cells or 900 μ in height; broader rays 3-12 cells or 60-180 μ in width and 40-120 cells or 600-2400 μ in height (Pl. 2, fig. 8); ray tissue heterogeneous, rays made up of big, angular *Pterospermum* type of tile cells with clusters of small procumbent cells (Pl. 1, fig. 6; Pl. 2, fig. 8). *Fibres* aligned in radial rows in between the consecutive xylem rays (Pl. 2, fig. 7).

Elements — *Vessels* thin-walled, circular to oval when solitary, with flat contact walls when in groups (Pl. 2, fig. 7), t.d. 60-120 μ, r.d. 75-150 μ; vessel members 300-375 μ long with truncate ends; perforations simple; intervessel pit-pairs small, 4-6 μ in diameter, bordered, alternate, oval with lenticular apertures. *Parenchyma cells* thin-walled, about 30 μ in diameter and 30-60 μ in height. *Ray cells* thin-walled; procumbent cells circular to oval in tangential section with dark contents, vertical height up to 15 μ, radial length 75 μ; tile cells without contents, brick-shaped in radial section, vertical height 30-40 μ, radial length 15-20 μ. *Fibres* moderately thick-walled, usually appearing thin-walled due to cellulosic degradation, polygonal in cross section, non-septate, 20-30 μ in diameter and 350-500 μ in length, showing tendency towards storied arrangement. *Ripple marks* indistinctly present.

Affinities — Of all the anatomical features of the fossil wood, the one which is of considerable diagnostic value is the presence of *Pterospermum* type of tile cells in the xylem rays. This type of tile cells occur in various genera of the families Bombacaceae, Sterculiaceae and Tiliaceae (Chattaway, 1933). However, considering this feature along with other anatomical structures of the fossil wood, particularly the vessel and parenchyma distribution and the fibre structure, the fossil resembles the modern wood of *Grewia laevigata* Vahl. of the family Tiliaceae from which it differs only in the absence of terminal parenchyma. Fossil woods of *Grewia* have been assigned to the genus *Grewioxylon* (Schuster) Prakash & Dayal (1965) and so far all the three species of *Grewioxylon* known are from India only. These are *Grewioxylon intertrappea* Shallom (1963), *G. mahurzariense* Prakash & Dayal (1965) and *G. indicum* Prakash & Dayal (1965) from the Deccan Intertrappean beds of Mahurzari near Nagpur. The present fossil wood compares very closely with *Grewioxylon mahurzariense* in all the minute anatomical characters except in the absence of terminal parenchyma (Table 1).

Although terminal parenchyma is an important character and may be a constant feature in some modern species, it has also been seen that it can be present in some and absent in other specimens of a particular species. Particular mention may be made here of *Grewia oppositifolia* in which terminal parenchyma has been seen demarcating the growth rings in some specimens while it is absent in others where the growth rings are delimited by thick-walled fibres. Considering this fact, the present fossil wood, which is similar to *Grewioxylon mahurzariense* in all the features except the terminal parenchyma, might also belong to another tree of this species lacking this character. However, in both the cases we are dealing with fragments of petrified woods where the material is limited, and it is not possible to study the range of variation in this feature. Consequently, we wish to describe our fossil wood as *Grewioxylon* sp. cf. *G. mahurzariense* Prakash & Dayal till some more specimens are studied to show the presence of terminal parenchyma.

Another fossil wood of *Grewia* described as *Grewioxylon intertrappea* Shallom (1963) from Mahurzari also shows close similarity to the present fossil wood as well as to *G. mahurzariense*. The only difference between these is the presence of diffuse parenchyma in *G. intertrappea* and its absence in the other two fossil woods discussed above.

Specimen — B.S.I.P. Museum no. 132/1505.

Family — Elaeocarpaceae

Genus — *Elaeocarpoxylon* Prakash & Dayal emend. Prakash & Tripathi, 1975

3. *Elaeocarpoxylon mandlaensis* sp. nov.

Pls. 2, 3, figs. 9-12

The present description is based on a piece of secondary wood showing well-preserved anatomical details. Knots are sometimes seen increasing the width of the xylem rays.

Topography— *Wood* diffuse-porous. *Growth rings* absent (Pl. 2, fig. 9). *Vessels* small, solitary, more often in radial multiples of 2-6, rarely up to 13 cells, forming conspicuous radial lines on the cross-surface, uniformly distributed, 30-40 per sq mm (Pl. 2, figs. 9, 10); tyloses absent. *Parenchyma* scanty paratracheal associated with some of the vessels (Pl. 2, fig. 10). *Xylem rays* normally 1-8 seriate, closely spaced, 10-18 per mm, but in the region of knots the rays are broader, up to 20 cells in width; ray tissue heterogeneous, rays divisible into two types (Pl. 2, fig. 10; Pl. 3, fig. 11), narrow rays numerous, 1-2 seriate or 15-40 μ wide and 3-15 cells or 150-700 μ in height made up of both procumbent and upright cells; broad rays 3-8 seriate or 75-165 μ wide and 25-60 cells or 700-1500 μ in height composed of procumbent cells in the central portion and frequently with uniseriate extensions of upright cells at one or both the ends (Pl. 3, fig. 11); end to end ray fusion present; sheath cells present in the broad rays. *Fibres* aligned in regular radial rows in between the xylem rays (Pl. 2, fig. 10).

Elements — *Vessels* circular to oval when solitary, with flat contact walls when in groups (Pl. 2; figs. 9, 10), t.d. 30-75 μ, r.d. 45-75 μ; vessel members 300-450 μ long with oblique ends; perforations simple; intervessel pit-pairs about 4 μ in diameter, bordered, alternate to opposite, circular to oval in shape with lenticular apertures (Pl. 3, fig. 12). *Parenchyma cells* about 30 μ in diameter and 45 μ in height. *Ray cells* usually filled with dark contents; procumbent cells 20-25 μ in vertical height and 50-60 μ in radial length; upright cells 60-70 μ in vertical height and 15-20 μ in radial length. *Fibres* non-libriform, polygonal in cross section, septate, 15-30 μ in diameter and 300-600 μ in length; interfibre pits not seen.

Affinities — Important anatomical characters of the fossil wood such as small vessels, sparse paratracheal parenchyma, heterogeneous ray tissue with numerous uniseriate rays and septate fibres suggest the affinities of the fossil with the genera *Elaeocarpus* L. and *Echinocarpus* Bl. of the family Elaeocarpaceae (Moll & Janssonius, 1906, pp. 534-547; Pearson & Brown, 1932, pp. 180-189; Desch, 1957, pp. 153-154; Kukachka & Rees, 1943, pp. 1-70; Metcalfe & Chalk, 1950, pp. 262-266; Chowdhury & Ghosh, 1958, pp. 241-247). Fifteen species of *Elaeocarpus* and four species of *Echinocarpus* were studied in detail from the slides available at the xylaria of the Birbal Sahni Institute of Palaeobotany and the Forest Research Institute, Dehra Dun. Besides,

TABLE I – SHOWING ANATOMICAL CHARACTERS OF THE KNOWN SPECIES OF *GREWIOXYLON*

Sl No.	Species	Wood	Growth rings	Vessels			Parenchyma	Xylem rays	Tile cells	Fibres	Ripple marks	Modern Comparable Species
				Size	Frequency	Distribution						
1.	*Grewioxylon intertrappea* Shallom, 1963	Diffuse-porous	Present, indistinct	t.d. 100-150 μ	—	Solitary and in radial multiples of 2-6.	Paratracheal, vasicentric and diffuse	1-12 or more cells broad and up to 4 mm in height; narrow rays indistinctly storied	*Pterospermum* type	Non-libriform, non-septate, indistinctly storied	Present, indistinct	*Grewia laevigata*
2.	*Grewioxylon mahurzariense* Prakash & Dayal, 1965	Diffuse-porous	Distinct due to presence of terminal parenchyma	t.d. 60-180 μ, r.d. 60-150 μ	5-15 per sq mm	Solitary and in radial multiples of 2-4 or in clusters	Terminal and paratracheal, vasicentric forming 1-3 seriate sheath, strands irregularly storied	1-12 cells broad and up to 4 mm in height; narrow rays with storied tendency	*Pterospermum* type	Thin to moderately thick-walled, non-septate, irregularly storied	Present, indistinct	*Grewia laevigata*
3.	*Grewioxylon indicum* Prakash & Dayal, 1965	Diffuse-porous	Present, delimited by terminal parenchyma	t.d. 45-105 μ, r.d. 45-90 μ	4-12 per sq mm	Solitary and in radial multiples of 2-4	Paratracheal, terminal and diffuse with storied tendency	1-7 cells broad and up to 2 mm height, storied	*Pterospermum* type	Thin to moderately thick-walled, non-septate, irregularly storied	—	*Grewia tiliaefolia*
4.	*Grewioxylon* sp. cf. *G. mahurzariense* Prakash & Dayal	Diffuse-porous	Usually absent, sometimes indistinctly seen	t.d. 60-120 μ, r.d. 75-150 μ	18-25 per sq mm	Solitary and in radial multiples of 2-4 or rarely in clusters	Vasicentric forming 1-2 seriate sheath around most of the vessels	1-12 cells broad and up to 5 mm in height; ray tissue heterogeneous	*Pterospermum* type	Moderately thick-walled, non-septate, tendency towards storied arrangement	Present, indistinct	Probably *Grewia laevigata*

description and photographs of *Elaeocarpus grandis* F.V.M. (Metcalfe & Chalk, 1950, pp. 264-265, fig. 64C), *E. calomala* (Blanco) Merril. (Kanehira, 1924, p. 14), *E. dubius* A.D.C. (Lecomte, 1926, pl. 31), *E. robustus* Roxb. (Pearson & Brown, 1932, pp. 183-184, fig. 67; Desch, 1957, pp. 153-154; Chowdhury & Ghosh, 1958, p. 246, pl. 30, fig. 180), *E. oxypyren* Koord. & Valet., *E. pierrei* Koord & Valet., *E. longifolius* Bl., *E. glaber* Bl., *E. grandiflorus* Sm., *E. petiolatus* Wall., *E. acronodia* Mast., *E. macrophyllus* Bl., *E. leptomischus* Ridl., *E. parvifolius* Wall., *E. obtusus* Bl., *E. stipularis* Bl., *E. subglobosus* Merr., *E. wrayi* King (Moll & Janssonius, 1906, pp. 534-547; Desch, 1957, pp. 153-154) and *Echinocarpus dasycarpus* Benth., *E. assamicus* Benth., and *E. sigun* Bl. (Pearson & Brown, 1932, pp. 180-181, fig. 66; Chowdhury & Ghosh, 1958, pp. 242-243, pl. 30, fig. 177) were also studied. This study revealed that the fossil wood shows close similarity with *Echinocarpus sigun* Bl., *E. assamicus* Bl., and some species of *Elaeocarpus* but more with *Echinocarpus*. The similarity could be observed in the parenchyma pattern, and in the structure of xylem rays and septate fibres. However, the only observable difference between the wood structure of *Echinocarpus sigun* and the fossil is that in the extant species the growth rings are demarcated by a thin band of thick-walled fibres, and long radial multiples of vessels like those of the fossil are not observed. However, similar radial multiples of vessels up to 11 cells long are present in another species of *Echinocarpus*, i.e. *E. assamicus*, but the xylem rays of this species are only up to 5 cells in width. Wood anatomy of the modern species of *Elaeocarpus* and *Echinocarpus* has been critically studied by Prakash (1974) who states that wood structure in *Elaeocarpus* is heterogeneous. Some of the species of this genus are so similar to *Echinocarpus* in their wood anatomy that it is not possible to distinguish them by their wood structure alone. So, Prakash (*loc. cit.*) has classified the woods of these two genera into the following three groups.

Group I — It includes only those species of *Elaeocarpus* which possess diffuse parenchyma in addition to the terminal type and the traumatic gum canals.

Group II — Includes only those species of *Echinocarpus* which are quite distinct from *Elaeocarpus* in having diffuse-in-aggregate parenchyma forming distinct, uniseriate lines.

Group III — This includes both *Elaeocarpus* and *Echinocarpus* possessing only scanty paratracheal parenchyma.

As the present wood shows only scanty paratracheal parenchyma, it resembles anatomically similar species of *Elaeocarpus* and *Echinocarpus*. As stated above, Prakash (*loc. cit.*) suggested the use of organ genus *Elaeocarpoxylon* for such fossil woods which show affinities with both *Elaeocarpus* and *Echinocarpus*. Therefore, this fossil wood from the Deccan is being placed under the genus *Elaeocarpoxylon*. Two fossil woods resembling the modern woods of *Elaeocarpus-Echinocarpus* are so far known. These are *Elaeocarpoxylon antiquum* Prakash & Dayal (1964) from the Deccan Intertrappean series of Mahurzari and *Elaeocarpoxylon hailakandiense* Prakash & Tripathi (1975) from the Tipam Sandstones of Assam. Both these species can be distinguished easily from the fossil described here. Thus, *Elaeocarpoxylon antiquum* differs from the present fossil in having less frequent vessels (5-14 per sq mm), narrower, 1-3 seriate xylem rays and in possessing traumatic gum canals. The vessel frequency is 30-40 per sq mm, the rays are 1-8 seriate, and the gum canals are absent in the present fossil. *Elaeocarpoxylon hailakandiense* also differs from the fossil wood from Mandla in a number of anatomical characters. The vessels in *E. hailakandiense* are bigger (t.d. 25-190 μ, r.d. 52-210 μ) than in the present fossil (t.d. 30-75 μ, r.d. 45-75 μ) and their frequency is less (8-10 per sq mm) in comparison to the Deccan Intertrappean wood (30-40 per sq mm). Besides, the vessels of *E. hailakandiense* are arranged in short radial groups of 2-5 against longer radial multiples of 2-13 in the present fossil. Lastly, although the xylem rays are 1-8 seriate in both the species, they are usually 4-5 seriate in *E. hailakandiense*, whereas 6-8 seriate rays are much more frequent in the fossil wood from Deccan.

One more fossil wood, *Elaeocarpus chitaleyi* Nambudiri & Tidwell (1975), has recently been described from the Deccan Intertrappean beds of Mohgaon Kalan. From its description and photographs it does not appear to show any similarity with the wood structure of Elaeocarpaceae and is at a very immature stage of development.

As the present fossil is quite distinct from both the known species of *Elaeocarpoxylon*, it has been placed in a new species, *Elaeocarpoxylon mandlaensis*, the specific name is after the name of the Mandla District where it has been found.

Elaeocarpaceae is a family of twelve genera and 350 species of trees and shrubs with a tropical and subtropical habitat (Willis, 1973). The genus *Echinocarpus* Bl. consists of 120 species (Willis, 1973, p. 1073), distributed mostly in south-east Asia and Australia. Five species are known to occur in India and are distributed in the region of Bhutan, Sikkim, Assam and throughout the eastern Himalayas (Chowdhury & Ghosh, 1958, pp. 241-242). *Echinocarpus sigun* Bl. with which the fossil shows maximum resemblance is a large tree of Khasi Hills and Burma, found growing at elevations from 900-1500 m. It also occurs in Cambodia and Java (Chowdhury & Ghosh, 1958, p. 242). *E. assamicus* Blume with which also the fossil shows some similarity is a common tree throughout Assam occurring more or less gregariously on river banks. It is also found in Sikkim (Chowdhury & Ghosh, 1958, p. 242).

SPECIFIC DIAGNOSIS

Elaeocarpoxylon mandlaensis sp. nov.

Wood diffuse-porous. *Growth rings* absent. *Vessels* small, t.d. 30-75 μ, r.d. 45-75 μ, circular to oval, solitary and more often in radial multiples of 2-13 cells, uniformly distributed, 30-40 per sq mm; perforations simple; intervessel pit-pairs about 4 μ in diameter, bordered, alternate to opposite, circular to oval in shape with lenticular apertures. *Parenchyma* scanty paratracheal, associated with some of the vessels. *Xylem rays* normally 1-8 cells broad, narrow rays quite common, rays up to 60 cells or 1500 μ in height, 10-18 per mm; ray tissue heterogeneous, rays heterocellular, consisting of both procumbent and upright cells; sheath cells present in the broader rays. *Fibres* non-libriform, septate, polygonal in cross section, 15-30 μ in diameter and 300-600 μ in length; interfibre pits not preserved.

Holotype — B.S.I.P. Museum no. 124/1505.

FAMILY — RUTACEAE

Genus — *Atalantioxylon* gen. nov.

4. *Atalantioxylon indicum* sp. nov.

Pl. 3, figs. 13-17

The description is based on a piece of secondary wood about 20 cm in length and 8 cm in diameter. The preservation of the fossil is fairly good to allow a detailed study.

Topography— Wood diffuse-porous. *Growth rings* present, demarcated by a line of terminal parenchyma (Pl. 3, fig. 15). *Vessels* small to medium in size, solitary and mostly in radial multiples of 2-4 (Pl. 3, fig. 15), more or less evenly distributed showing some crowding at the beginning of the growth rings, 20-36 per sq mm; tyloses present. *Parenchyma* paratracheal, terminal and apotracheal diffuse; paratracheal parenchyma sparse, present as few cells around some of the vessels (Pl. 3, fig. 14); terminal parenchyma forms 2-3 seriate continuous lines demarcating the growth rings (Pl. 3, fig. 15); diffuse parenchyma very sparse, difficult to locate in cross section. *Xylem rays* fine to medium, 1-3 (mostly 2) seriate (Pl. 3, fig. 17), 6-8 per mm, separated by rows of fibres, 5-20-(30) cells or 75-300 μ-(500 μ) in height (Pl. 3, fig. 17); ray tissue homogeneous, rays made up of procumbent cells only. *Fibres* moderately thick-walled with big lumen (Pl. 3, fig. 14), aligned in radial rows in between the xylem rays.

Elements — Vessels thin-walled, circular to oval when solitary, sometimes elliptical due to pressure during fossilization (Pl. 3, figs. 14, 15), t.d. 30-120 μ, r.d. 60-150 μ; vessel members 150-400 μ long with oblique ends; perforations simple; intervessel pit-pairs small, about 4-6 μ in diameter, bordered, alternate, circular to oval in shape with linear to lenticular apertures (Pl. 3, fig. 13). *Parenchyma cells* thin-walled, 20-25 μ in diameter and 45-60 μ in length. *Ray cells* polygonal in tangential section, often with dark contents, 30-45 μ in radial length and 15-20 μ in vertical height. *Fibres* polygonal in cross section, non-septate (Pl. 3, fig. 17), 15-20 μ in diameter and 400-600 μ in length; interfibre pits not seen.

Affinities — Important anatomical characters of the fossil wood, namely small to

medium sized vessels, thin bands of terminal parenchyma along with the scanty paratracheal and diffuse type, 1-3 (mostly 2) seriate, homogeneous xylem rays and moderately thick-walled, non-septate fibres, strongly indicate the affinity of this fossil wood with the family Rutaceae (Metcalfe & Chalk, 1950, pp. 305-316; Pearson & Brown, 1932, pp. 190-212; Negi, 1963, pp. 13-49). A detailed anatomical study of various genera of this family revealed a close resemblance of the fossil wood with the modern woods of *Atalantia* Correa, and *Limonia* L. which are anatomically very similar. A comparison was made with the woods of *Atalantia monophylla* DC., *A. missionis* Oliv. and *Limonia acidissima* Linn. which were available to us at the Forest Research Institute, Dehra Dun. Besides, photographs and published description of *Atalantia monophylla* and *Limonia acidissima* were also studied (Pearson & Brown, 1932, pp. 200-204; Negi, 1963, pp. 20-21, 35-37, pls. 32, 34, figs. 90, 200). This study indicated that the species *Atalantia monophylla* and *Limonia acidissima* are very similar in wood structure and that they cannot be separated from each other anatomically. The fossil wood under consideration resembles very closely both these species in all the anatomical characters such as shape, size and distribution of vessels, parenchyma pattern, 1-3 seriate, homogeneous xylem rays, and non-septate fibres. The only difference observed between the living and the fossil species is the presence of crystalliferous apotracheal parenchyma in the living and its absence in the fossil. As the fossil shows resemblance with both *Atalantia* and *Limonia* in wood structure, it is placed under a new organ genus *Atalantioxylon* instituted to include the fossil woods showing wood structure similar to those of *Atalantia* and *Limonia* of Rutaceae.

In 1962, Chitaley and Shallom described a fossil wood from the Deccan Intertrappean beds near Nagpur. Although they placed it in the family Rutaceae but from its photographs and text-figures it does not appear to belong to this family. It also differs markedly from our fossil in the absence of terminal parenchyma and in having two types of xylem rays, short and long, made up of both procumbent and erect cells. The xylem rays are of one type and homogeneous in our fossil. As such, the present petrified wood is the first authentic record of Rutaceae in fossil state from India.

Rutaceae is a large family of 150 genera and 900 species of tropical as well as temperate habitat (Willis, 1973, p. 1014). In the Indian subcontinent, it is represented by about 19 genera (Negi, 1963, p. 15). *Atalantia monophylla* and *Limonia acidissima* with which the fossil shows close resemblance grow quite widely in India. *A. monophylla* is found throughout the mountainous regions of South India, Bihar, Orissa, Assam and Ceylon extending to the Andamans and Burma (Negi, 1963, p. 20). *Limonia acidissima* is found in the sub-Himalayan tract from the Ravi eastwards ascending to 1200 m almost throughout the dry hill forests in the Punjab, Uttar Pradesh, Bombay, Mysore, Madras, Andhra Pradesh and Upper Burma forests down to Prome (Negi, 1963, p. 136).

GENERIC DIAGNOSIS

Atalantioxylon gen. nov.

Wood diffuse-porous. *Growth rings* present, demarcated by terminal parenchyma. *Vessels* small to medium sized, solitary and in radial multiples; perforations simple; intervessel pit-pairs bordered, alternate, circular to oval with linear to lenticular apertures. *Parenchyma* terminal, paratracheal, and diffuse. *Xylem rays* fine to medium, homogeneous. *Fibres* non-septate, thick-walled.

Genotype — *Atalantioxylon indicum* gen. et sp. nov.

SPECIFIC DIAGNOSIS

Atalantioxylon indicum sp. nov.

Wood diffuse-porous. *Growth rings* present, demarcated by a line of terminal parenchyma. *Vessels* small to medium in size, t.d. 30-120 μ, r.d. 60-150 μ, solitary and in radial multiples of 2-4, almost evenly distributed, 20-36 per sq mm; vessel members 150-400 μ long with oblique ends; perforations simple; intervessel pit-pairs about 4-6 μ in diameter, bordered, alternate, circular to oval in shape with linear to lenticular apertures. *Parenchyma* terminal, paratra-

cheal and diffuse; terminal parenchyma forming 2-3 seriate tangential lines demarcating the growth rings; paratracheal parenchyma sparse, as few cells around some of the vessels; diffuse parenchyma extremely sparse. *Xylem rays* 1-3 (mostly 2) seriate and 5-30 cells or 75-500 μ in height, 6-8 per mm; ray tissue homogeneous, the rays made up of procumbent cells only. *Fibres* moderately thick-walled with big lumen, polygonal in cross section, non-septate, 15-20 μ in diameter and 400-600 μ in length.

Holotype — B.S.I.P. Museum no. 63/1505.

DISCUSSION

A survey of the fossil woods described from Mohgaon and Parapani, the two Deccan Intertrappean localities of Mandla District in Madhya Pradesh, shows that the modern genera represented by fossil woods at these localities are *Polyalthia, Homalium, Bischofia*, (Bande, 1973, 1974), *Syzygium*, ?*Vitex* (Ingle, 1972, 1973; Prakash, 1974), *Sterculia, Grewia, Elaeocarpus-Echinocarpus* and *Atalantia-Limonia*. They belong to the families Anonaceae, Flacourtiaceae, Euphorbiaceae, Myrtaceae, Verbenaceae, Sterculiaceae, Tiliaceae, Elaeocarpaceae and Rutaceae respectively. Out of these nine families, Sterculiaceae is a new addition to the list of known dicot families from the Palaeogene flora of India (Lakhanpal, 1974). The presence of Rutaceae in the Palaeogene of India which was so far doubtful, is now established with the discovery of *Atalantia-Limonia* from the Deccan Intertrappean beds of Mandla District. Except *Grewia* and *Elaeocarpus* none of the genera recorded from these two localities of Mandla is known from other areas of the Deccan Intertrappean Series. Whether this assemblage of plants represents a distinct florule in the Deccan Intertrappean flora can be said only after more fossil plants are discovered from this region.

ACKNOWLEDGEMENT

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REFERENCES

BANDE, M. B. (1973). A petrified dicotyledonous wood from the Deccan Intertrappean beds of Mandla District, Madhya Pradesh. *Botanique*, **4**(1): 41-48.

BANDE, M. B. (1974). Two fossil woods from the Deccan Intertrappean beds of Mandla District, Madhya Pradesh. *Geophytology*, **4**(2): 189-195.

BOUREAU, E. (1949). Etude Palaéoxylologique du Sahara (VI) — Sur une forme nouvelle de *Sterculioxylon* (*Nicolia*) *aegyptiacum* (Unger) Kräusel, des couches Post-Eocenes du Tibesti. *Bull. Mus.*, 2 e Serie, **21**(6): 776-787.

BOUREAU, E. (1957). Etude Palaéoxylologique du Sahara (XXIII). Sur une nouvelle espece de bois fossile de Sterculiaceae récotée a Ouaou en Namous (Libya): *Sterculioxylon freulonii* n. sp. *Bull. Mus.*, 2 e Serie, **29**(1): 112-120.

BRAZIER, J. D. & FRANKLIN, G. L. (1961). Identification of hard woods. A microscopic key. *Forest Prod. Res. Bull.*, **46**: 1-96.

CHATTAWAY, M. M. (1932). The wood of the Sterculiaceae. 1. Specialization of the vertical wood parenchyma within the sub-family Sterculieae. *New Phytol.*, **31**: 119-132.

CHATTAWAY, M. M. (1933). Tile cells in the rays of the Malvales. *New Phytol.*, **32**: 261-273.

CHATTAWAY, M. M. (1937). The wood anatomy of the family *Sterculiaceae*. *Phil. Trans. R. Soc.*, **228**: 313-366.

CHITALEY, S. D. & SHALLOM, L. J. (1962). A fossil wood of Rutaceae from Deccan Intertrappean beds of India. *Proc. Rajasthan Acad. Sci.*, **9**(2): 31-34.

CHOWDHURY, K. A. & GHOSH, S. S. (1958). *Indian woods, their identifications, properties and uses*. Delhi.

DESCH, H. E. (1957). Manual of Malayan Timbers. 1. *Malayan For. Rec.*, **15**: 1-328.

HENDERSON, F. Y. (1953). An atlas of end-grain photomicrographs for the identification of hard woods. *Forest Prod. Res. Bull.*, **26.** London.

INGLE, S. R. (1972). A new fossil dicotyledonous wood of Verbenaceae from Mandla District of Madhya Pradesh, India. *Botanique*, **3**(1): 7-17.

INGLE, S. R. (1973). *Syzigioxylon mandlaense* gen. et sp. nov. A fossil dicotyledonous wood from Mandla District of Madhya Pradesh, India. *Botanique*, **4**(1): 71-76.

KANEHIRA, R. (1924). *Identification of Philippine Woods by Anatomical Characters*. Taihoku.

KRÄUSEL, R. (1939). Ergebnisse der Forschungsreisen. Prof. E. Stromers in den Wüsten Ägyptens. IV. Die fossilen Floren Ägyptens. *Abh. bayer. Akad. Wiss. N.F.*, **47**: 5-140.

KUKACHKA, B. F. & REES, L. W. (1943). Systematic anatomy of the woods of the Tiliaceae. *Tech. Bull. Minist. Agric.*, **158**: 1-70.

LAKHANPAL, R. N. (1974). Floristic evidence in the stratigraphical subdivision of the Indian Tertiary. In: K. R. Surange *et al.* (Eds.) — *Aspects & Appraisal of Indian Palaeobotany*.

Birbal Sahni Institute of Palaeobotany, Lucknow: 496-501.

LECOMTE, H. (1926). *Les bois de L' Indochine.* Paris.

METCALFE, C. R. & CHALK, L. (1950). *Anatomy of the Dicotyledons.* Vols. **1** & **2.** Oxford.

MOLL, J. W. & JANSSONIUS, H. H. (1906). *Mikrographie des holzes der auf Java vorkommenden Baumarten.* 1. Leiden.

MÜLLER-STOLL, W. R. UND, H. (1949). *Sterculioxylon rhenanum* nov. spec. aus dem alttertiär Sudwest Deutschlands (Studien uber Fossile Laub-Hölzer 1). *Palaeontographica,* **89B**: 204-217.

NAMBUDIRI, E. M. V. & TIDWELL, W. D. (1975). *Elaeocarpus chitaleyi* sp. nov. from the Deccan Intertrappean beds of India. *Geology studies,* **22**(1): 29-37.

NEGI, B. S. (1963). Family Rutaceae — In: *Indian woods, their identification, properties and uses.* Dehra Dun.

PEARSON, R. S. & BROWN, H. P. (1932). *Commercial Timbers of India,* Vols. **1** & **2.** Calcutta.

PRAKASH, U. (1973). Fossil woods from the Tertiary of Burma. *Palaeobotanist,* **20**(1): 48-70.

PRAKASH, U. (1974). Palaeogene angiospermous woods from India. In: K. R. Surange *et al.* (Eds.) — *Aspects & Appraisal of Indian Palaeobotany.* Birbal Sahni Institute of Palaeobotany, Lucknow: 306-320.

PRAKASH, U. & DAYAL, R. (1964). Fossil woods resembling *Elaeocarpus* and *Leea* from the Deccan Intertrappean beds of Mahurzari near Nagpur. *Palaeobotanist,* **12**(2): 121-127.

PRAKASH, U. & DAYAL, R. (1965). Fossil woods of *Grewia* from the Deccan Intertrappean Series, India. *Palaeobotanist,* **13**(1): 17-24.

PRAKASH, U. & TRIPATHI, P. P. (1974). Fossil woods from the Tertiary of Assam. *Palaeobotanist,* **21**(3): 305-316.

PRAKASH, U. & TRIPATHI, P. P. (1975). Fossil dicotyledonous woods from the Tertiary of Eastern India. *Palaeobotanist,* **22**(1): 51-62.

SHALLOM, L. J. (1963). A fossil dicotyledonous wood with tile cells, from the Deccan Intertrappean beds of Mahurzari. *J. Indian bot. Soc.,* **42**(2): 170-176.

WILLIS, J. C. (1973). *A dictionary of the Flowering Plants and Ferns.* Cambridge.

EXPLANATION OF PLATES

PLATE 1

1. *Sterculioxylon deccanensis* — Cross section showing shape, size and distribution of vessels, parenchyma and uniseriate and multiseriate xylem rays. × 30. Slide no. 5185-8/1505.

2. *Sterculioxylon deccanensis* — Cross section magnified to show paratracheal and diffuse-in-aggregate lines of apotracheal parenchyma, multiseriate and uniseriate xylem rays. × 65. Slide no. 5185-8/1505.

3. *Sterculioxylon deccanensis* — Intervessel pit-pairs. × 550. Slide no. 5186-8/1505.

4. *Sterculioxylon deccanensis* — Radial longitudinal section showing procumbent and upright cells. × 120. Slide no. 5187-8/1505.

5. *Sterculioxylon deccanensis* — Tangential longitudinal section showing broad multiseriate rays with sheath cells and uniseriate rays. × 45. Slide no. 5188-8/1505.

6. *Grewioxylon* sp. cf. *Grewioxylon mahurzariense*— Radial longitudinal section showing tile cells. × 180. Slide no. 5189-132/1505.

PLATE 2

7. *Grewioxylon* sp. cf. *Grewioxylon mahurzariense* — Cross section showing shape, size and distribution of vessels, uniseriate and multiseriate rays. × 40. Slide no. 5190-132/1505.

8. *Grewioxylon* sp. cf. *Grewioxylon mahurzariense* — Tangential longitudinal section showing multiseriate xylem rays with tile cells and uniseriate rays. × 35. Slide no. 5191132/1505.

9. *Elaeocarpoxylon mandlaensis* — Cross section showing shape and size of the vessels arranged in radial multiples. × 80. Slide no. 5192-124/1505.

10. *Elaeocarpoxylon mandlaensis* — Cross section enlarged to show radial multiples of vessels, scanty paratracheal parenchyma and xylem rays. × 120. Slide no. 5192-124/1505.

PLATE 3

11. *Elaeocarpoxylon mandlaensis* — Tangential section showing uniseriate and multiseriate xylem rays. Note sheath cells in the multiseriate rays. × 55. Slide no. 5193-124/1505.

12. *Elaeocarpoxylon mandlaensis* — Intervessel pit-pairs. × 400. Slide no. 5194-124/1505.

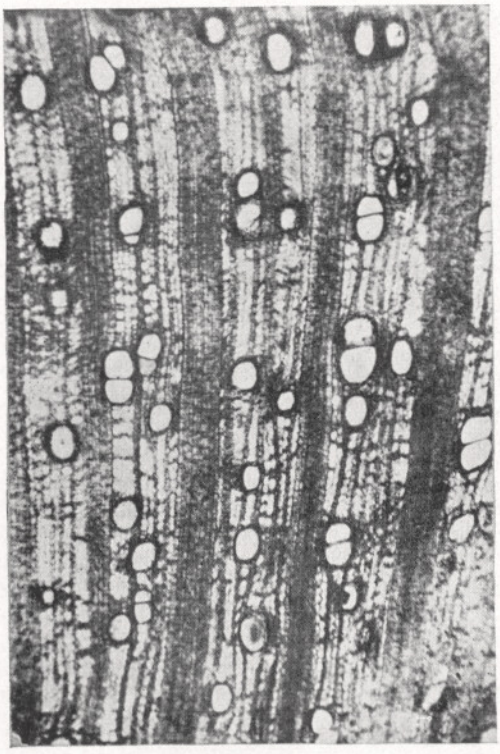
13. *Atalantioxylon indicum* — Intervessel pit-pairs. × 300. Slide no. 5195-63/1505.

14. *Atalantioxylon indicum* — Cross section showing shape and size of the vessels, scanty paratracheal parenchyma and radial rows of fibres. × 90. Slide no. 5196-63/1505.

15. *Atalantioxylon indicum* — Cross section showing distribution of vessels and terminal parenchyma demarcating the growth rings. × 35. Slide no. 5196-63/1505.

16. *Atalantioxylon indicum* — Radial longitudinal section showing homogeneous xylem rays. × 120. Slide no. 5251-63/1505.

17. *Atalantioxylon indicum* — Tangential longitudinal section showing homogeneous xylem rays. × 120. Slide no. 5197-63/1505.



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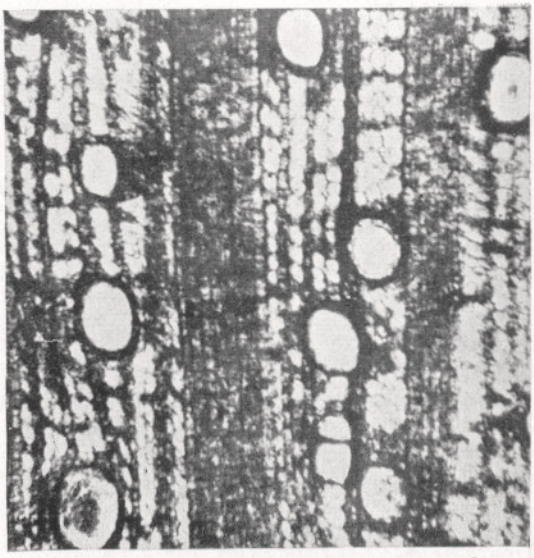

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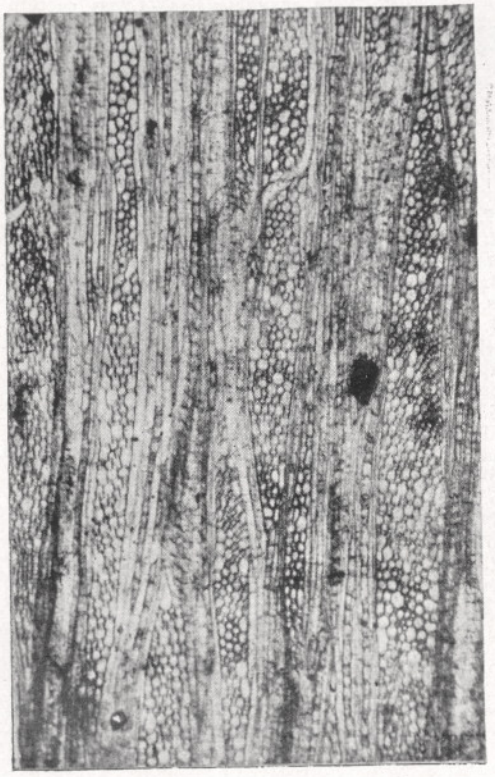

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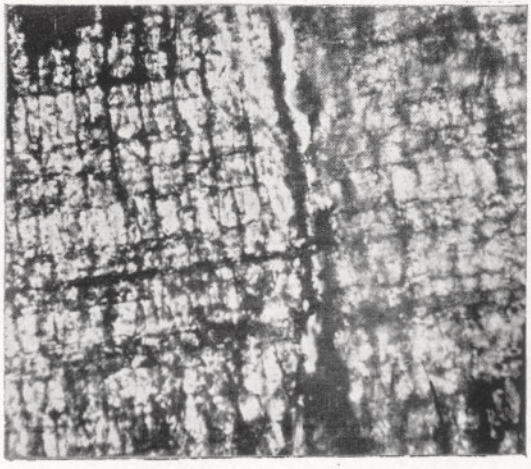

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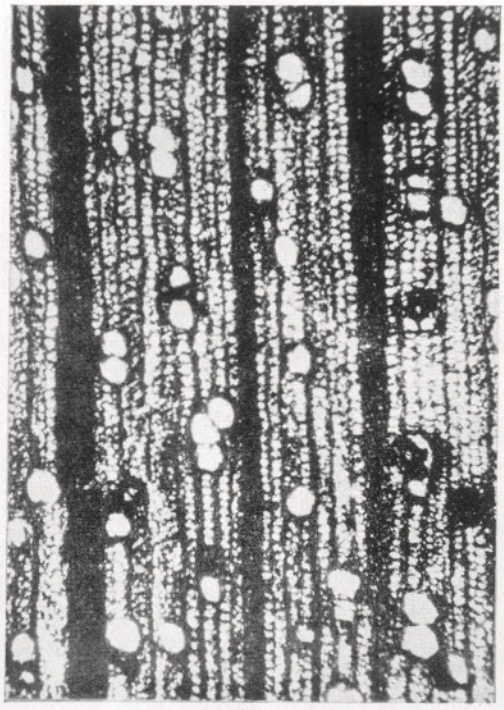

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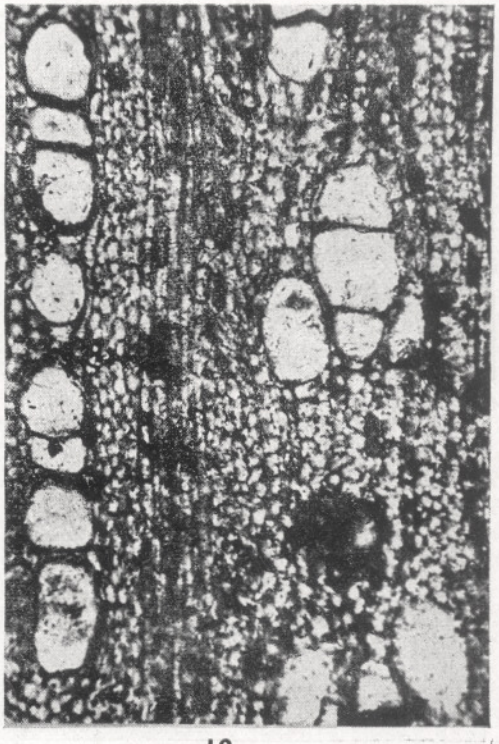

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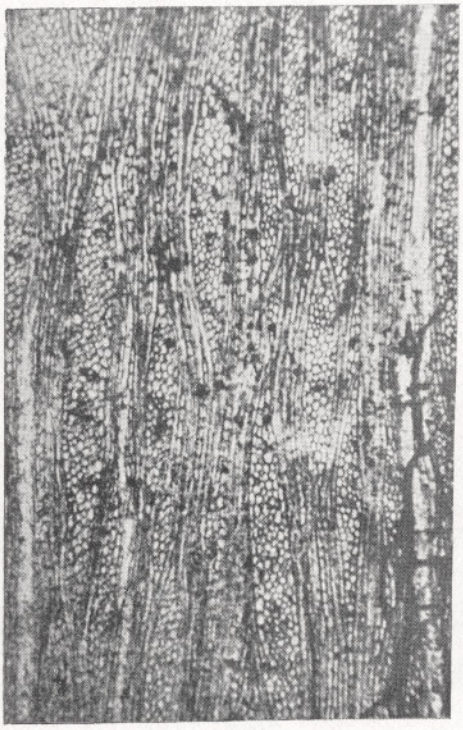

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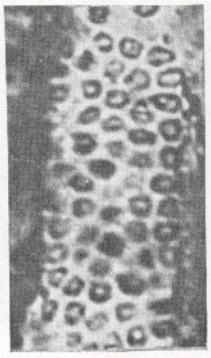

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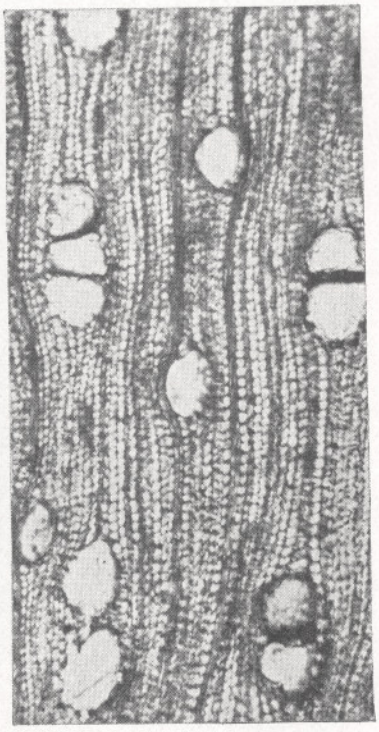

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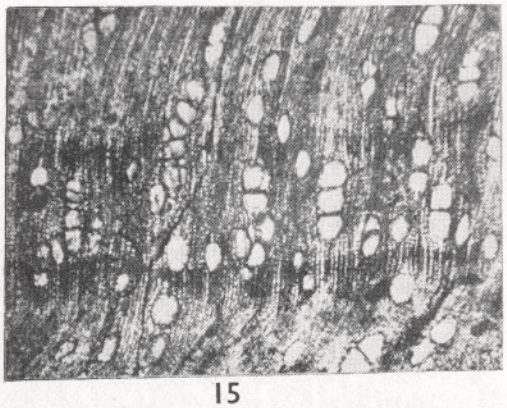

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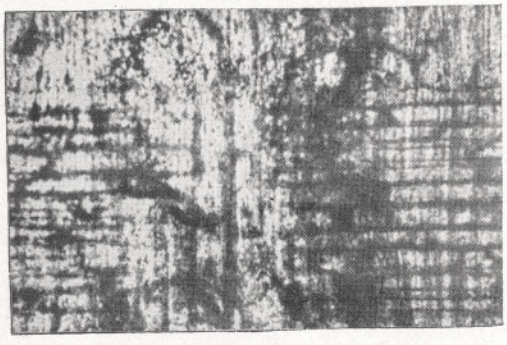

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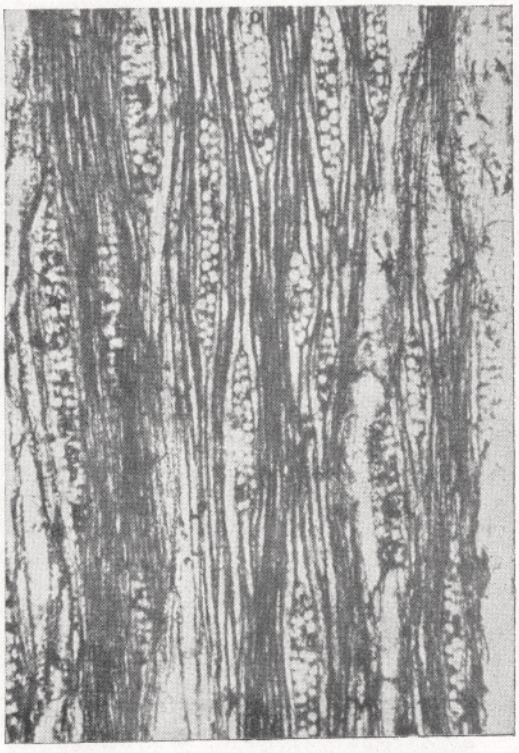

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PLATE 3