FOSSIL DICOTYLEDONOUS WOODS FROM BIKANER, RAJASTHAN, INDIA

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Abstract

Angiospermic woods are described for the first time from the Late Cenozoic sediments of Bikaner in Rajasthan. The genera represented by the fossils are *Lagerstroemia*, *Ougeinia* and *Dialium* belonging to family Lythraceae and Fabaceae. They show close resemblance with the woods of *Lagerstroemia speciosa*, *L. parviflora*, *Ougeinia oojeinensis* and *Dialium* spp. Contrary to prevailing hot and desertic conditions and xeric vegetation in the area the genera indicate the existence of tropical conditions with good amount of rainfall and rich vegetation. The fossils also provide clue about the age of the the sediments.

Introduction

Inspite of the fact that the Late Tertiary flora of Rajasthan has a great bearing on the advent of desertic conditions our knowledge of this flora is meagre. In order to fill this gap the author undertook extensive survey of the western part of Rajasthan and initiated work on the fossil woods of the area (Guleria, 1984a, 1986, 1990). The present communication is the further effort in the same direction. Until now practically nothing is known from the Late Tertiary sediments as far as the megafossils are concerned from the Bikaner region. However, a gymnospermous wood said to belong to Eocene has been described by Harsh and Sharma (1988) though the authors have not given the exact location from where the wood was collected.

Bikaner is located in the northen part of the Thar Desert, Rajasthan and experiences a semi-arid climate. The temperature rises to 49°C or more in summer and dips to -2°C or less in winter months and the average annual rainfall is about 25.4 mm (Climatological Tables of Observatories in India, 1931-1960). The south westerly winds accompanied by dust storms are active in summer while north easterly winds blow during winter. In accordance with the extreme of temperatures, low rainfall and high velocity winds, the vegetation of the area is xerophytic in nature (Sharma 1957; Shetty & Singh, 1987). One can see the city of Bikaner rising from the sandy tract like a highland from a distance. The fossil woods were collected from the outskirts of the highland bordering the sandy tract. A detailed survey of the area from Sivabari to Ganga Shahar to Karmisar including all the bajri mines was done in search of the fossils. Most of the woods were collected about 1 km from Nathusar Gate towards Karmisar Village near the forest department's wood depot on the left side of the road as one proceeds from Bikaner to Karmisar (approx. 28° 08′ : 73° 18′ 45″). A few samples were collected from further east and also between a graveyard and pucca talao north of Gopeshwar Basti, adjoining the main road which leads to Ganga Shahar (see Map1). The woods were recovered from friable and loose sandstones as well as from fairly compact congnlomeratic sandstones. The sediments of this lithology belong to the Mar Formation, which have been assigned to post-Eocene to Late Pleistocene or Quaternary by Shrivastava (1971, pp. 4, 17-18). Das Gupta (1977, p. 232, Table III) on the other hand dated the age of "conglomerate beds" encountered in the subsurface as Plio-Pleistocene.

Family—Lythraceae

Genus—*LAGERSTROEMIOXYLON* Mädler, 1939

Lagerstroemioxylon eoflosreginum Prakash & Tripathi, 1970

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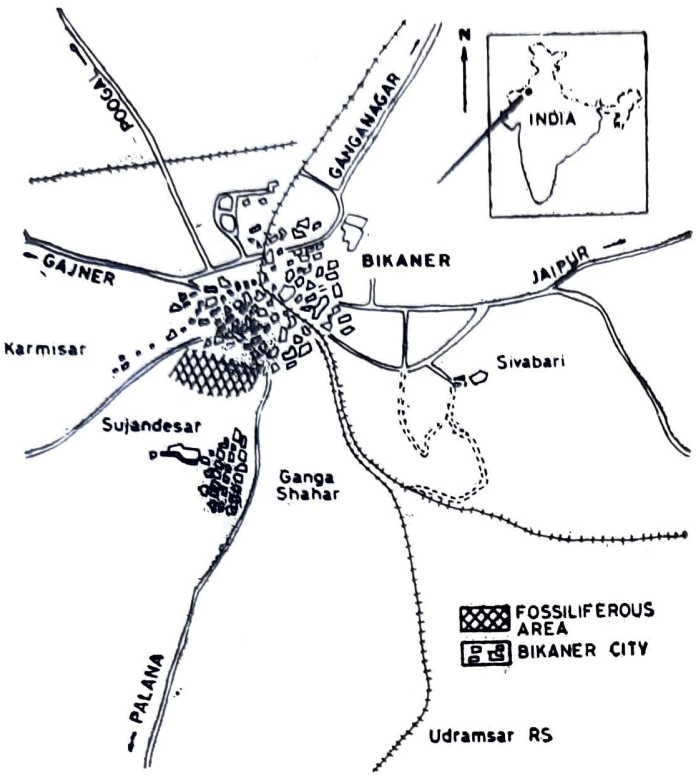

Map 1

Pl. 1, figs 1-3.

The present species is based on a number of samples of secondary woods of varying dimensions. The preservation is good.

Description—Wood ring-porous (Pl. 1, figs 1-2). *Growth rings* present, delimited by larger vessels at the beginning of the growth ring and dense fibres at the outer margin of the ring, size of vessels changes gradually as well as abruptly from very large to small in the outer portion of the ring (Pl. 1, fig. 1). *Vessels* very small to large, almost all solitary, rarely in multiples of two, round to oval in shape, 4-9 per sq. mm, large vessels forming tangential rows at the beginning of the early wood (Pl. 1 fig. 1), late wood vessels smaller in size, open or sometimes filled with gummy contents, tyloses not seen, t. d. of vessels 50 μm-320 μm, r.d. 40 μm—204 μm; vessel members 230-680 μm in length, intervessel pit-pairs alternate, bordered, vestured, 4-6μm in diameter, round to oval or elliptical in shape with oval to linear aperture. *Parenchyma* paratracheal as well apotracheal; paratracheal parenchyma abur dant, vasicentric to aliform, confluent and sometimes forming small forked or continous bands up to 10 cells wide, apotracheal parenchyma sparse, cells solitary or in small groups scattered in the fibrous tracts (Pl. 1, figs 1-2); parenchyma cells thinwalled, round, oval to polygonal in cross section, t.d. 16-32 μm, r.d. 24-32 μm. *Xylem rays* fine, almost all uniseriate, rarely biseriate due to pairing of cells, 16-24 μm wide, 2-21 cells or 60-540 μm high, closely spaced (Pl. 1, fig. 3), 16-20 per mm; rays homocellular (Pl. 1, fig.3), consisting of procumbent cells, tangential height of procumbent cells 16-28 μm, radial length 32-60 μm, crystals present in ray cells. *Fibres* aligned in radial rows in between the rays, round, oval to polygonal in cross section, 8-16 μm in diameter, wall up to 4 μm thick, septate, crystalliferous strands present; interfibre-pits not seen.

Museum specimen No.—B.S.I.P. 7A/4011,11/4011, 2/4011.

Affinities—In all the above mentioned characters the fossil shows close resemblance with the modern woods of genus *Lagerstroemia* Linn. of the family Lythraceae. A number of Indian and foreign species of *Lagerstroemia* were examined from their thin sections and published literature (Lecomte, 1926; Chowdhury, 1932, 1945; Pearson & Brown, 1932; Metcalfe & Chalk, 1950; Desch, 1957; Kribs, 1959; Hayashi *et al.*, 1973; Miles, 1978; Purkayastha, 1982) in order to find out the nearest modern comparable species. From the study it was found that the fossil shows closest resemblance with the wood of *L. speciosa* Pers. (syn. *L. flos-reginae* Retz and *L. macrocarpa* Kurz) particularly with the wood samples of *L. macrocarpa* (Purkayastha, 1982, pp.29-30,34, pl. 100, fig. 598) in having mostly solitary vessels to sometimes in multiples of two. It is pointed out here that a similar specimen like the present fossil and showing affiinities with *L. speciosa* has already been described by Lakhanpal *et al.* (1984, pp.258-259) from the Lower Miocene of Kachchh. A re-examination of the slides of the Kachchh specimen shows that the vessels in it are almost solitary or rarely in multiples of two as seen in the present fossil.

As far as the author knows there are eight validly published species of *Lagerstroemioxylon* which are listed in Table-I for ready reference. Among these *L. irrawaddiensis* Prakash & Bande (1980), *L. benkoelense* Du (1988) and *L. deomaliensis* Lakhanpal *et al* (1981) have been compared with *Lagertroemia venusta*, *L. colletti—L. venusta* and *L. villosa*, respectively. In view of the overlapping wood structure of these species of *Lagerstroemia* and *L. parviflora* (Purkayastha, loc. cit. pp. 29-30) it would be appropriate to

TABLE 1

Taxa	*Modern comparable form*	*Locality*	*Age*
1. *Lagerstroemioxylon durum* Mädler, 1939		Frankfurt am Main, West Germany	Pliocene
2. *L. parenchymatosum* Prakash, 1965, 1973	*L. parviflora Roxb.*	Burma	Mio--Pliocene
3. *L. eoflosreginum* Prakash & Tripathi, 1970	*L. flosreginae* Retz. Syn. *L. speciosa* Pers.	Assam, India	Miocene (Tipam Sandstone)
Kramer, 1974		Sumatara, Indonesia	Late Tertiary?
Lakhanpal *et al.*, 1984		Kachchh India	Lower Miocene
4. *L. irrawaddiensis* Prakash & Bande, 1980	*L. venusta* Wall.	Burma	Mio-Pliocene
5. *L. arcotense* Awasthi, 1981		Near Pondicherry, India	Mio-Pliocene
6. *L. deomaliensis* Lakhanpal *et al* , 1981	*L. villosa* Wall.	Arunachal Pradesh, India	Mio-Pliocene
7. *Lagerstroemioxylon* sp. Kramer, 1974	*L. lanceolata* Wall.	Sumatra, Indonesia	Late Tertiary
8. *L. benkoelense* Du* 1988	*L .colletti* Graib. *L. venusta* Wall.	Sumatra, Indonesia	Quaternary

* The two species, viz; *Lagerstroemioxylon tomentosum* and *L. parviflorum* referred by Du (1988, Table 2, p. 356) have not been taken into account for two reasons, (i) they are unpublished and (ii) the woods of modern *Lagerstroemia tomentosa* and *L.parviflora* ar anatomically very similar (Purkayastha, *loc.cit*, p. 30) and repre ented in fossil by *Lagerstroemioxylon parenchymatosum* Prakash.

marge *Lagerstroemioxylon irrawaddiensis, L. benkoelense and L. deomaliensis* with *L. parenchymatosum* Prakash (1965, 1973) which was instituted for the fossil woods of *Lagerstroemia parviflora* and has got the priority.

Since the present fossil shows close similarity with the woodstructure of *Lagerstroemia speciosa* it is placed under *Lagerstroemioxylon eoflosreginum* Prakash & Tripathi, 1970 which represent the fossil woods of *Lagerstroemia speciosa.*

The genus *Lagerstroemia* consists of 53 species (Willis, 1973, p. 630) of trees and shrubs and is confined to Old World. Its centre of distribution is in south-east Asia However, it extends from Madagascar through south-east Asia the East Indies to tropical eastern Australia, China and Japan (Pearson & Brown, 1932, p. 573). *Lagerstroemia speciosa* with which the fossil shows resemblance is a medium-sized to large deciduous tree and is found throughout Assam, Bengal, western and southern India and north Kanara through Malabar to Travancore; in the Godavari Basin and Kurnool division of Andhra Pradesh. It also occurs in Bangla Desh, Burma, Malay Peninsula and Java. This species is found typically on river banks, low lying places and in similar habitats.

Lagerstroemioxylon parenchymatosum Prakash 1965, 1973

Pl.1, figs 4-5

This species is represented by a small piece of petrified wood measuring 6 cm in length and 3.5 cm in width. The preservation is good.

Description— *Wood* semi-ring porous (Pl. 1, fig.4). *Growth rings* distinct, demarcated by large vessels of early wood and denser fibre cells near the outer margin of the ring (Pl. 1, fig. 4). *Vessels* very small to large, solitary or in multiples of 2-3, rarely 4-6, round

to oval in shape, 4-8 per sq mm, large vessels forming tangential rows at the beginning of early wood (Pl. 1, fig.4), late wood vessels smaller in size, open or sometimes filled with some gummy deposists, tyloses not seen, t.d. of vessels 62-248 μm, r.d. 42-434 μm, vessel-members mostly 170-495 μm, rarely upto 695 μm in length with truncated ends; perforations simple; intervessel pit-pairs alternate, bordered, vestured, 4-6 μm in diameter, round to oval or elliptical in shape with oval to linear aperture. *Parenchyma* paratracheal as well as apotracheal, paratracheal parenchyma abundant, vasicentric, mostly aliform to confluent, apotracheal parenchyma spare, cells solitary or in small groups scattered in the fibrous tracts (Pl.1, fig.4). Parenchyma cells thin walled, round, oval to polygonal in cross section, t.d. 16-48 μm, r.d. 28-80 μm. *Xylem rays* fine, almost all uniseriate rarely biseriate (Pl. 1, fig.5), 24-40 μm wide, 2-16 cells or 75-558 μm high, closely spaced, 13-18 per mm; ray tissue homogeneous, rays homocellular consisting of procumbent cells, tangential height of procumbent cells 28-40 μm, radial length up to 100 μm, crystals not seen. *Fibres* aligned in radial rows in between the rays, round, oval to polygonal in cross section, 12-20 μm in diameter, wall up to 4 μm thick, septate, sometimes appearing crystalliferous, interfibre pits could not be seen.

Museum specimen no.—BSIP 14/4011

The above characters of the fossil wood indicate its similartity with hat of extant *Lagerstroemia*. A survey of the wood structure of a number of Indian as well as foreign species of *Lagerstroemia* has shown that the fossil shows close resemblance with the wood of *L. microcarpa* Wight (syn. *L. lanceolata* Wall.) and *L. parviflora* Roxb. which are xylotomically quite similar (Purkayastha, 1982, pp. 30-33). However, the two can be separated on he basis of width of rays (Pearson & Brown, 1932, p.527). In *L. microcarpa* the rays are uniseriate or rarely with paired cells having maximum width less than 30 μm as compared to *L. parviflora* wherein the rays are 1-2 (mostly 1) seriate with a maximum width of rays 30-40 μm and 11-20 rays/mm. Since the rays in the present fossil are uni to biseriate, up to 40 μm wide and 13-18 per mm so it tends to show better resemblance with *L. parviflora* rather than *L. microcarpa*. Among the known fossil species of *Lagerstroemia* based on their wood structure, *Lagerstroemioxylon parenchymatosum* Prakash (1965; 1973) shows close resemblance with the wood of *Lagerstroemia parviflora* and the present fossil. Hence, it is placed under *Lagerstroemioxylon parenchymatosum*.

Lagerstroemia parviflora is a moderate to large sized deciduous tree and is widely distributed throughout the greater part of India. It occurs in the sub-Himalayan region from the Sutlej eastward through Bihar, Bengal, to Assam ascending up to 900 m, Central and South India as far south as the Nilgiris, Orissa and eastern part of Andhra Pradesh. It is also common in Upper Burma (Pearson & Brown, 1932, p.576).

Family Fabaceae

Genus—*OUGEINIOXYLON** Prakash & Tripathi, 1977

Ougeinioxylon tertiarum Prakash & Tripathi, 1977

Pl.2, figs 1-2

The species is represented by a single piece of petrified wood measuring 10 cm in length and 4.5 cm in diameter. The preservation is fairly good.

Description.—Wood diffuse porous (Pl. 2, fig.1). *Growth rings* present, delimited by 1-2 cells thick lines of terminal parenchyma. *Vessels* small to medium, round to oval, solitary or in short radial rows of 2-4 (Pl. 2, fig.1), t.d. 60-173 μm, r.d. 46-76 μm, 4-10 per sq mm, tyloses absent, vessel-members short 220-440 μm in length with truncated or tailed ends, storied; perforation simple, intervessel pit-pairs small, 3-5 μm in diameter, vestured, bordered, alternate, oval to elliptical with lenticular aperture. *Parenchyma* paratracheal and apotracheal (Pl. 2 fig.1), paratracheal parenchyma abundant, mostly vasicentric to aliform, occasionally aliform-confluent joining 2-4 or more vessels; apotracheal parenchyma diffuse, occurring as solitary cells and in 1-2 cells thick lines of terminal parenchyma, parenchyma cells round to oval in shape in cross section, thin walled, t.d.20-40 μm, r.d. 20-44 μm, storied, parenchyma strands crystalliferous. *Xylem rays* fine to medium, 1-3 seriate, mostly biseriate often uniseriate, triseriate rare (Pl. 2, fig.), 12-40 μm wide, 4-15 cells or 108-248μm high, 10-14 per mm; ray tissue

*Originally spelt as *Ougenioxylon* which is now corrected as *Ougeinioxylon*.

homog neous (Pl.2, fig.2); rays homocel'-ular consisting wholly of procumbent cells, storied, ray cells 16-32 μm in tangential height, 32-80 μm in radial length. *Fibres* aligned in radial rows, oval to polygonal in cross section, thickwalled, wall 4-6 μm thick, semi-libriform to libriform, 12-32 μm in diameter. *Ripple marks* present due to storied vessel segments, parenchyma strands and xylem rays.

Affinities—Apparently the fossil shows similarity with the wood structure of *Cassia* Linn., *Ormosia* Jacks and *Ougeinia* Benth. of the family Fabaceae. However, the first two genera can ea ily be differentiated from the present fo sil in the absence of storied rays. Thus in all the above characters the fossil shows close similarity with the wood of *Ougeinia oojeinensis* (Roxb.) Hocht. The author is aware of only one species of *Ougeinioxylon*, i.e., *O. tertiarum* described by Prakash and Tripathi from the Tipam Sandstones near Hailakan i in Cachar District of Assam. It shows some variable differences with *O. tertiarum*. However, keeping in view the wide variations observed in the thin-sections of *O. oojeinensis* obtained from a number of wood specimens, the wood described here is placed under the known species, viz., *Ougeinioxylon tertiarum*.

Ougeinia Benth. is a monotypic genus with a single species *O. oojeinensis* (Roxb.) Hocht endemic to India, occurring in central region of the country and extending in the north to sub-Himalayan region from Sutlej to Sikkim ascending up to 1200 m. In South it is fairly common up to Godavari in the east and North Kanara on West but is less common further down (Champion & Seth 1968, p. 25; Ramesh Rao & Purkayastha, 1972).

Genus—*DIALIUMOXYLON* Lemoigne, 1978

Dialiumoxylon indicum Guleria, 1984b

Pl. 2, figs 3-4.

The fossil is represented by a single piece of petrified wood measuring 9 × 5 cm. The preservation is fairly satisfactory.

Description—*Wood* diffuse porous. *Growth rings* not clear. *Vessels* small to medium, solitary as well as in radial multiples of 2-5 (mostly 2-4), rarely forming clusters (Pl. 2, fig.3), uniformly distributed, 6-10 vessels per sq mm, round to oval in cross section, t. d. 60-140 μm, r.d. 45-90μm, perforations simple, vessel members 232-683 μm in length with truncated or slightly oblique ends; storied with parenchyma strands and rays; inter-vessel pits alternate, bordered, vestured, 3-5 μm in diameter, vessels occasionally filled with gummy contents. *Parenchyma* in regular concentric bands, alternating with relatively broad fibre bands (Pl.2, fig.3), bands straight to slightly undulating touching or enclosing the vessels, closely spaced, 6-11 per mm, each 1-4 (mostly 1-2) cells wide, parenchyma strands storied, 4 cells per strands, cells round to oval in cross section, 16-32 μm in diameter, crystalliferous strands present. *Xylem rays* fine, 1-3 (mostly biseriate), 16-40 μm wide, 8-12 cells or 152-280 μm in height, storied (Pl. 2, fig.4) sometimes irregularly storied, 11-15 rays per mm; ray tissue homogeneous; rays homocellular, consisting of procumbent cells only, 8-20 μm in tangential height, cells filled with infiltration. *Fibres* forming concentric bands alternating with relatively narrow parenchyma bands (Pl. 2, fig. 4), cells circular, oval to angular in cross section, 6-10 μm in diameter with narrow lumen, thick walled, walls about 4-6 μm thick, non-septate. *Ripple marks* present, visible due to storied arrangement of vessel segments parenchyma strands and rays.

Affinities—The fossil wood shows close similarity with the wood structure of the extant genus *Dialium* Linn. An examination of thin sections, published descriptions and photographs of a number of species of *Dialium* (Moll & Janssonius, 1914; Lecomte, 1926; Normand, 1950; Lebacq, 1957; Kribs, 1959; Ramesh Rao & Purkayastha, 1972; Hayashi *et al.*, 1973) has revealed that *D. angolense* Welw ex. Oliv, *D. gosseweileri* Aak f., *D. laurinum* Baker, *D. pentandrum* Louis ex Steyaert, *D. tr vancoricum* Bourd. and *D. zenkeri* Harms how close resemblance with the present fossil although the vessels are relatively small in it. As per author's knowledge only two species of *Dialiumoxylon* are known, viz, *D. aethiopicum* Lemoigne (1978) and *D. indicum* Guleria (1984b). The former has been reported from the Miocene deposits of Ethiopia and the later from the Pliocene sediments of Kachchh. Except for some minor variable differences the present fossil shows close resemblance with *D. indicum*, hence it is placed under the same species.

The genus *Dialium* consists of 41 spe-

cies found in the tropics of South America, Africa, Madagascar and Malaysia (Willis, 1973, p. 252). *Dialium travancoricum* Bourd. is the only species which is found in India. It is a large evergreen tree attaining a height of 30 m and is found in the forests of South Travancore between 300 to 600 m (Ramesh Rao & Purkayastha, 1972).

Museum Specimen No. B.S.I.P. 56/4011.

Discussion

All the woods described in the paper are known from the Neogene deposits of India and adjoining areas. Thus the age of the fossil bearing sediments cannot be older than Neogene which is also supported by the stratigraphic position of the sediments (Shrivastava, 1971; Das Gupta, 1977). The occurrence of *Dialium* in these sediments is particularly interesting. Until now the *Dialium* in India has only been reported from the Kankawati Series of Kachchh which according to Biswas (1990, p. 38) is of Pliocene age. This indicates that the age of the sediments containing the woods most probably be Pliocene. Further work on the woods of this area may help in deciphering the age of Mar Formation more precisely. It is pointed out that the araucarian wood reported by Harsh and Sharma (1988) in all probablity comes from the same sediments and hence belongs to Pliocene rather than Eocene as Eocene rocks are nowhere exposed in the vicinity of Bikaner city. It is worth mentioning that the occurrence of araucarian wood has already been reported from the Pliocene sediments of Jaisalmer (Guleria, 1986) and from the Miocene deposits of West Bengal (Srivastava & Prakash, 1984) in association with other tropical elements. In view of this fact and the genera reported in this paper provide enough evidence to refute the contention of Harsh and Sharma (*loc. cit.* p.114) that "The occurrence of extinct broad, large leaves of angiosperms at Barmer and an araucarian gymnospermous wood at Bikaner suggest temperate climate during the Eocene in the extant area of the Thar desert". The identity of the temperate leaves reported by Deshmukh and Sharma (1978) from Barmer has already been questioned (Guleria, 1984a).

While describing *Lagerstroemioxylon benkoelense* Du (1988, p. 357) has stated "ring porous wood structure appears to come from diffuse porous wood when the plants grew under the cooler climate in the late Cenozoic period". The later half of the above statement has to be taken with caution as far as *Lagerstroemia* is concerned. In all probabiltiy semi-ring porosity and ring porosity in *Lagerstroemia* has something to do with its genetic characters rather than cooler climate as the woods of *Lagerstroemia* have been reported from Lower Miocene onwards from different sites in India and south-east Asia along with other typical tropical elements.

Thus compared to the xeric vegetation of Bikaner today, the presence of *Lagerstroemia speciosa*, *L. parviflora*, *Ougeinia oojeinensis* and *Dialium* sp. indicate the existence of moist deciduous to semi-evergreen elements during Pliocene. It can be inferred from the available data that the climate of Bikaner region must have been warm and humid for the luxuriant growth of tropical vegetation during Pliocene. Evidently, the desertic conditions are the result of post-Pliocene changes in the climate.

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Explanation of Plates

Plate 1

Lagerstroemioxylon eoflosreginum Prakash & Tripathi.

1. Cross section showing ring porous nature of the wood, growth rings and distribution of parenchyma. ×35. Slide no. BSIP. 36565-1.
2. Another cross section slightly enlarged showing vessels in multiples of two in the centre of the section. × 50. Slide no. BSIP. 36566-1.
3. Tangential longitudinal section showing homocellular xylem rays × 100. Slide no. BSIP. 36565-2.

Lagerstroemioxylon parenchymatosum Prakash

4. Cross section showing semi-ring porous nature of the wood, growth ring and distribution of parenchyma and fibres. ×35. Slide no. BSIP. 36567-1.
5. Tangential longitudinal section showing uni to biseriate homocellular xylem rays. ×110. Slide no. BSIP. 36567-2.

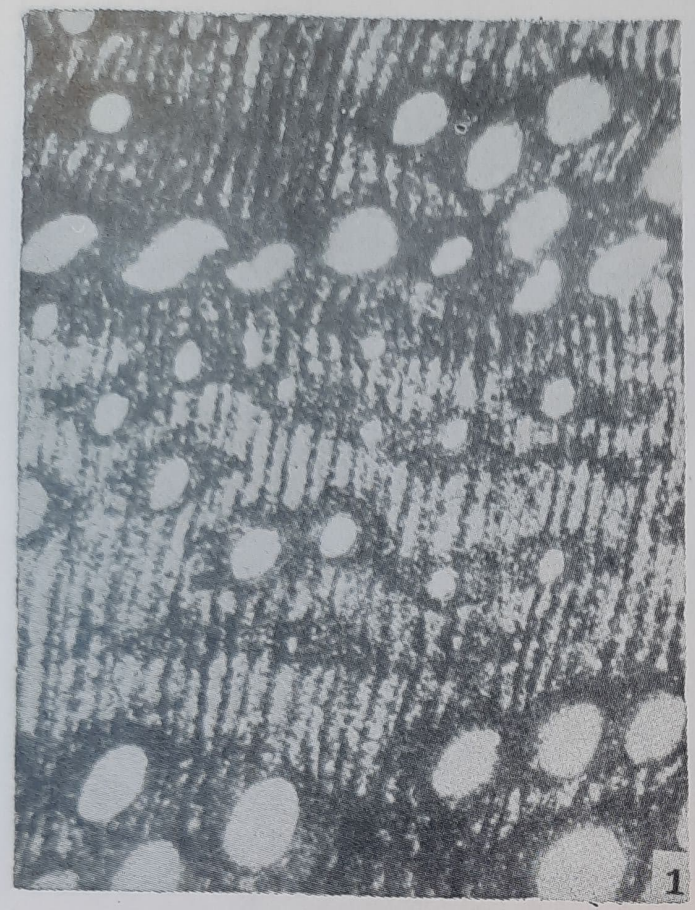
Plate 2

Ougeinioxylon tertiarum Prakash & Tripathi

1. Cross-section showing shape, size and distribution of vessels and parenchyma. × 33. Slide no. BSIP. 36568-1.
2. Tangential longitudinal section showing 1-3 seriate homogeneous rays and storied nature of elements. ×100. Slide no. BSIP. 36568-2.

Dialiumoxylon indicum Guleria

3. Cross section showing size and distribution of vessels, parenchyma and fibrous tissues. ×57 Slide no. BSIP. 36569-1.
4. Tangential longitudinal section showing storied nature of xylem rays. ×100. Slide no. BSIP. 36569-2.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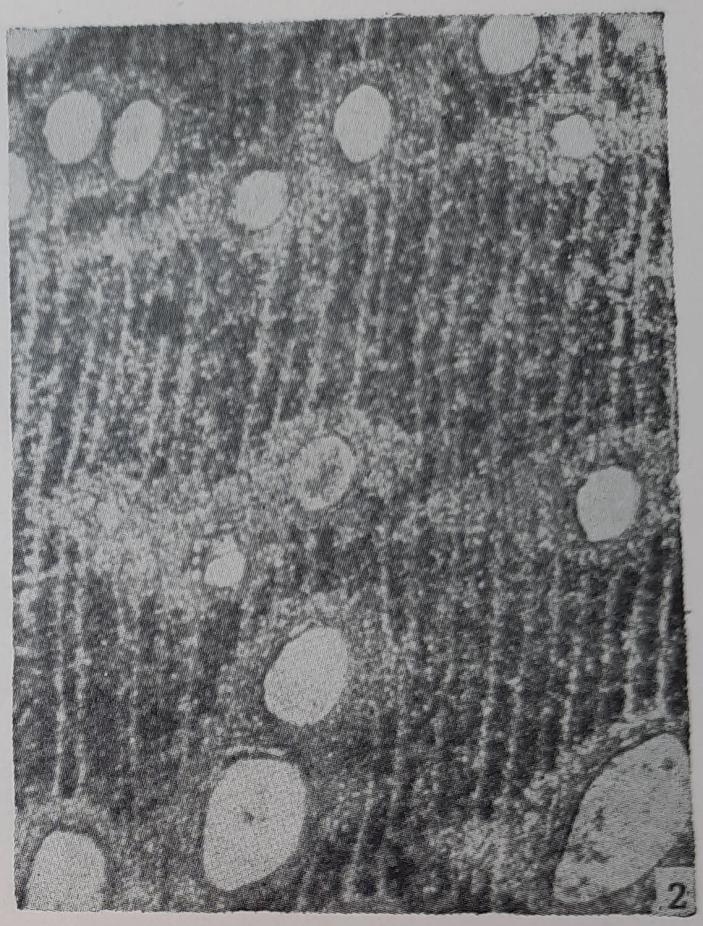
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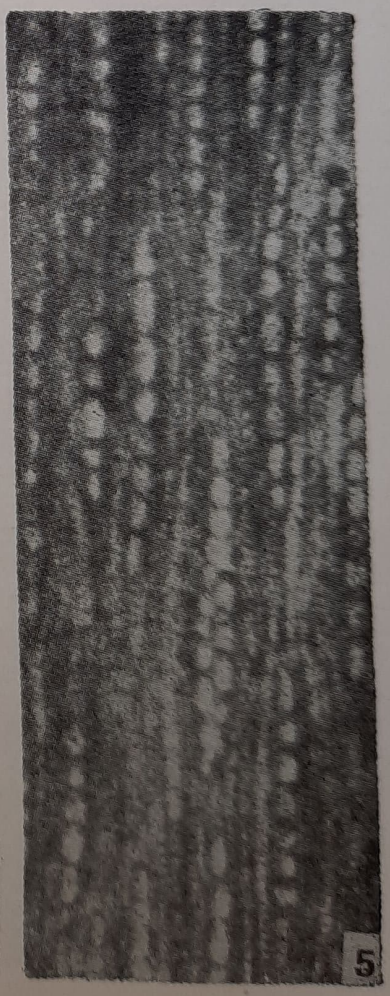
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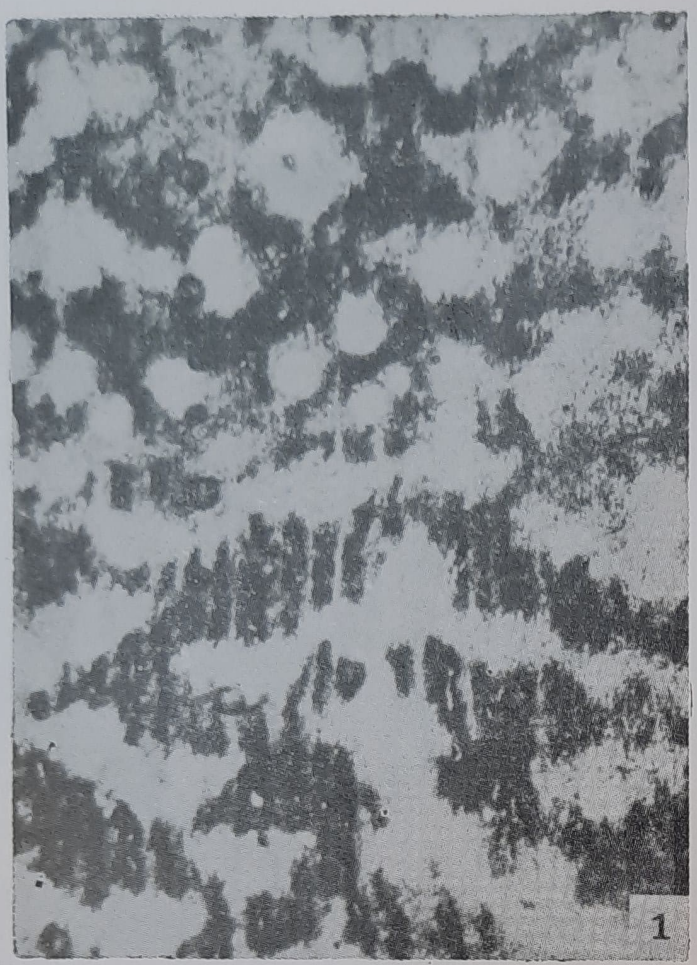
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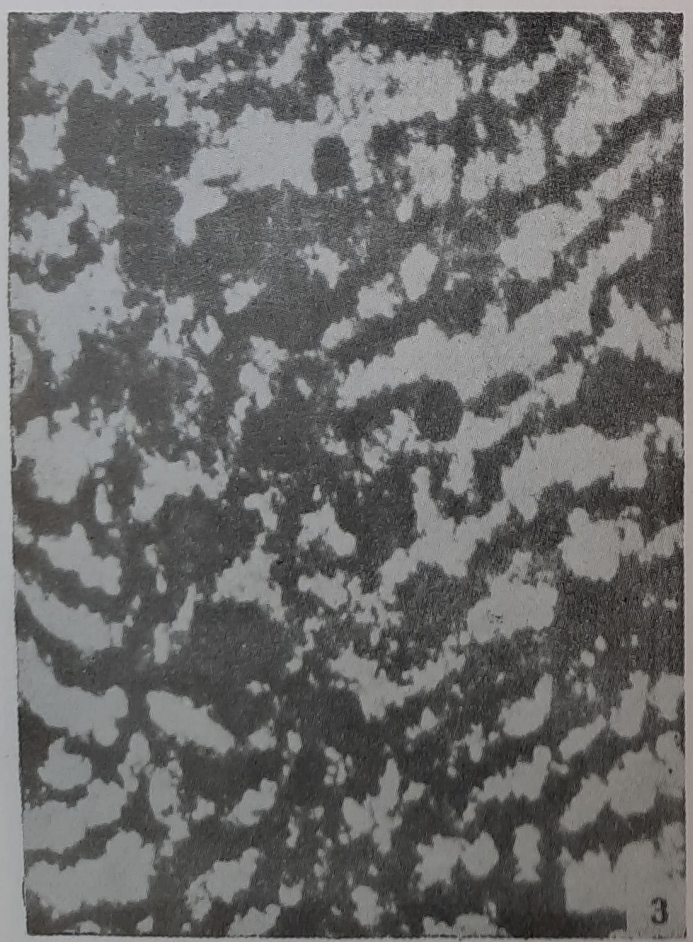
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