THE KOTA FORMATION : FOSSIL FLORA AND STRATIGRAPHY

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Abstract

Morphotaxonomic and xyletomical studies of the fossil plants from Kota Formation, Maharashtra have been carried out. The floral assemblage is dominated by conifers, followed by pteridophytes, cycadophytes and ginkgophytes respectively. Pteridosperms have not been recorded. The assemblage comprises the leaf genera : *Cladophlebis*, *Sphenopteris*, *Pagiophyllum* and wood genera—*Araucarioxylon*, *Podocarpoxylon*, *Taxaceoxylon* and *Cupressinoxylon*. Floristic and other evidences suggest Middle Jurassic or slightly younger age to the Kota Formation.

Introduction

The Kota Formation is named after the village Kota (Long 18°55′ Lat. 79°59′) situated on the east bank of the river Pranhita in the Chandrapur District, Maharashtra. This Formation is characterised by a limestone band, grits of light brown colour with red clay bands and sandstone. The geology and stratigraphy of this formation is known through the work of King (1881) Kutty (1969) and Rudra (1972).

Rich invertebrate and vertebrate fauna including variety of fish, crocodilian remains, dinosaurs, estherids, micromammals, ostracods, insects etc. have been reported from this formation by Owen (1952) Rao and Shah (1959), Satsangi and Shah (1973), Govindan (1975), Datta *et al.* (1978), Yadagiri *et al.* (1980) and Jain (1959, 1973, 1983).

As regards the plant-remains, Rao and Shah (1963) recorded *Equisetites*, *Cladophlebis*, *Otozamites*, *Sphenopteris*, *Hausmannia* and *Pagiophyllum* from a stream section about a kilometer southeast of the village Chitur in Chandrapur District, Maharashtra. Mahabale (1967) recorded *Elatocladus*, *Mesembrioxylon*, *Taxoxylon* and *Podocarpoxylon*. Shah *et al.* (1973) listed plant fossils from the Kota limestone bed, viz., *Equisetites* sp., *Hausmannia* sp., *Coniopteris hymenophylloides*, *Coniopteris* sp., *Cladophlebis indica* sp., *P. peregrinum*, *Pagiophyllum* cf. *P. peregrinum*' *Pagiophyllum* sp., *Araucarites cutchensis*, *Elatocladus* sp., *E. jabalpurensis* and *Torreyites* cf. *T. constrictus*. Biradar and Mahabale (1978) described *Ginkgoxylon dixitii* from Kota. Srinivasa Rao *et al.* (1979) recorded *Cladophlebis indica*, *C. reversa*, *Ptilophyllum acutifolium*, *P. cutchense*, *Elatocladus plana* and *Brachyphyllum*. Biradar (in Mahabale & Satyanarayana 1978) reported *Taxoxylon* sp. cf. *T. rajamahalense*. However, except *Ginkgoxylon dixitii* none of the plant fossils has so far been systematically described and illustrated. The palynology of Kota sediments is not known.

For the present study a number of silicified woods were collected from nalas, road cuttings and river sections near the Kota Village (Map 1). The sediments are characterized by grits of light brown colour along with red clay bands and sandstones. Woods were mostly found in the sandstone horizon lying in the bedding plane and also scattered in the river beds. None of the limestone beds near Kota yielded plant impressions.

A number of silicified woods were also collected from road cuttings and nala sections near the Chitur Village (18° 46′ : 80° 07′)

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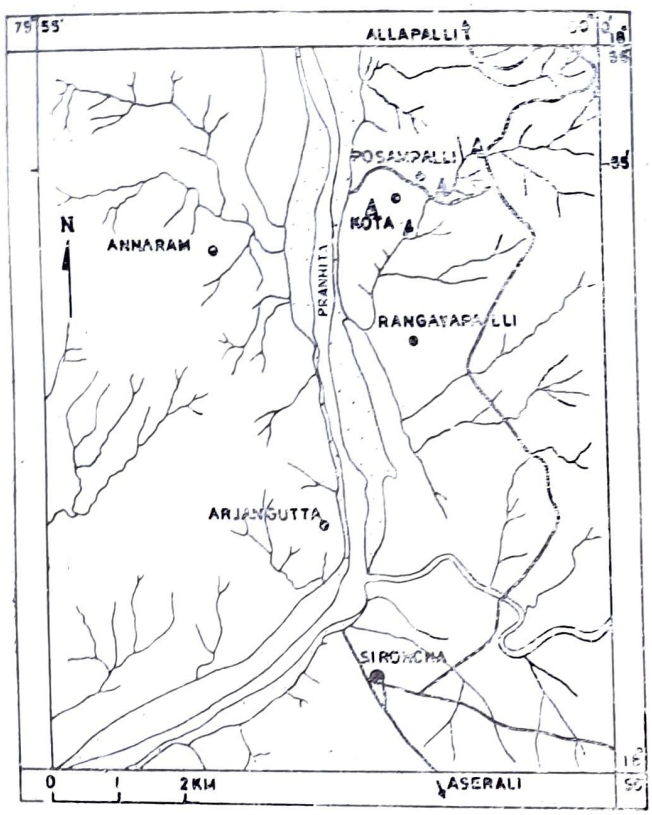
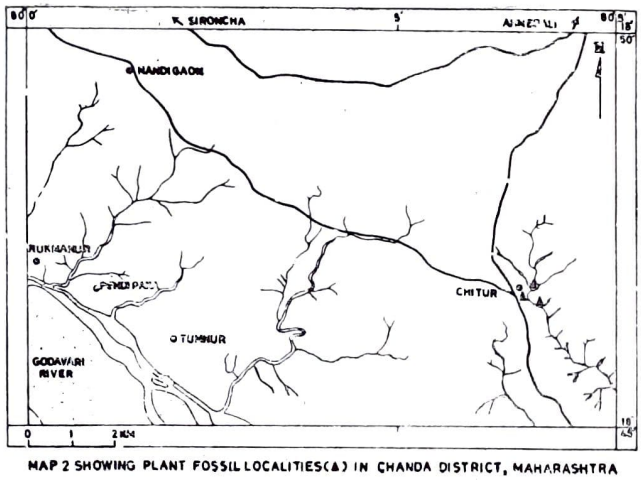


MAP 1 SHOWING PLANT FOSSIL LOCALITIES (2) IN CHANDA DISTRICT, MAHARASHTRA

which lies about thirty kilometres southeast of Kota (Map 2). Beside woods, a few fragmentary plant-impressions were also found in the limestone bed of a stream section about one kilometer southeast of Chitur. Rao and Shah (1963) collected some plants mentioned earlier and also a pterosaur from this bed.

The lithological characters of the section are as under in descending order. The basal carbonaceous, shaly bed is devoid of mega- and microfossils :

A	8″	alternating yellow, grey, soft and hard sandstones
B	14″-16″	yellow and grey mixed sandy clay overlain by yellowish sandy clay
C	6″-9″	yellowish hard sandy clay
D	4″-10″	grey micaceous hard clay
E	2″-3″	yellowish soft brittle limestone with animal and plant megafossils
F	4″-8″	ash coloured coarse sandy shale
G	2″-5″	black carbonaceous shale



MAP 2 SHOWING PLANT FOSSIL LOCALITIES(2) IN CHANDA DISTRICT, MAHARASHTRA

Description

UNCLASSIFIED FERNS

Genus—*CLADOPHLEBIS* Brongniart, 1849

Cladophlebis sp. A.
Pl. 1, figs. 9, 10; Text-fig. 1

Description—Frond fragmentary, measuring 9 mm × 7 mm, ? imparipinnate. Rachis distinct, slender, Pinnules small, alternate, connected at base and making an angle of about 70°-85° to rachis. Margin entire. Apex obtuse or rounded. Midrib present, lateral veins arising at an angle of about 30°-40°, forked once or twice.

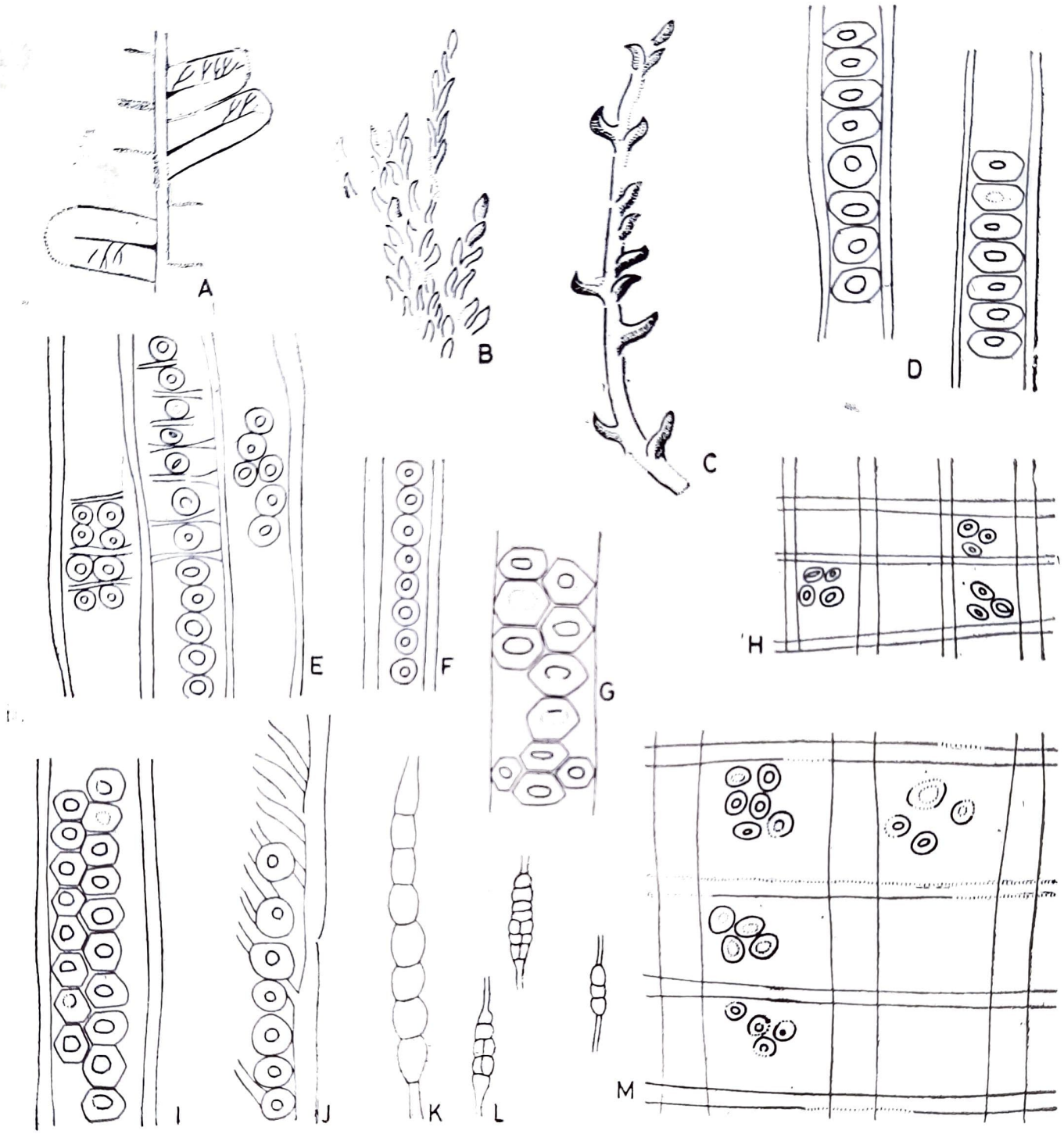
Comparison—*Cladophlebis* sp. A resembles to some extent *Cladophlebis* sp. described by Sukh-Dev and Rajanikanth (1988) from the Gangapur Formation in general morphology of frond, but it is smaller in size. *Cladophlebis* sp. also shows apparent resemblance with the smaller pinnules of *Cladophlebis daradensis* Bose & Banerji (1984).

Genus—*SPHENOPTERIS* Sternberg, 1825

Sphenopteris sp. A.
Pl. 1, figs. 3, 8

Description—Fragmentary pinna 5 mm × 2 mm in size, imparipinnate. Rachis distinct, slender. Pinnules alternate, short, lanceolate, dissected into 2-3 forwardly directed lobes. Pinnules of the same side connected at the base by narrow lamina. Margin entire. Apices of lobes acute or subacute. Each lobe having a vein which further gives rise to a few small veins.

Comparison—*Sphenopteris* sp. A resembles *Sphenopteris* sp. A described by Zeba-Bano



Text-figure 1.—A. *Cladophlebis* sp. A, Specimen no. BSIP 36233, x 4; B. *Pagiophyllum* sp. A, Specimen no. BSIP 36255, x 1; C. *pagiophyllum* sp. B, Specimen no. BSIP 36238, x 2; D. *Araucarioxylon* sp. R. L. S. showing uniseriate hexagonal radial wall pits, Slide no. BSIP 36241-III, x 200; E. *Cupressinoxylon kotaensis* n. sp., R.L.S. showing uni-biseriate radial wall pits with crassulae, Slide no. BSIP 36248-III, x 200; F. *Taxaceoxylon* sp. A., R.L.S. showing uniseriate radial wall pits, Slide no. BSIP 36246-III, x 200; G.*Araucarioxylon pranhitensis* n. sp. R.L.S. showing bi-triseriate alternate hexagonal radial wall pits, Slide no. BSIP 36240-III, x 250; H. *Araucarioxylon santalense* (Sah & Jain) Bose & Maheshwari, R.L.S. showing cross-field pits, Slide no. BSIP 36239-III, x 200; I. Same, R.L.S. showing uni-biseriate hexagonal radial wall pits, Slide no. BSIP 36239-III, x 350; J. *Taxaceoxylon sahnii* n. sp., R.L.S. showing uniseriate radial wall pits and spiral thickenings, Slide no. BSIP 36245-III, x 200; K. *Cupressionxylon kotaensis* n. sp., T.L.S. showing uniseriate xylem rays, Slide no. BSIP 36248-II, x 125; L. *Taxaceoxylon* sp. T.L,S. showing uni-biseriate xylem rays, Slide no. BSIP 36246-II, x 50; and *Araucarioxylon pranhitensis* n. sp., R.L.S. showing cross-field pits, Slide no. BSIP 36240. x 250.

(1980) from Jabalpur, except that the pinnules in the former species are too small. *Sphenopteris* sp. A also resembles *Sphenopteris fittoni* Seward described by Halle (1913) from Graham Land in general appearance only.

CONIFERALES

Genus—*PAGIOPHYLLUM* Heer, 1881

Pagiophyllum sp. A
Pl. 1, figs. 1, 2, 5, 11; Text-fig. 1 B

Description—Leafy twigs, measuring 3 cm×1.8 cm, branched. Branches slender, 2-5 mm wide, making an angle of about 20°-35°, Leaves spirally borne, straight or slightly falcate, lanceolate, directed forward at an angle of about 10°-30°, typically 2 mm long and less than 1 mm broad. Leaf-base decurrent, concealed by lower leaves. Margin entire. Apex acute or obtuse.

Comparison—*Pagiophyllum* sp. A closely resembles *Pagiophyllum* sp. in form and size. A described by Bose, Banerji and Jana (1984) from the Lower Cretaceous of Gardeshwar. But apices of leaves in the latter species are sharply pointed. *Sphenolepidium? oregonense* Fontaine described by Halle (1913) from Graham Land closely resembles *Pagiophyllum* sp. A in general appearance, but the tips of leaves are strongly incurved.

Pagiophyllum sp. B
Pl. 1, figs 4, 7; Text-fig. 1C

Description—Unbranched leafy shoots, about 1.7-3.4 cm long and 0.5-0.8 cm broad, slightly bending on one side. Leaves small, about 1-3 mm long and 0.5 mm wide, lanceolate, falcate, spirally borne at an angle of about 40°-90°. Margin entire. Apex acute or apiculate. Leaf-base decurrent.

Comparison—*Pagiophyllum* sp. B is quite distinct from *Pagiophyllum* sp. A described above in having large and comparatively sparsely arranged leaves. The present species is also somewhat comparable in external morphology with *Pagiophyllum* sp. described by Sitholey (1940) from Afghanistan and *Pagiophyllum* sp. described by Halle (1913) from Graham Land.

Family—ARAUCARIACEAE

Genus—*ARAUCARIOXYLON* Kraus, 1870

The fossil wood showing picnoxylic secondary wood with araucaroid pitting are generally described either under *Dadoxylon* Endlicher (1847) or *Araucarioxylon* Kraus (1870, in : Schimper 1870-72). Seward in 1963 mentioned that fossil woods with araucaroid pitting from the Palaeozoic be assigned to *Dadoxylon* and those from the younger strata to *Araucarioxylon* because *Dadoxylon* type of woods were thought to belong to Cordaitales and *Araucarioxylon* to Araucariaceae. Potonie (1902) and Gothan (1905) preferred to retain the name *Dadoxylon* irrespective of age of the wood. Maheshwari (1972) suggested that the name *Araucarioxylon* be used for the secondary woods with araucaroid radial pitting and cupressoid crossfield pits having uniseriate or rarely partly biseriate rays. Accordingly Bose and Maheshwari (1974) transferred some Indian Mesozoic *Dadoxylon* species to *Araucarioxylon.* But, it has been found that there is considerable variation in the height and width of xylem rays in the woods (Bailey & Paul, 1934; Daval, 1972).

Lepekhina (1972) suggested that the difference between *Dadoxylon* and *Araucarioxylon* woods lies in the presence of endarch primary xylem with large nonseptate pith without secretary canals in *Dadoxylon* and the presence of only secondary wood in *Araucarioxylon.* Lakhanpal *et al.* (1977) supported this view.

In the present study three fossils woods under the generic name *Araucarioxylon* are described. It is considered here that fossil woods having only secondary xylem with araucaroid pitting be assigned to *Araucarioxylon* and those having primary xylem and pith be assigned to the genus *Dadoxylon* irrespective of their age. Thus, only the change in name from *Dadoxylon* to *Araucarioxylon* as suggested by Bose and Maheshwari (1974) is adopted here, but in a different sense as mentioned above.

Araucarioxylon santalense (Sah & Jain) Bose & Maheshwari
Pl. 1, figs. 6, 12, 13, 14; Text-figs. 1H, I; 2A

Remarks—The present fossil wood possesses distinct growth-rings and occasional

tangential wall pits and lacks resin tracheids, but the other characters are similar to *A. santalense*.

Araucarioxylon pranhitensis n. sp.
Pl. 2, figs. 1, 2, 6, 9; Text-figs. 1G, M

Diagnosis—Growth rings present; resinous cells scattered; wood parenchyma absent; radial wall pits uni-to tri-seriate, mostly uni-or biseriate, alternate. sometimes sub-opposite or opposite, hexagonal, bordered, contiguous; cross-field pits 3-6, arranged in groups, circular or elliptical, 6-8 μm in size, xylem rays mostly uniseriate, sometimes bi-or triseriate, long, 1-52 cells in height, cells longer than broad, walls smooth and thin.

Holotype—Specimen no. BSIP 36240 (slide nos. 36240 I-III)

Locality—Kota.

Horizon & Age—Kota Formation, Middle Jurassic—slightly younger.

Comparison—*Araucarioxylon pranhitensis* is charactered by the presense of long, mostly uniseriate or sometimes bi-triseriate xylem rays, araucaroid pitting and 3-6 crossfield pits. In having uni-triseriate radial pits *A. pranhitensis* resembles *Araucarioxylon amraparense* (Sah & Jain) Bose & Maheshwari (1974) known from the Rajmahal Hills. However, it differs in having more cross-field pits and longer xylem rays. In the height of xylem rays *A. pranhitensis* is closer to *Araucarioxylon bindrabunense* (Sah & Jain) Bose and Maheshwari (1974). *A. pranhitensis* resembles *Dadoxylon deccani* Shukla (1938) described from the Deccan Intertrappeans in the height of xylem rays, but it differs in having 1-6 cross-field pits and 1-2 rows of radial wall pits. *A. pranhitensis* also resembles *Dadoxylon keuperianum* Seward (1963) in the height of xylem rays, but in the latter the xylem rays are always uniseriate unlike *A. pranhitensis*, where sometimes bi-triseriate xylem rays are present. *A. pranhitensis* is also comparable with *A. huzinamiense*, described by Ogura (1960) from Japan, in the height of xylem rays and 2-3 biseriate radial wall pits.

Araucarioxylon sp. A
Pl. 2, figs. 3, 4, 5, 7, 8; Text-figs. 1D, 2F

Description—Wood light brown in colour; Growth rings present, transition from early to late wood gradual. Early wood zone 24-42 cells wide. Late wood zone narrow, 3-5 cells wide. Resin cells scattered. Early wood tracheids squarish to polygonal, 32-58 × 56-78 μm in size, wall 16-24 μm thick. Late wood tracheids nearly squarish, 14-30 μm × 16-40 μm in size. Radial wall pits mostly uniseriate, contiguous, 13-16 μm in size, more or less hexagonal, 5-6 μm in diameter. Cross-field pits 2-5, bordered, arranged in groups, 4-5 μm in size, oval, sometimes circular. Xylen rays mostly uniseriate rarely partly biseriate, 1-18 cells (18-430 μm) in height. Cells longer than broad, walls smooth and thin.

Comparison—*Araucarioxylon* sp. A. closely matches with *Dadoxylon* (*Araucarioxylon*) sp. A described by Sahni (1931) from the Triassic of South Rewa Basin in the nature of growth rings, radial wall pits and xylem rays. *Araucarioxylon* sp. A. also resembles to some extent *Araucarioxylon rajmahalense* Sahni (1931) in the height of xylem rays and absence of tangential wall pits. In having long uniseriate and contiguous radial wall pits the present wood is comparable with *Araucarioxylon* sp. (No. 2) described by Greguss (1967) from the Lower Liassic of Hungary. The present wood specimen differs from all of them in the nature of cross-field pits.

FAMILY—PODOCARPACEAE

Genus—*PODOCARPOXYLON* Gothan, 1905

Podocarpoxylon rajmahalense (Jain) Bose & Maheshwari
Pl. 3, figs. 1-8

Remarks—Besides the diagnostic features of *P. rajmahalense* (Jain) Bose & Maheshwari the present wood specimen shows longer radial wall pits and occasional tangential wall pits as well.

Podocarpoxylon krauselii n. sp.
Pl. 4, figs. 3, 4, 8, 10

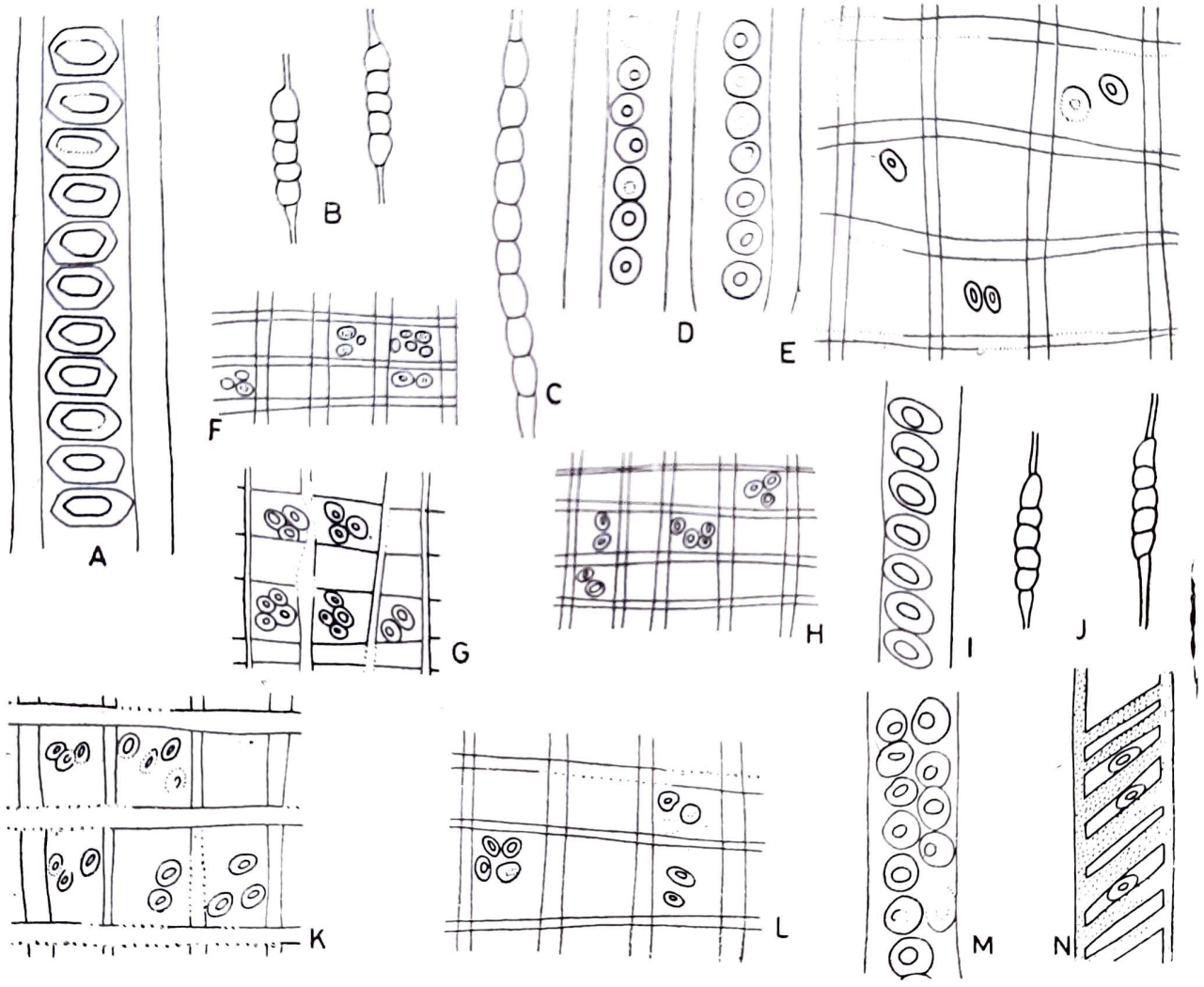
Diagnosis—Growth rings distinct, transition from early to late wood abrupt, xylem parenchyma scattered; Early wood tracheids polygonal, 20-38 μm × 25-55 μm in size; late wood tracheids round or polygonal, 16-25 μm × 25-32 μm in size; radial wall pits uniseriate, circular, bordered, contiguous or separate, aperture oval to round; cross-field pits 4-5, elliptical, arranged in groups, bordered; xylem rays mostly uniseriate, 2-28 cells in height, cells oval or beed-like, cell wall smooth and thin.

Holotype—Specimen no. BSIP 36243 (Slide no. 36243 I-III).

Locality—Kota.

Horizon & Age—Kota Formation, Middle Jurassic—slightly younger.

Comparison—*Podocarpoxylon krauselii* resembles *P. parthasarthyi* (Sahni) Bose & Maheshwari 1974 in possessing growth rings, xylem parenchyma and uniseriate radial wall pits. But, in the former the xylem rays are 2-28 cells in height, whereas in the latter they are 1-18. *P. kraeuselii* is quite distinct from *P. rajmahalense* (Jain) Bose & Maheshwari 1974 in having distinct growth rings, longer xylem rays and greater number of cross-field pits. The present species and *Podocarpoxylon kutchensis* Lakhanpal *et al.* (1975) show xylem parenchyma and predominantly uniseriate xylem rays but the latter possesses tangential wall pits. *P. kraeuselii* and *P. vikramii* Bande & Prakash 1984 resemble each other in



Text-figure 2.—A. *Araucarioxylon santalense* (Sah & Jain) Bose & Maheshwari, R.L. S. showing uni-seriate hexagonal radial wall pits, Slide no. BSIP 36239-III, x 250; B. *Taxaceoxylon sahnii* n. sp., T.L.S. showing uniseriate xylem rays, Slide no. BSIP 36245-II, x 50; C. *Cupressionoxylon kotaensis* n.sp., T.L.S. showing uniseriate xylem rays, Slide no. BSIP 36248-II, 125; D. *Podocarpoxylon chandrapurensis* n. sp., R.L.S. showing uniseriate radial wall pits, Slide no. BSIP 36244-III, x 250; E. Same, R.L.S. showing cross-field pits, Slide no. BSIP 36244-III, x 250; F. *Araucarioxylon* sp., R.L.S. showing cross-field pits, Slide no. BSIP 36241-III, x 200; G. *Taxaceoxylon sahnii* n. sp., R.L.S. showing cross-field pits, Slide no. BSIP 36245-III, x 200; H. *Cupressinoxylon kotaensis* sp., R.L.S. showing cross-field pits, Slide no. BSIP 36248-III, x 200; I. *Taxaceoxylon* sp. B, R.L.S. showing uniseriate radial wall pits, Slide no. BSIP 36247-III, x 200; J. Same, T.L.S. showing uniseriate xylem rays, Slide no. BSIP 36247-II, x 50; K. Same, R.L.S. showing cross-field pits, Slide no. BSIP 36248-II, x 125; L. *Taxaceoxylon* sp. A., R.L.S. showing cross-field pits, Slide no. BSIP 36246-III x 200; M. *Taxaceoxylon* sp. P, R.L.S. showing biseriate radial pits, showing biseriate radial pits, Slide no. BSIP 36247-III, x 200; and N. same, R. L. S. showing spiral thickenings on radial wall, Slide no. BSIP 36247-III, x 200.

having xylem parenchyma and growth rings, but differ in nature of xylem rays and cross-field pits.

Podocarpoxylon chandrapurensis n. sp.
Pl. 4, figs. 1, 2, 5, 7, 9; Text-figs. 2 D, E

Diagnosis—Growth rings distinct, transition from early to late wood abrupt, resinous parenchyma scattered; early wood tracheids 6-54 cells wide, cells squarish, 18-32μm × 19-30 μm in size; radial walls pitted, pits mostly uniseriate, rarely biseriate, contiguous, separate, simple, bordered, circular, 10-12 μm in size, aperture oval; cross-field pits 1-2, ? bordered, round, 6-7 μm, pore round; xylem rays mostly uniseriate, simple 1-18 cells high, ray cell longer than broad.

Holotype—Specimen no. BSIP 36244 (Slide nos. 36244 I-III).

Locality—Chitur.

Horizon & Age—Kota Formation; Middle Jurassic—slightly younger

Comparison—*Podocarpoxylon chandrapurensis* is characterised by the presence of distinct growth rings, uniseriate, 1-18 celled xylem rays and circular contiguous or solitary radial wall pits. It is comparable with *P. godavarianum* (Sahni) Bose & Maheshwari (1974) in the height of xylem rays, in the absence of tangential wall pits and crassulae and in the presence of xylem parenchyma. However, the present species shows distinct growth rings and less number of cross-field pits. *P. chanddrapurensis* is also comparable with *P. parthasarathyi* (Sahni) Bose and Maheshwari (1974) in possessing uniseriate, circular radial wall pits and in the height of xylem rays, but it lacks pith. To some extent *P. chandrapurensis* does resemble *P. rajmahalense* (Jain) Bose and Maheshwari (1974) in the presence of uniseriate circular radial pits and in the number of cross-field pits; the former species, however, possesses longer xylem rays and scattered parenchyma. *P. aikaense* Greguss described by Ramanujam (1972) from the Oldham Formation (Upper Cretaceous) of Alberta to some extent is comparable with *P. chandrapurensis* in having growth rings, uniseriate, separate rounded radial wall pits and scattered xylem parenchyma.

FAMILY—TAXACEAE

Genus—*TAXACEOXYLON* Krausel & Jain, 1964

Taxaceoxylon sahnii n. sp.
Pl. 5, figs. 1-6; Text-figs. 1 J, 2B

Diagnosis—Growth rings present, transition from early to late wood gradual, resin cells and parenchyma absent; tracheids squarish to polygonal, 26-54 × 34-66 μm in diameter. Radial wall pits mostly uniseriate, sometimes biseriate, opposite, circular, bordered, contiguous, 14-16 μm in size, pore oblique, sometime round, crassulae absent; spiral thickenings mostly double, 5-6 μm thick, occur at a distance of 12-20 μm at an angle of 30°-45°; cross-field pits 2-5, cupressoid, bordered, pore oblique; xylem rays uniseriate, 1-9 cells in height, cells oval to elliptical, spirals on tangential walls mostly double, arranged at a distance of 8-20 μm at an angle of 30°-42°.

Holotype—Specimen no. BSIP 36245 (Slide nos. I-III).

Locality—Kota.

Horizon & Age—Kota Formation, Middle Jurassic—slightly younger.

Comparison—*Taxaceoxylon sahnii* resembles *T. rajmahalense* (Bharadwaj) Kräusel & Jain year in possessing spiral thickenings on both radial and tangential walls of tracheids and in the height of xylem rays and absence of tangential wall pits. However, the present species has biseriate radial pits and lacks crassulae. *Taxaceoxylon* sp. cf. *T. rajmahalense* described by Kräusel and Jain (1964) too possesses 1-2 seriate radial wall pits and lacks tangential wall pits as in *T. sahnii*, but the latter has longer xylem rays. Both *T. sahnii* and *T. intertrappeanum* Mahabale & Satyanarayana 1978 resemble in the height of xylem rays. *T. antiquum* (Boershore & Grey) Kräusel and Jain and *T. sahnii* have in common 1-2 seriate radial wall pits and lack tangential wall pits. *T. mcmurrayensis* Roy 1972 described from the Lower Cretaceous of Alberta, Canada resembles *T. sahnii* in having uniseriate xylem rays, spiral thickenings of the tracheids and in lacking crassulae.

Taxaceoxylon sp. A
Pl. 4, figs. 6; Pl. 5, fig. 7; Pl. 6, figs. 1, 2, 4; Text-figs. 1F, L; 2L

Description—Growth rings faintly marked, variable in size, transition from early to late wood gradual. Resinous parenchyma and resin canals absent.

Early wood tracheids squarish to nearly

round, thin-walled, cells 32-52 μm × 28-58 μm in size, radial wall thickness 8.5-10 μm, tangential wall thickness 10-12.5 μm. Late wood zone 8-10 cells wide, trachieds angular, 17-28 μm in size, wall thickness 2.5-3 μm. Pits on radial walls of trachieds uniseriate, circular, bordered, contiguous or separate, 12.5-15 μm in size, pore round, 4.5-5 μm in diameter. Spiral thickenings on radial walls of tracheids making an angle of 40°-80°, 4-5 μm thick, single and double, sometimes thickenings horizontal, 2-5 μm thick, band-like cross-field pits 2-4, cupressoid, 3.5-5 μm in size, bordered, pore round or oval. Xylem rays uniseriate, rarely partly biseriate, simple, 1-22 cells (25-575 μm) in height, mostly 3-12 cells, cells barrel or dumb-bell shaped, 30-55 μm broad, walls smooth and thick,

Comparison—*Taxaceoxylon* sp. A closely resembles *T. antiquum* (Boershore & Grey) Kräusel & Jain 1964 in possessing growth rings, long xylem rays, spiral thickenings on the radial walls of tracheids and uniseriate radial pits, but it lacks pits on tangential wall and biseriate radial pits. *Taxaceoxylon* sp. A differs from *T. sahnii* in possessing horizontal thickenings on the radial and tangential walls. It is also distinct from *Taxaceoxylon* sp. B in having longer xylem rays and uniseriate radial wall pits.

Taxaceoxylon sp. B

Pl. 5, figs. 8; Pl. 6, figs. 3, 5, 6; Text-figs. 2, I, J K, M N

Description—Wood piece measures 8.2 × 3.4 cm. Growth rings faintly marked, trasition from early to late wood gradual. Resinous parenchyma scattered. Resin canals absent. Tracheids squarish to polygonal, 35-70 × 30-50 μm in size, radial walls 5-10 μm and tangential walls 8-10 μm thick; Pits on radial walls uni-to biseriate, when biseriate both alternate and opposite, circular, bordered, contiguous, rarely separate, 12.5-17.5 μm in size, pore round to oval, sometimes lenticular, rarely oblique, 4-5 μm in size. Crassulae absent. On radial walls both right and left handed spirals present, spirals solitary or paired, 6-7 μm thick, occurring at a distance of 5-7 μm and at an angle of 38°-50°. Spirals on tangential walls mostly solitary and horizontal. Cross-field pits 2-4, oval to elliptical, bordered, 6-7.5 μm broad; Pore oblique and sometimes elongated. Xylem rays uniseriate, homocellular, 1-12 cells (20-300 μm) in height, mostly 2-7 cells, ray cells more or less squarish to oval, 36-40 μm broad; walls thin and smooth.

Comparison—*Taxaceoxylon* sp. B is comparable with *Taxaceoxylon rajmahalense* (Bharadwaj) Krausel & Jain 1964 in having spiral thickenings on radial and tangential walls of trachieds and in the absence of tangential wall pits. However, *Taxaceoxylon* sp. B possesses longer xylem rays, but lacks crassulae and biseriate radial wall pits. *Taxaceoxylon* sp. B and *T. kateruense* Mahabale & Rao 1973 resemble each other in the height of xylem rays and absence of tangential wall pits.

FAMILY—CUPRESSINOXYLON

Genus—*CUPRESSINOXYLON* Goeppert, 1850

Cupressinoxylon kotaense n. sp.

Pl. 5, fig. 9; Pl. 6, figs. 7-10; Text-figs. 1E, K, 2C, H

Diagnosis—Growth rings faintly marked; xylem parenchyma scanty, scattered; resin cells present; trachieds mostly round, 24-52 × 28-54 μm in size; radial wall pits unibiseriate, in the latter condition opposite, bordered, contiguous or separate, 14-18 μm in size, pore oblique; crassulae present, 6-8 μm thick; cross-field pits 2-4, cupressoid; xylem rays uniseriate, 1-13 cells, mostly 2-6 cells in height, cells oval, cells wall smooth and thin.

Holotype—Specimen no. BSIP 36248 (Slide nos. I-III).

Locality—Kota.

Horizon & Age—Kota Formation, Middle Jurassic/slightly Younger

Comparison—*Cupressinoxylon kotaensis* is comparable with *C. coromandelinum* Sahni 1931 in the nature of radial wall pits and presence of crassulae. The latter has numerous crowded long xylem rays and abundant resin parenchyma. *C. kotaense* to some extent resembles *C. alternans* Sahni 1931 in having uniseriate xylem rays and 1-2 seriate radial wall pits. However, in *C. alternans* the radial wall pits are alternate and tangential wall pits are present. *C. sahnii* Billimoria 1948 differs from *C. kotaense* in the absence of parenchyma, in the height of xylem rays and in the nature of radial wall pits. *Cupressinoxylon* (*Taxodioxylon*) *rajmahalense* Bhardwaj 1953 is distinct from *C.*

kotaense in having long xylem rays, less number of cross-field pits and in the presence of tangential wall pits. *C. walkomii* described by Sahni (1920) from the Walloon Series (Jurassic) of Queensland to certain extent comes closer to *C. kotaensis*. Both the species have uni-biseriate, bordered, circular, opposite radial wall pits and crassulae. But, they differ in the height of xylem rays and nature of cross-field pits.

Discussion

The present floral finds together with earlier records from the Kota Formation include 17 genera and 33 species (see Table 1). This assemblage is dominated by conifers and pteridophytes. Cycadophytes and ginkgophytes are poorly represented.

These are chiefly represented by the genera *Equisetites*, *Hausmannia*, *Coniopteris*, *Cladophlebis*, *Sphenopteris*, *Otozamites*, *Ptilophyllum*, *Elatocladus*, *Brachyphyllum*, *Pagiophyllum* and *Araucarites* which constitute the bulk of the flora of the Jurrassic-Lower Cretaceous periods. The other constituents of this assemblage are conifer woods belonging to *Araucarioxylon*, *Podocarpoxylon*, *Taxaceoxylon* and *Cupressinoxylon*, common to the Rajmahal flora. Moreover, among these conifer woods

Table 1—Distribution of fossil plants in the Kota Formation (based on present work and earlier reports)

Taxa	Locality		
	Kota	Chitur	Narasimhagutta
Equisetites sp.	—	+	—
**Cladophlebis* sp. A	—	+	—
Cladophlebis indica (Oldham & Morris) Feistmantel	—	—	+
Cladophlebis reversa	—	—	+
**Sphenopteris* sp. A	—	+	—
Coniopteris hymenophylloides (Brongniart) Seward	+	—	—
Coniopteris sp.	+	—	—
Hausmannia sp.	—	+	—
Otozamites sp.	—	+	—
Ptilophyllum acutifolium Morris	—	—	+
Elatocladus plana (Feistmantel) Seward	—	—	+
Elatocladus jabalpurensis (Feistmantel) Sahni	+	—	—
Elactocladus sp.	+	—	—
**Pagiophyllum* sp. A	—	+	—
**Pagiophyllum* sp. B	—	+	—
Pagiophyllum cf. P. *peregrinum* (Lindley & Hutton) Schimper	+	—	—
Pagiophyllum peregrinum (Lindley & Hutton) Schimper	+	—	—
Brachyphyllum sp.	—	—	+
Araucarites cutchensis Feistmantel	+	—	—
Araucarites sp.	+	—	—
**Araucarioxylon santalense* (Sah & Jain) Bose & Maheshwari	+	—	—
**Araucarioxylon pranhitaensis* n. sp.	+	—	—
Araucarioxylon sp. A	+	—	—
**Podocarpoxylon rajmahalense* (Jain) Bose & Maheshwari	+	—	—
**Podocarpoxylon krauselii* n. sp.	+	—	—
**Podocarpoxylon chandrapurense* n. sp.	—	+	—
**Taxaceoxylon sahnii* n. sp.	+	—	—
**Taxaceoxylon* sp. A	+	—	—
**Taxaceoxylon* sp. B	—	+	—
Taxaceoxylon cf. *T. rajmahalense* (Bhardwaj) Krausel & Jain	+	—	—
**Cupressinoxylon kotaense* n. sp.	+	—	—
Ginkgoxylon dixitii Biradar & Mahable	+	—	—

*Present finds

Araucarioxylon santalense (Sah & Jain) Bose & Maheshwari, described from Rajmahal Hills is commonly found in the Kota Formation. *Taxaceoxylon* cf. *T. rajmahalense* (Bhardwaj) Kräusel and Jain is another species in the Kata Formation which closely resembles *T. rajmahalense* from the Rajmahal Formation. This study is suggestive of close floral similarity between Kota and Rajmahal formations. The flora of Rajmahal is considered to be Early Cretaceous in age (Sukh-Dev, 1987). Broad leaved cycadophytes and other characteristic fossils of the Rajmahal flora are not recorded in the present assemblage. Interestingly the Nipania floral assemblage is slightly younger and is dominated by conifers, but such wood genera as mentioned above are not known. These differences can be ascribed to different depositional environments.

Stratigraphically the Kota Formation conformably overlies Dharmaram Formation The flora from the Dharmaram Formation is not definitly known, except *Palissya conferta* and *Chirolepis munsteri* recorded from the Annaram beds (King, 1881; Bandopadhyay & Rudra, 1985). Faunal evidences of Dharmaram beds support an Upper Triassic (Upper Norian to Rhaetic) age (Kutty, 1969). The Kota sediments are unconformably overlain by the Gangapur beds which show a fairly well represented flora of Early Cretaceous age (Sukh-Dev & Rajanikanth, 1988).

The age of the Kota Formation was considered Lower Jurassic on fish evidences (Jain, 1973, 1983; Satsangi & Shah, 1973; Robinson, 1970; Yadagiri *et al.*, 1980). On the basis of ostracod Middle Jurassic age has been suggested to these beds. (Govindan 1975; Misra & Satsangi, 1979; Tripathi 1975). Overall palaeontological, geological and palaeobotanical evidences favour Middle Jurassic or slightly younger age for the Kota Formation. The view expressed by Rajeshwar Rao *et al.* (1983) that the Middle to Upper Jurassic strata are missing in the Upper Gondwana sequence of Pranhita Godavari Valley is not in concurrence with the present study. It was probable that during the time of deposition of Kota sediments there was abundant vegetation comprising of mostly conifers with probably subtropical environment with moderately good rainfall. Presence of growth rings in the woods points out alternating seasonal variations. The fish and ostracod evidences indicate the presence of freshwater expanding and very shallow lake (Govindan, 1975, Jain, 1983). The presence of some fish and pterosaur which are elsewhere known from marine deposits indicates the deposition of Kota sediments was not far away from the sea (Shah & Pant, 1979), and also the occurrence of coccoliths in limestones of the Kota Formation indicates marine transgression as well (Bhattacharyya, 1981).

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Explanation of Plates

Plate 1

1. *Pagiophyllum* sp. A. Specimen No. BSIP 36235, x 2.
2. Same, x 1.
3. *Sphenophyllum* sp. pinna enlarged, Specimen No. BSIP 36234, x 4.
4. *Pagiophyllum* sp. B, Specimen No. BSIP 36238, x 1.
5. *Pagiophyllum* sp. A. Specimen No. BSIP 36236, x 1.
6. *Araucarixylon santalense* (Sah & Jain), Bose & Maheshwari, transverse section showing growth rings. Slide No. BSIP 36329-1 x 30.
7. *Pagiophyllum* sp., Specimen No. BSIP 36238, x 2.
8. *Sphenopteris* sp., Specimen No. BSIP 36234, x 1.
9. *Cladophlebis* sp., Specimen No. BSIP 36233, x 1.
10. Same, enlarged, x 8.
11. *Pagiophyllum* sp. A, Specimen No. BSIP 36236, x 2.
12. *A. santalense*, radial longitudinal section showing uniseriate contiguous bordered hexagonal pits, Slide No. BSIP 36329-III. x 400.
13. *A. santalense*, tangential longitudinal section showing uniseriate xylem rays, Slide No. BSIP 86329-II x 100.
14. *A. santalense*, R. L. S. SEM photograph showing single hexagonal radial wall pit, x 1400.

Plate 2

1. *Araucarioxylon pranhitensis* n. sp. Transverse section. Holotype Slide No. BSIP 36240-I, x 30.
2. Same, radial longitudinal section showing uni-bi-tri seriate contiguous hexagonal wall pits, Slide No. BSIP 36240-III, x 100.
3. *Araucarioxylan* sp. radial longitudional section showing uniseriate contiguous hexagonal wall pits, Slide No. BSIP 36241-III, x 100.
4. Tangential longitudional section showing uniseriate xylem rays, Slide No. BSIP 36241-II, x 100.
5. Radial longitudional section showing cross-field pits, Slide No. BSIP 36241-III, x 400.
6. *A, pranhitensis* n. sp., tangential longitudional section showing uni-triseriate xylem rays, Slide No. BSIP 36240-II, x 100.
7. *Araucarioxylon* sp. transverse section, Slide No. BSIP 37240-II, x 100.
8. Radial longitudional section showing uniseriate contiguous bordered hexagonal wall pits, Slide No. BSIP 36241-III, x 400.
9. *A. pranhitensis* n. sp., radial longitudional section showing crossfield pits, Slide No. BSIP 36240-III, x 400,

Plate 3

1. *Padocarpoxylon rajmahalense* (Jain) Bose & Maheshwari, Tangential longitudinal section showing uniseriate xylem rays, Slide No. BSIP 36342-II, x 100.
2. Radial longitudinal section showing uniseriate circular wall pits, Slide No. BSIP 36242-III x 200.
3. Radial section showing biseriate alternate wall pits, Slide No. BSIP 36242-III, x 400.
4. Tangential longitudinal section showing tangential wall pits, Slide No. BSIP 36242-II, x 400.
5. Transverse section, Slide No. BSIP 36242-I, x 100.
6. Radial longitudinal section showing cross-field pits, Slide No. BSIP 36242-III, x 400.
7. SEM photograph, uniseriate circular bordered radial wall pits, x 1300.
8. S. E. M. photograph, biseriate opposite radial wall pits, x 320, x 1000.

Plate 4

1. *Podocarpoxylon chandrapurensis* n. sp., Transeverse section showing distinct growth rings, Slide No. BSIP 36244-1, x 30.
2. Radial longitudinal section showing uniserate radial wall pits, Slide No. BSIP 36244-III, x 200.
3. *Podocarpoxylon krauselii* n. sp., Tangential longitudinal section showing long uniseriate xylem rays, Slide No. BSIP 36243-II, x 50.
4. Transverse section, Slide No. BSIP 36243-I, x 3.
5. *P. chandrapurensis* n. sp., Tangential longitudinal section showing uniseriate xylem rays, Slide No. BSIP 36244-II, x 50.
6. *Taxaceoxylon* sp. A., Radial longitudinal section showing spiral thickenings and uniseriate circular wall pits, Slide No. BSIP 36246-III, x 400.
7. *P. chandrapurense* n. sp., Radial longitudinal section showing cross-field pits, Slide No. BSIP 36244-III, x 400.
8. *P. krauselii* n. sp. Radial longitudinal section showing cross-field pits, Slide No. BSIP 36243-III, x 400.
9. *P. chandrapurensis* n. sp., Radial longitudinal section showing uniseriate circular contiguous wall pits, Slide No. BSIP 36244-III, x 400.
10. *P. krauselii* n. sp., Radial longitudinal section showing uniseriate contiguous radial wall pits, Slide No. BSIP 36243-III, x 400.

Plate 5

Taxaceoxylon sannii n. sp.

1. Transverse section, Slide No. BSIP 36245-I, x 30.
2. Radial longitudinal section showing spiral thickenings, Slide No. BSIP 36245-III, x 100.
3. Radial longitudinal section showing uniseriate radial wall pits, Slide No. BSIP 36245-II, x 400.
4. Tangential longitudinal showing uniseriate short xylem rays, Slide No. BSIP 36245-II, x 40.
5. Radial longitudinal section showing spiral thickening and uniseriate wall pits, Slide No. BSIP 36245-III, x 400.
6. Tangential longitudinal section showing spiral thickening, Slid No. BSIP 36245-II, x 400.
7. *Taxaceoxylon* sp. A, Radial longitdinal seetion showing horizontal wall thickenings, Slide No. BSIP 36246-III, x 100.
8. *Taxaceoxylon* sp. B, Radial longitudinal section showing cross-field pits, Slide No. BSIP 36247-III, x 400.
9. *Cupressinoxylon kotaense* n. sp., Radial longitudinal section showing cross-field pits, Slide No. BSIP 36248-III, x 400.

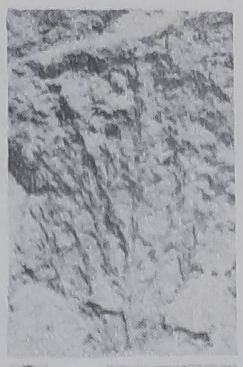
Plate 6

1. *Taxaceoxylon* sp. A, Transverse section, Slide No. BSIP 36246-1, x 30.
2. Tangential longitudional section showing xylem

rays, Slide No. BSIP 36246-II, x 100.

3. *Taxaceoxylon* sp. B, Radial longitudinal section showing uni-biseriate radial wall pits and spiral thickenings, Slide no. BSIP 36247-III, x 400.
4. *Taxaceoxylon* sp. A, Radial longitudinal section showing uniseriate wall pits and spiral thickenings, Slide no. BSIP 36246-III, x 400.
5. *Taxaceoxylon* sp. B, Radial longituditinal section showing uniseriate wall pits and spiral thickenings, Slide no. BSIP 36247-III, x 400.
6. *Taxaceoxylon* sp. B, Tangential longitudinal section showing uniseriate short xylem rays, Slide no. BSIP 36247-II, x 190.
7. *Cupressinoxylon kotaense* n. sp., Radial longitudinal section showing crassulae on radial walls. Slide no. 36248-III, x 400.
8. Transverse section, Slide no. BSIP 36248-I, x 100.
9. Tangential longitudinal section showing uniseriate narrow xylem rays, Slide no. BSIP 36248-II, x 400.
10. Radial longitudinal section showing uniseriate radial wall pits and crassuale, Slide no. BSIP 36248-III, x 400.


1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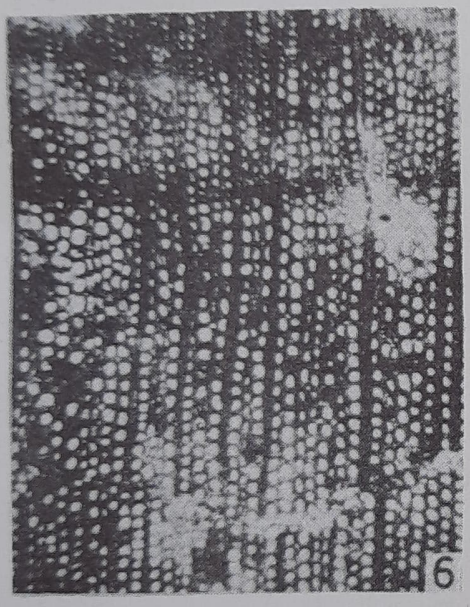
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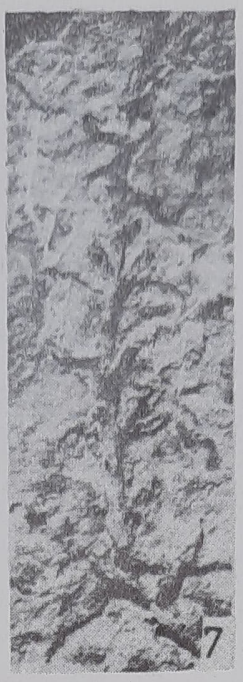
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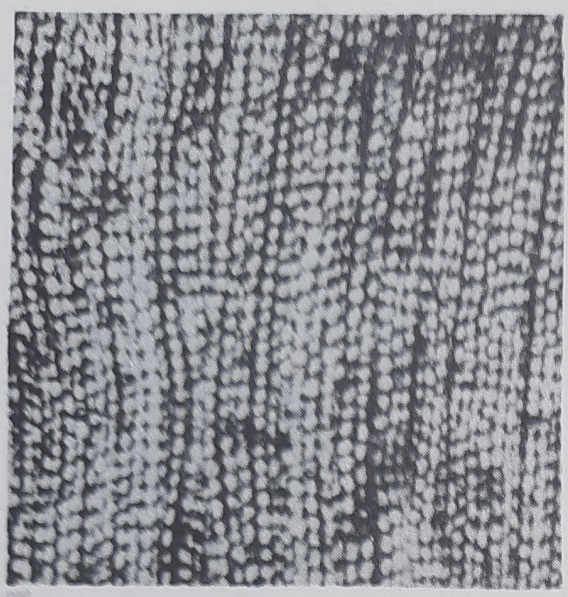

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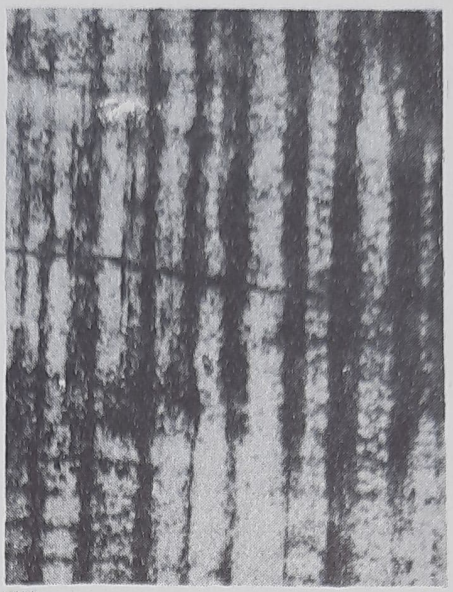

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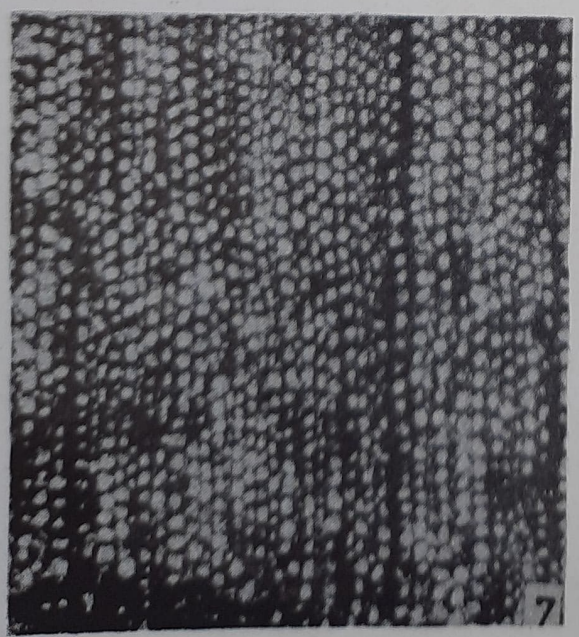

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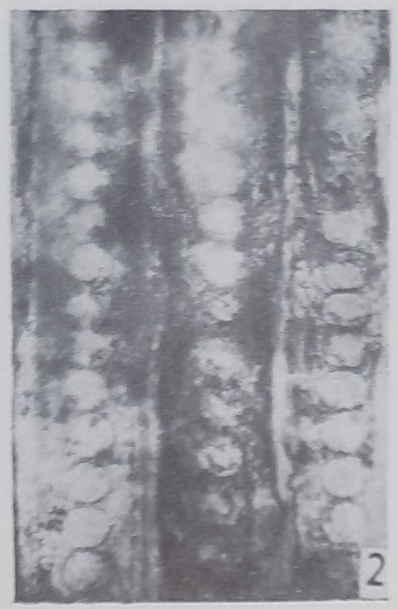
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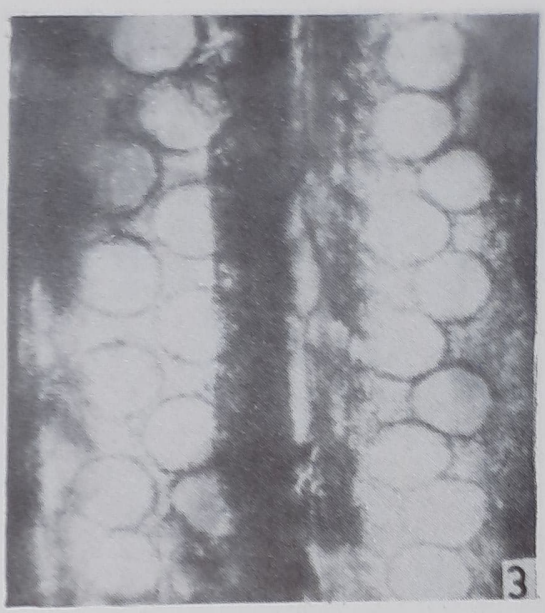
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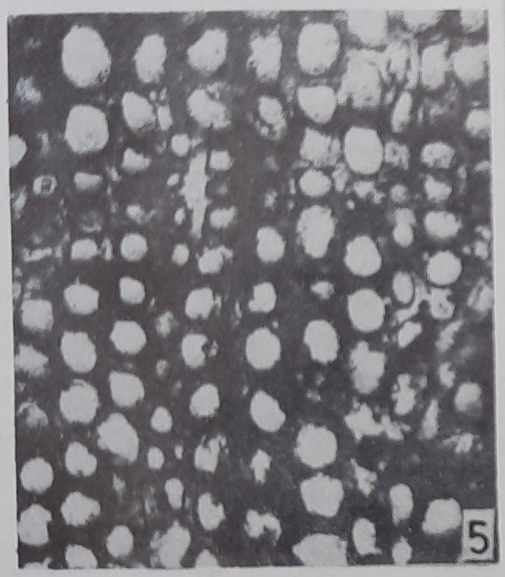
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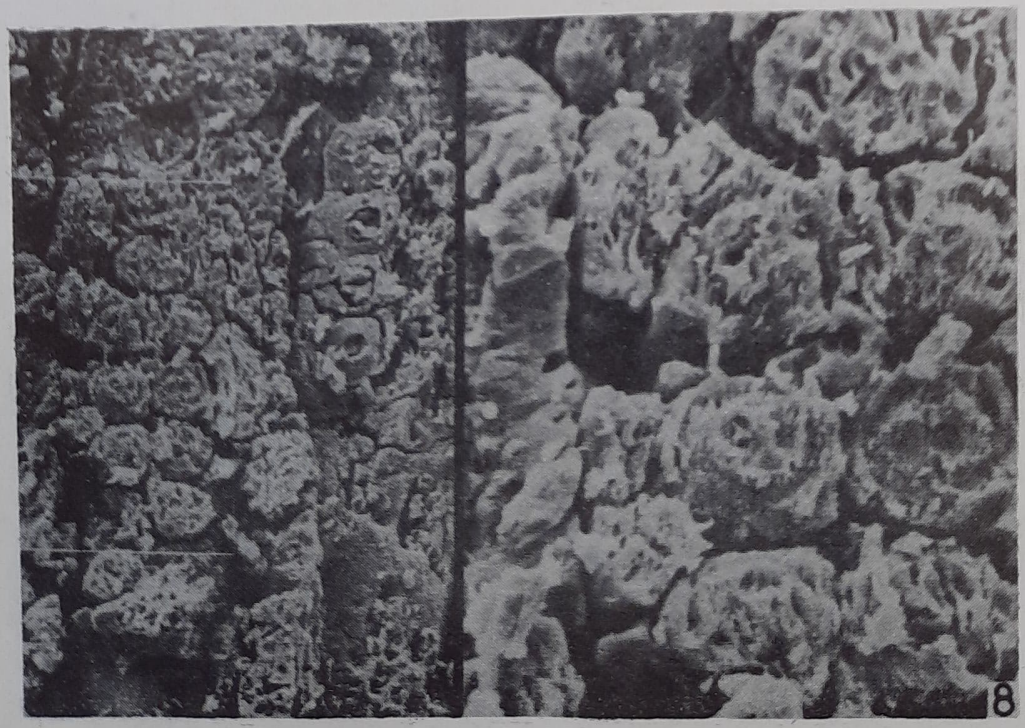
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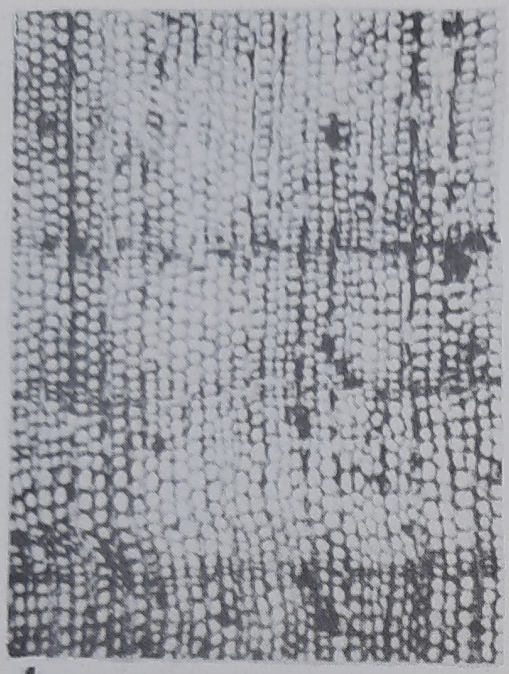

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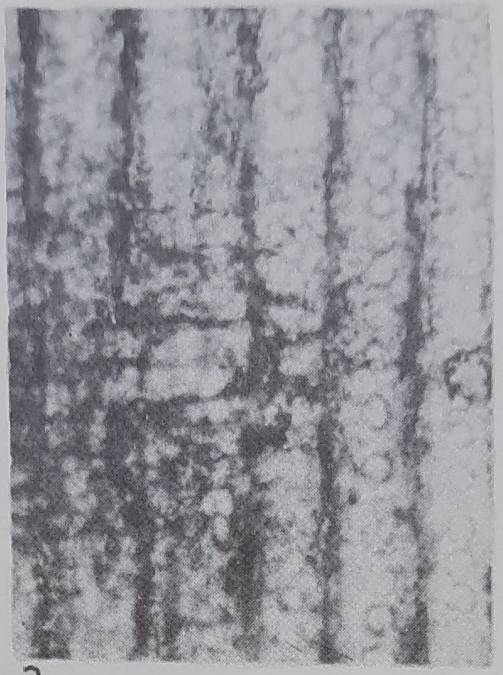

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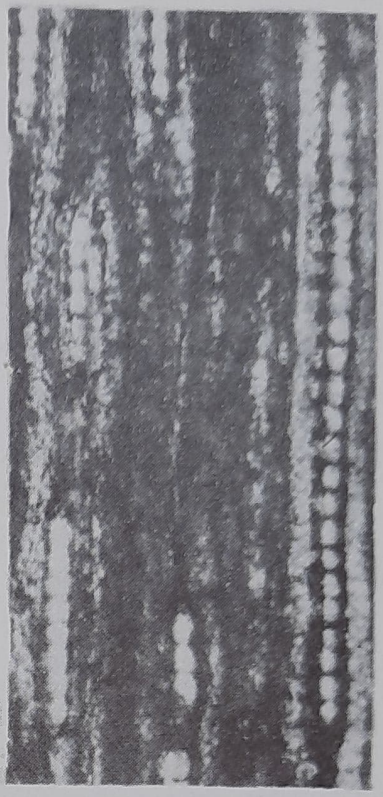

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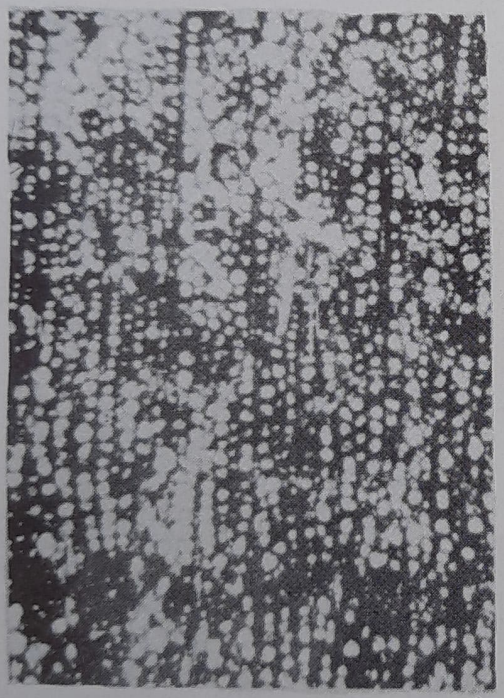

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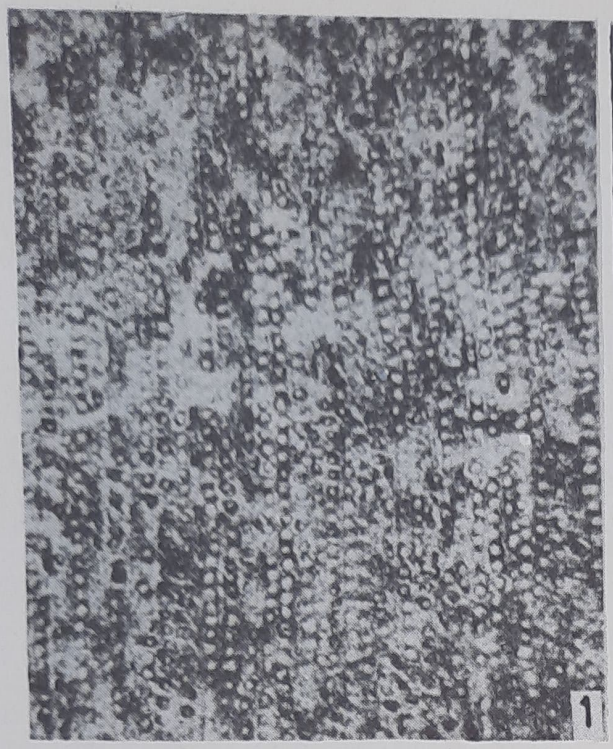
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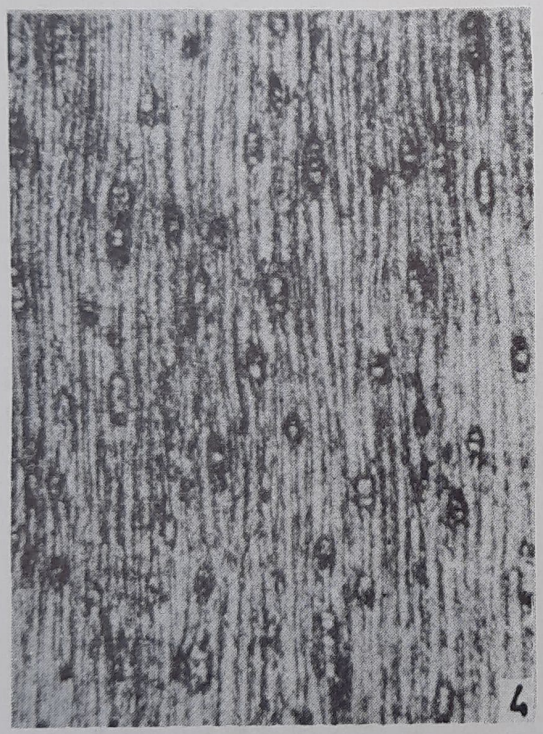
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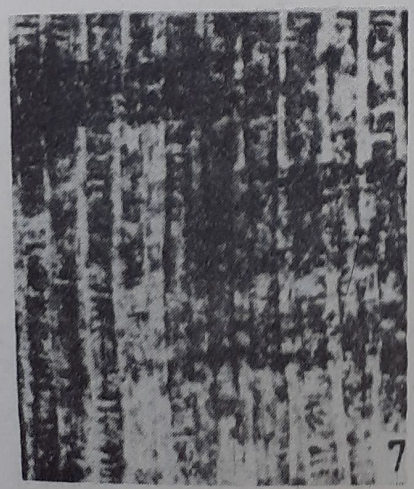
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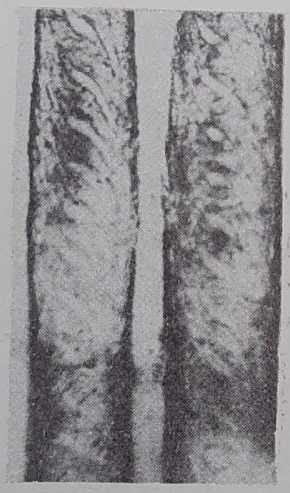

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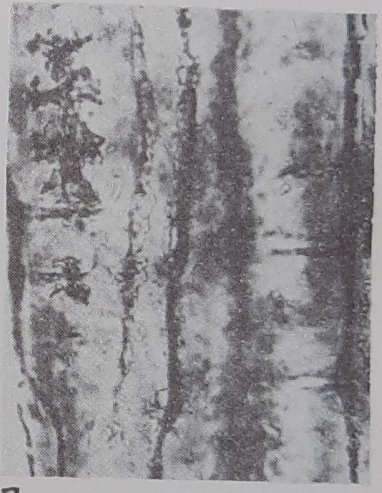

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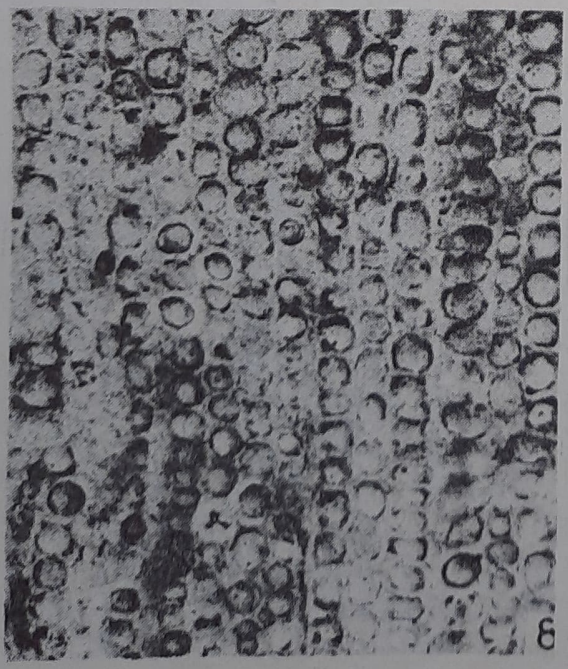

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