STUDIES IN THE GLOSSOPTERIS FLORA OF INDIA—28. ON SOME FOSSIL WOODS FROM THE RANIGANJ STAGE OF THE RANIGANJ COALFIELD, BENGAL

HARI K. MAHESHWARI
Birbal Sahni Institute of Palaeobotany, Lucknow

ABSTRACT

The present paper contains a description of some fossil woods from the Raniganj stage in the eastern sector of the Raniganj coalfield, Bengal. One new genus, viz. *Damudoxylon* has been instituted and three genera, viz. *Trigonomyelon* Walton, *Megaporoxylon* Kräusel and *Kaokoxylon* Kräusel are being reported for the first time from India.

INTRODUCTION

FOSSIL woods have been known to occur in the Lower Gondwana formations since long. Most of the specimens are only pieces of secondary wood but some woods with pith and primary xylem have also been described. These woods are characterized by uniseriate to multiseriate bordered pits of 'araucarian' type on the radial walls of the tracheids, sometimes on the tangential walls also. Because of the similar type of tracheidal pitting, formerly almost all these woods were placed in the genus *Dadoxylon* Endl. The specific delimitation in these woods was based upon the character of the xylem rays, tracheidal pitting and the growth zones; no importance was attached to the nature of pith and primary xylem. In recent years much emphasis has been placed on the importance of pith and primary xylem resulting in the delimitation of a number of genera (WALTON, 1925; KRÄUSEL, 1956; KRÄUSEL & DOLIANITI, 1958; SURANGE & MAITHY, 1962, 1963). Kräusel *et al.* (1963) have reviewed the state of our knowledge of the fossil woods from the Lower Gondwana formations.

Though fossil wood had long been known to occur in the Lower Gondwana horizons of India, no adequate description was published before Schenk (1882) described, under the name *Araucarioxylon robertianum*, a fragment of fossil wood collected from Asansol. First complete description of a fossil wood from the Lower Gondwanas of India was published by Holden (1917). She reported two new species, viz., *Dadoxylon indicum* and *D. bengalense* from the Barakar stage. Sahni (1932) described a new species of fossil wood (*D. zalesskyi*) from the Kumarpur sandstone near Asansol. Rao (1935) reported another new species, viz., *D. parbeliense* from a sphaerosiderite from the Raniganj stage of the western sector of the Raniganj coalfield. Some more fossil woods were recorded (GEE, 1932; FOX, 1934; J. K. VERMA, 1950; N. C. VERMA, 1950; NARSIMHAN, 1954) but no detailed accounts of these are available.

Surange & Sah (1957) described a new species, viz., *Dadoxylon jhariense* from the Barakar stage of Jharia coalfield, Bihar. This wood which seems to be identical with *D. lafoniense* (HALLE, 1911) was later transferred by Surange & Maithy (1962) to their new genus *Barakaroxylon*. These authors (1963) reported a new wood under the name *Indoxylon canalosum* from tha same area. Earlier Surange & Saxena (1959) described a fossil wood with xylem parenchyma and named it as *D. barakarense*. Maheshwari (1964) reported a new species, viz., *D. jamudhiense* from the Raniganj stage of Jharia coalfield. This author reported (1965) two more fossil woods, viz., *D. jamuriense* and *D. ningahense* from the Raniganj stage of the eastern sector of Raniganj coalfield, Bengal. Maithy (1965) reported two new species of *Dadoxylon* from the Barakar stage of Jharia coalfield. The other fossil woods known from the Lower Gondwanas of India are *Spiroxylon indicum* (MEHTA, 1950) from the Singrauli

coalfield, Madhya Pradesh and *Dadoxylon sahnii* (SINGH, 1958) from the Olive shales of Punjab Salt Range. *Dadoxylon chandaensis* (CHITALEY, 1950) is said to be from the Lower Gondwana horizons but its exact horizon is open to doubt.

The material for the present study was collected from the colliery rejections of the West Jamuria, Nagkothi and Lodna Collieries in the eastern sector of the Raniganj coalfield. As such the woods belong to the Raniganj stage. The woods occur in strata overlying the coal seams and in the course of drilling and digging operations are broken into small pieces. The fossils are considerably heavy and chocolate brown to dull black in colour. Most of the fossils are only secondary wood pieces but a few of them also contain pith and primary xylem. None has, however, been found with the cortical region.

DESCRIPTION

Trigonomyelon Walton 1925

Zeiller (1896) reported a fossil wood from Brazil under the name *Dadoxylon pedroi*. This wood which was characterized by a three-lobed pith with secretory cells interspersed amongst normal parenchymatous cells was later transferred by Walton (1925) to a new genus, viz., *Trigonomyelon*. However, Walton gave no definition of the new genus. Kräusel (1956) instituted the genus *Lobatoxylon* for woods with a lobed pith and he designated *Dadoxylon pedroi* Zeill. as the type species of this genus, besides he described one more species of this genus as *Lobatoxylon kaokense*. As Kräusel believes that both the woods, viz., *L. pedroi* and *L. kaokense* belong to one genus, on the basis of priority of publication both these woods must be referred to the genus *Trigonomyelon* which though not well-defined is a validly published name. As no diagnosis of the genus *Trigonomyelon* is available, the diagnosis of *Lobatoxylon*, which now becomes a junior synonym, may be taken to be as that of *Trigonomyelon*. The diagnosis will thus run as follows: pith 1-4 cm. wide, with 2-many lobes, parenchymatous with isolated cells or groups of secretory cells; primary xylem endarch; tracheidal and cross-field pitting araucarioid; secondary wood zone with distinguishable growth zones.

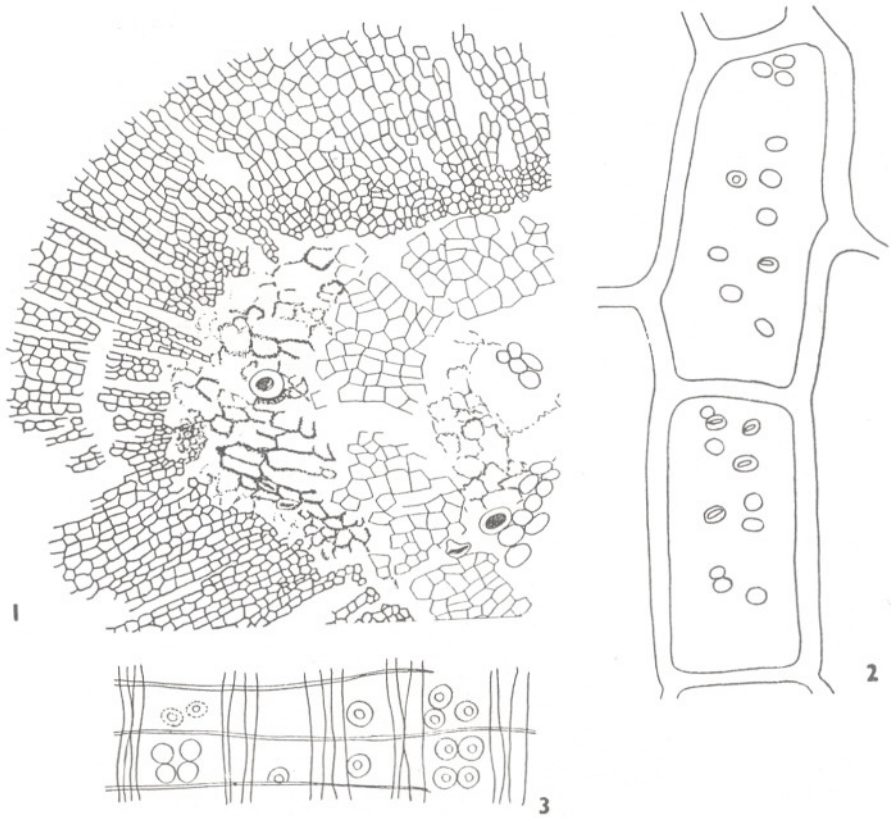
Trigonomyelon raniganjense[1] sp. nov.

The specimen is a decorticated piece of a petrified wood with pith, primary xylem and secondary xylem preserved partly. The colour of the specimen is dark brown. The secondary xylem is badly crumpled and only at a few places the growth zones could be seen under the microscope (PL. 1, FIG. 2). The autumn wood zone is 2-3 cells wide and consists of oblongly rectangular tracheids with a narrow lumen. Radially these tracheids measure 15-21 μ. The extent of spring wood zone could not be ascertained due to crushing of the cells during course of preservation. The tracheids of this zone are thick-walled and polygonal with broadly oval to circular lumen. The spring wood zone tracheids measure 46-60 μ radially (average 45 μ). Tangentially the tracheids measure 18-42 μ. The double walls between the tracheids measure 15-22 μ.

Pith — The specimen is broken at the pith, only a part of which has remained in the specimen (PL. 1, FIG. 1). The preserved portion of the pith measures 8×8 mm., but the complete pith was probably at least 15 mm. in diameter. The pith is not exactly cylindrical but forms lobes which protrude in the secondary xylem (PL. 1, FIG. 1). Five such lobes, whose number in the complete specimen was probably eight, are present in the pith. As suggested by Zeiller (1902) these structures have probably some relation with the departure of the leaf or branch traces. The cells of the pith are parenchymatous, thick-walled, oval to isodiametrical and compactly arranged. The average dimensions of the cells are comparatively more in the central part than in the peripheral region of the pith. The pith cells measure from 18 μ×18 μ to 153 μ×132 μ. Longitudinally these cells are almost rectangular, some times with oblique end walls, higher than broad, arranged end to end in longitudinal series (PL. 1, FIG. 4) and are 72-285 μ high. The cells of the pith have on their vertical walls 1-2 seriate, alternate or opposite pits with a very indistinct border and a prominent aperture (PL. 1, FIG. 5; TEXT-FIG. 2).

Scattered throughout the parenchymatous pith are isolated or sometimes grouped

1. In the review of fossil woods from the Lower Gondwana horizons (Kräusel *et al.* 1963) this wood was referred to as *Polyloboxylon raniganjense*.



TEXT-FIGS. 1-3 — *Trigonomyelon raniganjense* sp. nov. 1, A portion of transverse section of the wood showing a lobe with secondary xylem, primary xylem, parenchymatous sheath and pith cells. × 45. 2, Two cells of the pith in radial longitudinal section showing pits on the cell walls. × 250. 3, Radial longitudinal section through the secondary xylem showing pits in the cross-field. × 250.

thick-walled cells usually filled with dark contents. These cells seem to have had some secretory function. The diameter of these cells varies from 30μ to 90μ. Longitudinally the secretory cells are much higher than broad and are placed end to end (PL. 1, FIG. 4). At one place they were found to cover at least 4·2 mm. vertically. These cells are 141-270 μ long.

Parenchymatous Sheath — Separating the pith from the primary xylem is a zone of almost rectangular, thin-walled cells forming a sort of sheath (PL. 1, FIG. 3; TEXT-FIG. 1). The cells of this zone differ completely from the cells of the pith. Vertically the cells of this zone are irregular in shape, not much higher than broad and are arranged irregularly. This zone, however, does not seem to represent a transfusion tissue as found in *Dadoxylon indicum* Hold. The transverse dimensions of these cells are 30-90 μ radially and 60-75 μ tangentially. Vertically these cells are 45-90 μ long.

Primary Xylem — Abutting on the parenchymatous sheath is the 6-8 cells wide primary xylem. In transverse section there is no clear distinction between the primary and the secondary wood, as all the elements are arranged in radial series. In longitudinal section, elements near the pith have spiral thickening and probably represent the protoxylem. Towards the periphery they are followed by scalariform and reticulate elements which then pass into pitted tracheids of the secondary xylem (PL. 1, FIG. 6).

Xylem Rays — The xylem rays are homogeneous, uniseriate, some times biseriate and 1-15 cells deep. The average depth of the xylem rays is 3-4 cells. The ray

cells are barrel-shaped and higher than broad, measuring 22-28 μ in height and 18-22 μ in breadth. Radially they are much longer than high. Tangential walls of the tracheids sometimes show uniseriate, separate and almost circular pits.

Pitting — Radial walls of the tracheids have 1-2 seriate (PL. 1, FIG. 7; PL. 2, FIG. 9), occasionally 3-seriate (PL. 1, FIG. 8) bordered pits. The pits are alternate or opposite, contiguous and flattened. Sometimes even in triseriate condition the pits may be opposite and almost circular. Isolated pairs of oppositely placed pits have also been observed. In uniseriate condition the pits are wide apart and more circular. Rims of Sanio, however, are absent though at certain places transverse bar-like structures are seen between the pits. These seem to be simply artefacts produced by flattening of the pits. In uniseriate condition the pits measure 12 μ×12 μ, 10·5 μ ×10·5 μ, 12 μ × 10·5 μ, etc. and thus the coefficient (e=d/D; where 'e' is the coefficient, 'd' is height and 'D' is width of the pits) is from 1 to 0·88. In biseriate and triseriate conditions the pits measure 12 μ ×12 μ, 12 μ×10·5 μ, 12 μ× 9 μ, 13·5 μ× 12 μ, 15 μ×10·5 μ, etc. and hence the coefficient is 1-0·7. The pit aperture is central and circular or broadly oval with a diameter of 3·5-5 μ. Pits in the cross-field have not been well preserved though at places 1-6 pits (bordered ?) can be recognized.

DIAGNOSIS

Trigonomyelon raniganjense sp. nov.

Pith lobed, parenchymatous, cells of pith oval to isodiametrical and thickwalled, longitudinally pith cells rectangular, sometimes with oblique end walls, higher than broad, arranged end to end in longitudinal series and having 1-2 seriate, alternate or opposite pits on their walls. Isolated or groups of secretory cells filled with dark contents present in pith.

Between the pith and the primary xylem a zone of thin-walled, almost rectangular parenchymatous cells present. Primary wood zone of spiral, scalariform and reticulate elements.

Secondary wood zone with distinguishable growth zones; autumn wood zone 2-3 cells wide, oblongly rectangular tracheids measuring 15-21 μ radially; spring wood zone tracheids thick-walled, polygonal, with broadly oval to circular lumen and measure 46-60 μ radially; tangentially the tracheids measure 18-42 μ; thickness of the double walls between tracheids 15-22 μ.

Xylem rays homogeneous, uniseriate, sometimes biseriate, 1-15 cells deep, average depth 3-4 cells; ray cells 22-28 μ high, 18-22 μ broad. Tangential walls of the tracheids pitted.

Radial pits bordered, 1-2 seriate, rarely 3 seriate; alternate or opposite, contiguous and flattened. In uniseriate condition pits have the coefficient — 1-0·88 and in multiseriate condition coefficient is 1-0·7. Pit pore central and circular or broadly oval. Pits in cross-field 1-6 (bordered ?).

Holotype — 32892/496, Birbal Sahni Institute of Palaeobotany, Lucknow.

Horizon — Raniganj stage.

Age — Upper Permian.

Locality — West Jamuria Colliery, Raniganj Coalfield, Bengal.

Comparison — The main feature of the genus *Trigonomyelon* is lobed pith with isolated or grouped secretory cells and a sheath of thin-walled, rectangular parenchymatous cells intervening between the pith and the primary xylem. In this respect it resembles to some extent *Dadoxylon indicum* Hold. known from the Barakar stage of the Lower Gondwanas of India. In both the cases secretory elements are present in the pith and there is an intervening tissue between the primary xylem and the pith. However, the nature of this layer in two cases is different. In *Dadoxylon indicum* the cells of this layer resemble smaller cells of the pith in cross-section though they are easily differentiated from them in the longitudinal section by their characteristically reticulate, tracheidal markings. In *Trigonomyelon* on the other hand these cells are almost rectangular in cross-section while in the longitudinal section they do not show any sign of reticulate tracheidal markings. In *Dadoxylon indicum* the primary elements have been described as endarch though the figures of these structures (HOLDEN, 1917; PL. 19, FIGS. 13, 14) suggest some sort of a mesarch structure and as such this wood needs reinvestigation (KRÄUSEL *et al.* 1963). Of the two species of *Trigonomyelon*, *T. pedroi* (Zeill.) Walt. has got only three pith bays and *T. kaokense* (Kräus.) only two

as compared to more than five pith bays in *T. raniganjense*. Furthermore the former two species lack the parenchymatous sheath and also the pitting on the walls of the pith cells. *Megaporoxylon* Kräus. resembles the present wood in the presence of secretory cells in the pith but in the former the pith is not lobed and the parenchymatous sheath is absent. The other wood from the same horizon as *T. raniganjense*, is *Dadoxylon zalesskyi* Sahni. In the latter wood the pith is parenchymatous with isolated or grouped sclerenchymatous cells and without the pith lobes and the intervening parenchymatous sheath. *Barakaroxylon* Surange & Maithy and *Indoxylon* Surange & Maithy differ from *T. raniganjense* in having secretory canals in the pith besides the secretory cells while *T. ranigagnjense* has got only secretory cells.

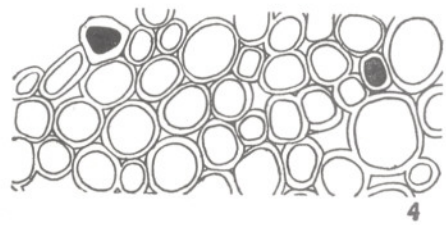
Damudoxylon[2] gen. nov.

Damudoxylon waltonii sp. nov.

It is a decorticated piece of fossil wood showing a partially preserved pith, a zone of primary xylem and the secondary wood. The colour of the fossil is dark brown. The growth rings are not visible to the naked eye but are, however, distinct under the microscope (PL. 2, FIG. 11). The autumn wood zone is 1-3 cells wide and consists of thick-walled tracheids, 15-24 μ radially. The spring wood zone is 14-110 cells wide and consists of oblongly-polygonal tracheids, radially 39-63 μ, with a broadly oval to circular lumen. Tangentially the tracheids measure 24-47 μ. The thickness of the double walls between the tracheids is 13-15 μ.

Pith — The pith is oval (PL. 2, FIG. 10), transversely measuring 10 × 2·5 mm. but from the crushing in the centre of the pith it is evident that originally the pith was circular. The pith cells are isodiametrical or broadly oval and thick-walled (PL. 2, FIG. 12). The cells of the pith vary very much in size but there is no zonation and no evidence of a transfusion tissue like that found in *Dadoxylon indicum* Hold. The size of the pith cells varies from 33 μ × 30 μ to 97 μ × 81 μ. The thickness of the wall of the pith cells is about 6 μ. Longitudinally the pith cells are almost rectangular, higher than broad and generally placed end to end in vertical series (PL. 2, FIG. 13) and measure 45-99 μ in height.

Scattered amongst the pith cells are isolated thick-walled polygonal cells filled with dark contents (PL. 2, FIG. 12; TEXT-FIG. 4). These cells probably form some sort of secretory tissue. They are comparatively smaller in size than the parenchymatous cells of the pith and measure 30 μ × 48 μ to 54 μ × 57 μ. Longitudinally usually two secretory cells occur at a place one above the other. These cells are much higher than broad (PL. 2, FIG. 13) measuring 75-133 μ.



TEXT-FIG. 4 — *Damudoxylon waltonii* gen. et sp. nov. Pith and secretory cells in transverse section. × 100.

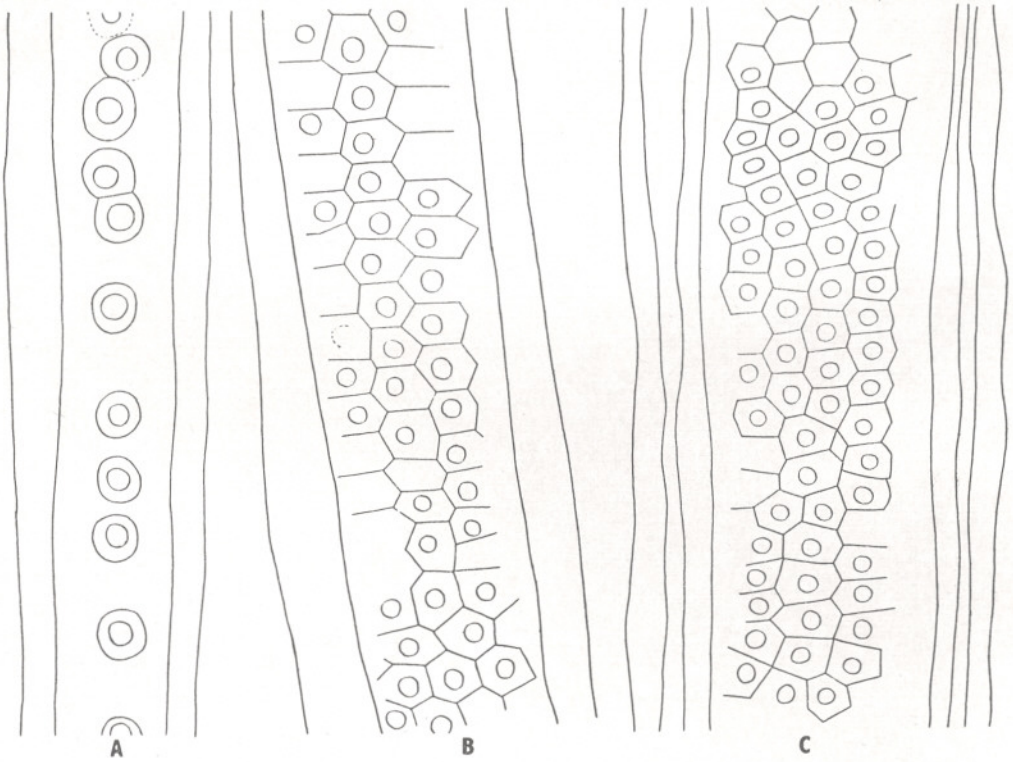
Primary Xylem — Surrounding the pith is a 7-9 cells wide zone of endarch primary xylem. In transverse section there is very little difference between primary xylem and secondary xylem, all the elements being arranged radially. In radial longitudinal section the elements of the primary xylem near the pith show extended spirals while the subsequent ones show close spirals to scalariform thickening with a gradual transformation into reticulate and bordered pitting (PL. 2, FIG. 14).

Xylem Rays — The xylem rays are numerous, homogeneous, uniseriate, rarely biseriate and 1-14 cells deep with an average depth of 2-3 cells (PL. 3, FIG. 15). The ray cells are barrel-shaped, higher than broad and measure 24-31·5 μ × 18-24 μ. The size of the xylem rays is quite interesting. Out of a total of 500 rays counted from six different sections 50 per cent are 2 cells deep, 27 per cent are 1 cell deep,

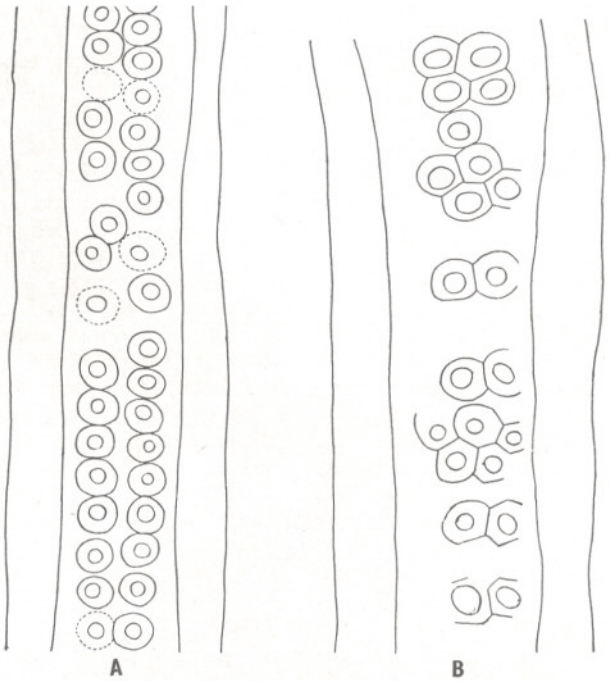
2. In the review of fossil woods from the Lower Gondwana horizons (Kräusel *et al.*, 1963) this wood was referred as *Gondwanoxylon*; but as recently the name *Gondwanoxylon* has been used for an angiospermous wood from the Tertiary of India (Saksena, 1963), the present wood is therefore renamed as *Damudoxylon*.

and 13 per cent are 3 cells deep while only 10 per cent are more than 3 cells deep. Less than 3 per cent of the rays are biseriate. It was further observed that the maximum depth of the rays near the pith was 8 cells while at a distance of half an inch from the periphery of the pith it becomes 11 cells. Between a distance of 1 to 1½ inches from the pith it is 14 cells. This is interesting as it shows that the depth of the xylem rays varies from one part of the stem to the other and as such not much reliance can be put upon this character for taxonomic purposes. However, average ray depth in this specimen was throughout 2-3 cells. The tangential walls of the tracheids are smooth.

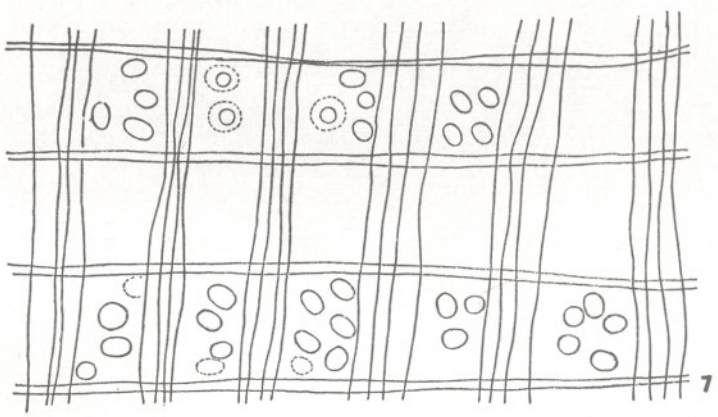
Pitting — The radial walls of the tracheids have 1-3 seriate, sometimes 4-seriate (PL. 3, FIGS. 16-18; TEXT-FIG. 5B-C) bordered pits. The pits are alternate; contiguous, rarely separate; and hexagonal but rarely circular or flattened. When in two files, the pits are sometimes opposite, separate and circular with a central and circular or broadly oval pore (TEXT-FIG. 6A). In some tracheids the pits show a tendency towards grouping (PL. 3, FIG. 18; TEXT-FIG. 6B). These pit groups are occasionally of stellate shape and consist of 2-7 pits. However, when viewed in oil immersion it was found that in most cases the pit groups are actually results of partial disintegration of pits and pit borders in between, though in some tracheids real grouping might be present. When uniseriate (TEXT-FIG. 5A) the pits are wide apart and more circular. In uniseriate condition the pits measure 10·5 μ × 10·5 μ and hence the coefficient (e=d/D) is 1. In multiseriate condition the pits measure 12 μ × 9 μ, 12 μ × 12 μ, 10·5 μ × 10·5 μ, 10·5 μ × 9 μ, etc. and hence the coefficient varies from 1 to 0.75. The pit pore measures 3 μ. Pits in the cross-field number 1-9 and are bordered with a broadly oval pore (PL. 3, FIG. 19; TEXT-FIG. 7). Due to bad preservation the border is not easily visible and at many places



TEXT-FIG. 5A-C — *Damudoxylon waltonii* gen. et sp. nov. Radial longitudinal sections through the secondary xylem showing: A, uniseriate pits, B, triseriate pits and C, tetraseriate pits. × 500.



TEXT-FIG. 6A, B — *Damudoxylon waltonii* gen. et sp. nov. Radial longitudinal sections through the secondary xylem showing: A, biseriate separate and circular pits and B, pit groups. × 500.



TEXT-FIG. 7 — *Damudoxylon waltonii* gen. et sp. nov. Radial longitudinal section through the secondary xylem showing pits in the cross-field. × 500.

the pits apparently look simple. The pit pore measures 3-6 μ.

DIAGNOSES

Damudoxylon gen. nov.

Pith heterogeneous, about 10 mm. in diameter with scattered secretory cells. Primary xylem endarch. Tracheidal pitting multiseriate with many small pits in the cross-field.

Genotype — Damudoxylon waltonii sp. nov.

Damudoxylon waltonii sp. nov.

Pith small, 1 cm. or less in diameter, parenchymatous; pith cells isodiametrical or broadly oval and thick-walled, vertically

rectangular, higher than broad and placed end to end in vertical series. Distributed in pith are secretory cells of comparatively smaller dimensions. Primary wood zone 7-9 cells wide, endarch with spiral, scalariform and recticulate elements.

Secondary wood with growth rings; autumn wood zone 1-3 cells wide; spring wood zone 14-110 cells wide; radial diameter of autumn wood tracheids 15-24 μ, of oblong-polygonal spring wood tracheids 39-63 μ; tangential diameter of tracheids 24-47 μ; thickness of double walls between tracheids 13-15 μ.

Xylem rays numerous, homogeneous, uniseriate, rarely biseriate (less than 3 per cent), 1-14 cells deep, average depth 2-3 cells; ray cells barrel-shaped and higher than broad. Tangential walls of tracheids smooth.

Radial pits bordered, 1-3 seriate, occasionally 4-seriate; alternate; contiguous rarely separate; hexagonal, rarely circular or flattened; sometimes show a tendency towards grouping, pit groups often stellate in shape. Uniseriate pits measure 10·5 μ × 10·5 μ (coefficient e=d/D, 1), multiseriate pits 12 μ × 9 μ to 10·5 μ × 9 μ (coefficient 1-0·75). Pits in cross-field 1-9 (bordered ?).

Holotype — 32895/496, Birbal Sahni Institute of Palaeobotany Lucknow.

Horizon — Raniganj stage.

Age — Upper Permian.

Locality — West Jamuria colliery, Raniganj coalfield, Bengal.

Comparison — Fossil woods from the Gondwanaland with secretory cells in the pith belong to the following genera: *Trigonomyelon* Walt., (syn. *Lobatoxylon* Kräus.), *Megaporoxylon* Kräus. and *Dadoxylon* Endl. *Trigonomyelon* differs from *Damudoxylon* in having bays in the pith which in the latter case was probably almost circular. *Megaporoxylon* resembles the present wood in having secretory cells in the pith. In *Megaporoxylon* the secretory cells are found in groups while in *Damudoxylon* they occur isolated. The main difference between the two woods, however, is that in the former genus pits in the cross-field are simple and usually number only one or two (rarely three) while in the latter genus they are bordered, smaller and many. In *Dadoxylon indicum* Hold. the secretory cells are found in the outer portion of the pith while in *Damudoxylon waltonii* they occur all over the pith. Then the transfusion tissue as found in *Dadoxylon indicum* is missing in *Damudoxylon waltonii*.

Present wood resembles in most of the anatomical features various woods ascribed to the species *Dadoxylon nicolii* Seward. It is well-known that so many woods, some times with widely different characters, have been placed in *Dadoxylon nicolii* Seward. Primary structures are little known in them. Due to this state of affairs with woods of *D. nicolii* type Walton (1925) had suggested " when any wood with well preserved primary structure and possessing the *Dadoxylon arberi* — type of secondary wood is found, it must be given a distinct name." Later Kräusel (1928) also supported this view. An important difference of the present wood from *D. nicolii* type of wood is that in the former bordered pits are found in the cross-field though their border is not always distinct while in the latter case so far only simple pits have been reported in the cross-field.

Of the other woods from India, *Barakaroxylon* Surange & Maithy and *Indoxylon* Surange & Maithy possess well preserved secretory canals in the pith while the present specimen has a parenchymatous pith with secretory cells only. *Dadoxylon zalesskyi* Sahni differs from the present wood in having sclerotic cells in the pith.

Megaporoxylon Kräusel 1956

Kräusel (1956) established the genus *Megaporoxylon* for a fossil wood with secretory cells in the pith and one or two large pits in the cross-field. Recently a piece of fossil wood was collected from West Jamuria colliery, Raniganj coalfield, which shows the above characters and hence has been described as a new species of the genus.

Megaporoxylon kraeuselii sp. nov.

The specimen is a decorticated piece of a fossil stem, with partially preserved pith and primary xylem surrounded by a crushed secondary wood. Due to bad state of preservation the growth zones are not clearly marked out. However, at certain places where the preservation is satisfactory the growth zones could be seen under the microscope (Pl. 4, Fig. 21). The autumn wood zone is 2-4 cells wide. The width of the spring wood zone could not be as-

certained due to distortion. The tracheids of the spring wood zone are oblongly-polygonal, measuring 39-54 μ radially and with a broadly-oval lumen. The tracheids of the autumn wood zone are somewhat rectangular with an oval lumen and radially measure 15-18 μ. Longitudinally the tracheids show truncated end walls (Pl. 3, Fig. 23). Tangentially the tracheids measure 30-50 μ. The thickness of the double walls between the tracheids is 13-15 μ.

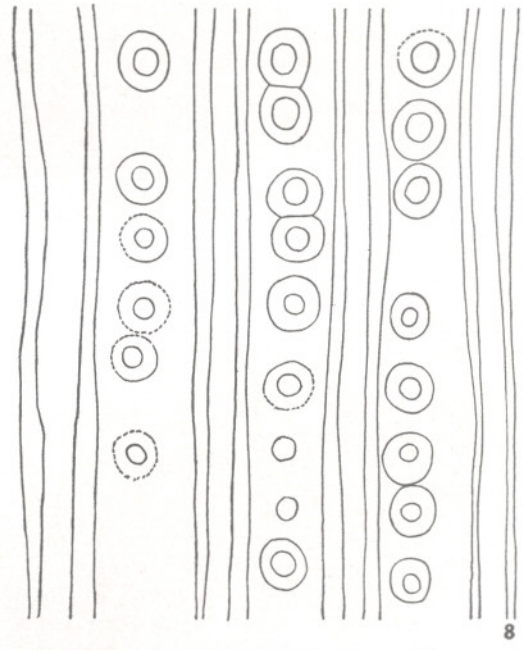
Pith — The pith is oval (Pl. 3, Fig. 20) in shape measuring 9 × 4·5 mm. and is badly crushed. At places where the preservation is somewhat satisfactory the pith cells are broadly oval to isodiametrical in shape and thick-walled. The cells of the pith vary very much in size but there is no zonation and no trace of a transfusion tissue as found in *Dadoxylon indicum* Hold. The size of the pith cells varies from 48 μ × 57 μ to 115 μ × 153 μ. Longitudinally the pith cells are almost rectangular, broader than high with oblique end walls placed end to end in vertical series and measure 54-75 μ.

Scattered amongst the pith cells are isolated or sometimes grouped small cells filled with dark contents (Pl. 4, Fig. 25). These cells were probably secretory in function. They are comparatively smaller in size than the normal pith cells and measure 47 μ × 47 μ to 52 μ × 52 μ. Longitudinally many secretory cells occur one above other running for from 500-800 μ or even more. These cells are much higher than broad and measure 150-200 μ.

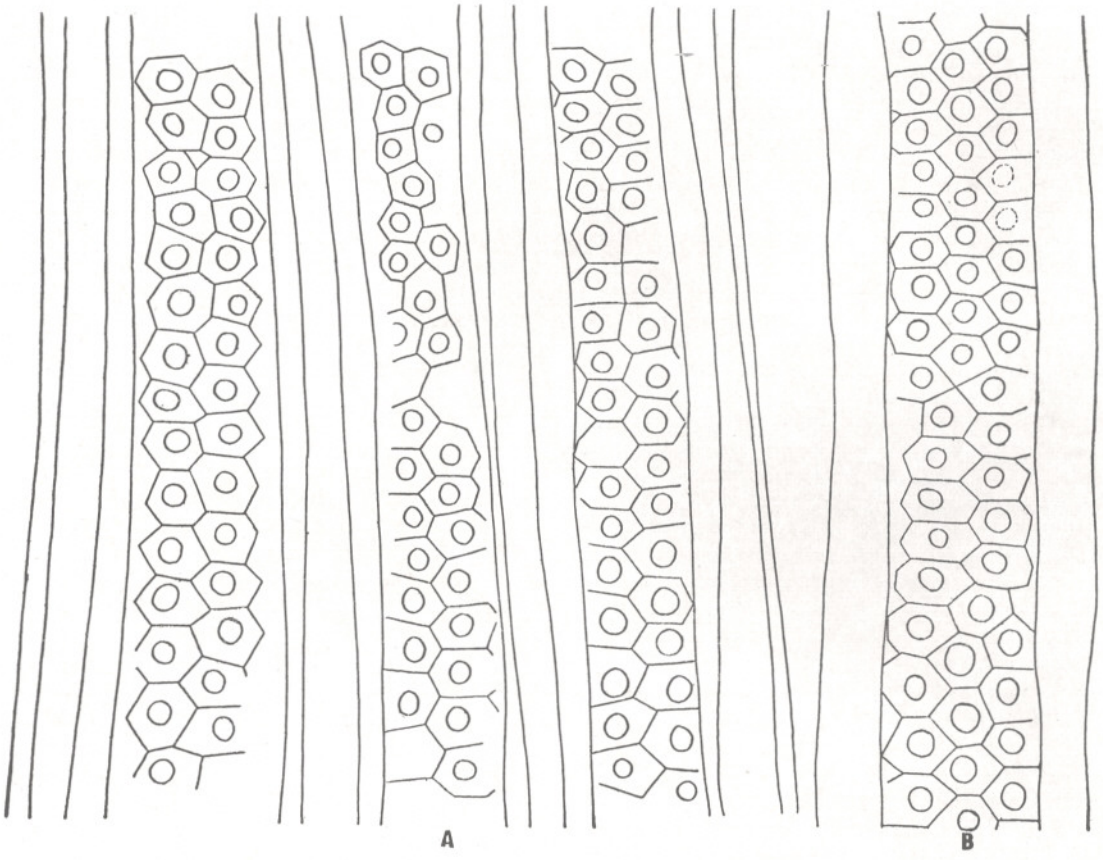
Primary Xylem — In a transverse section it is difficult to make out the primary xylem firstly due to bad preservation and secondly due to the fact that all the elements of primary and secondary xylem are disposed radially. The primary xylem which is endarch is many cells wide and consists of spiral, scalariform and reticulate elements (Pl. 4, Fig. 22).

Xylem Rays — The xylem rays are numerous, uniseriate, homogeneous and 1-23 cells deep with an average depth of 5-6 cells (Pl. 4, Fig. 24). The ray cells are barrel-shaped, higher than broad and measure 21-27 μ × 13-19 μ (average dimensions 24 μ × 16 μ). Radially the ray cells are much longer than high, each cell spanning 2-5 tracheids. Sometimes the cells are chambered by wavy walls in the plane of tracheid walls. Tangential walls of the tracheids are smooth.

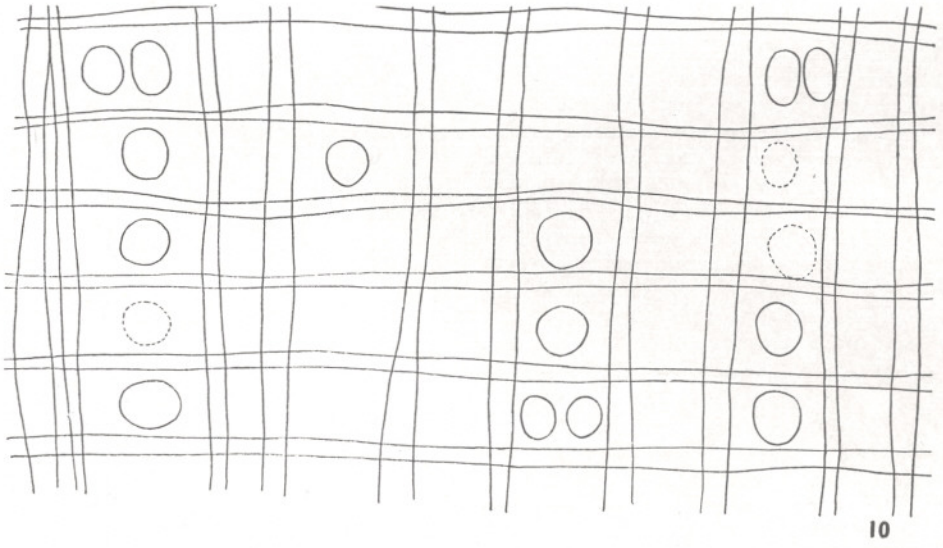
Pitting — The radial walls of the tracheids have 1-2 (Pl. 4, Figs. 26, 27), often 3 seriate pits (Pl. 3, Fig. 28; Text-fig. 9B) which are bordered, alternate or opposite, contiguous or separate, polygonal and very often circular or flattened. When uniseriate (Text-fig. 8) the pits are wide apart and more circular, measuring 15 μ × 15 μ to 15 μ × 16·5 μ, thus with a coefficient, 1-0·91. When in two files the pits are sometimes separate, opposite and circular. The pits in the biseriate condition (Text-fig. 9A) measuring 12 μ × 12 μ, 12 μ × 13·5 μ, 13·5 μ × 13·5 μ, 12 μ × 15 μ, etc. and hence the coefficient is 1-0·8. The pit pore is central and circular or broadly oval and sometimes very large measuring 6-7·5 μ. The number of the pits in the cross-field is very small, usually one or two big, apparently simple pits occurring in each field (Pl. 4, Fig. 29; Text-fig. 10). Very rarely, however, three pits may be found in the field. The cross-field pits are oval in shape. When only one pit is present it measures 12 μ × 15 μ to 10·5 μ × 16·5 μ. When two pits are present they are smaller in



Text-fig. 8 — *Megaporoxylon kraeuselii* sp. nov. Radial longitudinal section through the secondary xylem showing uniseriate separate and circular pits. × 500.



TEXT-FIG. 9A, B — *Megaporoxylon kraeuselii* sp. nov. Radial longitudinal section through the secondary xylem showing: A, biseriate pits and B, triseriate pits. × 500.



TEXT-FIG. 10 — *Megaporoxylon kraeuselii* sp. nov. Radial longitudinal section through the secondary xylem showing pits in the cross-field. × 500.

size measuring 9 μ × 13 μ to 9 μ × 10·5 μ. In the case of three field pits they measure 9 μ × 9 μ.

DIAGNOSIS

Megaporoxylon kraeuselii sp. nov.

Pith solid, parenchymatous; cells broadly oval to isodiametrical and thick-walled; vertically cells broader than high with oblique end walls; small thick-walled secretory cells filled with dark contents distributed all over parenchymatous pith, longitudinally secretory cells much higher than broad. Primary xylem endarch, 6-8 cells wide, elements spiral, scalariform and reticulate.

Secondary wood zone with distinguishable growth zones; autumn wood zone 2-4 cells wide, cells rectangular 15-18 μ radially; spring wood tracheids oblongly-polygonal, 39-54 μ radially; tangentially tracheids 30-50 μ; thickness of double walls between tracheids 13-15 μ.

Xylem rays numerous, homogeneous, uniseriate, 1-23 cells deep, average depth 5-6 cells; ray cells 21-27 μ high (average 24 μ) and 13-19 μ broad (average 16 μ). Tangential walls of tracheids smooth.

Radial pits bordered, 1-3 seriate, alternate or opposite, contiguous or separate, circular, flattened or hexagonal; uniseriate pits measure 15 μ × 15 μ, 16·5 μ × 16·5 μ, etc. (coefficient 1-0·91) and multiseriate pits measure 10·5-12 μ × 12-15 μ, etc. (coefficient, 1-0·88); pit pore central and circular or broadly oval. Pits in cross-field usually one or two large, very rarely three, apparently simple measuring 10·5-12 μ × 15-16·5 μ (when one), 9-10·5 μ × 13·5-13·5 μ (when two) and 9 μ × 9 μ (when three).

Holotype — 32896/496, Birbal Sahni Institute of Palaeobotany, Lucknow.

Horizon — Raniganj stage.

Age — Upper Permian.

Locality — West Jamuria colliery, Raniganj coalfield, Bengal.

Comparison — In the possession of secretory cells in the pith this species resembles the species of *Trigonomyelon* Walt., *Megaporoxylon* Kräus., *Damudoxylon* Maheshw. and *Dadoxylon* Endl. (*Trigonomyelon* is characterized by the presence of a lobed pith which in the present case is not so. Then the number of pits in the cross-field is more in *Trigonomyelon* as compared to *Megaporoxylon kraeuselii*. In the case of *Dadoxylon indicum* Hold. a transfusion tissue is present at the periphery of the pith while there is no trace of such tissue in the present specimen.

The present wood agrees in most of the details with the diagnosis of *Megaporoxylon* Kräus., e.g., in possession of the secretory cells in the pith and the number of pits in the field. However, for *Megaporoxylon* Kräusel (1956b, p. 423) says "..... auf dem Kreuzungsfelde je eine grosse, seltener zwei kleinere Eiporen", while in the present specimen there are one to three pits in the cross-field though three pits are very rare. Taking other characters into account the present wood, however, is best placed in the genus *Megaporoxylon*. Of the three known species of *Megaporoxylon*, *M. kaokense* (KRÄUSEL, 1956b) differs from *M. kraeuselii* in radial pitting as well as pits in the cross-field. In *M. kaokense* the radial pits are uniseriate, round or oval and often higher than broad while in *M. kraeuselii* the radial pits are 1-3 seriate, polygonal or flattened and usually broader than high. Then in the former species there is only one pit in the cross-field while in the latter there may be as many as three pits in the cross-field. In *M. scherzi* Kräusel (1956c) the pith is much larger (up to 3 cm. as compared to 9 mm. in *M. kraeuselii*) and the tracheidal pits are uniseriate as compared to multiseriate radial pitting of the tracheids in *M. kraeuselii*. These two woods resemble, however, in the nature and depth of xylem rays. *M. zellei* Kräusel resembles in radial tracheidal pitting but like other species of *Megaporoxylon* differs in the cross-field pitting. In *M. zellei* the long axis of the cross-field pits is usually oblique while in *M. kraeuselii* it is always vertical.

In the cross-field pits *M. kraeuselii* resembles *Phyllocladoxylon* Goth. but in the latter the long axis of the cross-field pits is always horizontal while in the former the long axis is always vertical. Similarly in *Phyllocladopitys capensis* Kräus. there is usually only one big oval pore in the cross-field but in this wood prominent centripetal wood is present in the pith while there is no such tissue in *M. kraeuselii*. Other known species of fossil wood from the Indian Lower Gondwana strata also differ from the present wood. *Barakaroxylon* Surange & Maithy and *Indoxylon* Surange & Maithy

have got secretory canals in the pith. *Dadoxylon zalesskyi* Sahni is characterized by the presence of sclerotic cells in the pith while in the case of *M. kraeuselii* the pith contains secretory cells. Pits in the cross-field in both cases are simple though in the former wood they are larger in number as compared to the latter. *Dadoxylon bengalense* Hold., *Dadoxylon ningahense* Maheshw., *Dadoxylon jamuriense* Maheshw., *Dadoxylon parbeliense* Rao and *Dadoxylon sahnii* Singh also differ from *M. kraeuselii*.

Kaokoxylon Kräusel 1956

Kaokoxylon zalesskyi (Sahni) nov. comb.

Sahni (1932) described a petrified wood from the Kumarpur Sandstone as *Dadoxylon zalesskyi*. The pith and primary xylem were fairly well preserved in this specimen. While dealing with the petrified woods from the Raniganj Coal-field I happened to examine the type sections of *Dadoxylon zalesskyi* for comparison with my specimens. This species has got isolated or grouped sclerotic cells distributed all over the parenchymatous pith which is 7-8 mm. wide. In the thick walls of these sclerotic cells concentric layers of growth as well as pit canals are sometimes clearly seen. The xylem is centrifugal and the tracheids have more or less araucarioid pitting on their radial walls. The structure of *Dadoxylon zalesskyi* strikingly resembles that of *Kaokoxylon* Kräus. which has been defined as (Kräusel, 1956b, p. 424) "Markweite gering, 10 mm. wohl nicht überschreitend, im Mark Stränge oder Nester von Sklerenchymzellen. Holzkörper zentrifugal. Tracheiden-Tüpfel ± araucarioid." Hence *Dadoxylon zalesskyi* should now be transferred to the genus *Kaokoxylon*.

For further examination some more sections were prepared from the type specimen as well as two other specimens, provisionally referred to this species, placed in the museum of Birbal Sahni Institute of Palaeobotany, Lucknow. In the tangential section it was noted that the xylem rays are deeper than reported and often exceed 18 cells in depth at the periphery of the specimen (about 5″ away from the pith). On examination of the type specimen it appears that the type slides were prepared from near the pith. Hence it is likely that the depth of xylem rays varies from pith to periphery. A similar situation has already been reported for *Damudoxylon waltonii* where, too, the xylem ray depth was found to increase from near the pith towards the periphery. The maximum depth of the xylem rays in the new sections is 18 cells while the average depth comes to 6 cells. The ray cells are higher than broad and measure 21-33 μ × 12-15 μ.

The pits on the radial walls of the tracheids are bordered, alternate, separate or contiguous and flattened or circular. They measure 10 μ × 10 μ, 10 μ × 9 μ, 10·5 μ × 8 μ, 7·5 μ × 7·5 μ, etc. and hence the coefficient (e=d/D) varies from 1 to 0·76. The pit pore is oval to circular with a diameter of 4-5 μ. The pits in the cross-field are simple and usually oval. They measure 9 μ × 6 μ, 7·5 μ × 7·5 μ, 7·5 μ × 6 μ and 6 μ × 6 μ, etc.

EMENDED DIAGNOSIS

Kaokoxylon zalesskyi (Sahni) comb. nov.

Pith cylindrical, solid, parenchymatous, groups of sclerotic cells or some times isolated sclerotic cells lie scattered among the parenchymatous cells of pith; longitudinally pith cells arranged in vertical series; walls of sclerotic cells clearly show concentric rings of growth as well as pit canals.

Leaf trace at its origin single wedge-shaped endarch bundle.

Primary wood zone up to 12 cells wide, metaxylem elements rather wider in radial than in tangential direction; protoxylem endarch.

Secondary wood zone with clearly marked growth zones; tracheids squarish and regularly arranged. Xylem rays homogeneous, uniseriate some times biseriate, 1-18 cells deep, average depth 6 cells; ray cells 21-33 μ high, 12-15 μ broad. Tangential walls of tracheids smooth.

Pits on the radial walls of tracheids bordered, alternate, separate or contiguous and flattened or circular, pits measure 7·5 μ × 7·5 μ to 10 μ × 10 μ (coefficient 1-0·76); pit pore oval to circular with a diameter of 4-5 μ. Pits in cross-field 1-4, simple and oval with average diameter 6 μ.

Discussion — Two earliest described woods with nests or bundles of sclerotic cells in the pith are *Dadoxylon scleroticum*

(GOTHAN, 1908) and *Dadoxylon sclerosum* (WALTON, 1925). *D. scleroticum* was transferred by Kräusel (1928) to the genus *Medullopitys* as it possessed a large pith, long strands of sclerenchymatous cells and diploxylic leaf traces. In 1956, Kräusel described from South Africa one wood which was much similar to *D. sclerosum*. He thought that the anatomical structures of these two woods were different from that of *Dadoxylon* as well as *Medullopitys* and hence he instituted a new genus *Kaokoxylon*. To cite him (KRÄUSEL, 1956b, p. 424) "Beide Fossilien stehen sich also recht nahe. Es wurde bereits botont, dass man solche Hölzer mit erthaltenem Mark nicht einfach als 'Dadoxylon' bezeichnen sollte, beiten seid doch Merkmale, wie sie auch sonst für die Augstellung einer neuen Gattung also bestimmend angesehen werden." As such *Dadoxylon zalesskyi* should also be separated and grouped with *Kaokoxylon*. Of the three known species of *Kaokoxylon*, *K. sclerosum* (Walt.) Kräus. resembles *K. zalesskyi* (Sahni) in pith structure and the number of pits in the cross field (1-4). The radial pitting in the two cases, however, differ. In *K. sclerosum* the radial pits are only 1-2 seriate while in *K. zalesskyi* they are 1-5 seriate. The size of the radial pits in *K. sclerosum* is larger (13-17 μ) as compared to that in *K. zalesskyi* (7·5-10 μ × 5-10 μ) though the coefficient (e=d/D) in both cases is the same, i.e. 1-0·76. Then in the case of *K. sclerosum* the xylem rays are deeper (1-33 cells) as compared to *K. zalesskyi* (1-18 cells). In the other species *K. reuningi* Kräus. the pith is comparatively smaller (2-6 mm.) than in *K. zalesskyi* (7-8 mm. in branch). In the former species the sclerenchyma groups are only confined to the boundary of the pith while in the latter they are irregularly distributed all over the pith. In *K. reuningi* the radial pits are less crowded (1-2 seriate) as compared to *K. zalesskyi* (1-5 seriate). In the third species, *K. durum* Kräus., too, the pith is smaller (2-3 mm.) and many angled. The sclerenchyma nests are lenticular in shape while in *K. zalesskyi* they are irregular in shape. *Dadoxylon farleyense* Walk. (WALKOM, 1928) (which probably also belongs to *Kaokoxylon*) also possesses groups of sclerotic cells in the pith. These nests, however, are more or less spherical as compared to irregular ones in *K. zalesskyi*. Furthermore in the former species the adjacent sclerenchyma nests are sometimes interconnected either transversely or vertically while that is not the case in the latter species. The secondary woods of these two species are also different. The radial pits in *D. farleyense* are 1-3 seriate and circular while in *K. zalesskyi* the pits are 1-5 seriate and flattened. The tangential walls of the tracheids in the former species are pitted while those in the latter species are smooth. Thus *Kaokoxylon zalesskyi* clearly maintains a separate entity.

ACKNOWLEDGEMENT

I am grateful to Dr. K. R. Surange for his inspiring guidance and helpful suggestions during the course of this study. To Prof. J. Walton and the late Prof. Dr. R. Kräusel I am indebted for kind advice. Thanks are also due to the managements of Nagkothi, Lodna and West Jamuria collieries for permitting me to collect fossils on their property.

REFERENCES

BRADSHAW, E. J. & SAHNI, B. (1925). A fossil tree in the Lower Gondwanas near Asansol. *Rec. geol. Surv. India.* **58**: 75-79.

CHITALEY, S. D. (1950). *Dadoxylon chandaensis* sp. nov. from the the district of Chanda, C. P. *J. Indian bot. Soc.* **28**: 172-180.

FOX, C. S. (1934). The Lower Gondwana Coalfields of India. *Mem. geol. Surv. India.* **59**: 78-85.

GEE, E. R. (1932). The geology and coal resources of the Raniganj Coalfield. *Ibid.* **61**: 1-50.

HALLE, T. G. (1911). On the geological structure and history of the Falkland islands. *Bull. geol. Instn. Univ. Upsala.* **11**: 1-117.

HOLDEN, R. (1917). On the anatomy of two Palaeozoic stems from India. *Ann. Bot. Lond.* **31**: 315-326.

KRÄUSEL, R. (1956a). Lianen aus den Karru-Schichten Süd-Afrika. *Senck. Leth.* **37**: 1-16.

Idem (1956b). Der "Versteinerte Wald" in Kaokoveld, Südwest-Afrika. *Ibid.* **37**: 411-445.

Idem (1956c). Hölzer aus dem südlichen Gebeit der Karru-Schichten Südwest-Afrikas. *Ibid.* **37**: 447-453.

Idem (1962). Antarctic Fossil Wood. In Trans-Antarctic Expedition (1955-1958). Scientific Reports No. 9. Appendix. *London.*

KRÄUSEL, R. & DOLIANITI, E. (1958). Gymnospermen hölzer aus dem Paläozoikum Brasiliens. *Palaeontographica.* **104B**: 115-137.

KRÄUSEL, R., MAITHY, P. K., & MAHESHWARI, H. K. (1963). Gymonospermous woods with primary structures from Gondwana rocks — A review. *Palaeobotanist* **10**: 97-107 (1961).

KRÄUSEL, R. & RANGE, P. (1928). Beiträge zur kenntnis der Karru formation Deutsch-Südwest-Afrika. *Beit. geol. Erforsch. dtsch. SchGeb.* **20**: 1-54.

MAHESHWARI, H. K. (1964). Studies in the Glossopteris flora of India — 16. *Dadoxylon jamudhiense*, a new species of fossil wood from the Raniganj stage of Jharia Coalfield, Bihar. *Palaeobotanist.* **12**: 267-269 (1963).

Idem (1965). Studies in the Glossopteris flora of India — 24. On two new species of fossil wood from the Raniganj stage of Raniganj coalfield. *Palaeobotanist.* **13**: 148-152 (1964).

MAITHY, P. K. (1965). Studies in the Glossopteris flora of India — 19. Two new species of *Dadoxylon* from the Lower Gondwanas of India. *Palaeobotanist.* **13**: 89-93.

MEHTA, K. R. (1950). *Spiroxylon indicum* sp. nov. A taxinean wood from the Lower Gondwanas of India. *Ibid.* **1**: 330-334.

NARSIMHAN, T. (1954). On a fossil wood (*Dadoxylon* ?) from Lower Gondwana formations of Kurasia Colliery, Chirimiri, Madhya Pradesh. *Proc. 41st Indian Sci. Congr.*: 286-287.

RAO, H. S. (1935). On a sphaerosiderite containing a new species of *Dadoxylon* (*D. parbeliense*) from Lower Gondwana Coal-Measures of India. *Rec. geol. Surv. India.* **59**: 174-183.

SAHNI, B. (1932). *Dadoxylon zalesskyi*, a new species of Cordaitean trees from the Lower Gondwanas of India. *Ibid.* **56**: 418-429.

SAKSENA, S. D. (1963). On two fossil dicotyledonous woods from South Rewa, Central India. *Palaeobotanist.* **11**: 30-37 (1962).

SINGH, S. N. (1958). *Dadoxylon sahnii* from the Olive series of Salt Range, West Punjab, Pakistan. *J. palaeont. Soc. India.* **3**: 42-46.

SURANGE, K. R. & MAITHY, P. K. (1962). Studies in the Glossopteris flora of India — 13. *Barakaroxylon*, a new genus of petrified wood from the Lower Gondwanas of India. *Palaeobotanist.* **10**: 108-113 (1961).

Idem (1963). Studies in the Glossopteris flora of India—14. Two new fossil woods from the Lower Gondwanas of India. *Ibid.* **11**: 96-102 (1962).

SURANGE, K. R. & SAH, S. C. D. (1957). Studies in the Glossopteris flora of India — 7. *Dadoxylon jhariense* sp. nov. from the Jharia coalfield, Bihar. *Ibid.* **5**: 100-103 (1956).

SURANGE, K. R. & SAXENA, Y. N. (1959). Studies in the Glossopteris flora of India — 10. *Dadoxylon barakarense* sp. nov. from the Jharia coalfield, India. *Ibid.* **7**: 1-5 (1958).

WALKOM, A. B. (1928). Fossil plants from the Upper Palaeozoic rocks of New South Wales. *Proc. Linn. Soc. N.S.W.* **43**: 255-269.

WALTON, J. (1925). On some South African fossil woods. *Ann. S. Afr. Mus.* **22**: 1-26.

Idem (1956). *Rhexoxylon* and *Dadoxylon* from the Lower Shire region of Nyasaland and Portuguese East Africa. *Colon. geol. Min. Res.* **6**: 159-168.

WHITE, D. (1908). Fossil Flora of the Coal-Measures of Brazil. In I. C. White — Commisao de estudos das minas de carvao de pedra de Brazil. *Rio de J.*

ZEILLER, R. (1896). Note sur la flore fossile des gisements houillers de Rio Grande do sul. *Bull. Soc. gêol. France.* (3), **23**: 601-629.

EXPLANATION OF PLATES

PLATE 1

Trigonomyelon raniganjense sp. nov.

Fig. 1. Transverse section showing pith lobes and a part of the secondary xylem. × 5.

Fig. 2. Transverse section showing autumn and spring wood tracheids. × 90.

Fig. 3. Transverse section showing the parenchymatous sheath (p). × 60.

Fig. 4. Radial longitudinal section through primary xylem. × 90.

Fig. 5. Radial longitudinal section through the pith showing parenchymatous sheath cells (p) and secretory cells (s). × 30.

Fig. 6. Radial longitudinal section showing pits on the walls of pith cells. × 90.

Fig. 7. Radial longitudinal section through the secondary xylem showing biseriate, bordered pits. × 260.

Fig. 8. Radial longitudinal section through the secondary xylem showing triseriate bordered pits. × 260.

PLATE 2

Trigonomyelon raniganjense sp. nov.

Fig. 9. Radial longitudinal section through the secondary xylem showing uniseriate bordered pits. × 260.

Damudoxylon waltonii gen. et sp. nov.

Fig. 10. Transverse section showing pith and xylem. × 5.

Fig. 11. Transverse section showing autumn and spring wood tracheids. × 60.

Fig. 12. Group of secretory cells (s) in the pith. × 90.

Fig. 13. Radial longitudinal section through the pith showing secretory cells (s). × 90.

Fig. 14. Radial longitudinal section through primary xylem. × 175.

PLATE 3

Damudoxylon waltonii gen. et sp. nov.

Fig. 15. Tangential longitudinal section showing xylem rays. × 60.

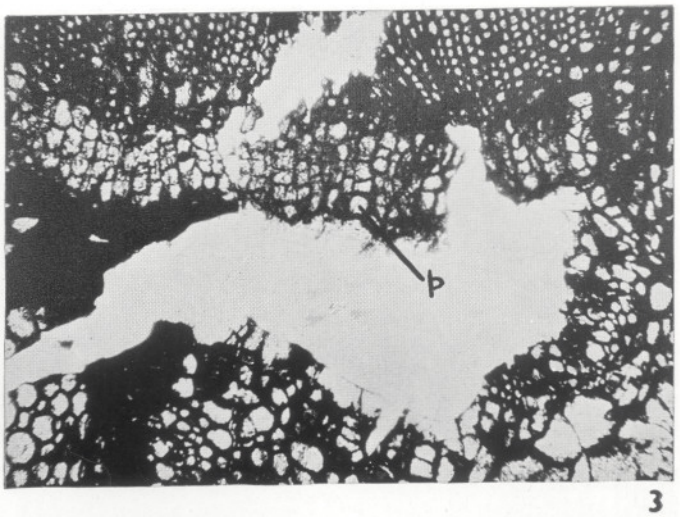
Fig. 16. Radial longitudinal section through secondary xylem showing multiseriate bordered pits. × 275.

Fig. 17. Radial longitudinal section through the secondary xylem showing multiseriate pits. × 275.

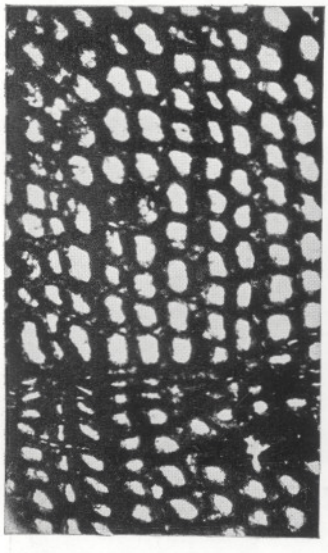
Fig. 18. Radial longitudinal section through the secondary xylem showing (?) pit groups. × 275.

Fig. 19. Radial longitudinal section through the secondary xylem showing pits in the cross-field. × 275.

1



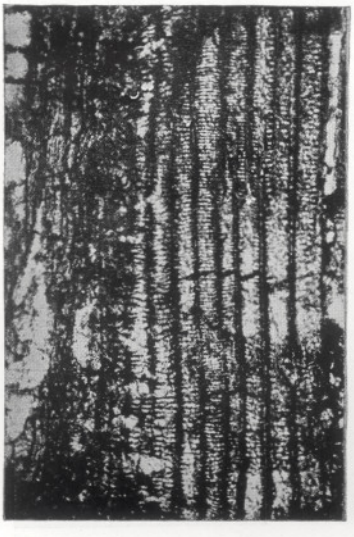
3



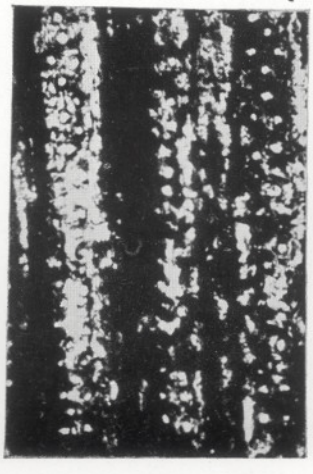
2

4

5

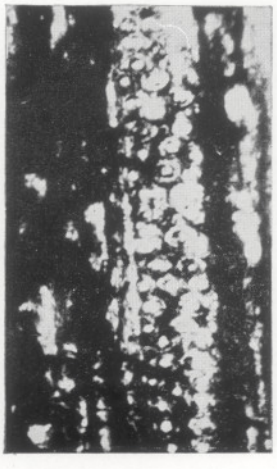


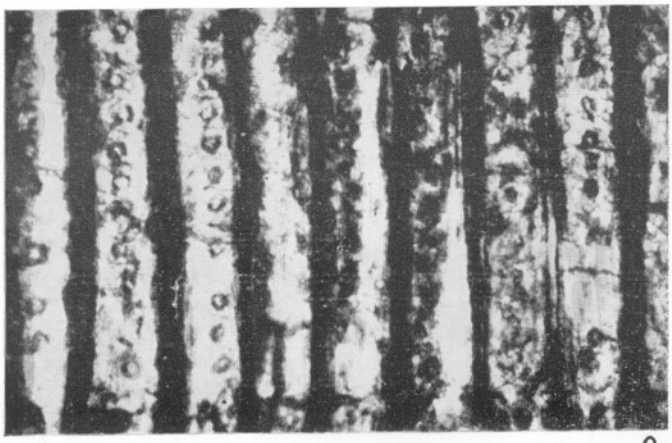
6



7

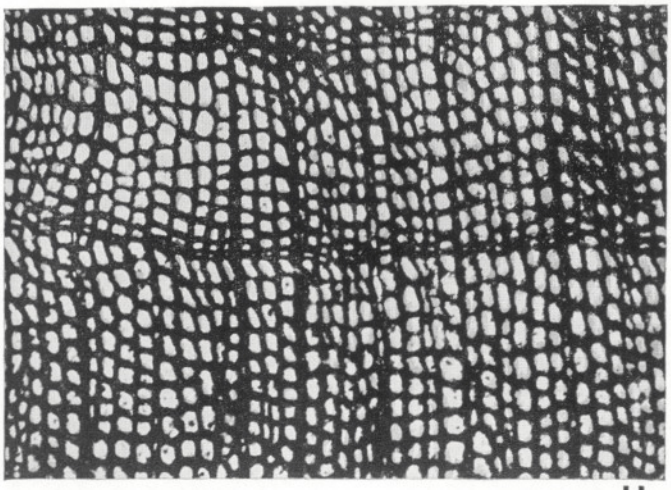
8



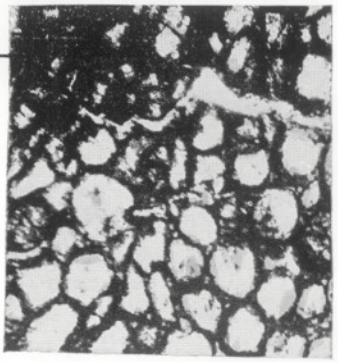


9

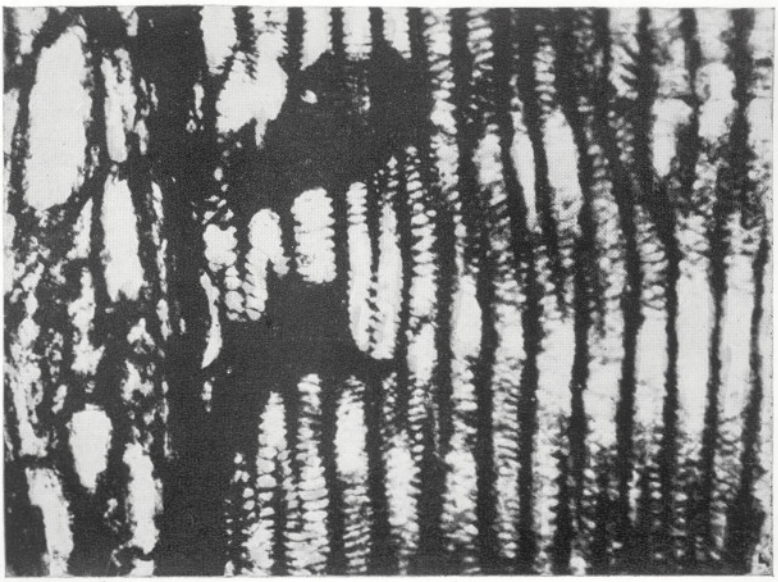
10



11

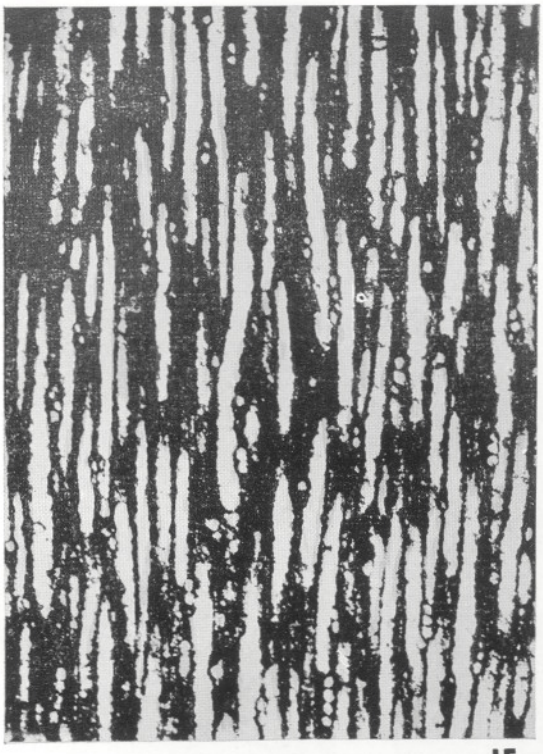


12

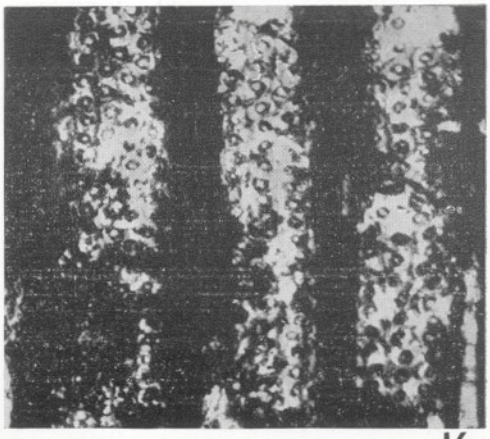


14

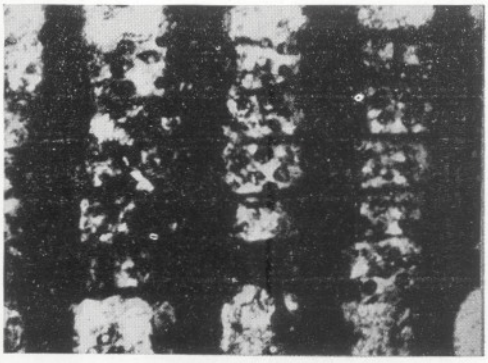
13



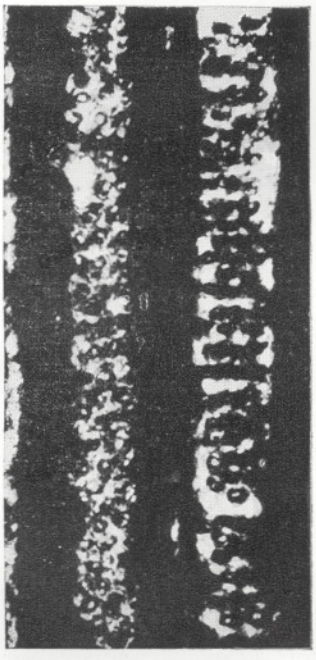
15



16

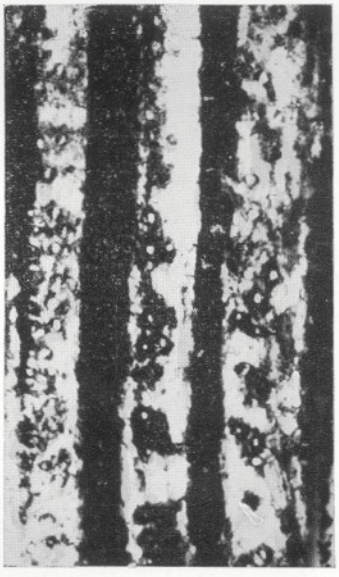


19

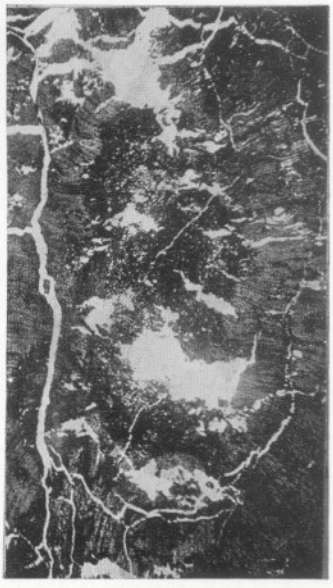


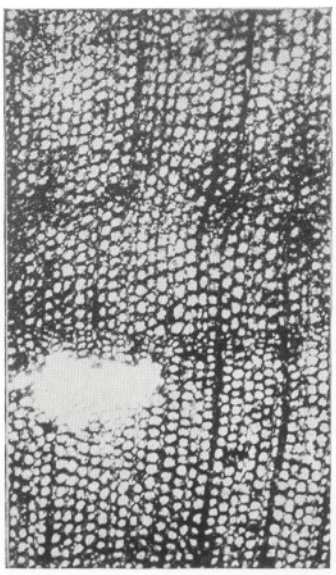
17

18

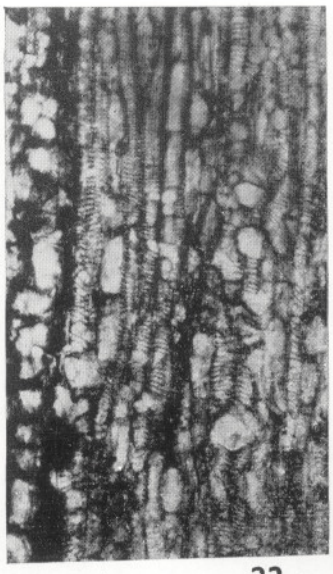


20

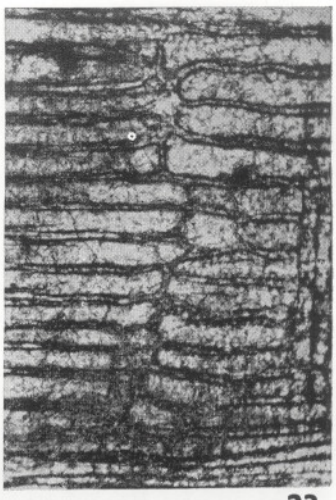




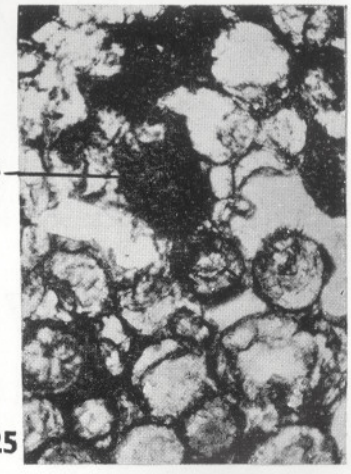
21



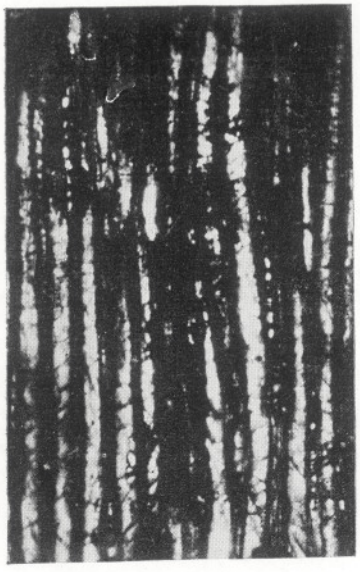
22



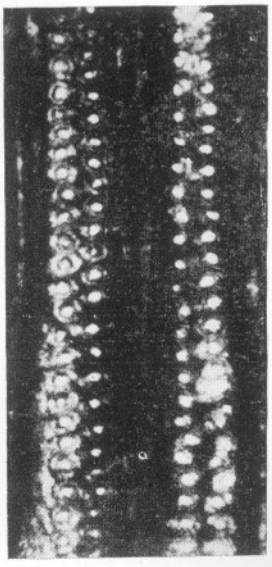
23



25

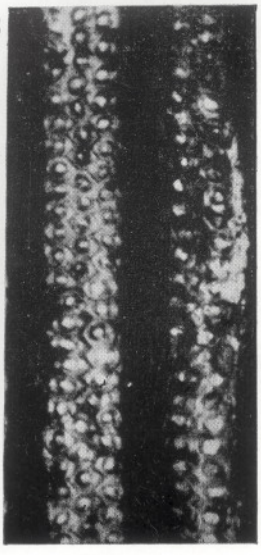


24

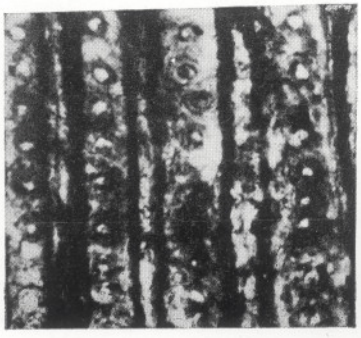


27

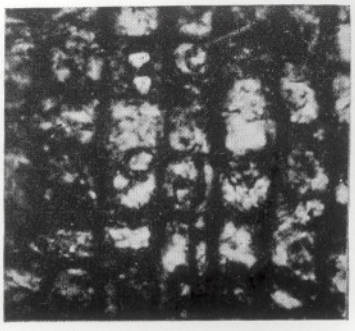
28



26



29



Megaporoxylon kraeuselii sp. nov.

Fig. 20. Transverse section showing pith and a part of secondary xylem. × 5.

PLATE 4

Megaporoxylon kraeuselii sp. nov.

Fig. 21. Transverse section showing autumn and spring wood tracheids. × 30.

Fig. 22. Radial longitudinal section through primary xylem. × 60.

Fig. 23. Longitudinal section through the secondary xylem showing truncated end of the tracheids. × 90.

Fig. 24. Tangential longitudinal section showing xylem rays. × 75.

Fig. 25. Transverse section of the pith showing secretory cells (s). × 90.

Fig. 26. Radial longitudinal section through the secondary xylem showing uniseriate pits. × 275.

Fig. 27. Radial longitudinal section through the secondary xylem showing biseriate pits. × 275.

Fig. 28. Radial longitudinal section through the secondary xylem showing triseriate pits. × 275.

Fig. 29. Radial longitudinal section through the secondary xylem showing pits in the cross-field. × 275.