JURASSIC WOODS FROM THE RAJMAHAL HILLS, BIHAR

D. C. BHARDWAJ
Birbal Sahni Institute of Palaeobotany, Lucknow

ABSTRACT

Three new species of coniferous woods from the Jurassic of Rajmahal hills are described. These are referred to three different genera, viz. *Mesembrioxylon*, *Cupressinoxylon* (*Taxodioxylon*), and *Dadoxylon* (*Araucarioxylon*). *Mesembrioxylon* and *Cupressinoxylon* are reported from this area for the first time.

INTRODUCTION

IN an earlier paper (BHARDWAJ, 1952) I described the structure of a new species of *Taxoxylon* Unger from Rajmahal hills. Later on I have studied three other petrified specimens of coniferous woods from Amarjola (district Amarapara) which are described here. The study of fossil coniferous woods of Rajmahal has hitherto been neglected in spite of rich occurrences of well-preserved specimens in these strata. Sahni (1931) described the only species, *Dadoxylon* (*Araucarioxylon*) *rajmahalense* Sahni from Rajmahal, of which the exact locality is not known. However, this study is intended to enhance our meagre knowledge of the petrified woods from Rajmahal, which may ultimately contribute to the understanding the nature and composition of the Jurassic flora of this region.

DESCRIPTION

Mesembrioxylon indicum sp. nov.

Pl. 1, Figs. 1-6; Text-figs. 1-4

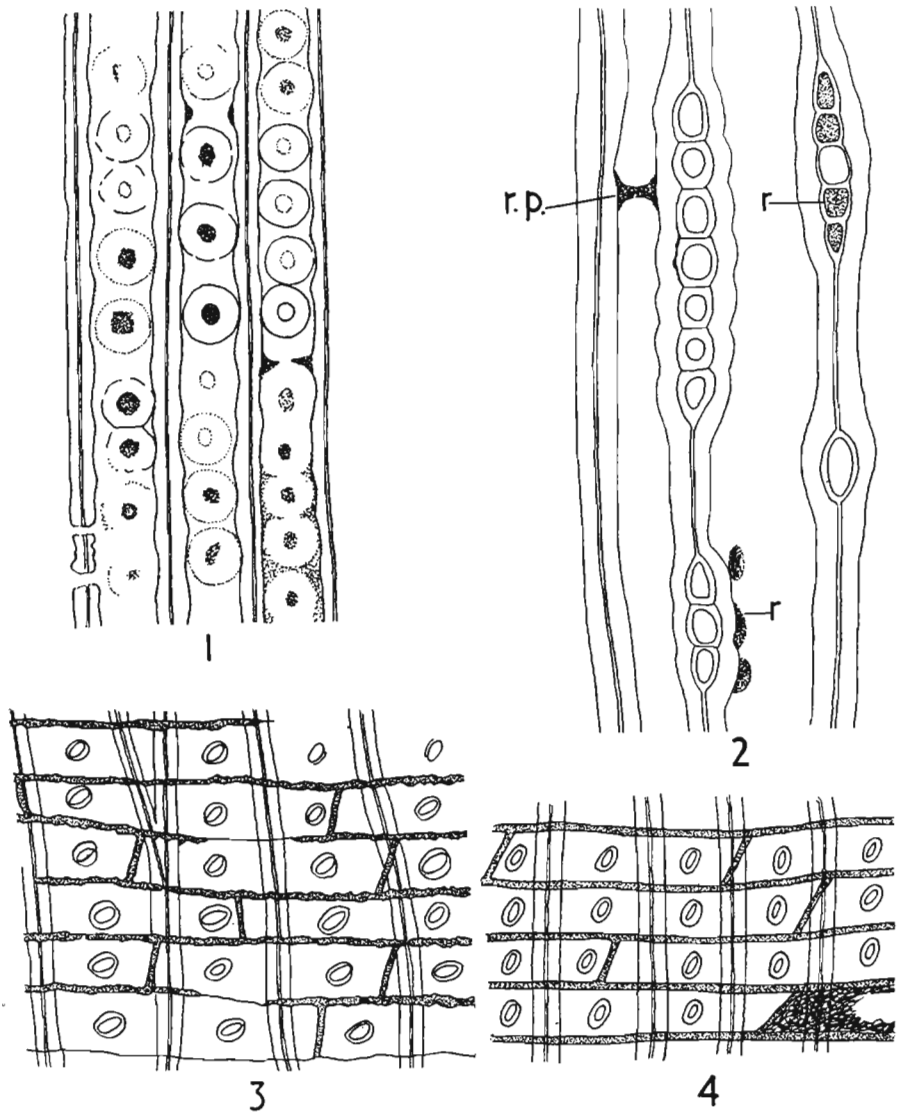
The species is founded on a small piece of decorticated branch. The specimen is grey due to weathering, soft, but still it has withstood sectioning. The replacement is uniform. The specimen consists of secondary wood with small pith in the centre. The present diameter is only 30 mm. and shows 18 well-defined growth rings. The cortex or the bark is absent.

Pith — Very small, not well preserved, circular, consisting of large thick-walled prosenchymatous cells, some of them filled with resinous matter. Stone cells present.

Primary Xylem — The protoxylem groups, situated at the tip of wood wedges, lie near the margin of the circular pith. In all, 8 protoxylem groups were seen. The primary xylem seems to be entirely centrifugal, no centripetal xylem has been recognized.

Growth Rings — During early years of growth the differentiation of the secondary xylem elements into autumn or spring tracheids is not clearly seen, although faint evidence of the changeover from one year to the next can be discerned. Further out the wood shows well-defined, broad growth rings (PL. 1, FIG. 1), 36-60 tracheids wide, with regular alternation of autumn and spring elements. *Autumn wood* (PL. 1, FIG. 2) narrow, 5-6 cells in width, elements thick-walled, squarish or elliptical, tangentially flattened and with small, elliptical or spherical lumen. *Spring wood* 30-35 elements wide, tracheids sub-rounded to squarish and thin-walled. Transition from autumn wood to spring wood is sharply defined (PL. 1, FIG. 2). Vertical resin canals or resin-filled parenchyma is absent. In Pl. 1, Fig. 1, a number of opaque elements are seen scattered through the spring wood, giving the impression of a Cupressinean wood. These are resin-filled tracheids.

Details of Elements — Tracheids 1·5-2 mm. long, 20-24 μ wide, mostly rounded, elliptical or squarish, closely packed and with small intercellular spaces (PL. 1, FIG. 2). Autumn elements 20 × 12-15 μ, tangentially flattened, elliptical or rounded and thick-walled. Spring elements 20 × 20-24 μ, squarish with rounded corners or occasionally pentangular, thick-walled. Radial walls are pitted with uniseriate bordered pits (TEXT-FIG. 1) which are usually not well preserved. These are usually separated from each other, round and 10-12 μ in diameter with a circular pore. No tangential pitting is seen. In some of the younger spring elements, highly inclined or horizontal, irregularly distributed, spiral markings are occasionally seen. They appear to be the etching marks or striation, so commonly mistaken for genuine spiral thickening (PL. 1, FIG. 3).



TEXT-FIGS. 1-4—*Mesembrioxylon indicum* sp. nov. 1, radial view of tracheids showing uniseriate bordered pits. Note the thick walls. × 940. 2, tangential section showing medullary rays, resin plate (r.p.) in the tracheid lumen and resin (r) filled in ray cells. × 940. 3, radial section through medullary ray showing nature and distribution of cross-field pits. × 940. 4, another radial section through medullary ray. × 940.

Resinous tracheids are abundant in *M. indicum*. These are like normal tracheids in structure, having radial bordered pits and cannot be distinguished from them but for the presence of characteristic resin plates (TEXT-FIG. 2). Such tracheids are profusely distributed throughout and it is rather difficult to find any tracheid which does not contain resin. The resin plates are highly refractory and all stages in their development can be traced. These are normally located nearer the medullary rays (TEXT-FIG. 2 and PL. 1, FIG. 4). The origin and significance of resinous tracheids have been discussed in detail by Penhallow (1907, pp. 39-58), Thomson (1913, pp. 23-28, as cited by STOPES, 1914) and Record (1918, pp. 61-67).

TABLE I — COMPARATIVE TABLE OF MICROSCOPIC CHARACTERS FOR IDENTIFICATION OF FOSSIL WOODS

Mesembrioxylon Seward

No.	Name of species	General, growth rings distinct or indistinct	Tracheids: Pits uniseriate or multiseriate	Tracheids: Pits separate or contiguous	Tracheids: Pits alternate or opposite	Tracheids: Spiral thickening present or absent	Tracheids: Tangential pitting present or absent	Tracheids: Spring tracheid, size	Parenchyma: Abundant or scanty	Parenchyma: Terminal or diffused	Resin canals: Vertical or horizontal	Resin canals: Terminal or diffused	Resin canals: Number per sq. mm.	Medullary ray: Uniseriate or biseriate	Medullary ray: Fusiform with or without transverse canals	Medullary ray: Average height in cells	Medullary ray: Ray tracheids marginal or diffused	Medullary ray: Ray tracheids dentate or smooth	Medullary ray: Horizontal walls pitted or unpitted	Field pits in spring wood: Average number	Field pits in spring wood: Number of horizontal rows	Field pits in spring wood: Greatest number per row	Field pits in spring wood: Bordered or simple
1	*Mesembrioxylon indicum* sp. nov.	+	+	+	.	−	−	20 × 24 μ	...	..	...	...	...	+	...	2	...	...	−	1	1	1	±
2	*M. sewardi* Sahni	+	+	+	...	−	+	...	+	−	...	...	...	+	...	3	...	...	−	1	1	1	−
3	*M.* sp. (Gothan) Seward	...	+	...	...	−	...	...	...	...	...	...	...	+	...	...	...	...	...	1	1	2	...
4	*M. godaverianum* Sahni	−	+	+	±	−	−	...	+	−	...	...	...	+	...	5½	...	...	−	4	2	2	+
5	*M. parthasarthyi* Sahni	+	+	+	...	−	...	...	...	...	...	...	...	+	...	8	...	...	−	4	2	2	+
6	*M. malerianum* Sahni	−	+	+	...	−	−	...	...	...	...	...	...	+	...	3	...	...	−	6	3	3	+
7	*M.* sp. Sahni	+	+	+	−	−	−	...	...	...	...	...	...	±	...	20	...	...	..	2	2	1	...
8	*M. woburnense* (Stopes) Sew.	+	+	+	−	−	+	35 × 55 μ	+	−	...	...	...	+	...	5	...	...	−	1	1	2	+
9	*M. bedfordense* (Stopes) Sew.	+	+	−	...	−	+	20 × 28 μ	+	−	...	...	...	+	...	3	...	...	−	1	1	1	+
10	*M. gothani* (Stopes) Sew.	+	+	+	...	...	...	25 × 40 μ	−	−	...	...	...	+	...	3	...	...	−	1	1	2	−
11	*M. schwendae* (Kubart) Sew.	...	+	...	...	−	...	...	+	−	...	...	...	+	...	...	..	...	...	2	2	2	+
12	*M. aparenchymatosum* (Gothan) Sew.	...	+	...	...	−	...	...	...	...	...	...	...	+	...	...	...	...	...	2	1	2	+
13	*M. antarcticum* (Gothan) Sew.	...	+	...	...	−	...	...	...	...	...	...	...	+	...	...	...	...	...	2	1	2	−
14	*M. hookeri* (Arber) Sew.	+	+	...	...	−	+	...	+	−	...	...	...	+	...	8	...	...	...	1	1	1	−
15	*M. fluviale* Sahni	+	+	+	...	−	...	...	+	−	...	...	...	+	...	3	...	...	−	1	1	2	−
16	*M. fusiforme* Sahni	+	+	−	...	−	...	...	...	...	...	...	...	+	...	4	...	...	−	2	1-2	2	−
17	*M. schmidianum* (Schleid) Sahni	±	..	+	−	−	...	...	−	...	...	...	...	+	...	36	...	...	−	1	1	2	±

(+), primary character; (−), alternative character; (±), mixed occurrence.

TABLE II — COMPARATIVE TABLE OF MICROSCOPIC CHARACTERS FOR IDENTIFICATION OF FOSSIL WOODS

Cupressinoxylon Goeppert

No.	Name of species	General, growth rings distinct or indistinct	Tracheids: Pits uniseriate or multiseriate	Tracheids: Pits separate or contiguous	Tracheids: Pits alternate or opposite	Tracheids: Spiral thickening present or absent	Tracheids: Tangential pitting present or absent	Tracheids: Spring tracheid, size	Parenchyma: Abundant or scanty	Parenchyma: Terminal or diffused	Resin canals: Vertical or horizontal	Resin canals: Terminal or diffused	Resin canals: Number per sq. mm.	Medullary ray: Uniseriate or biseriate	Medullary ray: Fusiform with or without transverse canals	Medullary ray: Average height in cells	Medullary ray: Ray tracheids marginal or diffused	Medullary ray: Ray tracheids dentate or smooth	Medullary ray: Horizontal walls pitted or unpitted	Field pits in spring wood: Average number	Field pits in spring wood: Number of horizontal rows	Field pits in spring wood: Greatest number per row	Field pits in spring wood: Bordered or simple
1	*Cupressinoxylon* (*Taxodioxylon*) *rajmahalense* sp. nov.	+	−	+	−	−	+	28× 40 μ	...	...	−	...	...	+	...	7	...	...	−	2	1	2	+
2	*C.* (*Taxodio.*) *taxodii* Gothan	+	−	+	−	−	+	...	+	−	...	...	...	+	...	...	...	...	−	3	1	3	+
3	*C.* (*Taxodio.*) *sequoianum* Merck	+	−	+	−	−	+	200 × 400 μ	+	−	±	...	7	+	...	6	...	...	−	4	2	4	+
4	*C. koetlitzi* Seward	+	−	+	−	−	+	...	...	...	...	...	...	+	...	1-25	...	...	−	3	1	4	−
5	*C. coromandalianum* Sahni	+	−	+	−	−	−	30× 40 μ	+	−	...	...	...	+	...	10	...	...	−	1	1	2	+
6	*C. alternans* Sahni	+	+	+	+	−	+	60× 80 μ	+	−	...	...	...	+	...	10	...	...	−	2	1	2	+
7	*C. walkomi* Sahni	+	±	+	−	−	...	...	+	−	...	...	...	+	...	8	...	...	−	4	2	3	−
8	*C. dunstani* Sahni	+	+	+	...	−	...	...	−	...	...	...	...	+	...	7	...	...	−	4	irreg.	2	−
9	*C. diskoens* Walton	+	+	+	...	−	...	...	+	−	...	...	...	±	...	1-16	...	...	−	3	2	2	+
10	*C. vectense* Barber	+	+	+	...	−	+	12× 25 μ	+	−	...	...	...	+	...	5	...	...	−	1	1	2	−
11	*C. luccombense* Stopes	+	+	+	...	−	...	30× 40 μ	+	−	...	...	...	+	...	3	...	...	−	3	2	2	−
12	*C. cryptomerioides* Stopes	−	+	+	...	−	+	20× 25 μ	+	−	...	...	...	+	...	3	...	...	−	2	1	2	−
13	*C. hortii* Stopes	+	+	+	...	−	+	33× 55 μ	+	−	...	...	...	±	...	50	...	...	−	1	1	1	−

(+), primary character; (-), alternative character; (±), mixed occurrence.

TABLE III — COMPARATIVE TABLE OF MICROSCOPIC CHARACTERS FOR IDENTIFICATION OF FOSSIL WOODS

Dadoxylon (*Araucarioxylon*)

No.	Name of species	General, growth rings distinct or indistinct	Tracheids: Pits uniseriate or multiseriate	Tracheids: Pits separate or contiguous	Tracheids: Pits alternate or opposite	Tracheids: Spiral thickening present or absent	Tracheids: Tangential pitting present or absent	Tracheids: Spring tracheid, size	Parenchyma: Abundant or scanty	Parenchyma: Terminal or diffused	Resin canals: Vertical or horizontal	Resin canals: Terminal or diffused	Resin canals: Number per sq. mm.	Medullary ray: Uniseriate or biseriate	Medullary ray: Fusiform with or without transverse canals	Medullary ray: Average height in cells	Medullary ray: Ray tracheids marginal or diffused	Medullary ray: Ray tracheids dentate or smooth	Medullary ray: Horizontal walls pitted or unpitted	Field pits in spring wood: Average number	Field pits in spring wood: Number of horizontal rows	Field pits in spring wood: Greatest number per row	Field pits in spring wood: Bordered or simple
1	*Dadoxylon* (*Araucarioxylon*) *jurassicum* sp. nov.	−	±	−	+	−	−	30 μ	...	...	−	...	...	+	...	4	...	...	−	6	3	2	+
2	*D.* (*Arauc.*) *rajmahalense* Sahni	+	−	−	+	−	...	...	...	...	...	...	...	+	...	6	...	...	...	...	...	...	...
3	*D.* [*Arauc.*) *novaezealandiae* (Stopes) Sew.	+	−	−	+	−	...	...	...	...	−	...	...	+	...	3	...	...	−	5	3	6	+
4	*D.* sp. Holden	...	−	−	+	−	...	...	...	...	...	...	...	+	...	...	...	...	...	...	...	...	...
5	*D.* (*Arauc.*) *breveradiatum* (Lignier)	...	±	−	+	−	...	...	+	−	−	...	...	+	...	2	...	...	−	11	3	4	−
6	*D.* (*Arauc.*) *kergnelense* Sew.	+	±	−	+	−	...	...	...	...	...	...	...	...	...	7	...	...	−	6	2	3	−
7	*D. pseudoparenchymatosum* Gothan	+	±	−	+	−	...	10-12 μ	...	...	...	...	...	±	...	2-10	...	...	...	3	2	2	−
8	*D. keuperianum* (Goepp.) Sew.	...	±	−	+	−	...	...	...	...	...	...	...	+	...	2-50	...	...	...	3	2	2	−
9	*D. septentrionale* Gothan	+	−	−	+	−	...	...	+	−	...	...	...	+	...	bis 20	...	...	...	4	3	2	−
10	*D. mahajambjense* (Fliche) Sew.	...	−	−	+	−	...	...	...	...	...	...	...	+	...	8-16	...	...	...	...	...	...	−
11	*D. divescence* (Lignier) Sew.	...	−	−	+	−	...	...	...	...	...	...	...	...	...	8-11	...	...	...	...	...	...	−

(+), primary character; (−), alternative character; (±), mixed occurrence.

Medullary rays simple, usually uniseriate, 1-5 cells high, the average of 24 counts being 2 (PL. 1, FIG. 5). Ray cells narrowly oblong with end-cells tapering. In tangential section, the lateral sides of these cells are coated with a thick layer of resinous substance (TEXT-FIG. 2). Ray cells thick-walled (TEXT-FIGS. 3, 4; PL. 1, FIGS. 4, 6), end-walls unpitted and straight or slightly curved, indentures absent; cross-field pits solitary (PL. 1, FIGS. 4, 5), bordered; slits narrow or wide, oval, inclined 30°-45° in spring tracheids (TEXT-FIG. 3), and inclined 70°-80° in autumn tracheids (TEXT-FIG. 4).

Comparisons — This wood is easily distinguished from others in view of several characteristics. These are: (1) well-defined growth rings; (2) thick-walled, narrow lumened tracheids with rounded corners; (3) absence of wood parenchyma; (4) the presence of solitary, large, bordered cross-field pit with oblique slit; and (5) stone cells in the pith. Such features as (3) and (4) refer the specimen to *Mesembrioxylon* Sew. as defined by its author (SEWARD, 1919, p. 206). The angle of inclination of the pore of field pits is normally 45° in spring tracheids and is never horizontal as it is in the typical *Cupressinoxylon* according to Gothan (1905, p. 46) and Sahni (1931, p. 53). From amongst a large number of Mesozoic and Tertiary species of *Mesembrioxylon* (TABLE 1) only a few are closely comparable with this form. *M. aparenchymatosum* (Gothan) Sew. and *M. antarcticum* (Gothan) Sew. can be compared in view of the absence of parenchyma — a characteristic in agreement with *M. indicum*. In *M. aparenchymatosum*, which is a Tertiary species and rather scantily described, the medullary ray cells have 1 to 2 elliptical — circular (simple ?)— pits in the field. The radial section not being well preserved in *M. aparenchymatosum*, the real nature of field pits is not known and hence it is rather difficult to reach any conclusion with regard to this species. *M. antarcticum* is a Tertiary species from Seymour Island and has large, single, simple pit in the field. On the basis of the type of cross-field pitting both the above-mentioned species can be easily distinguished from *M. indicum*. Another species which may be compared is *M. Gothani* (Stopes) Sew. (1919, p. 207). Stopes (1915, p. 229) considers it to show affinity to *Phyllocladus*. This species has small amount of wood parenchyma and wider tracheids and has a single large, oval, simple pit (Eipore) in the field. Among the Indian species of *Mesembrioxylon*, *M. schmidianum* (Schleiden) Sahni (SAHNI, 1931, p. 54), a Tertiary species, possesses scanty parenchyma and very high medullary rays. The field pitting, though ill-preserved, is fairly comparable with my specimen. The other Jurassic species from India, *M. Parthasarathyi*, described by Sahni (1931), is devoid of parenchyma, and shows higher medullary rays and 2-5 pits in the field, although this species has stone cells in the pith. *M. malerianum* does not show any parenchyma, but has as many as 3-10 pits in each tracheid field. *M. godaverianum* has abundant xylem parenchyma and 2-5 pits in the field. Thus *M. indicum* cannot be directly referred to any of the existing species of *Mesembrioxylon* as far as known to me.

A comparison of *M. indicum* with the species of *Xenoxylon* is also desirable. This genus has three species and, as Seward (1919, p. 242) puts it, these are difficult to distinguish from *Mesembrioxylon*. However, *M. indicum* differs from all the species of *Xenoxylon* in the absence of contiguous and vertically flattened bordered pits on the radial walls of the tracheids. The cross-field pit in *M. indicum* is bordered as opposed to the simple pit in the species of *Xenoxylon*.

The well-marked growth rings, thick-walled, small-lumened tracheids with rounded corners, absence of resin canals and parenchyma and the presence of solitary, bordered, cross-field pit and of stone cells in the pith of *M. indicum* are closely comparable to the stem-anatomy of *Phyllocladus*. *P. trichomanoides* (GREGUESS, 1949, p. 21) shows a close resemblance to *M. indicum* in respect of all characteristic features. Other species, *P. rhomboidalis*, has simple large solitary pore in the field, although in all other respects this species of *Phyllocladus* shows nearness to the fossil specimen from Rajmahal.

Diagnosis of M. indicum — Species founded on a small, decorticated branch, 3 cm. in diameter. Growth rings regular but variable, pith with stone cells. Autumn wood 6-8 tracheids wide, elements squarish to subrounded, thick-walled, 20 × 12-15 μ; spring wood elements 20 × 20-24 μ. Tracheids 1·5-2·0 mm. long with uniseriate bordered radial pitting; resinous tracheids with abundant resin plates. Wood parenchyma and resin canals absent. Tangential pitting not

evident. Medullary rays uniseriate, 1-6 cells high; horizontal walls pitted, end walls thick and unpitted; cross-field pits one, rarely two, bordered, slits oblique; ray tracheids absent.

Type — F. 510, and Sections a-h.

Cupressinoxylon (*Taxodioxylon*) *rajmahalense* sp. nov.

Pl. 1, Fig. 7; Pl. 2; Text-figs. 5-7

The specimen is a large block of well-petrified secondary wood, 11 cm. long and 7 cm. wide. Radially it is 6 cm. broad and shows 45 growth rings which are wider towards the pith and narrower towards the cortex. Considering the low curvature of the growth rings, it is evident that this piece is the petrified remnant of a trunk which, before fossilization, must have been a few feet in diameter. Pith and cortex are not present. The wood seems to have shrunk before fossilization. A number of cracks are noticeable which are filled with agate.

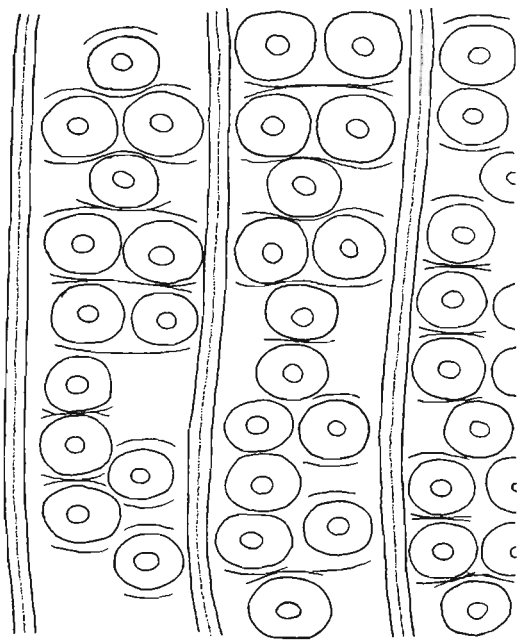
Growth Rings — Distinct to the naked eye as well as under the microscope. The inner growth rings may be 2-3 mm. in width, but the outer ones only up to 1 mm. wide. *Autumn wood* is a fairly wide band consisting of up to 30 small, thick-walled tracheids showing narrow lumen. *Spring wood* is composed of more thin-walled, larger elements which are polygonal, having wide, open lumen. The ratio between the autumn wood and the spring wood ranges from 1 : 1 to 1 : 2. The limit between autumn and spring wood is sharply defined (Pl. 1, Fig. 7). Compound growth rings absent. Vertical resin canals absent. No clearly preserved xylem parenchyma is seen. However, occasionally elongated cells with dark contents are seen and also frequently resinous matter is found deposited in a manner suggesting thick transverse walls of parenchyma cells (Text-fig. 6).

Secondary Elements — Autumn tracheids 12-20 × 28 μ and spring tracheids 28 × 36-40 μ. The elements are closely packed, usually without any intercellular spaces. The radial walls show crowded bordered pits in 1-3 series (Pl. 2, Figs. 1-4), pits usually elliptical or almost circular, 16 × 20 μ, with their longer axis horizontal and occasionally appearing somewhat flattened by mutual contact. The pits, when in more than one series, are opposite (Pl. 2, Fig. 3) and rims of Sanio are clearly seen (Text-fig. 5; Pl. 2, Fig. 2). The pore is usually circular and measures 4 μ in diameter. The tangential walls show scattered, small, bordered pits (Text-fig. 6; Pl. 2, Fig. 5).

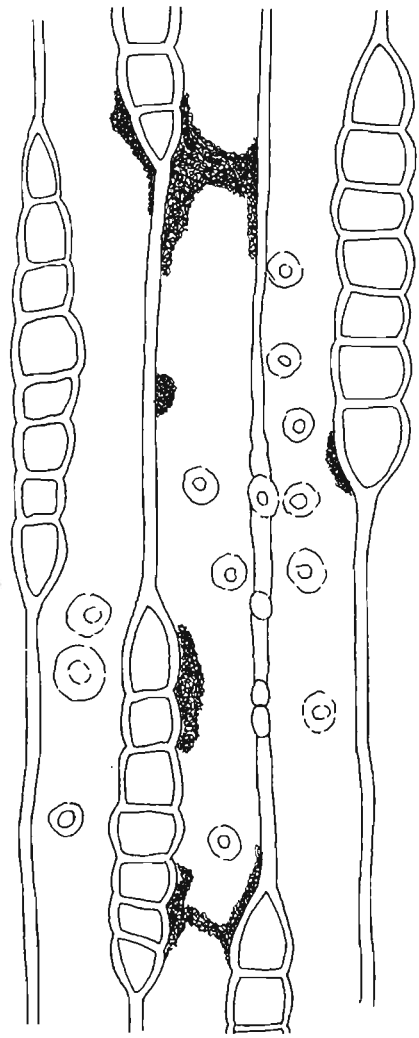
Medullary Rays — Simple, normally uniseriate (Pl. 2, Figs. 6, 7), but in rare cases partly biseriate, 1-23 cells high (average of 24 counts = 7), 20-30 tracheids in depth. As seen in tangential view, the ray cells are thick-walled, rounded and the end-cells are bluntly rounded at the apex (Text-fig. 6; Pl. 2, Fig. 6). In radial section the ray cells have horizontal walls thickened but unpitted, end walls thin, unpitted, inclined or curved at a low angle, indentures absent; cross-field pits large, bordered, horizontally elliptical, usually two in one row (Text-fig. 7a; Pl. 2, Fig. 4) or one in autumn wood (Text-fig. 7b), cupressoid, slits horizontal in spring wood and vertical in autumn wood.

Comparisons — This specimen shows certain noteworthy features in its anatomy such as (1) multiseriate, opposite bordered pits on the radial walls of tracheids, (2) rims of Sanio, (3) medullary rays pitted only on the radial walls having one, vertically elliptical, bordered pit in autumn wood and usually two, horizontally elliptical, bordered pits arranged in a horizontal row in spring wood. A comparison of these characters with those of the subgenus *Taxodioxylon* of *Cupressinoxylon*, as summarized by Seward (1919, p. 200), shows marked agreement of the two. Especially the nature of cross-field pits in autumn wood and in spring wood is a marked taxodioid feature. As compared to the known species of *Taxodioxylon* (Table II), the Rajmahal specimen agrees very closely with *C.* (*Taxodioxylon*) *taxodii* Gothan, a Tertiary species from Senftenberg. The only difference between these is the presence of xylem parenchyma in *C.* (*Taxodioxylon*) *taxodii* and its absence (?) in the Rajmahal specimen. Although the absence of xylem parenchyma in the latter is not definitely established, yet it presents a striking contrast as compared to the conspicuous and well-defined parenchyma in the former.

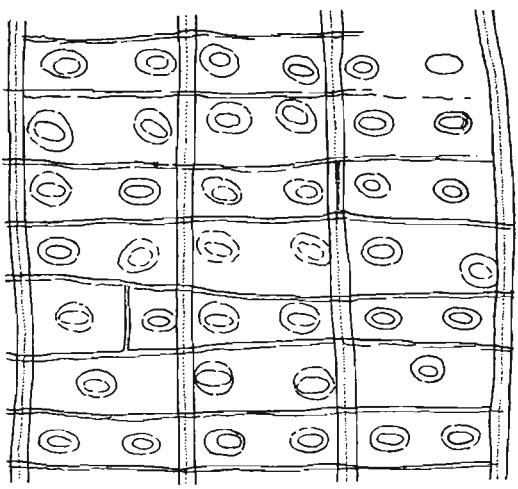
Among the large number of species of *Cupressinoxylon* described (Table II), the specimen is closely comparable to *C. koettlitzi* Sew. described from Franz Josef Archipelago. Both agree in most of the details such as the distinct growth rings, absence of xylem parenchyma, nature of tracheal



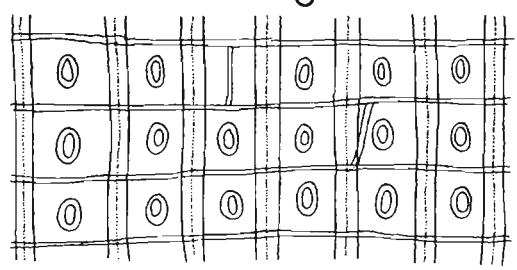
5



6



7a



7b

TEXT-FIGS. 5-7 — *Cupressinoxylon* (*Taxodioxylon*) *rajmahalense* sp. nov. 5, part of two tracheids in radial section showing 1-2 seriate, opposite bordered pits and bars of Sanio. × 750. 6, part of a tangential section showing medullary rays and also sparse bordered pits on the tangential wall of tracheids. × 750. 7a, part of radial section through spring wood medullary ray showing cross-field pitting. × 750. 7b, part of radial section showing autumn wood with medullary ray cross-field pitting. × 750.

pitting, occurrence of rims of Sanio and the height of medullary rays. The difference is notable only in the number and structure of pits in the field. *C. koettlitzi* has 2-4 small, circular or oval (simple?) pits in the field, but the Rajmahal specimen always has 1-2 small, bordered, horizontally elliptical pits. The difference is significant especially because both the species seem to be based on the structure of mature wood. Another species with which Rajmahal fossil shows nearness is *C. coromandalianum* Sahni, which is described to contain abundant resin parenchyma in contrast to absence of these structures in the Rajmahal specimen. The structure of the pits in the field also differs in the two cases. Thus the species is assigned a new name *Cupressinoxylon* (*Taxodioxylon*) *rajmahalense* sp. nov. However, the general similarity of *C.* (*Taxodioxylon*) *rajmahalense*, *C.* (*Taxodioxylon*) *taxodii*, *C. coromandalianum* and *C. koettlitzi* is striking and it may not be wrong to suggest that these may be allied species. The age of the specimen from Franz Josef Archipelago is not decided and, according to Seward (1919, p. 195), may be Upper Jurassic, Cretaceous, or possibly Tertiary. The Indian species, however, are definitely Jurassic.

Diagnosis of Cupressinoxylon (*Taxodioxylon*) *rajmahalense* — Growth rings distinct and regular, autumn wood 20-30 cells wide, elements small, thick-walled, 28 × 12-20 μ; spring wood 30-60 cells wide, 28 × 40 μ. Tracheids with bordered pits on radial walls in 1-3 series, opposite. Tangential walls pitted with small bordered pits. Wood parenchyma and resin canals absent. Medullary rays simple, high, 1-23 cells (average 7), ray cells thick-walled, cross-field pits large, 1-2, cupressoid, with horizontal slit.

Type — F. 513 and Sections a-d.

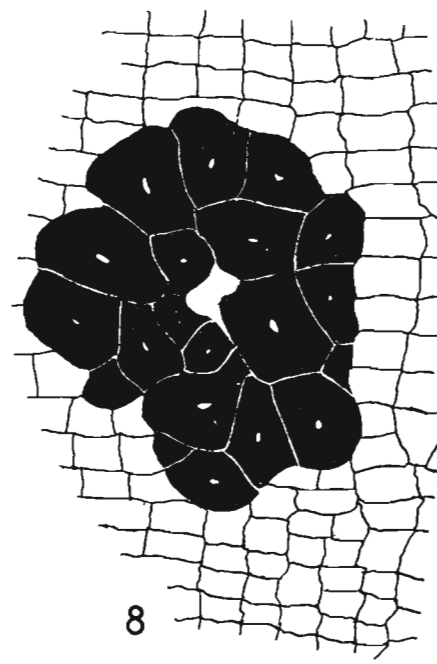
Paratype — F. 512 and Sections a-b.

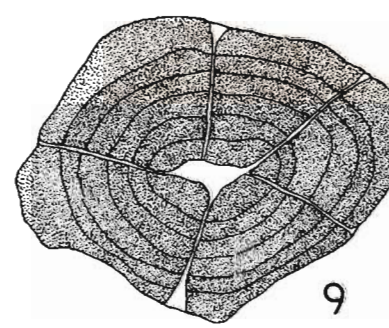
Dadoxylon (*Araucarioxylon*) *jurassicum* sp. nov.

Pl. 3; Text-figs. 8-14

This is another well-petrified fossil wood from Amarjola. Externally it is soft and almost white in colour due to weathering. The interior consists of well-preserved, hard, brownish to black secondary wood with pith. The fossil is rather brittle and, therefore, difficult to grind into thin sections. However, the material was boiled in thin canada balsam for a few hours before grinding, thus eliminating the risk of breakage. The fossil is a decorticated stem at present 4 cm. in diameter.

Pith — The whitish pith is about 1·5-2 mm. in diameter. The cells constituting the pith are small, thick-walled and rectangular with hardly any intercellular spaces. The cells frequently show resin-like contents (Pl. 3, Fig. 2). Interspersed with them are also numerous stone cells arranged in sclerotic nests (Text-fig. 8). The stone cells are very thick-walled, the thickening having been laid in layers, with a minute





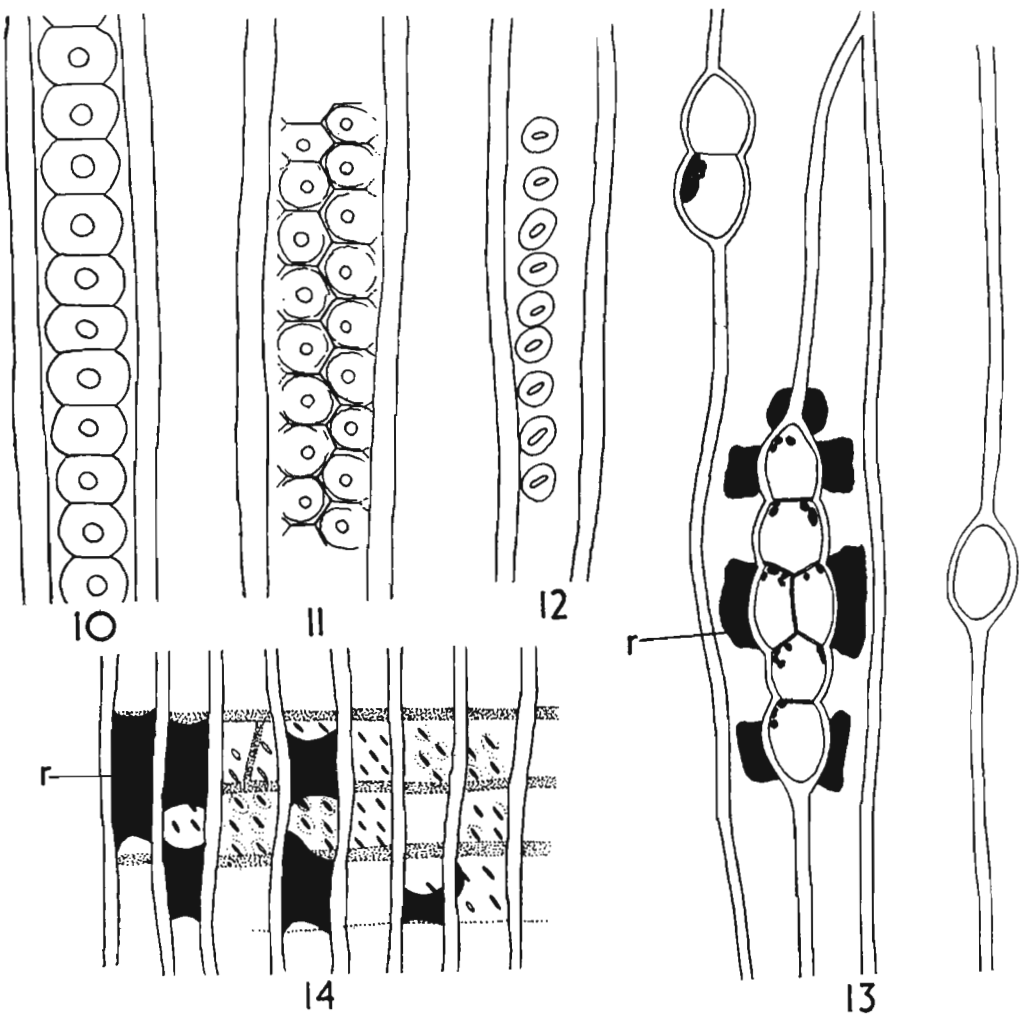
Text-figs. 8-9 — *Dadoxylon* (*Araucarioxylon*) *jurassicum* sp. nov. 8, a sclerotic nest in the pith consisting of a number of stone cells with very small lumen. × 155. 9, one of the stone cells showing the structure. × 760.

central lumen (TEXT-FIG. 9) communicating to the exterior through narrow radial canals.

Primary Xylem — The pith is surrounded by about 12 primary bundles which give the former a stellate character. The protoxylems are extensive and centrifugal. The elements are very well preserved and there are 6-8 annular to scalariform tracheids lying in one radius (PL. 3, FIG. 2).

Growth Rings — Apparent with naked eye, but are difficult to recognize under the microscope (PL. 3, FIG. 1). The last formed of spring tracheids and the autumn tracheids are nearly similar in size but for the slightly thicker wall of the first autumn elements. A normal-sized growth ring is 16-20 cells wide. It is difficult to delimit the autumn and spring formed elements of the same year. Numerous elements are full of dark contents so that in a transverse section it is difficult to ascertain if there is any xylem parenchyma present.

Secondary Elements — The average width of autumn and spring tracheids is almost the same (20-30 μ). The elements are thick-walled, closely packed, without any



TEXT-FIGS. 10-14 — *Dadoxylon* (*Araucarioxylon*) *jurassicum* sp. nov. 10, 11, showing the nature of radial pitting of the tracheid walls. × 1010. 12, showing tangential pitting on the tracheid wall. × 1010. 13, part of a tangential section showing a partly biseriate medullary ray. Note the resin plates (r) in the lumen of the tracheids. × 760. 14, part of a radial section through medullary ray showing the distribution and structure of the cross-field pitting. Note the copious resin (r) in this region. × 760.

intercellular spaces (PL. 3, FIG. 1). The radial walls show uniseriate contiguous (TEXT-FIG. 10) or biseriate contiguous, alternate (araucarian) pitting (TEXT-FIG. 11; PL. 3, FIGS. 3, 4). On the tangential walls small, uniseriate, separate, bordered pits with elliptical pores were also observed (TEXT-FIG. 12). The bordered pits are normally 5-7 μ in diameter with a rounded or elliptical pore 2 μ in diameter. The tracheids are usually filled with resinous matter. The typical resin plates described in *M. indicum* as well as described by Penhallow (1907), Thomson (1913) and also Stopes (1915) are not seen in this species, but long barrel-like inclusions or thick discs (TEXT-FIG. 13; PL. 3, FIG. 5) of presumably similar origin are abundantly seen. Xylem parenchyma could not be made out and is presumably absent.

Medullary Rays — The normal medullary rays are simple, uniseriate, 1-11 cells high (average of 24 counts — 4) (PL. 3, FIG. 5); the ray cells in tangential section 20 × 12 μ, oval, end-cells larger with their apices rounded. Rarely partly biseriate condition may be seen in a ray (TEXT-FIG. 13; PL. 3, FIG. 6). The cells are mostly filled with resinous matter. The ray cells adjoining the primary bundles are much broader than those in mature secondary wood. In a radial view, the rays are fairly deep extending across 60-80 tracheids. The horizontal and tangential walls of ray cells are slightly thickened but unpitted (PL. 3, FIG. 7). End walls normally straight, but occasionally curved, indentures absent. Radial walls heavily pitted with 4-8, contiguous, cross-field pits in 2-4 rows, pits with distinct elliptical pore (PL. 3, FIGS. 7, 8), borders of the pits feebly developed (TEXT-FIG. 14). Thomson (1913) has discovered that in recent Araucarineae radial walls of ray cells are unpitted. It is difficult to ascertain this aspect in the case of this wood, although the cross-field pits are distinctly different from the normal nature of radial pitting of the tracheids.

Comparisons — This fossil wood from Rajmahal is characterized by features such as (1) growth rings not sharply differentiated, (2) tracheids with uniseriate contiguous or biseriate contiguous, alternate, polygonal pits on the radial walls, (3) tangential walls unpitted, (4) xylem parenchyma absent, (5) resiniferous tracheids present, (6) medullary rays uniseriate, (7) ray walls thin and unpitted, (8) pits in the field 4-8, usually contiguous, in 2-3 series and with an oblique pore with the border only feebly developed, and (9) the pith composed of thin-walled isodiametric cells having sclerotic nests which are made up of a number of stone cells. These features agree with the characters of *Dadoxylon* (*Araucarioxylon*) to a great extent. The structure of the pith and the tracheal pitting exclude all Cordaitalean species described under *Dadoxylon* (SEWARD, 1917). Among the Mesozoic and Tertiary species (TABLE III) the Rajmahal fossil approaches *D.* (*Araucarioxylon*) *kerguelense* Sew. closely, but for the biseriate pitting in the latter. The Rajmahal species also differs from *D.* (*Araucarioxylon*) *novaezeelandiae* (Stopes) Sew., which shows the presence of growth rings, normal, uniseriate, radial pitting of the tracheids and in having narrower tracheids as compared to the latter. *D.* (*Araucarioxylon*) *pseudoparenchymatosum* Gothan differs in having distinct growth rings, narrower tracheids and shallow medullary rays as compared to *D.* (*Araucarioxylon*) *jurassicum*. Among the Indian species of *Dadoxylon* described from Mesozoic and Tertiary, none show such combination of characters as described for the Rajmahal specimen (TABLE 3). *D.* (*Araucarioxylon*) *rajmahalense* Sahni differs from *D.* (*Araucarioxylon*) *jurassicum* in having distinct growth rings with wide autumn wood and 2-3 seriate radial pitting of tracheids. Hence it is proposed to give a new name *Dadoxylon* (*Araucarioxylon*) *jurassicum* sp. nov., the specific name referring to the age of the beds from which it was recovered.

Diagnosis of Dadoxylon (*Araucarioxylon*) *jurassicum* — Growth rings faintly seen, pith with stone cells, primary xylem wide, autumn and spring tracheids 20-30 μ in diameter, isodiametric, xylem parenchyma absent, radial pits hexagonal, uniseriate contiguous or biseriate, alternate, contiguous; resinous tracheids present, rims of Sanio absent. Medullary rays uniseriate, 1-11 cells high (average of 24 counts — 4), 60-80 tracheids deep; cross-field pits 4-8, with oblique slits, border usually not easily seen.

Type — F. 502 and Sections a-h.

CONCLUDING REMARKS

The fossil coniferous woods from the Mesozoic strata of India, so far described,

are not many. The first comprehensive account of the coniferous remains of India by Sahni (1931) described 10 different woods mostly from the Rhaetic or Jurassic horizons. Two specimens out of these were too poorly preserved to afford generic identification, three could be assigned to genera only and the rest were described fully and were recognized as distinct species. These consist of three species of *Mesembrioxylon*, two species of *Cupressinoxylon* and one of *Dadoxylon* (*Araucarioxylon*). Very little has been added to this list in subsequent years but for a species referred to *Taxoxylon* Unger by me (BHARDWAJ, 1952) and the three species included in the present paper. From the Jurassic of Rajmahal hills in particular, so far, only one species of *Dadoxylon* (SAHNI, loc. cit.) has been described. My investigations, however, indicate that the coniferous flora of this region as well was as comprehensive as that of the other Jurassic localities in India, and included plants showing araucarian, taxinean, podocarpinean and taxodinean affinities. As in the other Jurassic strata in India, abietinean woods have not been found so far from Rajmahal hills.

I am grateful to Professor O. A. Höeg for very kindly revising the manuscript and for many useful suggestions.

REFERENCES

BHARDWAJ, D. C. (1952). On a new species of *Taxoxylon* Unger from the Jurassic of Rajmahal hills, Bihar (India). *Lloydia*. **15**(4): 234-240.

GOTHAN, W. (1905). Zur Anatomie lebender und fossiler Gymnospermer-Hölzer. *Abhande. d. kgl. preuss. geol. Landesanstalt*. **44** (N.F.): 1-108.

GREGUSS, P. (1949). Xylotomic investigation of some uncommon tropical coniferous genera. *Acta Botanica*. **4**: 1-26.

PENHALLOW, D. P. (1907). A manual of North American gymnosperms. *Boston*.

RECORD, S. J. (1918). Significance of resinous tracheids. *Bot. Gaz*. **64**: 61-67.

SAHNI, B. (1920). Petrified plant remains from the Queensland Mesozoic and Tertiary formations. *Queensland Geol. Surv. Publ*. **267**: 7-38.

Idem (1931). Revision of Indian fossil plants. Part II. Coniferales (b. Petrifactions). *Mem: Geol. Surv. India. Pal. Indica*. **11** (N.S.): 50-124.

SEWARD, A. C. (1917). Fossil plants. **3**. *Cambridge*.

Idem (1919). Ibid. **4**.

STOPES, M. C. (1914). A new *Araucarioxylon* from New Zealand. *Ann. Bot*. **28**: 341-350.

Idem (1915). Catalogue of the Cretaceous flora. II: Lower Greensand (Aptian) plants of Britain. *London*.

EXPLANATION OF PLATES

The type specimens are preserved at the Birbal Sahni Institute of Palaeobotany

PLATE 1

Mesembrioxylon indicum sp. nov.

1. Part of a transverse section of the type specimen showing distinct autumn and spring wood elements. Note the small, rounded, thick-walled elements. × 70.
2. Part of a transverse section at the junction of autumn (a) and spring (b) woods. × 430.
3. A tracheid showing spiral etching. × 840.
4. Part of a radial section through a medullary ray showing the ray-cell walls and cross-field pits. Resin plate (r.p.). × 360.
5. Part of a radial section through a medullary ray showing the structure of cross-field pits. × 360.
6. Part of a tangential section showing distribution and height of medullary rays. × 100.

Cupressinoxylon (*Taxodioxylon*) *rajmahalense*

7. Part of a transverse section showing demarcation between autumn and spring woods. × 70.

PLATE 2

Cupressinoxylon (*Taxodioxylon*) *rajmahalense* sp. nov.

1. Part of a radial section. × 70.
2. Part of the same radial section showing the nature of radial pitting. Note the rims of Sanio (s). × 320.
3. Part of a radial section showing the nature and distribution of bordered pits on spring tracheids. Note 2-3 series of rounded or elliptical, opposite bordered pits with a circular conspicuous pore. × 600.

4. Part of a radial section showing part of a medullary ray with cells having thick, unpitted walls and having two, cupressoid pits in each field. × 320.

5. Part of a tangential section showing a small bordered pit on a tracheid wall. × 600.

6. Part of a tangential section showing distribution and height of medullary rays. × 70.

7. Part of a tangential section, magnified to show the structure of the medullary ray. Note the thick walls of cells. × 320.

PLATE 3

Dadoxylon (*Araucarioxylon*) *jurassicum* sp. nov.

1. Part of a transverse section of the type specimen showing absence of conspicuous distinction between autumn and spring wood. Note all the tracheids are isodiametric. × 70.

2. Part of a longitudinal section through primary xylem (p.x.) and pith (ph). × 360.

3. Radial longitudinal section showing radial pitting of the tracheids. Note the alternate hexagonal bordered pits (x). × 360.

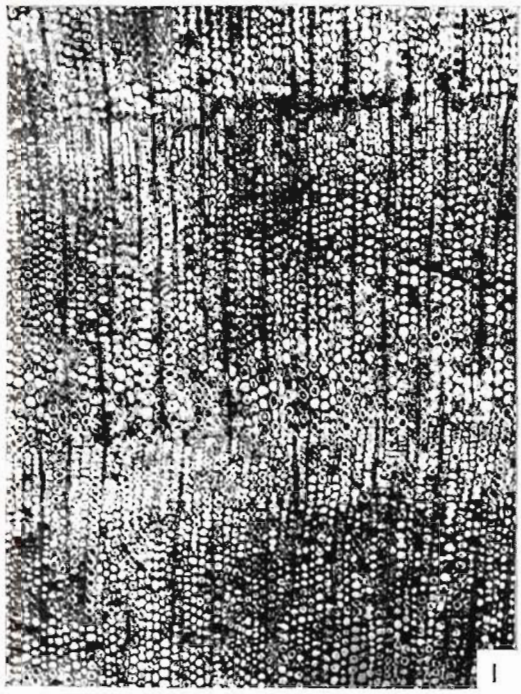
4. Another section showing similar radial pitting (x). × 360.

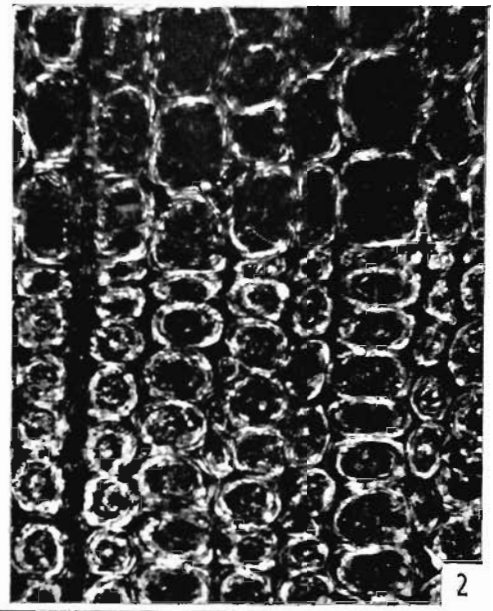
5. Part of a tangential section showing distribution and height of medullary rays. × 81.

6. A partly biseriate medullary ray in tangential section. × 240.

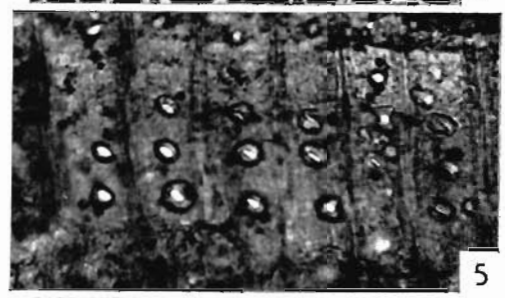
7. Part of a radial section showing cells of medullary ray and cross-field pitting. × 360.

8. Part of a radial section showing nature and distribution of cross-field pitting. × 360.


1



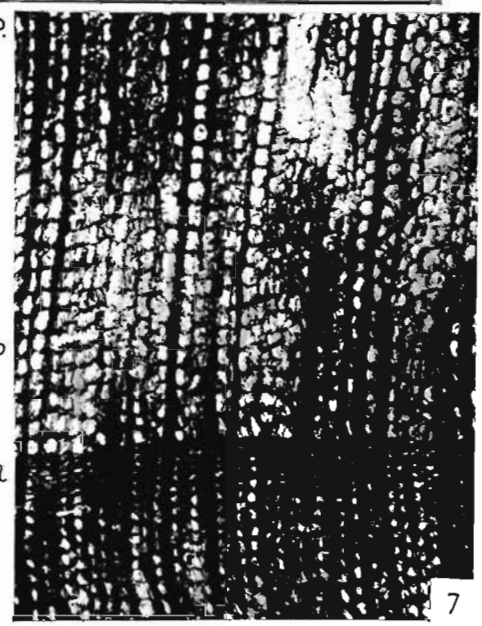
2

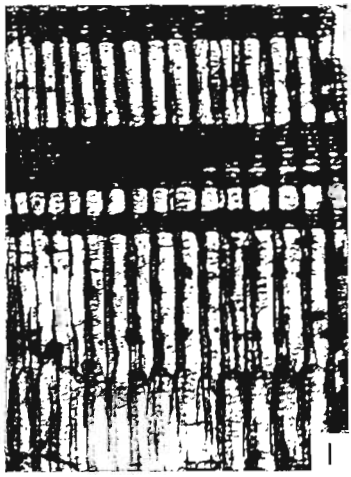

5

4


3

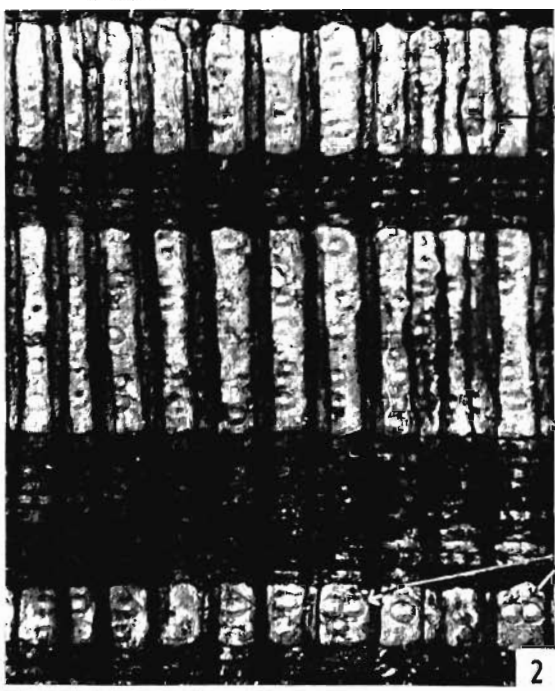
6


7

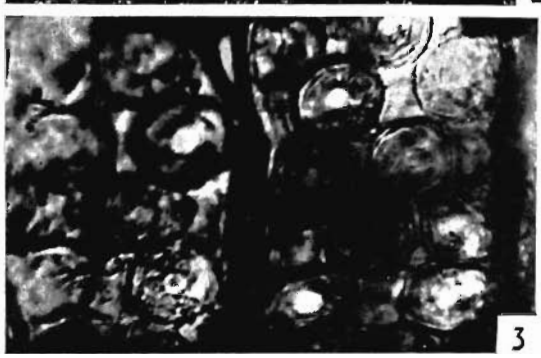

1

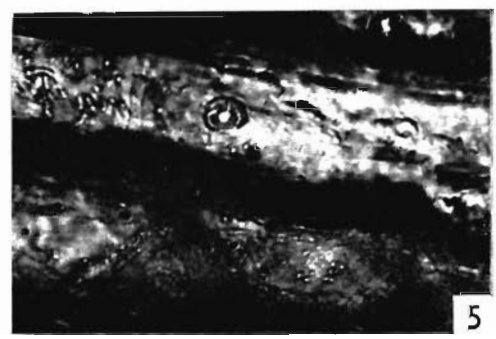

4

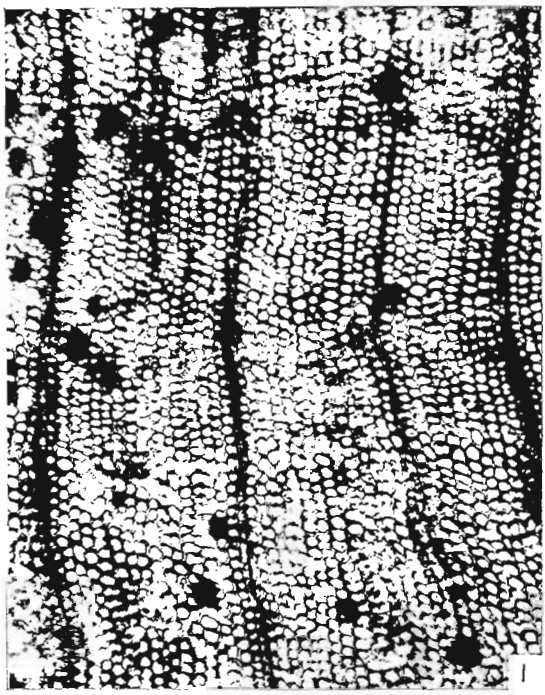

6


8
8
2


7


3

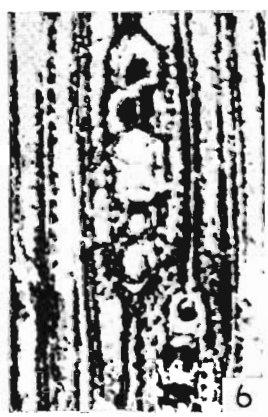

5

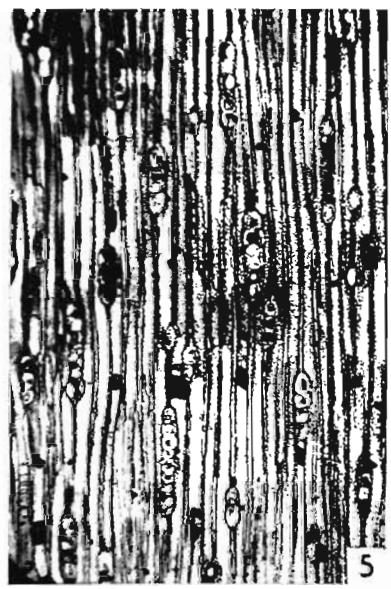

1

2


3

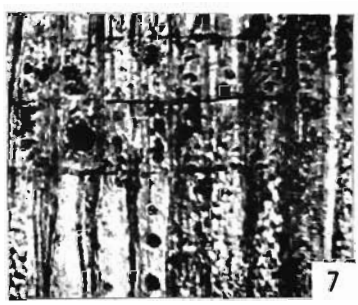
x


6


5


4

x


7


8