

Studies in fossil gymnospermous woods—Part X; Three new species of *Araucarioxylon* from Lower Gondwana Strata of Chandrapur District of Maharashtra, India

SHRIPAD N. AGASHE AND M.S. SHASHI KUMAR

Palaeobotany Research Laboratory, Department of Botany, Bangalore University,
Bangalore 560 056, India.

(Received 01 July 1999; revised versions accepted 12 April 2001)

ABSTRACT

Agashe SN & Shashi Kumar MS 2001. Studies in fossil gymnospermous woods—Part X; Three new species of *Araucarioxylon* from Lower Gondwana Strata of Chandrapur District of Maharashtra, India. Palaeobotanist 50(2 & 3) : 381-393.

Recent paleobotanical expedition to several Lower Gondwana (Permian) localities occurring in Chandrapur District of Maharashtra has brought to light several well preserved petrified gymnospermous woods. In the present paper three new species of *Araucarioxylon* i.e., *A. aravii* sp. nov., *A. chandrapurensis* sp. nov. & *A. shailae* sp. nov. are described based on distinct anatomical characters.

Key-words—Fossils, Gymnospermous woods, Lower Gondwana, *Araucarioxylon*, Permian.

भारत के महाराष्ट्र प्रान्त के चन्द्रपुर जिले के अधो गोण्डवाना स्तर से प्राप्त अराउकैरियोक्सीलॉन
श्रीपाद एन. अगाशे एवं एम.एस. शशि कुमार

सारांश

महाराष्ट्र के चन्द्रपुर जिले में अवस्थित विभिन्न अधो गोण्डवाना (परमियन) संस्थितियों के हाल ही में किए गए पुरावानस्पतिक भ्रमण से अनेक सुसंरक्षित अश्मीभूत अनावृतबीजी काष्ठ प्राप्त हुई हैं। प्रस्तुत शोध पत्र में सुस्पष्ट शारीरिक अभिलक्षणों के आधार-पर अराउकैरियोक्सीलॉन की तीन नयी प्रजातियाँ, ए. अरावाइ नव प्रजाति, ए. चन्द्रपुरेन्सिस नवप्रजाति तथा ए. शैलाइ नवप्रजाति अभिलक्षणित की गयी हैं।

संकेत शब्द—पादपाश्म, अनावृतबीजी काष्ठ, अधोगोण्डवाना, अराउकैरियोक्सीलॉन, परमियन.

INTRODUCTION

EXTENSIVE paleobotanical investigation has been done on Lower Gondwana petrified woods occurring in the Lower Gondwana Strata of central, north and north

eastern part of India such as Assam, Bengal, Bihar, Madhya Pradesh and Maharashtra. The main contributions to our knowledge of Lower Gondwana woods from India include the works of Greguss (1955, 1967), Lepekhina (1972), Maheshwari (1972), Lakhnupal *et al.* (1977), Agashe and Gowda (1978),

(1978), Ramanujam (1978), Varadpande (1978), Agashe *et al.* (1981), Prasad (1982, 1986), Agashe and Prasad (1984, 1989), Agashe and Shashi Kumar (1996).

The genus *Araucarioxylon* Kraus seems to be well represented in the Lower Gondwana formations in various parts of the world. Kraus (1870) reported *A. carbonaceum* as type species from Czechoslovakia. The first report of *Araucarioxylon* from India was made by Schenk (1882), when he reported *A. robertianum* from Asansol. Stopes (1914) reported *Araucarioxylon* from New Zealand. Lepekhina (1972) reported 24 species of *Araucarioxylon* from Northern Eurasia. She also gave a list of 24 genera of paleozoic woods belonging to the group- *Dadoxyleae* along with the description of all genera. All these woods were classified on the basis of secondary wood characters. Maheshwari (1972) reported 12 new species of *Araucarioxylon* from various Lower Gondwana formations of the world. He reported *A. manieroi*, *A. meridionale*, *A. nummularium* and *A. roxoi* from S. America, *A. allanii* from Antarctica, *A. ningahense* from India and Antarctica, *A. arberii* from Australia, *A. gondwanense*, *A. bengalense*, *A. parabeliense*, *A. kharkhariense* and *A. barakarensis* from various localities of Lower Gondwana formations in India. Lakhanpal *et al.* (1977), described *A. mohgaensis* from Mohgaon-kalan beds of Madhya Pradesh (Early Tertiary formations).

Earlier it was confined only to Miospore analysis of coal samples from Nagpur District. Later on thorough investigations of petrified woods from Chandrapur District gained much momentum. The main contributions on Lower Gondwana petrified woods from Maharashtra include the discoveries of Agashe *et al.* (1972-1998).

Agashe and Gowda (1978) described *Araucarioxylon loharensis* from Lower Gondwana localities i.e., Lohara of Chandrapur District. Agashe *et al.* (1981) described two new species of *Araucarioxylon* i.e., *A. surangeii* and *A. lathiense* from Lathi of Chandrapur District. Agashe and Prasad (1984) described *Araucarioxylon kothariensis* from Wejgaon of Chandrapur District. Agashe and Prasad (1989) described *Araucarioxylon bhivkundense* from Bhivkund of Chandrapur District. Agashe and Shashi Kumar (1996) described *Araucarioxylon wejgaense* from Wejgaon of Chandrapur District. Vagyani and Raju (1981) described *Araucarioxylon nandori* from Nandori of Chandrapur District. Maithy (1968) made some observations and gave some remarks on *A. diantreii* Chapman. Pant and Singh (1987) reported *A. semibiseriatum* from Raniganj Coalfield.

The above reports indicate that *Araucarioxylon* as the highly diversified genera in the Lower Gondwana beds.

AREA OF INVESTIGATION

Chandrapur District is encompassed roughly by latitude 18°15' : 15°15' N and longitude 78°65' : 80°85' E. The district is

bounded on the north by Nagpur and Bhadra districts and on west by Wardha, Yeotmal and Andhra Pradesh, and to the south by Andhra Pradesh and on the east by Madhya Pradesh (Geology & Mineral resources of Maharashtra - 1975).

All the rock formations starting from the Archean to the Upper Cretaceous are met in Chandrapur District. The important rivers flowing in Chandrapur District are Wardha, Wainganga and Pranahita (Fig. 1). Stratigraphically and structurally the entire area of Chandrapur District forms a part of the peninsular shield.

It can be seen in Fig. 1 that Sironcha, Chimur, Brahmपुरi and many localities near Chandrapur like Bhandak, Lohara, Ballarpur, Sarandi, Camp IV, Wejgaon, Lathi, Kanhargaon, Rangenapalli and Medaram come under the Lower Gondwana formations. These represent the lower most formations in the Gondwanas deposited during the Glacial Period. Deposition started during the Talchir Period, which comprises boulders, pebbles, rock fragments, mud stones, greenish shales, greenish to brown sandstones and clays.

Subsequently there was a thick series of fluvial deposition of sandstones, shales and coal seams. This group is called as Barakar Series. This series is overlain by rocks of Kamthi Series, which comprises brownish to white shales and clay. These three series are generally met in all the coalfields of Maharashtra. In these areas abundant plant fossils like petrifications, impressions and compressions occur.

MATERIAL AND METHODS

Numerous well preserved petrified woods were collected from different Lower Gondwana localities of Chandrapur District of Maharashtra during our paleobotanical field trips for the past five years. The present paper deals with the detailed anatomical investigation of three well preserved decorticated petrified woods selected among many species collected.

The petrified woods described in the present paper were collected from Wejgaon, which is a small village situated at a distance of about 60 km south east of Chandrapur and also from Wejgaon-Aravi *nala* on the outskirts of the village in open fields and dried-up *nalas*. In *nalas* the fossil woods have been transported by water to the present place from surrounding areas in past. Many of them might have preserved *in-situ*. Three new species of petrified woods are described in this paper, are numbered as B.U.P.W. Nos.: 2018, 2028 and 2090. After thorough microscopic observations the three fossil woods were assigned to *Araucarioxylon*.

Nature of preservation of petrified woods—Although most of the petrified woods investigated in the present work were of silicified type, they were extremely well preserved in certain parts with lot of organic matter. Before sectioning the woods the different measurements of each wood like length, breadth and diameter were recorded as in Fig. 5. In certain cases where the specimens were very big, the woods were

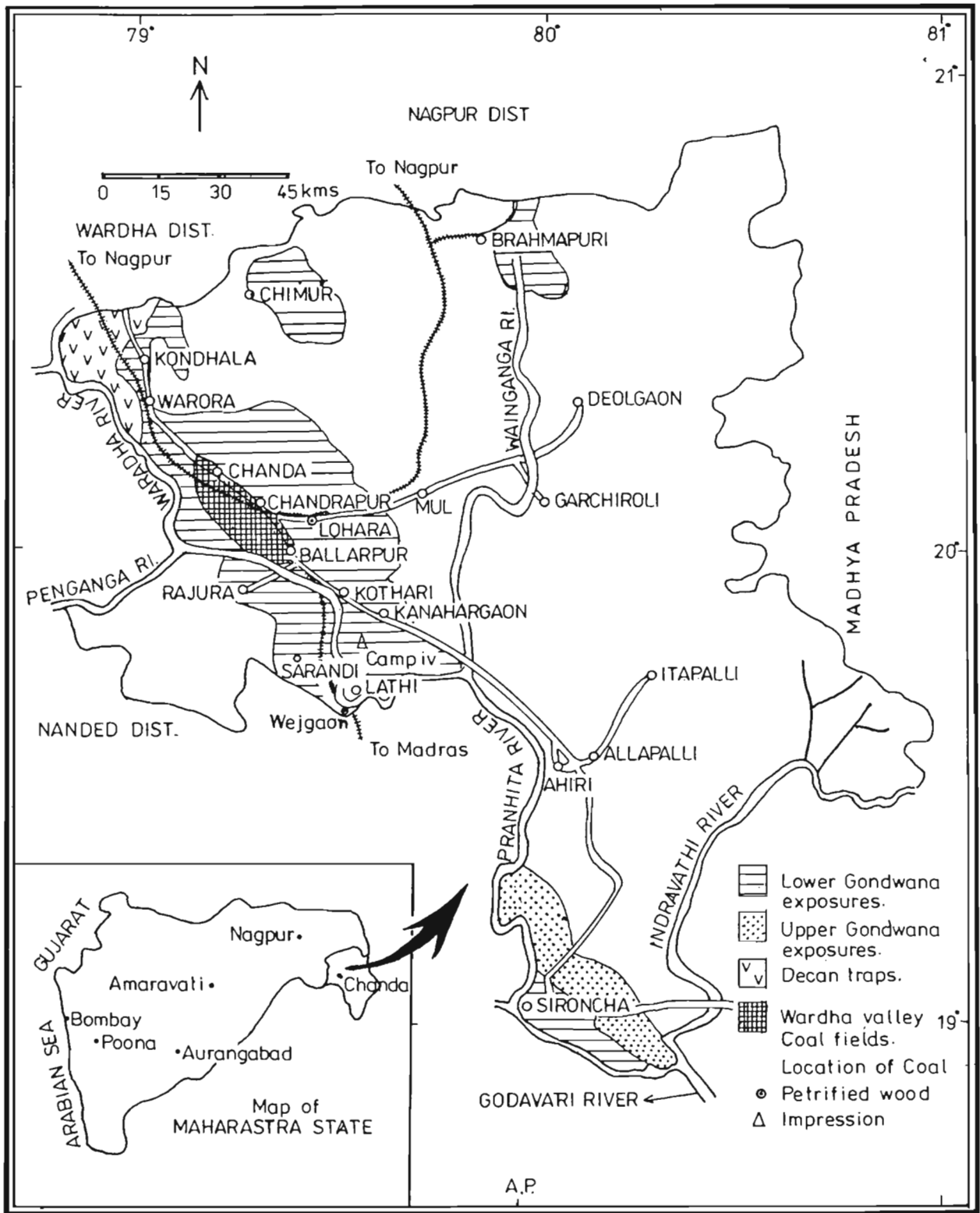


Fig. 1—Geological Map of Chandrapur District of the Maharashtra.

broken down into small pieces of convenient size using geological hammer. Only well preserved portion of the wood was selected for further sectioning and investigation. Usually woods which are brownish to blackish or part of the wood showing brownish to black colour were well preserved with lot of organic matter. After selecting the woods, several sections in different planes like T.S., T.L.S., R.L.S. were made by employing standard methods of sectioning by using Diamond saw cutting machine and later grinding and polishing the sections by using carborandum powder of grades no. 100 and 400 on grinding lap.

RESULT

Anatomical description of petrified woods—After detailed anatomical investigations and comparison, the woods were designated as the new species of *Araucarioxylon*. The detailed anatomical description of each petrified wood selected in present study along with some of the salient features of the genera to which they are assigned are given below.

Araucarioxylon: is a commonly occurring genus of Lower Gondwana gymnospermous woods reported from India in general and Chandrapur District of Maharashtra in particular. It differs from *Dadoxylon* in the absence of a pith and primary xylem (Lepekhina, 1972). As far as we know, more than 51 species of *Araucarioxylon* occur in various parts of world, 15 of these species are reported from India.

Reports of the occurrence of *Araucarioxylon* species from Chandrapur District of Maharashtra are mainly due to the investigations of Agashe *et al.* (1972-1998) from Paleobotany Research Laboratory, Department of Botany, Bangalore University, who described *A. loharense*, *A. surangeii*, *A. lathiense*, *A. kotharensis*, *A. bhivkundense*, *A. wejgaoense*. Vagyani and Raju (1981) described *A. nandori* from Chandrapur District.

Emended generic diagnosis of *Araucarioxylon* (Kraus, 1870) emend Maheshwari (1972)

Growth rings distinct to absent, tracheidal radial pitting of araucarian type, usually multiseriate, alternate, hexagonal, sometimes uniseriate and contiguous, cross field pits cupressoid, spiral thickening in trachieds are absent xylem rays are uniseriate, partly biseriate.

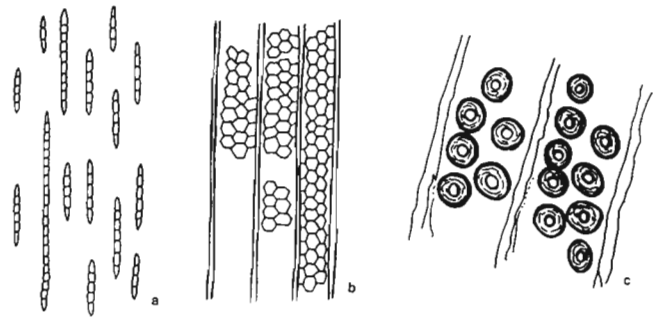


Fig. 2—*Araucarioxylon aravii* sp. nov. a. T.L.S. showing medullary rays. x 100. b. R.L.S. showing hexagonal biseriate alternate pits. x 100. c. R.L.S. showing circular, biseriate, alternate and opposite pits. x 250. d. Cross field showing two, three, four, five, six and single field pits. x 250.

ARAUCARIOXYLON ARAVII sp. nov.

Pl. 1.1-8; Fig. 2

Specific Diagnosis—Decorticated secondary wood with distinct growth rings, rays 1-3 seriate, 2-15 cells high, 3 seriate, rays being rare, tangential pits present, radial pits 1-3 seriate, araucarioid, cross-field pits 1-6 cupressoid.

Holotype—B.U.P.W. no. 2018 with slides deposited in Paleobotany and Palynology Laboratory, Department of Botany, Bangalore University, Bangalore.

Locality—Wejgaon – Aravii nala, Chandrapur District, Maharashtra, India.

Etymology—The present new species of wood has been described as *Araucarioxylon aravii* sp. nov., the specific epithet being derived from Aravi nala from where the fossil wood was collected.

PLATE 1

Araucarioxylon aravii sp. nov.

- | | |
|---|--|
| 1. Transverse section showing growth rings with early wood. x 100. | 5. Radial wall showing circular, biseriate, alternate pits with oblique/elliptic pore in center. x 1000. |
| 2. Radial wall showing biseriate, hexagonal alternate pits. x 250. | 6. Radial wall showing circular, biseriate, alternate pits. x 1000. |
| 3. Radial wall showing biseriate, partly triseriate hexagonal alternate bordered pits. x 250. | 7. Cross field showing two, three, five cupressoid field pits. x 1000. |
| 4. Radial wall showing alternate, hexagonal biseriate pits. x 250. | 8. Cross field showing six cross field pits. x 1000. |

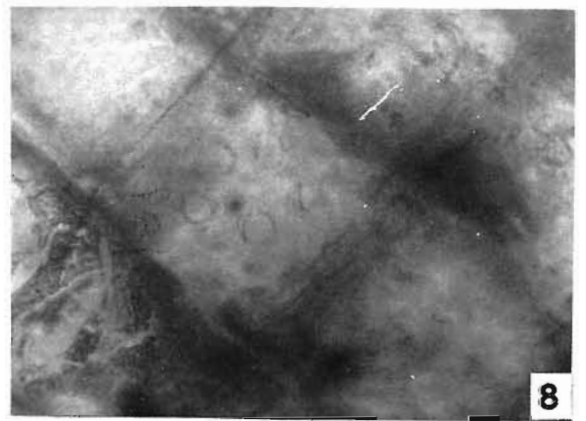
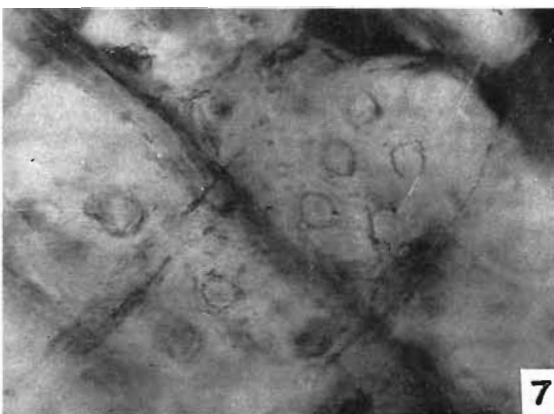
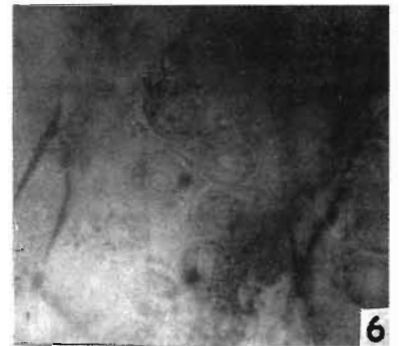
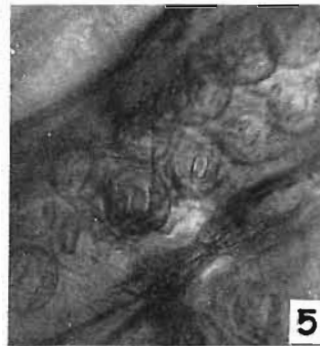
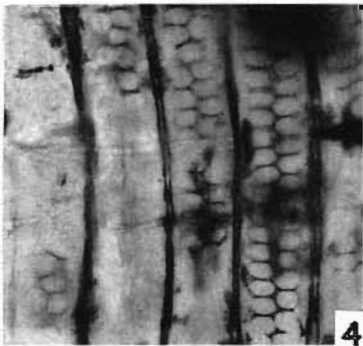
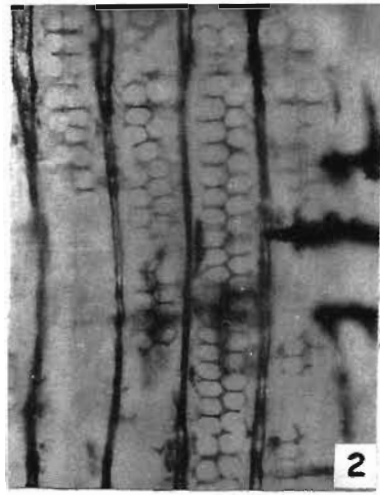


PLATE I

Geological Age—Lower Gondwana (Permian).

On the basis of generic characters the present wood is assigned to *Araucarioxylon*, it is evident that the present wood belongs to a new species of *Araucarioxylon* as explained below.

Anatomical Description—The material consists of a decorticated secondary wood measuring 8 cm in length and 4 x 3.5 cm in thickness. In T.S. the secondary wood shows distinct growth rings (Pl. 1.1). The early wood tracheids are 120-180 cells thick and are mostly rectangular in shape. The tracheids of early wood measure 1.35 x 2.57 mm in size whereas late wood tracheids are comparatively narrower, squarish 4-5 cells thick measuring 0.16 x 0.28 mm in size.

Tangential longitudinal section shows the medullary rays which are 1-3 seriate, commonly uniseriate, 3 seriate rays being rare (Fig. 2a) and 2-15 cells high with average height of the rays being 5-8 cells. Tangential pits are distinct.

Radial longitudinal section reveals the radial pits which range from 1-3 seriate, mostly 2 seriate araucarioid, sometimes pits are found in groups of 2 or 3. The bordered pits are arranged in various manners. Biseriate and triseriate hexagonal pits are alternate or sub-opposite (Pl. 1.2-4; Fig. 2b). Biseriate circular pits are opposite, uniseriate (Pl. 1.5, 6; Fig. 2c), radial pits are contiguous. The bordered pits are circular as well as hexagonal with distinct border. The maximum diameter of bordered pit is 11.2 mm and shape of pit pore is spherical and diameter of pit pore is 4 mm. The cross field pits are 1-6 cupressoid, spherical-oval in shape, commonly 2-5 pits occur per field. The average diameter of cross field pit is 6.2 mm (Pl. 1.7, 8; Fig. 2d).

Discussion and Comparison—The petrified wood described above shows generic diagnostic characters of *Araucarioxylon* Kraus (1870), emend Maheshwari (1972) in having cupressoid cross-field pits and araucarioid radial pits.

The present specimen or B.U.P.W. no. 2018 differs from all the described species of *Araucarioxylon*, but resembles some species of *Araucarioxylon* in some of the anatomical characters. In having a maximum number of 6 cross-field pits the present specimen resembles *A. nandori* (Vagyani & Raju, 1981) and *A. wejgaense* (Agashe & Shashi Kumar, 1996) but differs from the described species in medullary ray and radial wall pitting characters.

However, this new species of wood does not have any resemblance with *A. mohgaensis* (Lakhanpal *et al.*, 1977) in

cross-field pitting and medullary ray characters. The only similarity is in radial wall pitting. In both *A. mohgaensis* and the present wood, the radial pits are 1-3 seriate mostly 2 seriate.

The present newly described wood differs from *A. kothariensis* (Agashe & Prasad, 1984) in radial wall pitting and cross-field pitting characters. In both *A. kothariensis* (Agashe & Prasad, 1984) and in *A. aravii* sp. nov. medullary ray is 1-3 seriate with the average height of 8 cells. The comparison of new species with all the described species of *Araucarioxylon* has been shown in comparative Fig. 5.

The present new species of wood has been described as *Araucarioxylon aravii* sp. nov., the specific epithet being derived from Aravi *nala* from where the fossil wood was collected.

ARAUCARIOXYLON CHANDRAPURENSIS sp. nov.

Pl. 2.1-9; Fig. 3

Specific Diagnosis—Decorticated secondary wood with distinct growth rings, 1-2 seriate medullary rays, mostly uniseriate, 2-36 cells high, tangential pits present, 1-3 seriate araucarioid radial pits, cross-field pits 1-7 cupressoid type.

Holotype—B.U.P.W. no. 2028 along with slides deposited in Paleobotany and Palynology Laboratory, Department of Botany, Bangalore University, Bangalore.

Locality—Wejgaon - Aravi *nala*, Chandrapur District, Maharashtra, India.

Etymology—The present wood is described as a new species of *Araucarioxylon*, *A. chandrapurensis* sp. nov., the specific name is given after Chandrapur District, from where the wood is collected.

Geological Age—Lower Gondwana (Permian).

On the basis of generic characters the present wood is assigned to *Araucarioxylon*. It is evident that the present wood belongs to a new species of *Araucarioxylon* as explained below.

Anatomical Description—The material consists of decorticated secondary wood measuring 10.4 cm in length and 5.2 x 4.9 cm in thickness with distinct growth rings. In T.S. the growth rings are clear (Pl. 2.1). The early wood tracheids are 80-120 cells thick and rectangular in shape. The tracheids of early wood measure 2.20 x 2.62 mm in size, whereas late wood tracheids are comparatively narrower, 2-4 cells thick measuring 0.14 x 0.46 mm in size.

PLATE 2

Araucarioxylon chandrapurensis sp. nov. →

- | | |
|--|---|
| 1. Transverse section showing growth rings with early wood. x 100. | 6. Cross field showing two, three, four, five, circular oval pits. x 250. |
| 2. TLS showing uniseriate and biseriate medullary rays. x 100. | 7. Cross field showing two, four, five, seven cupressoid field pits. x 250. |
| 3. Cross field showing one, two, three, four cross field pits. x 250. | 8. Cross field showing three, four, five, seven cupressoid field pits. x 250. |
| 4. RLS showing hexagonal biseriate, triseriate alternate radial pits. x 250. | 9. Cross field showing two, three, four field pits. x 250. |
| 5. Cross field showing two, three cupressoid pits. x 250. | |

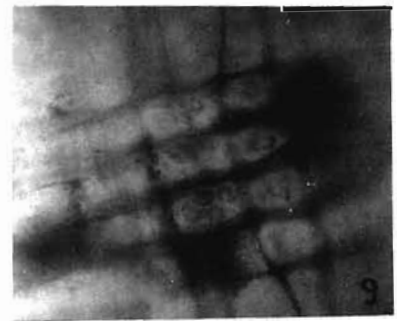
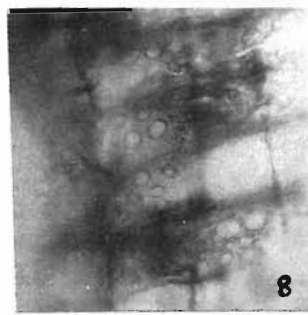
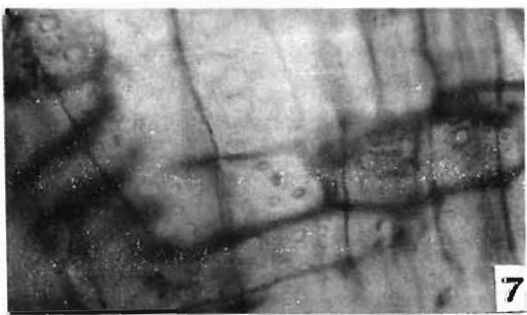
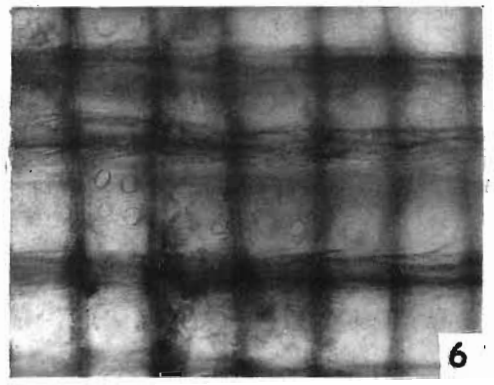
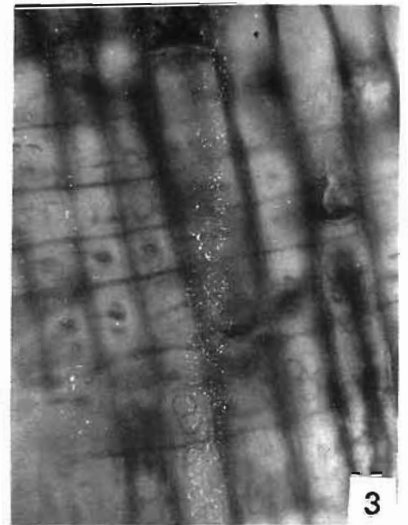
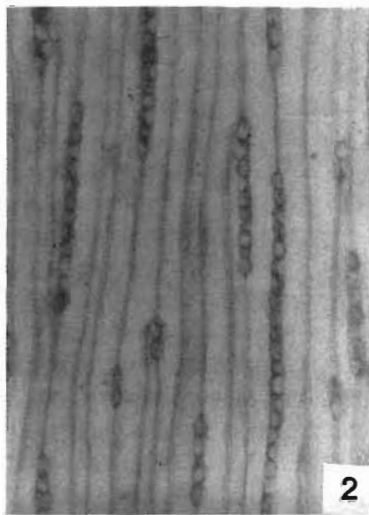


PLATE 2

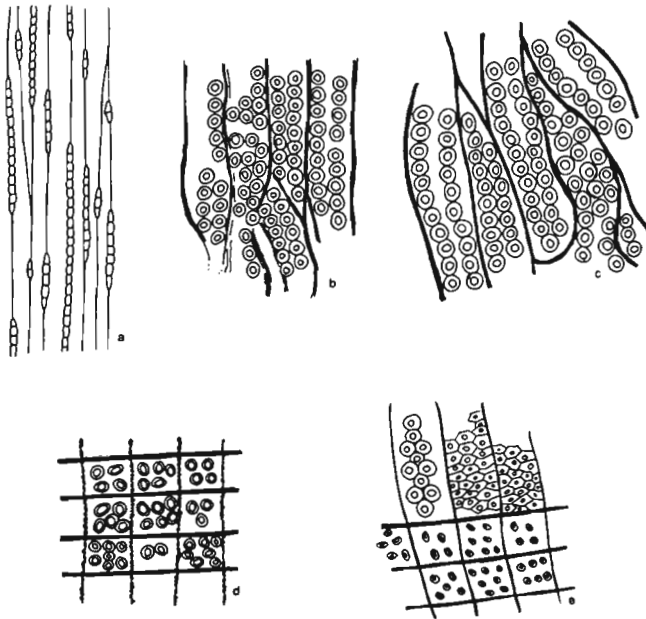


Fig. 3—*Araucarioxylon chandrapurensis* sp. nov. a. T.L.S. showing uniseriate medullary rays. x 100. b. R.L.S. showing uniseriate, biseriate and triseriate circular alternate pits. x 250. c. R.L.S. showing uniseriate, biseriate, triseriate circular alternate and opposite pits. x 250. d. Cross field showing two, three, four, five, six and seven field pits. x 400. e. R.L.S. showing uniseriate/partly biseriate circular pits and three-four seriate hexagonal alternate pits and cross-field showing four, five, six and seven field pits. x 250.

Tangential longitudinal section shows medullary rays which are 1-2 seriate, mostly uniseriate 2-36 cells high on an average height of 15 cells. Tangential pits are distinct (Pl. 2.2; Fig. 3a).

Radial longitudinal section reveals the radial pits which are 1-3 seriate, araucarioid mostly 2 seriate with distinct pit pore in centre. Radial pits are arranged in various manner. Biseriate circular pits are alternate or sub-opposite, but biseriate circular pits are oppositely placed in some areas. Triseriate circular pits are alternately placed. Uniseriate pits are contiguous, while biseriate and triseriate hexagonal pits are alternate (Pl. 2.4; Figs 3b, c, e). The maximum diameter of radial pit is 10 mm and that of pit pore is 3.84 mm. The cross-field pits are 1-7 cupressoid, spherical, oval, commonly 2, 4, 5 pits occur per cross field (Pl. 2.3, 5-9; Figs 3d, e).

Discussion and Comparison—The petrified wood B.U.P.W. no. 2028 is assigned to *Araucarioxylon*, as it shows the diagnostic characters of *Araucarioxylon* by having cupressoid cross-field pits and araucarioid radial wall pits. The present specimen differs from all the described species of *Araucarioxylon* by having a maximum number of seven cross field pits, but it resembles few described species of *Araucarioxylon* in other anatomical characters.

The new Araucarian wood resembles *A. mohgaoensis* (Lakhanpal *et al.*, 1977) in medullary ray and radial wall pitting characters, but differs from *A. mohgaoensis* (Lakhanpal *et al.*, 1977) in cross-field pitting characters. In new species of wood and *A. mohgaoensis* (Lakhanpal *et al.*, 1977), medullary ray is uniseriate 2-36 cells high, the average height of the ray is 8-15 cells. Radial wall pits 1-3 seriate, mostly 2 seriate, contiguous alternate. The new species of fossil wood resembles *A. surangei* (Agashe *et al.*, 1981), *A. nandori* (Vagyani & Raju, 1981), *A. bhivkundense* (Agashe & Prasad, 1984), *A. wejgaense* (Agashe & Shashi Kumar, 1996) in medullary ray characters, but differs from all the four species of *Araucarioxylon* in radial pitting and cross-field pitting characters. The new species of Araucarian wood and *A. nandori* (Vagyani & Raju, 1981), *A. surangei* (Agashe *et al.*, 1981), *A. bhivkundense* (Agashe & Prasad, 1984), *A. wejgaense* (Agashe & Shashi Kumar, 1996) resemble each other in having 1-2 seriate medullary ray mostly uniseriate 2-35 cells high on an average height of the ray is 8-15 cells. The comparison of new species of wood with all the described species of *Araucarioxylon* prompted us to describe the present wood as a new species of *Araucarioxylon* as shown in comparison Fig. 5.

ARAUCARIOXYLON SHAILAE sp. nov.

Pl. 3.1-10; Fig. 4

Specific Diagnosis—Decorticated secondary wood with distinct growth rings, 1-2 seriate mostly uniseriate, 2-46 cells high medullary rays, tangential pits are distinct, 1-3 seriate araucarioid radial pits, 1-8 cupressoid cross-field pits.

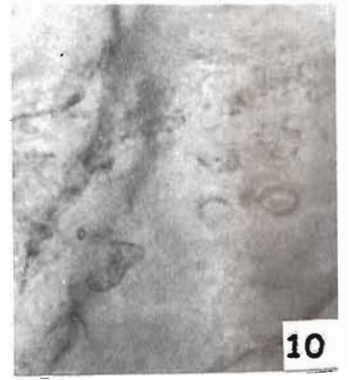
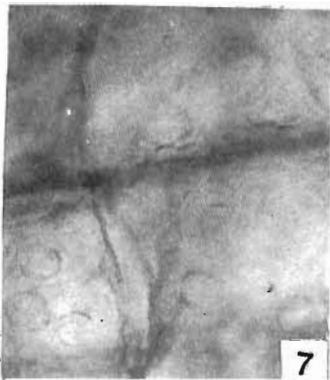
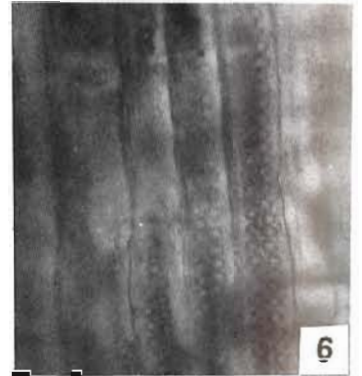
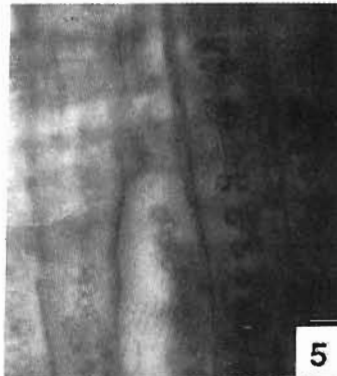
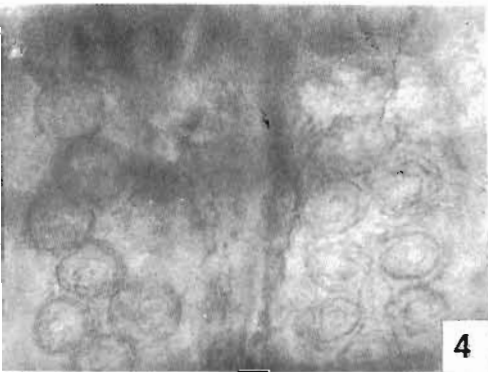
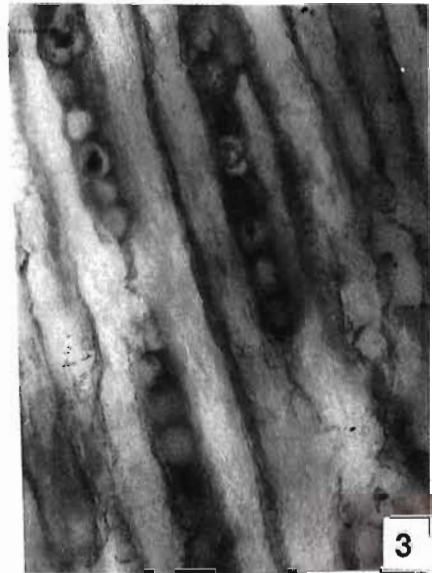
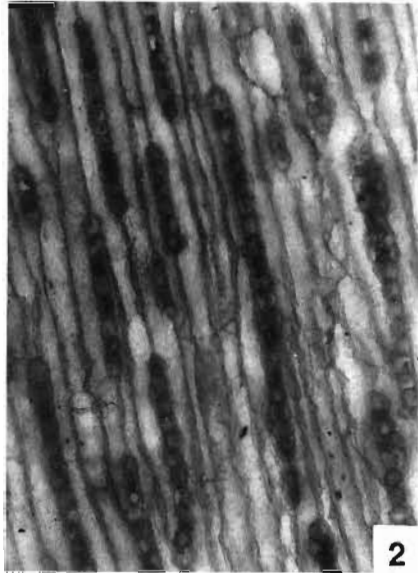
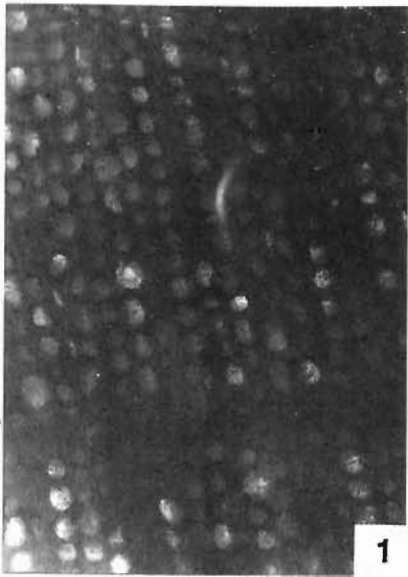
Holotype—B.U.P.W. no.: 2090 along with slides deposited in Paleobotany and Palynology Laboratory, Department of Botany, Bangalore University, Bangalore.

Locality—Wejgaon Village, Chandrapur District, Maharashtra, India.

PLATE 3

Araucarioxylon shilae sp. nov.

1. Transverse section showing growth rings with early wood tracheids. x 100.
2. TLS showing uniseriate and biseriate radial pits. x 250.
3. TLS showing uniseriate and biseriate medullary rays and tangential pits. x 400.
4. RLS showing uniseriate and biseriate circular radial pits biseriate radial pits are opposite, uniseriate / partly biseriate pits are opposite. x 1000.
5. RLS showing biseriate circular radial pits in groups of 2, 3, 4 and uniseriate circular contiguous pits. x 250.
6. RLS showing biseriate circular opposite pits. x 250.
7. RLS showing 3, 5 cupressoid cross field pits. x 1000.
8. RLS showing 2, 4 circular cupressoid cross field pits. x 250.
9. RLS showing 2, 4, 6 circular cupressoid cross field pits. x 400.
10. RLS showing 4 circular cupressoid cross field pits. x 1000.



Sl. No.	Name of the Genus & Species	Geological Age	Growth ring	Medullary ray	Tangential pits	Border pitting on radial walls	Cross field pits	Locality
1.	<i>A. arberi</i> (Seward, 1919) comb. nov. Maheshwari 1972	Upper Carboniferous	Distinct	1-21 cells high, usually 6-12 cells high	Absent	1-4 seriate, circular	1-10 oblique	Australia
2.	<i>A. manieroi</i> (Krausel & Dolianiti, 1958) comb. nov. Maheshwari 1972	Upper Carboniferous	Distinct	1-47 cells high, on an average of 9-10 cells high	Absent	1-4 seriate, pore elliptical	1-9, sometimes in groups	Brazil
3.	<i>A. mohgaensis</i> Lakhnampal <i>et al.</i> , 1977	Early Tertiary	Distinct	Uniseriate, 2-30 cells high, mostly 8-15 cells	Absent	1-3 seriate, mostly 2 seriate, contiguous alternate / hexagonal	1-2 bordered, cupressoid, circular-oval in shape	Mohgaon - Kalan Chindwara Dist., M.P.
4.	<i>A. gondwanense</i> (Maithy, 1964) comb. nov. Maheshwari 1972	Lower Permian	Distinct	13% rays are 2 seriate. 1-43 cells high, average of 9-10 cells high	Absent	1-5 seriate, alternate / sub opposite	2-8 contiguous / separate, circular - oval in shape	Jharia C.F. (Bihar)
5.	<i>A. parbeliense</i> (Rao, 1935) comb. nov. Maheshwari 1972	Permian	Distinct	1-24 cells high, mostly 2-3 cells high	Absent	1-5 seriate, pore circular - oval	8-9 bordered, pores oblique slit like	Parbelia colliery, Bengal
6.	<i>A. loharensis</i> Agashe & Gowda, 1978	Permian	Distinct	1-2 seriate, 2-27 cells high, on an average height of 11 cells high	Present	1-4 seriate, round - hexagonal with distinct border	2-9, most commonly 2, 4, 6 pits / field	Lohara, Chandrapur, M.S.
7.	<i>A. lathiense</i> Agashe <i>et al.</i> , 1981	Permian	Distinct	Uniseriate, 1-27 cells high on an average height of 5 cells	Absent	1-4 seriate, alternate / separate, contiguous	1-10 cupressoid, circular-oval with thin border	Lathi, Chandrapur, M.S.
8.	<i>A. surangeii</i> Agashe <i>et al.</i> , 1981	Permian	Distinct	1-2 seriate, commonly 1 seriate, 1-35 cells on an average of 4 cells high	Present	1-4 seriate alternate, separate contiguous hexagonal	1-11 cupressoid, commonly 2, 4 round-oval	Lathi, Chandrapur, M.S.
9.	<i>A. nandori</i> Vagyani & Raju, 1981	Upper Permian	Distinct	1-2 seriate, mostly uniseriate 2-30 cells high	Absent	1- multiseriate, free contiguous / hexagonal	2-6, cupressoid	Nandori, Chandrapur: M.S.
10.	<i>A. bhivkundense</i> Agashe & Prasad, 1984	Permian	Distinct	1-2 seriate free, 1-33 cells high with an average height of 8 cells	Present	1-2 seriate free / contiguous sometimes in groups of 2, 3, 4	1-8 cupressoid, commonly 2, 4 pits occur / field	Bhivkund, Chandrapur, M.S.

11	<i>A. kolhariensis</i> Agashe & Prasad, 1984	Permian	Distinct	1-3 seriate, 1-44 cells high with an average height of 8 cells	Present	1-4 seriate, araucarioid free / contiguous radial pits in groups of 2, 3, 4	1-12 cupressoid, with thin border commonly 4-8 field pits occur / field	Wejgaon, Chandrapur, M.S.
12.	<i>A. semibiseriatum</i> Pant & Singh, 1987	Permian	Distinct	Uniseriate or partly biseriate, 1-24 cells high, rarely up to 38 cells on an average height of 2-9 cells	Present	1-4 seriate, rarely 5 seriate, circular/oval pits, contiguous, sub-opposite or alternate pits	4-16 cupressoid, usually 6-12 pits occur / field	Raniganj Coalfield
13.	<i>A. wejgaonense</i> Agashe & Shashi Kumar, 1996	Permian	Distinct	1-2 seriate free, 2-34 cells high, with an average height of 8-12 cells, mostly uniseriate	Present	1-2 seriate, mostly 2 seriate contiguous / alternate sub-opposite may be in groups of 2, 3, 4	1-6 cupressoid, commonly 2-4 pits occur / field	Wejgaon, Chandrapur, M.S.
14.	<i>A. aravii</i> sp. nov. Agashe & Shashi Kumar, 1998	Permian	Distinct	1-3 seriate, uniseriate condition is common, 2-15 cells on an average height of 5-8 cells	Absent	1-3 seriate, araucarioid, hexagonal, alternate, bars of sanio seen, mostly hexagonal, biseriate pits are alternate	1-6 cupressoid, circular-oval, commonly 3 pits occur / field	Wejgaon, Chandrapur, M.S.
15.	<i>A. chandrapurensis</i> sp. nov. Agashe & Shashi Kumar, 1998	Permian	Distinct	1-2 seriate, mostly uniseriate, 2-36 cells high on an average of 15 cells	Present	1-3 seriate, araucarioid mostly 2 seriate with distinct lumen in center. Circular-hexagonal, 2 seriate pits are alternate / sub-opposite	1-7 cupressoid, commonly 2, 4, 5 pits occur commonly / field	Wejgaon, Chandrapur, M.S.
16.	<i>A. shailae</i> sp. nov. Agashe & Shashi Kumar, 1998	Permian	Distinct	1-2 seriate, mostly uniseriate, 2-46 cells high on an average height of 20 cells, uni - 60% bi - 40%	Distinct	1-3 seriate araucarioid, mostly 2 seriate uniseriate circular pits are contiguous, biseriate circular pits are oppositely placed, 3 seriate pits are also alternately placed / oppositely place 2 seriate hexagonal pits are alternately placed	1-8 cupressoid, circular, commonly 2, 4, 5 pits occur / field	Wejgaon, Chandrapur, M.S.

Fig. 5—Comparative anatomical characters of different species of *Araucarioxylon*.

Geological Age—Lower Gondwana (Permian).

Etymology—The present wood is described as a new species of *Araucarioxylon*, *A. shailae* sp. nov., the specific epithet is given in honour of Dr Shaila Chandra, Palaeobotanist at the Birbal Sahni Institute of Palaeobotany, Lucknow, for her significant work on Lower Gondwana megafossils.

On the basis of generic characters the present wood is assigned to *Araucarioxylon*, it is evident from the present characters, the wood belongs to new species of *Araucarioxylon* as explained below.

Anatomical Description—The material consists of decorticated secondary wood measuring 7 cm in length and 5.8 x 3 cm in thickness showing distinct growth rings (Pl. 3-1). The early wood tracheids are 40-80 cells thick, they are rectangular in shape. The early wood tracheids measure 0.5 x 2.0 mm in size, whereas late wood tracheids are 2-4 cells thick measuring 0.075 x 0.125 mm in size.

Tangential longitudinal section shows medullary rays which are 1-2 seriate, mostly uniseriate, 2-46 cells high with an average height of 20 cells. Uniseriate medullary rays represent 60% and biseriate medullary rays are represented by 40% of total rays. Tangential pits are distinctly circular, contiguous (Pl. 3.2, 3; Figs 4a, b).

Radial longitudinal section reveals the radial pits which are 1-3 seriate, mostly 2 seriate, araucarioid with distinct pit pore in the centre. Radial pits are arranged in various manners. The uniseriate circular pits are contiguous, biseriate; triseriate circular pits are alternately placed. Sometimes radial pits are found in groups (Pl. 3.4-6; Figs 4c-e). The maximum diameter of radial pit is 10.27 mm and shape of the pit pore is spherical and diameter of pit pore is 4 mm. The cross-field pits are 1-8 cupressoid, circular, 2, 4, 5 pits occur/field. The average diameter of cross-field pits is 6.7 mm (Pl. 3.7-10; Figs 4f, g).

Discussion and Comparison—The petrified wood described above shows generic diagnostic characters of *Araucarioxylon* by having cupressoid cross-field pits and araucarioid radial wall pits. The present specimen differs from all the described species of *Araucarioxylon*, but resembles some species of *Araucarioxylon* in certain anatomical characters.

The new araucarian wood closely resembles *A. maneroi* (Krausel & Dolianiti, 1958; comb. nov. Maheshwari, 1972) in medullary ray characters, but differs from it in other anatomical characters (radial wall pitting and cross-field pitting characters). In both *A. maneroi* and the present wood medullary rays are 2-46 cells high.

The present wood also resembles *A. mohgaensis* (Lakhanpal *et al.*, 1977) in radial wall pitting characters but differs from *A. mohgaensis* (Lakhanpal *et al.*, 1977) in other anatomical characters. In both *A. mohgaensis* and present wood radial pits are 1-3 seriate.

In both *A. bhivkundense* (Agashe & Prasad, 1984) and present wood similarity in cross-field pitting is seen, but it differs in other anatomical characters. In both *A. bhivkundense*

(Agashe & Prasad, 1984) and present wood cross-field pits are 1-8 cupressoid.

Although present wood resembles some species of *Araucarioxylon* as discussed above, but it differs from all the described species of *Araucarioxylon* in medullary ray, radial wall pitting and cross-field pitting characters. Hence this wood is described as a new species of *Araucarioxylon* as shown in Fig. 5.

DISCUSSION

Paleobotanical exploration of Maharashtra which was carried out during the past 5-6 years has brought to light several new fossil bearing localities suggesting strongly the existence of highly diversified flora during the Lower Gondwana Period. The real picture of past vegetation may be reconstructed by studying the organic remains of the plants in various forms. Petrified plant material forms the best evidence of the past plant life because of the varied anatomical characters which can be studied from it.

The secondary xylem is very well preserved in all the three species of fossil woods. Pith, primary xylem or cortical tissues are not preserved properly. The xylotomical studies of

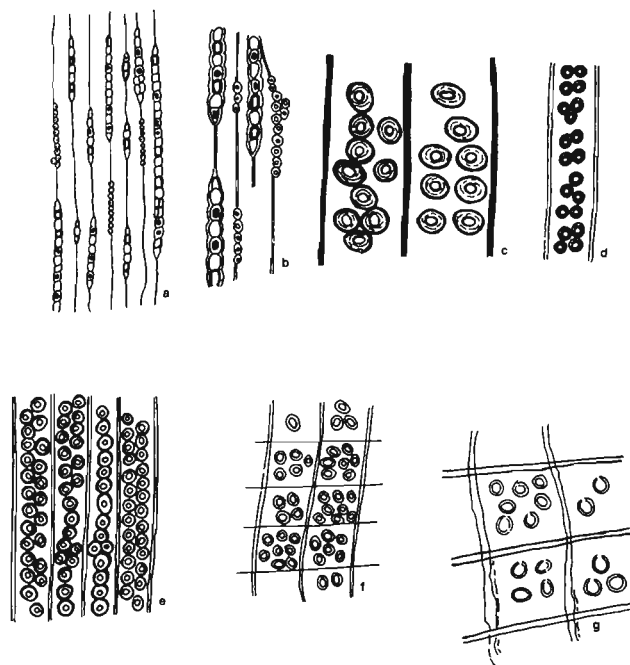


Fig. 4—*Araucarioxylon shailae* sp. nov. a. T.L.S. showing uniseriate and biseriate medullary rays. x 100. b. T.L.S. showing uniseriate medullary rays and tangential pitting. x 250. c. R.L.S. showing circular biseriate opposite pits and pits in groups of two and three. x 400. d. R.L.S. showing circular biseriate opposite pits in groups of two, three and four. x 100. e. R.L.S. showing uniseriate contiguous pits and biseriate alternate pits. x 250. f. Cross field showing one, two, three, four, five, six, seven and eight field pits. x 250. g. Cross field showing two, three, four, seven field pits. x 400.

woods from Wejgaon and Wejgaon-Aravi *nalas* exhibit remarkable resemblance. These woods were characterised by distinct growth rings uniseriate to triseriate nature of rays (uniseriate being most common). Uniseriate to multiseriate border pits which are mostly typically araucarioid type in nature i.e., horizontally compressed and hexagonal arranged in groups and cupressoid cross field pits with thin borders. On account of the presence of these characters all the three species of fossil woods have been assigned to genus *Araucarioxylon* Kraus. However, these three woods differ from each other in characters such as thickness and height of medullary rays and number of cross-field pits and hence differs from all the described species of *Araucarioxylon*. The occurrence of these three new species of *Araucarioxylon* and also *A. lathiense*, *A. surangeii*, *A. loharensis*, *A. bhivkundense*, *A. kothariensis* and *A. wejgaonense* by Agashe *et al.* (1978-1997) from Lower Gondwana Horizon of Chandrapur District suggests that *Araucarioxylon* was rather a well established conifer in Chandrapur District during the Lower Gondwana Period. This discovery of 3 new species of *Araucarioxylon* adds to the diversity of gymnospermous vegetation of Lower Gondwana.

Acknowledgements—We are thankful to the Department of Science and Technology for financial assistance to the major research scheme, entitled "Macrofossil investigation of Lower Gondwana Strata occurring in Maharashtra" during which the above work was carried out. Assistance of Dr P.R.N. Gowda and Mr K.P. Nagaraj in collection of material and Dr Mary Scinthia J.D and Dr Mini Susan Philip in preparation of manuscript and Shashidhar J in preparation of photographic plates are gratefully acknowledged.

REFERENCES

- Agashe SN & Gowda PRN 1978. Anatomical study of a fossil gymnospermous woods from the Lower Gondwana Strata of Maharashtra. *Phytomorphology* 28: 15-19.
- Agashe SN & Prasad KR 1984. Studies on fossil gymnospermous woods Part VI: Two new species of *Araucarioxylon* & *Australoxylon* from Lower Gondwana Strata of Chandrapur District, Maharashtra state, India. Proceedings of the Fifth Indian Geophytological Conference, Lucknow (1983), Spec. Publ. 1984, pp. 278-287.
- Agashe SN & Prasad KR 1989. Studies on fossil gymnospermous woods Part VII: Six new species of Lower Gondwana (Permian) gymnospermous woods from Chandrapur District of Maharashtra state, India. *Palaeontographica* 212 B : 71-102.
- Agashe SN & Shashi Kumar MS 1996. Studies in fossil gymnospermous woods Part VIII: A new species of *Araucarioxylon* i.e., *A. wejgaonense* from Lower Gondwana Strata of Chandrapur District of Maharashtra. *Palaeobotanist* 45 : 15-19.
- Agashe SN, Prasad KR & Suresh FC 1981. Two new species of (*Araucarioxylon* i.e., *A. surangeii*, *A. lathiense*) petrified woods from Lower Gondwana Strata (Dr K.R. Surange Comm. Vol.). *Palaeobotanist* 28-29 : 122-127.
- Greguss P 1955. Identification of living gymnosperms on the basis of xylotomy Budapest Akad Kiado : 1-263.
- Greguss P 1967. Fossil gymnosperm woods in Hungary from Permian to Pliocene. Budapest Akad Kiado : 1-136.
- Kraus G 1870. Bois fossiles de conifers. In : Schimper WP (Editor) – Traite de Palaeontologie vegetale on la flore du Monde Primitif 2, - Paris : 363-385.
- Lakhanpal RN, Prakash U & Bande MB 1977. An Araucarian fossil from the Deccan Intertrappean beds of Mohgoan Kalan. *Palaeobotanist* 24: 125-131.
- Lepekhina VG 1972. Woods of Palaeozoic pycnoxylic gymnosperms with special reference to North Eurasia representatives. *Palaeontographica* 138B : 44-106.
- Maheshwari HK 1972. Permian woods from Antarctica and revision of some Lower Gondwana wood taxa. *Palaeontographica* 138B : 1-43.
- Maithy PK 1968. Some further observations and remarks on *Araucarioxylon daintheii* Chapman. *Palaeobotanist* 16: 145-147.
- Pant DD & Singh VK 1987. Xylotomy of some woods from Raniganj Formation (Permian) Raniganj Coalfield, India. *Palaeontographica* 203B : 1-82.
- Prasad MNV 1982. An Annotated Synopsis of Indian Palaeozoic gymnospermous woods. Review of Palaeobotany and Palynology 38: 119-156.
- Prasad MNV 1986. Xylotaphoflora of the Kamthi Formation Indian Lower Gondwana with remarks on its biostratigraphic importance of its taphoflora. *Palaeontographica* 201B : 111-134.
- Ramanujam CGK 1978. Geological history of Araucariaceae. The Botanique 9 : 1-4.
- Schenk A 1882. Die von den Gebrudern Schlagenwelt in Indian gesammelten fossilen Holzer. *Engl. Bot. Jahrb.* 3 : 353-358.
- Stopes 1914. A new *Araucarioxylon* from New Zealand. *Annals of Botany* 28(110) : 341-350.
- Text book of Geology and Mineral Resources of Maharashtra 1975. Published by Geological Survey of India.
- Vagyani BA & Raju AVV 1981. A new species of gymnospermous wood *Araucarioxylon* (Kraus) from Nandori Maharashtra state. *India Biovignanam* 7 : 11-13.
- Vardapande 1978. *Dadoxylon satnauriense* – a new species of petrified gymnospermous wood from the Lower Gondwana of India. *J. Univ. Poona, Sci. Technol.* 50 : 159-162.