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Similar tree ring pattern in the Gymnosperm woods from Late Permian of Antarctica and India

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ABSTRACT

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Tree rings revealed in a newly described gymnosperm wood *Araucarioxylon ghoshii* sp. nov. from Raniganj Formation, Raniganj Coalfield, India are similar to the tree rings described in the *in situ* gymnosperm fossil woods from the Late Permian of Antarctica.

The rings of the fossil woods from Antarctica and India have higher proportion of early woods compared to little amount of late wood. Characteristic zigzag pattern of early wood tracheids formed due to collapsing and crushing of tracheid files and false rings occur in the woods recorded from two distant areas. The characters suggest occurrence of rapidly growing young forest in both the continents during Late Permian. Quantitative analysis of growth rings in *A. ghoshii* reveals a CSDM curve with right skewedness +19% suggesting its possible evergreen nature with small to moderate leaf retention time.

Key-words—Late Permian, Antarctica, *Araucarioxylon.*

अण्टार्कटिका एवं भारत के अन्तिम परमियनयुगीन अनावृतबीजी काष्ठों का सममित वृक्ष वलय विन्यास

सुबीर बेरा एवं मंजु बनर्जी

सारांश

भारत के रानीगंज कोयला क्षेत्र अवस्थित रानीगंज शैलसमूह से प्राप्त *अराउकेरियॉक्सीलॉन घोषाइ* नवप्रजाति से तुलनीय नवीनतम अभिलक्षणित अनावृतबीजी काष्ठ में प्रदर्शित हुए वृक्ष वलय अन्तिम परमियनयुगीन अण्टार्कटिका से प्राप्त स्वस्थाने अनावृतबीजी अश्मित काष्ठ के वृक्ष वलयों के समरूप हैं।

अण्टार्कटिका एवं भारत से प्राप्त अश्मित काष्ठों के वलयों में पश्चदारु की अल्प मात्रा की तुलना में अग्रदारु उच्चतर अनुपात में विद्यमान है। दो सुदूरवर्ती क्षेत्रों से अंकित किए गए काष्ठों में संवाहिका (ट्रेकीड) फाइलों एवं कूट वलयों के निपातन एवं संदलन के कारण निर्मित अग्रदारु संवाहिकाओं के अभिलाक्षणिक टेढ़े-मेढ़े विन्यास प्रदर्शित हुए हैं। ये अभिलक्षण अन्तिम परमियन कल्प के दौरान दोनों महाद्वीपों में नूतन वनों की अतिशीघ्र वृद्धि को प्रस्तावित करते हैं। *ए. घोषाई* में वृद्धि वलयों के गुणात्मक विश्लेषण से दक्षिण विषमतल +19 प्रतिशत युक्त सी.एस.डी.एम. वक्र प्रदर्शित हुआ है, जो हल्के से मध्यम पर्ण धारण शक्ति युक्त सम्भावित सदाबहारी प्रकृति को प्रस्तावित करता है।

संकेत शब्द—अन्तिम परमियन, अण्टार्कटिका, *अराउकेरियॉक्सीलॉन.*

INTRODUCTION

TREE growth rings are evidence of growth rhythm in trees. Correspondence of differential rate of cambial activity with climatic condition is considered as the primary factor for the formation of the annual growth rings in plants. Tree ring research thus has attracted the climatologists to assess the pattern of climatic change in the immediate past few thousand years. The climate consideration, mainly the seasonal variations in temperate conditions applied in the geologically older horizons of Palaeozoic eras also. Dendroclimatology, Palaeodendroclimatology have thus equally gained importance in Palaeoclimate research (Brown, 1925; Chaloner & Creber, 1973; Creber & Chaloner, 1984, 1985; Jefferson, 1982, 1983; Francis, 1984, 1986; Ash & Creber, 1992; Taylor *et al.*, 1992; Tidwell & Medlyn, 1993; Chapman, 1994; Yadav & Bhattacharyya, 1994, 1996a, b; Creber & Francis, 1999).

Major support to accept the seasonal climate change in the Permo-Carboniferous supercontinent Gondwana land comes from the distinct growth rings of the most common Lower Gondwana petrified woods identified as species of *Dadoxylon* and *Araucarioxylon*. Emergence and flourishing of the Lower Gondwana forests preceeding millions of years of phases of glaciation, deglaciations are regarded as the obvious reason for a temperate climate influence in the Southern hemisphere coal forming vegetation. However, the factors of morphographic characteristics of the large assemblage of *Glossopteris* species, association of the glossopterid members with the tropical Euramarian flora (Banerjee, 1988) or Euramarian like flora (Banerjee & D'Rozario, 1999) and the typical features of growth rings recorded in the *in situ* Permian petrified wood forest preserved in close association with *Glossopteris*, *Vertebraria* from Antarctica (Taylor *et al.*, 1992) lying in a much higher Palaeolatitude (80° to 85°) are significant data to reconsider the palaeoclimate of the Permo-Carboniferous forests.

In the present paper some permineralised woods collected from Raniganj Coalfield (Raniganj Formation – Late Permian) are described which show the typical growth ring pattern with small late wood and zigzag pattern of collapsing of tracheids in the early wood similar to the Antarctic Late Permian petrified woods.

MATERIAL AND METHODS

The permineralised wood specimens of the present study were collected from Andal Railway Station, Raniganj Formation, Raniganj Coalfield. The logs range from 18-29 cm in diameter, consisting of secondary wood only; its pith, primary xylem, phloem and cortex are not preserved. Woods were studied using ground thin sections.

The radial diameters of successive tracheid cells were measured across each growth increment. Using these data the cumulative algebraic sum of each cell deviation from the mean of the radial diameters was calculated and plotted as a zero trending curve, the CSDM curve after Creber and Chaloner (1984). The percentage skew of the zenith of the CSDM curve with respect to the centre of the plot was calculated (Falcon-Lang, 2000).

DESCRIPTION

Genus—ARAUCARIOXYLON Kraus, 1870

ARAUCARIOXYLON GHOSHII sp. nov.

(Pl. 1·1-4; Pl. 2·1-6)

Diagnosis

Secondary wood with distinct growth rings, Growth rings with scanty (3-6 cells wide) late wood. Xylem rays homogenous, uniseriate or rarely biseriate, 3-29 (mostly 3-15 cells) cells high. Radial walls of tracheids with 3-4 seriate (mostly 3-seriate), contiguous, subopposite to alternate, subcircular to hexagonal bordered pits. Cross field pits weakly bordered, 2-6 (usually 3-4) in number.

Holotype Specimen Number—PPL/PW/1-4.

Locality—Andal Railway Station, Raniganj Coalfield.

Horizon—Raniganj Formation, Upper Permian.

Collected by— A.K. Ghosh 1945.

Repository—Palaeobotany & Palynology section, Department of Botany, University of Calcutta.

Derivation of specific name—The species is named after late Professor A.K. Ghosh, the founder teacher of Palaeobotany & Palynology Section, Department of Botany, University of Calcutta, Kolkata.

Detail Description

This species is represented in the present collection by four specimens of silicified woods (PPL/PW/1-4) showing only secondary wood of 18-29 cm diameter. Pith, primary xylem and extra xylary elements are not preserved in any of the woods.

Growth rings occur with clearly distinguishable zones of early and late woods. 26-33 rings varying between 2·65-5·34 mm in width (mean ring width 3·86 mm) are recorded.

The growth rings show a large amount of early wood with narrow (3-6 cells wide) late wood. In some of the rings a few layers of early wood tracheids have comparatively small radial dimensions. This false late wood is easily recognized for its more thicker walls and appearing more dense than rest of the wood. The ring boundaries are marked by late

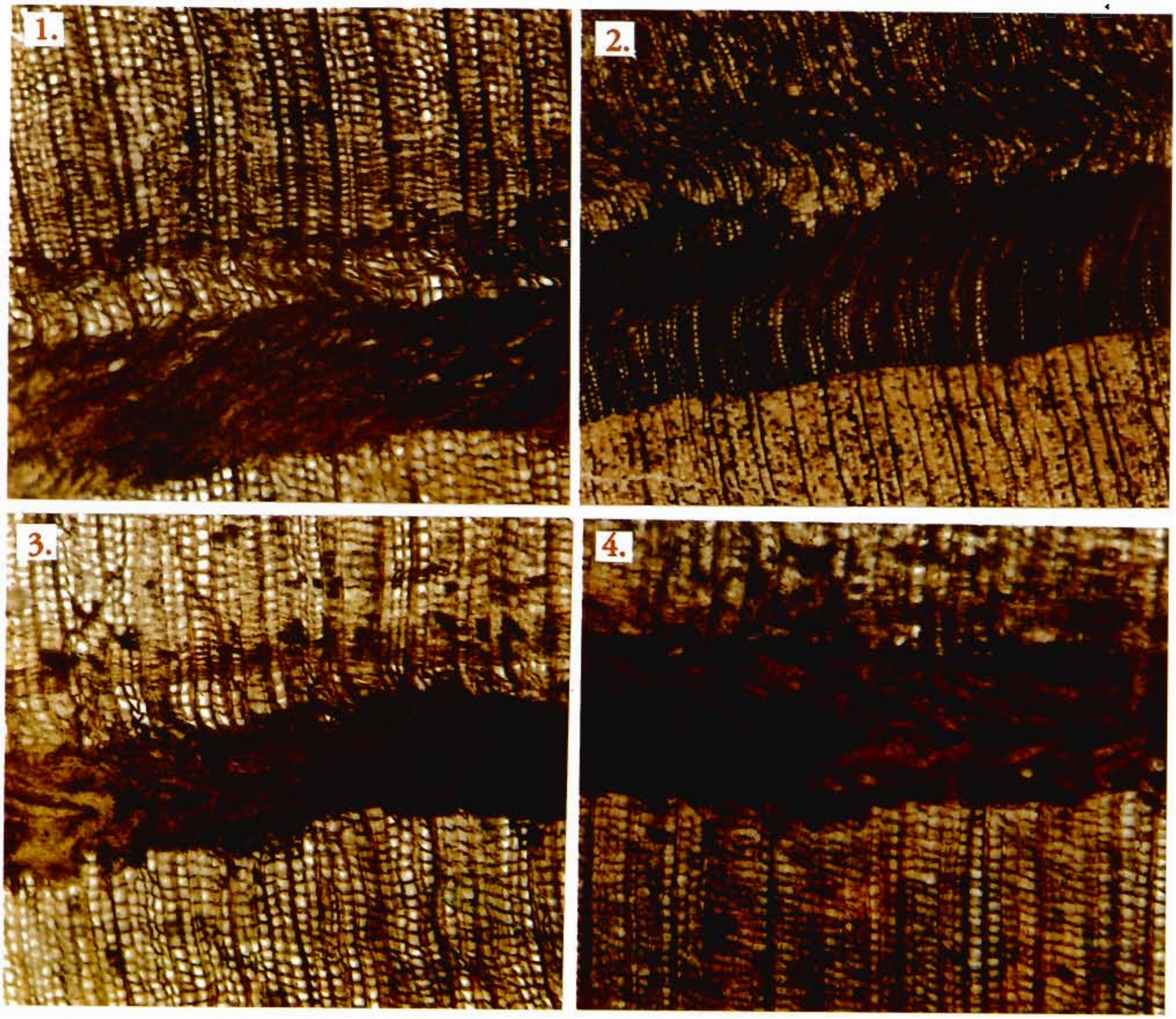


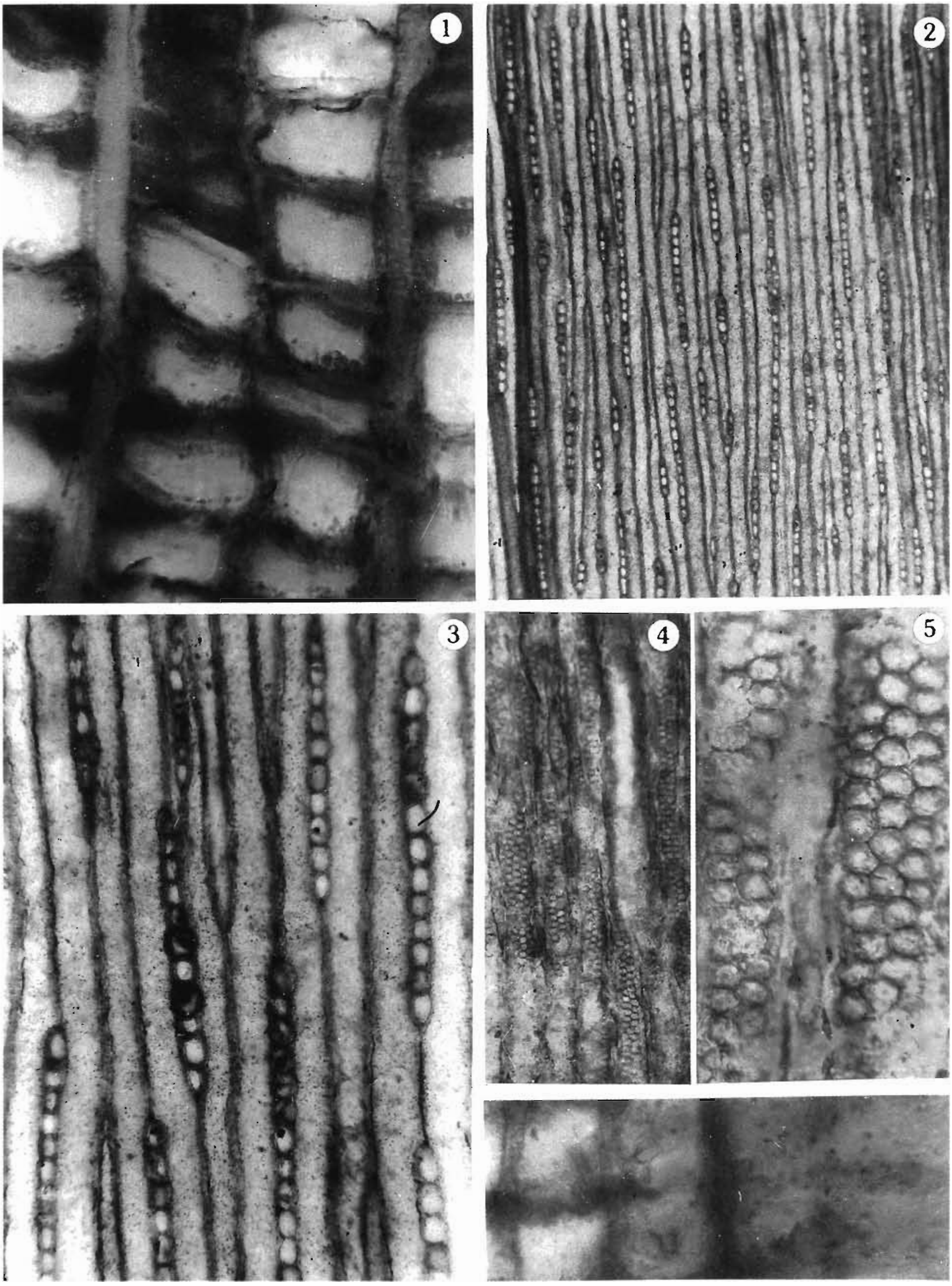
PLATE 1

1. Cross section of *Araucarioxylon ghoshii* sp. nov. showing growth ring boundary and false ring. x 60.
2. Zigzag pattern of tracheid files. x 60.

3 & 4. Cross section of *A. ghoshii* showing arrowhead pattern of tracheid files. x 60.

wood cells with thick walls and narrow lumens. No frost rings are evident at the beginning or end of annual rings. The early wood is characterized by the presence of thick, collapsed and distorted files of tracheids developing arrowhead or zigzag pattern (Pl. 1·1-4) of the growth rings. These features are not reported in the woods described so far from Indian Lower Gondwana (Fig. 1).

The early wood tracheids are polygonal to subcircular in transverse section and range from 35.5-50 µm in radial plane, tracheid walls 4-6 µm thick (Pl. 2.1). The late wood tracheids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Growth ring characters of woods	Mount Acherner wood, Antarctica	Raniganj Coalfield wood, India
Diameter of the wood	9-18 cm	18-29 cm
No. of growth rings	15 (highest number recorded)	26-33
Mean ring width	4·5 mm (Maximum ring width 11.38 mm)	3·86 mm (Maximum ring width)
Proportion of late wood	Very small	Very small (3-6 cells wide)
Frost ring	Absent	Absent
False ring	Present	Present
Zigzag/arrowhead pattern in early wood	Zigzag pattern	Zigzag & arrowhead pattern

Fig. 1—Comparative account of growth ring features of Permian Woods from Antarctica and India.

are more or less rectangular with rounded angles. The radial dimension of the latewood tracheids ranges between 34·5-37·5 µm.

The xylem rays are homogenous, mostly uniseriate or sometimes partly biseriate due to the presence of middle or terminal ray cell pair, 3-29 cells high (commonly 3-15 cells), 34-37/mm^2, tangentially ray cells are 20-26 µm wide (Pl. 2·2, 3).

Radial walls of tracheids with 3-4 seriate (mostly 3 seriate) pits; pits subcircular to hexagonal, contiguous (araucariod), subopposite to alternate, bordered (Pl. 2·4, 5).

The cross-field pits are weakly bordered, 2-6 (usually 3-4) in number; pit pore subcircular to circular, 3-4 µm in diameter (Pl. 2·6).

COMPARISON

Araucarioxylon ghosii sp. nov. has been compared with other Permian species of *Dadoxylon* and *Araucarioxylon* from India and abroad. The presence of araucarian tracheary pitting, uniseriate or rarely partially biseriate rays indicates that the present wood may be a species of *Araucarioxylon*. About fourteen species of the genus *Araucarioxylon* have been described so far from the Indian Lower Gondwana. A comparative analysis of characters of the new species with the known species of *Araucarioxylon* from India and abroad has been made (Fig. 2). *A. ghoshii* differ from all the described species in radial and cross field pitting and characteristic growth ring features.

A new species *Araucarioxylon ghoshii* has been proposed for the presently investigated wood.

DISCUSSION

While comparing with the other Permian woods from India and abroad, the presently described *Araucarioxylon ghoshii* sp. nov. wood shows similar tree ring features in the wood described from the Permian Mount *Glossopteris* Formation, Mount Weaver Formation, Antarctica (Maheshwari, 1972) and Late Permian deposits of Mount Acherner, Antarctica (Taylor *et al.*, 1992). In these woods comparatively fewer numbers of rings are observed some of which are fairly wide. This type of growth ring character is suggestive of a young and rapidly growing forest (Taylor *et al.*, 1992).

In *A. ghoshii* the structure of individual rings with well developed early wood and scant late wood is also comparable to that seen in the Permian polar forest of Antarctica. Another significant feature shared by these woods is the presence of thick tracheid files in early wood developing a zigzag or arrowhead pattern, giving the appearance of growth rings. Scant development of late wood and absence of frost rings in both the woods also suggest a warm climate at the time of deposition. Presence of small amount of latewood suggests sudden cessation of cambial activity at the end of the growing season. This feature coupled with absence of frost rings suggests that late wood production and cessation of cambial

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PLATE 2

1. T.S. of *Araucarioxylon ghoshii* sp. nov. showing early wood tracheids and ray cells. x 450.

2 & 3. T.L.S. of *A. ghoshii* sp. nov. showing distribution and dimension of rays. (2) x 120; (3) x 300.

4 & 5. R.L.S of *A. ghoshii* sp. nov. showing araucariod radial pitting. (4) x 300; (5) x 450.

6. R.L.S. of the same showing cross field pits. x 450.

Name of species	Growth rings	Pitting Radial	Tangential	Xylem rays (in cells) Width	Height	Cross field pits
Araucarioxylon ghoshii sp. nov.	Distinct	3-4 seriate (mostly 3) subcircular to hexagonal, contiguous, araucaroid	Absent	Uniseriate rarely biseriate	1-29 (average 3-15)	2-6, weakly bordered
A. bhivkundense Agashe & Prasad, 1984	Distinct	1-2 seriate in groups of 2, 3, 4	Present	1-2 seriate	1-33 (average 8)	1-8 (commonly 1-2), cupressoid
A. wejgaoense Agashe & Shashi Kumar, 1996	Distinct	1-2 seriate, mostly biseriate	Present	1-2 seriate, mostly uniseriate	2-34 (average 8-12)	1-6 (commonly 2-4), cupressoid
A. parbeliense (Rao) Maheshwari, 1972	Present	1-5 seriate, araucaroid, pit pore circular to oval	Absent	Uniseriate	1-24 (average 2-3)	8-9, bordered pore slit like
A. ningahense Maheshwari, 1965	Distinct	1-4 seriate, alternate or opposite, contiguous, hexagonal	Present	Uniseriate	1-11 (average 2-3)	1-6, bordered, pore oval
A. gondwanense (Maithy) Maheshwari, 1972	Distinct	1-5 seriate, alternate or subopposite, contiguous	Absent	Uniseriate and partly biseriate (13%)	1-43 (average 8-9)	2-8, contiguous or separate, pore circular
A. kharkhariense (Maithy) Maheshwari, 1972	Distinct	1-3 seriate, biseriate pits alternate or opposite, triseriate pits alternate, contiguous	Absent	Uniseriate, biseriate common	1-29 (average 6-7)	2-7, contiguous, pore elliptical
A. loharense Agashe & Gowda, 1978	Present	1-4 seriate, separate or contiguous, hexagonal or circular or elongated	Present	Uniseriate, biseriate common	1-27 (average 11)	2-9; 2, 4, 6 common
A. nandori Vagyani & Raju, 1981	Present	1-3 seriate, araucaroid	Absent	Uniseriate	2-30 (average 8)	2-6, cupressoid, pore circular to oval
A. surangei Agashe *et al.*, 1981	Present	1-4 seriate, separate or contiguous, opposite or alternate, pit pore circular or oblique	Present	Uniseriate and biseriate	1-35 (average 4)	1-11, cupressoid, round to oval
A. lathiense Agashe *et al.*, 1981	Present	1-4 seriate, separate or contiguous, round, oval to hexagonal	Absent	Uniseriate	1-27 (average 3-4)	1-10, cupressoid circular to oval with thin border
A. bengalense (Holden) Maheshwari, 1972	Present	1-3 seriate, araucaroid	Absent	Uniseriate	1-20	2-7 cupressoid
A. bradshawianum Bajpai & Maheshwari, 1986	Distinct	1-5 seriate, araucaroid	Absent	Uniseriate to biseriate	1-21 (average 2-7)	2-4, bordered
A. kumarpurensis Bajpai & Singh, 1986	Distinct	1-2 (rarely 4) seriate, araucaroid	Absent	Uniseriate to biseriate	1-19 (average 3-11)	2-8, cupressoid
A. kothariensis Agashe & Prasad, 1984	Distinct	1-4 seriate, free or contiguous, araucaroid	Present (1-3 seriate)	Uniseriate (55%) or biseriate (43%) or triseriate (< 2%)	1-44 border, cupressoid	1-12, with thin
A. arberi (Seward) Maheshwari, 1972	Distinct	1-4 seriate	Absent	Uniseriate	1-21 (average 6-12)	1-10, oblique
A. meridionale (White) Maheshwari, 1972	Absent	Uniseriate, pit pore oval or oblique	Absent	Uniseriate	1-30	
A. nummularium (White) Maheshwari, 1972	Doubtful	Mostly uniseriate, rarely biseriate	Absent	Uniseriate or often biseriate	1-30 (average 6-7)	many
A. roxoi (Maniero) Maheshwari, 1972	Distinct	1-2 seriate, pore boat shaped	Present	Uniseriate	1-36 (average 9)	2-4 (rarely 5-6)
A. allanii (Kräusel) Maheshwari, 1972	Distinct	1-2 seriate (rarely 3), pits circular to subcircular	Absent	Uniseriate, partly biseriate	1-27 (average 5)	1-6 (rarely 8)
A. africanum Bamford, 1999	Distinct	Mostly biseriate, sporadically uniseriate	Absent	Uniseriate	2-18	2-7, round to oval, araucaroid
A. karooensis Bamford, 1999	Distinct	Mostly biseriate, rarely uni or triseriate	Absent	Uniseriate sporadically biseriate	3-25	2-4, round to oval

Fig. 2—Comparative anatomical features in different species of *Araucarioxylon* from India & Abroad.

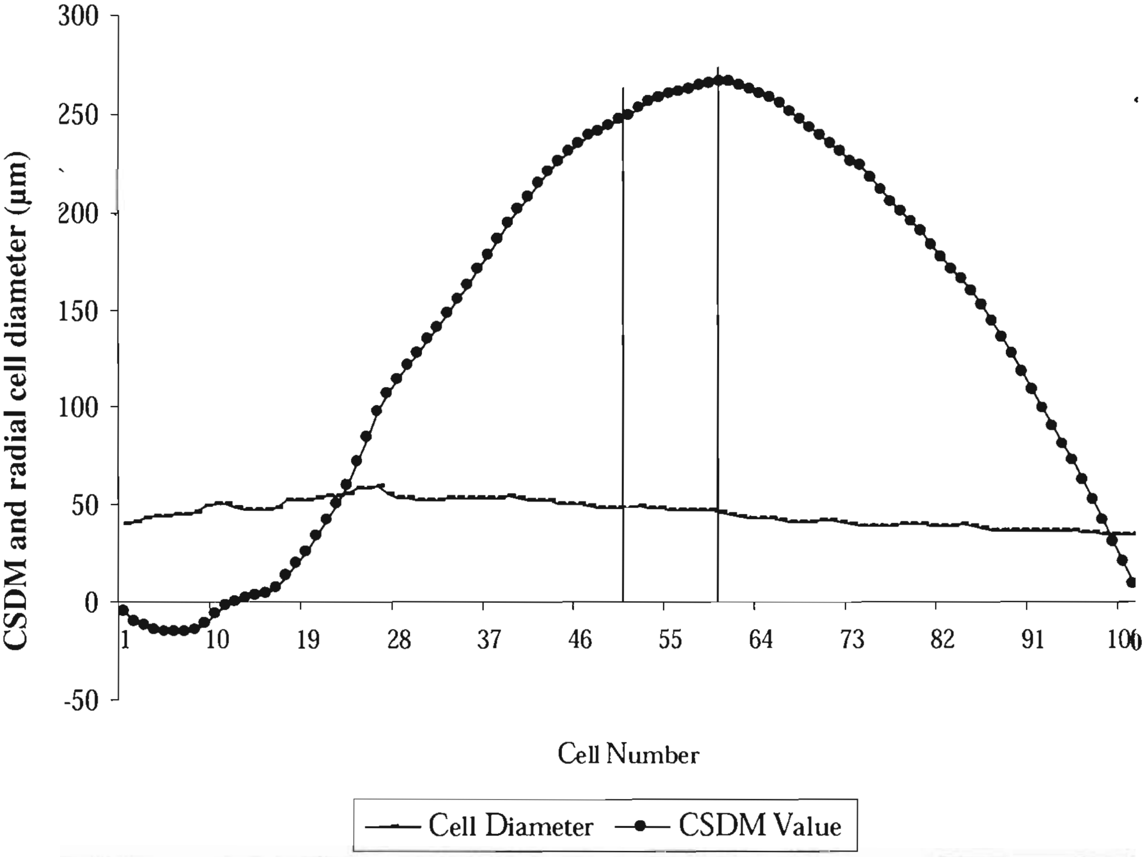

Fig. 3—CSDM Curve skewness data of *A. ghoshii* sp. nov.

activity were a response to lower light levels in the autumn (Taylor *et al.*, 1992). Such a minimal development of latewood points towards a lack of winter hardening of the trees and experienced only short periods of freezing weather, if any (Basinger, 1991).

Recently, Falcon-Lang (2000) outlined a method in which woods of deciduous and evergreen coniferopsids may be distinguished from one another on the basis of a quantitative analysis of growth ring anatomy. He advocated deciduous nature of the conifer woods dominantly with symmetrical or left-skewed CSDM curves and evergreen conifer woods dominantly possess right-skewed CSDM curves. In addition, the magnitude of right skewedness in evergreen conifers seems to be positively related to leaf longevity, i.e., the higher the leaf life span, the greater will be the right-skewedness value (Falcon-Lang, 2000).

Quantitative analysis of growth rings in *A. ghoshii* wood reveals a CSDM curve with right skewedness +19% (Fig. 3). This value suggests that these trees were possibly evergreen with small to moderate leaf retention time (LRT). No CSDM data on the Antarctic woods studied by Taylor *et al.*, (1992) are available. However, Francis (1996) quantitatively analysed growth rings in some glossopterid woods from Allan Hills in the Transantarctic Mountains and found that CSDM curves were symmetrical suggesting their deciduous nature. More CSDM data is required to support this interpretation related to leaf retention time of Permian glossopterid plants.

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