

# What do the petrified woods of the Sriperumbudur Formation indicate?

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## ABSTRACT

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Of the several outcrops of Upper Gondwana exposures along the East Coast of the Indian Peninsula, the Sriperumbudur Formation near Chennai, Tamil Nadu has yielded many well-preserved petrified woods. Extensive anatomical studies were carried out on these woods during the past decade at Tambaram, Chennai. A study of these woods helped to understand the variation in the wood structure. Based on these woods, the diversity of the arborescent palaeoflora was traced in the region during the Late Jurassic-Early Cretaceous times. It has also been possible to interpret the climatic conditions that prevailed during the time of deposition through the study of the wood anatomy. The paper discusses some evolutionary trends indicated by the wood studies. A suggestion is made for the taxonomic revision of one of the woods.

**Key-words**—Petrified woods, Floral diversity, Climate, Taxonomy, Evolution, Sriperumbudur Formation, Tamil Nadu, South India.

श्रीपेरंबुदूर शैलसमूह की अशमीभूत काष्ठें क्या संकेत देती हैं?

डी.ई.पी. जयसिंह

## सारांश

भारतीय प्रायद्वीप चैन्ने के निकट श्रीपेरंबुदूर, तमिलनाडु के पूर्वी तट के सहारे ऊपरी गोंडवाना अनावरण के बहुतेरे दृश्यांशों से बहुत-सी भलीभाँति परिरक्षित अशमीभूत काष्ठें प्राप्त हुई हैं। पिछले दशक के दौरान तांबरम, चैन्ने में इन काष्ठों पर गहन शारीरिक अध्ययन किए गए। इन काष्ठों के अध्ययन ने काष्ठ संरचना के उतार चढ़ाव को समझने में मदद मिली। इन काष्ठों के आधार पर, अंतिम जुरैसिक-प्रारंभिक चाकमय काल के दौरान प्रदेश में वृक्षसम पुरापेड़-पौधे की विविधता का पता लगाया गया। जलवायवी स्थितियों की व्याख्या भी संभव हो गई जो काष्ठ शरीर के अध्ययन के माध्यम से निक्षेपण के दौरान प्रबल हो गईं। शोध-पत्र काष्ठ अध्ययनों द्वारा ईंगित की गई कुछ विकासात्मक प्रवृत्तियों पर विचार करता है। एक काष्ठ के वर्गिकीय परिशोधन हेतु परामर्श दिया है।

**मुख्य शब्द** - अशमीभूत काष्ठें, पुष्पी विविधता, जलवायु, वर्गिकी, विकास, श्रीपेरंबुदूर शैलसमूह, तमिलनाडु, दक्षिण भारत।

## INTRODUCTION

**A**LL along the eastern coast of Indian peninsula, Upper Gondwana outcrops occur in isolated patches. These are referred to as East Coast Gondwanas. They mostly range in age from Upper Jurassic to Lower Cretaceous. One such outcrop developed in and around the small town of Sriperumbudur (12°59'N: 79°57'E) lying about 40 km west of

the city of Chennai (Madras) in Tamil Nadu, is referred to as the Sriperumbudur Formation. This outcrop, and the slightly younger Sathyavedu Formation found near the town of Sathyavedu (13°26' N: 80°0'E), about 55 km northwest of Chennai (Madras) occur in the region of the Palar Basin. The geology of this region was well documented by Kumaraguru (1991).

Impressions of plant fossils and petrified woods have been collected and described from the Sriperumbudur Formation since 1870. Fossils from the Sriperumbudur Formation were first studied by Feistmantel (1879) and were included in the revision of fossil plants by Sahni (Seward & Sahni, 1920; Sahni, 1931). Subsequent additions were made by Suryanarayana (1953, 1954, 1955). Intensive search and fresh collections made in the last three decades from the well-known localities of this formation and also from a new locality, have yielded several new taxa that have been described in scientific publications and unpublished M.Phil and Ph.D. dissertations (Edmund, 1986; Jeyasingh & Kumarasamy, 1994a, b, 1995; Kumarasamy, 1997; Kumarasamy & Jeyasingh, 1995a, 2004, 2007).

The impression fossils of plant parts and the variety of petrified woods give us a fairly accurate picture of the palaeoflora that existed in this region of Indian peninsula about 100 to 150 million years ago, that is, during the Upper Jurassic to Lower Cretaceous times. This paper specifically deals with the petrified woods of the Sriperumbudur Formation.

#### (i) Variation in the wood structure and the diversity of palaeoflora assessed from petrified woods

There is positive evidence to show that the family Araucariaceae was represented among the conifer trees growing in the coastal region of the peninsula during the Late Jurassic-Early Cretaceous times. For the first time in 1955 Suryanarayana (1955), reported a well-preserved piece of petrified wood from this formation and assigned it to the species *Dadoxylon (Araucarioxylon) rajmahalense*, which was described from the Rajmahal area earlier (Sahni, 1931). Recent collections and anatomical investigations have shown that petrified woods assignable to *Dadoxylon (Araucarioxylon)* were fairly common in the fossil flora of this formation. Woods differing slightly in their fine anatomical details have been reported under the species *Araucarioxylon giftii* and *A. rajivii* (Jeyasingh & Kumarasamy, 1994a). The fact that leafy twigs and cone scales assignable to the Araucariaceae have been found as impression fossils from these beds confirms the presence of trees of this family in the Jurassic-Cretaceous landscape of this locality. Cone-scales assigned to the genus

*Araucarites* have been reported from the Vemavaram area in Andhra Pradesh (Seward & Sahni, 1920), and similar impression fossils (Pl. 1-8) have also been found in the Sriperumbudur beds and are assigned to *Araucarites cutchensis* (Edmund, 1986; Kumarasamy, 1997). The occurrence of leaf impressions (Pl. 1-6) of *Ginkgoites crassipes* (Seward & Sahni, 1920; Edmund, 1986; Kumarasamy, 1997) in these beds also indicates the presence of Ginkgoalean members in the region, though positive evidence from reproductive structures or from woods belonging to this group have not yet been reported.

An interesting wood specimen (No. AKM/81) that comes from a new locality that was considered to be part of the Sriperumbudur Formation near the town of Arkonam, while showing certain features of *Araucarioxylon*, such as the characteristic alternate pitting on the tracheid walls, is clearly different from other species of this genus reported from the Indian peninsula. Though the specimen was assigned to *Araucarioxylon* (Jeyasingh & Kumarasamy, 1995), the authors have drawn special notice to the unusual features of this wood, which seems to agree more to a wood reported from the Cretaceous of Antarctica. Moreover, this wood shows features that seem to indicate the origin of woods with vessels. The cross section of the wood shows enlarged tracheids that simulate vessels seen in cross section in some primitive dicot woods (Pl. 1-2). Thus *Araucarioxylon mosurensense* coming from a small village near the town of Arkonam is considered as one of the forerunners of the plants with Ephedroid anatomy (see page 411). However, it is to be emphasized that no phylogenetic connection is implied between this wood and that of *Ephedra*.

There is also evidence to show that the coastal region of the Indian peninsula during the Late Jurassic-Early Cretaceous times was occupied by the growth of conifer trees that shed their shoots periodically. Woods belonging to the genus *Mesembrioxylon (=Podocarpoxylon)* and genus *Cupressinoxylon* have been reported from this formation and the area, since long. Sahni (1931) described *M. Parthasarathyi (=P. parthasarathyi)* from specimens collected from Vellum, a village about 8 km south of Sriperumbudur town and *Cupressinoxylon coromandelinum* from specimens collected by R.B. Foote in 1873 near Madras. Recently, Kumarasamy

### PLATE 1



1. *Sahnioxylon coromandelense* Kumarasamy & Jeyasingh (2007): smaller hand specimen with pith and primary xylem (95/SPR/GPR/11) and larger hand specimen of secondary wood (95/SPR/GPR/33). Both before sectioning. x 0-5.
2. *Araucarioxylon mosurensense* Jeyasingh & Kumarasamy (1995): C.S. of wood showing enlarged vessel-like tracheids at places (AKM/ 81). x 100.
3. *Sahnioxylon coromandelense* Kumarasamy & Jeyasingh (2007): RLS of secondary wood (95/SPR/GPR/33). x 300.
4. *Araucarioxylon mosurensense* Jeyasingh & Kumarasamy (1995): RLS of secondary wood showing swollen ends of tracheids with crowded hexagonal bordered pits (AKM/21). x 150.
5. *Otozamites kachchhensis* Bose & Banerji: A complete frond from the Sriperumbudur beds (SPR/VKT/20). x 1-3.
6. *Ginkgoites crassipes* (Feistmantel) Seward: A complete leaf from the Sriperumbudur beds (SPR/P/60). x 1-5.
7. *Sahnioxylon coromandelense* Kumarasamy & Jeyasingh (2007): C.S. of the pith region showing circular pitted cells and secretory ducts surrounded by epithelium-like cells (95/SPR/GPR/11). x 80.
8. *Araucarites cutchensis* Feistmantel: A complete cone scale from the Sriperumbudur beds (SPR/VGL/79). x 4-5.

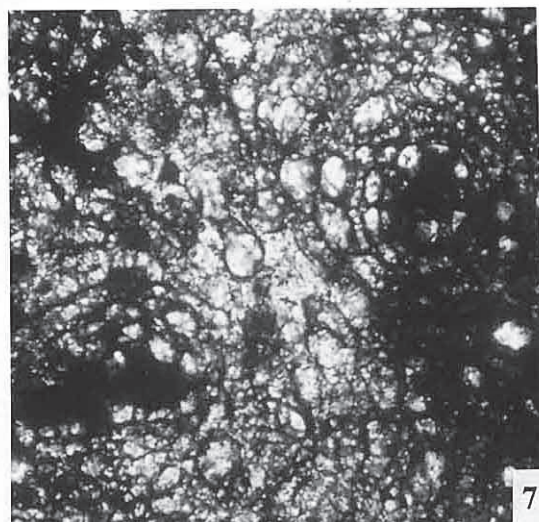
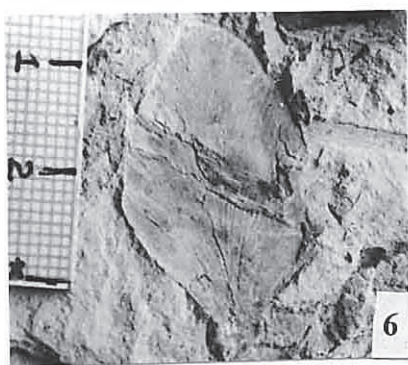
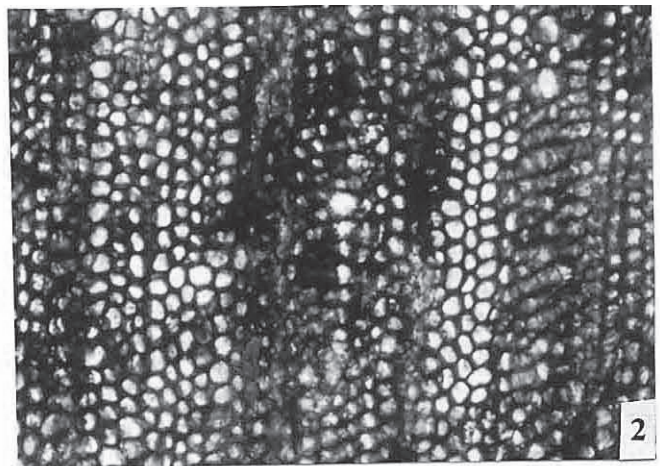


PLATE 1

Sl. No.	Name of the specimen with catalogue number	Type Locality	No. of Growth rings analysed	Average no. of tracheids per growth ring in the radial file	Width of the Growth ring in mm (average in parenthesis)	Mean sensitivity in mm	Diameter of the tracheid (average in parenthesis)	Average length of the tracheids in mm	Tracheids per mm <sup>2</sup> in the early wood	Vulnerability Index (IV)	Mesomorphy (M)	Reference
1.	<i>Araucarioxylon giftii</i> 89/SPR/GPR/3	Sri-perumbudur	17	14	0.24-1.05 (0.51)	0.291	17.00-55.00 (29.96)	3.51	1524	0.019	69.0	Jeyasingh & Kumarasamy, 1994
2.	<i>Araucarioxylon rajivii</i> 70/SPR/1	Sri-perumbudur	9	32	0.90-2.17 (1.20)	0.199	11.25-71.25 (46.23)	4.02	502	0.092	370.2	Jeyasingh & Kumarasamy, 1994
3.	<i>Araucarioxylon</i> sp. SPR/VGL/164	Sri-perumbudur	3	39	1.34-1.58 (1.49)	0.154	25.00-52.00 (32.55)	4.26	850	0.038	163.1	Present report
4.	<i>Araucarioxylon</i> sp. 89/SPR/GPR/2	Sri-perumbudur	14	27	0.60-1.27 (0.85)	0.168	18.00-56.00 (34.73)	3.38	1210	0.028	97.0	Present report
5.	<i>Araucarioxylon</i> sp. SPR/112	Sri-perumbudur	4	28	0.60-0.71 (0.64)	0.112	15.00-50.00 (22.14)	2.84	2294	0.010	28.6	Present report
6.	<i>Araucarioxylon</i> sp. SPR/VKT/100	Sri-perumbudur	3	47	(1.80)	0.374	15.00-43.75 (30.89)	7.83	1209	0.025	200.0	Present report
7.	<i>Cupressinoxylon</i> sp. VLM/2	Sri-perumbudur	13	97	0.49-1.00 (0.76)	0.204	25.00-46.00 (35.66)	2.58	838	0.042	109.7	Present report
8.	<i>Sahnioxylon</i> sp. 95/SPR/GPR/33	Sri-perumbudur	7	63	1.43-3.10 (2.00)	0.229	11.00-68.00 (30.68)	NM	964	0.031	-	Kumarasamy & Jeyasingh, 1995
9.	<i>Sahnioxylon</i> sp. 95/SPR/GPR/11	Sri-perumbudur	-	-	-	-	(27.30)	NM	1736	0.015	-	Kumarasamy & Jeyasingh, 1995
10.	<i>Araucarioxylon mosurensense</i> AKM/81	Arakonam	2	180	5.32-7.05 (6.10)	0.278	15.00-53.75 (35.00)	NM	1500	0.023	-	Jeyasingh & Kumarasamy, 1995
11.	<i>Araucarioxylon mosurensense</i> AKM/21	Arakonam	-	-	-	-	(23.15)	NM	1820	0.012	-	Jeyasingh & Kumarasamy, 1995
12.	<i>Araucarioxylon</i> sp. AKM/235	Arakonam	3	77	1.52-5.12 (2.70)	0.546	18.70-53.70 (34.70)	NM	1221	0.028	-	Present report
13.	<i>Araucarioxylon</i> sp. AKM/285	Arakonam	-	148	-	-	(23.15)	NM	2016	0.011	-	Present report
14.	<i>Araucarioxylon</i> sp. AKM/320	Arakonam	2	86	2.50-3.03 (2.70)	0.312	12.50-43.75 (28.50)	NM	1221	0.023	-	Present report

Fig. 1—Showing analysis of the growth-ring dimensions and other parameters from fourteen pieces of petrified woods collected from two different localities of the Sriperumbudur Formation—NM=Not measurable.

and Jeyasingh (2004) have reported a new species of *Cupressinoxylon* (*C. gondwanensis*) from this region. Coupled with the recovery of fossil foliage shoots belonging to possible Cupressaceae and possible Podocarpaceae from the Sriperumbudur beds, these woods, which positively come from trees of some girth and height, bear witness to the fact that conifer trees with close affinities with these two families occupied the eastern coastal areas of the Indian peninsula during the Upper Gondwana times. Nevertheless, we have to be cautious in assuming that the anatomical structure of the Jurassic-Cretaceous wood alone is sufficient to decide about the affinities of the plants to which these woods belong. The possibility of some of these foliage belonging to the Cheirolepidaceae cannot be ruled out, though positive evidence for the presence of this family of conifers in this region has not been properly assessed. Intense search has to be made for the recovery of petrified reproductive structures in association with twigs and foliage to positively assess their true affinities.

Of great interest are two pieces of petrified wood (Pl. 1-1) with scalariform pitting on the tracheid walls (Pl. 1-3), which have been collected from the Sriperumbudur Formation. The discovery of these specimens from the Sriperumbudur Formation was reported earlier (Kumarasamy & Jeyasingh, 1995b). The wood has been assigned to the Bennettitalean genus *Sahnioxylon* and has been described under a new species, *S. coromandelense* sp. nov. (Kumarasamy & Jeyasingh, 2007). The excellently preserved wood pieces, one with a wide pith with secretory ducts (Pl. 1-7) indicate positively that woody Bennettitalean plants were abundant in the coastal region of the peninsula when it was moving as an island in the Tethys Sea during the Late Jurassic-Early Cretaceous times. The occurrence in abundance of impressions of foliage assignable to such genera as *Ptilophyllum*, *Dictyozamites* and *Otozamites* (Pl. 1-5) belonging to the Bennettitales, bear unequivocal testimony to the fact that the coastal vegetation of that time was replete with a wide diversity of cycadophytes that underwent secondary growth. The possibility of some pre-angiospermous plants having existed in this vegetation cannot be totally ruled out. But positive fossil evidence for this is not available at present (however, see Sharma, 1997).

#### (ii) Prevailing climatic conditions in this region as assessed from wood anatomy

The fact that pieces of fossil woods of gymnosperms can be used as environmental indicators of the palaeoenvironment that existed during the time when the plants to which these woods belonged were actively growing, has been well documented (Creber, 1977; Creber & Chaloner, 1984; Chapman, 1994; Philippe *et al.*, 2004; Rajanikanth & Tewari, 2004). The authors analyzed the growth-ring dimensions and other parameters from fourteen pieces of petrified woods collected from two different localities of the Sriperumbudur

Formation (Jeyasingh & Kumarasamy, 1996a). Climatic implications were derived by calculating (i) the Mean Sensitivity (MS); (ii) Vulnerability Index (VI); (iii) Mesomorphy (M) and (iv) the number of cells per growth ring along the radius. The details of these parameters along with other relevant information for these fourteen woods are presented in Fig. 1. On the basis of these calculations it can be concluded that (a) the palaeoclimate in the Sriperumbudur area during the Early Cretaceous times was more or less uniform without much climatic fluctuation year after year; (b) the plants were thriving in a xeric environment and (c) during the growing period, the plants did not experience any water-stress or adverse temperatures. At this point it is essential to point out that the number of growth rings from the various wood pieces available for analysis being so limited; these climatic deductions apply only to a very small segment of time of a very long geological period that lasted for over 75 million years.

#### (iii) Evolutionary considerations

The fossil wood *Araucarioxylon mosurensense* (Jeyasingh & Kumarasamy, 1995) shows certain features that are very peculiar for conifer woods. These peculiar features include the following: (i) swollen ends of some tracheids with multiseriate pitting (Pl. 1-4); (ii) tangential pitting in at least some parts of the tracheids (Jeyasingh & Kumarasamy, 1995; Pl. II, fig. 10) and (iii) multiplication of ray cells due to radial divisions in the central part of the rays, which become multiseriate (Jeyasingh & Kumarasamy, 1995; Pl. II, figs 9 & 11). These features are not commonly encountered in coniferalean woods, living and fossil. Some of these features are also present in the Cretaceous wood reported from Antarctica by Chapman and Smellie (1992). In addition, the Antarctic wood shows erratic swollen regions along the entire length of some tracheids in the RLS. These features may well indicate trends that foreshadow the evolution of wood structure with vessels. It is here proposed that trends similar to the one seen in *Araucarioxylon mosurensense* may have given rise to the wood structure resembling that seen in *Ephedra* (Fig. 2). It is further speculated that if similar trends were to set in among pycnoxylic woods with scalariform tracheids (such as *Sahnioxylon*, for example), then the resulting wood structure will greatly resemble the anatomy of primitive dicots (Jeyasingh & Kumarasamy, 1996). It is to be noted that these trends, as envisaged here, substantiate the independent origin of vessels among the phanerogames as already proclaimed by comparative plant anatomists quite early in the last century (Bailey, 1953).

#### (iv) Suggested taxonomic revision

In the light of what has been said above regarding *Araucarioxylon mosurensense* (Jeyasingh & Kumarasamy, 1995) and the Cretaceous Antarctic wood described by Chapman and Smellie (1992, p.176) as Palaeotaxon *Coniferwood-*

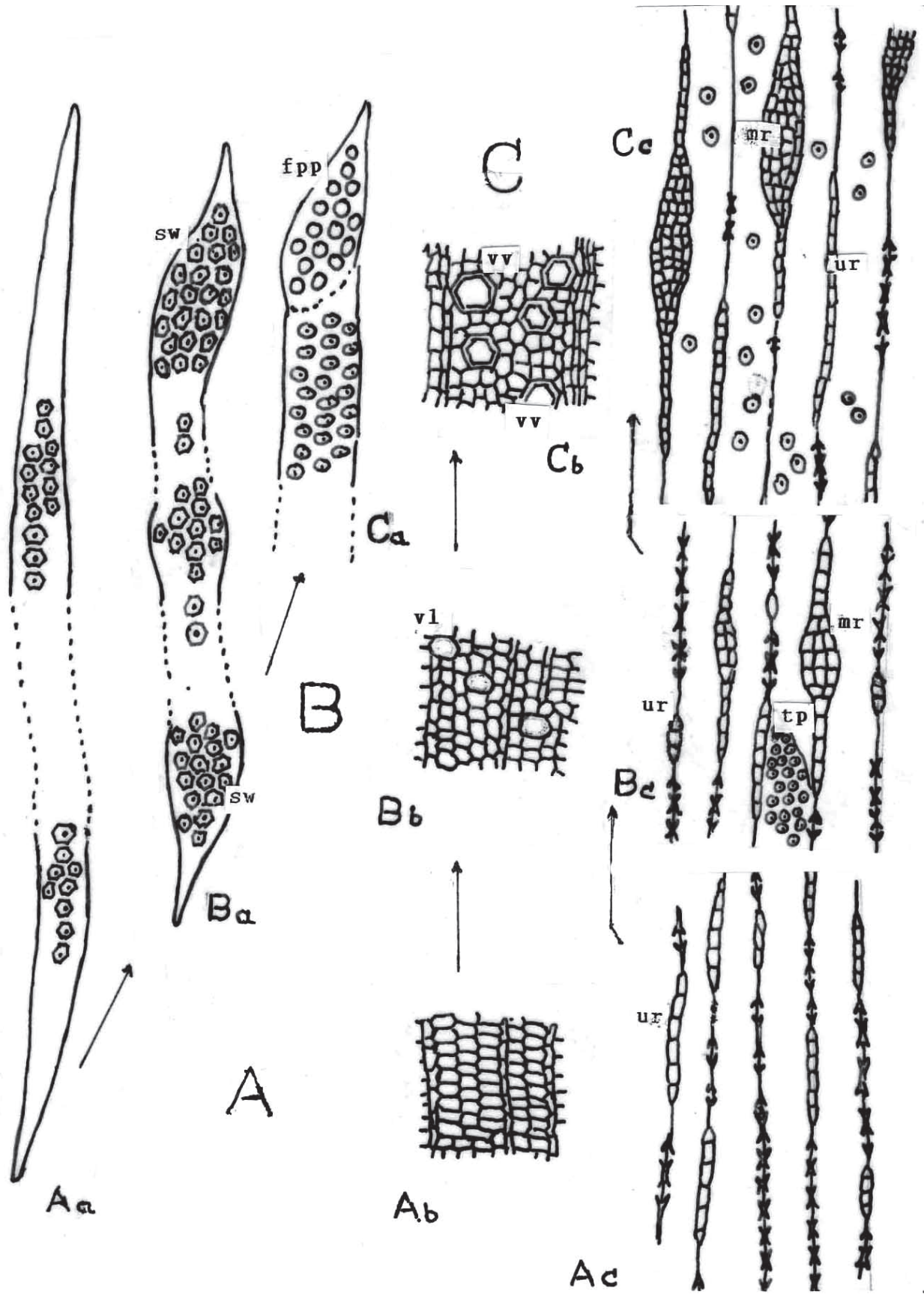


Fig. 2

*Cretaceous-clusteredpits*, under the PDHC (Palaentologic Data Handling Code) proposed by Hughes (1989), it is hereby mooted that in view of the overall anatomical similarity of the two woods, and the combination of their peculiar features normally not encountered among fossil conifer woods, the two taxa may be assigned to a new genus.

### CONCLUSION

On the basis of the diversity of the petrified woods in the Sriperumbudur Formation, it can be safely concluded that conifer trees belonging to the Araucariaceae were quite widespread in the eastern coastal region of the Indian peninsula during the Late Jurassic and Early Cretaceous times. There were also other conifers with affinities to Podocarpaceae and Cupressaceae that were present either sparsely or as thick forest formations. There were also some woody plants with affinities to the Bennettitales, probably occupying the fringes of water bodies or forming the understory amidst the conifers. Besides, there must have been some strange conifer-like trees, especially during the Late Cretaceous times, which had advanced anatomical features, the true affinities of which we are unable to guess in the absence of their leaves and reproductive parts.

Climate wise, the region had more or less a uniform climate without much fluctuation year after year. The plants must have been thriving in a xeric environment and during their growing period they would not have experienced any water-stress or adverse temperatures.

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Fig. 2—**A**: *Araucarioxylon* type of wood. **Aa**: Diagrammatic representation of a tracheid from RLS. **Ab**: Cross sectional view of the wood showing radial alignment of tracheids. **Ac**: TLS of the wood showing mostly uniseriate rays (ur) and tracheids showing pits in cross sectional view on their radial walls. **B**: Wood similar to that of *Araucarioxylon mosurensense*. **Ba**: Diagrammatic representation of a tracheid from the RLS showing swollen ends (sw) with crowded araucarioid pitting. Note erratic swellings along the length of the tracheid as seen in the Antarctic wood. **Bb**: Cross sectional view of the wood showing vessel-like (vl) appearance of the swollen regions of tracheids. **Bc**: TLS of the wood with mostly uniseriate rays (ur) some of which showing a tendency to become multiseriate (mr). Tracheids show mostly radial wall pitting except at the end-walls where crowded tangential pitting (tp) may occur. **C**: Wood similar to that of *Ephedra*. **Ca**: A vessel member showing characteristic foraminiferous perforation plate (fpp) at the end-wall. **Cb**: Cross sectional view of the wood showing angular vessels (vv) amidst other tracheary elements. **Cc**: TLS of the wood showing uniseriate rays (ur) as well as many multiseriate rays (mr) with uniseriate extremities. Note regular occurrence of tangential pitting.

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