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Addition to the Mesozoic flora of the Rajmahal Hills, Jharkhand, India

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ABSTRACT

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Anatomy is described of three new organ genera–stem, petiole and leaflet of petrified cycadean plants. In addition, information about a bisexual bennettitalean fructification is given and free nucelli of conifer seeds are recorded. Comparison and critical remarks are given on the fossil plants included in this paper.

Key-words—Anatomy, Petrified cycadean plants, Bennettitalean fructification, Conifer seeds, Lower Cretaceous.

भारत में झारखंड की राजमहल पहाड़ियों के मध्यजीवी वनस्पतिजात में अभिवृद्धि

बी.डी. शर्मा, ओ.पी. सुथार एवं डी.आर. बोहरा

सारांश

शरीर-रचना विज्ञान में अश्मीभूत साइकैडीय पौधों के तीन नए अंग वशों - तना, पर्णवृंत एवं पर्णक का वर्णन किया गया है। इसके अतिरिक्त एक द्विलिंगी बेनेटिटेलीय फलन के बारे में जानकारी दी गई है तथा शंकुवृक्ष बीजों के स्वतंत्र न्युसेल्लि भी अभिलिखित किए गए हैं। इस शोध-पत्र में विलुप्त पौधों की तुलना एवं आलोचनात्मक टिप्पणियाँ दी गई हैं।

संकेत शब्द–शरीर-रचना विज्ञान, अश्मीभूत साइकैडीय पौधे, बेनेटिटेलीय फलन, शंकुवृक्ष बीज, निम्न क्रिटेशस।

INTRODUCTION

THE fossil flora of the Mesozoic rocks of the Rajmahal Hills, Jharkhand has been in literature since the publication of Oldham and Morris (1863) who described a number of fossil plants belonging to pteridophytes and gymnosperms from the area. Since then a number of research papers and review articles have been published on fossil plants of Rajmahal Hills (Banerji, 2000; Banerji & Jana, 2003; Bohra & Sharma, 1979; Bose, 1953; Bose & Sah, 1954, 1968, Bose *et al.*, 1985; Feistmantel, 1877; Ganju, 1946; Gupta, 1943, 1971; Sah & Jain, 1965; Sahni 1932a, b, 1948; Sen Gupta, 1988; Seward & Sahni, 1920; Sharma

1967a, 1970, 2002, 2004; Suthar & Sharma 1988, Suthar *et al.*, 1986; Vishnu-Mittre 1953, 1954, 1957, 1959). In addition to the mega fossils isolated seeds, spores and pollen grains are also described from the area (Sah & Jain, 1965; Tripathi, 2004; Vishnu-Mittre, 1954).

The major constituents of the fossil flora are pteridophytes and gymnosperms. However fossil algae (Sharma & Harsh, 1994; Sharma & Suthar, 1989; Sharma & Tripathi, 1997; Sharma *et al.*, 2002), bryophytes (Bose & Pal, 1982) and angiosperms (Banerji, 2000; Sharma, 1997; Sharma *et al.*, 2002) are also recorded from the Rajmahal Hills. Sharma and Harsh (1987) also studied amino acids in the petrified plants of this area.

The bennettitalean plants occur frequently in majority of Mesozoic rocks of the Rajmahal Hills leaving aside a few fossiliferous exposures like Nipania and Sonajori (Banerji & Jana, 2003; Sharma & Bohra, 1976; Vishnu-Mittre, 1953, 1959). The fructification *Williamsonia* occurs commonly in the area and is represented by many species like *W. microps* Feistmantel (1877), *W. sewardiana* Sahni (1932b), *W. sahnii* Gupta (1943), *W. harrisiana* Bose (1968), *W. guptai* Sharma (1968), *W. amarjolense* Sharma (1968), etc. All are unisexual seed-bearing fructifications except *W. sahnii* Gupta which was believed to be (doubtfully) a bisexual one. The pollen bearing fructification *Weltrichia* Braun is quite distinct and different from *Williamsonia* (Sharma, 1969a; Sitholey & Bose, 1953, 1971). Bose (1966) described a bisexual fructification *Cycadeoidea dactylota* which was later transferred to *Amarjolia dactylota* by Bose *et al.* (1984). It resembles in general plan of construction to *Cycadeoidea* sp. (Delevoryas, 1962, 1968).

In conifers the nucellus in seed is free from the integument like Medullosales, Pentoxylales and Cordaitales (Sharma, 2002; Stewart & Rothwell, 1993; Taylor & Taylor, 1993). Suthar *et al.* (1988) described a number of taxa of isolated petrified seeds of conifers from the Sonajori locality.

Earlier investigators described the age of the Rajmahal Hills as Middle Jurassic (Bose, 1953; Ganju, 1946; Rao, 1972; Sahni, 1932a, 1948; Sharma, 1967a, 1969a, b; 1974) but during recent years on the basis of palaeopalynological and geological data many scientists consider age as Lower Cretaceous (Banerji & Jana, 2003; Sen Gupta, 1988). Tripathi (2004) assigned Jurassic to Lower Cretaceous age to the Dubrajpur Formation which underlies the Rajmahal Formation.

The cycadean plants in the Rajmahal fossil flora include two stems *Sewardioxylon sahnii* Gupta (1971) and *Fascisvarioxylon mehtae* Jain (1964) and one petiole/rachis *Cycadinorachis omegoides* Sharma (1973). In the present paper a new stem *Manomesarchioxylon heptaxylica* gen. et sp. nov.; a new petiole *Stangeriorachis heterospinulata* gen. et sp. nov. and anatomy of an unreported leaflet *Macrozamiphyllum mucilagica* gen. et sp. nov. are described.

MATERIAL AND METHODS

The petrified material of the cycadean stem and *Williamsonia* fructification was collected from Amarjola, 2 km north-east of the village Amarapara while the new petiole comes from Chilgujari, a locality 2 km east of Amarjola. Petrified leaflets are found in association with the rachis of *Cycadinorachis omegoides* at Nipania located 6 km north-west of Amarapara, while the isolated nucelli were collected from Sonajori chert situated 4 km west of the Pakur Railway Station on Amarapara Road. All these locations are in district Dumka of Jharkhand State. Slides were prepared by the usual techniques of cutting, grinding and polishing methods and mounted in canada balsam.

Slides containing type and figured specimens are housed at the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow (India).

DESCRIPTION AND DISCUSSION

Cycadean fossils—The descriptions included in this paper are of a stem (*Manomesarchioxylon heptaxylica*), a petiole (*Stangeriorachis heterospinulata*) and a leaflet (*Macrozamiphyllum mucilagica*).

MANOMESARCHIOXYLON gen. nov.

Type Species—***Manomesarchioxylon heptaxylica*** sp. nov.

Diagnosis—Stem with U, V or C shaped xylem strands in a ring facing concavity outward, manoxylic, xylem in two rows, protoxylem mesarch, leaf traces originate from free ends of vascular strands. Pith and cortex large.

Manomesarchioxylon heptaxylica sp. nov.

(Pl. 1.1-4; Fig. 1a-h)

Diagnosis—Stem cross section circular with peripheral leaf bases, 9 to 11 mm in diameter. Pith and cortex wide parenchymatous; xylem strands seven, U, V & C shaped in ring facing concavity towards cortex, strands measure 2.2 x 1.0 to 2.8 x 0.6 mm; two rows of xylem in each strand; inner row (pith side) narrower and less developed than the wider and more developed outer row (cortex side); xylem manoxylic, protoxylems of the two rows face each other and mesarch. Leaf traces originate from the free ends of xylem strands.

Holotype—BD 201/Raj. A, BSIP slide no. 13198.

Repository—Birbal Sahni Institute of Palaeobotany, Lucknow (India).

Locality—Amarjola.

Horizon—Lower Cretaceous.

Description—Study based on two slides — BD 201/Raj A (BSIP slide no. 13198) and BD 202/Raj A (BSIP slide no. 13199) representing serial cross sections. Remaining portion of the specimen is not available. Surface uneven suggesting presence of leaf bases; leaf bases unpreserved. Xylem strands seven, U, V or C shaped surrounding a wide circular unpreserved pith (Fig. 1a). Xylem in strand either continuous (Pl. 1.1; Fig. 1d-h) or broken into two arms forming V shaped structure (Pl. 1.2; Fig. 1b-c). Xylem well preserved, in two rows, the row towards pith comparatively less developed with protoxylem facing outward (Pl. 1.4); outer row (towards cortex side) better developed, xylem manoxylic bearing protoxylem on the inner side (Pl. 1.3). Tracheids square to circular (in cross section), thick walled, arranged in radial rows (Pl. 1.2-4). Rays wide and indistinct; phloem not preserved. Out of seven vascular strands, two have faintly preserved leaf traces from free arms of the xylem strands; scalariform thickenings in tracheids of leaf traces.

Comparison—In addition to the present new stem, two more cycadean stems are known from the fossiliferous locality of Amarjola i.e., *Sewardioxylon sahnii* Gupta and *Fascisvarioxylon mehtae* Jain. Similar to the present material, the xylem is made up of two rows with protoxylems facing each other in *S. sahnii* but there are approximately 70 collateral and conjoint bundles in each ring in the latter unlike the seven U, V or C shaped strands of the present material. Pith bundles present (Gupta, 1971; Sharma, 1971). In *F. mehtae,* the vascular strands in ring are many in number and of variable sizes. The inner portion of the xylem is less developed than the outer one and has mesarch protoxylems (Jain, 1964). It differs from the present new stem on the points as described above in *S. sahnii* e.g., number and morphology of bundles and presence of medullary bundles.

Comparison is also made with the pentoxylean stem *Nipanioxylon guptai* Srivastava (1945) in which 6-9 vascular strands (steles) are present surrounding a wide pith. Each strand has a compact secondary xylem on both sides of primary xylem, more on outer side than that of the inner side. The steles are neither U, V or C shaped nor made up of manoxylic xylem unlike the present material. However, the two stems resemble in the manner of origin of leaf traces from the free arms of the vascular strands. Other details are unlike *Manomesarchioxylon heptaxylica*.

In the short shoot of *Pentoxylon sahnii* Srivastava (1945) described by Sahni (1948) and Vishnu-Mittre (1957) there are 5-7 little curved (facing concavity outward) xylem strands (Sharma, 1979) resembling a little with the present material. But the former has pycnoxylic wood with uniseriate rays unlike that of *M. heptaxylica*.

Generally in cycads the vascular zone is made up of many collateral, conjoint, endarch or mesarch

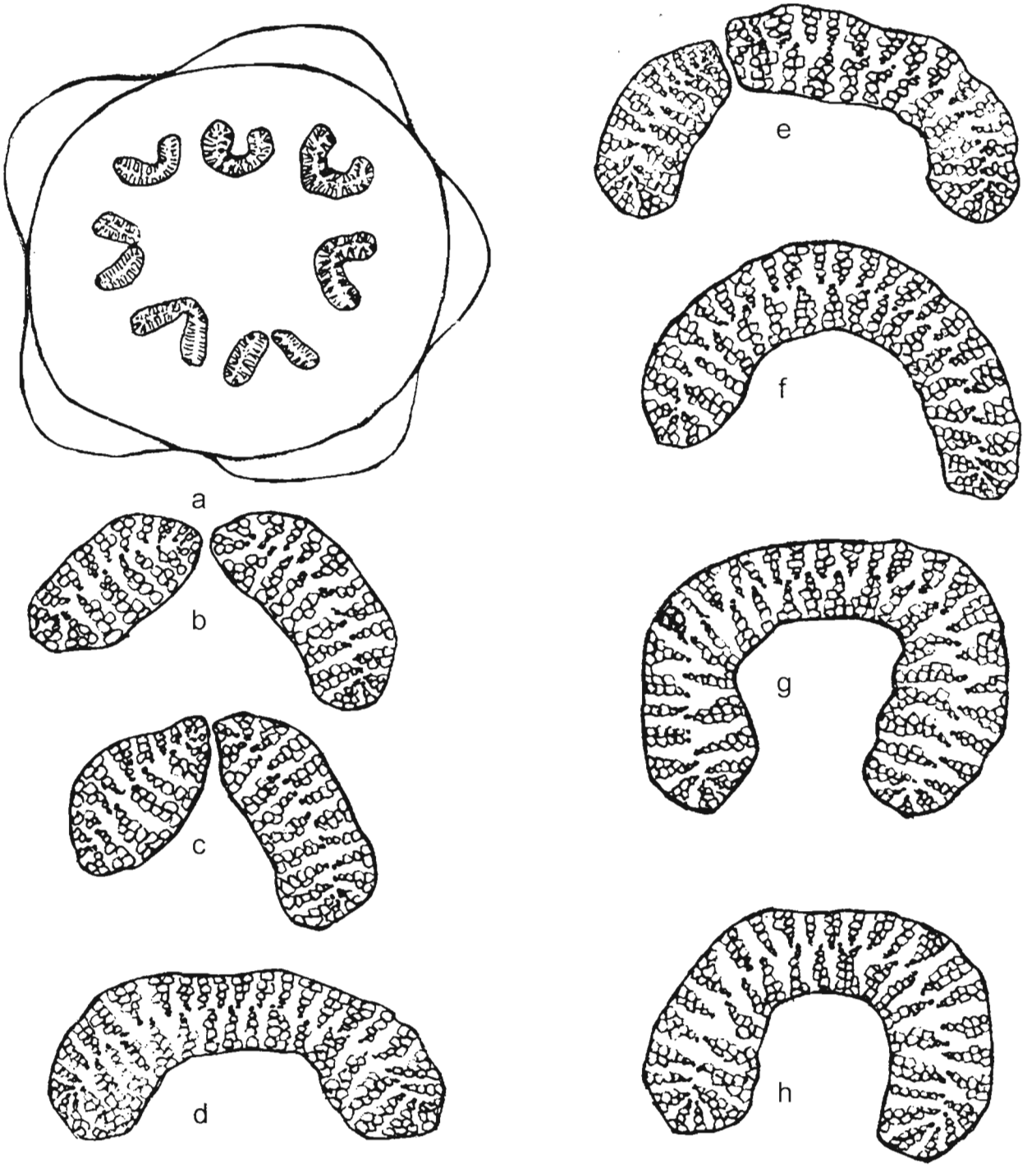

Fig. 1—*Manomesarchioxylon heptaxylica* – (a). Cross section with U, V and C shaped vascular strands (partly diagrammatic) x 10. (b-h). Vascular strands enlarged to show two rows of xylem in each strand. x 72.

bundles surrounding a wide pith. Secondary wood manoxylic. The present material resembles cycads in manoxylic nature of xylem but differs in having less number of vascular strands and in this character it is closer to the conifers (Chamberlain, 1935; Greguss, 1955). However, more and better preserved material is required for further investigations on the new stem *Manomesarchioxylon heptaxylica*.

STANGERIORACHIS gen. nov.

Type Species—*Stangeriorachis heterospinulata* sp. nov.

Diagnosis—Petiole with uneven surface and two kinds of spines arranged in regular sequence; epidermis distinct of squarish cells, hypodermis present; cortex with mucilage canals and tannin cells. Vascular trace large, C-shaped with distinct sheath and many collateral, conjoint and endarch bundles.

Stangeriorachis heterospinulata sp. nov.

(Pl. 2.1, 2; Fig. 2)

Diagnosis—Petiole with spiny surface; spine bases large and small arranged in regular sequence; between two large bases two smaller spines present at equal

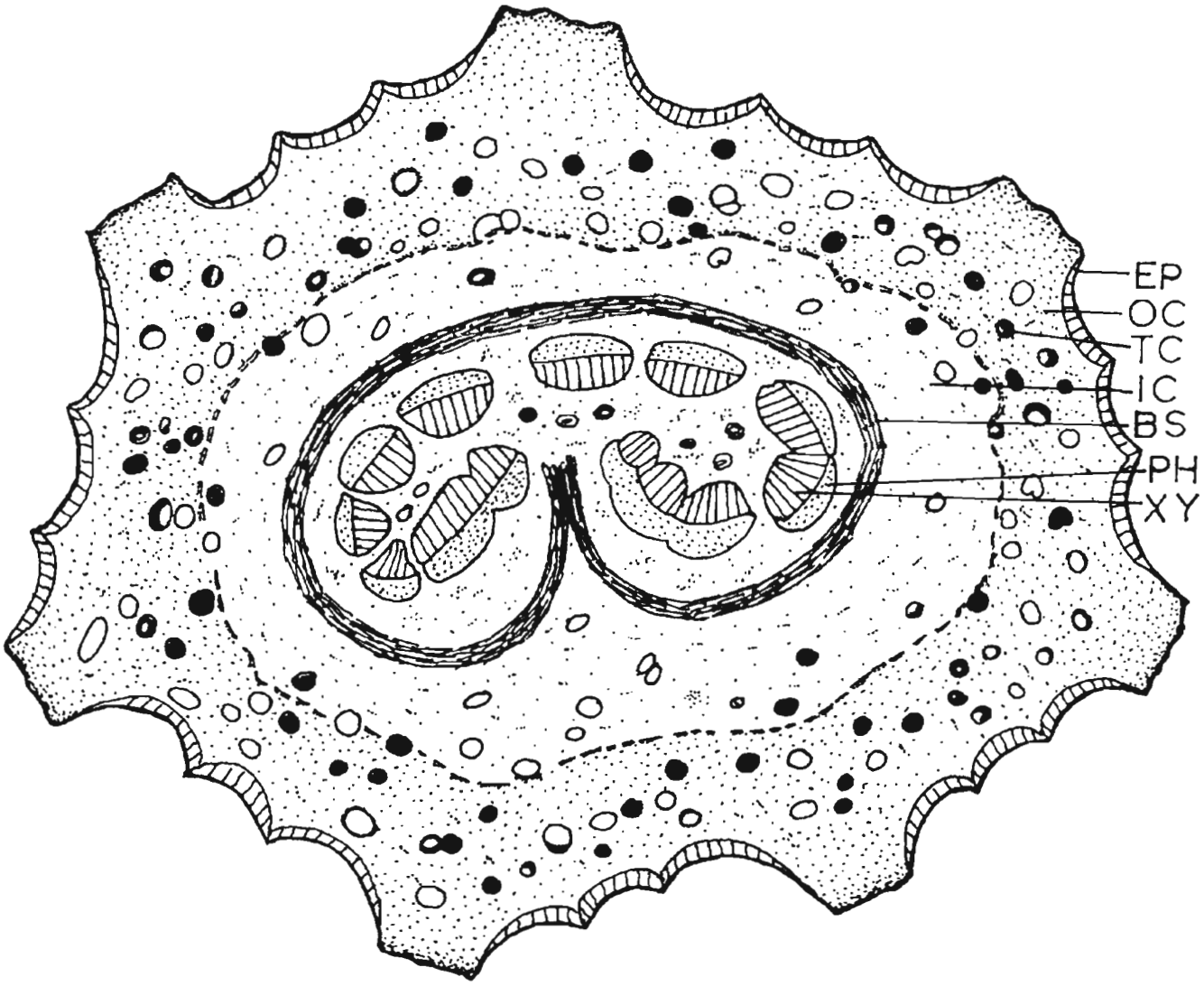

Fig. 2—*Stangeriorachis heterospinulata* – Reconstruction based on BSIP slide no. 13200, 13201, showing two kinds of spine bases, cortex with mucilage ducts and tannin cells, C-shaped vascular trace with a distinct sheath. Epidermis made up of squarish cells. x 72 (Abbreviations: EP – Epidermis, OC – Outer Cortex, TC – Tannin Cell, IC – Inner Cortex, BS – Bundle Sheath, PH – Phloem, Xy – Xylem).

distance. Epidermis distinct, curved between spines; cortex with scattered canals and tannin cells. Vascular region large, C-shaped enclosed by a distinct sheath; bundles 10-12, collateral, conjoint and endarch.

Holotype—BD 250/Raj. C, BSIP slide no. 13200.

Repository—Birbal Sahni Institute of Palaeobotany, Lucknow (India).

Locality—Chilgujari.

Horizon—Lower Cretaceous.

Description—There are two slides no. BD 250/ Raj. C, BSIP slide no. 13200 and BD 251/Raj. C, BSIP slide no. 13201 representing serially cut cross-sections through a piece of Chilgujari chert. It measures 5.7 x 6.1 mm. The material (petiole) present at the margin of the chert piece so the cross-sections are not complete. Surface uneven due to the bases of bigger and smaller spines (Pl. 2.1; Fig. 2). Epidermis distinct, consisting of squarish cells (Pl. 2.2), curved between the adjacent spines. Cortex wide with an outer thick walled and an inner thin walled portion. Mucilage canals and tannin cells scattered throughout the cortex, either solitary or in groups of two (Pl. 2.1). Vascular zone well developed surrounded by a distinct sheath. Vascular bundles 10-12, collateral, conjoint and endarch, arranged in a C-shaped manner with free arms curving inward into the C (Pl. 2.1; Fig. 2). In the bundles xylem facing inner side while phloem facing outward.

Reconstruction—On the basis of the description given above, a reconstruction is attempted of the complete cross-section of the petiole (Fig. 2). It is partially a camera lucida sketch.

Comparison—There are many extant cycadean genera in which petiole has spines either in two lateral rows (*Cycas, Dioon, Macrozamia*) or in several rows (*Zamia, Ceratozamia*). In these plants, vascular strands of the petiole has either diploxylic bundles (*Cycas*) or collateral and conjoint bundles (*Macrozamia, Stangeria, Dioon*) (Gaussen, 1950-52; Pant, 2002). But the C-shaped arrangement of the bundles in the present material is quite distinct and different from majority of extant cycads, except *Stangeria eriopus* in which the bundles in the petiole/ rachis are more or less in C-shaped arrangement and the cortex has scattered, solitary mucilage canals similar to the present material. However, in *S. eriopus* neither there is a distinct sheath surrounding the vascular zone nor the surface has regularly arranged smaller and bigger sized spines.

Comparison is also made with *Cycadinorachis omegoides* Sharma (1973) recorded from Amarjola. Suthar *et al.* (1986) described some better preserved specimens of *C. omegoides* (Pl. 1.5) from Nipania. In them the surface is smooth and mucilage canals and tannin cells are rare. Moreover, sheath surrounding vascular zone is absent and the diploxylic bundles are arranged in an omega. Thus *C. omegoides* is quite different from the present material.

In the locality Chilgujari from where the present material was collected yields a very rich assemblage of bennettitalean plants e.g., *Ptilophyllum, Dictyozamites, Bucklandia, Williamsonia*, etc. (Sharma, 1994, 2000; Sharma *et al.*, 2002). The petioles of *Ptilophyllum* and *Dictyozamites* have

PLATE 1 →

1. *Manomesarchioxylon heptaxylica* (Holotype BD 201/ Raj. A, BSIP slide no. 13198) Cross section. U-shaped vascular strand facing concavity outward. x 48.
2. V-shaped vascular strand broken into two arms. Centrifugal side xylem more developed than of centripetal side x 72.
3. Manoxylic well developed xylem of centrifugal side. x 140.
4. Comparatively lesser developed centripetal side xylem. x 140.
5. *Cycadinorachis omegoides* (BSIP slide no. 13204) cross section, omega shaped arrangement of bundles. Centripetal xylem well developed, phloem unpreserved. x 72.
6. *Macrozamiphyllum mucilagica,* (Holotype, BD 51/Raj. N, BSIP slide no. 13202). Cross section of a curved leaflet with alternating bundles and mucilage canals. x 60.
7. Epidermis papillate, vascular bundle adhered with epidermis by sclerenchyma strands. Phloem unpreserved. x 72.
8. Mucilage canal filled with dark contents. x 72.

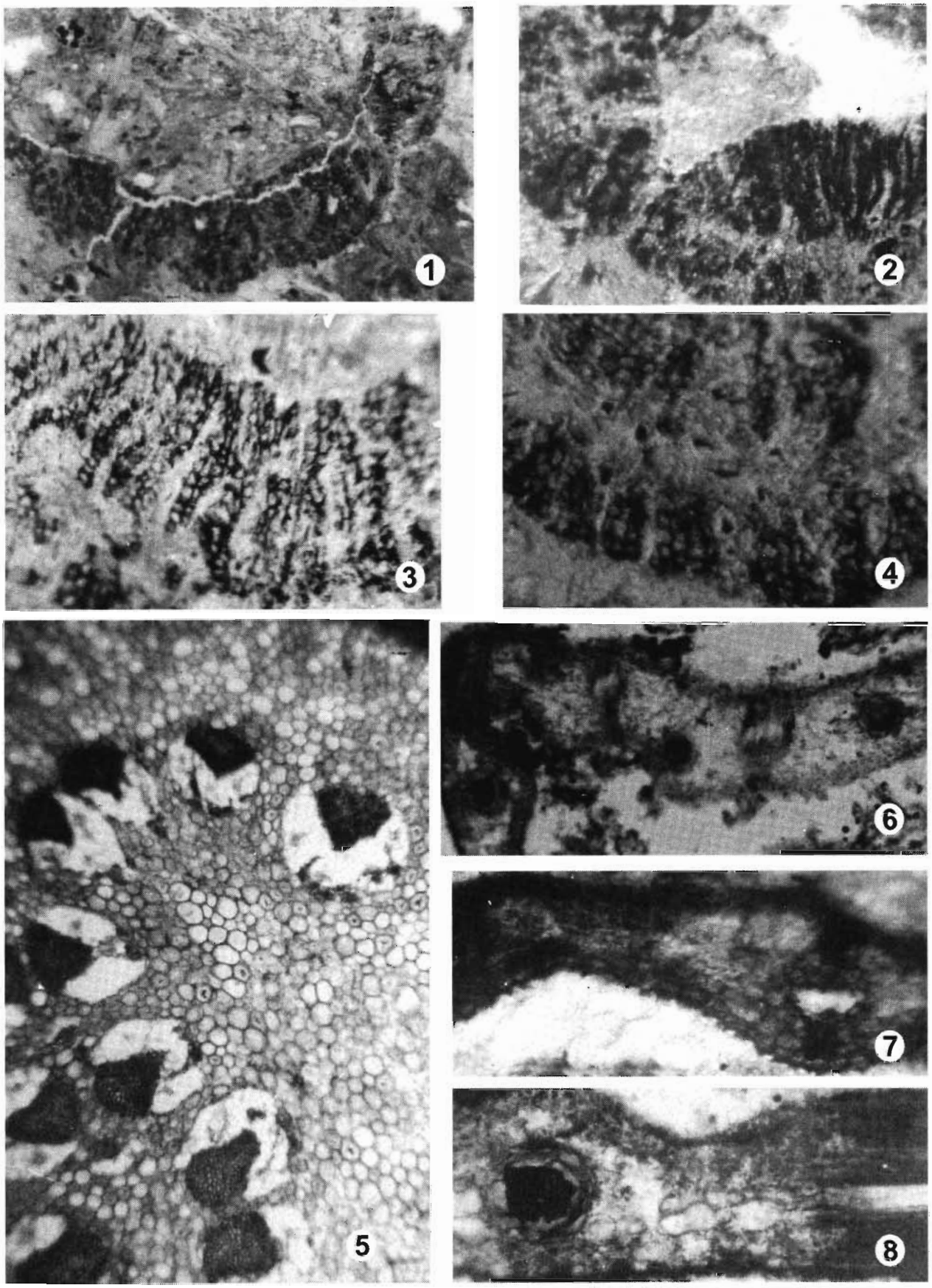

PLATE 1

double U-shaped vascular strands and there is no sheath surrounding the vascular zone. Mucilage canals are absent in cortex (Bose & Zeba-Bano, 1976; Bose & Banerji, 1981; Sharma, 1967a). As such *Stangeriorachis heterospinulata* is quite different from the bennettitalean fronds in anatomy and morphology.

MACROZAMIPHYLLUM gen. nov.

Type Species—*Macrozamiphyllum mucilagica* sp. nov.

Diagnosis—Leaflet with thick lamina, venation parallel with alternating bundles and mucilage canals. Bundles of veins adhered with upper and lower surfaces by sclerenchyma strands. Mesophyll undifferentiated, parenchymatous. Mucilage canals large with distinct sheath. Both upper and lower epidermis papillate, papillae pointed.

Macrozamiphyllum mucilagica sp. nov.

(Pl. 1.6-8; Fig. 3a-d)

Diagnosis—Lamina 6.0 to 8.0 mm thick, veins parallel, in between veins or vein bundles mucilage canals either empty or filled with dark inorganic matter, canal with a distinct sheath similar to that of vein bundle. Bundles hang in mesophyll by sclerenchyma strands and each with distinct sheath; xylem towards upper side centripetal, centrifugal xylem doubtful. Mesophyll undifferentiated, parenchymatous, epidermis distinct, papillate.

Holotype—BD 51/Raj. N, BSIP slide no. 13202.

Repository—Birbal Sahni Institute of Palaeobotany, Lucknow (India).

Locality—Nipania.

Horizon—Lower Cretaceous.

Description—There are three slides — BD 51/Raj. N, BSIP slide no. 13202, BD 52/Raj. N, BSIP slide no. 13203 and BD 53/Raj. N, BSIP slide no. 13204 showing cross sections of leaflets. Slide no. 13202 showing sharply curved leaflet (Pl. 1.6; Fig. 3a), while others are straight. Both upper and lower epidermis distinct with pointed papillae (Pl. 1.7; Fig. 3a-d). Stomata not discernable in any specimen. Mesophyll wide, homogeneous and is made up of isodiametric parenchyma (Fig. 3 a-d). The vein bundles and mucilage canals alternate as in *Macrozamia heteromera* and *M. stenomera* (Pant, 2002). The bundles adhered with both upper and lower epidermis by distinct sclerenchyma strands (Pl. 1.6, 7; Fig. 3c, d) and enclosed in a distinct one cell thick sheath (Pl. 1.7; Fig. 3a). The centripetal xylem multicellular and adaxial. Presence of centrifugal xylem doubtful. Phloem not preserved, represented by a cavity (Pl. 1.7; Fig. 3d). The canals well developed, each with a distinct sheath (Pl. 1.6, 7; Fig. 3a-c) either filled with dark inorganic contents or empty.

Comparison—Only the impressions of the cycadean leaves and pinnae are known from the Rajmahal Hills and other Mesozoic exposures in India (Bose & Banerji, 1981; Seward & Sahni, 1920; Sharma, 1969). The present material is the first record of petrified leaflet, which preserves the anatomical details. These leaflets are found in close association (not organically connected) with the cycadean rachis *Cycadinorachis omegoides* Sharma (Suthar *et al.*,

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PLATE 2 →

1. *Stangeriorachis heterospinulata* (Holotype BD 250/Raj. C, BSIP slide no. 13200). Cross section showing bigger and smaller bases of spines, mucilage canals and tannin cell in cortex and C-shaped vascular strand with a distinct sheath. x 72.
2. A portion of cortex enlarged to show curved epidermis of squarish cells. x 140.
3. Bennettitalean fructification (BSIP slide no. 13205). Cross section showing bracts with numerous scales, rounded bodies in a row. x 60.
4. A portion enlarged to show scales. x 120.
5. Tangential section showing fertile portion with circular micropyles surrounded by hexagonal sterile scales. x 72.
6. Free nucelli of conifer seeds. x ½.

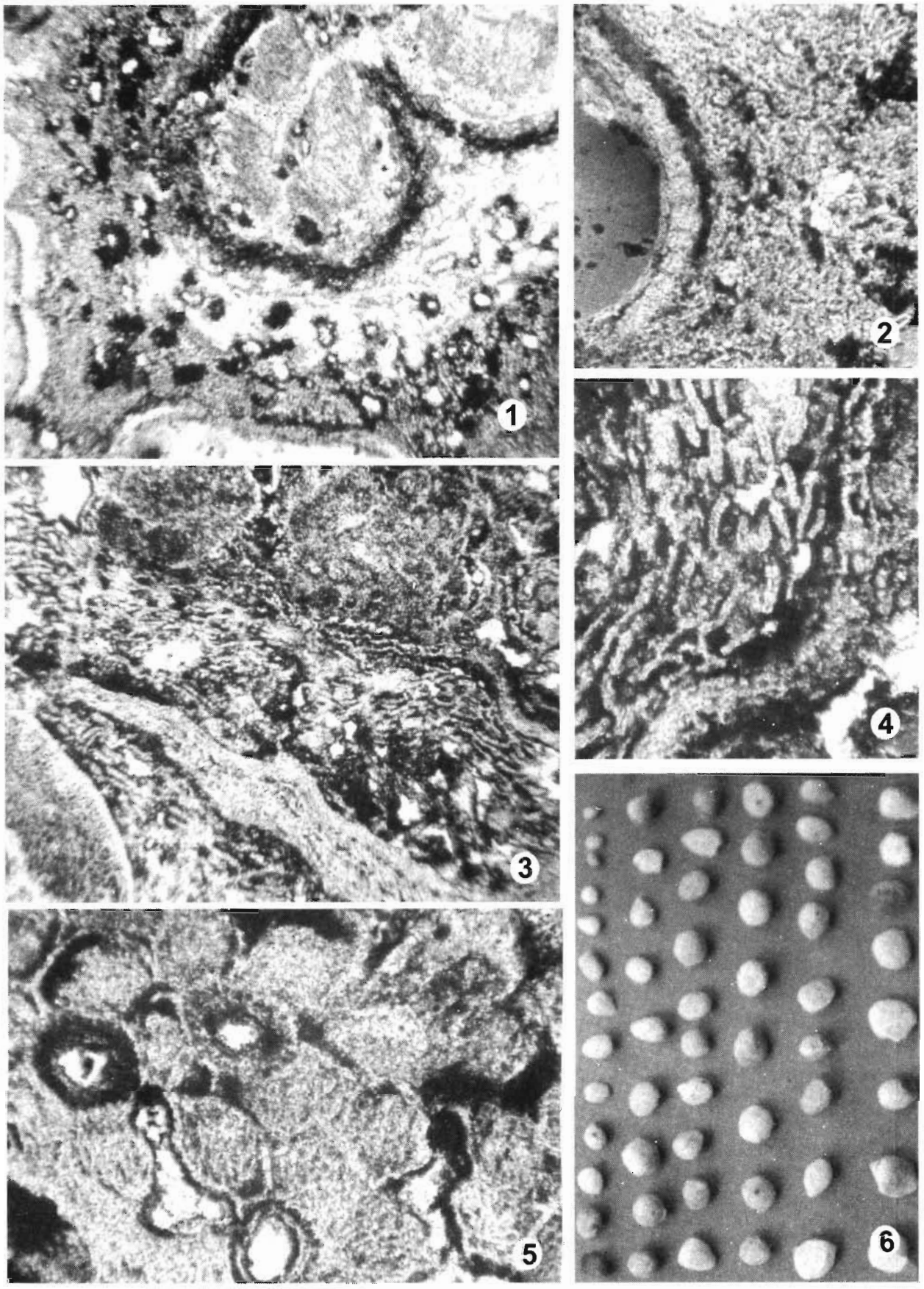

PLATE 2

1986) from the Nipania chert (Pl. 1.5). This rachis has omega-shaped arrangement of bundles which have distinct, multicellular centripetal xylem. The rachis looks more like the extant genus *Cycas* than *Macrozamia* in which an omega-shaped arrangement of bundles is not known (Gaussen, 1950-52). But the anatomy of the leaflets described here is quite similar to those of *Macrozamia heteromera* and *M. stenomera* in having parallel venation, alternate arrangement of bundles, mucilage canals and homogeneous parenchymatous mesophyll. That is why the present material is named *Macrozamiphyllum*. It may be that during the Mesozoic some species of *Macrozamia* or *Macrozamia* like leaves had an omega-shaped arrangement of bundles in their rachises.

BENNETTITALEAN FRUCTIFICATION

(Pl. 2.3-5)

Important bennettitalean fructifications known from the Rajmahal Hills are seed-bearing *Williamsonia* Carr., pollen cone *Weltrichia* Braun and the bisexual *Amarjolia* Bose *et al.* The present material is probably a doubtful bisexual fructification with interesting morphological characters.

Description—Three serially cut slides no. BD 81/Raj. A, BSIP slide no. 13205, BD 82/Raj. A and BD 83/Raj. A (last two slides with authors), oblique transverse sections through a bud showing outer whorl of protecting bracts covered with dense growth of ramenta/scales, 6-15 cells or more in cross section (Pl. 2.3, 4). Inside bracts circular bodies in a linear row probably represent microsporophylls, but no fertile structures i.e., microsporangia or microspores visible. In centre tangentially cut sterile and fertile scales visible (Pl. 2.5); each fertile scale (micropyle) surrounded by 5-8 angular sterile scales.

Comparison—Sahni (1932b) described *Williamsonia sewardiana* from the Rajmahal Hills in which ramenta/scales were present in the basal portion of bracts while tuft of hairs near the terminal ends. This resembles the present material but differs in absence of a row of circular bodies (microsporophyll ?) surrounding sterile and fertile scales and dense growth of scales on the entire length of bracts.

Present material is also comparable to the doubtful bisexual fructification *W. sahnii* Gupta (1943) but differs in the gross morphology of the fructification. Bose *et al.* (1984) described the presence of only long hairs on bracts in the bisexual fructification *Amarjolia dactylota*. It differs markedly from the present material in the morphology of ramenta/scales.

ISOLATED FREE NUCELLI OF CONIFERS

(Pl. 2.6)

Description—Hundreds of free nucelli collected from Sonajori locality range between 6.5 to 9.0 mm in length and show variation in shape i.e., circular or elongated (Pl. 2.6), surface smooth or two or three ridged. Majority of nucelli are silicified and preserves embryo rarely (Suthar *et al.*, 1988).

Comparison—Nucelli free from integument are found in Medullosales, Pentoxylales, Cordaitales and majority of conifers (Andrews, 1961; Stewart & Rothwell, 1993; Taylor & Taylor, 1993). The present collection of nucelli is probably related to conifers and with the families Podocarpaceae and Taxaceae because associated seeds have epimatium and aril (Sharma & Bohra, 1976; Suthar *et al.*, 1988).

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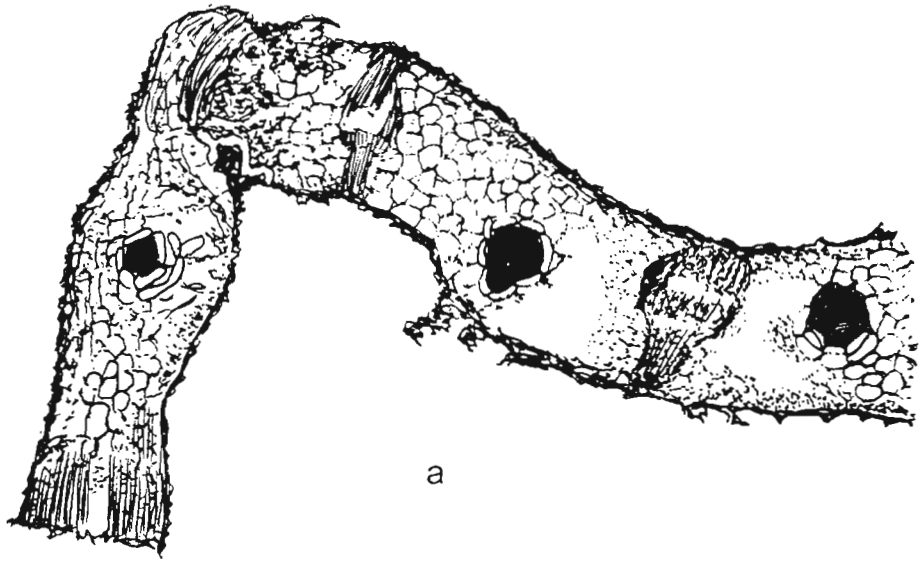
Fig. 3—*Macrozamiphyllum mucilagica* - (a). Holotype BD 51/Raj N. (BSIP slide no. 13202). Cross section – a curved leaflet with alternating bundles and mucilage canals. x 72. (b). Papillate epidermis and a mucilage canal filled with dark contents. x 72. (c). Bundles and alternating mucilage canals. x 72. (d). Papillate epidermis, parenchymatous mesophyll and a bundle with supporting sclerenchyma strands, bundle sheath and centripetal xylem distinct. Phloem is unpreserved. x 100 (All drawings partly diagrammatic).



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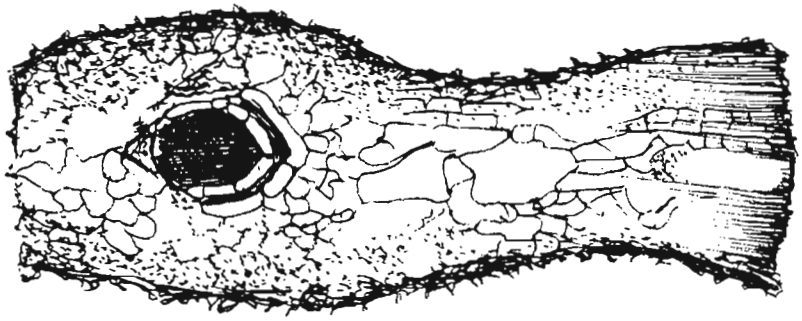

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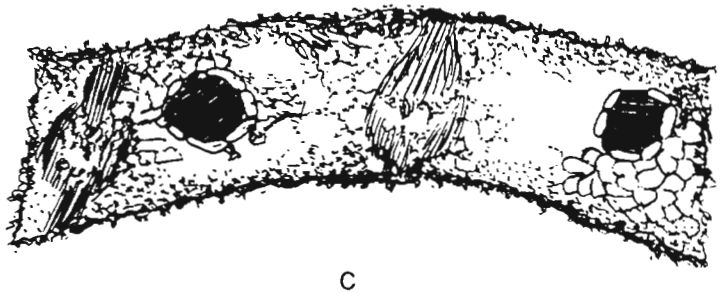

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REFERENCES

Andrews HN 1961. Studies in Palaeobotany. John Wiley & Sons, New York.

Banerji J 1996. Early Cretaceous megaflora from Murlipahar, Rajmahal Basin, India. Geophytology 25 : 41-46.

Banerji J 2000. Megafloral diversity of the Upper Gondwana sequence of the Rajmahal Basin, India. African Earth Science 31 : 133-144.

Banerji J & Jana BN 2000. Early Cretaceous megaflora from Bartala Hill, Rajmahal Basin, India. Palaeobotanist 49 : 51-59.

Banerji J & Jana BN 2003. Petrified araucarian remains from Sonajori, Rajmahal Basin, India. Palaeobotanist 52 : 55-62.

Bohra DR & Sharma BD 1979. Jurassic petrified filician plants from the Rajmahal Hills, India. Annals of Botany (NS) 44 : 749-756.

Bose MN 1953. *Bucklandia sahnii* sp. nov. from the Rajmahal Hills. Palaeobotanist 2 : 41-50.

Bose MN 1966. A petrified bennettitalean flower from the Rajmahal Hills, India. Current Science 35 : 569-570.

Bose MN 1968. A new species of *Williamsonia* from the Rajmahal Hills, India. Botanical Journal of the Linnean Society, London 61 : 121-127.

Bose MN & Banerji J 1981. Cycadophytic leave from Jurassic – Lower Cretaceous rocks of India. Palaeobotanist 28-29 : 218-300.

Bose MN & Pal PK 1982. *Hepaticites pantii* sp. nov. from Rajmahal Hills, Bihar. *In* Nautiyal DD (Editor)—Studies on living and fossil plants (Pant Comm. Vol.) *Phyta* : 31-33.

Bose MN & Sah SCD 1954. *Sahnioxylon rajmahalense* a new name for *Homoxylon rajmahalense* Sahni and *S. andrewsii*, a new species of *Sahnioxylon* from Amrapara in the Rajmahal Hills. Palaeobotanist 3 : 1-10.

Bose MN & Sah SCD 1968. Some pteridophytic remains from the Rajmahal Hills, Bihar. Palaeobotanist 16 : 12-28.

Bose MN & Zeba-Bano 1976. The genus *Dictyozamites* Oldham from India. Palaeobotanist 25 : 79-99.

Bose MN, Banerji J & Pal PK 1984. *Amarjolia dactylota* (Bose) comb. nov. a bennettitalean bisexual flower from the Rajmahal Hills, India. Palaeobotanist 32 : 217-229.

Bose MN, Pal PK & Harris TM 1985. The *Pentoxylon* plant. Philosophical Transactions of the Royal Society, London 110B : 77-108.

Chamberlain CJ 1935. Gymnosperms – Structure and Evolution. Chicago University Press, Chicago.

Delevoryas T 1962. Morphology and Evolution of Fossil plants. Holt, Rinehart and Winston, New York.

Delevoryas T 1968. Investigations on North American Cycadeoids : Structure, ontogeny and phylogenetic considerations of cones of *Cycadeoidea*. Palaeontographica B 121 : 121-133.

Feistmantel O 1877. Jurassic (Liassic) flora of the Rajmahal Group in the Rajmahal Hills. Memoir Geological Survey of India. Palaeontologica Indica series 2, 1(2) : 53-162.

Ganju PN 1946. On a collection of fossil plants from the Rajmahal Hills, Bihar. Journal of Indian Botanical Society (Iyangar Comm. Vol) : 51-85.

Gaussen H 1950-52. Les gymenospermes actuelles et fossiles. III Les cycadales. Toulouse, France. Les. Frires Douladosure.

Greguss P 1955. Identification of living gymnosperms on the basis of their xylotomy. Akademiai Kiodq. Budapest.

Gupta KM 1943. A new species of *Williamsonia* (*W. sahnii*) from the Rajmahal Hills. Journal of the Indian Botanical Society 22 : 181-189.

Gupta KM 1971. Investigations on the Jurassic flora of the Rajmahal Hills, India 9. On the structure and affinities of *Sewardioxylon sahnii* gen. et sp. nov. Gupta, a petrified cycadean wood from the Rajmahal Hills, India. Palaeontographica B 131 : 160-166.

Jain KP 1964. *Fascisvarioxylon mehtae* gen. et sp. nov., a new petrified cycadean wood from the Rajmahal Hills, Bihar, India. Palaeobotanist 11 : 138-143.

Oldham T & Morris J 1863. Fossil flora of the Rajmahal Series in the Rajmahal Hills. Fossil Flora of Gondwana System. Memoirs of the Geological Survey of India, Palaeontologica Indica Series II, Part 1 : 1-52.

Pant DD 2002. An introduction to gymnosperms – Cycas and cycadales. Memoir No. 6. Birbal Sahni Institute of Palaeobotany, Lucknow, India.

Rao AR 1972. The Jurassic flora of the Rajmahal Hills. 18th Sir A.C. Seward Memorial Lecture. Birbal Sahni Institute of Palaeobotany, Lucknow.

Sah SCD & Jain KP 1965. Jurassic spores and pollen grains from the Rajmahal Hills, Bihar, India with a discussion on the age of the Rajmahal intertrappean beds. Palaeobotanist 13 : 264-290.

Sahni B 1932a. *Homoxylon rajmahalense* gen. et sp. nov., a fossil angiospermous wood, devoid of vessels, from the Rajmahal Hills, Bihar. Memoir Geological Survey of India, Palaeontologica Indica 20(2) : 1-19.

Sahni B 1932b. A petrified *Williamsonia* (*W. sewardiana* sp. nov.) from the Rajmahal Hills, India. Memoir Geological Survey of India, Palaeontologica Indica 20(3) : 1-19.

Sahni B 1948. The Pentoxyleae – a new group of Jurassic gymnosperms from the Rajmahal Hills of India. Botanical Gazette 110 : 47-80.

Sen Gupta S 1988. Upper Gondwana stratigraphy and palaeobotany of Rajmahal Hills, Bihar, India. Memoir Geological Survey of India, Palaeontologica Indica 48 : 1-182.

Seward AC & Sahni B 1920. Indian Gondwana plants – a revision. Memoir Geological Survey of India, Palaeontologica Indica 7(1) : 1-41.

Sharma BD 1967a. Investigations on the Jurassic flora of Rajmahal Hills 3. A review of the genus *Ptilophyllum* of

Morris with description of two new species from Amarjola in the Rajmahal Hills. Palaeontographica B 120 : 139-150.

Sharma BD 1967b. On a new species of Indian *Bucklandia* (*B. guptai*) with remarks on *B. sahnii* of Bose. Ameghiniana 4 : 35-40.

Sharma BD 1968. Epidermal studies in the bracts of two new species of *Williamsonia, W. guptai* and *W. amarjolense*. Acta Botanica Hungerica 14 : 373-383.

Sharma BD 1969a. Further observations on *Williamsonia santalensis* Sitholey & Bose with description of a new species. Palaeontographica B 125 : 93-103.

Sharma BD 1969b. On some fossil cycadean fronds from India. Bulletin Botanical Survey of India 11 : 115-119.

Sharma BD 1970. On the structure of *Williamsonia* cf. *W. scotica* from the Middle Jurassic of Rajmahal Hills. Annals of Botany (NS) 34 : 1063-1070.

Sharma BD 1971. Further observations on *Sewardioxylon sahnii* Gupta collected from the Middle Jurassic of Rajmahal Hills, India. Acta Botanica Neerlandica 20 : 475-480.

Sharma BD 1973. Anatomy of petrified rachises collected from the Jurassic of Amarjola Rajmahal Hills, India. Proceedings of the Linnean Society, New South Wales 98 : 43-49.

Sharma BD 1974. Ovule ontogeny in *Williamsonia* Carr. Palaeontographica B 146 : 137-143.

Sharma BD 1979. Further observations on the dwarf shoot of *Pentoxylon sahnii* Sriv. collected from the Rajmahal Hills, India. Acta Palaeobotanica 20 : 129-136.

Sharma BD 1994. Fossil flora of the Rajmahal Hills – some landmark discoveries. *In* : Sharma TA, Saini SS, Trivedi ML & Sharma M (Editors)—Current researches in plant sciences : 139-145. Bisan Singh Mohinder Pal Singh, Dehradun, India.

Sharma BD 1997. An early angiosperm fructification resembling *Lesqueria* Crane & Dilcher from the Rajmahal Hills, Bihar. Phytomorphology 47 : 305-310.

Sharma BD 2000. Vegetation diversity during Upper Jurassic in the Rajmahal Hills, India. *In* : Chauhan DK (Editor)—Recent trends in botanical researches : 173-179. Department of Botany, University of Allahabad, Allahabad, India.

Sharma BD 2002. Misinterpretations about the 'Pentoxyleae' – a Mesozoic gymnosperm group of plants. Palaeobotanist 50 : 255-265.

Sharma BD 2004. Mesozoic pteridophytes of India – an overview. Indian Fern Journal 21 : 1-12.

Sharma BD & Bohra DR 1976. A new assemblage of fossil plants from the Rajmahal Hills, India. Geobios (France) 9 : 111-123

Sharma BD & Harsh R 1987. Study of amino acids in petrified plants from the Rajmahal Hills. Palaeobotanist 36 : 207-209.

Sharma BD & Harsh R 1994. Polysiphonous algae from the Mesozoic non-marine deposits of the Rajmahal Hills, India. Phytomorphology 44 : 261-264.

Sharma BD & Suthar OP 1989. Algal symbiotic gymnospermous roots from the Mesozoic of Rajmahal Hills, India. Phytomorphology 39 : 161-163.

Sharma BD & Tripathi RP 1997. A petrified coenobial alga from the Mesozoic rocks of the Rajmahal Hills, Bihar (India). Phytomorphology 47 : 371-374.

Sharma BD, Bohra DR & Suthar OP 2002. Some interesting plant fossils from the Mesozoic rocks of the Rajmahal Hills, India. Palaeobotanist 50 : 207-212.

Sitholey RV & Bose MN 1953. *Williamsonia santalensis* sp. nov.-a male fructification from the Rajmahal Series with remarks on the structure of *Ontheanthus polyandra* Ganju. Palaeobotanist 2 : 29-39.

Sitholey RV & Bose MN 1971. *Weltrichia santalensis* (Sitholey & Bose) and other bennettitalean male fructification from India. Palaeontographica B 131 : 151-159.

Srivastava BP 1945. Silicified plant remains from the Rajmahal Hills, India. Proceedings of the National Academy of Sciences, India 15 : 185-311.

Stewart WN & Rothwell GW 1993. Palaeobotany and the evolution of plants. Cambridge University Press, Cambridge.

Suthar OP & Sharma BD 1988. A new interpretation on the structure of *Sahnia nipaniensis* Mittre from the Rajmahal Hills, India. Palaeobotanist 37 : 90-93.

Suthar OP, Bohra DR & Sharma BD 1986. Further observations on *Cycadinorachis omegoides* Sharma from the Jurassic of Rajmahal Hills, India. Palaeobotanist 35 : 297-300.

Suthar OP, Bohra DR & Sharma BD 1988. Petrified isolated gymnospermous seeds from the Jurassic of Rajmahal Hills, India. Acta Palaeobotanica 28 : 15-20.

Tripathi A 2004. Palynology evidences of hitherto unrecognized Jurassic sedimentation in Rajmahal Basin, India. Revista Italiana di Paleontologia e stratigrafia 110 : 35–42.

Taylor TN and Taylor EL 1993. The Biology and Evolution of fossil plants. Prentice Hall Inc, New Jerrsy (USA).

Vishnu-Mittre 1953. A male flower of the Pentoxyleae with remarks on the structure of the female cones of the group. Palaeobotanist 2 : 75-84.

Vishnu-Mittre 1954. Petrified spores and pollen grains from the Jurassic rocks of the Rajmahal Hills, Bihar. Palaeobotanist 3 : 117-127.

Vishnu-Mittre 1957. Studies on the fossil flora of Nipania (Rajmahal Series), India – Pentoxyleae. Palaeobotanist 6 : 31-46.

Vishnu-Mittre 1959. Studies on the fossil flora of Nipania (Rajmahal Series), India – Pteridophyta and general observation on Nipania fossil flora. Palaeobotanist 7 : 47-66.