

# Petrified araucarian remains from Sonajori, Rajmahal Basin, India

JAYASRI BANERJI AND B.N. JANA

*Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.*

(Received 21 August 2001; revised version accepted 18 December 2002)

## ABSTRACT

Banerji J & Jana BN 2003. Petrified araucarian remains from Sonajori, Rajmahal Basin, India. *Palaeobotanist* 52(1-3) : 55-62.

Permineralized araucarian ovulate and pollen cones are described here for the first time in close association from Early Cretaceous intertrappean rocks of the Sonajori Locality in the Rajmahal Basin, Jharkhand. These cones were found associated with woods and leafy shoots bearing spirally arranged falcate to oblanceolate leaves. The leaf, in longitudinal section shows epidermis followed by parenchymatous mesophyll and transfusion tissue. Ovulate cones, elliptical-spherical in shape, with spirally attached bracts and ovuliferous scales bearing mostly one and rarely two ovules/seeds per cone scale complex. Cone scale complex is characterised by the presence of "circa" (ligular sulcus). In one specimen, cross-section shows close association of numerous pollen grains with the cone scale complex of the cone indicating the preservation of cone at pollination stage. In another specimen, cross-section shows cone scale with oblong inverted ovule/seed, ovule integument/seed testa with three distinct layers, nucellus free except at chalazal end, shrunken at micropylar region and the presence of an embryonic tissue shows a post fertilisation stage of cone preservation. Anatomical features of these cones indicate various stages of cone maturity. The microsporangiate cone elongated in shape, in tangential view shows microsporophylls as well as circular-oval sporangia in cross-section. Transverse-sections of cone shows a central axis surrounded by numerous elongated narrow sporangia in longitudinal section and rhomboidal tip of the microsporophyll. The microsporophyll shows only parenchymatous tissue in sectional view of distal part; dispersed circular alete pollen grains are found associated with ovulate/seed cone and sterile shoots. Morphological and anatomical features of all the Indian species of araucarian cone described earlier are also critically assessed.

**Key-words**—Araucarian remains, Sonajori, Rajmahal Formation (Intertrappeans), Early Cretaceous, India.

## भारत की राजमहल द्रोणी के सोनाजोरी से प्राप्त अश्मीभूत अराउकेरियन अवशेष

जयश्री बनर्जी एवं बृजेन्द्र नाथ जाना

### सारांश

झारखण्ड की राजमहल द्रोणी की सोनाजोरी संस्थिति के प्रारंभिक क्रिटेशस अन्तर्द्वितीय शैल प्रस्तरों से निकटस्थ साहचर्य में प्रथम बार प्राप्त पर खनिजीय अराउकेरियन बीजाण्डी तथा परागाणु शंकुओं का वर्णन यहाँ अभिप्रेत है। ये शंकु सर्पिलतः व्यवस्थित हैंसियाकार से प्रतिकुन्ताकार पत्तियों से युक्त काष्ठ एवं पर्ण प्ररोह से साहचर्य में पाए गए। अनुदैर्घ्य परिच्छेद में पर्ण बाह्यत्वचा प्रदर्शित करती है, तत्पश्चात् क्रमशः मृदुतकी पर्णमध्योत्क तथा संचरण ऊतक आते हैं। बीजाण्डी शंकु जो दीर्घवृत्तीय-गोलाकार है तथा सर्पिलतः संयुग्मित सहपत्रों तथा बीजाण्डीय मापन से युक्त है, में प्रायः अधिकतम एक अथवा विरलतः दो बीजाण्ड/बीज प्रति शंकु मापक संकुल पाए गए हैं। शंकु मापक संकुल को "सिरका" (जीभिकाकार सल्कस) की उपस्थिति द्वारा अभिलक्षणित किया गया है। एक प्रादर्श में, क्रॉस परिच्छेद अनेक परागकणों की परागण अवस्था के दौरान शंकु के संरक्षण को इंगित करने वाले शंकु के शंकु मापक संकुल के साथ निकटस्थ साहचर्य

प्रदर्शित करता है। एक अन्य प्रादर्श में क्रॉस परिच्छेद बीजाण्डद्वारीय क्षेत्र संकुचित, विभाग; कैलाजा छोर अतिरिक्त बीजाण्डकाय युक्त, तीन सुस्पष्ट परतों से युक्त बीजाण्ड अध्यावरण/बीज चोल, दीर्घयत्त प्रतिलोमित बीजाण्ड/बीज से युक्त शंकु मापक प्रदर्शित करता है तथा एक भ्रूणीय ऊतक की उपस्थिति शंकु संरक्षण की एक उत्तर निषेचन अवस्था प्रदर्शित करती है। इन शंकुओं के शारीरिक अभिलक्षण शंकु परिपक्वता की विभिन्न दशाएँ इंगित करते हैं। स्पर्श रेखीय दृष्टिकोण से दीर्घित सूक्ष्म बीजाणुधरू शंकु क्रॉस परिच्छेद में सूक्ष्म बीजाणुपूर्ण तथा वृत्ताकार अण्डाकृतिक बीजाणुधानी प्रदर्शित करता है। शंकु का अनुप्रस्थ परिच्छेद एक मध्य अक्ष प्रदर्शित करता है, जो अनुप्रस्थ परिच्छेद में अनेक दीर्घित संकुचित बीजाणुधानियों तथा सूक्ष्म बीजाणुपूर्ण के चतुष्कोणी टिप द्वारा घिरी हुई है। ससूक्ष्म बीजाणुपूर्ण दूरस्थ भाग के परिच्छेदीय प्रदर्शन में मात्र मृत्तक ही प्रदर्शित करता है। परिक्षिप्त वृत्ताकार अरहीन परागकण बीजाणुडी/बीज शंकु तथा बन्ध्य प्ररोह के साथ साहचर्य में पाए गए हैं। पूर्व वर्णित अराउकेरियन शंकु की सभी भारतीय प्रजातियों के आकारवर्गिकीय तथा शारीरिक अभिलक्षणों का भी इस शोध पत्र में समीक्षात्मक मूल्यांकन किया गया है।

संकेत शब्द—अराउकेरियन अवशेष, सोनाजोरी, राजमहल शैल समूह (अन्तर्द्वीपीय), प्रारंभिक क्रिटेशस, भारत ।

## INTRODUCTION

THE family Araucariaceae appeared during Permian, diversified in Jurassic-Early Cretaceous in Northern and Southern Hemispheres and declined during Upper Cretaceous Period. At present this family is confined only in the Southern Hemisphere with a restricted distribution. Evidence of *Araucarites* (detached cone scale complexes) is well known from the Rajmahal Basin but the ovulate/seed cones are recorded so far only from Bindrabun, Amarjola and Sonajori localities of Rajmahal Basin. Vishnu-Mittre (1954) described well preserved cones from the Bindrabun Locality as *Araucarites bindrabunensis* showing resemblance with the living species of *Araucaria bidwillii* Hook. of the section—*Bunya* (Wilde & Eames, 1952). Miller (1977) suggested that the *Araucarites bindrabunensis* Vishnu Mittre perhaps represents an extinct species of the section- *Bunya* of *Araucaria*. Bohra and Sharma (1980b) described *Araucarites mittrii* from Sonajori locality near Pakur in the Rajmahal Basin.

## MATERIAL AND METHODS

The present cones and cone fragments are recovered as permineralised specimens from the Sonajori Locality of Rajmahal Basin. This locality is about 4 km west of Pakur Railway Station near an abandoned quarry at Sonajori. The petrified cherts are found scattered in the field near the quarry. Four cones with ovules/seeds and a few pieces of seed cone

fragments have been recovered from this locality. Out of which, two are broken parts of probably elongated-spherical mature cone in transverse section with well preserved cone scales and another two cones are young elliptical in shape. The rest specimens appear to be shattered pieces of mature cones. While sectioning the cherts, in one chert slice an oblique tangential section of a pollen cone and a transverse section of another specimen have also been recovered. Besides these fossils, conifer shoots with spirally arranged falcate leaves, stem with secondary wood and numerous araucarian root sections have been recognised which shows the dominance of conifers (Araucariaceae) in this assemblage. Slides were prepared by usual method of cutting, grinding, polishing process and mounted in Canada Balsam.

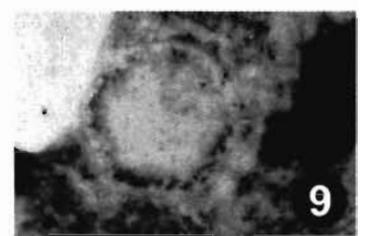
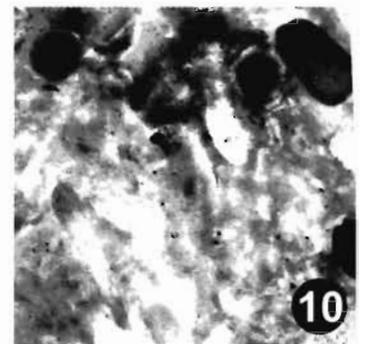
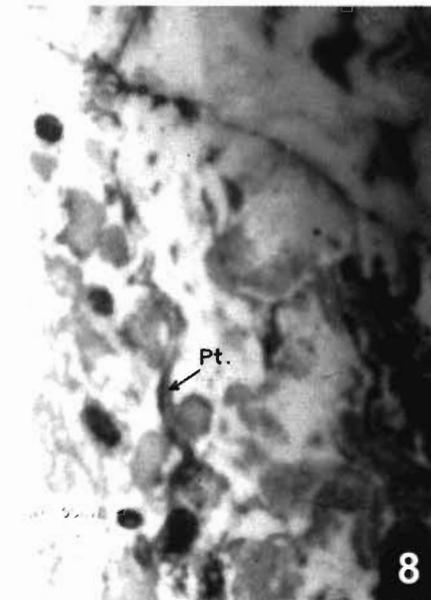
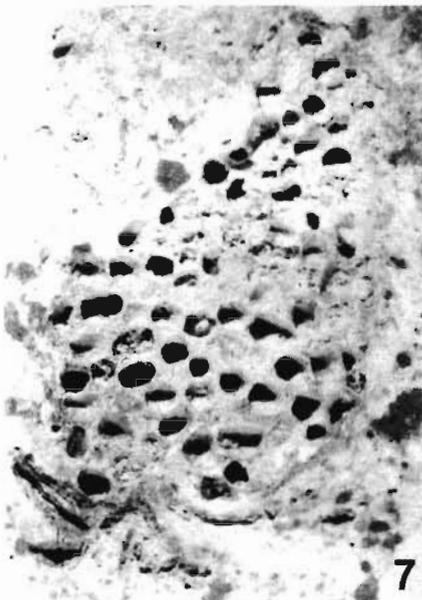
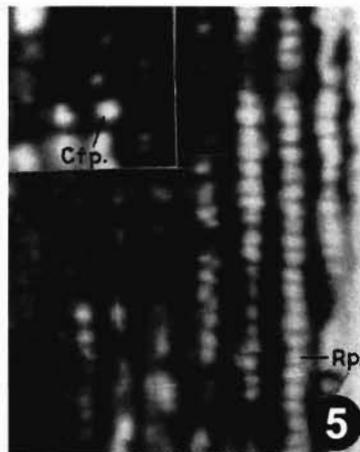
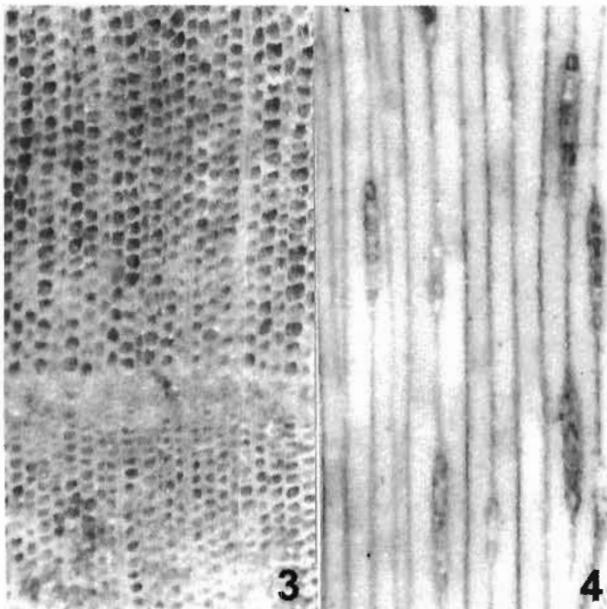
## DESCRIPTION

*Root*—Numerous sections of petrified diarch-triarch roots preserved as silicified condition (Pl. 1-1), and identified as *Araucamyelon pakurensis* Bohra and Sharma (1980a). Cross-section of roots usually 7-9 mm in diameter. Periderm is generally about 0.5 mm wide, comprised of rectangular cells. The inner cortex in young roots is about 0.2-0.3 mm wide and is parenchymatous. Primary xylem not preserved in older roots. Secondary xylem is equally or unequally developed showing growth rings.

*Remarks*—Bohra and Sharma (1980a) and Sharma (1989) show a similar type of equal and unequal lobing of excentric secondary growth in extinct coniferous roots.

## PLATE 1

- |   |   |
|---|---|
| <ol style="list-style-type: none"> <li>1. <i>Araucamyelon pakurensis</i> Bohra &amp; Sharma, showing diarch condition, Slide No. BSIP 12628. x 8.</li> <li>2. Cross-section of decorticated secondary wood of <i>Araucarioxylon</i> sp., Slide No. BSIP 12629. x 1.</li> <li>3. Transverse section showing growth rings, Slide No. BSIP 12630. x 60.</li> <li>4. Tangential longitudinal section showing radial pits, Slide No. BSIP 12631 x 120.</li> <li>5. Radial longitudinal section showing tracheidial pits (Rp.) and cross field pits (Cfp.), Slide No. BSIP 12632. x 160.</li> </ol> | <ol style="list-style-type: none"> <li>6. Leafy shoot. Slide No. BSIP 123633. x 6.</li> <li>7. Male cone in oblique longitudinal section. Specimen No. BSIP 38882. x 4</li> <li>8. T.S. of female cone showing bract-scale complex associated with pollen bearing hyphae-like pollen tube (Pt.), Slide No. BSIP 12634. x 8.</li> <li>9. Doubtful pollen, Slide No. BSIP 12633. x 28.</li> <li>10. Leafy shoot found associated with pollen, Slide No. BSIP 12633. x 8.</li> </ol> |
|---|---|



**Stem**—Large block of decorticated stem (Pl. 1.2) perhaps preserved in *in-situ* was vertically deposited in the rock matrix. The block is about 14 cm in diameter, with distinct growth rings (Pl. 1.3). The pith is well defined consisting of parenchymatous tissue, 0.9 cm wide. Protoxylem at places is faintly visible and appears endarch. Radial walls of the tracheids usually have one row of hexagonal, contiguous, bordered pits with a circular aperture (Pl. 1.5), rarely biseriate. Alternate crossfield pits are mostly not preserved except in few places where they appear circular. Tangential sections of wood show (Pl. 1.4) medullary rays, uniseriate, 2-12 cells high. Xylem parenchyma is absent.

**Comparison**—On the basis of the presence of araucaroid hexagonal, contiguous bordered pits on the tracheid wall of the present wood, it is assigned to the taxon-*Araucarioxylon* sp. In anatomical features this wood differ from all the known species of the Rajmahal Basin except *A. santalense* (Sah & Jain) Bose and Maheshwari (1974). It can be distinguished from *A. santalense* in possessing a single circular pit in the cross-field instead of 2-6 circular bordered pits in the crossfield as in *A. santalense*.

**Shoot**—Twigs with spirally attached leaves are present at this locality (Pl. 1.6, 10). Leaves 2 x 0.5 mm in size, attached at an angle of 45°-50°, lanceolate-falcate in shape with acute-subacute apex. Leaf bases are rhomboidal. In sectional view leaves show a single midvein accompanied by transfusion tissue. The mesophyll is loose, poorly preserved and cannot be differentiated into palisade and spongy parenchyma. The epidermis is distinct.

**Comparison**—In general appearance these twigs show resemblance to *Pagiophyllum araucaroides* Vishnu-Mittre (1957, pl. 12, fig. 92).

**Pollen Cone**—Two incomplete pollen cones are recognised in the chert. One is cut in tangential (oblique) longitudinal section (Pl. 1.7) showing a cone in terminal end, 1.3 x 0.7 cm in size. The axis bearing spirally attached microsporophylls with circular-oval depressions that may be sporangia and at places microsporophylls also partly visible. In another slide, a cone in cross sectional view (Pl. 2.1) is faintly visible. The distal end of microsporophyll in sectional view (Pl. 2.1M) shows parenchymatous cells. No anatomical

details of the central axis is discernable except elongated sporangia could be seen (Pl. 2.1sp.) in longitudinal sectional view.

**Remarks**—Pollen is not preserved in the pollen sac but large no. of pollen grains are found associated with the pollen cone as well as the seed cone (Pl. 2.1, 6). The pollen (Pl. 1.8-10) are alete, circular, and the exine is probably granulose, although the exinal pattern is not very distinct. However, in size, exinal features and alete nature these pollen are similar to *Araucariacites*-type pollen confirming the affinity of these dispersed pollen with Araucariaceae. Moreover, the close-association of these pollen cones, seed cones and pollen conclusively prove their affinity with Araucariaceae.

**Ovulate or Seed Cone**—Four well preserved young and mature cones were recovered that show the cone scale complex with typical features of araucarian cones, i.e., spirally attached large hairy bracts, overlain by thin ovuliferous scale, distal part of ovuliferous scale is free forming a "ligular sulcus". The depth of the sulcus varies, depending upon the maturity of cone as stated by the study of ovule and seed of *Araucaria bidwillii* (Wilde & Eames, 1948) and is also observed by Stockey (1978) in *Araucaria mirabilis* (Segazzini) Windhausen. Two elliptical cones are found embedded in the rock matrix. The weathered specimens have exposed ovules/seeds in places (Pl. 2.2, 3) and 5.5 x 3.0 cm in size. Other two specimens recovered show half portion (Pl. 2.6; 9) of a spherical cone in transverse section. Besides these, cone fragment that is the best preserved is about 5.5 cm in diameter. These fragments may be shattered portion of a mature cone showing well preserved anatomical features.

**Cone Axis**—In cross section of the cone axis (Pl. 2.5) is 5.5 x 3.5 mm in diameter. It consists of a parenchymatous pith with sclerotic cells at places in the central region, that is surrounded by secondary vascular tissue 2 mm thick, cortex is not preserved. The vascular traces seem to be originated separately for bract scale and ovuliferous scale as shown in Pl. 2.8. Separate origins of ovuliferous scale and bract scale traces from cone axis is represented by extant species *Araucaria bidwillii* (Wilde & Eames 1948, text-fig. 10A) of the section- *bunya-bunya* of Araucariaceae.

## PLATE 2

- |  |   |
|--|---|
| <ol style="list-style-type: none"> <li>1. Male cone in transverse section showing elongated sporangia (Sp.) and distal part of microsporophyll (M), Slide No. BSIP 12635. x 15.</li> <li>2. Half portion of mature cone preserved in the rock matrix, Specimen No. BSIP 38883. x ca 1.</li> <li>3. Elliptical young cone showing seeds, Specimen No. BSIP 38884. x 1.</li> <li>4. Sterile bract scale with hairs, Slide No. BSIP 12636. x 8.</li> <li>5. Cross section of cone axis showing central pith and secondary tissue, Slide No. BSIP 12636. x 7.</li> </ol> | <ol style="list-style-type: none"> <li>6. Cross section of cone showing spirally attached seed scale complex, Slide No. BSIP 12634. x 1.</li> <li>7. Cross section of cone-scale at distal region showing bract scale (B.S.) with loose parenchymatous cells and ovuliferous scale (O.S.) with vascular tissue, Slide No. BSIP 12637. x 6.</li> <li>8. Cross section of cone scale complex showing separate vascular traces of bract scale (shown by upward arrows) and ovuliferous scales (shown by downward arrows) and resin ducts. Slide No. BSIP 12638. x 8.</li> <li>9. Cross section of cone showing seed scale complex, Slide No. BSIP 12639. x 1.</li> </ol> |
|--|---|

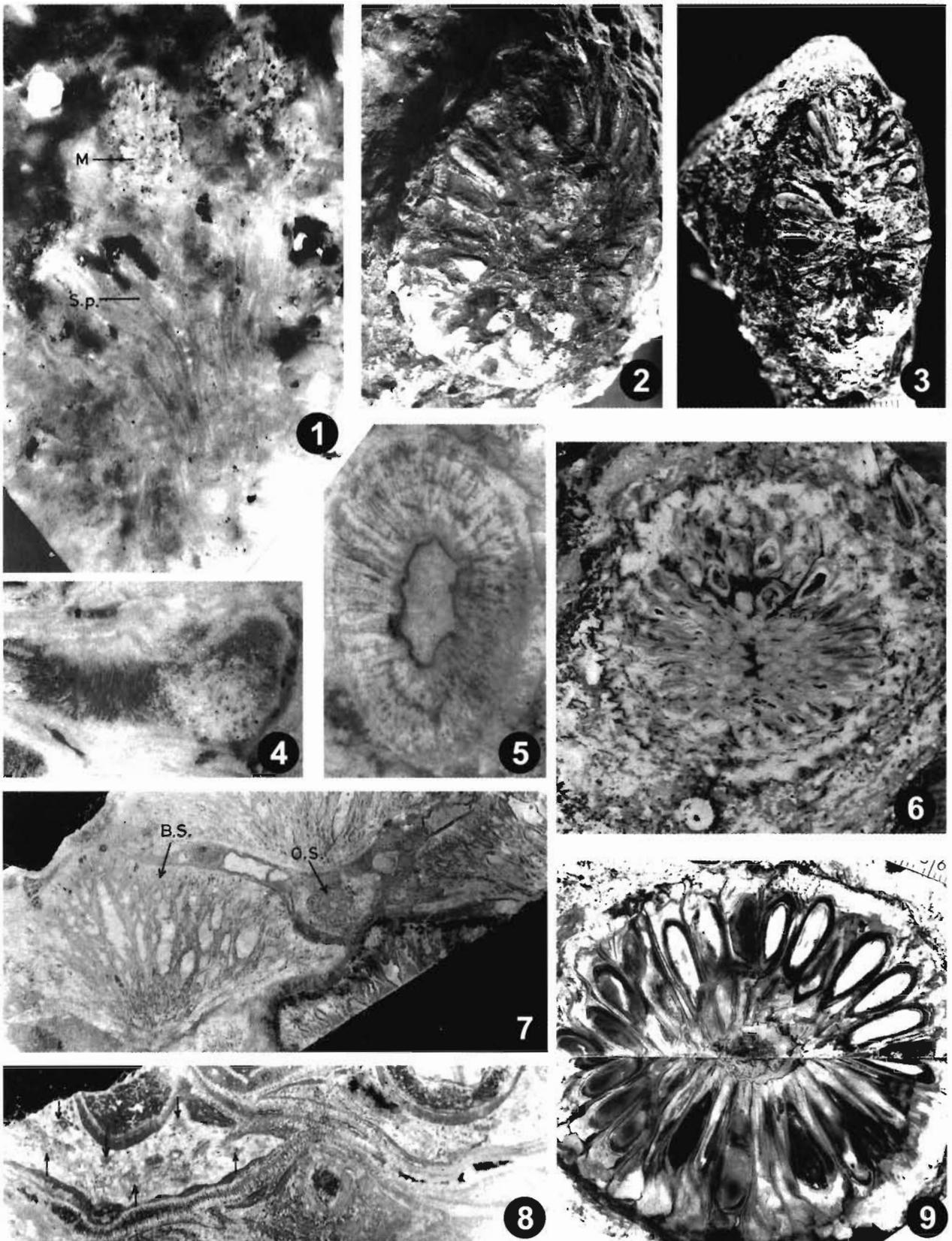


PLATE 2

**Cone-Scale Complex**—Cone scale complex typically consists of a bract and ovuliferous scale with free distal tip the so-called "ligule". The space between the ovuliferous scale and the bract scale—"ligular sulcus" (shown in Pl. 3.2) varies in different specimen probably depending upon the maturity of the cone. Ovuliferous scale tip is vascularised (Pl. 2.7) as in *A. mirabilis* (Stockey, 1978) and in *A. bidwillii* (Wilde & Eames, 1948). Each cone scale complex shows two rows of vascular traces, one row of vascular trace for bract scale and other for ovuliferous scale as shown in Pl. 2.8. Bract scales are spirally attached to the cone axis. Proximally a few bract scales are sterile without any ovules and they are densely hairy as shown in Pl. 2.4. The bracts with lateral wings, wings measure 2.0-2.1 x 0.6-0.7 cm. In cross section the bract (Pl. 2.8) shows outer epidermal cells with trichomes followed by 1-2 layers of thick hypodermal cells. Ground tissue consists of parenchymatous thin wall cells. Vascular tissue could be differentiated at places in a row. Resin canals are also present in a series but their position are not exactly marked whether they are alternate with the vascular trace or below the vascular trace.

The ovuliferous scale can easily be differentiated (in cross-section) upon the bract scale and partially adhered with the bract scale. This feature is visible in radial longitudinal and cross-sections of the cone scale complex (Pl. 3.1, 2, 6). Ovuliferous scale also has epidermal trichomes, a hypodermis and parenchymatous cells. Vascular traces could be seen at places in a row with resin ducts. Epidermis in surface view consists of elongated cells with hairy appendages as shown in Pl. 2.8; Pl. 3.1, 3.

Each cone scale complex has an ovuliferous scale and a ovule or seed embedded in its upper surface. Seed is cylindrical in shape, 4-8 mm long and 1.4-1.5 mm broad, inverted, micropyle facing towards cone axis. The ovule/seed integument usually consists of three layers (Pl. 3.1) i.e., an outer layer- sarcotesta (thin, 0.1 mm thick and mostly fused with the ovuliferous tissue), middle layer -sclerotesta (0.5 mm thick and consists of branched and simple sclerotic cells forming zig-zag pattern) and the inner layer—endotesta (thin and about 0.2 mm thick). Ovule/Seed integument differentiation is seen well in the chalazal end of the mature seed (Pl. 3.2). Ovule/Seed integument differentiation is a feature which developed after pollination (Wilde & Eames, 1948) and presence of marking of pollen tube penetration in nucellus (Pl.

3.5P.t.) indicates that this cone is preserved or buried after pollination stage. The nucellus is quite distinct and free except at the chalazal end of the ovule (Pl. 3.6, 8). Mature ovule/seed also shows megagametophyte and embryo with coiled suspensor (Pl. 3.4, 6, 7) indicating post-fertilisation stage. The nucellus tissue, as in extant *Araucaria* (Eames, 1913) has a wavy or undulating appearance (Pl. 3.8) at micropylar end which also confirms that this cone was buried after pollination and fertilisation stages. Embryo perhaps with two laminar cotyledons and with coiled suspensor.

## DISCUSSION AND CONCLUSIONS

Petrified cones, recently recovered from Sonajori Locality of Rajmahal Basin, are best preserved Indian silicified cones of *Araucaria* belonging to the section—*Bunya* of the family Araucariaceae. Cones with helically arranged cone scale complexes, winged bracts adhered with ovuliferous scales except at distal ends and a single inverted ovule are the characteristic features of the family Araucariaceae. The presence of a distinct ligular sulcus and wingless seeds embedded in the ovuliferous scale tissue suggest affinity with the extant genus *Araucaria*. Winged nature of cone scale complex with a large seed, distinct ligular tip with vascularisation, the presence of double vascular supply to the cone scale complex i.e., the separate vascular supply for bract scale and ovuliferous scale are the significant features (Wilde & Eames, 1948, p. 316) of the section *Bunya* are clearly visible in the present cone anatomy (Pl. 2.8). In other morphological and anatomical features, these present specimens of cones come closer to *Araucaria mirabilis* (Spegazzini) Windhausen described by Calder (1953) and Stockey (1975, 1978) from Jurassic-Cretaceous bed of Cerro Cuadrado, Patagonia. Besides the present study of petrified cones from Sonajori, morphological and anatomical features of earlier described Indian species—*Araucarites bindrabunensis* Vishnu-Mittre (1954) from Bindrabun and *A. mitrii* Bohra and Sharma (1980b) from Sonajori have also been reassessed. *A. bindrabunensis*, according to the author, "resembles the cones of *Araucaria mirabilis*. However, it differs from *A. mirabilis* in the longer scales and seeds, in the absence of sclereids and the presence of mucilage duct in the

## PLATE 3



1. Cross section of seed scale complex showing bract scale (B.S.) and ovuliferous scale (O.S.) with a seed (S) showing well defined three layers of seed integument, Slide No. BSIP 12638. x 16.
2. Longitudinal section of cone showing distal tip of cone scale complex, Slide No. BSIP 12640. x 6.
3. Surface of ovuliferous scale showing papillate (p) epidermal cells, Slide No. BSIP 12640. x 12.
4. L.S. of seed scale complex showing seed with embryo (E) and coiled suspensor (S), Slide No. BSIP 12639. x 8.
5. L.S. of seed showing shrunken nucellus and marking of pollen tube (Pt.) penetration, Slide No. BSIP 12641. x 12.
6. L.S. of seed scale complex showing shrunken nucellus and embryonal tissue at the chalazal end of seed, Slide No. BSIP 12641. x 6.
7. L.S. of seed, Slide No. BSIP 12639. x 6.
8. L.S. of cone scale complex showing shrunken nucellus (S.N.) at the micropylar region, Slide No. BSIP 12639. x 8.

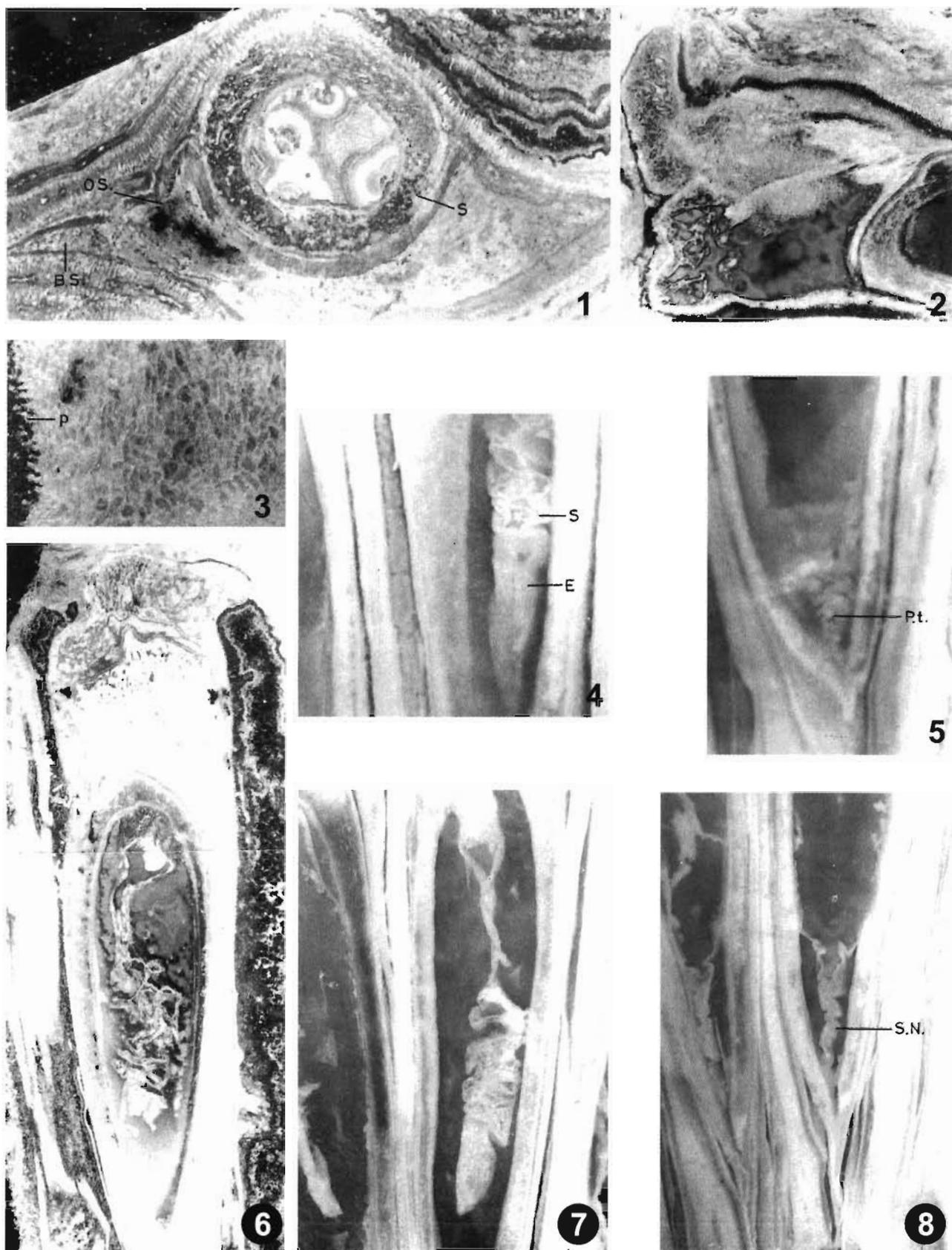


PLATE 3

pith and the absence of the resin cells from below the vascular bundles of the scales and the ligules". Moreover, Bohra and Sharma (1980b) suggested that *A. mitrii* can be compared with *A. bindrabunensis*, but differs in the absence of long distal end of bract scales, absence of mucilage ducts in the pith, differentiation of integument layers, shrunken nucellus in the micropylar region of the seed, nucellus is free from integument and sometimes two ovules are seen on a single scale. After critical assessment of the above variable characters of Indian species and their comparison with *A. mirabilis* and ontogenetic features of extant species of *A. bidwillii*, it has been observed that most of the features of differentiation are developmental (ontogenetic) features and those characters should not be used for taxonomic delimitation unless we know at what stage of maturity those cones had been preserved. Absence or presence of sclereids and mucilage duct or resin cells which are obliterated on the maturity of the cone, differentiation of seed integument layer and shrinkage of nucellus are also developed in the mature stage after pollination. Bohra and Sharma (1980b) used these feature for comparison, on p. 7 stated that the nucellus is free from the integument in the new species where as nothing is known about this structure in *A. bindrabunensis*. According to Eames (1913, figs 33, 35) araucarian nucellus is 'stipitate' i.e., it is free from the enclosing integuments except at the chalazal region. This character is a feature of the genus—*Araucaria* and should not be used further for specific differentiation. So, the only difference left between *A. mitrii*, and the present specimens is the presence of 1-2 ovule per scale which seems to be a normal feature often present in the extant *Araucaria* also (Biswas & Johri, 1997, p. 259). Thus, the creation of a new species on the basis of this generic character only is not justified. Bohra and Sharma (1980b, p. 4) in their description mentioned that in cross-section of some of the scales two ovules are also seen, the two nucellar cavities enclosed by a common integument and the two nucellar cavities are produced either due to false partitioning of nucellus or as a result of fusion of two ovules. In comparison, Bohra and Sharma suggested that the *A. mitrii* differs from *A. bindrabunensis* in the absence of long distal end of bract scale. But, the specimen figured by Bohra and Sharma (1980b) in Pl. 1 fig. F, the distal end of bract scale is somewhat similar in length as shown in Pl. 1 fig. 7 by Vishnu-Mittre (1954). So at

present, the Indian species *Araucarites bindrabunensis* Vishnu-Mittre, *A. mitrii* Bohra & Sharma and the present cones are placed under *Araucaria mirabilis* (Spegazzini) Windhausen.

**Acknowledgements**—We are thankful to Professor Anshu Kumar Sinha, Director, BSIP for providing necessary facilities.

## REFERENCES

- Biswas Chhaya & Johri BM 1997. *The Gymnosperms. Narosa Publishing House, Delhi* : 494p.
- Bohra DR & Sharma BD 1980a. *Araucamyelon pakurensis* gen. et sp. nov. from the Jurassic of Rajmahal Hills, India. Bulletin of National Science Museum Series-Geology. Tokyo 6 : 93-96.
- Bohra DR & Sharma BD 1980b. *Araucarites mitrii* sp. nov. a petrified megastrobilus from the Rajmahal Hills, India. Ameghiniana 17 : 3-8.
- Bose MN & Maheshwari HK 1974. Mesozoic conifers. In : Surange KR *et al.* (Editors)—Aspects & Appraisal of Indian Palaeobotany : 212-223. Birbal Sahni Institute of Palaeobotany, Lucknow.
- Calder MG 1953. A coniferous petrified forest in Patagonia. Bulletin of British Museum (Natural History) Geology, London 2 : 99-138.
- Eames AJ 1913. The morphology of *Agathis australis*. Annals of Botany 27: 191-204.
- Miller Jr CN 1977. Mesozoic conifers. Botanical Review 43 : 217-280.
- Sharma BD 1989. Petrified conifers with anomalous secondary growth from the Rajmahal Hills, India. Geophytology 19 : 49-51.
- Stockey RA 1975. Seed and embryos of *Araucaria mirabilis*. American Journal of Botany 62 : 856-868.
- Stockey RA 1978. Reproductive biology of Cerro Cuadrado fossil conifers : ontogeny and reproductive strategies in *Araucaria mirabilis* (Spegazzini) Windhausen. Palaeontographica 166 : 1-15.
- Vishnu Mittre 1954. *Araucarites bindrabunensis* sp. nov. a petrified megastrobilus from the Jurassic of Rajmahal Hills, Bihar. Palaeobotanist 3 : 103-106.
- Vishnu Mittre 1957. Studies on the fossil flora of Nipania, Rajmahal Hills- Coniferales. Palaeobotanist 6 : 82-112.
- Wilde MH & Eames AJ 1948. The ovule and "seed" of *Araucaria bidwillii* with discussion of the taxonomy of the genus I Morphology. Annals of Botany 12 : 311-326.
- Wilde MH & Eames AJ 1952. The ovule and "seed" of *Araucaria bidwillii* with discussion of the taxonomy of the genus. II-Taxonomy. Annals of Botany 16 : 27-47.