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Mesozoic conifers of India – megafossils – an overview

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भारत के मिसोजोइक शंकुधारी (कोनिफर्स) पादप– बृहदजीवाश्म : एक अवलोकन

सारांश

भारतीय उप महाद्वीप के निम्न क्रेटेसियस चट्टानों से ऊपरी ट्रायसिक परत से प्राप्त विवरण एवं वर्णित किये गये अनावृतबीजी जीवाश्म का महत्वपूर्ण मूल्यांकन किया गया है। आकारिकी एवं काष्ठ (तना) जड़, टहनियां पत्तों की संरचना एवं जननक्षम और फलदायी बीज की प्रजनन संरचना एवं पृथक प्रस्तरीभूत बीज को भी इस समीक्षा में शामिल किया गया है। विलुप्त होने वाले शंकुधारी वृक्ष अधिकतर पोडोकार्पेसी व ऐरोकेरिएसी से संबंधित है। इस शोध में टैक्सोडियेसी, क्यूप्रेसेसी व टेक्सासी के प्रतिनिधि भी दिये गये हैं। यह हमारे मिसोजोइक वनस्पति के वितरण, वनों के प्रकार और विधमान शंकुधारी वृक्ष टैक्सा के जातिवृत के बारे में ज्ञानवर्धन करता है। इस शोध में परागकण विज्ञान व भूस्तरविज्ञान पर चर्चा नहीं की गई है । भारत के मिसोजोइक शंकुधारी वनस्पति साहित्य पर विस्तृत समीक्षा की गई है।

ABSTRACT

Critical assessment is given of the fossil conifers (gymnospersm) reported and described from the Upper Triassic to Lower Cretaceous rocks of the Indian sub–continent. Morphology and anatomy of woods (stems) roots, twigs, leaves and fertile structures both male and seed-bearing fructifications and isolated petrified seeds are included in this review. Majority of extinct conifers belong to Podocarpaceae and Araucariaceae. Representatives of Taxodiaceae, Cupressaceae and Taxaceae are also reported in this paper. This account will enhance our knowledge of the Mesozoic vegetation, distribution and kind of forests and in tracing the phylogeny of controversial taxa of extant conifers. Palynology and stratigraphy are not discussed in this paper. A detailed review of literature on Mesozoic conifers of India is given.

Keywords: Conifers, Gymnosperms, India, Mesozoic Megafossils, Review

INTRODUCTION

The Gondwana System [sensu lato] is divided into Lower, Middle and Upper Gondwana (Lela 1956, 1963, Surange 1966). The Lower Gondwana ranges from Upper Carboniferous (after ice age) to the Permian Period. The Middle Gondwana has a portion of Lower and Middle Triassic Periods while the Upper Gondwana ranges from

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Upper Triassic to the Lower Cretaceous Period (before the ice age). Studies on the Mesozoic rocks of India began by the work of Oldham and Morris (1863) on the fossil plants of the Rajmahal Hills, Bihar followed by Feistmantel who described the fossil floras of Cutch (1876), Rajmahal Hills (1877), Gollapilli (near Ellore) (1877a), Jabalpur (1877b), Madras Outliers (1879), Rajmahal group (1881), South Rewa Basin [1882] etc. He described a number of impressions and incrustations of confier twigs, leaves, seed scales and fructifications like *Araucarites latifolia* Feist. *A. cutchense* Feist. *A. macropterus* Feist etc. Bancroft (1913) published a paper on Jurassic Gynmosperms of India. Seward and Sahni (1920) published a revision of Indian Gondwana plants. From the Mesozoic strata they described a number of conifers like *Araucarites cutchense, A. macropteris, A. latifolia, Torreyites constricta, Pagiophyllum sp., Retinosporties indica, Elatocladus plana, E. conferta, Brachyphyllum expansum* etc. However, a detailed revision on fossil conifers was published by Sahni (1928–impressions and incurstations and 1931–Petrifactions). He described conifer twigs like *Brachyphyllum mamillare, B. rhombicum, B. feistmanteli, B. expansum, Desmiophyllum indicum, Voltzia heterophylla, Elatocludus plana, E. conferta, E. jabalpurensis, Retinosporites indica, Pagiophyllum peregrinum, Athrotaxites feistmanteli, Torreyites constricta, Araucarites latifolia, A. cutchense, A. macropterus, Conites sripermaturensis, C. sessilis, C. rajmahalensis, C. verticellatus, Strobilites sewardi, S. pascoei, Musculostrobus* sp. etc. In 1931 Sahni described the petrifactions of woods like *Mesembrioxylon godaverianum*, *M. parthasarthyi, M. malorianum, Cupressinoxylon coromandelinum, C. alternans, Dadoxylon (Araucarioxylon) rajmahalense* etc. the conifer cones described by Sahni (1931) were from the Tertiary Horizon.

Sahni and Rao (1933) published a paper on the Jurassic plants of the Rajmahal Hills and included it in the conifers like *Ontheodendron florini* gen. et. sp nov., *Araucarites sp., Elatocladus conferta, E. tanerrima, Brachyphyllum expansum* etc. Rao (1943) described an ovulate conifer fructification *Nipaniostrobus* related to an extant taxon *Dacrydium* of Podocarpaceae from Nipania. In the paper he also described two new species of male fructification of *Musculostrobus.* In 1947 Rao established the genus *Nipanioruha,* species *N. granthia* for a vegetative shoot and in 1950 Rao reported its associated megastrobilus. Ganju (1947) described a number of twigs of extinct confiers from the Rajmahal Hills like *Eladoclatus, Taxites, Torreyites, Brachyphyllum* etc. Bose (1952) published an account of the anatomy of a petrified specimen of *Brachyphyllum spiroxylon* from Amarjola locality of the Rajmahal Hills. The tracheids have tertiary spiral thickenings. Bose and Hsu (1953) described a cone like structure associated with *Brachyphyllum* twig. Gupta (1954) published a new species *Coniferocaulon rajmahalense* on the basis of markings of leaf bases. Sitholey (1954) published a review on Mesozoic and Teritary floras of India. Vishnu Mittre (1955) described a petrified araucarian megastrobilus of *Araucarites binderabunensis* from the Rajmahal Hills, and a male podocarpaceous fructification *Musculostrobus sahnii* bearing 2–4 winged pollen grains from Nipania, Rajmahal Hills in 1956. Singh (1956) described a new species of *Araucarites, A. nipaniensis* on the basis of a petrified seed scale. Vishnu Mittre (1959) described a number of petrified podocarpinean fructifications and twigs from Nipania e.g. *Nipaniostrobus sahnii, N. pagiophylloides, N. acutifolia, Mehatia rajmahalensis, M. nipanica, M. santalensis, Sitholeya rajmahalensis, Nipanioruha granthia, N. lanceolata, N. curvifolia, Indophyllum sahnii, Elatocladus sahnii, Brachyphyllum florini, Pagiophyllum araucarites, Musculostrobus rajmahalensis, M. podocarpoides* etc. Rao and Bose (1971) erected a new genus *Podostrobus,* and in *P. rajmahalensis* and placed in it all the then known species of *Musculostrobus* from India, which was accepted by Bose and Maheshwari (1974). Pant and Srivastava (1968) described the cuticular structure of *Araucarites cutchensis* from Jabalpur formation. Rao (1963) published a paper on Podocarpaceae in India.

Bhardwaj (1952) described the anatomy of a new species of *Taxoxylon*, *T. rajmahalense* bearing tertiary spiral thickenings on tracheids. In 1953 Bhardwaj described the anatomy of Jurassic woods from the Rajmahal Hills and identified the new species *Mesembrioxylon indicum, Cupressinoxylon [Taxodeoxylon] rajmahalense* and *Dadoxylon [Araucarioxylon] jurassicum.* Sah (1957) described the anatomy of a wood of *Coniferocaulon latisulcatum* sp. nov. from Amarjola in the Rajmahal Hills. Krausel and Jain (1964) studied fossil woods from the Rajmahal Hills and identfied new species *Dadoxylon agathioides* with multiseriate contiguous bordered pits and having cross shaped pit pores. *Circoporoxylon amarjolense* with pits in cross fields small, circular and simple, *Taxoceoxylon cf. T. rajmahalense* has distinct growth rings, rays uniseriate and spiral thickenings on tracheids. Sah and Jain (1964) published an account of wood anatomy collected from the Rajmahal Hills, viz., *Dadoxylon*

(Araucarioxylon) amarparense sp. nov. with loose and contiguous bordered pits on tracheids, D *(Araucarioxylon) mandroense* sp. nov. growth rings distinct, bordered pits uni to biseriate, pits in crossfield many, *D (Araucarioxylon) bindrabunense* sp. nov. growth rings indistinct rays 1–45 cells long, pits in cross field 4–12, *D (Araucarioxylon) santalense* sp. nov. growth rings not clear rays 1–10 cells high, pits in cross field 2–6, resin plugs present. Agashe (1969) described a new species of *Mesembrioxylon, M. mahabalei.* Sharma (1970) published an account of the anatomy of a wood of *Taxaceoxylon cupressioides* sp. nov. collected from Dhokuti, Rajmahal Hills, Bihar. Growth rings distinct, tracheids with 1 to 2 rows of seprate bordered pits and bear tertiary spiral thickenings.

Bose and Sukhdev (1971) described 3 new species of *Pagiophyllum* from Bansa, Madhya Pradesh. Bose and Maheshwari (1973) published an account of *Brachyphyllum sehoraenisis* from Sehora, Madhya Pradesh. They (1973a) also described an account of detached araucarian seed scales from the Indian Mesozoic strata. Bose and Maheshwari (1974) in a review article on 'Mesozoic conifers' discussed podocarpinean affinities of *Elatocladus, Indophylum, Stachyotaxus, Nipaniostrobus, Nipanioruha, Mehtaia, Sitholeya, Strobilites, Podostrobus, Musculostrobus, Podocarpoxylon, Circoporoxylon* etc. They agreed with the suggestion of Rao and Bose (1971) that all known species of *Musculostrobus* from India be merged into *Podostrobus.* Bose and Maheshwari (1974) also proposed that all known species of *Mesembrioxylon* from India be merged into *Podocarpoxylon.* They also discussed the affinities of Araucariaceae with the taxa like *Brachyphyllum, Pagiophyllum, Allocladus, Desmiophyllum, Moranocladus, Araucarties, Dadoxylon, Araucarioxylon* etc. and relationships of uncertain taxa like *Torreyites, Taxaceoxylon, Prototaxoxylon, Coniferocaulon, Athrotaxites, Cupressinoxylon, Conites* etc. Sharma and Bohra (1975) described the presence of araucarian roots at Sonajori in the Rajmahal Hills. Sukhdev and Zeba Bano (1976) described *Araucaria indica* and two other conifers from Jurassic - Cretaceous beds of Madhya Pradesh. Sharma and Bohra (1977) reported the presence of an araucarian megastrobilus in Sonajori locality. In the same year (1977a) they described petrified sporangia of ferns and isolated seeds of conifers from Sonajori. Zeba Bano & al. (1979) reported the impressions of *Strobilities* and *Araucarites* from Pathargama locality of the Rajmahal Hills. Bohra and Sharma (1980) described a new megastrobilus of *Araucarites, A. mittrii* from Sonajori locality. In 1980 they described the anatomy of an araucarian root *Arauamyelon pakurense* sp. nov. from this locality. The root is diarch with well developed secondary xylem. Bose & al. (1982) published an account of fossils from Gangapur formation. Bose and Banerji (1984) published fossil flora of Kachchh part I. Mesozoic megafossils including conifers. Banerji and Pal (1986) reported a new species of *Allocladus, A. papillosus* from salt range (Jurassic) of Pakistan. Murlidhara Rao and Ramanujam (1986) described fossil woods from Kota formation and established two new taxa i.e. *Baieroxylon ciatricum* and *Platyspiroxylon parenchymatosum*. In 1991 Murlidhara Rao discovered a silicified wood *Prototaxoxylon liassicum* from Kota formation [Liassic] of the Pranhita– Godavari Basin. Suthar and Sharma (1986) described petrified fructifications of conifers collected from Nipania and Sonajori localities of the Rajmahal Hills and added much to the studies made earlier by Vishnu Mittre (1955, 1959) from Bindraban and Nipania localities. In 1988 Suthar & al. published an account of petrified isolated seeds of confiers collected from Sonajori locality and assigned affinities with Podocarpaceae and Taxaceae. Sharma and Suthar (1989) described algal association with the young araucarian roots i.e. coralloid roots collected from Sonajori area. Sharma (1989) published an account of anomalous secondary growth in extinct roots and stems of conifers collected from Sonajori.

Sukhdev and Rajanikanth (1988) described fossils from Gangapur formation and reported coniferales like *Elatocladus, Pagiophyllum, Allocladus, Araucarites* and *Coniferocaulon.* Sukhdev and Rajnikanth (1989) studied Shivganga formation and reported fossil conifers like *Elatocladus plana, E. tenerrimus, Brachyphyllum regularis, B. theraniense* sp. nov. *Araucarites cutchensis, A. minutes* etc., Rajnikanth and Sukhdev (1989) studied Kota formation and described a number of extinct conifers like *Pagiophyllum* sp. *Araucarioxylon santalense* (Sah & Jain) Bose and Maheshwari, *A. pranhitensis* sp. nov., *Podocarpoxylon rajmahalense* (Jain) Bose and Maheshwari, *P. krauselii* sp. nov., *P. chandrapurensis* sp. nov., *Taxaceoxylon sahnii* sp. nov., *Cupressinoxylon kotaense* sp. nov., etc. Pandya and Sukhdev (1989) and Prakash & Sukhdev (1990) described the fossil flora of Gollapilli [near Ellore] of the Rajmahal Group. Pandya & al (1990) reported a new species of *Elatocladus, E. vemavaramensis* from the Lower Cretaceous of Vemavaram. Bose & al. (1990) correlated the Gondwana Floras of India and Antartica. Chandra and Tiwari (1991)

published a catalogue of fossil plants part 2. Palaeozoic and Mesozoic megafossils. Patra and Sahoo (1992) studied megafossils of Athgarh formation and identified fossil conifers of *Brachyphyllum, Pagiophyllum, Araucarites* and *Coniferocaulon*. Prakash N (2000) reported conifer taxa from two localities of the Rajmahal Hills. Prakash and Sukhdev (1994) also reported above mentioned conifers from the area. Sharma (1992) published a paper on evolutionary status of fossil conifer seeds from the Rajmahal Hills. Banerji (1993) reported two species of *Elatocladus* from Chunakhal locality of the Rajmahal Hills, also two species from the Rajmahal Hills and Murli Pahar locality of the area (1996). Banerji (1995) discovered two new localities bearing magafossils of conifers from the Rajmahal Hills. Jeyasingh and Kumarswamy (1994) described two new species of *Araucarioxylon* from Sriperumbudur formation. Srivastava & al. (1999, 2004) studied the Lower Cretaceous flora of Amaravati and Betual districts of central India and recorded impressions and incrustations of seed scales of *Araucarites* sp. Sharma and Tripathi (2002) described conifer woods of podocarpinean affinity from Lathi formation at Lathi [Jaisalmer–western Rajasthan] Akal fossil woods National Park. (Jaisalmer has unidentified 10–12 logs of fossil woods of Lathi formation). Bonde (2008) described the anatomy of a piece of fossil wood collected from Jaislamer and identified it as a new taxon *Prepodocarpoxylon gregussii* and related to podocarpaceae. Jana (2003) studied Lower Cretaceous flora of Gujrat and reported the presence of *Pagiophyllum* sp., *Brachyphyllum* sp., *Elatocladus* sp. and *Araucarites* sp. Bose & al. (1984) had also reported similar flora from Gardeshwar [Gujrat]. Banerji & Ghosh (2005) studied fossil plants from the silicified cherts of Hiranduba (near Amarapara) Rajmahal Hills and recorded the presence of *Brachyllum* sp. Guleria and Shukla (2007) described a poorly preserved wood of *Podocarpoxylon haburensis* n.sp. from the Mesozoic of Habur (Jaisalmer). Except cross section nothing is visible in the photographs included in the paper. Goswami (2010) described two new wood taxa *Tikioxylon hughesii* and *T. spiralli* from Tiki formation Lower Jurassic Madhya Pradesh. Prakash (2013) reported two new species of *Elatocladus, E. kasatii* and *E. sehorensis* from Jabalpur Horizon. Chinnappa & al. (2014) reported the presence of four species of *Elatocladus* and two species of *Pagiophyllum* from Gangapur formation (Telangana). Sharma & al., (2014) published a chapter on the fruntifications of Mesozoic gymnosperms in the book published from Germany. Shendoge and Manik (2015) studied the fossil flora of Gollapilli (Early Cretaceous) Godavari district, Andhra Pradesh and reported the presence of *Brachyphyllum* sp., *Desmiophyllum* sp., *Araucarites* sp. and *Conites* sp. from the area.

DESCRIPTION

The gymnosperms are terrestrial, carpel-less archegoniate (except *Gnetum* and *Welwitschia*), ovulate plants which have been surviving on earth since Upper Devonian to the present (Taylor & al 2009). Majority are trees with secondary growth. In cycads, the leaves are large, pinnate compound, while in conifers these are simple, generally reduced to green scales or needles. Plants monoecious or dioecious, male and seed-bearing cones separate. Pollen grains vary from non winged to monolete or trilete or 1–5 winged. Ovules mostly unitegmic of 1–3 layers. Embryo, di or multicot (Chamberlin 1935, Sporne 1969, Bold & al., 1987). In a broad sence the gymnosperms are divided into Cycadophyta, Coniferophyta and Gnetophyta. Coniferophyta is further divided into Ginkgopsida, Cordaitopsida, Coniferopsida and Taxopsida (Pant 1957, 2002 Miller 1977). Coniferopsida includes early conifers like *Lebachia, Ernestiodendron, Voltzia* etc. [Florin 1951] and the advanced types like. Abietineae [Pinaceae], Taxodiaceae, Cephalotaxaceae, Cupressaceae, Podocarpaceae, Araucariaceae, and Taxaceae.

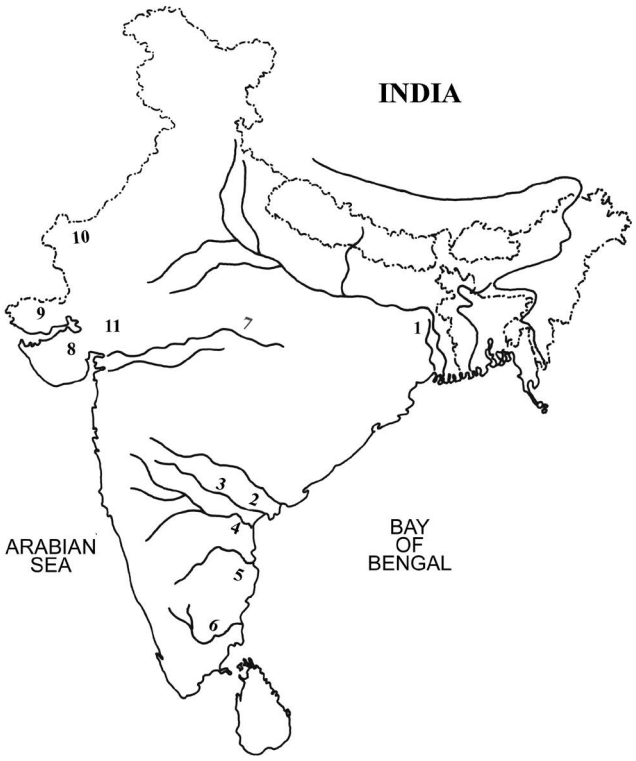
All these are found in both extinct and extant forms. However, their origin is not simultaneous. Among these families the Podocarpaceae and Araucariaceae are oldest and originated during the Permian period (Beck 1970, Miller 1977). Following Bose and Maheshwari (1974) the description is given on the basis of relationship with Podocarpaceae, Araucariaceae etc.

In India the Mesozoic rocks (Upper Triassic to Lower Cretaceous) are exposed at several places eg. Rajmahal Hills, Gollapilli (near Ellore), Madras outliers, Godavari Basin, Nidpur, Gangapur, Caveri, Tiki Formations, Jabalpur, South Rewa Basin, Himmatnagar, Kachchh, Jaisalmer etc. **(Map 1).**

Extinct conifers with podocarpaceous affinities:–

TWIGS

Elatocladus Halle_ Many of the species of *Elatocladus* known today were earlier identified as *Palissya* Endlicher



Map 1: Map showing distribution of Upper Gondwana fossiliferous areas in India

1. Rajmahal Hills; 2. Golapilli; 3. Kota; 4. Ongole; 5. Madras; 6. Trichinopoly; 7. Jabalpur; 8. Kathiawar; 9. Kutch; 10. Jaisalmer

or *Taxites* Brongniart (Feistmantel 1876, 1977, 1877a, 1879, 1881, 1882). Twig is branched or unbranched with linear lanceolate or oblong leaves, spirally attached but look like in two rows. Following are the species known from the Indian Mesozoic rocks.

Elatocladus conferta (Oldh. Morr.) Halle (1913) (Fig. 1A)
E. jabalpurensis (Feist) Seward (1919) (Fig. 1C)
E. plana (Feist.) Seward (1919)
E. tenerrima (Fiest.) Sahni (1928) (Fig. 1B)
E. sahnii Vishnu Mittre (1959)
E. bosei Maheshwari & Kumaran (1976)
K. kingianus Bose & al. (1982)
E. chawadensis Bose of Banerji (1984)
E. longifolia Jana (2003)
E. kasatii Prakash (2013)
E. sherensis Prakash (2013)
E. vemavaramensis Pandya & al. (2014)
E. andharensis Chinnappa & al. (2014)

Indophyllum Vishnu Mittre (1959) Leaves linear closely appressed, stomata longitudinally oriented. The species are–

I. sahnii Vishnu Mittre (1959) (Fig. 1D)
I. raoi Vishnu Mittre (1959)
I. nipanica Vishnu Mittre (1959)

Bose and Maheshwari (1974) suggested re–examination and further investigations on the three species, may perhaps prove to be related to *Brachyphyllum* or *Pagiophyllum* of Araucariaceae. At Nipania podocarpinean plants occur frequently while Araucariaceae is rare. We believe that Vishnu Mittre was probably right in calling *Indophyllum* a podocarpinean twig.

WOODS

Mesembrioxylon Seward (1919) Seward created this taxon by merging three taxa i.e. *Podocarpoxylon*, *Phyllocladoxylon* and *Paraphyllocladoxylon*. Stopes (1915) had already merged *Phyllocladoxylon* into *Podocarpoxylon*. Bose and Maheswari (1974) believed that *Paraphyllocladoxylon* is not different from *Podocarpoxylon*. On the basis of priority of nomenclature, they suggested merging of *Mesembrioxylon* into *Podocarpoxylon* and approved following changes – *Podocarpoxylon godavarianum* [Sahni 1931] comb. nov. for *Mesembrioxylon godavarianum* Sahni.

Podocarpoxylon malerianum (Sahni 1931) comb. nov. for *Mesembrioxylon malerianum* Sahni.

Podocarpoxylon parthasarthyi (Sahni 1931) comb. nov. for *Mesembrioxylon parthasarthyi* Sahni.

Podocarpoxylon indicum (Bhardwaj 1953) comb. nov. for *Mesembrioxylon indicum* Bhardwaj (Fig. 2A, B)

Podocarpoxylon sarmae (Verma 1954) comb. nov. for *Mesembrioxylon sarmae*. Verma

Podocarpoxylon tirumangalense (Suryanaryana 1953) comb. nov. for *Mesembrioxylon tirumangalense* Suryanarayana.

Podocarpoxylon *rajmahalense* (Jain 1965) comb. nov. for *Mesembrioxylon rajmahalense* Jain.

Prakash and Rajnikanth (2004) described a new species *Podocarpoxylon bansaense* from Bansa, South Rewa Basin, Madhya Pradesh. Poor photographs of longisections. Neither pits in cross fields nor pits on tracheids are visible. Drawings should have been given. Rajnikanth and Sukhdev (1989) described two new species of *Podocarpoxylons, Podocarpoxylon krauselii* and *P. chandrapurensis* from the

Fig. 1. Extinct conifer twigs etc. **A.** *Elatocladus confertus,* **B.** *E. tenerriuma,* **C.** *E. jabalpurensis,* **D.** *Indophyllum sahnii,* **E.** *Nipanioruha granthia,* **F.** *Pagiophyllum rewaensis,* **G.** *P. morrisii,* **H.** *P. chawadensis,* **I.** *P. marwarensis,* **J.** *P. bansaensis.* **K.** *Brachyphyllum theraniensis,* **L.** *M. Mehtaia santalensis* **N.** *M. rajmahalensis* (Left), & *M. nipaniensis* (right) ovules, **O.** *Araucarites cutchensis* (seed scale) (redrawn from many published literature noted in text).

Kota stage. Guleria and Shukla (2007) established a new species of *Podocarpoxylon, P. haburensis* on the material collected from Habur (Jaisalmer) Rajasthan. It is a poorly preserved wood showing tracheieds only in cross section. Longisections not clear.

Prepodocarpoxylon Bonde_Bonde (2008) established a new taxon *Prepodocarpoxylon gregusii* for a podocarpinean wood of Lathi formation, Jaisalmer [Western Rajasthan]. Tracheids have uniseriate contiguous borded pits. A similar wood was described earlier from same place and formation by Sharma and Tripathi (2002) having podocarpaceous anatomy.

Coniferocaulon Fliche. Surface of stem has transversely elongated, narrow markings probably of leaf bases. Gupta (1954) described a new species *C. rajmahalensis* showing only external surface, while Sah (1957) described the anatomy of a petrified wood under the name *C. latisulcatum* from Amarjola locality of the Rajmahal Hills. Wood has growth rings, rays are short and uniseriate, tracheids have uniseriate podocarpoid pits, pits in cross field 1–2. Sah believed it to be a podocarpinean wood. Bose and Maheshwari (1974) considered the affinity doubtful.

Cupressinoxylon Goppert. Sahni (1931) established two species of it from the Mesozoic rocks of India i.e. *C. coromandalianum* Sahni from the Eastern coast and *C. alternans* from Raghuvapuram. Bhardwaj (1953) created a new species *C. (Taxodioxylon) rajmahalense* (Fig. 2 C–E) and suggested its affinities with podocarpaceae.

Circoporoxylon Krausel_ Charecterised by pits in cross field circular and simple. In India it is represented by *C. amarjolense* Krausel and Jain (1964) (Fig. 2 K, L).

FRUCTIFICATIONS

Male fructification – Rao (1943 a) described two-winged pollen grains in the fructification named as *Musculostrobus rajmahalensis*. Vishnu Mittre (1956) from the same locality Nipania described another species of *Musculostroubs, M. sahnii* bearing also three-winged pollen grains. Rao and Bose (1971) described a male fructification *Podostrobus sahnii* bearing 2–3 saccate pollen grains. Suthar and Sharma (1986) described further *P. sahnii* (Plale 1, 8) Rao and Bose and observed 2–4 winged pollen grains comparable to an extant taxon *Microcachrys* of Podocarpaceae.

SEED BEARING FRUCTIFICATIONS

Stachyotaxus Nathorst Rao (1950) described fructification from another locality having two ovules per seed scale/megasporophyll. In 1964 Rao named it *S. sampathkumarani*. Bose and Maheshwari (1974) correlated it with the cycadean fructification *Beaniopsis rajmahalensis* Ganju. We agree with their view.

Nipaniostrobus Rao (1943). Scales single seeded arranged spirally on cone axis in loose or compact manner and called it *N. sahnii* (plate 4, 6) and correlated with that of extant taxon *Dacrydium* of Podocarpaceae. Vishnu Mittre (1959) studied a number of strobili from Nipania cherts and emended the diagnosis given by Rao (1943). He established two new species *N. pagiophylloides* and *N. acutifolia*. He also studied the associated twigs and their vegetative characters. In all species the seed scale is reduced while the bract scale is well developed. Ovules inverted. Single per scale and with curved micropyle Suthar and Sharma (1986) gave further observation on *N. shanii* Rao on the basis of beautifully preserved material and well prepared slides.

Nipanioruha Rao (1947) A petrified shoot bearing needle like spirally arranged leaves (Fig. 1E). In 1949 Rao discovered an associated megastrobilus with *N. granthia*. Cone axis is fleshy and ovules curved. Mittre (1959) described two new species *M. lanceolata* and *N. curvifolia* from the Nipania locality based on vegetative characters. Suthar and Sharma (1986) gave further observations on an ovulate strobilus of *N. granthia* prepared from Nipania chert.

Mehtia Vishnu Mittre (1954) Megastrobilus lax or compact, seed scales complexes spirally attached, bract scales larger than the seed scales, ovules erect, micropyle strongly curved. Integument single, two layered. Vishnu Mittre (1959) described three species of *Mehatia*. These are *M. rajmahalensis* (Plate 12.7, Fig. 1N Left), *M. nipaniensis* (Plate 1.5, Fig. 1 N Right) and *M. santalensis*. Suthar and Sharma (1986) added more knowledge to *M. rajmahalensis* and *M. nipaniensis* on the basis of study of better preserved and well-prepared slides.

Sitholeya Vishnu Mittre (1959). *Sitholeya rajmahalensis* is a single species of the genus prepared from the Nipania chert. Ovule is single, terminal and inverted. In these characters it resembles the extant taxa *Dacrydium* and *Podocarpus* of Podocarpaceae.

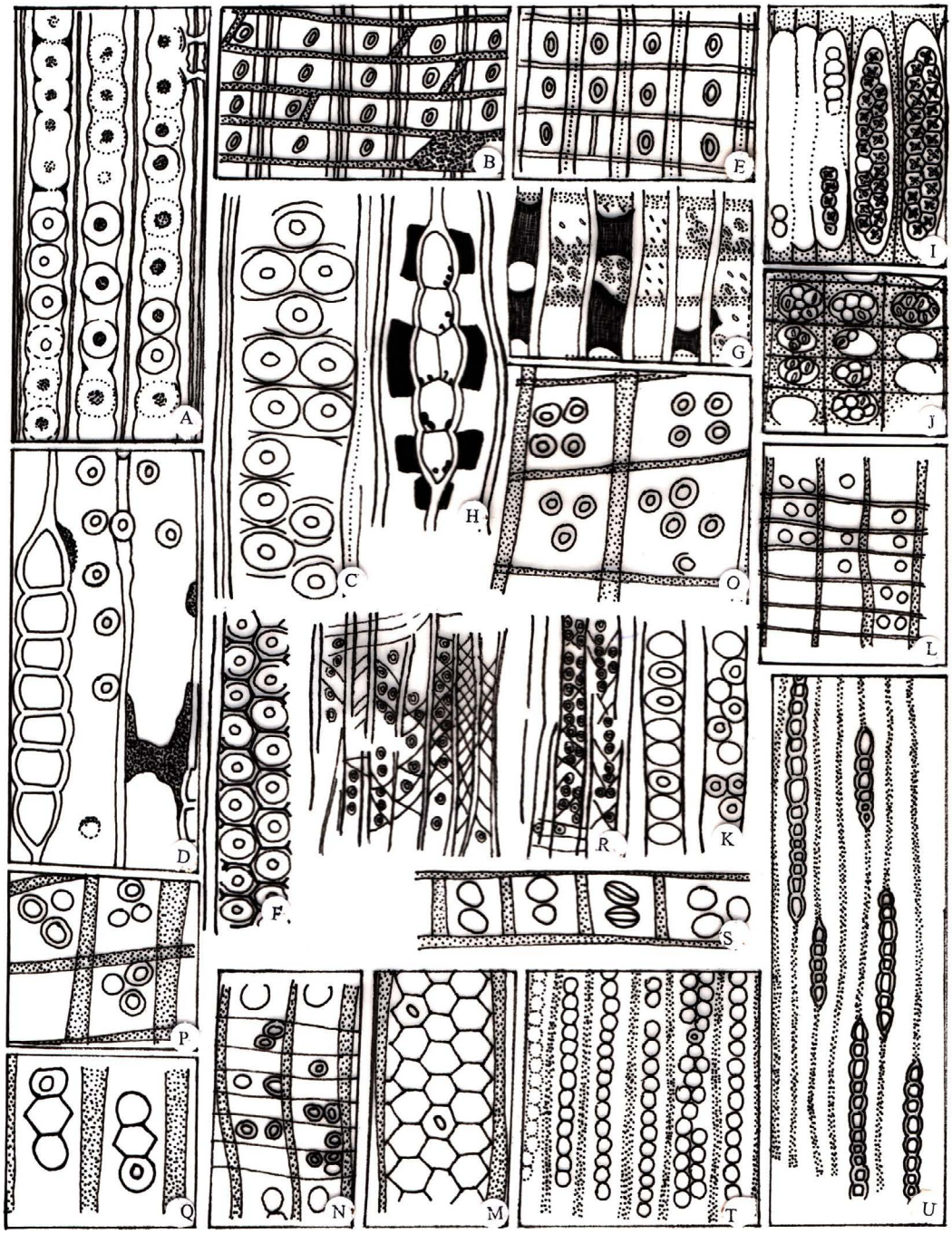


Fig. 2. Anatomy of extinct woods of conifers. **A.** *Mesembrioxylon indicum* tracheids with podocarpoid pittings. **B.** Same pits in cross fields. **C.** *Cupressinoxylon (Taxadioxylon) rajmahalense* pittings on a trachied **D.** Same. TLS showing a ray and bordered pits on trachied. **E.** Same, pits in cross field. **F.** *Dadoxylon (Araucarioxylon) jurassicum* contiguous bordered pits on a tracheid **G.** Same. Pits in cross field. **H.** Same A ray and associated resin. **I.** *Dadoxylon agathioides.* Tracheids with contiguous borded pits having cross type pit proes. **J.** Same Pits in cross fields. **K.** *Circoporoxylon amarzolense*. Tracheids with pits. **L.** Same pits in cross fields small simple and circular. **M.** *Dadoxylon amarparense* multiseriate contiguous bordered pits on a trachied **N.** Same. pits in cross fields **O.** *Dadoxylon mandroense* pits in cross fields. **P.** *Dadoxylon santalense* pits in cross fields **Q.** same. pits on tracheids. **R.** *Taxoceoxylon cupressoides* tracheids with bordered pits and tertiary spiral thickenings. **S.** *Araucarioxylon giftii.,* pits in cross fields. **T.** Pittings on radial wall of tracheids **U.** Same, T.L.S. uniseriate long rays. (Redrawn from many literature noted in text).

Stobilites Lindley and Hutton_ Feistmantel (1877) considered it a cycadean inflorescence. Sahni (1928) established two species *S. pascoei* and *S. sewardii.* Accordingly, to Bose and Maheshwari (1974) podocarpinean affinity is doubtful.

ARAUCARIAN AFFINITIES

In the mesozaic rocks of India extinct araucarian plants are found as twigs, leaves, seed scales, woods, roots, and well preserved megastrobili. Male cones are yet to be discovered.

TWIGS

Brachyphyllum Brongniart. Twigs having spirally attached thick but small leaves. Apex blunt or obtuse forming the leaves triangular, conical or hexangular. following species are known from Indian mesozoic Horizon.

B. mamillare Brong. Twig branched with elliptical apressed leaves, apex pointed known from Rajmahal and Jabalpur stages. Sahni (1928) reported four species from upper Gandwana system e.g. *B. Mamiliare, B. rhombicus* [Halle] Sahni, *B. expansum* (sternb.) Sahni *B. feistmanteli* (Halle) Sahni and *B. expansum* var. *Indica* Sahni (1928).

B. spiroxylum Bose [1952]

B. sehorensis Bose and Maheshwari (1973) [Borker and Chiplankar, 1973] reported the presence of some conifers from the Umia beds of Saurashtra. Sen Gupta (1988) reported *B. mamillare* and *B. rhombicum* from Kulkipara and Nipania localities respectively. Sukh Dev and Rajnikanth (1989) described Shivganga formation and reported *B. theraniense* (Fig. 1K) from the area. Prakash and Sukh Dev (1994) studied Athgarh formation and reported *B. regularis* from the area. Bose and Banerji (1984) published the fossil flora of Kachchh and established a new species *B. royi* from the Lower Cretaceous horizon. Patra and Sahoo (1992) reported the pressence of *B. rhombicum* from Athgrah Formation.

Jana (2003) reported the occurrence of *B. expansum* and *B. regulare* from the Mesozoic of Gujarat. Chinnappa & al. (2014) recorded presence of *B. sehoraensis* from Gangapur formation. Shendage and Manik (2015) observed *B. rhombicum* at Gollapilli formation.

Pagiophyllum Halle. - It is a vegetative twig with spirally arranged leaves, more or less identical to those of *Brachyphyllum*. Feistmantel [1876, 1881, 1882] reported specimens of *Pagiophyllum* under the taxa *Pachyphyllum* and *Cheirolepis*. Sahni (1928) described the cuticular structure of *Pagiophyllum peregrinum* (L & H) Sahni.

Vishnu Mittre (1959) described a new species *P. araucaroides* from Nipania. Jain (1968) reported *Pagiophyllum* from Vemavaram (Kota Stage). Bose and Sukhdev (1972) recorded three new species from Bansa (Jabalpur) formation vig. *P. bansaensis* (Fig. 1J), *P. marwarensis* (Fig. 1I), *P. rewaensis* (Fig. 1F). *P. seregrinum,* Sahni (1928) is now merged in *P. marwarensis* (Bose and Maheshwari 1974). Bose and Banerji (1984) described three new species of *Pagiophyllum, P. grantii, P. chawadensis* (Fig. 1H) and *P. morrisii (*Fig. 1G) from Kachchha and differentiated these on morphological and cuticular characters. Patra and Shaoo (1992) reported the presence of *P. grantii* Bose & Banerji (1984) in Athgarh Formation. Sukhdev and Rajnikanth (1988) described *P. spinosum* from Gangapur formation. Chinnapa & al. (2002) also reported this species from Gangapur Formation.

Allocladus Townrow_It is *Echinostrobus rajmahalensis* of Festimantel (1877). Sahni (1928) considered it a *Brachyphyllum* sp. for want of cuticular characters. Bose and Maheshwari (1974) also called it a *Brachyphyllum* sp. Bose and Banerji (1984) described a new species of *Allocladus, A. biswasianus* from Kachchh. The twig is simple with apressed rhomboidal leaves. Cuticle with stomata, epistomatic in nature. Jana (2003) reported an uncertain species? *A. bansaensis cf. Coniferocaulon rajmahalense. A papillosus* sp.nov. was reported by Banerji and Pal (1986) from the SaltRange (Jurassic) Pakistan.

Morandocladus Seward and Sahni.,- Zeiller (1902) described from Morand valley, Madhya Pradesh as *Araucarties oldhamii.* Seward and Sahni (1920) assigned Tertiary Horizon to Morand and called it *Morandocladus.* Sah and Singh (1965) assigned Jabalpur stage to Morand and *A. oldhamii. Zeiller as Morandocladus.* It is a vegetative shoot whereas *Araucarites* is a name for fertile megastrobilus.

Desmiophyllum lesquereux_ Sahni (1928) instituted the species *D. indicum.* The leaves resemble those of an *Araucaria* sp.

WOODS

Compact araucarian woods with or without growth rings are described under two genera, *Dadoxylon* Endlicher and *Araucarioxylon* Kraus. Lepekhina (1972)

and Maheshwari (1972) studied these taxa in detail. According to Lepekhina (1972) structure and presence of pith and primary xyem (endarch) are characteristics of *Dadoxylon* while absence in *Araucarioxylon*. Maheshwari distinguished *Araucarioxylon* and *Dadoxylon* on the basis of wood rays unseriated in *Araucarioxylon*, (Fig. 2 U) and bi to multi-seriate in *Dadoxylon*. Bordered contiguous pits uni- to multi-seriate are present in both the wood taxa. Pits in cross field one to many.

Araucarioxylon Kraus

Maheshwari (1972) and Bose and Maheshwari (1974) made following changes in *Dadoxylon* species. *Araucarioxylon agathioides* (Krausel & Jain 1964) comb. nov. for *Dadoxylon agathoidies* Krausel & Jain (Fig. 2–1J).

A. jurassicum (Bhardwaja) comb. nov. for *Dadoxylon jurassicum* Bhardawaj (Fig. 2 F–4).

A. amaraparense (Sah & Jain 1964) comb. nov. for *Dadoxylon amaraparence* Sah & Jain (Fig. 2M, N).

A. bindrabunense (Sah & Jain 1964) comb. nov. for *Dadoxylon* bindrabunense Sah & Jain.

A. mandroense (Sah & Jain 1964) comb. nov. for *Dadoxylon mandroense* Sah & Jain (Fig. 2, O).

A. santalense (Sah & Jain 1964) comb. nov. for *Dadoxylon santalense* Sah & Jain (Fig. 2 P,Q).

A. rajmahalense (Sahni 1931) comb. nov. for *Dadoxylon [Araucarioxylon] rajmahlense* Sahni., which also includes report of suryanarayana (1955) report from the eastern coastal Gondwana. Sukhdev and Zeba Bano (1976) described *Araucaria indica* from the Mesozoic of Madhya Pradesh. Jayasingh and Kumarswamy (1994) reported two new species *Araucarioxylon giftii* (Fig. 2. S–U) and *A. rajivii* from Sriperumbudur Formation Tamil Nadu. Growth rings distinct, rays uniseriate, bordered pits contiguous in 1 to 2 rows on radial walls of tracheids, pits in cross field two.

ROOTS

Presence of araucarian roots from Sonajori Locality was reported by Sharma and Bohra (1975). In 1980 Bohra and Sharma described *Araucamyelon pakurense* gen. et sp. nov. It was the first report of an araucarian root from the Rajmahal Hills. It is diarch with well developed secondary wood. In 1989 Sharma and Suthar recorded association of blue green alga in young araucarian roots identical to that of the coralloid roots of *Cycas* (Pant 2002).

FRUCTIFICATIONS

Araucarites Presl. A large number of detached seed scales have been recorded from the Mesozoic strata of India (Feistmantel 1876, b, 1877a, 1882, Seward & Sahni 1920, Sahni 1928, Bose & Maheshwari 1973 Bose & Banerji 1984, Zeba Bano & al 1979, Patra & Sahoo 1992) etc. (specify) These are now described either as *Araucarites* Presl. or *Araucaria* Bose and Maheshwari (1974). Some of the well known and common species of *Araucarities* are *A. cutchense* Feist (Plate 10, 11 Fig. 1 O) *A. macropterus* Feist. etc. Sahni (1928) also reported these two species from Jabalpur formation. Vishnu Mittre (1955) described a well preserved megastrobilus, *A. bindrabunensis* from the Rajmahal Hills. Seed scale is reduced to a ligule while the bract scale is large and has a long terminal whip. Singh (1956) established a new species *A. nipaniensis,* a petrified seed scale from Nipania in the Rajmahal Hills. Bose and Maheshwari (1973) established two new species *A. minutus* and *A. sehoraensis* from India. In 1977 Sharma and Bohra reported the presence of petrified megastrobilus of *Araucarites* from the newly discovered locality Sonajori, Rajmahal Hills. In 1980 Bohra and Sharma described it a new species *A. mittrii* bearing sprially arranged seed scales complexes (Florin 1951) (Plate 1, 2). Bract scales are well developed but without whip like terminal end (unlike *A. bindrabunensis).* The seed scales are reduced to ligules. Each seed scale has single adaxial inverted ovules. (Plate 1, Fig. 3A). Integument single, differentiated into sarcotesta, sclerotesta and endotesta. Nucellus free with a spirally twisted micropylar end (Fig. 3A). Embryo dicot but rarely preserved. Zeba Bano & al. (1979) reported the presence of *Strobilities* and *Araucarites* (seed scales) from Pathargama locality in the Rajmahal Hills. Patra and Sahoo (1992) noticed the presence of *A. cutchense* from Athgarh formation. Bose and Banerji (1984) reported *A. cutchenses* Feist., *A. minutus* Bose and Maheshwari, *A. janaianus* n. sp. and *A.* cf. *nipaniensis* Singh from the Mesozoic of Kachchh. In 1989 Srivastava & al. reported seed scales of *A. cutchense* and *A. minutus* from Bairam Belkher area of Amaravati district, Maharastra (Lower Cretaceous). Prakash and Sukhdev (1994) noticed the presence of *A. cutchensis* and *A. minutus* from Athgarh formation. Banerji and Ghosh (2005) recorded petrified seed scales of *A. cutchensis* and *A. nipaniensis* from Hiranduba locality (near amarapara), Rajmahal hills.

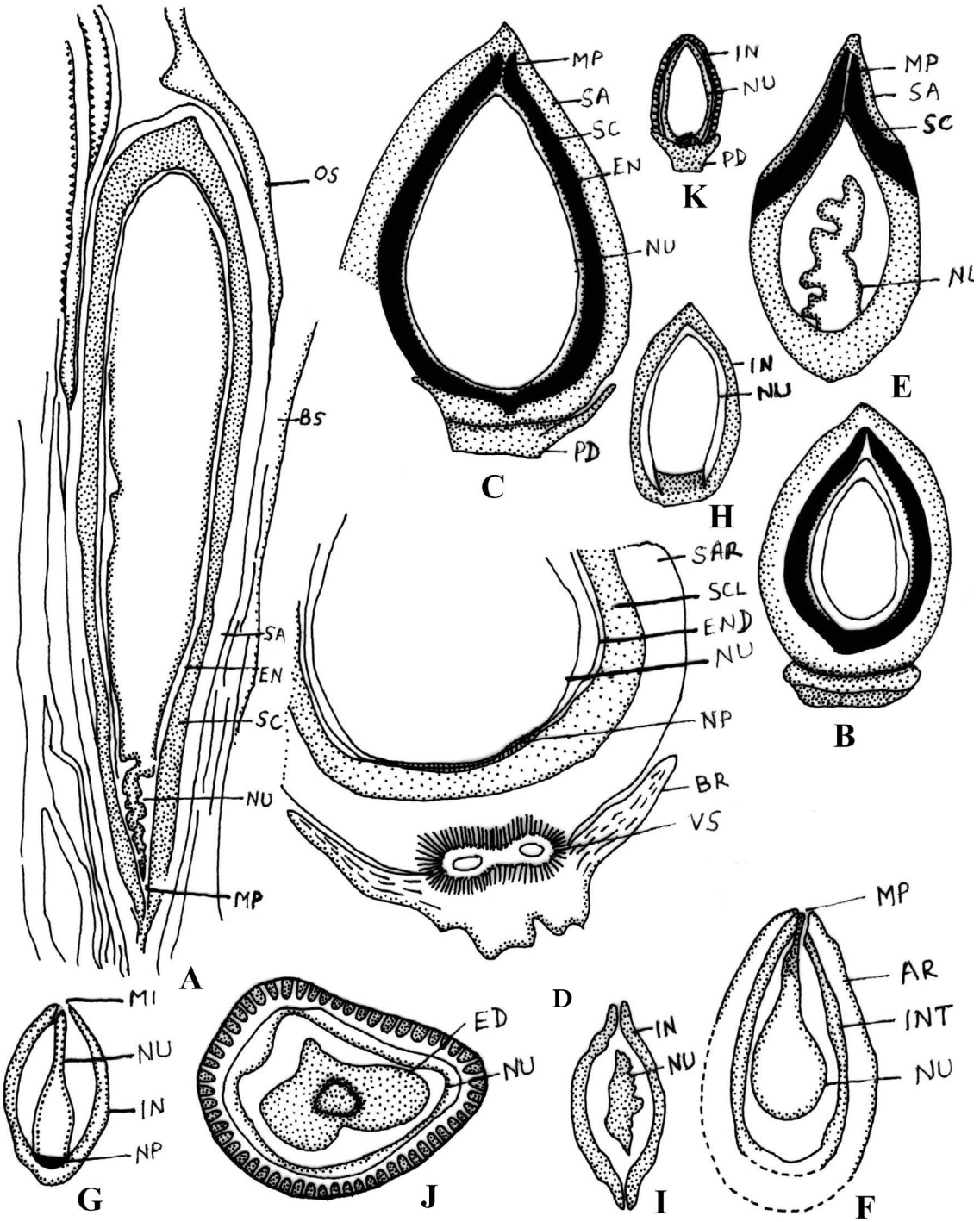
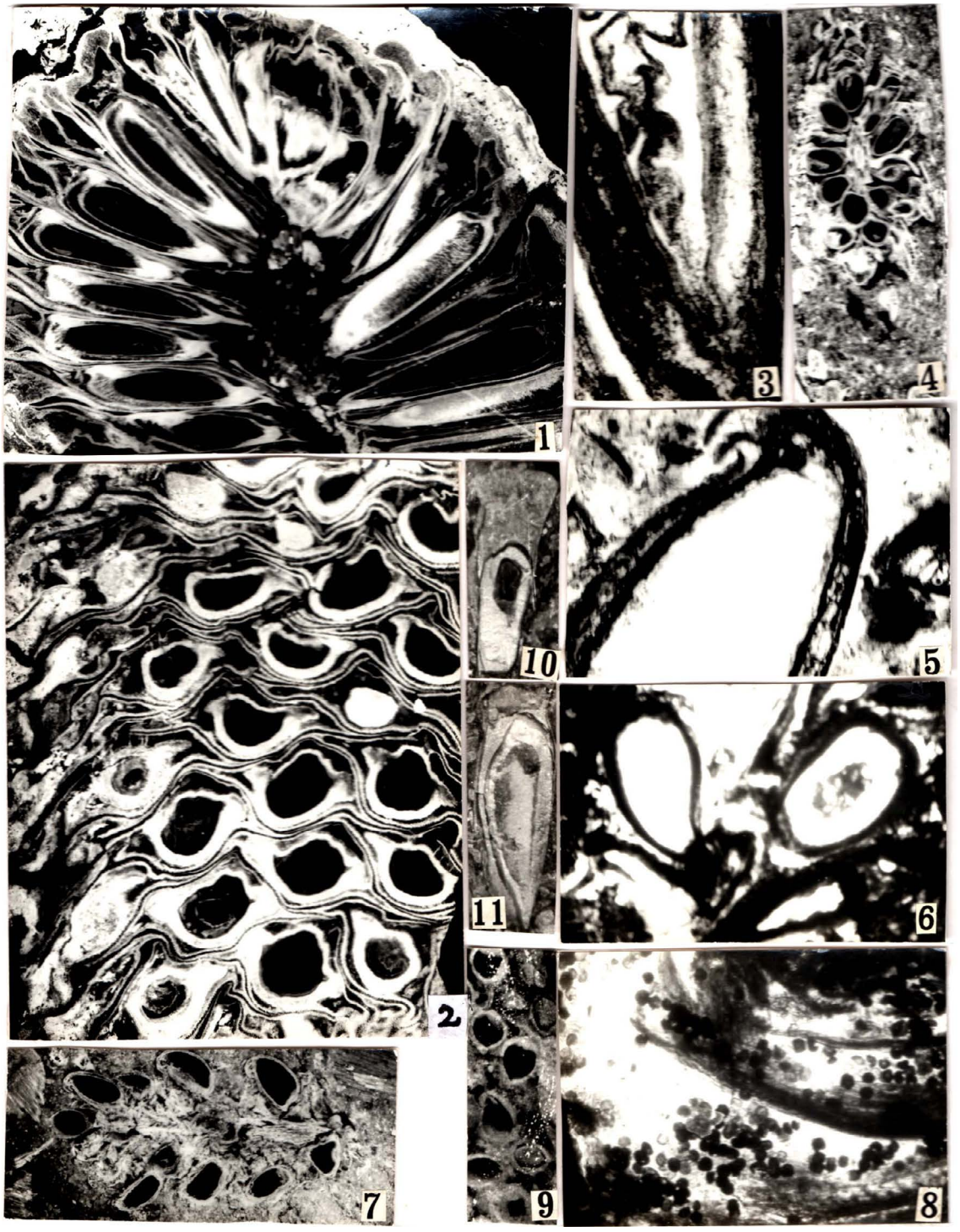


Fig. 3. Petrified isolated seeds. **A.** *Araucarites mittrii* L.S. Inverted ovule with three layered thick integument micropylar portion of ovule twisted. **B.C.D.** *Pakuriospermum pachytestoides;* L.S. Ovules. integument thick heterogeneous, epimatium like structure [BR] originates from basal portion. **E.** *Pakuriospermum heterotestoides*. Nucellus free **F.** *Taxaliospermum arilloides* L.S. Ovule covered by an aril. **GHI.** *Sonajorispermum homotestoides* L.S. Ovules. Bivalved seed, nucellus free, integument homogeneous. **J.K.** *Triangulospermum minimum* in cross section seed triangular, in L.S. it is oval [k] integument heterogeneous, Nucellus free. (OS–Ovuliferous scale, BS–bract scale, SA Sarcotesta, SC–Sclerotesta EN–endotesta, Nu–Nucellus, MP– Micropyte, Pc–Pedicel, IN–Integument, NP–Nucellar pad, BR–Epimatium, VB–Vascular bnndle. AR–Aril) (Redrawn from many literature noted in text).



Plate–1 Fructifications of extinct conifers – **1** *Araucarites mittrii.* L.S. Mega strobilus. Ovules inverted single per seed scale complex **–2.** Same, T.L.S. of megastrobilus showing spirally arranged seed scale complexes **3.** Same L.S. An inverted ovule with twisted micropylar portion of the nucellus. **4.** *Nipaniostrobus sahnii oblique* Longisection of cone. Ovules inverted and spirally arranged. **5.** *Methaia nipaniensis* An erect ovule with curved microply. **6.** *Nipaniostrobus sahnii*– T.S. Cone with inverted ovules. **7.** *Methaia rajmahalensis* L.S. Cone with spirally arranged erect ovules [dark coloured]. **8.** *Podostrobus sahnii* A portion of cone with scattered winged pollen grains. **9.** A portion of Sonjori chert with isolated petrified seeds. **10, 11.** *Araucarites* sp. Isolated petrified seed scales.

Shendage and Manik (2015) noticed the presence of *A. minutus* from Gallapilli formation, Orissa.

TAXALES

Torreyites Seward (1919) - Feistmantel (1879) described *Cycadites constricta* from Vemavaram shales. Seward and Sahni (1920) transferred it to *Torreyites constricta.* Ganju (1947) described another new species of *Torreyites, T. sitholeyi* from the Rajmahal Hills.

Taxaceoxylon Krausel and Jain (1964). Bhardwaj (1952) described a taxacean wood from kulkipara, Rajmahal Hills on the basis of anatomy, *Taxaceoxylon rajmahalensis.* Growth rings present but may be irregular. Tracheids bear spiral thickneings and uniseriate separate bordered pits with circular or cross shaped pit pores. Pits in cross field 3–6, simple circular. Rays uniseriate, 1–6 cells high. Sharma (1970) described the anatomy of a wood collected from Dhokuti, Rajmahal Hills and described as *Taxaceoxylon cupressoides*. Tracheids have bordered pits and teritary spiral thickings similar to other Taxacean woods. (Fig. 2R). Rajnikanth and Sukhdev (1989) and Murlidhara Rao (1991) described *Prototaxoxylon liassicum* from Kota stage.

CONIFERS OF UNCERTAIN AFFINITIES

Some of taxa are of uncertain affinities like *Strobilites* (described above with Podocarpinean affinities) *Conites* etc.

Conites sternburg.- *Conites rajmahalensis* Sahni (1928) was descried earlier by Feistmantel (1877) as a cycadean cone. *C. sessilis* Sahni (1928) was related to *Sequoia* (Taxodiaceae) *C. sriparmaturensis* Sahni (1928) is probably a seed bearing cone of *Elatocladus plana. C. verticillatus* Sahni (1928) was described from Kota stage. Affinities of all these cones are doubtful and further investigations are required.

ISOLATED PERMINERALISED SEEDS

Sharma (1975) announced the discovery of a new assemblage of fossil plants in the Rajmahal Hills, India. In 1976 and 1977 Sharma and Bohra published accounts of conifers in the new assemblage including isolated seeds of gymnosperms which are found frequently in some of cherts from Sonajori locality (Plate 1.9). Bohra and Sharma (1980) also described a new megastrobilus of *Araucarites, A. mittrii* from Sonajori locality, Rajmahal Hills. In 1988 Suthar & al. published a detailed account of petrified isolated seeds of conifers from the new assemblage. The seeds described were– *Pakuriospermum pachytestoides* gen. et sp. nov. Podocarpinean affinity. Integument thick, three layered, heterogeneous. Nucellus free, epimatium like structure present at the base of the seed (fig. 3B–D). *Paradoxispermum heterotestoides* gen. et sp. nov. Taxacean affinity. Micropyle long aril covers the entire seed (Fig. 3E).

Taxaliospermum arilloides gen. et sp. nov. Taxacean affinity. Integument thin, homogeneous, covered by an aril (Fig. 3F).

Sonajorispermum homotestoides gen. et. sp. nov. Pentoxylean affinity. Seed bivalved. Integument homogenous, nucellus free (Fig. 3G–I). *Triangulospermum minimum* gen. et ap. nov. Podocarpinean affinity, seed traingular, integument thin, heterogeneous, nucellus free (Fig. 3 J,K).

Some of chert pieces are full of isolated seeds of various sizes and shapes [Plate 1.9]. Further investigations are required on these petrified isolated seeds and other fossiliferous pieces of cherts. Banerji (2000) also reported even angiospermic remains from this locality.

CONCLUSION

In India extinct conifers occur from Late Palaeozoic i.e. Upper Carboniferous and Permian Periods to the Cenozoic Era but these were at the peak during the Mesozoic Times (Seward 1931, Sahni 1931) and declined towards the Tertiary (Ramanujam 1953, 1954, Trivedi 1974, Agashe 1969, Lakhanpal et al. 1976, Bande & Prakash 1984, Bera & Sen 2004 etc.) Majority of these references are related to extinct Podocarpinean plants from the Deccan intertrappean Beds and Assam Teritary rocks. In the peninuslar India the Mesozoic conifet have been collected from Kota stage (Vemavaram etc.), Athgarh formation, Sripermabudur, Gangapur Formation, Cauveri Basin etc. exposures. Further investigations are required on megafossils for correcting the taxonomic variations of the Mesozoic conifers in the Indian sub–continent. This kind of study will also help in tracing the phylogenetic relationship in various families of the conifers and with other allied groups of gymnosperms. Mehra (1988) in his monographic publication suggested a chronology and phylogenetic relationships of gymnosperms. He started with the early ferns and progymnosperms

(aneurophytales and coenopteridales) which survived during the Late Devonian period. They gave rise origin to Cordaitales and early confiers like Voltziales and Palissyales. Cordaitalean plexus gave rise to the origin of Pinaceae Taxodiaceae and Cupressaceae while the Palissyales are related to Araucariaceae, Podocarpaceae and Cephalotaxaceae. Separation of these lines took place during the Mesozoic Era. Pant (2002) also discussed various theories proposed by earlier workers regarding the origin of seed of gymnosperms. He believed an early separation of Cycadophyta and Coniferophyta during the Triassic period i.e. Early Mesozoic Era. Enough work is required specially on megafossils of conifers for tracing the phylogenetic relationships among various allied families.

From the above description it is clear that number of form genera and species have been erected of the twigs like *Elatocladus, Indophyllum, Brachyphyllum, Pagiophyllum* etc. on the basis of minor differences in morphological characters. These have been collected from widely separated places like Rajmahal Hills Bihar [now Jharkhand]. Jabalpur, Madhya Pradesh, Kachchh [Gujrat] etc. We believe ecological parameters must have played an important role in creation of variations in morphological features. Similarly, the extinct woods of various families of conifers especially of Podocarpaceae and Araucariaceae have been described in different form genera and species on the basis of study of anatomical characters. Amalgamation of majority of species of *Mesembrioxylon* into *podocarpaceae* and *Dadoxylon* into *Araucarioxylon* (Bose & Maheshwari 1974) needs further investigations. Lepekhina (1972) considered pith morphology and endarch position of protoxylem as important characters while Maheshwari (1972) analysed uni and biseriate thickness of wood rays as important features for separating *Dadoxylon* and *Araucarioxylon*. Variations in these characters (mentioned above) have been observed even in a single extant species growing in different climatic conditions, (Greguss 1955, 1972). We believe these are not constant characters and further investigations are required for merging of extinct taxa and species.

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