PETRIFIED FRUCTIFICATIONS OF CONIFERS FROM THE JURASSIC OF RAJMAHAL HILLS, INDIA

O. P. SUTHAR & B. D. SHARMA

Department of Botany, University of Jodhpur, Jodhpur 342 001, India

Abstract

Description of petrified gymnospermous cones which were collected from the Rajmahal Hills, Bihar is given. Podocarpaceous plants, e.g. *Podostrobus*, *Nipaniostrobus*, *Nipanioruha* and *Mehtaia* occur frequently here and further observations on them are also included in the paper. Additional informations have been given about *Araucarites mittrii* on the basis of collections of a number of well preserved specimens.

Introduction

Fossil conifers occur frequently in the Mesozoic rocks of India. Since the publications of Sahni (1928, 1931) on the conifers from the Gondwana System of India, a number of papers have been published but, for the present purpose, mention may be made here of such papers in which fertile structures are described. These are Bose and Hsü (1953); Singh (1956); Ramanujam (1980), Rao (1936, 1938, 1943, 1946, 1949), Rao and Bose (1970), Mittre (1954, 1954a, 1956, 1957), Bose and Jain (1964), Sharma and Bohra (1976, 1977), and Bohra and Sharma (1980).

The present paper describes the petrified cones of a number of fossil conifers belonging to the families Podocarpaceae and Araucariaceae. The material was collected from Sonajori and Nipania in the Rajmahal Hills. At both these places, the fossils are found preserved as petrifications in silicified cherts. Sections were cut with the help of diamond edge wheel and slides prepared by the usual technique of grinding and polishing processes.

Male cone—*PODOSTROBUS* Rao & Bose

Seward (1911) established the genus *Masculostrobus* to include male cones of fossil conifers. Rao (1943) described *Masculostrobus rajmahalensis* from India bearing biwinged pollen grains. Mittre (1956) described *M. sahnii* from Nipania in the Rajmahal Hills which contained bi- and triwinged pollen grains. Rao and Bose (1970) changed the name of *Masculostrobus* to *Podostrobus* for the Indian material and identified two species, i. e. *Podostrobus rajmahalensis* (Rao) Rao & Bose and *P. sahnii* (Mittre) Rao & Bose. In this paper further observations are also given on *P. sahnii* and an incompletely known specimen of *Podostrobus* sp.

P. sahnii (Mittre) Rao & Bose

A portion of the cone measuring 11 ×0.4 mm in size is present in slide No. NS. 165 with spirally arranged, linear, 0.16 to 0.18 mm long upward curving microsporophllys (Text fig. 1). Each sporophyll has a large, abaxial sporangium measuring 129 to 179 μm.

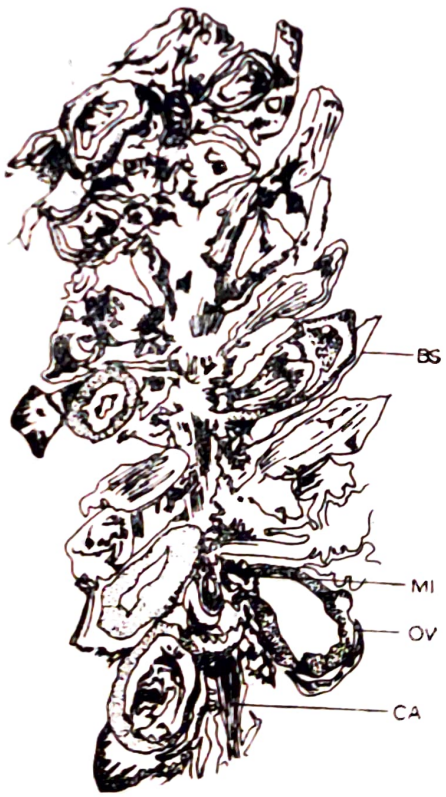
Young spores are non saccate, while mature pollen grains are 2-4 saccate. The ornamentation on exine also changes with the development of spores. In young, non winged pollen the exine is more or less smooth while in mature, saccate pollen it is tuberculated or reticulate. In an another slide No. NS. 74 the spores are very well preserved and show all stages of their development (Pl. 1, Fig. H).

Podostrobus sp.

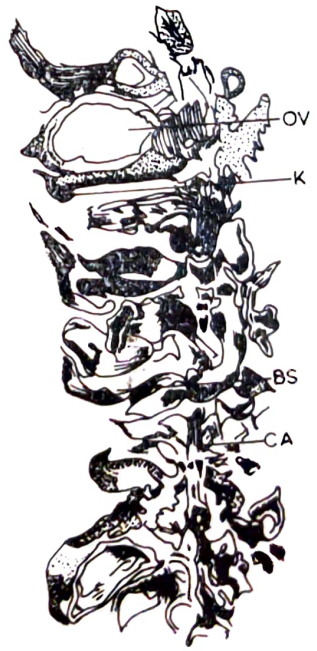
Slide no. NS 70 represents the species. It is an incomplete longitudinal section of the male cone measuring 3.0 to 1.7 mm in size. It possesses two or three close spirals of microsporophylls (Pl. 1, fig. E). Each microsporophyll is a fleshy structure, having distal portion curving upward and bears 2-3 microsporangia on abaxial surface (Pl. 1, fig. F). Microsporangium is more or less a circular structure, measuring 104 × 353 μm in size. Its wall is one cell thick and encloses a large number of bi and tri-saccate pollen grains. Majority of spores are biwinged and measure 17.4 × 12.4 μm in size. The wings are semicircular with reticulate exine.

Comparison—The present material resembles *P. rajmahalensis* (Rao) Rao & Bose (1970) in close arrangement of sporophylls but differs in the shape, size and arrangement of sporophylls and in the presence of bi-as well as triwinged pollen. In *P. rajmahalensis* there are only biwinged pollen. *P. sahnii* (Mittre) Rao & Bose (1970) possesses bi-and triwinged pollen similar to that of the present specimen

TEXT FIG 1



TEXT FIG 2



TEXT FIG 3

Text-fig. 1. *Podostrobus sahnii* L. S. cone bearing spirally arranged linear microsporophylls (**SL**) with abaxial microsporoangia (**SP**). X24.

Text-fig. 2. *Nipaniostrobus sahnii* L. S. cone with closely placed seed scales; each bearing an inverted ovule (BS-Bract scale, **ML**-Micropyle, **OV**-Ovule, **CA**-Central axis). X24.

Text-fig. 3. *Nipanioruha granthia* L. S. cone with horizontal seed scales and inverted ovules. (**OV**- Ovule, **K**-Keel, **BS**-Bract scale, **CA**-Central axis). X24.

but in latter the sporophylls are fleshy, closely placed and pollen are bigger in size than that of the former. Tentatively it is described *Podostrobus* sp. and more material is needed for specific indentification.

Female Cone—*NIPANIOSTROBUS* Rao

The genus was established by Rao (1943) for the conifer cones bearing inverted ovules and having curved micropyles. The material was collected from Nipania and identified as *N. sahnii* Rao. Mittre (1959) added further observations on this genus and identified two new species.

N. sahnii Rao

The megastrobilus is seen in longitudinal as well as cross sections. It is 6 to 8 mm long and 2 to 4 mm broad. Surrounding the central axis spirally arranged seed scales are present each bearing an inverted ovule on its adaxial surface (Text-fig. 2). The bract scale is bigger than the ovuliferous scale and extends beyond the chalazal end of the ovule as a triangular structure. The seed scale is small and covers the basal portion of ovule as an aril or epimatium. The ovule is oval, 1.5×1.0 mm in size, provided with a thin, single integument forming a curved micropyle. The integument is 5 to 7 cells thick, the outer most forms an epidermis consisting of elongated, narrow cells. The inner layers of integument are parenchymatous. The nucellus is free from integument except at the basal portion with which it is adhered to the latter. Slide no. NS/125 (Pl. 1, fig. G) represents a partial longitudinal section through the cone.

Genus—*NIPANIORUHA* Rao

This genus was established by Rao (1946) for the vegetative shoots bearing needle like leaves. He described a megastrobilus, *N. granthia*, from Nipania in 1949 from the Rajmahal Hills. Mittre (1957) not only added two new species, i. e. *N. lanceolata* Mittre (1959) and *N. curvifolia* Mittre (1959) but emended the diagnosis of the genus *Nipanioruha* and *N. granthia*. The megastrobilus is identical to *Nipaniostrobus*. Rao (1946) accepts that the bract scale had a lobed abaxial keel. The present material also comes from the Nipania chert and two slides have been prepared.

Nipanioruha granthia Rao, 1949

A single female cone is cut longitudinally into two. The megastrobus is 7 to 9 mm in length. The central axis is surrounded by spirally arranged and almost horizontally placed seed scales (Text-fig. 3). Each seed scale has a well developed 1.2 mm long bract and a small free portion of the ovuliferous scale. The distal portion of the bract bends upward and forms an abaxial keel. Each scale possesses an inverted ovule with a slightly curved micropyle. The ovule is 1.2×0.5 mm in size having a single, homogeneous, non-vascularized integument which is 6 to 9 cells thick with a differentiation of epidermis and inner 3-4 layers made up of isodiametric, compactly placed squarish cells. The nucellus is free from the integument except at the basal portion with which it is adhered to the latter.

MEHTAIA Mittre

The genus was established by Mittre (1959) for the coniferous cones with spirally arranged seed scales bearing erect ovules and having curved micropyles. He established

three species of this genus, i.e. *M. nipaniensis*, *M. rajmahalensis* and *M. santalensis*. The first one is described below.

M. nipaniensis Mittre

The cone is 7.0×4.0 mm in size with loosely placed and spirally borne erect ovules on the seed scale complexes (Pl. 1, fig. A). The cone is fleshy with a thick central axis. Each seed scale complex is made up of a small fleshy bract and an adaxially adhered seed scale (Pl. 1, fig. B). Ovule is axillary and attached to the seed scale by a broad base. The ovule is oval, 1.3×0.71 mm in size, unitegumic and with a sharply curved, long micropyle (Pl. 1, fig. C). The nucellus is free from the integument except at the basal portion with which the former is adhered to the latter. This portion is quite distinct and look like a nucellar pad. Vascular supply to the pad could not be seen. A number of biwinged pollen grains are present surrounding the ovules and in one of the ovule pollen are seen even in the curved portion of the micropyle (Pl. 1, fig. D). Whether these pollen grains belonged to this plant is not known.

Araucarian Plant Remains

Araucariaceae is one of the oldest family of true conifers known since Triassic (Seward & Ford, 1906; Miller, 1977) and had a world wide distribution in the past. Only two extant genera are known, i.e. *Araucaria* and *Agathis*, which are restricted to the southern Hemisphere (Sporne, 1965; Dellimore & Jackson, 1966). The extinct araucarian plants are found preserved as woods, twigs, roots (Ramanujam, 1980) megastrobili and pollen grains (Stockey, 1982). Male cones are rare in occurrence (Miller, 1977; Stockey, 1982). During recent years several papers have been published on extinct araucarian plants (Stockey, 1975, 1980, 1980a; Stockey & Taylor, 1978) and their evolutionary perspective (Stockey, 1982).

Representatives of this family occur frequently in the Mesozoic rocks of India in the forms of woods, vegetative twigs, seed scales and megastrobili (Feistmantel, 1876, 1977; Sahni, 1928, 1931; Sahni & Rao, 1933; Mittre, 1954; Bose & Jain, 1964; Bose & Maheshwari, 1973; Bose, 1975; Sukh Dev & Zeba Bano, 1978; Sharma & Bohra, 1977; Bohra & Sharma, 1980). Mittre (1954) and Ramanujam (1980) have reviewed the Indian work on Araucariaceae. In the present paper further observations are given on the megastrobilus of *Araucarites mittrii* Bohra & Sharma (1980) on the basis of freshly collected specimens from Sonajori in the Rajmahal Hills, Bihar.

Araucarites mittrii Bohra & Sharma

More than 20, well preserved specimens are present in the collection. Some are complete while in others the strobili are seen in tangential, longitudinal or cross section view. The cones vary in size from 4×6 to 7×11 cm. In surface view rhomboid terminal ends of the bract scales are seen in close spirals. In a cross section numerous scales are seen surrounding the cone axis, while in longitudinal view the scales are seen originating at right angle in the middle portion of the cone and obliquely in apical part. Accordingly, the sections have been cut through transverse, longitudinal (Pl. 1, fig. I) and tangential plains (Pl. 1, fig. M).

A single, adaxial, inverted ovule is produced per scale (Pl. 1, figs. J, K). Integument is differentiated into three layers in which the sclerotesta is well developed. Nucellus is free from integument and its shrinked apical (micropylar) portion is seen clearly in all

ovules (Pl. 1, fig. L). Endosperm and dicotyledonous embryo could be seen only in few seeds.

Discussion

The coniferophyta attained their greatest diversity and abundance during the Mesozoic Era. Among the families of extant genera, Podocarpaceae is believed to be the oldest followed by Araucariaceae, Cupressaceae, Taxodiaceae and Taxaceae (Miller, 1977). In the Rajmahal Hills, Podocarpaceae and Araucariaceae dominated the vegetation. Representative of Cupressaceae, Taxodiaceae and Taxaceae are also known from the area. *Podostrobus*, *Nipaniostrobus*, *Nipanioruha* and *Mehtaia* were believed to be Podocarpaceous plants (Mittre, 1959; Miller, 1977). Of course, in none of them the epimatium could be seen which occurs in majority of the extant genera of Podocarpaceae. Townrow (1969) and Miller (1977) believed that the reduction in the number of ovules per seed scale and the folded over tips of the latter in *Nipaniostrobus* and *Nipanioruha* may represent the forerunner of the epimatium of certain members of modern Podocarpaceae. On the other hand Mittre (1959) suspected the origin of epimatium *de novo*. On the basis of the present material it is suggested that epimatium is a modified portion of seed scale or represents the entire seed scale.

Mittre (1959) traced the origin and history of Podocarpaceae and believed *Mehtaia* as a primitive type of seed bearing cone from which all other types originated along different lines. He suggested that *Sitholeya* is an advanced type which might be the ancestor of *Podocarpus* and *Dacrydium*. Should it mean, erect position of an ovule is a primitive feature and inverted one is a derived condition. Similarly, reduction in the number of ovules in the cone is believed to be an advanced feature (Mittre, 1959; Florin, 1951, 1958; Townrow, 1969; Miller, 1977). In *Mehtaia* the cone is loose and possesses only few ovules whereas, in *Nipaniostrobus* the cone is compact and a large number of ovules make a cone. Thus in Podocarpaceae, the evolution of characters took place along diverging lines as in many other groups of plants.

Occurrence of more than one species of male cone of Podocarpaceae in the Rajmahal Hills is expected as a number of type of seed bearing fructifications are present. However, the variation is less pronounced in the former (*Podostrobus sahnii* and *P. rajmahalensis*) than the latter (*Mehtaia*, *Nipaniostrobus*, *Sitholeya*). The pollen grains show variations from non-saccate to tetrasaccate condition even in the same sporangium. The wings differentiate along with the maturation of spores. The elaborate wing system in pollen grains is probably related to the curved structure of micropyle. In majority of Podocarpaceous cones described from the Rajmahal Hills, the ovule, both erect as well as inverted, possess slightly or sharply curved micropyles.

Mittre (1954) assigned *Araucarites bindrabunensis* Mittre to the *Bunya* group of the extant genus *Araucaria*. Sharma and Bohra (1977) and Bohra and Sharma (1980) connected *A. mittrii* also to the section *Bunya*, but the seeds remain adhered to the scales even after shedding from the cone, i.e. a character of the section of *Eutacta* Endlicher (Stockey, 1982).

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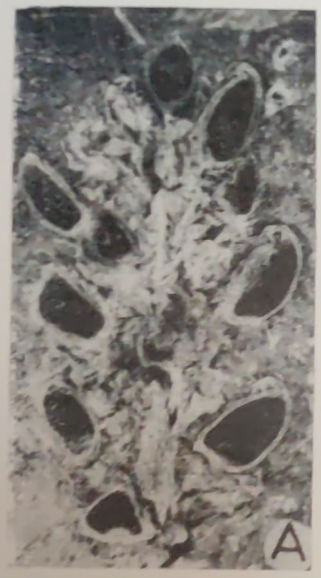
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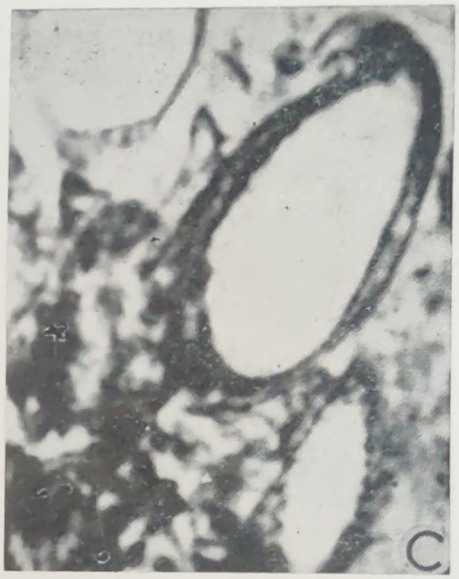
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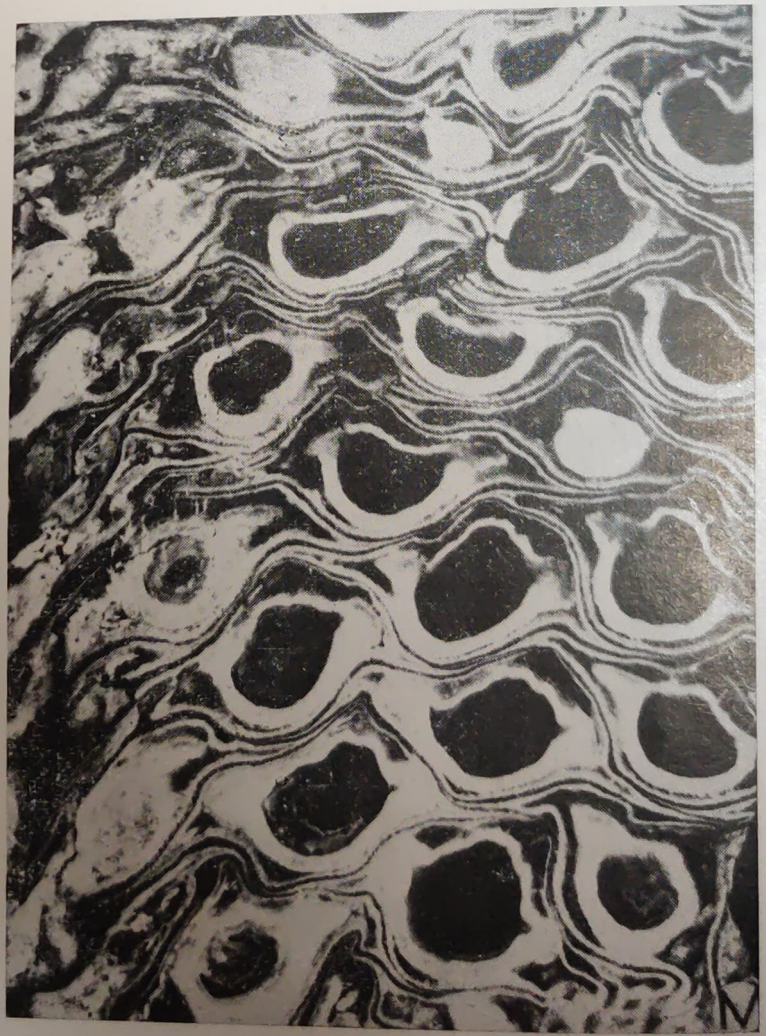

Suthar & Sharma—Plate 2

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Explanation of Plate

A. *Mehtaia nipaniensis*. L. S. of cone with loosely attached ovules. X 8.
B,C. Same. Ovules attached with broad bases and possess curved micropyles. X 45.
D. Same. Curved micropyle portion with associated pollen grains. X 96.
E. *Podostrobus* sp. Microsporophylls in close spirals bearing sporangia. X 24.
F. Same. A microsporophyll enlarged. X 48.
G. *Nipaniostrobus sahnii*. Partial longitudinal section through the cone with closely placed, inverted ovules. X 8.
H. *Podostrobus sahnii*. Obliquely cut cone with pollen grains. X 64.
I. *Araucarites mittrii*. L. S. cone with compactly arranged seed scales surrounding central axis. X1.
J.K. Same. Single adaxial, inverted ovule on each seed scale. X8, 2.
L. Same. Micropylar portion of ovule enlarged showing shrinked nucellus. X12.
M. Same. Tangential longitudinal section through the cone showing spiral arrangement of seed scales. X6.