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THE JURASSIC FLORA OF THE RAJMAHAL HILLS,  
INDIA — ADVANCES AND CHALLENGES

Flora jurajska z Rajmahal Hills w Indiach

ABSTRACT

A concise and systematic account of the fossil flora of the Rajmahal Hills is given, including informations about the recent discoveries made on the Jurassic plants of this area. Presence of a number of gaps is shown which are still to be bridged. Lines of future working on the fossil flora of the Rajmahal Hills are also suggested.

INTRODUCTION

Jurassic plants of the Rajmahal Hills are known since 1863, when Oldham and Morris published for the first time a systematic account of the fossil flora of this area. In this work they identified 16 species of pteridophytes, 25 gymnosperms and a number of fragmentary fossils of unknown taxonomic positions. Schimper (1869—71) also included the descriptions of the fossil plants then known from the Rajmahal Hills into his work „Traité de Paléontologie végétale”. He transferred a number of Indian species of *Pterophyllum* into his new genus *Anomozamites*. Feistmantel (1877) who followed Oldham and Morris did not agree with Schimper and retransferred these species

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of *Anomozamites* back into the genus *Pterophyllum* Brongn. He, however, also made changes in the identifications of Oldham and Morris and described some more species of fossil plants from the Rajmahal Hills. In all, Feistmantel (1877) described 21 species of pteridophytes, 26 *Cycadaceae* and 5 conifers from this area.

For more than fifty years no important paper was published on the fossil plants from the Rajmahal Hills. In the year 1920, Seward and Sahni published a revision of the Indian Gondwana plants. They made drastic changes in the nomenclature and systematic positions of then known fossil plants from the Gondwana System of India. Seward and Sahni identified 3 species of pteridophytes, 12 *Cycadophyta* and only a single species of coniferous plant, *Elatocladus conferta* (O. and M.) Sew. and Sahni. Sahni (1928, 1931) also published a revision of Indian fossil conifers and reported the presence of as many as 8 species of conifers in the Jurassic rocks of the Rajmahal Hills. Since then a large number of papers have been published on the fossil plants of this area and at present our knowledge is quite sufficient about the Jurassic plants of the Rajmahal Hills. In the present paper a concise and systematic account has been given on the fossil flora of this area, besides suggesting the shortcomings and lines of working for future research. Author's observations are based on the study of collections present at the Geological Survey of India, Calcutta, Birbal Sahni Institute of Palaeobotany, Lucknow, Prof. K. M. Gupta's collection, Ajmer and a large number of specimens present in his own collections.

## DESCRIPTION

### PTERIDOPHYTA

In the Rajmahal Hills, fossil ferns are found quite commonly but the other groups of pteridophytes occur rarely, so much so, that only a few specimens of herbaceous lycopods and *Equisetites* have been discovered so far. Mostly these plants are known in the form of their leaves. Stems and fertile parts are rare in occurrence. Fronds are found preserved as impressions and thus generally they do not show the epidermal structures. Surange (1966) has included the descriptions of all the then known fossil pteridophytes from the Rajmahal Hills in his monograph „Indian Fossil Pteridophytes”. Recently, some more papers have been published on the fossil pteridophytes of this area by Bose and Sah (1968), Gupta (1970) and Sharma (1969b, 1971, 1971a).

## *Lycopsidea*

### *Lycopodiales*

Oldham and Morris (1863) figured a few specimens having heterophyllous, distichous leaves under the name *Araucarites? gracilis* Morr. Feistmantel (1877) described these fossils as *Cheirolepsis gracilis*, but later on he modified his views and in the year 1880, transferred these specimens to *Lycopodites gracilis* (Morr.) Fst. Seward and Sahni (1920), Surange (1966), and Bose and Sah (1968) also described these specimens as *Lycopodites gracilis*.

Recently, the present author has discovered two specimens of herbaceous lycopods possessing heterophyllous and spirally arranged leaves and described as *Selaginellites* sp. because of similarity with the living genus *Selaginella* in the mode of branching and position of sporangia (Sharma 1971).

## *Sphenopsida*

### *Equisetales*

A number of fragmentary specimens resembling the living genus *Equisetum* have been described as *Equisetites rajmahalensis* O. and M. No specimen of this species could be collected in petrified state so far and thus the anatomy is still unknown.

## *Filicopsida*

### *Marattiales*

Seward and Sahni (1920) included the fossil fronds described earlier as *Pecopteris macrocarpa* O. and M. (Oldham and Morris 1863) and *Asplenites macrocarpa* (O. and M.) Fst. (Feistmantel 1877) into *Marattiopsis macrocarpa* (O. and M.) Sew. and Sahni, because of the synangial nature of the fertile parts. These fronds are found very commonly in the Rajmahal Hills. Recently the present author has described another species of *Marattiopsis*, *M. reversa* Sharma (Sharma 1969b) from the Jurassic rocks of this area. The latter differs from the former in the arrangement of pinnules and the position of synangia.

*Daniaeopsis rajmahalense* Fst. is another example of the fossil *Marattiales* known from the Rajmahal Hills. But its occurrence is rare in comparison to the fronds of *Marattiopsis* and only a few vegetative specimens have been collected so far.

### Osmundales

This order is represented both by fronds as well as the rhizomes. Former are found more commonly than the latter. Vegetative fronds are described as *Cladophlebis* while the fertile forms have been put under the genus *Todites* (Bose and Sah 1968, Sharma 1971). *Cladophlebis* Brongn. is a commonly occurring frond genus in the Rajmahal Hills and it is represented by six species. These are *Cladophlebis denticulata* Brongn. (Sharma 1971), *C. indica* (O. and M.) Sahnii and Rao (1933), *C. srivastavii* Gupta (1954), *C. sahnii* Mittre (1959), *Cladophlebis* sp. Bose and Sah (1968) and *Cladophlebis* sp. Sharma (1971). Recently the present author has suggested that *C. indica* be merged into *C. denticulata* because of close similarities in the structure of the fronds of these two species.

In *Todites indica* (O. and M.) Bose and Sah (1968) and Sharma (1971) sori are naked, abaxial and each consisted of 6—8 circular sporangia.

Only two petrified osmundaceous rhizomes have been described so far from the Jurassic rocks of the Rajmahal Hills. These are *Osmunda-caulis sahnii* (Mittre 1955) and *O. rajmahalensis* (Gupta 1970). They differ from each other in the structure of the stele and distribution of sclerenchyma found in the ground tissue of petiolar base.

### Schizeales

Presence of this order in the Rajmahal Hills has only recently been reported by the present author (Sharma 1969b). It is represented by the frond genus *Klukia* with three species i. e. *Klukia rajmahalensis* Sharma (1969b), *Klukia* sp. A. Sharma (1971) and *Klukia* sp. B. Sharma (1971). Both sterile as well as fertile fronds are known of these species.

### Cyatheales

*Cyatheaceae*. Jacob (1937) described a cyatheaceous stem *Protocyathea rajmahalensis* from Sakarigalighat in the Rajmahal Hills which was later on described as a cycadean stem by Bose (1953). The present author has reported the occurrence of sterile as well as fertile fronds of *Haydenia thyrsopteroides* Sew. in the Jurassic rocks of the Rajmahal Hills. The fertile fronds possess cup shaped, cyatheaceous sori on the abaxial surface of the pinnules.

*Dicksoniaceae*. The family is represented by the following species in the Rajmahal Hills: *Coniopteris hymenophylloides* Brongn. (Surange 1966), *Dicksonia rajmahalensis* Sharma (1971), and *Tinpaharia sinuosa* Jacob (1943). The first two are the fronds while the third is a petrified rhizome. Only *Dicksonia rajmahalensis* Sharma has been found in the fertile state. Sori are kidney shaped and marginal. In *Tinpaharia sinuosa*

the petiolar stele is an adaxially curved C-shaped structure with a projected column of sclerenchyma.

*Dryopteridaceae*. Recently, the present author has reported the occurrence of fertile fronds resembling the living genus *Dryopteris* in the Rajmahal Hills and they are described as *Dryopteris indica* Sharma (1971).

### *Gleicheniales*

*Gleicheniaceae*. Like *Cladophlebis*, the frond genus *Gleichenites* is also found quite common in the Rajmahal Hills. It resembles very much with the living genus *Gleichenia* and thus such fronds are now described as *Gleichenia gleichenoides* (O. and M.) Bose and Sah (1968). *Gleichenites rewahensis* Fst. is probably a smaller form of *G. gleichenoides* (Sharma 1969b).

*Dipteridaceae*. This family is represented by a single frond genus *Hausmannia*. It is provided with reticulate venation. Recently, Bose and Sah have merged the earlier described species *Hausmannia indica* Gupta (1955) into *H. crenata* (Nath.) Moll.

### Ferns of doubtful affinities

A large number of fronds, rachises and rhizomes have also been discovered from the Rajmahal Hills which could not be assigned to their proper taxonomic positions either for the want of more material or due to poor preservation or because of the absence of fertile parts. *Sphenopteris* Brongn. is one of the commonly occurring frond genus in the Rajmahal Hills. As many as eight species of it have been described so far from this area, but none could be discovered with the fertile parts. Similarly, the anatomy of a number of isolated rachises and petioles of ferns collected from the Rajmahal Hills have been recently described by the present author (Sharma 1971a), but their affinities could not be established because of the want of our knowledge about the petrified rhizomes.

### GYMNOSPERMAE

Gymnosperms formed the major part of the vegetation of the Rajmahal Hills. They are found in all the fossiliferous localities of this area and occur in the form of leaves, stems and fructifications. Many of these are found preserved in petrified state and thus their anatomical characters are also known. Epidermal structures have also been studied

wherever they are preserved. Fossil gymnosperms of the Rajmahal Hills are divided into two main divisions i. e. *Cycadophyta* and *Coniferophyta*. In the former there are included four classes — *Pteridospermopsida*, *Pentoxyllopsida*, *Cycadopsida*, and *Bennettitopsida*, while the latter includes three classes i. e. *Ginkgopsida*, *Coniferopsida*, and *Taxopsida*.

## *Cycadophyta*

### *Pteridospermopsida*

Vegetative fronds of the pteridospermous genus *Thinnfeldia* are found commonly in some of the fossiliferous localities of the Rajmahal Hills. But unless and until the fertile parts are discovered in association with these leaves, their taxonomic position remains doubtful. Some of the important species of *Thinnfeldia* described from the Rajmahal Hills are *Thinnfeldia indica* Fst., *T. chunakhalensis* Sah and Sukhdev (1957), *T. amarjolense* Sharma et al. (1971).

Recently the present author has described a new stem genus *Guptioxylon amarjolense* Sharma (Sharma 1969a) from the Rajmahal Hills, which possesses the anatomical characters correlating *Medulloseae* on the one hand and *Pentoxyleae* on the other hand.

### *Pentoxyllopsida*

This group of gymnosperous plants was instituted by Sahnii in the year 1948 on the basis of the work done by late Prof. B. P. Srivastava (1945). Our knowledge was further enhanced about these plants by Mittre (1953, 1957), who also described the male fructification *Sahnia nipanensis* Mittre of the *Pentoxyleae*. Vascular organization is polystelic like the *Medulloseae* but without medullary vascular strands. Stomata are haplocheilic resembling the *Cycadaceae* (Mitre 1957, Sharma 1969c).

### *Cycadopsida*

Plants of this class occur in almost all the fossiliferous localities of the Rajmahal Hills and are represented mostly by large size fronds e. g. *Nilssonia*, *Cycadites*, *Macrotaenipteris* etc. Stems and fructifications have also been discovered, but they are comparatively rare in occurrence. *Nilssonia* Brongn. is one of the commonly occurring genus in the Rajmahal Hills. It is represented by as many as 7 species. These are: *Nilsso-*

*nia princeps* (O. and M.) Sew. (1917), *N. medlicottiana* (Morr.) Sew. and Sahni (1920), *N. morrisiana* (Oldh.) Sew and Sahni (1920), *N. bindrabunensis* Sew. and Sahni (1920), *N. sahnii* Gupta (1969), *N. distanse* (Morr.) Sharma (1971b), and *N. crassum* (Morr.) Sharma (1971b).

Indian species of the genus *Nilssonia* differ from the foreign types in a number of characters like the incomplete covering of the rachis by the bases of pinnae or laminae, frequent bifurcation of veins etc. The present author believes that these are minor variations and should not be given too much credit.

Only three petrified cycadean stems are known throughout the world, out of which two have been reported from the Jurassic rocks of the Rajmahal Hills. These are *Sewardioxylon sahnii* Gupta (1960, 1971) and *Fascisvarioxylon mehtae* Jain (1963). Both these possess peculiar vascular organization and are provided with medullary vascular strands. But they differ from each other in the structure of the stele and other anatomical details.

No true cycadean fructification is known from the Rajmahal Hills so far. Only a doubtful and poorly preserved female fructification was described under the name *Beaniopsis rajmahalense* by Ganju in the year 1947.

### *Bennettitopsida*

Bennettitalean plants occur very commonly in all the Jurassic rocks of the Rajmahal Hills, and are represented by fronds, stems and the fructifications. They resemble in external morphology the cycadean plants but differ from them in anatomy and other details. Fronds are generally pinnate with parallel or diverging veins, except the *Dictyozamites* Oldh. in which the venation is reticulate. *Ptilophyllum* Morr. is the most widely and commonly occurring frond genus in the Rajmahal Hills. It is represented by as many as 7 species in this area. Almost in all, the epidermal characters are known (Gupta and Sharma 1968, Sharma 1967). Other important bennettitalean fronds found in the Rajmahal Hills are: *Dictyozamites* Oldh. 5 sp., *Otozamites* Braun 2 sp., *Pterophyllum* Brongn. 2 sp., and *Anomozamites* Schimp. 2 sp.

Stems are found comparatively less commonly in the Rajmahal Hills than the fronds. Their outer surface is covered with spirally arranged, rhomboid leaf bases. Secondary wood is compact and well developed unlike the other bennettitalean stems known from outside India. The stem genus *Bucklandia* Presl is represented by four species in the Rajmahal Hills. These are *Bucklandia indica* Sew. (1917), *B. sahnii* Bose (1953a), *B. guptai* Sharma (1967a) and *B. dichotoma* Sharma (1970a).

*Sahnioxylon* (*Homoxylon* of Sahni 1932) Bose and Sah (1954) is

another bennettitalean stem genus found in the Rajmahal Hills. It is represented by two species i. e. *Sahnioxylon rajmahalensis* (Sahni) Bose and Sah (1954) and *S. andrewsii* Bose and Sah (1954). Tracheids are provided with scalariform and multiseriate bordered pits on the radial walls of the tracheids like those found in homoxylous angiosperms and in many species of cycadeoideas. The manner of formation of leaf traces in *Sahnioxylon* is yet to be discovered.

Both male and the female fructifications of the bennettitalean plants are known from the Rajmahal Hills. The former are large sized, open flowers having a whorl of microsporophylls surrounding a central cup shaped receptacle e. g. *Williamsonia santalensis* Sith. and Bose, *W. campanulatiformis* Sharma. Outside the microsporophylls, a whorl of sterile bracts is also present in these fructifications. Female flowers are mostly of the closed type except *W. sahnii* Gupta (1943). In these fructifications the fertile parts are produced on a conical receptacle and are enclosed by the surrounding sterile bracts. The vascular organization of the receptacles is peculiar in having inverted and exarch bundles forming the main stele (S h a r m a 1970b). A description of the internal structure of the seed of *Williamsonia* has also been given by the present author (S h a r m a 1970c). As many as ten species of the genus *Williamsonia* have been described so far from the Rajmahal Hills. These are: *Williamsonia microps* Fst. (1877), *W. indica* Sew. (1917), *W. seawardiana* Sahni (1932a), *W. sahnii* Gupta (1943), *W. santalensis* Sith. and Bose (1953), *W. guptai* Sharma (1968), *W. amarjolense* Sharma (1968), *W. harri-siana* Bose (1968), *W. campanulatiformis* Sharma (1969), and *Williamsonia* cf. *W. scotica* Sharma (1970). Out of these species, two are the male fructifications e. g. *Williamsonia santalensis* and *W. campanulatiformis*, while the remaining eight are the female flowers. In some of these fructifications, the epidermal structures of the bracts have also been studied and found useful in delimiting species (S h a r m a 1968).

Besides the williamsonias, a number of other bennettitalean fructifications or their parts have also been described from the Rajmahal Hills for example *Rajmahalia paradoxa* Sahni and Rao (1934), *Ontheostrobos sessilis* Ganju (1947a), *Cycadeospermum indicum* Gupta (1954), etc.

## Coniferophyta

### *Ginkgopsida*

A number of fragmentary leaves of *Ginkgoites* have been reported from the Jurassic rocks of the Rajmahal Hills. Recently, S a h and J a i n (1965) have described a new species of *Ginkgoites*, *G. rajmahalensis* from this area. These fossil fronds resemble the leaves of the living genus



*Ginkgo*, in their external morphology and in the nature of venation. Other parts of the plant body are still to be discovered.

### *Coniferopsida*

Fossil conifers are represented in the Rajmahal Hills mostly by the decorticated woods. Leaves and fructifications are rare in occurrence.

*Cupressaceae*. This family is represented by the stem genus *Cupressinoxylon rajmahalensis* Bhardwaja (1952). The secondary wood is characterized by the presence of uniseriate or biseriate, opposite bordered pits on the radial walls of the tracheids.

*Podocarpaceae*. A number of woods, twigs and fructifications of this family have been reported from the Jurassic rocks of the Rajmahal Hills. Woods are characterized by the presence of podocarpoid, uniseriate or biseriate, separate or contiguous bordered pits on the radial walls of the tracheids e. g. *Mesembrioxylon*, *Circoporoxylon*, etc. Vegetative twigs are provided with spirally arranged linear leaves e. g. *Nipanioruha*, *Indophyllum*, *Elatocladus*, etc. Structures of the male as well as female fructifications are also described from the Rajmahal Hills (Mittre 1957). Male fructifications bear microsporangia having triwinged microspores e. g. *Nipanioruha granthia* Rao. In the female plants each seed scale complex consists of a small and reduced ovuliferous scale having a single ovule. The bract scale is comparatively well developed e. g. *Nipaniostrobus sahnii* Rao.

*Araucariaceae*. It is considered to be one of the oldest family of the class *Coniferopsida*. Like *Podocarpaceae* it is also found quite commonly in the Rajmahal Hills and is represented by petrified woods, twigs and fructifications. Woods are characterized by the presence of uniseriate or multiseriate, contiguous bordered pits on the radial walls of the tracheids e. g. *Dadoxylon*, *Brachyphyllum*, etc. Twigs are provided with small sized, spirally arranged leaves. Fructifications resemble in structure with those of the living forms, for example *Araucarites bindrabunensis* Mittre (1954), *A. nipanensis* Singh (1956). *Ontheodendron florini* Sahnii and Rao (1933) is another fructification of the family *Araucariaceae* known from the Rajmahal Hills.

### *Taxopsida*

Plants of this class are also found in the Jurassic rocks of the Rajmahal Hills, but not so commonly as the conifers. They are represented by woods and twigs. Tracheids are provided with tertiary spiral thickenings besides, uniseriate or biseriate, opposite bordered pits on the radial

walls of the tracheids, e. g. *Taxaceoxylon rajmahalensis* (B h a r d w a j a 1952), *Taxaceoxylon* cf. *T. rajmahalensis* Kräusel and Jain (1964) and *T. cupressoides* Sharma (1971c).

A number of fructifications of doubtful coniferous affinities have also been described from the Rajmahal Hills, for example *Strobilites pascoei* Sahni (1931), *S. ontheaensis* Ganju (1946), etc.

#### DISCUSSION

From the account given above it is clear that the important constituents of the Jurassic vegetation of the Rajmahal Hills were the ferns, cycads, *Bennettitales*, *Pentoxylales* and the coniferous plants of the families *Podocarpaceae* and *Araucariaceae*. Among the ferns, *Marattiales*, *Osmundales* and *Gleicheniales* were the most commonly occurring plants. Our knowledge about these plants is based mainly on the study of fronds. Their rhizomes are still to be discovered. Anatomy of a number of isolated petioles and rachises of ferns described recently by the present author has not only added further information about the different types of ferns occurring in the Jurassic vegetation of the Rajmahal Hills but also increases our curiosity for the search of their rhizomes.

Discovery of the stem genus *Guptioxylon amarjolense* Sharma (1969a) which possesses a peculiar anatomy has helped us in tracing a line of evolution of vascular organization of the *Pentoxylales* from the *Medulloseae*. Similarly, the study of the internal structures of the stems of *Sewardioxylon sahnii* Gupta (1971) and *Fascisvarioxylon mehtae* Jain (1963) has added support to the ideas of Worsdell (1906) about the origin of the anatomy of the *Cycadaceae* from the medullosean plants.

Bennettitalean plants formed a major part of the Jurassic flora of the Rajmahal Hills. Leaves are found comparatively more common than the stems and fructifications. The frond genus *Ptilophyllum* is found in close association with the *Bucklandia* stems and probably the former was organically related with the latter. The possibly related stems of other bennettitalean fronds like *Dictyozamites*, *Otozamites*, *Anomozamites*, etc. are still to be discovered. Similarly, organic relations and mode of attachments are unknown of the male williamsonias occurring in the Rajmahal Hills.

Petrified coniferous woods are found in abundance in the Rajmahal Hills, but mostly in decorticated forms and thus difficulty arises in finding out their correlations with other woods, and in assigning them to their proper taxonomic positions. Coniferous twigs and fructifications have also been collected from the Rajmahal Hills but they are comparatively rare in occurrence. Besides *Podocarpaceae* and *Araucariaceae* which are the commonly occurring families, *Cupressaceae* and *Taxaceae*

have also been reported from the Rajmahal Hills, but *Pinaceae* are still also to be discovered from the Jurassic rocks of this area.

In many fossiliferous localities of the Rajmahal Hills like Amarjola, Nipania, Hiranduba, Chilgajari, etc. both soft as well as the hard plant parts are found in well preserved conditions. Leaves, stems and fructifications occur quite commonly in these localities, but the roots are still to be discovered from the Rajmahal Hills.

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## STRESZCZENIE

### FLORA JURAJSKA Z RAJMAHAL HILLS W INDIACH

Rozprawa zawiera zwięzłe opracowanie stanu ponad stuletnich badań nad florą jurajską z Rajmahal Hills oraz informuje o ostatnio dokonanych tam odkryciach. Wyniki dotychczasowych badań autor zestawia w systematycznej kolejności, zwraca uwagę na istniejące braki w dotychczasowych studiach oraz sugeruje kierunki przyszłych badań na tym stanowisku.