EIGHTEENTH
SIR ALBERT CHARLES SEWARD MEMORIAL LECTURE
1970

THE JURASSIC FLORA OF THE RAJMAHAL HILLS

BY

A. R. RAO, D.Sc.

Professor of Botany (Rtd.), Lucknow University,
U.G.C. Scientist, Bangalore University

Published by

BIRBAL SAHNI INSTITUTE OF PALAEOBOTANY
LUCKNOW

ISSUED 1972

THE JURASSIC FLORA OF THE RAJMAHAL HILLS

BY

A. R. RAO, D.Sc.

Professor of Botany (Rtd.), Lucknow University,
U.G.C. Scientist, Bangalore University

Published by

BIRBAL SAHNI INSTITUTE OF PALAEOBOTANY
LUCKNOW

ISSUED 1972

EIGHTEENTH SIR ALBERT CHARLES SEWARD MEMORIAL LECTURE

THE JURASSIC FLORA OF THE RAJMAHAL HILLS

PROFESSOR A. R. RAO

I CONSIDER that I have been selected to address you today not only because of my long association with the illustrious founder of this Institute who was also my *Guru* but also as a token of affection from the authorities of this Institute many of whom have been my students. Perhaps I do have a little right to deliver this lecture which is in memory of Sir Albert Charles Seward who was my *Guru's Guru* and I happen to be his disciple's disciple. Incidentally, I recall that Sir A. C. Seward was one of the examiners for my D.Sc. thesis.

I have chosen as the theme of this lecture "The Jurassic Flora of the Rajmahal Hills" a subject on which I was previleged to do a little work. The limited time at my disposal does not permit me to deal with this flora in great detail. I will refer to only those types that are important from some point of view or other. Of all the Jurassic floras known from India, the Rajmahal flora is the most fascinating as well as interesting. To Oldham and Morris and then to Ottokar Feistmantel we owe our early knowledge of this classical flora which was one of the earliest fossil floras to be described and to be used for correlation purposes. A general analysis of this flora shows a preponderance of Conifers, Cycadophyta and ferns most of which are referable to modern families (Rao, 1958) (See this for earlier references). Most of the Rajmahal flora was known only as impressions till the discovery of petrified plant material at Nipania in the Rajmahal Hills by Mr. Hobson of the Geological Survey of India. This was indeed an event of Great importance. Since then silicified plant remains have been found in plenty, in different places in the Rajmahals. Several people working on these petrified plant fossils have added considerably to our knowledge of this flora. In dealing with these plant relics it will not be possible for me to refer individually to the various genera and species. I will deal with a few select representative types that throw light on the evolution of flora in this country during the Jurassic period which was nearly 190 million years old.

The Conifers in this flora were represented by the Podocarpaceae, Araucariaceae and Taxaceae. The Podocarpaceae is now represented in India by a single genus *Podocarpus* which is confined to Peninsular India. But during the Jurassic period there existed in India quite a number of genera belonging to this family. I mention here a few examples many of whom are preserved in a fragmentary state.

Nipaniostrobus sahnii (Rao, 1943) was a seed-bearing cone with a number of single seeded scales arranged spirally round a moderately thick axis. Erect or suberect or inverted, slightly dorso-ventral seeds were partly buried in the scale. Each had a strongly curved micropyle as in the modern genus *Dacrydium laxifolium*. A thin flap of tissue possibly an epimatium covered the seed on its ventral side. The integument was thin — two to three-layered. The ovules were probably erect at first and later became inverted. The cone in all its features is comparable to

the living genus *Dacrydium* which also belongs to the Podocarpaceae.

Nipaniostrobus pagiophylloides (Vishnu-Mittre, 1959) is another similar cone described from the Rajmahals—possibly a variant of *N. sahnii* Rao. Leaves known as *Pagiophyllum* are found in organic connection with the cone.

Nipaniostrobus aciculifolia (Vishnu-Mittre, 1959) is another similar but smaller Podocarpinean cone borne by shoots with acicular leaves. *Nipanioruha granthia* (Rao, 1946 and 1949) is a pyconoxylic petrified shoot with intercalary thickenings and spirally disposed needle-like decurrent leaves, also bore cones exactly like *Nipaniostrobus sahnii* and appears to be also Podocarpinean. *Nipanioruha lanceolata* and *Nipanioruha curvifolia* (Vishnu-Mittre, 1959) are two sterile shoots similar to *N. granthia*.

Some of the other petrified cones from the Rajmahal Hills differ from the cones mentioned above in having seed scales with erect seeds and in having no sterile parts. These have been designated *Mehtaia rajmahalensis*, *M. nipaniensis*, *M. santalensis* (Vishnu-Mittre, 1959). Although their affinities are not very clear they cannot be assigned to any other family except to the Podocarpaceae. *Sitholeya rajmahalensis* (Vishnu-Mittre, 1959) represents another type of Podocarpaceous shoot with a single terminal inverted seed like that of the living genus Podocarpus.

Indophyllum sahnii, *I. raoi* and *I. nipanica* (Vishnu-Mittre, 1959) are some more sterile shoots found in the Rajmahal flora and which no doubt belong to the Podocarpaceae. *I. nipanica* is specially interesting as it shows attached microstrobili whose sporangia contain two-winged microspores like those of the Podocarpaceae.

In the matrix of the Rajmahal cherts from Nipania occur scattered, a number of microspores. One of them with three inflated wings grouped on the ventral side, has been designated *Podosporites tripakshi* (Rao, 1943a) as they are quite comparable to the microspores of living Podocarpaceous genera like *Microcachrys*, *Phaerosphaera* and *Podocarpus dacrydioides*. Similarly some of the two-winged microspores scattered in the matrix and known as *Pityosporites nipanica* Rao and *Pityosporites* sp. (Rao, 1943a) may also belong to the Podocarpaceae.

Masculostrobus rajmahalensis (Rao, 1943a) is a part of a male cone bearing microsporophyllus inside one of which were found three-winged microspores. This cone according to Vishnu-Mittre (1959) may be the microstrobilus of *Nipanioruha granthia* which on the basis of its foliage and cone characters has been assigned to the Podocarpaceae. *Masculostrobus sahnii* and *M. podocarpoides* (Vishnu-Mittre, 1959) are two other microstrobili which may be referred to this family of conifers. Recently Dr. M. N. Bose of this Institute and myself re-examined the above mentioned microstrobili and have in a recent paper thought it fit to transfer them to a new genus *Podostrobus* in view of their evident Podocarpaceous affinity. *Masculostrobus rajmahalensis* and *M. podocarpoides* have been merged into a single species *Podostrobus rajamahalensis* (Rao) Rao & Bose, while *M. sahnii* has been renamed *Podostrobus sahnii* (Vishnu-Mittre) Rao & Bose.

The list given below shows petrified woods and shoots of suspected Podocarpaceous affinity that have been found in the Rajmahal hills: *Mesembrioxylon indicum* Bharadwaj (1953), *M. rajmahalense* Jain (1965), *Circoporoxylon amarjolense*, *Coniferocaulon latisulcatum* Sah (1959) and *Retinosporites indica* (Old. & Morr.) Holden now known as *Pachypteris indica* (Bose & Roy, 1968). So far back as 1931 Professor Sahni (1931) assigning a Podocarpaceous affinity to some of these woods prophesied "undoubted Podocarpaceae may be discovered in the Mesozoic rocks of India". This prophecy has been more than fulfilled.

A solitary impression of *Stachyotaxus sampathkumarni* Rao (1964) with *Elatocladus conferta* like leaves found in the Rajmahal hills has been referred to the Podocarpaceae. The megastrobilus had distantly arranged megasporophylls each of which bore a single slightly tilted seed located in the spoon shaped distal end of the megasporophyll. *Strobilites sewardii* with *Elatocladus jabalpurensis* type of foliage was also regarded by Professor Sahni (1931) as Podocarpaceous. It is quite likely that the type described as *Beaniopsis rajmahalensis* by Ganju (1947) is really a *Stachyotaxus* which is essentially a Rhaetic genus.

I have laboured to draw attention to all these finds for they point out very clearly the rich Podocarpaceous vegetation that flourished in India during the Jurassic period. Incidentally it shows that this group of conifers is as old as the Jurassic or Rhaetic. As already discussed at length in an earlier paper (Rao, 1963) this conifer group though well represented in the Jurassic flora of India, is represented today by a single living genus *Podocarpus* which grows wild in some parts of penisular India, where it has also been found in a fossil state in Tertiary deposits as evidenced by a number of petrified woods. On the contrary Australia which was a Permo-Carboniferous neighbour of India shows Podocarpaceae in the present flora as well as in the Jurassic and Tertiary deposits according to the work of I. Cookson and her co-workers. The Podocarpaceous lifeline in Australia appears to be an unbroken one (Florin, 1940). The conifer flora of Antarctica, South America, New Zealand, and Tasmania show some Podocarpaceous remains in the Mesozoic although not to the same extent as those of India. The fact is that this family of conifers was widely spread over some parts of Gondwana land where it certainly evolved during the early Mesozoic. This Podocarpaceous flora continued to grow in the dismembered countries of Gondwana land till Tertiary and recent times. This was obviously due to the fact that all these Gondwana components still remained within the Southern hemisphere and continued to enjoy a temperate climate not different from the very one in which these conifers evolved. But with regard to India the story is different. When Gondwana land broke up into its components, peninsular India was perhaps the only land mass that moved into the northern hemisphere and naturally into a warm humid climate which was no longer favourable for the continued growth of the indigenous Podocarpaceous vegetation. This was, therefore, literally wiped out. But the genus *Podocarpus* had spread itself widely all over the Gondwana land by then and was perhaps in a position to migrate northwards and acclimatize itself to the northern hemisphere. This is the only way in which one can explain the occurrence of this essentially southern genus in a living state above the equator. The genus *Elatocladus* is represented by closely approximating forms in the Mesozoic flora of almost all the Gondwana components. It is not unlikely that *Elatocladus* is the precursor of *Podocarpus* which is the most successful in the Podocarpaceae not only from the point of view of evolution of different species but also from the point of view of distribution.

As pointed out elsewhere (Rao, 1963) the Indian Jurassic Podocarpaceae also throw light on the evolution of conifers. Discussing the living conifers of this family which are all confined to the southern hemisphere except the genus *Podocarpus*, Florin (1952) suggested that "the genus *Dacrydium* presumably developed in the Upper Mesozoic from some centre in the East Australian Antarctic region. *Acmopyle* appears to have spread from an original centre of distribution in the Indo-Australian region to Antractica and South America. *Phyllocladus* may also be looked upon as

a genuine southern genus. *Saxegothaea, Phaerosphaera* and *Microcachrys* are hardly known in the fossil state but there is no doubt of their southern origin". The *Dacrydium*-like aspect of some of the Rajmahal cones discussed above supports Florin's contention that this genus might indeed have evolved in the Indo-Australian region.

Bucholz and Gray (1948) were of the opinion that *Podocarpus* could have originated in the area from southern Japan, China, Nepal, and Sumatra to Australia including Tasmania and New Zealand and thence forwards to Fiji Islands and the Philippines. They concluded thus because this area includes seven out of eight sections into which this genus of sixty five species is divided. According to the fossil evidence also the region that is defined by Bucholz and Gray covers the area in which according to Florin the Podocarpaceae originated. Florin further maintained that the Permian onwards the conifers "divided into two groups one of which has its roots in the northern hemisphere and the other was markedly southern group". Judging by their present day distribution as well as their Mesozoic spread, this southern group is none other than the Podocarpaceae. They evolved during the Rhaetic and Jurassic periods in the southern hemisphere and spread themselves all over the Gondwana land. They continue to live in all their original homes still but disappeared from peninsular India as it drifted into the northern hemisphere. *Podocarpus* is the only surviving genus of the original Indian Mesozoic conifer family Podocarpaceae. It may be pointed out here that the various genera of conifers like *Pinus, Cedrus, Abies, Cephalotaxus* and *Cryptomeria* that now inhabit the Himalayan region are all northern genera that must have migrated south wards when the Tethys sea floor was elevated into the Himalayan ranges during the Pleistocene epoch, providing a hospitable climate for the growth of these conifers. This fact is supported by the absence of definite fossil evidence of any of the above genera in the pre-Pleistocene deposits of India.

Another conifer family represented in the Rajmahal flora is the Araucariaceae which again does not grow wild in India at the present time but is cultivated in Indian gardens. Petrified woods with Araucarian type of pitting are quite common in the Rajmahal Hills. It is not unlikely that many of them are really Araucarian. *Dadoxylon amraparense, D. mandroense* and *D. bindrabunense* (Sah and Jain, 1964) are examples. *Brachyphyllum florini, Pagiophyllum araucarioides* (Vishnu-Mittre, 1959) are other woods that might be Araucarian. *Dadoxylon agathioides* Kräusel and Jain (1964) is another petrified wood from the Rajmahals which bears close resemblance to the wood of the living genus *Agathis* — another member of the Araucariaceae. Araucarian cone scale impressions like *Araucarites cutchensis, A. macropterus* were described by Feistmantel (1876, 1877, 1879) and *A. nipaniensis*, a petrified cone scale was described by Singh (1957). An incomplete petrified cone belonging to the same species was described by Bose and Jain (1964a) from Amarjola in the Rajmahal Hills. A petrified megastrobilus with Araucarian affinity *Araucarites bindrabunensis* was also described by Vishnu-Mittre (1955a). The cone scales are comparable with those of the living *Araucaria bidwilli* or fossil *Araucaria mirabilis* (Speg.) Calder. Many species of *Brachyphyllum* have been compared to *Araucaria* and recently a petrified specimen of *Brachyphyllum* from the Rajmahal Hills showed in its stem region scalereids so characteristic of the living genus *Araucaria* (Menon, Malaviya and Rao, 1965). These facts point out that the Araucariaceae were coexistent with the Podocarpaceae in the Rajmahal

flora—although not quite so numerous. The Araucariaceae though present in the Jurassic flora of India are totally absent from the modern Indian flora except under cultivation. This discrepancy in their distribution is also significant.

Another group of conifers which seem to be represented in the Rajmahal flora judging by wood anatomy only are the Taxales. Characters peculiar to this family of conifers are exhibited by petrified wood designated *Taxaceoxylon* sp. cf. *rajamahalense* (Bharadwaj) Kräusel and Jain (1964), *Torreyites constricta* (Feist.) Seward and Sahni (1920) and *Torreyites sitholeyi* Ganju (1946), *Taxites lanceolata* and *Taxoxylon rajmahalense* Bharadwaj (1952)— all from Rajmahals. This shows that the Taxales were also coexistent with the Podocarpaceae and Araucariaceae in the Rajmahal flora. But this will have to be further confirmed by the discovery of definite Taxacean reproductive parts in the Rajmahal or other Indian Jurassic exposures.

Another very interesting and unique group of gymnosperms that seemed to be very conspicuous in the Rajmahal flora was the Pentoxyleae — a group of convenience erected by Professor Sahni (1948) for the reception of a number of interrelated genera, some of whom even showed organic connections with each other. The reconstruction of *Pentoxylon sahnii* Srivastava (1946) shows that it was a thin branched stem covered by scars of scale leaves. The stem was dimorphic — the long shoots traversed by five to six steles arranged in a ring with each stele showing exaggerated secondary growth on the inner side — a rather unique condition in gymnosperms. It has been found that the steles are not necessarily five in a number and that they may range from five to eight. The secondary wood which was pycnoxylic, with marked growth rings, showed in radial sections uni- or biseriate alternate of opposite bordered pits like those of conifers. The leaves now known as *Nipaniophyllum raoi* Sahni were borne on short shoots and displayed a generally cycadean anatomy although the epidermis and stomatal structures were more Bennettitalean. This plant bore cones known as *Carnoconites compactum* which were long and bore seeds compactly on a long axis, the micropylar part of each seed facing out wards, again a rather unusual feature in gymnosperms. The cones were placed at the ends of a branching system — the whole collection being an infructescene (Vishnu Mittre, 1953). The seeds had an inner stony and outer fleshy integument — the fleshy layers of adjacent seeds coalesced together and formed a fleshy pulp inside which the hard dorsoventral seeds were embedded. The male reproductive parts known as *Sahnia nipaniensis* Vishnu Mittre (1953) which according to him were filiform branched microsporophylls surrounded by deciduous bracts and which united at the base into a disc surrounding the broad conical receptacle. Recently discovered specimens show the above interpretation is not quite correct. The microsporophylls did not unite at the base. They were free and were disposed in a spiral phyllotaxis on the base of the receptacle. The sporangia contain boat shaped microspores or pollen. Vishnu-Mittre (1958) subsequently described several new anatomical details of vegetative parts of Pentoxyleae and emended the generic characters of *Nipaniophyllum*. Describing new specimens of *Pentoxylon sahnii* and *Nipaniophyllum raoi* from Amarjola, Sharma (1969) has made out some new points in their anatomy which rendered the stem comparable to the Triassic genus *Rhexoxylon*. He thinks that the fronds are more cycadean in nature.

Carnoconites laxum is another similar slightly thinner cone with more numerous seeds loosely arranged along an elongated axis. It is more likely that *C. laxum* is the petrified form of *Hattingeria* which is known only

as impressions. Associated with *Pentoxylon sahni* occurs *Nipanioxylon guptai* Srivastava (Sahni, 1948), another petrified stem which in cross sections shows a wide cortex and pith and a ring of eight vascular bundles each with equally well developed secondary growth all round. The metaxylem has scalariformly thickened tracheids while the secondary wood shows uniseriate, circular, contiguous boardered pits. The affinities of *N. guptai* are not clear nor are its reproductive structures clearly known.

The affinities of the Pentoxyleae are on the whole not clear. They represent a combination of Bennettitalean, Cycadean and Conifer characters. I do not agree with the view that the group is a very primitive member of the Cycadophyta as has been suggested. In fact the Pentoxyleae have not yet been fully examined. A more intensive as well as extensive study of the plant petrifactions in the Rajmahals may throw up better specimens which can spell out the affinities of this unique group.

Types representing the Pentoxyleae have not yet been reported from the Jurassic neighbours of India like Australia, South Africa, etc., although Harris (1962) has reported the occurrence of *Carnoconites — C. cranwelli* in the form of incrustations from New Zealand. He has also pointed out that the *Taeniopteris spathulata* type of leaves are quite common in these floras. Evidently *Taeniopteris spathulata* complex includes the foliage of different species of plants. Is this group to be ultimately interpreted as a "regional peculiarity" in the flora of a part of Gondwana land or is it that it has not yet come to light in the other Gondwana lands ? I think Indian students interested in the Jurassic botany must make a deliberate attempt to search for the Pentoxyleae in the above countries and examine their Jurassic floras critically.

The Pentoxyleae assume importance not only for their own unique characters but also because attempts have been made to derive the angiosperms from them (Meeuse, 1961). From a study of leaf cuticular features, Meeuse has suggested that the Pandanales may have been derived from the Pentoxyleae. This may not be so far fetched as may appear at first sight when we realize that there is a strong school of botanists who believe in the polyphyletic origin of the angiosperms. It might be recalled that the Caytoniales which were nearly mistaken for angiosperms and which do show some angiosperm characters, are Jurassic. The old monophyletic theory of the origin of angiosperms derived them also from a Jurassic group of gymnosperms — the Bennettitales. Consequently the Jurassic flora in general and the petrified Jurassic flora of India in particular is well worth a careful and critical study in our search for the origin of angiosperms.

Another group of gymnosperms which are well represented in the Rajmahal flora are the Bennettitales. This is not surprising as the Jurassic is essentially the age of fossil cycads. I will not catalogue the various species of Bennettitalean fronds described under the names *Ptilophyllum, Dictyozamites, Otozamites,* etc., several species of which have been described (see Rao, 1958). I will only refer to the more important ones among them. *Ptilophyllum* is an important upper Gondwana form genus — a large number of species of this have been recorded from the Rajmahals itself. It was in 1920 that Seward and Sahni instituted a comprehensive species *Ptilophyllum acutifolium* to include all detached leaves of the genus known from India. Sahni and Rao (1933) separated *Ptilophyllum cutchense* from *P. acutifolium* on the basis of cuticular features of the pinnae as seen in some Rajmahal specimens. These features were further confirmed by Ganju (1946) and Jacob and Jacob (1954). Some new species of this genus were also des-

cribed by Ganju (*loc. cit.*), Bose (1953), Jacob and Jacob (1954) and Vishnu-Mittre (1957). He also described the anatomy of *P. nipanica*. Bose (1953) studied the anatomy of *P. amarjolense* while Rao and Mrs. Achuthan (1968) studied the morphology and anatomy of a species of *Ptilophyllum* comparable to *P. cutchense*. *Ptilophyllum guptai* Sharma and *P. sparsifolium* Sharma are two species of petrified specimens studied by Sharma (1967). Meanwhile it has been found that the illustration of the original specimen of *P. cutchense* Morris as figured by Grant looks more like that of *P. acutifolium* and not at all like those which have all along been regarded as *P. cutchense*. It is indeed doubtful if the specific name *cutchense* has beer correctly applied after Morris. A very critical study based on cuticular features and correlated with anatomical characters if available, needs to be carried out to clear the confusion that now exists in the *Ptilophyllum* complex.

Associated with these *Ptilophyllum* leaves occur stems known as *Bucklandia* and flowers known as *Williamsonia*. Professor Sahni (1932) made it abundantly clear that *Bucklandia indica* was the stem and *Ptilophyllum cutchense* the foliage and *Williamsonia* the female flower of one and the same plant which is now known under a single name *Williamsonia sewardiana* Sahni. It is also suspected that the foliage known as *Ptilophyllum amarjolense* Bose (1953) was borne on stems known as *Bucklandia sahnii* (Bose 1953a). A dichotomously branched specimen of *Bucklandia* has been desciribed by Sharma (1969a) under the name *Bucklandia dichotoma*. The strange mixture of characters has induced him to compare it with the Bennettitales, Cycadeoidales and vesselless Magnoliales. Several new species of *Williamsonia* flowers have been described from the Rajmahal Hills like .*W gigas*, *W. indica*, Williamsonia sp., (Gupta, 1955) and *Williamsonia harrisiana* Bose (1968). *Williamsoinia santalensis* (Sitholey and Bose, 1953) is a male fructification with about twenty microsporophylls arranged in a whorl and each sporophyll bearing on its inner side two rows of spore producing appendages, although actual spores are not preserved. This is now known as *Weltrichia santalensis* (Bose, 1967). Ganju's (1947) *Ontheanthus polyandra* is another similar male flower. Describing a new species — *Williamsonia campanulatiformis* (Sharma, 1969b) has added to our knowledge of the male flowers of the Indian Bennettitales and the morphology of *Williamsonia santalensis* Sitholey and Bose. A well preserved *Williamsonia* from Amarjola comparable to *W. scotica* has been described by Sharma (1970). The bracts have been considered as pinnate leaves having pinnae in the form of vascularized appendages. Seminiferous and interseminal scales are regarded as morphologically dissimilar organs as their anatomy is different. The ovules are unintegumented and have long micropyles like the Gnetales. The correlation of various species of *Williamsonia*, *Bucklandia* and *Ptilophyllum* on the basis of morphological and anatomical characters is another problem that is awaiting a careful study. The petrified flowers from amongst these may have to be transferred to the genus *Bennetticarpus* or the genus *Williamsonia* was originally meant only for impressions of possibly Bennettitatean flowers.

A petrified wood from an unknown locality in the Rajmahal Hills showed anatomical and cuticular resemblances with some primitive dicotyledons like *Tetracentron*. In view of its homogenous wood devoid of vessels it was described as *Homoxylon rajmahalense* by Professor Sahni ((1932a). But subsequently investigations of more specimens of the same kind by Hsü and Bose showed that it is definitely Bennettitalean as was also suspected by Professor Sahni and K .M. Gupta. A new

generic name *Sahnioxylon* was proposed for this by Bose and Sah (1955) and a new species *S. andrewsi* has also been discovered in the Rajmahals.

While the Bennettitalean remains are abundant in the Rajmahal flora representatives of the Cycadophyta are not easily recognizable in the Cycadophytan complex of stems and leaves. *Fascivarioxylon mehtae* Jain (1964) is a petrified stem from the Rajmahal Hills whose morphology and anatomy show a close resemblance to living cycads — particularly *Stangeria*. One may recall here that in the Rajmahal flora there frequently occurs an impression of a pinnately compound leaf which was once referred to *Stangerites mcclellandi* O. & M., now known as *Morrisia mcclellandi* (Old. & Morr.) Bose (1959). Only petrified material of these when found can enlighten us further on the possible connection between these two.

Ontheodendron florini Sahni and Rao (1933) a badly preserved impression originally regarded as a strobilus possibly belonging to the Araucariaceae has been in view of better preserved specimens reinterpreted by Rao and Bose (1958) as a cydophytic stem and renamed as *Cycadophytites forini*.

Impressions of scale leaves found in the Rajmahal Hills and referred to the form genus *Cycadolepis* like *C. indica* Gupta (1955), *C. oldhami* (Feistmantel) Bose and Jain (1964), may belong to the Cycadales. The absence of a well preserved cuticle in the detached fronds makes it difficult to sort out definitely the Cycadalean leaves from those of the fossil cycads. Reproductive structures with a definite cycadean aspect or structure are not at all met with. This need not necessarily be interpreted as indicating their absence.

A group of Mesozoic plants which are rather conspicuous by their absence in the Rajmahal flora are the Caytoniales — although leaves like *Sagenopteris bambhani* Jacob and pollen like *Alisporites jurassicus* Rao, *A. auriculiformis* Rao (1943) from the Rajmahal Hills may well belong to the Caytoniales. But we have no other convincing proof. It is likely that Caytonialean remains are there but we may not have come across them yet. This shows how very essential a more thorough and intensive study of the Rajmahal flora is. *Thinnfeldia indica* (Fst.) and *T. chunakhalensis* (Sah and Sukhdev, 1958) represent the other Pteridosperm foliage in the Rajmahal flora.

The Ginkgoales were once thought to be absent in the Rajmahal flora. But Mehta and Sud (1953) reported genera like *Ginkgoites* and *Baiera* from two localities in the Rajmahal Hills. Sah (1953) also reported *Ginkgoites* like impressions from Sakrigalighat in the Rajmahals. Leaves with much divided lamina and forked once or twice and found in the Rajmahals have been described as *Ginkgoites rajmahalensis* Sah and Jain (1965). It thus appears that the Ginkgoales were also represented in the Rajmahal flora. This is not surprising as the Ginkgoales enjoyed a world wide distribution during the Mesozoic period.

The Pteridophytes are represented in the Rajmahal flora by a number of ferns and fern allies of very modern aspect. The Equisetales are represented by a slender species *Equisetites rajmahalensis* and a number of nodal diaphragms, both impressions. The Lycopodiales include shoot impressions like *Lycopodites gracilis* and the petrified *Lycoxylon indicum* Srivastava (1946) with an internal anatomy very similar to the modern *Lycopodium clavatum*. No reproductive parts have been found. So far back as 1943 Rao described some pteridophytic sporangia and spores like *Sporites maghadenses*, *S. naviculae* and others from the Nipania cherts. Many of them could be compared to the spores of *Lycopodium* and *Selaginella* while a few could not be

determined. Since then Vishnu-Mittre (1955), Bose and Sah (1968) and a few others have described a number of spores from the Rajmahal hills' silicified block. On the basis of these microfossils and other impressions known for a long time and a few petrifications that have been described in recent years the fern flora of the Rajmahals as far as we know them could be summarized in the table below. Those with an asterisk are petrifactions and the rest are impressions.

Osmundaceae:	*Todites indicus* (Old. & Morr.) Bose and Sah (1968) *Cladophlebis sahnii* Vishnu-Mittre and *Osmundites sahnii* Vishnu-Mittre (1956).
Schizaeaceae:	*Azonomonoletes Type I* (Spore) and frquently stem *Solenostelopteris nipanica* Vishnu-Mittre (1959a) *Solenostelopteris sahnii* Vishnu-Mittre, 1959a.
Cyatheaceae:	*Liratosporites* Type (Spores) I. Vishnu-Mittre (1959a).
Dicksoniaceae:	*Tinpaharia sinuosa* Jacob (1943, 1950) — rhizome.
Marattiaceae:	*Marattiopsis macrocarpa* (Old. and Morr.) Seward and Sahni.
Gleicheniaceae:	*Gleichenia gleichenoides*, *Gleichenia*-like petioles (Rao, 1948; Vishnu-Mittre, 1959a).
Matoniaceae:	*Phlebopteris* (*Lacopteris*) sp. Rao (1950) *Phlebopteris* sp. Bose & Sah (1968).
Dipteridaceae:	*Hausmannia crenata* (Nathorst) Möller (Bose and Sah, 1968)
Thyrsopterideae (?):	*Coniopteris hynenophylloides.*

Apart from the above there are a number of petrified petioles, rachii and rhizomes whose exact affinities cannot be traced accurately inspite of the anatomical data available (see Vishnu-Mittre, 1959a). A general perusal of the table will show how modern was the Rajmahal fern flora. This is as it should be for the Mesozoic vegetation was indeed modern quite in contrast to the Palaeozoic. Of special interest is *Thyrspopteris elegans* with its distribution restricted to only the Juan Fernandez Islands (where Robinson Crusoe was supposed to have been ship-wrecked) near South America. It was widely represented not only in the Rajmahal flora but also in the flora of some of its Gondwana neighbours by its extremely variable fossil counterpart *Coniopteris hymenophylloides*.

So far no fossil bryophytic remains have been found in the Rajmahal flora. Charophytic oospores (Vishnu-Mittre, 1952, Horn af Rantzien, 1957) belonging probably to the Nitelleae have been described from the Rajmahal hills. Fungal hyphae inhabiting the partly decayed seeds of *Nipaniostrobus sahnii* have been reported by Rao (1943).

I have given above a general analysis of the fossil flora of the Rajmahal Hills. I would like now to make some general observations on this flora, which was essentially a terrestrial one dominated by conifers and Bennettitales and ferns with a few fern allies associated with them. The Ginkgoales and the Pentoxyleae as well as the Pteridosperms and the Cycads were the other groups that formed a part of this flora.

We do not know much about the Mesozoic vegetation of the Gondwana constituents except Australia. There is the additional handicap that petrifactions have not come to light in these areas. Even so it is worthwhile for research workers to study in detail the Mesozoic micro- and megafossils of these lands and try to find out how much of correlation can be made between these fossil floras. In fact Professor Sahni's first palaeobotanical effort after his return to India in 1926 was to correlate the fossil floras of the southern hemisphere. We have not pursued this problem seriously after that although plenty of new material and facts have come to light. The late Professor T. G. Halle (1913) drew attention to the resemblances between the Indian Jurassic flora — particularly the flora of the Madras coast, known as the Kotah stage and the *in situ*

flora of Hope Bay in Grahamland. In 1953 I was able to show that the maximum resemblance rather lay between the Rajmahal flora and Hope Bay flora (Rao, 1953).

The age of the Rajmahals has been placed anywhere between the Liassic (Feistmantel, 1877) to the Cretaceous (Spath, 1933). Halle (1913), Sahni (1938) and Seward (1931) regarded it as of probably middle Jurassic age. As already pointed out by me elsewhere (Rao, 1953), many of the Rajmahal genera have their parallels in other Rhaetic floras. Du Toit (1927) too compared the Molteno flora of South Africa with the Rajmahal flora and suggested a Rhaetic age for the latter. The occurrence of well known Rhaetic types like *Stachyotaxus* and *Phlebopteris* in the Rajmahal flora leads me to think that this flora also may be of Rhaetic age.

There are several tantalizing elements in the Rajmahal flora. We have a number of *Brachyphyllum* and *Pagiophyllum* shoots at the same time several distinct types of conifer cones, which must belong to one or the other of these shoots. We have not been able to successfully show which cone belongs to which shoot. Fern rhizomes clubbed together under the name *Rhizomopteris* spp., and fern petioles occur scattered together in this flora along with various kinds of fern pinnae. They have to be pieced up together on the basis of morphological and anatomical resemblances. The *sporae dispersae* will have to be ascribed to their respective families by a careful scrutiny of their sporangial and annulus characters and spore architecture. But sorting out and correlation work like this can only be done after a careful and deep study of well preserved material obtained through a wide and intensive collection. This kind of reconstruction of a flora is not possible with a few sporadic Ph.D. theses based on fragmentary materials as is being done at present. Research has been more and more a means to an end rather than an end in itself. While no doubt valuable discoveries have been made in this process they have very often remained buried in these theses. It requires concentrated attention and careful study of a team of workers on a rich collection, unhampered by any imposition of time limit. Only an Institute like this can afford to pursue this kind of work. Palaeobotanical research must be more objective inspired only by the pursuit of academic problems which are of paramount interest to students of plant morphology and evolution.

The Rajmahal flora abounds in impressions and petrifactions. Since the days of Feistmantel we have been continuously adding to the genera and species. We have never paused to think how much of this was necessary or justified. New species have been found on insufficient material, badly preserved material and even on weathered specimens(!), just for the thrill of creating a new species: We have to overcome this temptation in future. Very few of us have turned our attention to the most important problem of correlating the impressions with the petrifactions. This should be the next phase of our study of this flora. A careful reexamination of the Rajmahal specimens and a critical revision of the Rajmahal flora is what is really indicated.

I have tried to cover in the brief time at may disposal a general survey of the Jurassic flora of the Rajmahal Hills. I shall be more than happy if it excites the curiosity of the listener and stimulates the interest of the student of Palaeobotany. The selected list of publications at the end will I hope be of some use to the worker on the Rajmahal floras. Many of the earlier references will be found in a publication issued by the Indian Botanical Society (Rao, 1958).

REFERENCES

BHARADWAJ, D. C. (1952). On a new species of *Taxoxylon* Unger from the Jurassic of Rajmahal Hills, Bihar, India. *Lloydia*, **16**: 234-240.

Idem (1953). Jurassic woods of the Rajmahal Hills, Bihar. *Palaeobotanist*, **2**: 59-70.

BOSE, M. N. (1953). *Ptilophyllum amarjolense* sp. nov., from the Rajmahal Hills, Bihar. *Proc. natn. Inst. Sci. India*, **19**: 605-612.

Idem (1953a). *Bucklandia sahnii* sp. nov. from the Jurassic of the Rajmahal Hills, Bihar. *Palaeobotanist*, **2**: 41-50.

Idem (1959). *Morrisia*, a new genus of Cycadophytic fronds from the Rajmahal Hills, Bihar. Ibid. **7** (i): 21-25, 1958.

Idem (1967). *Weltrichia singhii* n. sp. from the Rajmahal Hills, Bihar, *curr. Sci.*, **36** (2): 48-49.

Idem (1968). A new species of *Williamsonia* from the Rajmahal Hills, India. *J. Linn Soc.*, (Bot.), **61**: 121-127.

BOSE, M. N. & JAIN, K. P. (1964). *Cycadolepis saporta* from the Rajmahal Hills, Bhiar, India. *Palaeobotanist*, **12** (3): 224-225, 1963.

Idem (1964a). A megastrobilus belonging to the Araucariaceae from the Rajmahal Hills, Bihar, India. Ibid. **12** (3): 229-231, 1963.

BOSE, M. N. & ROY. S. K. (1968). On the Occurrence of *Pachypteris* in the Jabalpur Series of India. Ibid. **16** (1): 1-9, 1967.

BOSE, M. N. & SAH, S. C. D. (1955). On *Sahnioxylon rajmahalense* — a new name for *Homoxylon rajmahalense* Sahni and *S. andrewsii* — a new species of *Sahnioxylon* from Amarapara in the Rajmahal Hills, Bihar. Ibid. **3**: 1-8, 1954.

Idem (1968). Some pteriodophytic remains from the Rajmahal Hills, Bihar. Ibid. **16** (1): 12-28, 1968.

BUCHOLZ, T. & GRAY, M. E. (1948). A taxonomic revision of *Podocarpus*. I. The sections of the genus and their subdivisions with special reference to leaf anatomy. *J. Arnold Arbor.*, **29**: 49-63.

DU TOIT, A. L. (1927). The fossil flora of the upper Karro Beds. *Ann. S. Afr. Mujs.* **22**: 289-420.

FEISTMANTEL, O. (1876). Jurassic (Oolitic) flora of Kach. *Palaeont. indica*, **2**: (1) 1-80.

Idem (1877). Jurassic (Liassic) flora of the Rajmahal group in the Rajmahal Hills. Ibid. **1** (2): 53-162.

Idem (1879). Outliers on the Madras coast. Ibid. **1**(4): 191-224.

FLORIN, R. (1940). The tertiary fossil conifers of South Chile and their phytogeographical significance with a review of the fossil conifers of Southern lands. *K. svenska Vetensk. Akad. Handl.* **19**: 1-104.

Idem (1952). On two conifers from the Jurassic of South Eastern Australia. *Palaeobotanist*, Birbal Sahni *Memorial Volume*: 177-182.

GANJU, P. N. (1946). On a collection of Jurasssic plants from the Rajmahal Hills, Bihar. *J. Indian bot. soc.* (*M. O. P. Iyengar Commemoration Volume*): 51-85.

Idem (1947). *Beaniopsis rajmahalensis* gen. et. sp. nov., a new type of gymnosperm female fructification from the Rajmahal Hills, Bihar. *Proc. natn. Acad. Sci. India*, **25**: 95-104.

GUPTA, K. M. (1955). Notes on some Jurassic plants from the Rajmahal Hills, Bihar, India. *Palaeobotanist*, **3**: 18-25, 1954.

HALLE, T. G.(1913). The Mesozoic flora of Grahamland. *Wiss. FrgebnusseC* der Schwed. Sudpolar-Expedition. 1901-1903, **3** (14)

HARRIS, T. M. (1962). The occurrence of the fructification *Carnoconites* in New Zealand. *Trans. Soc.* N. Z. **88**: 17-27.

HORN AF RANTZIEN, H. (1957). Niteliaceous charophyte Gyrogonites in the Rajmahal series (Upper Gondwana) of India. *Stockh. Contr. Geol.* **1**: 1-29.

HSÜ, J. & BOSE, M. N. (1952). Further information on *Homoxylon rajmahalense* Sahni. *J. Indian bot. Soc.*, **31**: 1-12.

JACOB, K. (1943). *Tinpaharia* gen. nov., Palaeobotany in India, Ibid. 22: 175-176.

Idem (1950). The stele of *Tinpaharia*, a new genus of petrified Mesozoic ferns from the Rajmahal Hills, Bihar, India. *Proc. 7th Int. Natl. bot. Congress, Stockholm*, 564-565.

JACOB, K. & JACOB, C. (1954). Cuticular studies of Indian *Ptilophyllum* fronds from Kutch and Jabbalpore. *Palaeont. indica*,, 33: 1-33.

JAIN, K. P. (1964). *Fascivarioxylon mehtae* gen. et sp. nov., a new petrified cycadean wood from the Rajmahal Hills, Bihar, India, *Palaeobotanist*, **11** (3): 138-143, 1962.

Idem (1965). A new species of *Mesembrioxylon*, *M. rajmahalense* from the Rajmahal Hills, Bihar, India. Ibid. **13** (2): 153-154, 1964.

KRÄUSEL, R. & JAIN, K. P. (1964). New fossil coniferous woods from the Rajmahal Hills, Bihar, India. Ibid. **12** (1): 59-67, 1963.

MEEUSE, A. D. J. (1961). Pentoxylales and the origin of the Monocotyledons. *Proc. K. ned. Akad. Wet.*, **64**: 543-559.

MEHTA. K. R. & SUD, K. D. (1953). On some Ginkgoalean leaf impressions from the Rajmahal Hills. *Palaeobotanist*, **2**: 51-54.

MENON, K., MALAVIYA, M. & RAO, A. R. (1965). Notes on some fossil sclereids. *Curr. Sci.* **34**: 642-644.

RAO, A. R. (1943). *Nipaniostrobus sahnii* — a *Dacrydium*-like seed bearing plant from the Rajmahal Hills in Bihar. *Proc. natn. Acad. Sci.* India, **13**: 113-133.

Idem (1943a). Jurassic spores and sporangia from the Rajmahal Hills, Bihar. Ibid. **13**: 181-197.

Idem (1946). *Nipanioruha granthia* gen. et sp. nov. — a new petrified coniferous shoot from the Rajmahal Hills, Bihar. *J. Indian bot. Soc.* (*M.O.P. Iyengar Commemoration volume*): 389-397.

Idem (1948). Palaeobtoany in India, report (VI). Ibid. **26**: 253.

Idem (1949). The megastrobilus of *Nipanioruha granthia* Rao. *Curr. Sci.*, **18**: 447-448

Idem (1950). Two hitherto unreported plant fossils from the Rajmahal Hills of Bihar. Ibid. **19**: 378-80.

Idem (1953). Some observations on the Rajmahal flora. *Palaeobotanist*, **2**: 25-28.

Idem (1958). History of Botanical Researches in India, Burma and Ceylon. Part III. Palaeobotany. Indian Botanical Society, Madras.

Idem (1963). The Podocarpaceae in India. *Mem. Indian bot. Soc.*, **4**: 150-157.

Idem (1964). *Stachyotaxus sampathkumarani* sp. nov. from Onthea in the Rajmahal Hills, Bihar. Palaeobotanist, **12** (3): 217-219, 1963.

RAO, A. R. & ACHUTHAN, V. (1968). Further contribution to our knowledge of the anatomy of *Ptilophyllum*. *Palaeobotanist*. **16**: (3) 249-257, 1967.

RAO, A. R. & BOSE, M. N. (1959). Further observations on *Ontheodendron florini* Sahni and Rao. Ibid. **7** (1): 29-31, 1958.

SAH, S. C. D. (1953). On some species of *Ginkgoites* from the Jurassic of the Rajmahal Hills, Bihar. Ibid. **2**: 55-58.

Idem (1959). *Coniferocaulon latisulcatum* sp. nov. from the Rajmahal Hills, Bihar, with remarks on the affinities of the genus. Ibid. **6** (2): 71-76, 1957.

SAH, S. C. D. & JAIN, K. P. (1964). Some fossil woods from the Jurassic of Rajmahal Hills, Bihar, India. Ibid. **12** (2): 169-180, 1963.

Idem (1965). *Ginkgoites rajmahalensis* sp. nov. from the Rajmahal Hills, Bihar, India. Ibid. **13** (2): 155-157, 1964.

SAH S. C. D. & SUKH DEV (1958). *Thinnfeldia chunakhalensis* sp. nov., from the Jurassic of the Rajmahal Hills, Bihar. Ibid. **6** (1): 22-24, 1957.

SAHNI, B. (1931). Revisions of Indian fossil plants. II. Coniferales. (b. Petrifactions). *Palaeont. indica* (N.S.)' **11**: 51-124.

Idem (1932). A petrified *Williamsonia* (*W. sewardiana sp. nov.*) from the Rajmahal Hills, India. Ibid. (3): 1-19.

Idem (1932a). *Homoxylon rajmahalense* gen. et sp. nov., a fossil angiospermous wood, devoid of vessels, from the Rajmahal Hills, Bihar. Ibid. **20** (2): 1-19.

Idem (1938). Recent advances in Indian Palaeobotany. Presidential address, Botany section. *Proc.* 25th *Indian Sci. Congr.*: 138-176.

Idem (1948). The Pentoxyleae: A new group of Jurassic gymnosperms from the Rajmahal Hills of India. *Bot. Gaz.* **110:** 47-80.

SAHNI, B. & RAO, A. R. (1933). On some Jurassic plants from the Rajmahal Hills, Bihar. *J. Proc. Asiat. Soc. Beng.*, **27**: 183-208.

SEWARD, A. C. (1931). Plant Life through the Ages. Cambridge.

Seward, A. C. & SAHNI, B. (1920). Indian Gondwana Plants — A revision. *Palaeont. indica*, **7** (1): 1-41.

SHARMA B. D. 1967). Investigations on the Jurassic flora of Rajmahal Hills, India. 3. A review of the genus *Ptilophyllum* of Morris, with description of two new species from Amarjola in the Rajmahal Hills. *Palaeontographica*, B **120**: 139-150.

Idem (1969). On the Pentoxyleae remains from Amarjola in the Rajmahal Hills, India. *Ameghiniana*, **6**: 50-56.

Idem (1969a). *Bucklandia dichotoma* sp. nov. from the Middle Jurassic of Rajmahal Hills, India. *Revista de la Association Palaeontologica Argentina*, **6**: 303-308.

Idem (1969b). Further observations on *Williamsonia santalensis* Sitholey & Bose with the description of a new species. *Palaeontographica*, B **125**: 93-103.

Idem (1970). On the structure of a *Williamsonia* cf. *Williamsonia scotica* from the middle Jurassic rocks of the Rajmahal Hills, India. *Ann. Bot.*, **34**: 289-296.

SINGH, G. (1957). *Araucarites nipaniensis* sp. nov. — A female cone scale from the Rajmahal Series. *Palaeobotanist*, **5** (2): 64-65, 1956.

SITHOLEY, R. V. & BOSE, M. N. (1953) *Williamsonia santalensis* sp. nov. —a male fructification from the Rajmahal series, with remarks on the structure of *Ontheanthus polyandra* Ganju. Ibid. **2**: 29-39.

SPATH, E. (1933). Revision of Cephalopod faunas of Kach (Cutch). *Palaeontol. indica*, (N. S.), **9**:.

SRIVASTAVA, B. P. (1946). Silicified plant remains from the Rajmahal series of India. *Proc. natn. Acad. Sci. India*, **15**: 185-211.

VISHNU-MITTRE (1952). Charophyte remains from the Jurassic of the Rajmahal Hills, Bihar. *Curr. Sci.*, **21**: 41-42.

Idem (1953). A male flower of the Pentoxyleae with remarks on the structure of the female cones of the group. *Palaeobotanist*, **2**: 75-84.

Idem (1955). Petrified spores and pollen grains from the Jurassic rocks of the Rajmahal Hills, Bihar. Ibid. **3**: 117-127, 1954.

Idem (1955). *Araucarites bindrabunensis* sp. nov. — a petrified megastrobilus from the Jurassic of Rajmahal Hills, Bihar. Ibid. **3**: 103-108, 1954.

Idem (1956). *Osmundites sahnii* sp. nov., a new species of petrified Osmundaceous rhizomes from India. Ibid. **4**: 113-118, 1955.

Idem (1957). Studies on the fossil flora of Nipania, Rajmahal series, India — Bennettitales. Ibid. **5** (2): 95-99, 1956.

Idem (1958). Studies on the fossil flora of *Nipania* (Rajmahal Series) India — Pentoxyleae. Ibid. **6** (1): 31-46, 1957.

Idem (1959). Studies on the fossil flora of Nipania (Rajmahal Series), Bihar — Coniferales. Ibid. **6** (2) :89-112, 1957.

Idem (1959a). Studies on the fossil flora of Nipania, Rajmahal series, India — Pteridophyta and general observations on Nipania fossil flora. Ibid. **7** (1): 47-66, 1958.