SOME OBSERVATIONS ON THE RAJMAHAL FLORA*

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THIS interesting and classical flora has been the subject of wide and intensive study for the last twenty years and a number of papers has been published within the last ten years — since the last Gondwana Conference took place. It would, therefore, be not out of place here to review the more important results of this study and problems connected with it. I will here confine my observations to just three aspects of this flora.

COMPARISON BETWEEN THE RAJMAHAL FLORA AND HOPE BAY FLORA

So far back as 1913 Professor Halle in his monograph on the flora of Graham Land drew attention to the resemblances between the *in situ* flora of Hope Bay in Graham Land and the Indian Jurassic flora — particularly the flora of the Madras coast, known as the 'Kotah Stage'. Table I gives the Hope Bay genera (out of a flora of 61 species of plants) with identical species or closely comparable ones in the Rajmahal and the Kotah stages. When Professor Halle made this comparison, he found that there were six identical species between the Hope Bay flora and the Kotah stage. There were only four identical species in the Rajmahal flora and only four in the Jabalpur and Kachh stage also (not shown here). So he rightly observed that the maximum resemblance between the Hope Bay flora and the Indian Jurassic lay in the Kotah stage or Madras coast flora. Since then some more identical species, in addition to some closely comparable species, have been found in the Rajmahals (*see* HALLE, 1913; SEWARD & SAHNI, 1920; SAHNI, 1928, 1931; SAHNI & RAO, 1933, 1934; GANJU, 1946). The present position is that there are six identical species and seven closely comparable ones (*see* TABLE I). In view of the above great affinities it would, I think, be more accurate to say that the Hope Bay flora resembles more the Rajmahal flora than the Kotah or Madras coast flora. The Hope Bay flora is unique in that it shows some affinities with the Jurassic flora of England on the one side and with the Indian Jurassic flora on the other.

TABLE I

RAJMAHAL FLORA	HOPE BAY FLORA	MADRAS COAST FLORA (KOTAH STAGE)
Coniopteris lobata (Old.)	*Coniopteris lobata* (Old.)	
Pseudoctenis Medlicottiana (O. & M.)	*Pseudoctenis Medlicottiana* (O. & M.)	
Otozamites abbreviatus Fst.	*Otozamites abbreviatus* Fst.	*Otozamites abbreviatus* Fst.
Elatocladus conferta Halle	*Elatocladus conferta* Halle	*Elatocladus conferta* Halle
	Otozamites Hislopi (Old.)	*Otozamites Hislopi* (Old.)
	Araucarites cutchensis Fst.	*Araucarites cutchensis* Fst.
	Pagiophyllum Feistmanteli Halle	*Pagiophyllum Feistmanteli* Halle
Elatocladus jabalpurensis Fst.	*Elatocladus jabalpurensis* Fst.	*Elatocladus jabalpurensis* Halle
Coniopteris hymenophylloides (Brong.)	*Coniopteris hymenophylloides* (Brong.)	
	Closely comparable	
Equisetites rajmahalensis (Sch.)	*Equisetites approximatus* Nath.	
Thinnfeldia indica Fst.	*Thinnfeldia constricta* Halle	
Pterophyllum Morrissianum (Old.)	*Pseudoctenis ensiformis* Halle	
Pagiophyllum peregrinum (L. & H.)	*Pagiophyllum Heerianum* Sap.	
Cladophlebis indica (O. & M.)	*Cladotheca denticulata*	
Sphenopteris khairbanensis Ganju	*Sphenopteris Nordenskjoldii* Halle	
Sphenopteris rajmahalensis Sahni & Rao	*Sphenopteris Nauchkoffiana* Halle	

Professor Halle further drew attention to another similarity (though a negative feature) in the two floras, i.e. Hope Bay and Kotah, the absence of Ginkgoales and the rare occurrence of *Podozamites*. In the Rajmahals, however, *Podozamites* has since then been found frequently and the occurrence of Ginkgoalean leaves has also been recently reported (SAH, 1952).

* A paper read at the Symposium on the Stratigraphy of Gondwana Land, held under the auspices of the Palaeobotanical Society at the Birbal Sahni Institute of Palaeobotany, Lucknow, on 10 and 11 January 1952.

PODOCARPACEOUS PLANT REMAINS IN THE RAJMAHALS

In his monograph on the Coniferales of India, Professor Sahni (1931) listed all the fossil conifers according to their locality, horizon and natural affinities. Undoubted Podocarpineae are conspicuous by their absence in this list. Professor Sahni, however, mentioned the possible Podocarpaceous affinities of some woods like *Mesembrioxylon*, shoots like *Elatocladus jabalpurensis* Fst., *Elatocladus plana* (Fst.), *Elatocladus conferta* (O. & M.) Halle, *Retinosporites indica* (O. & M.) and reproductive organs like *Strobilites sewardi* (Sahni). These conifers have been reinvestigated by Professor Rudolf Florin who is an unrivalled authority on conifers living as well as extinct. From a study of the cuticular and epidermal features and stomatal structure and distribution he was able to place most of these definitely in the Podocarpaceae (FLORIN, 1940). Within the last ten years the following new Podocarpaceous fossils have also come to light in the Rajmahal Hills.

Nipaniostrobus Sahnii Rao (1943) is a petrified megastrobilus bearing single-seeded scales arranged in a lax spiral order over a slender axis. The slightly dorso-ventral ovules with two-layered non-fleshy integuments are partly buried inside the scale and have a characteristic ventrally curved micropyle like that of *Dacrydium laxifolium*. A possibly younger stage of this strobilus was represented by three other cones where seeds exactly like the above were found but in an erect posture. The mode of attachment and the nature of the scale were not at all clear in any of the above cones. Recently, however, there has been found a detached scale attached to which is an erect seed exactly like those of *N. Sahnii*. This clearly demonstrates that in all probability the seeds in *N. Sahnii* were erect at first but later on turned round to become inverted — a phenomenon commonly observed in many of the Podocarpineae, e.g. *Dacrydium* itself. This feature, the strongly curved micropyle and the epimatium-like flap of tissue above the posterior part of the ovule are definitely Podocarpinean characters.

A petrified coniferous shoot with spirally arranged needle-like decurrent leaves and intercalary swellings was described under the name *Nipanioruha granthia* Rao (1947). The wood is pycnoxylic with uniseriate bordered pits and the needles have a single central vascular bundle underlain by a secretory canal. These characters along with the total absence of secretory canals in the wood and the absence of special leaf-bearing shoots narrowed down the comparison of *N. granthia* to the Podocarpineae or Cupressineae. Recently another petrified megastrobilus (RAO, 1949) closely resembling *Nipaniostrobus Sahnii* was found in a thin rock section from Nipania. The cone is more compact and bears a number of single-seeded scales. The thick and possibly fleshy peduncle of the cone bears in addition two leaves, one on each side remarkably like the decurrent needle-like leaves of *Nipanioruha granthia*. This important organic connection proves that the cone really belonged to *Nipanioruha granthia*. Incidentally, it also shows that the cone of *Nipanioruha granthia* resembled *Nipaniostrobus Sahnii* and was also similarly Podocarpinean.

In these silicified blocks from Nipania there occur scattered in the matrix some small three-winged microspores described under the name *Podosporites tripakshi* Rao (1943). These microspores measure 30·5 μ long by 14·75 μ broad and have a granular wall which is specially thick on the dorsal side of the spore where the body bulges into a hemispherical form. The three inflated wings or bladders are grouped on the ventral side and have reticulate markings. These microspores are remarkably like those of *Microcachrys* and can also be compared to those of *Pherosphaera* and *Podocarpus dacrydioides*. Therefore, a Podocarpaceous affinity has been definitely assigned to these microspores. The two-winged pollen grains, belonging to *Masculostrobus rajmahalensis* (RAO, 1943) and *Pityosporites nipanica*, *Pityosporites* sp. (RAO, 1943), may also turn out to be Podocarpinean.

Recently a solitary specimen of *Stachyotaxus* with *Elatocladus conferta* type of leaves has been found in the Rajmahal Hills (RAO, 1950). *Stachyotaxus* is considered " as more nearly related to the Podocarpineae than to any other group of conifers ". The same opinion has been expressed by Professor Sahni about *Strobilites sewardi*, the fructifications of a plant whose foliage was *E. jabalpurensis*.

The above-listed plant remains show clearly that the Podocarpaceae were very well represented in the Rajmahal flora and besides extending the vertical range of the family fulfil a prophecy of Professor Sahni made more than thirty years ago that " undoubted

Podocarpineae may be discovered in the Mesozoic rocks of India ".

Professor Florin, after his exhaustive study of the conifers, living and extinct, from different lands, has arrived at some important conclusions. He (1940) thinks that there are no undoubted Podocarpaceae or Araucariaceae in the Palaeozoic. According to him from the Permian onwards " the conifers divided into two different groups, one of which had its roots in the northern hemisphere, while the other was a markedly southern hemisphere group ". This southern group was dominated by the Podocarpaceae. In fact it has been suggested by him that *Podocarpus* is definitely a southern genus. Since the Araucariaceae occur in the Mesozoic of both the northern and southern hemispheres it is difficult to say where exactly they originated, but it is obvious that they distributed themselves all over the Mesozoic lands. The presence of a large number of Podocarpaceae and Araucariaceae in the Rajmahals generally support the above conclusions of Professor Florin.

Professor Florin further thinks that the Jurassic vegetation was not quite so uniform as is generally described. Barring a few common types and the cosmopolitan Araucariaceae the Jurassic vegetation of Gondwanaland was quite distinct from that of the northern hemisphere. In spite of this Professor Florin thinks that interchange to some extent did take place between the conifer floras of the two hemispheres, Antarctica constituting an inter-continental bridge along which migration could take place. This probably explains why we find in the Hope Bay flora an equal mixture of southern as well as northern hemisphere types. But very few of the northern genera are supposed to have crossed the equator.

None of the recently described Rajmahal Podocarpaceous conifers have been reported from other Gondwana countries. Then there is the whole group of the Pentoxyleae (SAHNI, 1948) which include *Pentoxylon* — unique, five-steled dimorphic stems showing exaggerated secondary growth on the centripetal side of each stele, *Carnoconites* — equally unique cones the like of which are not found in any other group of plants and *Nipaniophylum* — leaves that incorporate in themselves the cuticular features of Bennettitales and the anatomy of Cycads.

The occurrence of the Podocarpaceae and Pentoxyleae in the Rajmahals may indeed support to some extent Professor Florin's view of the southern Gondwana vegetation being distinct from the northern Arcto-Carboniferous conifer vegetation. Of course, these plant remains, or closely comparable types, have not yet been found so far in the other Gondwana components. If they are found in course of time, they would only prove further the above views of Professor Florin. If, on the other hand, it is proved that they do not occur in any other Gondwana components except India, they would probably have to be interpreted as one of those " local peculiarities " of the southern vegetation. Seward (1931) and Halle (1913) did visualize the possibility of there being such regional peculiarities in the Jurassic vegetation.

GEOLOGICAL AGE OF THE RAJMAHAL FLORA

The age of the Rajmahals has been slightly disputed. It has been placed anywhere between the Liassic (FEISTMANTEL, 1877) to the Cretaceous (SPATH, 1933). The Cretaceous view is supported beside fossil Cephalopod evidence by just one fossil fern *Protocyathea* referred to the Cyatheaceae. But the Cyatheaceae existed probably from the middle part of the Mesozoic (JACOB, 1938) and there are well-known Jurassic types like *Cyathocaulis* and *Cibotiocaulis* (ARNOLD, 1947). *Protocyathea* has not been proved to be in any sense any kind of zone fossil and I feel that undue importance should not be attached to this single slender evidence. But

TABLE II

RAJMAHAL FLORA	OTHER RHAETIC FLORAS
Seed probably of *Nilssonia* (Sahni & Rao, 1933)	*Nilssonia incisoserrata* (Harris, 1932, East Greenland); *Nilssonia acuminata* (Gothan, 1921); *Nilssonia pterophylloides*, *Nilssonia brevis*, *Nilssonia polymorpha* (Nathorst, 1909)
Ontheodendron (*O. florini.*) (Sahni & Rao, 1933)	*Ontheodendron* (Harris, 1935, Scoresby Sound, East Greenland); *Laccopteris* sp. (Harris, 1926, 1937)
Laccopteris sp., *Stachyotaxus* sp. (Rao 1950)	*Stachyotaxus* spp. (Harris, 1935, Greenland); *St. septentrionalis*, *St. elegans* Nathorst, 1908

for this I think it is generally agreed that the Rajmahals represent a definitely Jurassic age — probably middle Jurassic (HALLE, 1913 ; SAHNI, 1938 ; GANJU, 1946) or even Rhaetic (SEWARD, 1931). In this connection the fact that several Rajmahal genera, which have come to light in recent years, have their parallels in other Rhaetic floras, may not be without significance (*see* TABLE II).

These well-known Rhaetic genera occurring in the Rajmahals shift the age of these beds far away from the Cretaceous towards the Liassic, to an even younger age as was suggested once by Professor Halle himself (1913), or even to the Rhaetic as was suggested by Du Toit (1927) after his comparison of the Molteno flora of South Africa with the Rajmahal flora.

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