JOURNAL OF THE PALAEONTOLOGICAL SOCIETY OF INDIA
VOL. 16, 1971, pp. 27 — 34.

JURASSIC PLANTS FROM AMARJOLA IN THE RAJMAHAL HILLS,

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ABSTRACT—Description is given of a number of species of ferns, *Thinnfeldia* and *Anomozamites*, collected from Amarjola in the Rajmahal Hills, Bihar. Some of these are new while others have been described for the first time from this locality. An attempt has also been made to discuss the age of the Amarjola beds on the basis of palaeobotanical evidence.

INTRODUCTION

Amarjola is situated about two miles North-East of the village Amarapara in the Rajmahal Hills, Bihar. This locality is famous since long for the occurrence of petrified material of Bennettitales, Conifers, Cycads and Pentoxyleae(Hsu and Bose 1952, Sharma 1969). Recently the authors were able to collect for the first time also leaves of Ferns, Thinnfeldias and *Anomozamites*, descriptions of which have been given in the present paper. The specimens are preserved in fragile condition in the characteristic dark brown, soft, sandy rock of Amarjola. Epidermal characters are poorly preserved except in *Anomozamites amarjolense* sp. nov. in which the peels were taken out by applying an adhesive known as'quickfix', stained with safranin and mounted in canada-balsam.

DESCRIPTION

Sphenopteris

(Text fig. 7)

The present specimen resembles in external morphology the Palaeozoic frond *Sphenopteris* sp. described and figured by Dr. Surange in his monograph 'Indian fossil Pteridophytes' (Surange 1966, p. 60, fig. 32b).

Cladophlebis indica (O. and M.) Sahni and Rao

Text fig. 9

The present material resembles in size, venation and other morphological features the frond of *Cladophlebis indica* described by Sahni and Rao (1931) and Surange (1966, fig. 52) from the Rajmahal Hills, Bihar.

Pecopteris sp.

Text fig. 4

In the nature of venation, the present specimen resembles *Pecopteris reversa* of Feistmantel (1879, P. 15, Pl. I, fig.5, Pl. II, figs.1,2 and 7), but unlike the latter, reverse arrangement of pinnules has not been seen in our material.

Stangerites ensis

Text fig. 8

Both in external morphological characters and in the nature of venation the present specimen resembles, the frond *Stangerites ensis* described by Oldham and Morris in their Fossil Flora of the Rajmahal Hills (1863, Pl. VI, figs. 8 and 9).

Thinnfeldia

Thinnfeldia amarjolense sp. nov.

Pl. 1. fig. 1, Text figs. 1, and 2

Diagnosis. Frond large, bipinnate; pinnae linear, length unknown, breadth 8—10 mm ; pinnules thick, papillate, rounded with entire or slightly wavy margins, 4 x 6 mm. in size, attached on the upper surface of rachis by entire bases. Upper basal angle round, lower decurrent. Pinnae opposite or sub-opposite, close or imbricate; lower margin of upper pinna covers the upper margin of lower pinna. Venation alethopteroid with a number of curved, diverging veins in each pinnule.

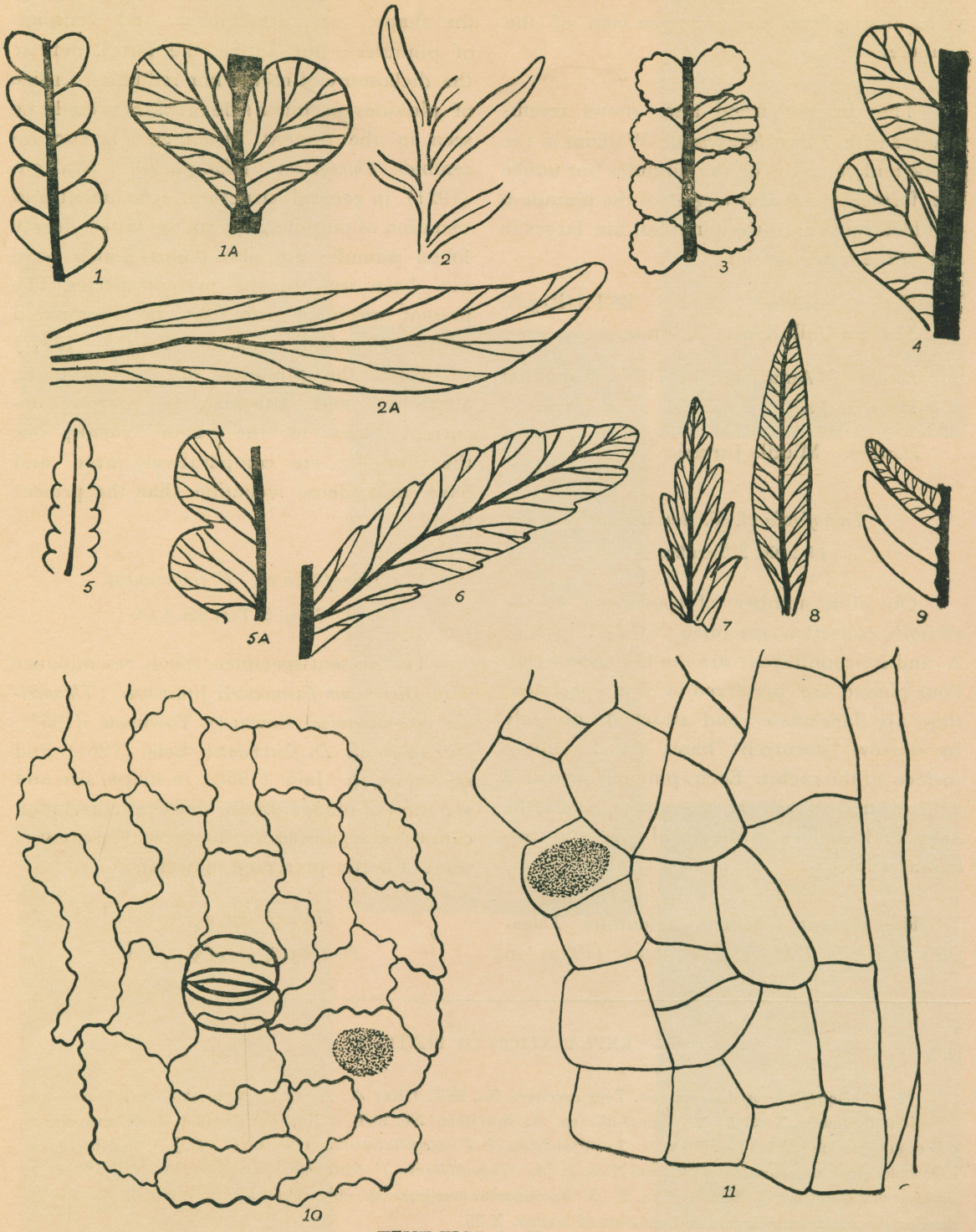
In the type specimen there are preserved two linear pinnae each having a number of small, rounded, thick pinnules on either side of midrib. On the lower surface of pinnules there are present irregularly scattered, raised papillae in between the veins. The pinnules are close, imbricated and attached on the upper surface of rachis by their decurrent bases. Three or four veins arise from the lower half of the pinnule base, and are curved, diverging and dichotomized. The uppermost of these veins is the strongest which gives 3—4 dichotomously divided veins on either side.

Comparison. In size and shape of the pinnules the present species resembles *Thinnfeldia odontopteriodes* (Morr.) Feist., *T. lancifolia* (Morr.) Walkom and *T. feistmanteli* Johnston, but differs in the absence of dichotomy of the rachis. In the latter forms, all the veins of the pinnules arise directly from the rachis of pinna whereas, in the present species only lower few veins arise directly from the rachis while the upper part of pinnule receives

EXPLANATION OF TEXT FIGURES 1—11

Figs. 1-9 showing shape, size, attachment and venation of pinnules.

1. *Thinnfeldia amarjolense* sp. nov. X 2. **1A.** Same. Two pinnae enlarged. X 6. **2.** *Thinnfeldia* sp. A. X 2. **2A.** Same : pinna enlarged. X 6. **3.** *Thinnfeldia* sp. B. X 6. **4.** *Pecopteris* sp. X 8. **5.** *Thinnfeldia* cf. *T. feistmanteli* X 2. **5A.** Same : Two lobes of pinna enlarged. X 6. **6.** *Thinnfeldia* cf. *T. lancifolia* X 6. **7.** *Sphenopteris* sp. X 1.5 **8.** *Stangerites ensis*. X 1.5. **9.** *Cladophlebis indica* X 15. **10.** *Anomozamites amarjolense* sp. nov. lower surface showing sinuous epidermal cells, papillae large, circular and present in few cells, stoma syndetocheilic, sunken and transversely oriented. X 300. **11.** Same : Upper surface showing polygonal, nonsinuous epidermal cells, papillae large, circular and only in few cells, stomata absent on this surface. X 300.



TEXT FIGS. 1—11

veins arising from the strongest vein of the pinnule.

The present frond also shows resemblances with *Thinnfeldia pinnata* Walkom in the shape and venation of the pinnules but unlike the former the basal angle of the pinnule is nondecurrent and the pinnules are larger in size in the latter species.

Type specimen No. BST.1/Raj.A. Sharma Coll., Univ. Jodhpur.

Locality. Amarjola in the Rajmahal Hills, India

Horizon. Middle Jurassic

Thinnfeldia cf. *T. lancifolia*

Pl. I, fig. 3, Text fig. 6

Out of a number of specimens in the author's collection, specimen No. BST. 3/Raj. A. and its counterpart are the best preserved. Four pinnae are preserved in this specimen, they are lanceolate and attached obtusely by narrow, decurrent bases on the upper surface of the rachis. Each pinna is provided with a midrib which does not reach the apex and divides in the distal part into two lateral veins.

The present specimen resembles *Thinnfelda lancifolia* (Morr.) Walkom (1925) in the shape, size, attachment and venation of pinnules ; but unlike the latter, neither the dichotomy of rachis nor reduction in size of pinnules on inner side of branch could be seen in the present specimen. It also resembles *Thinnfeldia talbragarensis* Walkom (1921) in general structure, attachment and venation of pinnules, but in the latter deeply lobed pinnules are also found which have not been seen in the present species. The present specimen can also be compared with *Thinnfeldia indica* Feist. (1877) in which the pinnules are lanceolate, alternate and attached by narrow, decurrent bases to the main rachis, but the pinnules are comparatively large and have more dense venation than the present frond.

Thinnfeldia cf. *T. feistmanteli*

Pl. 3, fig. 3, Text figs. 5 5A

The present specimen shows resemblance with *Dicroidium feistmanteli* Johnston (*Thinnfeldia odontopteroides* Seward) Townrow (1957), *Dicroidium* cf. *D. feistmanteli* Lele (1961) and *Dicroidium* sp. Jain (1968) in shape, size and venation of pinnae, but a definite correlation cannot be suggested for the present because of want of better preserved material.

Thinnfeldia sp. A

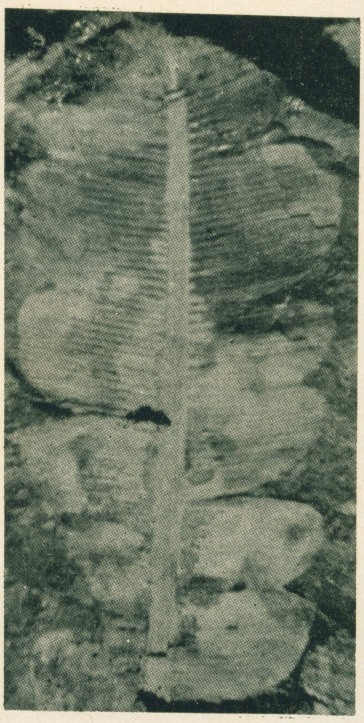
Pl. 3, fig. 2, Text figs. 2, 2 A

EXPLANATION OF PLATE—1

1. *Thinnfeldia amarjolense* sp. nov. Type specimen No. BST. 1/Raj. A. showing shape, size, attachment and venation of pinnules. X ca. 2. **2.** *Thinnfeldia* sp. A. Specimen No. BST. 5/Raj. A. showing shape, size, attachment and venation of pinnules. X ca. 2. **3.** *Thinnfeldia* cf. *T. lancifolia* Specimen No. BST. 3/Raj. A. showing shape, size, attachment and venation of pinnules X ca. 2. **4.** *Thinnfeldia* cf. *T feistmanteli* Specimen No. BST. 7/Raj. A. showing shape and size of pinnule. X ca. 2. **5.** *Anomozamites amarjolense* sp. nov. Type specimen No. BS A.1/Raj. A, showing shape, size, attachment and venation of lamina. X 25.

1

2



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The present specimen resembles *Thinnfeldia* cf. *T. lancifolia* described above in shape, attachment and venation of pinnae, but in the former the pinnae are comparatively narrow with entire margins ; median vein is indistinct and the lateral veins are few, arising at more acute angles, while in the latter the margins are lobed, midrib is distinct and lateral veins are many showing frequent dichotomies.

Comparison can also be made of the present species with some allied species of *Thinnfeldia* like *T. indica* Feist. *T. lancifolia* (Morr.) Walkom, but the former differs from all in the characteristic attachment and nature of venation of the pinnae.

Thinnfeldia sp. B

Text fig. 3

In size and venation the present frond shows resemblances with *Thinnfeldia subtrigona* Feist. (Feistmantel 1879, p. 13, Pl. I. fig. 7), but in the latter the pinnules are more or less, triangular while in the former they are rounded.

Anomozamites Schimper.

The genus was established by Schimper (1871-72) for some *Pterophyllum*-like fronds. He transferred several of the *Pterophyllum* species from India to *Anomozamites*, for example *Anomozamites* (*Pterophyllum*) *princeps* (O. and M.) Schimp., *Anomozamites* (*Pterophyllum*) *medlicottiana* (Morr.) Schimp., etc. (Schimper 1871-72). Feistmantel (1877) retransferred these fronds to *Pterophyllum* Brongn. However, he (1879) recognized three species of *Anomozamites* from India, two of which were new and the third resembled *Anomozamites lindleyianeous* Schimp. Seward (1895) emended the diagnosis of *Anomozamites* as follows "Frond comparatively small, linear or tongue shaped and usually divided into segments which present a more or less obvious difference in size, separate or confluent at the base, attached laterally to the rachis and never entirely covering the upper surface of frond axis, the frond bluntly rounded or truncate distally ; veins simple and parallel, generally at right angles to the rachis." Harris (1926, 1932) found several dissmilarities between *Anomozamites* and *Pterophyllum*. In *Pterophyllum* the pinnae are long, equal with acute, obtuse or round apices; in *Anomozamites* the pinnae are broad, unequal and with truncate apices. In *Pterophyllum* the epidermal cells have nonsinuous walls and the stomata are oriented transversely to the veins whereas in *Anomozamites* the epidermal cells are sinuous walled and the stomata are irregularly oriented.

Seward and Sahni (1920) merged the Indian *Anomozamites* into the genus *Nilssonia* Brongn., for example *Nilssonia* (*Anomozamites*) *fissa* (Feist.) Seward and Sahni. The latter species is an *Anomozamites* and should be named *Anomozamites fissa* Sharma, (Sharma 1969). As already shown by Seward and Sahni *Anomozamites jungene* Feist. and *A. lindleyianeous* Schimp. into *A. fissa* Feist. are not very different from the latter.

The specimen described here is preserved in a petrified state on counter parts. The epidermal structure was examined by reflected light and with the help of 'Quickfix' (a cellulose acetate solution) peels. The peels were

stained with safranin and mounted in canada balsam.

Anomozamites amarjolense sp. nov.

Pl. 1, 5, Text figs. 10 and 11

Diagnosis. Frond small, measuring 7 X 1.7 cm., simple or partially pinnate. Pinnae broad, unequal, 1–1.7 X 0.4–0.8 cm; bifid, with lower free corner round and upper more angular ; apex obtusely truncate. Pinnae bases continuous ; pinnae attached by entire bases at right angles to the sides of rachis ; rachis is longitudinally striated and one mm thick. Lamina in the distal part entire, gradually reducing to form an obtusely rounded apex. Veins parallel. 18–20 per cm, arising at right angles to the rachis; frequently branched, sometimes anastomosing.

Intercostal cells of upper epidermis squarish or polygonal, with straight or slightly wavy anticlinal ; papillae rare, large. Costal cells large, elongate, nonsinuous, nonpapillate. Stomata are absent on upper surface. Intercostal cells of lower surface irregular, sinuous walled, sometimes papillate. Costal cells more or less rectangular, sinuous walled, nonpapillate. Stomata sunken, syndetocheilic, scattered sparsely.

The specimen (in two counterparts) represents only the upper part of the frond but is well preserved (Pl. 1, fig. 5). The lamina appears to be thick, leathery attached to the sides of a prominent rachis. The characteristic transverse folds found on the rachis of a number of species of *Anomozamites* (Harris 1932) are absent in the present frond. The veins are closely placed and parallel with frequent branching. There are 13—14 dichotomies per cm. Vein connections like the one found in *Nilsonia princeps* (0. and M.) Seward and Sahni (1920) are present.

The upper and lower epidermal surfaces of the leaf are different and stomata are confined to the lower surface (Text Figs. 10 and 11).

Comparison. The specimen shows resemblances with *Anomozamites major* (Brongn.) Nath. (Harris 1926) in structure and venation of the pinnae. In both, the lower free corner of pinna is round and the upper is more angular. The veins are 18-20 per cm and arise at right angles to the rachis and the rachis is devoid of transverse wrinklings which are found in many other species of *Anomozamites*. However, the present specimen differs from *A. mojar* in the presence of bifid apices of pinnae and their close attachment on rachis. In the present specimen the veins do not curve upwards as they approach the margin, are frequently branched and show vein connections. These characters have not been observed in *Anomozamites major*. Our specimen differs from *Anomazamites minor* (Brongn) Nath. in morphological characters and cuticular structures. *A. minor* has numerous papillate epidermal cells (Harris 1932), while such cells are rare in the Rajmahal fossil. The new species resembles *A. andrupiana* Harris (1932) in general structure, size of the frond and in the absence of transverse wrinklings on the rachis. But the leaf apex in the two species differs ; the leaf in *A. andrupiana* terminates in a small, narrow, acute pinna, while in the present specimen the lamina is entire and ends in an obtusely round apex.

Type specimen No. BS. A1/Raj. A. Sharma Coll., Univ. of Jodhpur.

Locality. Amarjola in the Rajmahal Hills, India.

Horizon. Middle Jurassic.

DISCUSSION

Rajmahal Hills, Bihar are generally regarded as Middle Jurassic (Sahni 1932, Rao 1953, Sitholey 1954), but Bose (1966) has considered them to be little younger and assigned an Upper Jurassic age. On the basis of present study it seems that atleast the fossilferous locality of Amarjola is not younger than Middle Jurassic as it possesses an assemblage of fossil plants which are found mainly in the Triassic or early Jurassic rocks, for example Thinnfeldias. This view is further strengthened when the vegetation of Amarjola is compared with Talbargar Beds of New South Wales (Walkom, 1921), Ipswich Series of Queensland (Walkom, 1916) and Stromberg Beds of South Africa (Seward and Holttum, 1921) which are either Upper Triassic or Middle Jurassic.

ACKNOWLEDGEMENTS

The authors are thankful to Prof. K. M. Gupta for providing the necessary laboratory facilities and to Mr. P. R. Panwar for his assistance in photographic work.

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