

Addition to the knowledge of megafloal diversity from the Rajmahal Formation

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ABSTRACT

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Specimens of *Equisetites rajmahalensis*, *Marattiopsis macrocarpa* and *Cladophlebis salicifolia* collected from Bindaban and Chunakhali areas and their previous records of Rajmahal Formation have been investigated to determine their specific circumscription. In addition, pinnately compound leaf, bearing ovate-orbicular pinnae with reticulate venation is described for the first time from the formation.

Key-words—*Equisetites rajmahalensis*, *Marattiopsis macrocarpa*, *Cladophlebis salicifolia*, Leaf type-1, Rajmahal Formation, Lower Cretaceous.

राजमहल शैलसमूह से प्राप्त गुरुवनस्पति विविधता के ज्ञान में वृद्धि
पंकज के. पाल, एम.बी. एरेफिन एवं मौमिता बासु

सारांश

बिन्दाबन एवं चूनाखली क्षेत्रों से एकत्रित इक्वीसेटाइटिस राजमहलेन्सिस, मेराटिओप्सिस मेक्रोकार्पा एवं क्लेडोफ्लेबिज़ सेलिसीफिलिया नमूने तथा राजमहल शैलसमूह के उनके पिछले अभिलेखों का उनके विशिष्ट परिलेख को निर्धारित करने हेतु अनुसंधान किया गया है। इसके साथ ही जालीदार शिराविन्यासयुक्त अंडाकार गोल पंखधारी पत्ती को इस शैलसमूह से प्रथम बार वर्णित किया गया है।

संकेत-शब्द—इक्वीसेटाइटिस राजमहलेन्सिस, मेराटिओप्सिस मेक्रोकार्पा, क्लेडोफ्लेबिज़ सेलिसीफिलिया, पत्ती टाईप-1, राजमहल शैलसमूह, निम्न क्रीटेशस।

INTRODUCTION

The flora known from the Rajmahal Formation represents one of the most diversified Upper Mesozoic floras of the world, comprising mainly cycadophytes, ferns, conifers and *Pentoxylon* in association with lycopsids, sphenopsids, pteridosperms,

ginkgophytes and a few *incertae sedis*. Since McClelland (1850) described for the first time a few plant remains from the formation, significant contributions to the palaeofloristics of this horizon have been made from time to time by a number of workers (Lakhanpal *et al.*, 1976; Chandra & Tewari, 1991).

During the investigation of megafloral succession through the successive intertrappean beds of Rajmahal Formation, the present authors have recorded some specimens which either provided additional knowledge to previously known forms or constitute new report from the formation. Accordingly, circumscriptions of *Equisetites rajmahalensis* Oldham & Morris, *Marattiopsis macrocarpa* (Oldham & Morris) Seward & Sahni and *Cladophlebis salicifolia* (Morris) comb. nov. have been revised and single specimen of compound leaf is also described.

MATERIAL AND METHODS

The present work is based on a good number of specimens collected from Balbhadri Hili, Bindaban and

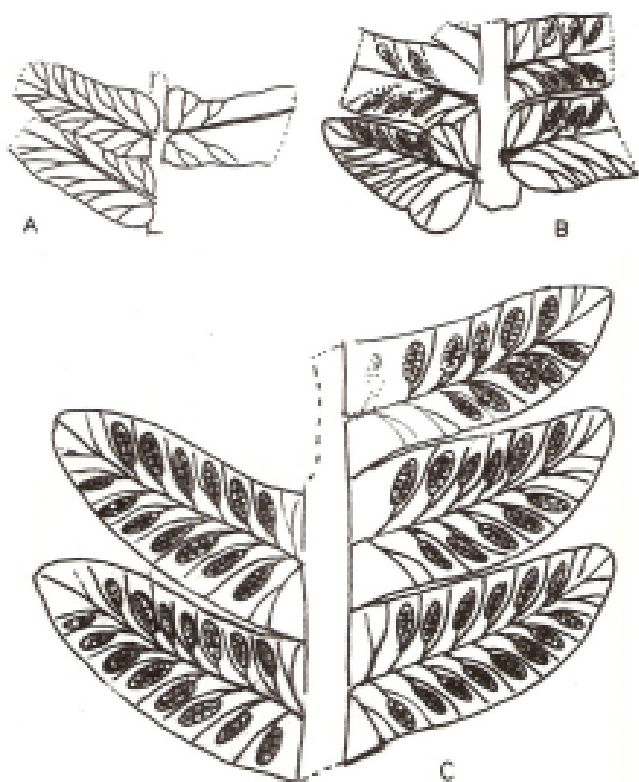


Fig. 1—A-C, *Marattiopsis macrocarpa* (Oldham & Morris) Seward & Sahni. A, Sterile frond, Specimen No. 12/4, x 2. B, Fertile frond abaxially preserved showing the attachment and base of pinnules, Specimen No. 35/4, x 2.5. C, Fertile frond adaxially preserved, Specimen No. 69/4, x 4.

Chunakhali localities of the Rajmahal Formation. Some specimens described by previous workers have also been studied. The specimens are preserved as impressions or as moulds. Buried parts of some specimens were degaged when required. Observations were made under Leica, Wild M3B, Stereobinocular microscope using strong incident light. Figured specimens are deposited in the repository of the Palaeobotany and Palynology Section, Botany Department, Burdwan University.

SYSTEMATICS

PTERIDOPHYTA

SPHENOPSIDA

EQUISETALES

EQUISETACEAE

Genus—*Equisetites* Sternberg 1833

Specimens resembling modern *Equisetum*, collected from the Rajmahal Formation, were originally described as *Equisetites rajmahalensis* by Oldham & Morris (1863). The generic name *Equisetites* was instituted by Sternberg (1833) for fossils comparable with modern *Equisetum* Linnaeus. Subsequent workers (Harris, 1961; Gould, 1968) opined that as no morphological difference is found between *Equisetum* and *Equisetites*, the fossils should be described under the generic name *Equisetum*. This view was followed by later workers and accordingly the Indian material was described as *Equisetum rajmahalense* (Bose & Sah, 1968; Sengupta, 1988). However, Sen and Sen (1973) proposed that *Equisetum* sensu Linnaeus comprises two distinct genera *Equisetum sensu stricto* and *Hippochaetae* Milde 1865. The idea was first conceived by Milde (1865) and subsequently substantiated by Campbell (1928), Rothmaler (1944), Manton (1950) and finally by Sen and Sen (1973). Rothmaler (1944) pointed out that though many interspecific hybrids occur within each of the two genera of the modern equisetaceae (*Equisetum sensu stricto*

and the *Hippochaetae* Milde) yet intergroup hybrids are totally absent. Sen and Sen's (1973) conclusion is based on morphological, anatomical, embryological, cytological and physiological differences. The generic status of *Hippochaetae* has also been corroborated by DNA homological data of *Equisetum sensu stricto* and *Hippochaetae* Milde (Sadhukhan, 1975).

Because it is difficult to assign a fossil specimen (particularly that preserved as an impression or a cast or a mold) to any of the two extant genera of Equisetaceae, therefore the comprehensive generic name *Equisetites* Sternberg has been preferred to describe the Indian material.

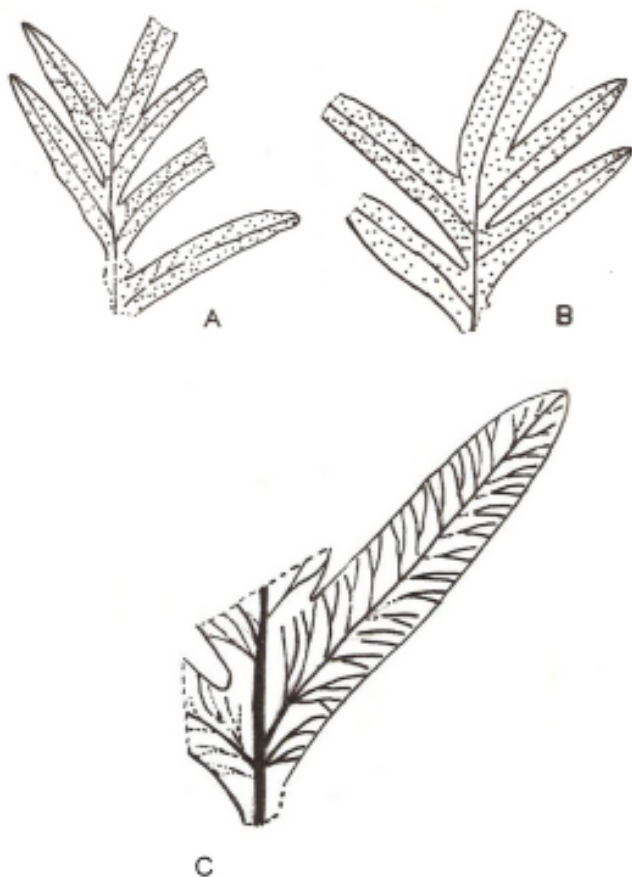


Fig. 2—A-C *Cladophlebis salicifolia* (Morris) comb. nov. A, Holotype (redrawn from Oldham & Morris 1863, Pl. 26, fig. 2) x 1. B, Specimen No. 16700 of the Birbal Sahn Institute of Palaeobotany, Lucknow, x 1. C, Part of specimen in fig. B magnified. x 2.5.

Equisetites rajmahalensis Oldham & Morris

Pl. 1.1-3

- 1863 *Equisetites rajmahalensis* Oldham & Morris, pl. 2, figs 2-5, pl. 35, figs 3, 4.
 1869 *Equisetum rajmahalense* Schimper p. 276.
 1877a *Equisetum rajmahalense* Schimper : Feistmantel, p.11.
 1933 *Equisetites rajmahalensis* Oldham & Morris : Sahni & Rao, p.188.
 1938 *Equisetites* sp. : Jacob, p. 152.
 1947 *Equisetites rajmahalensis* Oldham & Morris : Ganju, p. 56, pl. 1, fig. 1.
 1947 *Equisetites* sp. Oldham & Morris : Ganju, p. 57, pl. 1, fig. 2.
 1966 *Equisetites rajmahalensis* Oldham & Morris: Surange, p. 56, fig. 30A-B.
 1968 *Equisetum rajmahalense* (Oldham & Morris) Feistmantel : Bose & Sah p. 18, pl. 1, figs 1-6.
 1975 *Equisetites rajmahalensis* O. and M. : Sharma, p. 84, pl. 1, fig. 3.
 1982 *Equisetum rajmahalense* (Oldham & Morris) Feistmantel : Trivedi & Sukh-Dev, p. 335.
 1988 *Equisetum rajmahalense* (Oldham & Morris) Schimper : Sengupta, p. 50, pl. 3, figs 9, 10.

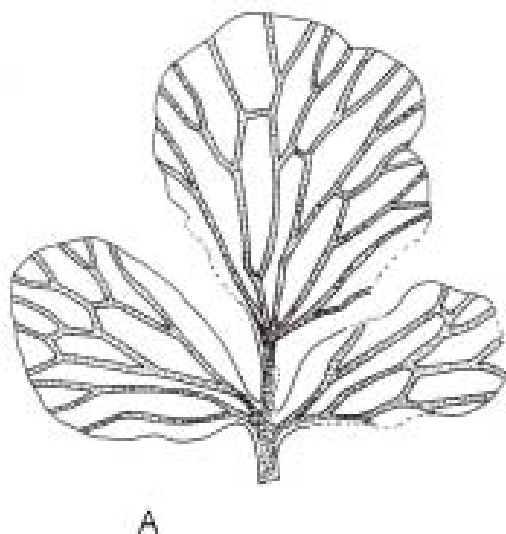


Fig. 3—A, Leaf Type - 1, Specimen No. 1/6, x 3.5.

Emended diagnosis—Rhizome horizontal, about 2.5 cm wide, obscurely marked with irregular longitudinal ridges and grooves; nodes not well marked but distinguished by small diaphragms (considered to be rotated); length of internodes about 7 cm; diaphragm 5 mm wide consisting of a rim about 1 mm wide with about 28 obscure tubercles, centre appearing sunken.

Aerial stem typically 4 cm wide; internodes up to 1.8 cm long but sometimes shorter; leaf sheath 1-1.5 cm long, composed of up to 30 segments (on whole sheath), segments consisting of leaf portions about 2 mm wide at base and tapering to 1.5 mm above where they are normally broken off, connected by sunken flanges which die away to a point below; leaf sheath segments marked by numerous stomatal pits; surface of internode smooth, not pitted (free leaves not observed, cones unknown).

Localities—Balbhadrhi Hill (*loc. typ.*), Bindaban, Chunakhali, Bartala, Borio, Sakrigalighat, Onthea, Chilgojhuri and Nipania.

Horizon & Age—Rajmahal Formation; Lower Cretaceous.

Lectotype—No. 4487 of the Geological Survey of India, Calcutta.

Discussion and Comparison – Present observations are based on a fresh collection of about a dozen of specimens collected from Balbhadrhi Hill (*loc. typ.*) and Bindaban localities of the Rajmahal Formation. Also, some specimens described by previous authors have been studied. *Equisetites rajmahalensis*, the only representative of Sphenopsida in the Indian Upper

Mesozoic, is rather uncommon in occurrence and not known in position of growth. The stems are preserved in the form of moulds of external surface. The commissural flanges are conspicuous, appearing as straight narrow ridges and the intervening leaf-segments spearing as sunken strips. The segments of the leaf-sheath are covered with numerous irregularly arranged tubercles representing the casts of stomatal pits. Thus, *Equisetites rajmahalensis* possessed sunken stomata and in this feature it resembles modern *Hippochaeta*. Bose and Sah (1968) mentioned a stem, 8 mm wide, no such stem is known to us. Trivedi and Sukh-Dev (1982) pointed out that pl. 1, figs 4, 6 of Bose and Sah (1968) be viewed upside down and therefore they furnished a fresh description of the leaf-sheath. While doing so the authors (Trivedi & Sukh-Dev, 1982) mentioned that the leaf teeth are short and pointed, overlooking that the free leaf teeth of *Equisetites rajmahalensis* are not known at all. In all the so far known specimens of *E. rajmahalensis*, including its selected lectotype, the leaves are always broken off which led us to believe that they probably diverge from the stem. The orientation of figure of Surange (1966, Fig. 30B) is correct, though Trivedi and Sukh-Dev (1982) erroneously mentioned that it should be viewed upside down.

Equisetites rajmahalensis is most similar to *E. columnare* Brongniart from English Middle Jurassic (Harris, 1961). But *E. columnare* has 50-60 leaf segments (though fewer on slender stem); its commissural furrows extend downward further. Its free

PLATE 1



- | | |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1-3. <i>Equisetites rajmahalensis</i> Oldham & Morris. | 4-5. <i>Marattiopsis macrocarpa</i> (Oldham & Morris) Seward & Sahni. |
| 1. Cast of aerial stem, with internodes and node bearing leaf-sheaths showing free-teeth broken off, collected from Balbhadrhi Hill (<i>loc. typ.</i>), Specimen No. 7/1. x 1. | 4. Bipinnate frond bearing synangiate fertile pinnules, Specimen No. 15/4. x 1. |
| 2. Aerial stem, part of stem figured by Bose & Sah, Specimen No. 16712 of the Birbal Sahni Institute of Palaeobotany. x 2. | 5. Part of a pinna exhibiting the upper surface of frond showing constricted pinnule-base with auricled acroscopic and basisopic basal margins, Specimen No. 35/4. x 4. |
| 3. Magnified view of part of leaf-sheath of an aerial stem preserved as mould of external surface, showing casts of stomatal pits appearing as small oval tubercles, Specimen No. 9/1. x 1.6. | 6-7. Leaf type-1. |
| | 6. Specimen No. 1/6. x 1. |
| | 7. Specimen in fig. 6 magnified showing details of venation. x 2. |

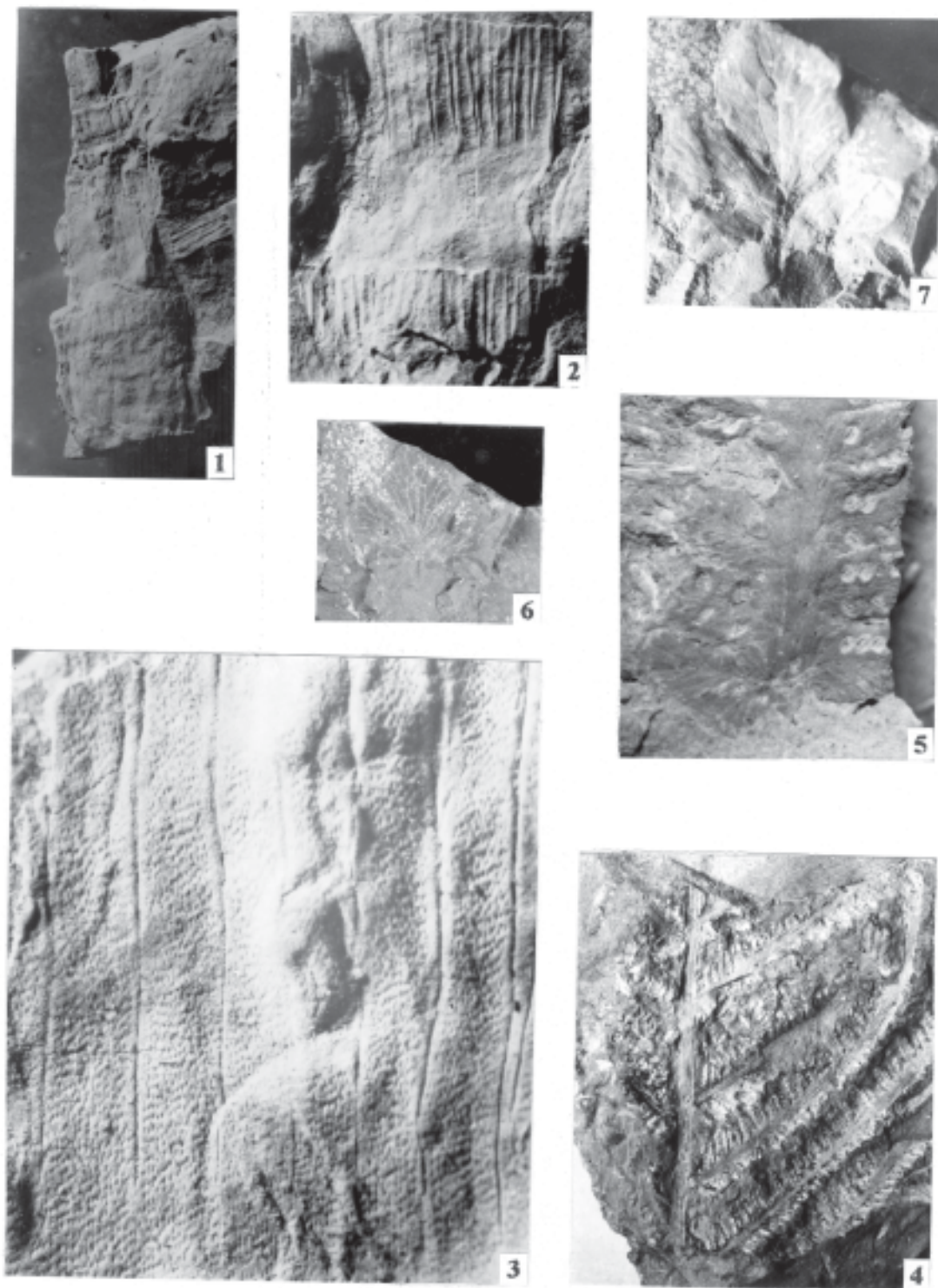


PLATE 1

leaves are also commonly broken off (because they diverge from the stem), but have been traced to an acute apex. Several features of *E. columnare* can not be compared because those are unknown in *E. rajmahalensis*. Feistmantel (1877a) made detailed comparison with *E. muensteri* Sternberg, a species, with much narrower stems, from European Rhaetic and Liassic.

FILICOPSIDA

MARATTIALES

MARATTIACEAE

Genus—*Marattiopsis* Schimper 1853

Marattiopsis macrocarpa (Oldham & Morris)
Seward & Sahni, 1920

Pl. 1.4, 5; Fig 1A-C

- 1863 *Pecopteris (Asplenites) macrocarpa* Oldham & Morris p. 51, pl. 28, figs 2, 3, 8a.
1877a *Asplenites macrocarpus* Oldham & Morris : Feistmantel p. 39, pl. 36, figs 5-7, pl. 37, figs 3, 3a-c, 4, 4a, pl. 48 figs 2, 2a.
1877b *Pecopteris (Asplenites) macrocarpa* Oldham & Morris : Feistmantel, p. 9. pl. 1, figs 1, 1a, 2.
1920 *Marattiopsis macrocarpa* Morris : Seward & Sahni, p. 20, pl. 7, figs 71, 71a, b.
1933 *Marattiopsis macrocarpa* Morris : Sahni & Rao, p. 184, pl. 11, figs 1, 2.
1934 *Marattiopsis macrocarpa* Morris : Sahni & Rao, p. 262, pl. 35, figs 5-7, pl. 36, figs 8-10, text fig. 4.
1947 *Marattiopsis macrocarpa* Morris : Ganju p. 59.
1957 *Marattiopsis macrocarpa* (Oldham & Morris) Seward & Sahni : Ramanujam, pl., text-figs 1, 2.
1966 *Marattiopsis macrocarpa* (Oldham & Morris) Seward & Sahni: Surange, p. 81, figs 48, A, B.
1968 *Marattiopsis macrocarpa* (Oldham & Morris) Seward & Sahni : Bose & Sah, p.19, pl. 1, figs, 9, 10; pl. 2, figs 11-13.

1969a *Marattiopsis reversa* Sharma, p. 57, pl. 32, fig. 1.

1969b *Marattiopsis macrocarpa* (Oldham & Morris) Seward & Sahni : Sharma, p. 57, pl. 32, fig. 8.

1971 *Marattiopsis reversa* Sharma : Sharma, p. 65, pl. 20 fig. 15.

1972 *Marattiopsis macrocarpa* (Oldham & Morris) Seward & Sahni : Sharma, p. 132, pl. 1, fig. 3.

1982 *Marattiopsis macrocarpa* (Oldham & Morris) Seward & Sahni : Trivedi & Sukh-Dev, p. 336.

Emended Diagnosis—Frond at least bipinnate, rachis + 3 wide, pinnae sub-opposite, arising at an angle of +70° pinna rachis + 1.25 mm wide, pinnules attached to the adaxial side of the rachis, suboppositely arranged, typically at an angle of 75° oblong, often slightly falcate, 5-10 mm long, 3-4 mm wide, base constricted, acroscopic and basiscopic basal margins auricled, lateral margins entire or little undulated, apex subacute or obtuse, midvein distinct, lateral veins alternate or subopposite, usually once forked, sometimes unforked; fertile pinnules similar to sterile ones, sporangia superficial, fused to form synangia, arranged in a row of 1 to 10 synangia on either side of mid rib; each synangium situated dorsally on the acroscopic branch of a secondary vein, oval in shape, with a prominent slit or groove in the middle region.

Locality—Bindaban and Basgo-Bedo.

Lectotype—No. 4508 of Geological Survey of India, Calcutta.

Horizon & Age—Rajmahal Formation; Lower Cretaceous.

Discussion—Our collection includes seventeen specimens of *Marattiopsis macrocarpa* majority from Bindaban and a few from Dhokuti of the Rajmahal Hills. Specimen in Pl. 1.4 shows the bipinnate nature of the frond. Sharma (1969b) also described a bipinnate specimen.

Most of the presently collected specimens exhibit the preservation of lower surface (i.e. dorsal surface) of the fronds, however, a few represent the imprints of the upper surface. All previous workers (Seward & Sahni, 1920; Bose & Sah, 1968; Sharma, 1969b; Trivedi & Sukh Dev, 1982) described that the pinnules are attached to the rachis by their whole broad bases. However, the specimens in the present collection, which

shows the upper surface of the fronds, clearly exhibit that the pinnules are attached to the upper surface of the rachis with distinctly constricted bases (Pl. 1.5; Fig. 1A, B). The basiscopic side of the pinnule base is distinctly auricled and there is also a feeble auricle on the acroscopic side. Sometimes both the acroscopic as well as the basiscopic sides of the pinnule-base are with almost equally developed auricles. Usually the secondary veins are unforked but sometimes the secondary veins of basiscopic side fork only once. As the pinnules are often falcate hence the basiscopic half of the lamina is greater than the acroscopic one and the synangia are larger on basiscopic side than those on the acroscopic one (Fig. 1C). In most cases the apices of fertile pinnae are sterile and the number of synangia over a distal pinnules is less than that of a proximal one. Sharma (1969b) also noted this feature.

FILICOPSIDA INCERTAE SEDIS

Cladophlebis salicifolia (Morris) Pal & Arefin
comb. nov.

Fig. 2A-C

1963 *Pecopteris* (?) *salicifolia* Morris, in Oldham & Morris, p. 47, pl. 26, fig. 2.

1876 *Alethopteris indica* O.M. : Feistmantel, p. 28.

1877a *Thinnfeldia indica* (part), Feistmantel, p. 87.

1968 *Cladophlebis* sp. A, Bose & Sah, p. 24, pl. 3, fig. 23.

Emended Diagnosis—Pinnate frond, imparipinnate, pinnae sub-oppositely set, lanceolate, often falcate, typically 2.5 cm long and 6 mm wide, attached by whole broad bases and gradually narrow toward their apices, acroscopic basal margin straight, basiscopic basal margin decurrent, lateral margin entire, apex acute, midvein distinct upto apex, lateral veins sub-opposite, arising at an angle of about + 45°, once or twice forked.

Locality—Ghutiari, Sugadih.

Holotype—No. 4446 of the Geological Survey of India, Calcutta.

Horizon & Age—Rajmahal Formation; Lower Cretaceous.

Discussion—Oldham and Morris described a specimen from Ghutiari as *Pecopteris* (?) *salicifolia* Morris. Feistmantel (1876) consider this specimen to be a distal part of *Alethopteris* India (*Cladophlebis indica*). However, later on Feistmantel (1877a) included it in his *Thinnfeldia indica*. Bose and Sah (1968) described a similar specimen as *Cladophlebis* sp. Both the specimens (Oldham & Morris, 1863; Bose & Sah, 1968) are identical in all available features. Now the confusion arises as to whether the specimens under consideration belong to *Thinnfeldia indica* Feistmantel or represent a species of *Cladophlebis* Brongniart. In *Thinnfeldia indica* (Zeba-Bano *et al.*, 1979), the pinnae are attached by a somewhat contracted base having the acroscopic basal margin deeply constricted and the lamina is widest at about 1/3rd distance, whereas in case of the present specimens the lamina is widest at the base and thus the pinna is attached by its whole broad base having no constriction at all. In *Thinnfeldia indica*, midrib is feebly marked and often evanescent near apex, whereas in the specimens in question the midrib in the lamina is distinct right up to the apex. In *Thinnfeldia indica* course of lateral veins is in much lower angles and far more denser than that of the present specimens. In view of those, the specimens in no way appear to represent *Thinnfeldia indica* and in all available features find a place under the genus *Cladophlebis* Brongniart, as has been done by Bose and Sah (1968). Therefore, those have been described here as *Cladophlebis salicifolia* (Morris) comb. nov.

INCERTAE SEDIS

Leaf Type-A

Pl. 1.6, 7; Fig. 3 A

Description—A specimen of a pinnately compound leaf was collected from the bluish grey shale bed exposed at about 1 km north-northwest of Onthea Village. Available length of the leaf is 2.2 cm. The preserved portion represents only the distal part of the

frond depicting its imparipinnate nature. The rachis is 0.8 mm wide, with a median longitudinal groove. Pinnae are suboppositely set at angles of + 50°. Lateral pinnae are ovate in shape, about 1 cm long and 5-6 mm wide. Terminal pinna almost orbicular in shape and is longer than the lateral ones, 1.2 cm long and 1 cm wide. Pinnae are constricted at their bases and are blunt at apices. Lateral margins of pinnae are slightly undulated or shallowly lobed. Single vein immediately after emergence at the pinna-base forks repeatedly and anastomoses forming distinct meshes covering whole of the lamina. Meshes are elongated polygonal, 3-6 mm long and 0.5-1.5 mm wide (typically 5 mm) and are devoid of included veinlets within the areoles. Ultimate veinlets end freely at lamina margins.

Locality—Onthea, Rajmahal Hills, Bihar, India.

Specimen—No. 1/6 of the Palaeobotany & Palynology Section, Botany Department, Burdwan University.

Horizon & Age—Rajmahal Formation; Lower Cretaceous.

Remarks—Several Mesozoic fern genera, viz. *Hausmania* Dunker, *Dictyophyllum* Lindley & Hutton, *Phleboteris* Brongniart, *Weichselia* Stiehler, etc. are characterised by reticulately veined lamina segments, however, the present specimen, neither in gross features nor in details of venation, resembles these taxa. In venation pattern, the present specimen resembles the extant fern genera *Hemionites* Linnaeus and *Anthrophyllum* Kaultus; some species of *Hemionites* also possess pinnatifid fronds (Copeland, 1947). However, in the absence of the epidermal characters and fertile structure of leaf type, it is difficult to ascertain its affinity.

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