ON PROTOCYATHEA RAJMAHALENSE SP. NOV.,
A CYATHEACEOUS TREE-FERN, WITH NOTES ON
THE GEOLOGICAL DISTRIBUTION OF THE
CYATHEACEAE.

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(Communicated by Prof. B. Sahni, sc.b., f.r.s.).

1. Introduction.

The specimens described below were collected in December 1934 in the
company of my friend, Mr. R. N. Mehrotra, M.Sc., from certain plant-bearing
beds at Sakrigalighat, situated about one mile north of Sakrigali railway
station in Behar (see map in Sahni and Rao1). The collection from this
locality was supplemented the following winter, when I had the privilege
of accompanying Prof. Sahni to this particular locality. A third visit was
made in December 1936. The specimens described in the present communica-
tion appeared to be of sufficient interest to deserve separate treatment.
The remaining specimens from Sakrigalighat will be described in a subse-
quently paper.

The plant-bearing beds are exposed about half-a-mile west of the ferry
on the northern slope of a small hill abutting on the Ganges. Surface
collections were made previously by others. Mr. W. N. Edwards was the
first to locate the fossiliferous beds at Sakrigalighat2; but as far as I know
none of the plant remains previously described from this locality were
collected in situ.

The plant-bearing beds are in two main zones (Pl. VII, Figs. 1–4). The
lower zone (A), composed mainly of highly brittle shales, immediately underlies
the upper hard silicified shales (B). The lower zone (A), over which the
river flows during the major part of the year, is further differentiated into
several bands which are, however, not clearly seen in the accompanying
photographs (Pl. VII, Figs. 1–4). The upper zone (B), about six inches
to one foot in thickness, can be traced almost horizontally along the base
of the cliff.

1 Sahni and Rao (1931), p. 184.
2 See Sahni and Rao (1931), p. 185, footnote.
*Cyatheaceous Tree-fern*: Protocyathea rajmahalense *sp. nov.*

The fossils described in the present communication were found in the upper band of hard silicified shales (B); the lower zone composed of brittle shales (A), though rich in other plant remains, has not so far yielded any fossils similar to those described below.

Cyatheaceous *stems* were hitherto described mainly from the Cretaceous rocks. Quite recently two Upper Jurassic species from Korea were described by Ogura. The discovery of these fossils in the Rajmahal series, which is at present considered to be probably of Middle Jurassic age, takes us further back in the geological scale, assuming, of course, that the Sakrigali beds are not higher than the rest of the Rajmahal series. A careful geological study of this and other plant-bearing localities in the Rajmahal Hills from the stratigraphical point of view should help to clear up much doubt regarding the exact horizons to which the various members of this classical flora belong.

2. *Description.*

*Protocyathea* Feistmantel 1877.

The genus *Protocyathea* created by Feistmantel is a convenient designation for all tree ferns of Cyatheaceous affinity, that are preserved either in the form of casts or impressions, and whose real affinity to any particular living genus cannot be determined owing to the absence of preserved internal structures. The vascular bundles within the leaf-scars are generally preserved as a number of warts arranged in the form of arcs. There is little doubt that, as at present understood, this comprehensive genus is highly artificial.

The type specimen of the genus, now preserved in the Museum of the Geological Survey of India (Pl. X), is a stem cast showing large spirally arranged leaf-scars with traces of a few vascular bundles within them; it was collected by H. F. Blanford from rocks regarded as Cretaceous in the Trichinopoly District of South India.

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9 Sahni (1932), pp. 14, 15.
10 The genus *Protocyathea* *Fst.* and the family *Protocyatheaceae* created by Bower (1926, pp. 282–292) to receive the two comparatively primitive genera *Lophosoria* and *Metaxyra* have no direct relationship whatever with each other.
12 See below page 82.
Protocathea rajmahalense sp. nov.

E 188; E 189; E 190 (unfigured); E 191.

(Plate VIII, Figs. 5-7; Plate IX, Figs. 8-11; Text-Figs. 1, 2.)

Type specimen: E 188 (Plate VIII, Fig. 5; Text-Fig. 1).

Diagnosis: Stem impressions with large spirally arranged leaf-cushions or bases, each bearing at its upper end the rhomboid scar of a fallen leaf. Cushions compactly arranged on the older parts of the stem, about 5.0 to 5.5 cm. by 1.7 to 2 cm., surface wrinkled. Scars roughly rhomboidal with their longer axes horizontal, about 0.9 to 1.0 cm. by 1.4 cm.; vascular bundles few (about fourteen?), in two curved rows, with two large median bundles at the top in the upper row (see Text-Fig. 2). In the younger parts of the stem the cushions are greatly reduced, the petiolar scars of adjacent leaves being almost contiguous; vascular bundles not preserved.

Four specimens are known of which one (E 190) is in a very bad state of preservation and is not figured. They represent impressions of the younger as well as the older regions of the stem. In the latter, the surface of the stem is seen covered over by spirally arranged persistent leaf-bases or cushions. But due to incomplete preservation it is difficult to determine the phyllotaxy. At the top of each leaf-cushion or leaf-base is seen the scar of a fallen leaf, with small marks, no doubt of vascular bundles (Pl. VIII, Fig. 5; Pl. IX, Fig. 11; Text-Figs. 1, 2). Below the scar the leaf-cushions exhibit a wrinkled appearance which is probably due to the scars of ramenta, though it may as well be due to a general shrinkage of the surface of the leaf-base. The leaf-cushions or bases are mostly elongated along the length of the stem (Pl. VIII, Fig. 5; Pl. IX, Fig. 8; Text-Fig. 1). This is the condition seen in specimens which probably represent the older parts of the stem. In other specimens the leaf-scars have their long axes horizontal (Pl. VIII, Fig. 6; Pl. IX, Fig. 8, top half), and the scars are densely crowded, apparently with hardly any trace of the leaf-cushions between them (Pl. VIII, Fig. 6, b). This condition seems to represent the younger parts of the stem. A similar compact arrangement of scars is seen in some of the living Cyatheaceae. In Fig. 6, on Pl. VIII, both these conditions are seen in one and the same specimen.

The arrangement of the relatively few vascular bundles within the scar is not complicated; it seems, however, that they are not all of them preserved; hence a clear description of their arrangement is impossible.

The four specimens are described separately below.

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8 Numbers in this form indicate the specimens from Sakrigalighat (locality E, in Sahni and Rao, 1931).
9 Ogura (1927 a), Figs. 35-37, 70.
Cyatheaceous Tree-fern: Protocathea rajmahalense sp. nov.
Text-Fig. 3.—Protocathea cyathoeides (Unger). One of the scars showing the arrangement of the leaf-trace bundles. (After Unger 1867, Taf. 1, Fig. 3.)

Text-Fig. 4.—Protocathea trichinopoliensis Feistmantel. One of the scars showing the arrangement of the leaf-trace bundles. (After Feistmantel, 1877, Pl. 1, Fig. 1.)

Text-Fig. 5.—Protocathea cretacea (Stenz.). One of the leaf-scars showing the arrangement of the leaf-trace bundles. (After Hosius und van der Marck, 1880, Taf. 43, Fig. 86.)

Text-Fig. 6.—Protocathea Tokunagai Ogura. One of the scars showing the arrangement of the leaf-trace bundles × 2/3. (After Ogura, 1931, Text-Fig. 1.)

Text-Fig. 7.—Cyathocaulis naktongensis Ogura. One of the scars showing the arrangement of the leaf-trace bundles. × 4/5. (After Ogura, 1927, Text-Fig. 1.)

Specimen 1. (Holotype).

E 188 (Plate VIII, Fig. 5; Plate IX, Figs. 9–11; Text-Figs. 1, 2).

This specimen shows the older part of the stem, with thirteen persistent leaf-cushions spirally arranged (Pl. VIII, Fig. 5; Text-Fig. 1). Each cushion measures about 5.0 to 5.5 cm. by 1.4 to 1.7 cm., and at the top of each can be seen the scar of a fallen leaf (Pl. IX, Fig. 11). The leaf-scars measure about 0.9 to 1.0 cm. by 1.4 cm., and show a few small marks of vascular bundles, which unfortunately are only partly preserved (Pl. IX, Fig. 11; Text-Fig. 2). The best preserved and completest scar is shown in Pl. IX, Fig. 11. As far as can be made out, about fourteen separate and wart-like vascular bundles are seen more or less regularly arranged as follows: about eight bundles are arranged in an arc in the centre of the scar, and an upper row of three or four bundles runs close to the upper margin; the two median bundles in this upper row are larger than the rest (Pl. IX, Fig. 11; Text-Fig. 2); below, and on one side of the central row of eight bundles, is seen a group of three bundles which perhaps formed part of the lowermost arc of vascular traces that are only incompletely preserved on one side. Impressions of certain elongated cells (sclerenchyma or ? tracheids) are preserved in certain parts of the stem (Pl. VIII, Fig. 5; Pl. IX, Fig. 10). A few marks of adventitious roots are also seen between the leaf-cushions, but the preservation is too poor to show the details.

Specimen 2.

E 191 (Plate VIII, Figs. 6, 7).

In this specimen the leaf-scars are densely crowded, apparently with hardly any trace of the leaf-cushions between them (Pl. VIII, Fig. 6 b). Lower
down, however, are seen one or two older scars with well-developed leaf-cushions somewhat similar in shape to those seen in the previous specimen (Pl. VIII, Fig. 6 a). The "wrinking" on the surface of these leaf-cushions is also similar. It is quite possible that the specimen belongs to a younger part of the stem, where the leaf-cushions have not yet developed (cf. Ogura, 1927 a, Figs. 35–37, 70). Vascular bundles are, however, not preserved. A few impressions, probably of adventitious roots, are present. One such root is seen clearly in the side view of the specimen in Plate VIII Fig. 7 r. The deep groove (marked l in this figure) which originates from one of the smaller rhomboidal scars may be the impression of an attached leaf-stalk (Pl. VIII, Fig. 7 l).

Specimen 3.
E 189 (Plate IX, Fig. 8).
This specimen is interesting in that it shows a gradation between the upper closely appressed scars which hardly possess any trace of cushions, and the lower scars which display well-developed leaf-cushions between them (Pl. IX, Fig. 8). As pointed out above, a similar differentiation in the arrangement of the leaf-scars in the younger and older parts of the stem is often clearly displayed in the living Cyatheaceae (cf. Ogura, 1927 a, Figs. 35–37, 70).

Specimen 4.
E 190 (Unfigured).
A badly preserved curved stem which shows indistinct leaf-cushions.

I have ventured to keep the above four specimens within the single species Protocyathea rajmahalense sp. nov. There can be very little doubt that Specimens 1 and 3 belong to the same species. Specimen 2 at first sight appears to be somewhat different from the rest, because it shows leaf-scars which possess practically no trace of cushions. But Specimen 3 displays a gradual transition from the lower scars with well-developed leaf-cushions to the upper leaf-scars with hardly any cushions. As a similar differentiation in the form of the leaf-scars of the younger and older parts of the stem is also seen in the living Cyatheaceae, I have little hesitation in considering the above specimens as belonging to the identical species.

3. Discussion.
(a) Systematic position of the Rajmahal species.

From the above description it seems fairly clear that our fossils belong most probably to tree-ferns of Cyatheaceous affinity. The large size of the leaf-cushions, the gradation between the scars of the lower and higher regions, and the arrangement of the vascular bundles, all point out—as far as mere impressions of vegetative parts can be a guide to affinity—that they are
Text-Fig. 8.—Map showing the Distribution of some Mesozoic and Tertiary Cyatheaceae.
(Fronds excluded; see Seward (33), pp. 343, 369 for the distribution of Cyatheaceous fronds).

▲ T = Tertiary
⊙ C = Cretaceous
□ J = Jurassic
Cyatheaceous Tree-fern: Protocytethea rajmahalense sp. nov. Probably related to the modern family Cyatheaceae. The characters of the fossils agree most nearly with those of the genus Protocytethea Feistmantel mentioned the following characters as distinctive of the genus—"Felix arborens, caule tereti; cicatricibus ramorum (foliorum) spiraliter dispositis, nunc maximis nunc mediocribus, structura earum cicatricibus Cyathearum viventium proxima." And our species can best be accommodated in Feistmantel's genus, within which should also be included all stem impressions or casts of Cyatheaceous affinity which show separate vascular bundles in the leaf-scar.

As far as I have been able to judge from the published records, our fossils are not identical with any species of Protocytethea previously described. They are therefore referred to a new species Protocytethea rajmahalense.

(b) A review of the genus Protocytethea Feistmantel.

A detailed comparison of the Rajmahal specimens with the described species of Protocytethea is best carried out after a general review of the genus. Four species of Protocytethea have hitherto been described; and the different species are distinguished primarily by the number and arrangement of the vascular bundles within the leaf-scar, and to some extent by the shape of the leaf-cushions. The chief characters of the four species are briefly dealt with below. For a detailed study of the individual species, see also Table I.

Protocytethea cyatheoides (Unger) Feistmantel.
(Text-Fig. 3; Table I).

1867 Caulopteris cyatheoides Unger.11
1877 Protocytethea Unger Feistmantel.12
1900 Alsophilina cyatheoides Potonié.13
1927 Protopteris cyatheoides Hirmer.14

From the Lower Cretaceous (Neocomian) of Ischl in Austria. The chief characters of this species are:—Leaf-scars large and spirally disposed, tapering towards the ends: leaf-trace composed of 40 to 60 bundles, somewhat irregularly arranged, as shown in Text-Fig. 3.

Protocytethea cretacea (Stenzel) Ogura.
(Text-Fig. 5; Table I).

1880 Protopteris punctata Hosius und van der Marck15 (only figured, not described).

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10 Feistmantel (77), p. 136.
11 Unger (67), p. 643; Pl. I, Figs. 1-4; Renault (83), p. 72; Stenzel (97), p. 16.
12 Feistmantel (77), p. 136; Posthumus (31), p. 137.
14 Hirmer (27), p. 641.
15 Hosius und van der Marck (80), Pl. 43, Fig. 186.
From the Upper Cretaceous (Senonian) of Westphalia in Germany. The chief characters of this species are:—Leaf-scars somewhat small, spirally arranged; leaf-trace composed of about twenty-six separate bundles, regularly arranged, as shown in Text-Fig. 5.

*Protocyathea* Tokunagai Ogura.

(Text-Fig. 6; Table I.)

From the Upper Cretaceous (Senonian) of Japan. The species is characterised by about thirteen vertical rows of spirally disposed large leaf-scars each of which shows about a hundred separate and regularly arranged bundles as shown in Text-Fig. 6. The arrangement recalls *Cyathocaulis naktongensis* Ogura (Text-Fig. 7), a species which has been placed under a separate genus as the internal anatomy is known.

*Protocyathea trichinopiensi* sis Feistmantel.

(Plate X; Text-Fig. 4; Table I.)

1877 *Protocyathea trichinopiensi* sis Feistmantel.

From the Upper Cretaceous (Cenomanian) of Trichinopoly in South India. Prof. L. Rama Rao of Bangalore in a letter to me expresses the opinion, (which I may be allowed to quote), that the fossil probably "belongs to the Utatur group which forms the oldest sub-division of the Trichinopoly Cretaceous". The leaf-cushions are spirally disposed. Feistmantel describes the formation of a convex disc in the upper portion of the scar. This disc is not well seen in the original specimen which, thanks to the kindness of the Director of the Geological Survey of India, I have been able to examine in Calcutta. Apparently the leaf-scar and leaf-cushion are not clearly differentiated. Each scar shows about twenty separate bundles of which nine or ten are seen arranged in a lower arc; a few bundles at the top of the scar which are seen in the type specimen, however, are indistinctly drawn in Feistmantel's figure, here reproduced as Text-Fig. 4; they are somewhat

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16 Stenzel (97), p. 17.
17 Hirmer (27), p. 641.
18 Ogura (31), p. 58.
19 Ogura (31), p. 58; Text-Fig. 1; Pl. IV.
20 Ogura (27), p. 352; Text-Fig. 1.
21 Feistmantel (77), p. 136, Pl. I, Figs. 1, 2.
22 Feistmantel (77), p. 136.
<table>
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<tr>
<th>Species</th>
<th>Locality</th>
<th>Age</th>
<th>State of preservation</th>
<th>Approximate diameter of Specimen</th>
<th>LOCAL-CUSHION OR SCAR</th>
<th>LEAF-TRACE BUNDLES</th>
<th>HAIRS OR SCALPS</th>
<th>Roots</th>
<th>Further Remarks</th>
<th>Synonyms</th>
</tr>
</thead>
<tbody>
<tr>
<td>P. cretacea</td>
<td>Westphalia, Germany</td>
<td>Upper Cretaceous</td>
<td>Cast</td>
<td>5 cm.</td>
<td>Fusiform</td>
<td>Rhomboido-oval ; upper part more obtuse</td>
<td>3 x 1.5</td>
<td>About 26</td>
<td>Marks of aerial roots</td>
<td>Ogura (31) compares it with Cyathea cretacea</td>
</tr>
<tr>
<td>P. ra/mahalense</td>
<td>Sakrigalighat, India</td>
<td>? Jurassic</td>
<td>Cast</td>
<td>11-12 cm.</td>
<td>Spiral disposition ; phyllotaxy 7/32; probably in 10 rows</td>
<td>Scars alternating; more closely arranged</td>
<td>About 14</td>
<td>Marks of aerial roots</td>
<td>Ogura (31) compares it with Cyathea cretacea</td>
<td></td>
</tr>
<tr>
<td>P. tokonomiensis</td>
<td>Trichinopoly, South India</td>
<td>? Cenomanian</td>
<td>Cast</td>
<td>5.7 cm.</td>
<td>Sparingly disposed; phyllotaxy 3/1, probably in 6 rows</td>
<td>10</td>
<td>Compressed roots</td>
<td>Unger (67) compares this with the living Cyathea complanata and Cyathea vestita</td>
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<tr>
<td>P. prlocyathea</td>
<td>Ischl, Austria</td>
<td>Lower Cretaceous</td>
<td>Cast</td>
<td>5-7 cm.</td>
<td>Obliquely rhomboidal; lower part more elongate and acuminate</td>
<td>3-5-8 x 3-5-8</td>
<td>Somewhat irregular; about 37 rows along the perimeter of the scar; about 9-12 towards the basal half arranged in two rows are directed downwards</td>
<td>40-60</td>
<td>Aerial roots</td>
<td>Unger (67) compares this with the living Cyathea complanata and Cyathea vestita</td>
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<td>P. tokonagaa</td>
<td>Iwaki, Japan</td>
<td>Upper Cretaceous</td>
<td>Cast</td>
<td>10 cm.</td>
<td>Obliquely rhomboidal; upper part obtuse; lower part more acuminate</td>
<td>5-5-8 x 3-7-5</td>
<td>About 15 or 14 vertical rows of leaf-scars; scars alternating</td>
<td>About 20</td>
<td>Feistmantel (77) compares it with Cyathea complanata</td>
<td></td>
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<tr>
<td>P. trichinopoliensis</td>
<td>Trichinopoly, South India</td>
<td>Upper Cretaceous</td>
<td>Cast</td>
<td>11-12 cm.</td>
<td>Spiral disposition; scars alternating; more closely arranged</td>
<td>About 26</td>
<td>Marks of aerial roots</td>
<td>Ogura (31) compares it with the Cyathea cretacea</td>
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**Species**
- P. prlocyathea
- P. tokonomiensis
- P. tokonagaa
- P. trichinopoliensis
- P. cretacea
- P. ra/mahalense

**Locality**
- Ischl, Austria
- Trichinopoly, South India
- Iwaki, Japan
- Westphalia, Germany
- Sakrigalighat, India
- Trichinopoly, South India

**Age**
- Lower Cretaceous
- ? Jurassic
- ? Cenomanian
- Upper Cretaceous
- Upper Cretaceous
- ? Jurassic

**State of preservation**
- Cast
- Cast
- Cast
- Cast
- Cast
- Cast

**Approximate diameter of Specimen**
- 5 cm.
- 10 cm.
- 8-10 cm.
- 5.7 cm.
- 11-12 cm.
- 11-12 cm.

**Leaf-cushion or Scar**
- Sparingly disposed; phyllotaxy 3/1, probably in 6 rows
- Obliquely rhomboidal; lower part more elongate and acuminate
- Obliquely rhomboidal; upper part obtuse; lower part more acuminate
- Obliquely rhomboidal; upper end obtuse; towm more elongate and acuminate
- Spiral disposition in 13 vertical rows; scars alternating
- Spiral disposition

**Leaf-trace bundles**
- 10
- About 15 or 14 vertical rows of leaf-scars; scars alternating
- About 26
- About 15
- About 14
- Sparsely disposed; scars alternating

**Hairs or Scalps**
- About 26
- About 100
- About 26
- About 26
- About 14
- About 100

**Roots**
- Compressed roots
- Marks of aerial roots
- Compression roots
- Marks of aerial roots
- Sparsely disposed
- Spiral disposition

**Further Remarks**
- Unger (67) compares this with the living Cyathea complanata and Cyathea vestita
- Feistmantel (77) compares it with Cyathea cretacea
- Ogura (31) compares it with the Cyathea cretacea
- Ogura (31) compares it with the Cyathea cretacea
- Ogura (31) compares it with the Cyathea cretacea
- Unger (67) compares this with the living Cyathea complanata and Cyathea vestita

**Synonyms**
- Cauloptera cymatopoda
- P. cretacea
- P. tokonomiensis
- P. tokonagaa
- P. prlocyathea
- P. ra/mahalense

**More important references**
- Unger (67)
- Schimper (69)
- Feistmantel (77)
- Stenzel (97)
- Tjotok and van der Marel (21)
- Hirmer (27)
- Ogura (31)
irregularly arranged in the original specimen. Certain oblong grooves are present in the lower half of the leaf-cushion (Pl. X). Feistmantel\(^{23}\) applies the term 'stigmata' to these structures. To judge from their appearance in the original specimen they are structures of a different nature from vascular bundles. These structures may be compared with pneumatophores as figured by Bower in *Alsophila*.\(^{24}\)

(c) **Comparison with the other species of Protocyathea.**

From a brief consideration of the different species of *Protocyathea* at present included within the form genus, it is clear that the Rajmahal species shows the closest resemblance with the South Indian species *P. trichinopoliensis* Fst.\(^{25}\) To some extent the shape and size and the arrangement of the leaf-scars in the older parts of the stem, is similar to that in *P. trichinopoliensis* Fst. The general plan of distribution of the few vascular bundles in *P. trichinopoliensis* Fst. is less complicated than in the other species of *Protocyathea* (cf. Text-Fig. 4 with Text-Figs. 3, 5–7). On the other hand, the irregular arrangement of the vascular bundles above the lower arc of bundles in *P. trichinopoliensis* Fst. (Text-Fig. 4) is quite different from that in the Rajmahal species, where the uppermost bundles are seen disposed quite regularly, running close to the adaxial margin (Text-Fig. 2). *P. trichinopoliensis* Fst., moreover, differs from the Rajmahal species in the absence of a clearly differentiated leaf-scar on the upper part of the cushion and of corrugations on the leaf-cushions. In the absence of 'stigmata' and in the presence of a smaller number of vascular bundles, our specimen shows further important differences from the Cretaceous species from South India. Therefore the species is described as new.

The other species of *Protocyathea* show little resemblance with *Protocyathea rajmahalense* sp. nov. The size and shape of the leaf-scars, and the arrangement of the numerous vascular bundles, both in *Protocyathea cyatheoides* (Unger)\(^{26}\) and *Protocyathea Tokunagai* Ogura,\(^{27}\) are totally different (see Text-Figs. 3, 6). As regards *P. cretacea* (Stenz.),\(^{28}\) although it comes nearer to the Indian species in the size of the scars and in the smaller number of vascular bundles, the arrangement of the bundles is different.

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\(^{23}\) Feistmantel (77), pp. 136, 137; Pl. I, Figs. 1, 2.

\(^{24}\) Bower (23), p. 203, Fig. 193.

\(^{25}\) Feistmantel (77), pp. 136, 137; Pl. I, Figs. 1, 2.

\(^{26}\) Unger (57), Pl. I, Figs. 1–4.

\(^{27}\) Ogura (31), Pl. IV, Text-Fig. 1.

\(^{28}\) Hosius und van der Marck (80), Pl. 43, Fig. 186.
**Table II**

*Cyatheaceae* (Ferns excluded). For the distribution of *Cyatheaceous* fronds, see Seward (33), pp. 345, 369, and th

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For the distribution of *Cyatheaceous* fronds, see Seward (33), pp. 345, 369, and th...
Pls. Figs. Figs.

Dendropteridium according stem traces, 

Our attention is confined mainly to the stem remains preserved in the form of petrifactions, casts or impressions, which may be reasonably referred to the Cyatheaceae (see Table II). Before entering into a discussion regarding their distribution, geological and geographical, the value of each genus as evidence of Cyatheaceous affinity should be considered. Posthumus\(^{30}\) and Bancroft\(^{31}\) have recently made similar attempts.

Petrifactions.—The most important and widely distributed stem genus referred to this group is Protopteris, which includes both petrifactions and casts.\(^{32}\) The probable Cyatheaceous affinities of this genus can be recognised by its leaf-trace with inwardly curved ends and plicate margin. The two east Asiatic species, Cibotiocaulis Tateiwa\(^{33}\) and Cibotium iwatense\(^{34}\) Ogura resemble the living genus Cibotium in the mode of departure of the leaf-traces and in the arrangement of the vascular bundles in the petiolar base. Caulopteris arborescens Stenzel\(^{35}\) and Caulopteris Brownii\(^{36}\) Renault show to a certain extent stelar similarity with the modern Cyatheaceae. But certain features in which the two above-mentioned species differ from the living Cyatheaceae were already pointed out by Bancroft\(^{37}\) and Rao.\(^{38}\) The stem anatomy of Cyathocaulis naktongensis Ogura\(^{39}\) can best be compared, according to Ogura, with that of the living species Dicksonia antarctica.

\(\text{Dendropteridium cyatheoides}\) Bancroft\(^{40}\) shows an undoubted polycyclic

\(^{20}\) Seward (33), pp. 343, 369; Seward (10), p. 367; Halle (13), pp. 17, 94; Hirmer (27), p. 637; Thomas (11), p. 387; Potonié und Gothan (21); Schenk in Zittel (90), pp. 92–95.

\(^{30}\) Posthumus (31).

\(^{31}\) Bancroft (32), p. 249.

\(^{32}\) Seward (10), pp. 370–375; see also for further references.

\(^{33}\) Ogura (27), pp. 364–368; Text-Figs. 10, 11; Pl. III, Figs. 13–15; Pl. VIII, Figs. 43–49.

\(^{34}\) Ogura (33), p. 748; Text-Figs. 1, 2; Pl. II, Figs. 1–4.

\(^{35}\) Stenzel (97), p. 10; Pls. I, II; III, Figs. 16–19.

\(^{36}\) Renault (83), p. 73; Pl. VIII, Fig. 10; Rao (34), pp. 221–225; Pl. XXXIII, Figs. 3–6.

\(^{37}\) Bancroft (32), p. 349.

\(^{38}\) Rao (34), p. 221.

\(^{39}\) Ogura (27), p. 351; Text-Figs. 1–9; Pl. II, Figs. 1–6; Pl. III, Figs. 7–12; Pls. IV–VI.

\(^{40}\) Bancroft (32), p. 241; Text-Figs. 1, 2; Pls. IX, X.
structure of Cyatheaceous type. The genus *Cyathorachis Fujiiana* Ogura\(^{41}\) is a well preserved piece of rachis showing numerous bundles arranged as in some modern Cyatheaceae. *Rhizodendron oppoliense* Göpp.,\(^{42}\) on the other hand, is a species of doubtful affinity which has been included under the Cyatheaceae by certain authors. It shows fibrous bundles in the cortex and pith with sclerenchymatous tissue outside the main stele. The leaf-trace has four or more strands.

**Impressions.**—Among the casts and impressions of Cyatheaceous affinity *Oncopteris*\(^{43}\) and *Protocyathea*\(^{44}\) are the two important genera. *Protopters*, as mentioned above, is also known as casts. The internal anatomy of the species included in the first two genera is at present unknown; and till their internal structure is known they cannot be removed from the present position of uncertain affinity to a more stable footing. But their affinities are no doubt more with the Cyatheaceae than with any other group of ferns. The genus *Oncopteris* shows, besides a ring of separate wart-like bundles, two \(<\)-shaped or \(C\)-shaped bundles at the top of the scar. A similar arrangement of the vascular bundles in the leaf-base is also noticed in some of the living Dicksoniaceae. The affinities of *Protocyathea* with the living Cyatheaceae have already been considered elsewhere in detail.

From the above brief discussion it would appear that as far as their anatomy is concerned, the Cyatheaceae have descended from their Mesozoic ancestors with but little modification.

Table II is intended to illustrate the distribution in space and time of such fossil stems as may be reasonably regarded, on data at present available, as members of the Cyatheaceae.

The geographical distribution of the living Cyatheaceae has been ably dealt with by Diels.\(^{45}\) Their distribution in a broad belt throughout the tropics and sub-tropics of the Old and the New Worlds forms a striking contrast to their distribution in the past.

According to Seward\(^{46}\) "We have as yet no satisfactory evidence of the existence of the Cyatheaceae in Palæozoic flora."

\(^{41}\) Ogura (27), p. 368; Text-Figs. 12, 13; Pl. VIII, Figs. 50–54.

\(^{42}\) Göppert (65), p. 397; Stenzel (86), p. 5; Pl. I, Figs. 1, 3, 5–12; Pl. II; Pl. III, Figs. 20–29; Rao (34), pp. 225, 226.

\(^{43}\) Krejci (53); Feistmantel (72); Velenovsky (88); Potonić (90); Früch und Bayer (91); Seward (10); Pelourde (11); (14); Engelhardt (81); Stenzel (97); Hirmer (27); Ogura (31); Velenovsky and Viníklár (29).

\(^{44}\) See Table I for full references.


\(^{46}\) Seward (10), p. 366.
Rhætic.—It is not till the Rhætic period is reached that we find anything like definite evidence of this family of ferns; and in these rocks, too, they have so far been found only in the form of leaf impressions. The only Rhætic record so far known is from Tonkin.

Jurassic.—During the Jurassic, however, the Cyatheaceæ had a worldwide distribution. We have several undoubted records of Cyatheaceous ferns (both stem remains and fronds). Of petrified stems, the earliest reliable evidence so far available was from the Upper Jurassic, namely, *Cibotiocalus Tateiwae* Ogura from Korea, and *Cyathocaulis naktongensis* Ogura from Japan. The discovery of *Protocyaethea rajmahalense* sp. nov. from the Rajmahal series, which is at present believed to be of Middle Jurassic age, therefore takes us further back in the geological scale (see Table II). In the Jurassic rocks fern fronds are more commonly found than stem remains. *Coniopteris hymenophylloides* (Brong.) and *Eboracia lobifolia* (Phill.) were well represented in the vegetation of this period. Another fern possibly belonging to the same family was *Stachypteris*.

Cretaceous.—The Cretaceous records are mainly confined to the stem remains, the largest number being found in the Upper Cretaceous (see Table II). The fronds which were abundantly represented in the Jurassic are singularly rare in these rocks. But there is enough evidence to show (from the stem remains so far known), that the Cyatheaceæ were more or less well represented during this period as well (see Table II), though probably not to such a great extent as in the Jurassic. *Protoperis punctata* Stern. described by Heer from the Cretaceous of Greenland, establishes the extreme northerly distribution of the group. *Protocyaethea trichinopoliensis* Fst. from the Cretaceous rocks of South India, also shows the wide range of the family during that period.

Tertiary.—There is great scarcity of Cyatheaceous records of any type after the Cretaceous. Except for two species of stems, *Oncopteris Laubeji* (Engelh.) probably from the early Tertiary of Bohemia, and *Dendropteridium cyatheoides* Banc. from the late Tertiary of E. Africa, there is no evidence of a reliable nature.

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47 Zeiller (03), p. 36, Pl. IV, Fig. I; Halle (13), p. 94; Seward (33), pp. 343, 350.
48 Ogura (27), p. 364.
49 Ogura (27), p. 351.
50 Sahni (32), pp. 14, 15.
52 Thomas (12); Seward (33), p. 350.
53 Heer (82), Pl. XLVII.
54 Engelhardt (81), p. 284, Taf. 1, Figs. 1–4.
Conclusion.—Thus, if we consider the records of stem remains and frond impressions collectively as evidence for the existence of Cyatheaceous ferns, it can safely be said that the group was abundantly represented in the vegetation of the Jurassic and Cretaceous periods, and enjoyed an almost cosmopolitan existence. By the end of the Cretaceous they had already started disappearing from the northern regions; and during the period that followed, in company with other groups of ferns such as the Gleicheniaceae and the Marattiacae, they became confined to their present restricted distribution within the tropics and south temperate zone.

(e) Geological age of the Sakrigalighat beds.

A definite opinion on the geological age of the beds cannot be ventured at this stage. It will, however, be discussed after the other specimens from this locality are examined and described. But it may be mentioned that Protocyathea is a genus previously recorded only from the Cretaceous rocks.

4. Summary.

1. Protocyathea rajmahalense sp. nov. is described from certain beds at Sakrigalighat, in Behar.

2. The earliest recorded species of Cyatheaceous stems are from the Upper Jurassic of Korea. The discovery of the Indian species takes us further back in the geological scale, because the Rajmahal series is probably not so young as the Upper Jurassic, unless of course, the Sakrigali beds are higher than the rest of the Rajmahal series, a question which deserves the attention of geologists.

3. The affinities of the Rajmahal species with the other species of Protocyathea are discussed. The closest resemblance is with Protocyathea trichinopoliensis Fst. from the Cretaceous of South India. Due to certain important differences from the latter, the Rajmahal form is described as a new species.

4. The distribution of the Cyatheaceae, both living and fossil, is briefly discussed.

5. Acknowledgment.

My grateful thanks are due to Professor B. Sahni, F.R.S., for his invaluable and most generous help and criticisms throughout the course of this work. For his personal inspiration, which has been a constant source of encouragement, and for all that my association with him for the last few years has meant for me, which is much more than I can mention here, I wish to express my deepest gratitude.
To the Director, Geological Survey of India, I am indebted for permission
to examine the type specimen of Protocathea trichinopoliensis at Calcutta,
and to reproduce a photograph of it (Pl. X).

I am also indebted to Prof. L. Rama Rao of the Department of Geology,
Central College, Bangalore, for valuable information regarding the probable
stage of the Trichinopoly Cretaceous to which P. trichinopoliensis Fst.
belongs.

My thanks are also due to the authorities of the Lucknow University
for the award of a Research Fellowship during the course of this work.

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EXPLANATION OF PLATES.

All figures are untouched photographs. With the exception of the original of Plate X, all the figured specimens come from Sakrigalighat, and are preserved in the Department of Botany, Lucknow University.

PLATE VII.

Fig. 1.—Photograph showing the band of hard silicified shale (Zone B) which runs along the base of the cliff, Sakrigalighat. All the specimens of Protocyathea rajumahalense here described were collected from this stratum.

Fig. 2.—A view of the same zone (Zone B) in the month of October when the river is in floods. The soft brittle strata (Zone A) are submerged.

Fig. 3.—A view of the soft strata (Zone A) from the north-west. The bed of hard silicified shales (Zone B) can be seen in the background overlying the soft shales.

Fig. 4.—Photograph showing the soft shales (Zone A) dipping north into the river. A view from the south-east, when the water has receded. The man is seen standing at the spot which yielded the major part of the collections from this zone (to be described in a subsequent paper). The hard band is seen higher up at B, also dipping north.

PLATE VIII.

Fig. 5.—Protocyathea rajumahalense sp. nov., showing the leaf-cushions and scars. × 5/6. Specimen 1 (E 188). a, b, two of the leaf-cushions magnified in Pl. IX, Figs. 11 and 9 respectively.

Fig. 6.—Protocyathea rajumahalense sp. nov., showing two types of leaf-scars. a, scars with well-developed leaf-cushions; b scars with more or less undeveloped leaf-cushions. Natural size. Specimen 2 (E 191).

Fig. 7.—Protocyathea rajumahalense sp. nov. A side view of Specimen 2 (E 191), figured in Plate VIII, Fig. 6, showing on the left an adventitious root (r), and on the right a leaf-stalk (l). Natural size.

PLATE IX.

Fig. 8.—Protocyathea rajumahalense sp. nov. Specimen 3 (E 189). Slightly reduced.

Fig. 9.—Protocyathea rajumahalense sp. nov. One of the leaf-scars marked (b) in Pl. VIII, Fig. 5, enlarged, showing impressions of scales or hairs. × 21/2.

Fig. 10.—Protocyathea rajumahalense sp. nov., showing impressions of sclerenchyma or tracheids × 4.

Fig. 11.—Protocyathea rajumahalense sp. nov. One of the leaf-cushions marked (a) in Pl. VIII, Fig. 5, enlarged, showing the leaf-trace bundles and impressions of scales or hairs below the leaf-scar. × 3.

PLATE X.

Fig. 12.—Protocyathea trichinopoliensis Fst. The type specimen (from the Cretaceous of S. India) preserved in the museum of the Geological Survey of India. From a photograph supplied by the Geological Survey of India. Natural size.