

# Some new pteridophytic remains from the Permian strata of Rajmahal Hills, India

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## ABSTRACT

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The paper describes two new species, one each of *Liknopetalon* (Smithies) Anderson & Anderson and *Lelstotheca* Maheshwari, from the Permian strata of the Rajmahal Hills, Jharkhand, India. The new species are named, respectively, as *Liknopetalon rajmahalensis* and *Lelstotheca harikrishnae*. On the basis of certain similar floristic elements, these strata appear to be floristically equivalent with those of Middle Ecca Series of South Africa and the Permian strata in a ravine section near Mamal Village in Liddar Valley of Kashmir Himalaya.

**Key-words**—Pteridophytic fossils, Permian, Rajmahal Hills, Jharkhand, India.

भारत की राजमहल पर्वतश्रेणियों के परमियन युगीन स्ट्राटा से प्राप्त कुछ नूतन टेरिडोफाइटों का अवलोकन  
प्रदीप चन्द्र श्रीवास्तव एवं दिव्यदर्शन पंत

सारांश

प्रस्तुत शोध पत्र में भारत के झारखण्ड प्रान्त की राजमहल पर्वतश्रेणियों के परमियन युगीन स्ट्राटा से प्राप्त *लिकनोपेटेलॉन* (स्मिथाइज़) एण्डरसन एवं एण्डरसन तथा *लेल्सटोथीका* माहेश्वरी की एक-एक प्रजाति का वर्णन किया गया है। नई प्रजातियों के नामकरण *लिकनोपेटेलॉन राजमहलेन्सिस* तथा *लेल्सटोथीका हरिकृष्णाई* किए गए हैं। कुछ समरूप वनस्पतिजात तत्त्वों के आधार पर ये स्ट्राटा दक्षिण अफ्रीका के मध्य एक्का श्रेणी से तथा कश्मीर हिमालय की लिड्डर घाटी के मामल ग्राम के समीप कन्दरा परिच्छेद में परमियन युगीन स्ट्राटा से वनस्पतिजातपरक ढंग से समतुल्य प्रतीत होते हैं।

**संकेत शब्द**—टेरिडोफाइटों पादपाशम, परमियन, राजमहल पर्वतश्रेणियाँ, झारखण्ड, भारत.

## INTRODUCTION

IT was Feistmantel (1880) who reported the first pteridophytic fossils from the Lower Gondwana strata of Rajmahal Hills exposed at Dubrajpur under the name *Phyllothea robusta* (see also Surange, 1964). After a gap of about eighty two years Surange and Prakash (1962) described similar fossils from Tattitola, a locality in the same area and assigned

Feistmantel's *Phyllothea robusta* along with their new specimens to a new genus, *Stellothea* as *Stellothea robusta* comb. nov. After renaming this genus as *Lelstotheca*, Maheshwari (1972) described an additional species, *L. striata*. Subsequently, Singh *et al.* (1987) described two more sphenopsids, *Sphenophyllum gondwanensis* and *Lelstotheca* sp. from the Permian strata exposed at Lalmatia Colliery in Rajmahal Hills area. We also collected some fossils from the



## MATERIAL AND METHODS

The fossils described in this paper were collected from interbedded grey-whitish arenaceous shales of Lalmatia coal seam of Rajmahal Hills, exposed near Lalmatia of Godda District of Jharkhand of India. The Lalmatia coal seam of the Hura tract which attains a thickness of about 78 m in the northern part of the Rajmahal Basin, divides southwardly in three parts (Fig. 1, Raja Rao, 1987) designated as bottom (LI- Hizukita), middle (LII) and top (LIII) seams. The shales between seams LI-LII and LI-LIII are rich in plant fossils and have yielded the investigated fossils, which are in the form of compressions with ill preserved fragmented carbon. The specimens were observed under oblique incident light with stereo-binocular. Cellulose acetate pulls were also made to look for structural details of axes and laminae. The sporangia were extracted by dissolving these pull preparations in amyl acetate and, thereafter, the carbonaceous material was macerated in Schulze's fluid to obtain the spores. The coherent spores of the spore mass were separated by ultrasonic shaking and also manually with needles. These were observed under LM and SEM.

## OBSERVATION

**Genus—*Liknopetalon* (Smithies) Anderson & Anderson**  
1985

At the first sight the fossils including the vegetative specimens described in the present paper as *Liknopetalon* seemingly resembled *Vinaykumaria* (Pant & Srivastava, 1991) described from the Permian of Kashmir Himalaya in having small cuneate leaves apparently attached to a slender axis and we were inclined to assign them to a new species of that genus since *Vinaykumaria indica* differs from the Rajmahal specimens assigned here to *Liknopetalon rajmahalensis* sp. nov. in having invariably rounded shoulders of the laminae (the laminae of *Liknopetalon rajmahalensis* sp. nov. have pointed shoulders). On the basis of reinvestigation of *Vinaykumaria indica* we now realize that the leaves could have been opposite as in Text fig. 1A and Pl. 1 fig. 1 of Pant and Srivastava (1991) while it was described as alternate in a loose spiral. However, in the meantime we noticed another genus *Liknopetalon* (Smithies, 1978) Anderson and Anderson (1985) having similar looking fan-shaped but only fertile leaves attached to slender axes described from the Lower Permian strata of Hammanskraal and Vereeniging localities in South Africa (Generitype Specimen No. BP/2/7414, pl. 52·1). Unlike these South African specimens our fossils from the Permian of Rajmahal Hills show only attached vegetative leaves but we were lucky in finding detached fertile leaves like those born on axes of *Liknopetalon* from South Africa. The detached fertile laminae were recovered from the same rock piece, which yielded the attached vegetative leaves. As the form of our

vegetative and fertile leaves are closely comparable but specifically different from that of the South African species, we assign our specimens to a new species of the same genus, herein named, *Liknopetalon rajmahalensis* after emending the generic diagnosis.

We suspect that *Vinaykumaria indica* (Pant & Srivastava, 1991) from Kashmir may ultimately prove to be yet another species of *Liknopetalon* but since its single specimen is only a small vegetative fragment and its details are not sufficiently known, we are unable to compare *Vinaykumaria* with *Liknopetalon* further and merge the two genera. Moreover, no attached or detached fertile leaves like those of *Liknopetalon* were found in case of *Vinaykumaria* and, accordingly, it would be best to continue to treat *Vinaykumaria* as a different genus at present (see Fig. 3).

*Emended Generic Diagnosis*—Unbranched slender axes with small, gracile cuneate or fan-shaped vegetative and fertile simple laminae in apparently opposite and decussate pairs. Laminae nonpetiolate; side margins entire and concave, distal margins convex and entire in vegetative laminae but apparently fluctuate in fertile laminae; veins in both kinds of laminae repeatedly dichotomised and divergent. Sporangia apparently sessile, inserted singly in a submarginal row along the distal margins.

*Type species*—*Liknopetalon enigmata* (Smithies) Anderson & Anderson, 1985.

### LIKNOPETALON RAJMAHALENSIS sp. nov.

(Pl. 1, 2, 3·1-3; Fig. 2A-D)

*Diagnosis*—Slender twigs bearing cuneate vegetative laminae apparently opposite and decussate in phyllotaxis. Laminae gently tapering towards base with slightly concave entire lateral margins; surface of laminae showing fine striations between divergent forked veins. Distal margins of vegetative laminae entire while in associated fertile laminae seemingly fluctuate with a submarginal row of apparently nonindusiate sessile, exannulate, ovate to obovate sporangia. Sporangial wall showing straight walled parallel rectangular cells; indusium absent. Spores spherical with trilete mark on proximal face and showing reticulate ornamentation both on proximal and distal sides, muri sinuous; laminae with numerous pits on their surface.

*Holotype*—Specimen no. B/R 150A, B.

*Duplicates*—Specimen nos. B/R 154, B/R 151, B/R 152, B/R 153 (showing vegetative laminae); B/R 155, & B/R 156 (showing detached fertile laminae) of Divya Darshan Pant Collection, Department of Botany, University of Allahabad.

*Locality & Horizon*—Lalmatia Colliery, Rajmahal Hills, Barakar Stage (Permian, Lower Gondwana), Jharkhand, India.

*Description and Comparison*—All the specimens assigned to *Liknopetalon rajmahalensis* sp. nov. were found by splitting a single thick piece of shale. On this basis and on

account of the occurrence of the detached fertile segments in close association with axes showing attached vegetative laminae, we believe that the detached cuneate fertile laminae belong to fertile axes of the same type but these lie detached in our material. The fragments of 2.0-3.0 mm wide axis are invariably unbranched and they bear 1.8-2.2 cm long and ca. 0.9 cm wide cuneate vegetative laminae arranged in apparently opposite and decussate phyllotaxis. Attempts were made to pull the carbon from the surface of vegetative laminae and axis but the fragmented carbon failed to yield any cellular details except in one preparation from the axis of the specimen no. B/R 154, in which straight walled vertically elongated cells of epidermis were visible. However, The carbon from fertile laminae yielded almost intact ovate to obovate sporangia ca. 1.0-2.0 mm long x 0.5 mm wide without any stalks. The sporangial surface failed to show an annulus but we could see elongated cell outlines with straight to slightly sinuous walls. We believe that these represent cells of the sporangial wall. However, we could not recognise an annulus. The distal margin of fertile laminae appears to be clearly fluctuate or undulate in one out of our two specimens. The slender axes bearing vegetative laminae show two longitudinal parallel ribs.

The spore out put per sporangium was found to be about 200. The spores are spherical, 30-45  $\mu\text{m}$  in diameter with trilete mark having almost equal arms on their proximal faces. The ornamentation of exine is reticulate with sinuous muri. The surface of laminae surrounded by muri showed a number of minute pits.

*Liknometalon rajmahalensis* sp. nov. differs from *L. enigmata* in having only attached vegetative leaves whereas *L. enigmata* shows only attached fertile leaves. The vegetative leaves of *L. enigmata* are unknown. The fertile leaves of *L. rajmahalensis* were only found detached but in close association. The fertile leaves of *L. enigmata* are broader than long while fertile as well as vegetative laminae of *L. rajmahalensis* are longer than broad. The side margins of leaves of *L. enigmata* are deeply concave but those of *L. rajmahalensis* are only slightly concave (Fig. 3).

The specific name of *Liknometalon rajmahalensis* sp. nov. is based on the Rajmahal Hills, the place of occurrence of the species in Jharkhand of India.

**Discussion**—At present the affinities of *Liknometalon* appear to be uncertain even though Anderson & Anderson (1985) believed that *Liknometalon enigmata* was remotely

comparable with *Sphenophyllum* Koenig but at the same time they adjudged it to be different and assigned fern affinity to this taxon. Its opposite and decussate vegetative and fertile laminae with apparently exannulate, submarginal and sessile sporangia along the distal margin are unique. Another possibility about the affinities of the genus would be that it is a fern whose pinnae are attached in opposite and decussate manner on the twigs which may be presumed to be rachis. Even so its affinities would remain enigmatic since we are not aware of any such fern. The fertile laminae could also be compared with those of *Cladoxylon scoparium* Krausel & Weyland (1926) if its fertile laminar segments are presumed to have become webbed with each other by their margins. This comparison may, however, appear far-fetched since *Cladoxylon scoparium* is of the Devonian age. Moreover, in this case we have to presume that *Liknometalon* is a persistent archetype. The opposite and decussate phyllotaxis of leaves in *Liknometalon* resembles that of the ultimate branches of *Archaeopteris macilenta* (Beck, 1971). However, the shape and venation pattern of the vegetative leaves of *Liknometalon rajmahalensis* sp. nov. resembles those of *Eddyia sullivanensis* Beck (1967), the possible seedling of *Archaeopteris* described from the Upper Devonian of New York.

*Liknometalon* is comparable in certain vegetative characters with *Noeggerathia* Sternberg and *Tingia* Halle among the noeggerathiophytes (see in Boureau, 1964; Taylor & Taylor, 1993) but its fertile laminae are quite different. The cuneate shape and dichotomous divergent venation of vegetative laminae of *Liknometalon rajmahalensis* sp. nov. closely resemble those of *Noeggerathia foliosa* Sternberg while their entire distal margin and opposite decussate phyllotaxis in the former differ from those of latter in which the distal margin is dentate and opposite leaves are arranged in two lateral rows. Further, the arrangement of vegetative laminae of *Liknometalon* may be somewhat compared with arrangement of anisophyllous vegetative leaves of *Tingia* set in four lateral rows but their shapes are different. The sporophylls of *Noeggerathia* and *Tingia* are condensed to form compact cones and bear sporangia on their adaxial surface whereas in *Liknometalon* fertile laminae are laxedly arranged with sporangia arranged only along the distal margins with precise mode of their attachment being presently unknown. It is best to assign *Liknometalon* to *incertae sedis* among pteridophytes till more details are known.

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Fig. 2—A-D *Liknometalon rajmahalensis* sp. nov. E-G *Lelstotheca harikrishnae* sp. nov. A. An axis bearing cuneate vegetative laminae in opposite and decussate arrangement. Holotype Specimen No. B/R 150A. x 1.8, B. Another axis with vegetative laminae. Specimen No. B/R 154. x 1.9, C. A fragment of fertile lamina with submarginal row of ovate to obovate sessile sporangia along the distal margin. Specimen No. B/R 155A. x 2.1, D. Another fragment of fertile lamina showing the same features. Specimen No. 156. x 4, E. An axis with three whorls of lanceolate-linear leaves. Holotype Specimen No. B/R 160. x 1.8, F. A fragment of axis with a six-leaved whorl. A prominent mid-vein is present in each leaf. Specimen No. B/R 162. x 1.3, G. Fragments of two axes, one with two whorls of leaves and the other with a single whorl. Specimen No. B/R 161. x 1.9.



Feature	<i>Liknopetalon enigmata</i> (Smithies) Anderson & Anderson	<i>Liknopetalon rajmahalensis</i> sp. nov.	<i>Vinaykumaria indica</i> Pant & Srivastava
Axis	2-3 mm wide	2-3 mm wide	4 mm wide
Nature of known leaves	Only fertile (attached/ detached)	Vegetative (attached/ detached) and fertile (detached only)	Only vegetative (apparently attached)
Shape of leaves/ laminae	Fan-shaped (broader than long)	Cuneate to fan-shaped (longer than broad)	Cuneate (longer than broad)
Size of leaves	1.5 x 1.8 cm	1.8-2.2 x 0.9 cm	2.0-2.5 x 1.5-2.0 cm
Side margins	Deeply concave	Slightly concave	Slightly concave
Distal margin	Convex	Convex	Convex
Shoulders of the leaves / laminae	Pointed	Pointed	Rounded
Venation	Open furcated, several veins in the basal part	Open furcated, several veins in the basal part	Open furcated, several veins in the basal part
Phyllotaxis	Apparently opposite and decussate, laxed	Apparently opposite and decussate, laxed	Apparently opposite, compact
Sporangia	Obovate, 1.0 x 0.5 mm	Ovate-obovate, 1.0-2.0 x 0.5 mm	Not known
Spores	Not known	Spherical with trilete mark on proximal face and reticulate ornamentation	Not known

Fig. 3—Comparison of two species of *Liknopetalon* (Smithies) Anderson & Anderson and *Vinaykumaria indica* Pant & Srivastava.

#### Genus—*Lelstotheca* Maheshwari 1972

Maheshwari (1972) renamed *Stellotheca robusta* Surange & Prakash (1962) as *Lelstotheca robusta* since the name *Stellotheca* was adjudged as a homonym in form of merely an orthographic variant of *Stellatheca*, the name applied by Danzé (1956) to a possibly fertile osmundaceous fern frond described from Wesphealian C of Pas-de-Calais, France. Up to date there are two named species of *Lelstotheca*, viz., *L. robusta* (Feistmantel) Maheshwari and *L. striata* Maheshwari & Srivastava. The specimens of *Lelstotheca* collected from the Permian of Rajmahal Hills differ from both the earlier described species and are, therefore, assigned here to a new species.

#### LELSTOTHECA HARIKRISHNAE sp. nov.

(Pl. 3-4-6; Fig. 2E-G)

*Specific Diagnosis*—Slender articulated axes with nodes and internodes. Slightly swollen nodes bearing whorls of up

to 10 lanceolate to linear sessile, entire margined leaves free up to their bases and with acute apices. Each leaf showing a prominent midvein from base to apex.

*Holotype*—Specimen No. B/R 160.

*Duplicates*—Specimen Nos. B/R 161, B/R 162 of Divya Darshan Pant Collection, Department of Botany, University of Allahabad, Allahabad and Specimen No. BSIP 35869 of Birbal Sahni Institute of Palaeobotany, Lucknow.

*Locality and Horizon*—Lalmatia Colliery, Rajmahal Hills, Barakar Stage (Permian, Lower Gondwana), Jharkhand, India.

*Description and Comparison*—Of the three specimens in the collection, one specimen (Holotype, Specimen No. B/R 160) shows an articulated axis with three whorls. It appears to be the terminal portion of the axis. The length of the internodes has been measured as 0.8 to 1.0 cm. The upper most whorl has 5 linear-lanceolate leaves with acute apices. The second and third incompletely preserved whorls have four and three leaves in each, respectively. The second specimen (No. B/R 161) shows two fragmentary axes, one with two incomplete whorls

#### PLATE 1

*Liknopetalon rajmahalensis* sp. nov.

1. A slender axis bearing cuneate vegetative simple laminae in opposite and decussate arrangement. Holotype Specimen No. B/R 150A. x 2.
2. Counterpart of the specimen in Pl. 1.1 showing the same features. Holotype Specimen No. B/R 150B. x 2.
- 3, 4, 5. Detached fragmentary laminae showing convex distal margins, concave side margins and spreading arched veins. Specimen Nos. B/R 151. x 3, B/R 152 x 3, B/R 153. x 3, respectively.



1



2



3



4



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PLATE 1

Feature	<i>Lelstotheca robusta</i> (Feistmantel) Maheshwari	<i>Lelstotheca striata</i> Maheshwari & Srivastava	<i>Lelstotheca harikrishnae</i> sp. nov.
Axis	0.3 cm wide	0.2 cm wide	0.3 cm wide
Internodal length	1.0-1.8 cm	1.0 cm	1.0-2.2 cm
Striations in internode	Not known	8-12 fine parallel ribs	Not known
Number of leaves in a whorl	10-15	8-12	3-10
Shape of leaves	Linear (widest near the base, gradually tapering towards the apex)	Linear-lanceolate (widest at middle of length or both margins parallel except at the base and apex)	Linear-lanceolate (widest at middle of length or both margins parallel except at the base and apex)
Size of leaves	Up to 2.0 cm long x 0.4 cm wide	Up to 0.8 cm long x 0.1-0.2 cm wide	Up to 2.0 cm long x 0.4 cm wide
Apex of leaf	Acute	Sharply acute	Acute
Base of leaf	Wide	Sharply constricted	Constricted
Midvein	Single, unstriated	Single, striated	Single unstriated
Striations on leaf surface	Absent	Longitudinal striations common, transverse thickenings occasionally seen	Absent
Leaf margins	Entire	Entire	Entire

Fig. 4—Comparison of three species of *Lelstotheca* Maheshwari.

and the another with only one. In this specimen the length of internode was measured as 2.2 cm. The third specimen (No. B/R 162) shows a fragmentary axis with an incomplete six leaved whorl. The specimen described by Singh *et al.* as *Lelstotheca* sp. (1987, Pl. 1, fig. 6) from Lalmatia top (LIII) seam of the same locality has been assigned here to *Lelstotheca harikrishnae* sp. nov. It shows stellate whorls with up to ten linear leaves up to 3.5 cm long and 0.3 cm wide. In our specimens the leaves are lanceolate to linear up to 2.0 cm long and 0.4 cm wide, each with a prominent midvein from the base to apex. At some points the leaves show false union near the point of attachment with axis due to close proximity and overlapping.

*Lelstotheca harikrishnae* sp. nov. is different from both the previously described species. It differs from *Lelstotheca robusta* (Feistmantel) Maheshwari (1972) in having a small number, three to ten only, of lanceolate to linear leaves in each whorl (*Lelstotheca robusta* has 10-15 leaves which are widest at their bases and gradually taper towards their apices).

The leaves of *Lelstotheca harikrishnae* sp. nov. differ from those of *Lelstotheca striata* Maheshwari & Srivastava (1987) in lacking its characteristic longitudinal striations running parallel to the midvein and also the transverse striations on the surface of leaves (see Fig. 4).

The specific name of *Lelstotheca harikrishnae* sp. nov. has been given in honour of Dr Hari Krishna Maheshwari of Birbal Sahni Institute of Palaeobotany, Lucknow, who has described several interesting taxa from the Permian of Rajmahal Hills.

## POSSIBLE CORRELATION OF PERMIAN STRATA AT LALMATIA

On the basis of floristic elements and lithology, Barakar affinity has been assigned to the Permian strata exposed at Lalmatia (Singh *et al.*, 1987; Raja Rao, 1987; Maheshwari & Bajpai, 1992). With the finding of heterophyllous

### PLATE 2

*Liknopetalon rajmahalensis* sp. nov. →

- An axis bearing vegetative laminae. Note ribbed nature of the axis. Specimen No. B/R 154. x 1.8.
- Fragment of a fertile lamina bearing submarginal row of ovate to obovate sporangia along the fluctuate distal margin. Specimen No. B/R 155A. x 2.5.
- Fragment of a fertile lamina with carbonized sporangia along the distal margin. Specimen No. B/R 156. x 4.
5. Sessile sporangia with obtuse apices showing straight to slightly sinuous walled elongated cells of sporangial walls. 4 Slide No. B/R 156/g & 5 - Slide No. B/R 156/c; both x ca. 80.
- Three spores isolated from the spore mass of a sporangium under LM. Slide No. 156/h x ca. 550.
- Single spore showing the trilete mark under LM. Slide No. B/R 156/h x ca. 1000.
- Two spherical spores isolated from the same sporangium. one large and other small at the same magnification. The smaller one shows the trilete mark. Slide No. B/R 156/h x ca. 770.
- Elongated straight walled cells of axial epidermis. Slide No. B/R 154/a x ca. 325.

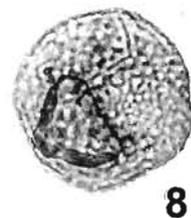
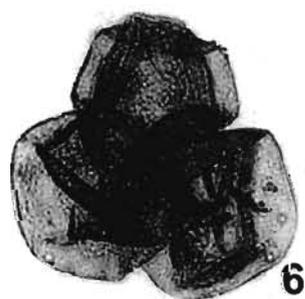
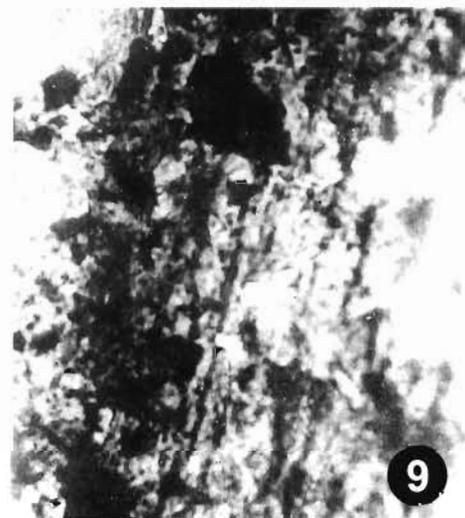
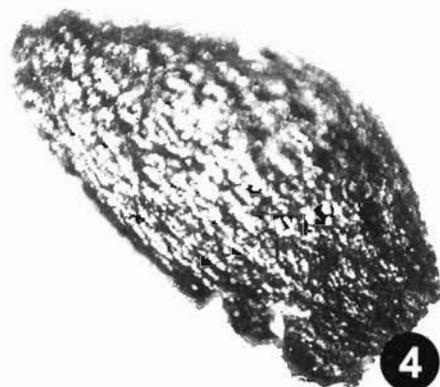
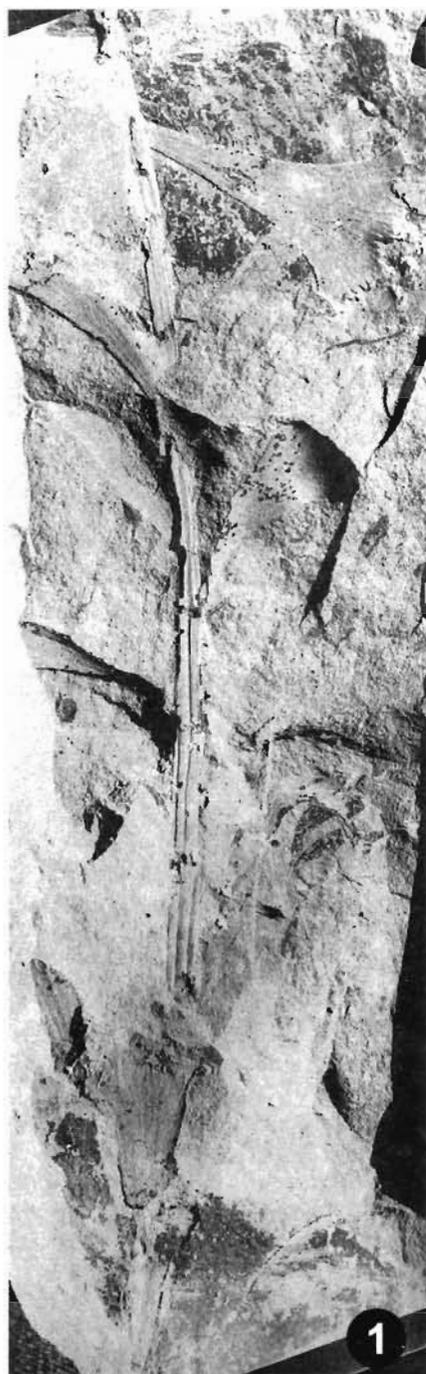


PLATE 2

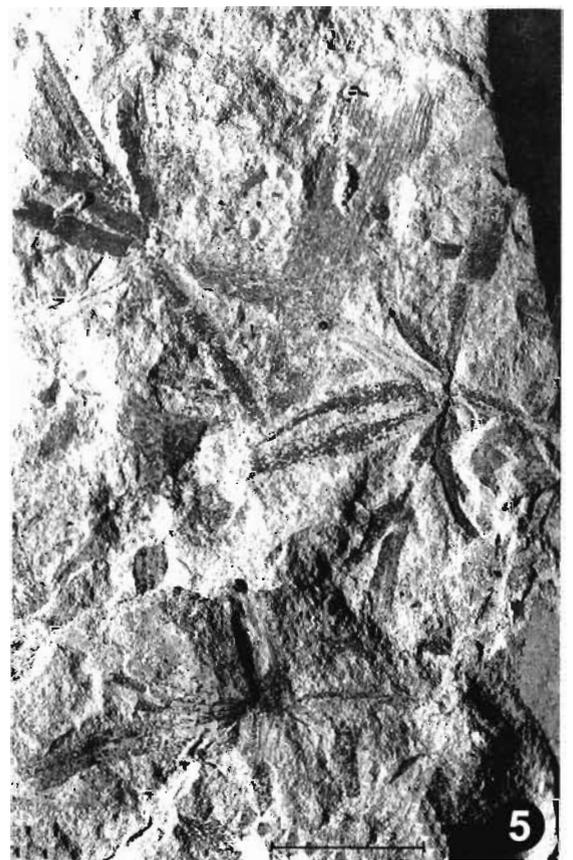
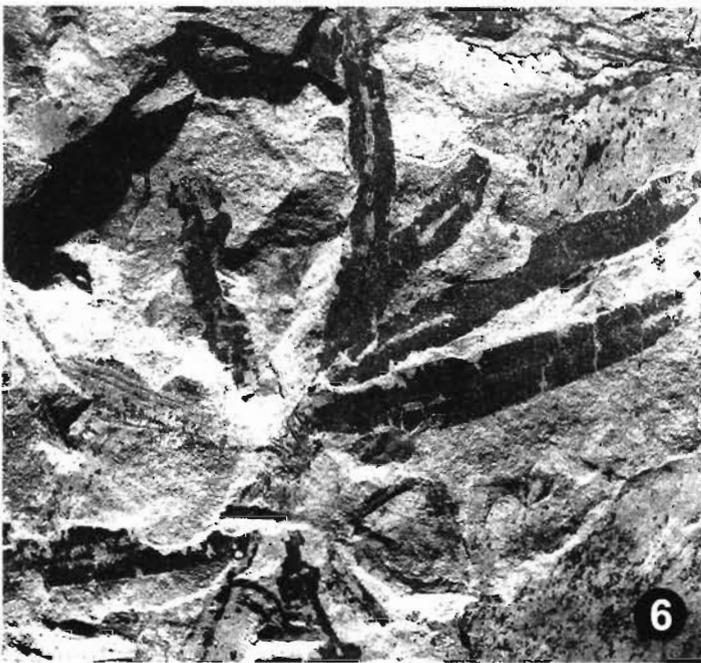
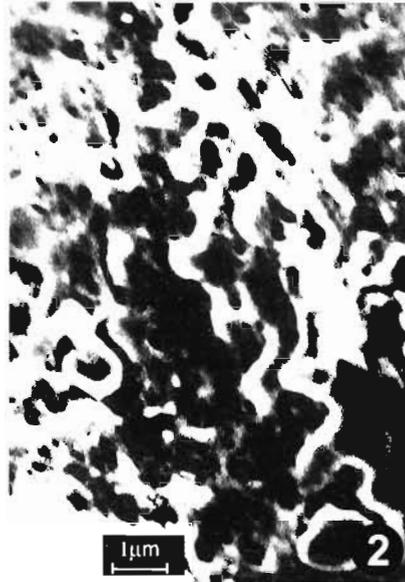
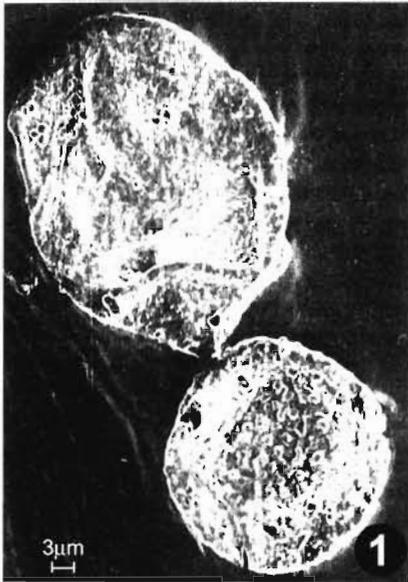


PLATE 3

*Sphenophyllum gondwanensis* Singh *et al.* (1987) with dentate and crenulate-smooth margined leaves and *Liknopetalon rajmahalensis* described in the present paper, the Permian strata in Rajmahal Basin appear to be floristically equivalent with those of Middle Ecce Series of South Africa wherefrom too a dentate and entire to crenulate leaved forms of *Sphenophyllum*, viz., *S. mesoeccaense* and *S. hamanskraalense* are reported along with *Liknopetalon enigmata* by Anderson & Anderson (1985). These strata also appear to be comparable with those exposed in a ravine section near Mamal Village in Kashmir Himalaya wherefrom dentate and crenulate leaved species of *Sphenophyllum*, viz., *S. thonii* var. *archangelskyii* and *S. thonii* var. *waltonii* have been described along with *Vinaykumaria indica* (adjudged here as similar to vegetative twigs of *Liknopetalon rajmahalensis*) by Pant *et al.* (1984) and Pant & Srivastava (1991).

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## PLATE 3

*Liknopetalon rajmahalensis* sp. nov.

1. Two spores from the same sporangium under SEM, one large and other small, showing muri of reticulate exine ornamentation. x 1000.
2. Pits on the surface of luminae under SEM. x 75000.
3. A spore showing trilete mark on the proximal face under SEM. x 1300.

*Lelstotheca harikrishnae* sp. nov.

4. An axis with three whorls of lanceolate-linear leaves, each with a midvein. Holotype Specimen No. B/R 160. x 2.5.
5. Fragments of two axes, one with two incomplete whorls of leaves and the other with a single incomplete whorl. Specimen No. B/R 161. x 2.
6. A fragment of axis with six-leaved whorl. Note the prominent midveins of the lanceolate-linear leaves. Specimen No. B/R 162. x 2.5.