FURTHER OBSERVATIONS ON *STELLOTHECA ROBUSTA* SURANGE AND PRAKASH

P. K. MAITHY & J. MANDAL

Birbal Sahni Institute of Palaeobotany, Lucknow-226007, India

ABSTRACT

The present paper deals in detail the morphology of *Stellotheca robusta* with remarks on the habit and affinities with related genera. The study demonstrates that the leaves in the whorl are distinctly free up to the base.

INTRODUCTION

SURANGE and Prakash (1962) transferred the forms earlier described under *Phyllotheca robusta* by Feistmantel (1880) under a new genus *Stellotheca*, because the forms do not confirm with the generic circumscription of *Phyllotheca*. The forms are characterized with robust looking verticillate leaf whorls borne on articulated stem. Leaves only united at the base; the free segments are linear, 8 to 14 in number and spread out horizontally like a star. Rigby (1966a) reported *Stellotheca* in organic connection with the *Paracalamites* type of stem from the New South Wales of Australia. Maheshwari (1972) rejected the name *Stellotheca* as it was an orthographic variant of the earlier reported *Stellatheca* Danzé (1956) and proposed a new name *Lelstotheca* for the Indian Lower Gondwana forms.

The present work deals in detail with the morphological structure of *Stellotheca robusta* collected from the northern bank of Bansloi River, near the village Tattitola, Santhal Pargana, Bihar. The material is preserved in form of impressions or casts on ferruginous shales. Occasionally a thin carbonised crust is also preserved. This, in a cellular pull, is translucent, brown in colour and without any epidermal structure.

All the specimens figured in this paper are preserved at the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow.

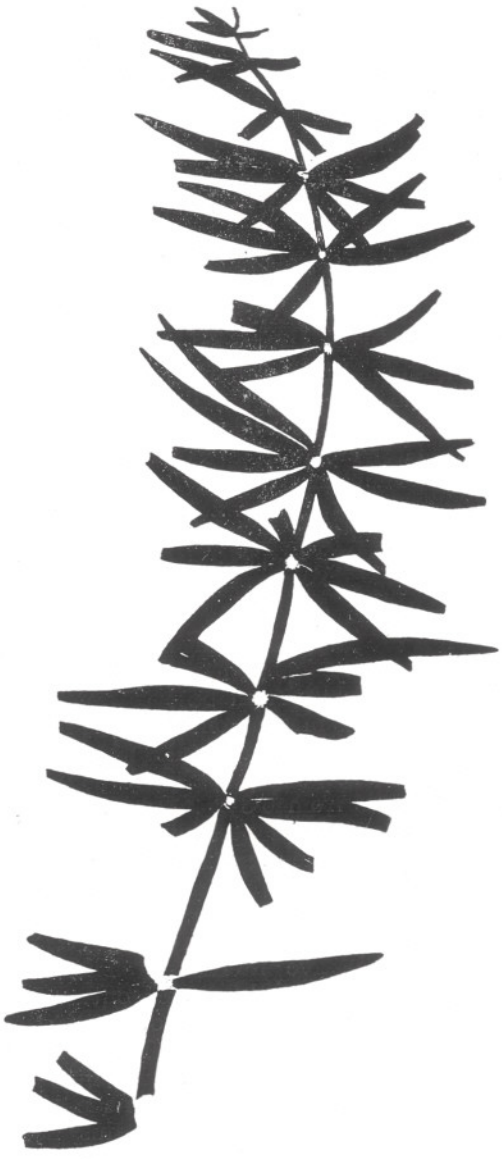
DESCRIPTION

Branch and Stem

Leafy shoots are slender in comparison to the large leaf whorls and have recorded maximum length of 11 cm. These branches are articulated with parallel running ribs and grooves, which occasionally are very faint. They are continuous at nodes (Pl. 1, fig. 1). The number of ribs ranges from 4 to 7 on the exposed surface. The branches are terete and possibly the central pith region was hollow in life. The distance in between two nodes varies from 4 to 22 mm. In the middle portion of the branch, the length of the internodes ranges from 10 to 13 mm. Generally, the length of internodes decrease gradually from base to apex, but some internodes may become short in length in between the long internodes. The width of the internodes in flattened condition usually varies from 0·8 to 2·2 mm. But in one specimen, which possibly be the basal part of plant, the axis reaches 3 mm in width. There is no leaf in the last node of this branch (Text-fig. 2B). The nodes are swollen and have 0·2-1 mm more in width than the respective internodes. The internodes are often slightly curved outward.

There is one specimen in our collection which appears to be branched (Text-fig. 2A). A slender leafy shoot found lying near the stem and extends upto the node. The main shoot is absent beyond this node. Whether the slender shoot is attached at the node is not sure because the possible attachment point is covered by an abaxially preserved upward directed leaf. But if this become a branch, then it has come up from upper side of the whorl. The width of the branch is 1·5-1·8 mm which is nearly half of the diameter of stem. Except the variation in the width of branch, the length of internodes and the length, width and the number of leaves per whorl in both branches and main stem remain the same.

Occasionally a large number of leafless articulated stems occur in association with



TEXT-FIG . 1 — A shoot having 12 leaf whorls × Nat. size.

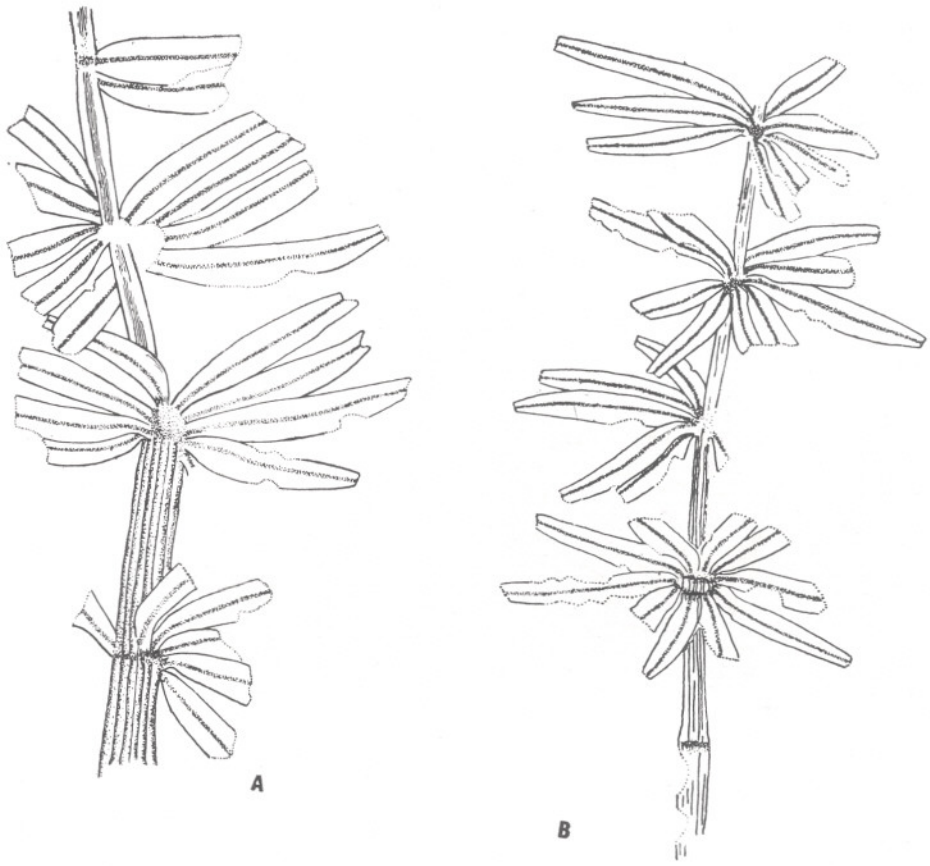
S. robusta. These stems are preserved as impression or cast with longitudinal rows of parallel running stout ribs and furrows. The ribs are always continuous in the next internode (Pl. 2, figs. 7, 9). The fragmentary stems have various length ranging upto 9 cm and the maximum number of nodes are five. The length of internodes varies from 9-20 mm. Stems are continuous on both the sides and the nodes are not swollen. The width ranges from 8-20 mm. The ribs on the stems are broad about 0·8-1·2 mm and almost double in width than the corresponding furrows. In one specimen, there occurs two oval depression on two nodes, which appear to be a branch scar (Pl. 2, fig. 9). A cast, possibly be the pith cast, is very nicely preserved. Ribs are 12 in number and the thickness of the cast is 1 mm.

Such articulated stems are frequently found in Gondwanaland. These stems are very similar in morphology and have been assigned in past to *Phyllotheca* or *Schizoneura*. Seward (1898) and Surange (1955) pointed out that in cast state it is extremely difficult to distinguish them. However, Rigby (1966a) proposed that " unidentifiable stem fragment, frequently referred to *Phyllotheca* sp., *P. deliquescens*, *Schizoneura* sp. from the Lower Gondwana deposits should be described as *Paracalamites* sp. — " the genus created by Zalessky (1918).

LEAF

Leaves are borne at nodes in a whorl. All the leaves in a whorl are arranged in the form of a star, except the young leaves which are ascending (Pl. 2, fig. 5; Text-fig. 3A). The whorls are oval (Text-fig. 3B) to circular in outline (Text-fig. 3C). The apical portions of the mature leaves are slightly turned upward. The number of leaves per whorl varies from 2-12, the number 10 being the most common. However, Feistmantel (1880) has recorded 14 leaves in some whorls. The leaves decrease in number and size towards the apex but the shape remains almost same. They are linear-lanceolate to lanceolate, sessile, acute with entire margin. Young leaves are always lanceolate. Rarely the leaves are preserved upto apex and possibly their length varies in a whorl. The length varies from 7-31 mm while the width measures 1-3·1 mm at the broadest point.

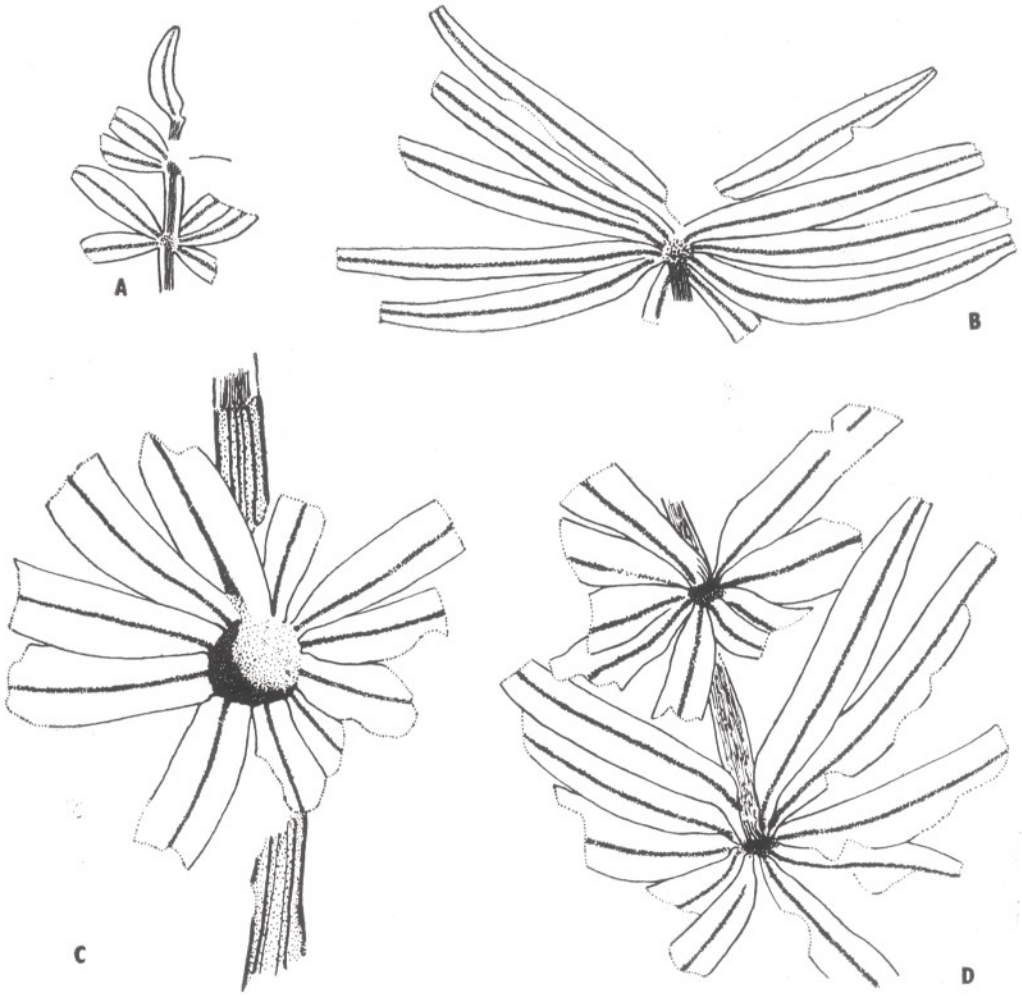
Most of the adaxially preserved whorls in top view show a small cup-like depression and the leaves appear to be united at the base for a short distance. The depth of the depressions are not more than 1 mm in height and also not uniform in all the way round (Pl. 1, fig. 3; Text-fig. 3C). But



TEXT-FIG. 2 — **A,** a specimen showing possible branching of the stem × 2. **B,** a shoot with four leaf whorls and without any leaf at the last node × 2.

on the other hand, the abaxially preserved whorls distinctly show that the leaves are free right upto the point of attachment at the base (Pl. 1, figs. 2, 4; Text-fig. 3D). The pseudo union of leaves is observed because the leaves overlap right from base to a varying distance of its length. The basal portion of leaves run parallel upto 1 mm with the stem and then spread out horizontally. Surange and Prakash (1962) have mentioned that the leaf segments are only united at the base, but in fact the parallel running portion of leaves with stem give such appearance from the adaxial surface and the overlapped parallel running portion of leaves are unable to spread fully during preservation, hence they appear as cup-like depressions. The free nature of leaves also supported by (i) overlapping of leaves and (ii) detachment of single leaf (rarely) from a whorl (Pl. 1, fig. 4 — last node). Furthermore, the young leaves are always free up to base (Pl. 2, fig. 5; Text-fig. 3A), which can be demonstrated from the adaxial surface.

The narrow base of leaf broadens slightly upward, about 2-3 mm away from the base and then gradually decreases in width leading to the acute apex. However, the young leaves are broadest near mid-region. Each leaf is traversed by a strong and prominent midrib extending upto apex. The vein is raised on the abaxial surface of lamina and sometimes there appears a furrow along the line of vein on the adaxial surface. The



TEXT-FIG. 3 — **A,** a branch showing young ascending leaves and free leaves × 3. **B,** a large oval leaf whorl × 2. **C,** adaxially preserved whorl showing cup-like depression of unequal depth from top view × 3. **D,** abaxially preserved whorls showing free leaves × 3.

width of the vein ranges from 0·2-0·5 mm at the proximal end of the leaves. Occasionally the vein is marked by white stain. The specimens, where internodal striations are distinct upto nodes show that each vein is connected with a striation. But at present we fail to confirm the observation in want of well-preserved specimens.

Most of the leaves show marking of the anastomosing network transverse to the vein (Pl. 2, fig. 8). This thickening-like structure occurs on both the surfaces throughout the lamina on either side of the vein and they run nearly parallel to each other. Towards margin they become slightly ascending and less prominent than the vein region. There are about 14-16 thickenings for each 1 mm along the vein.

The nature of these striations are debatable since long. This type of structure is reported in *Annularia, Asterophyllites, Raniganjia, Umbellaphyllites, Carpannularia* and *Phyllotheca*. However, Pant and Kidwai (1968) remarked that typical species of *Phyllotheca* do not have transverse striations. Surange and Prakash (1962) noted the presence of these striae and mentioned as lithological character. In our study we have

observed the presence of these striae in most of the leaves except in young and ill preserved ones. So it is very difficult to consider them merely as lithological character. Stürr (1887) and Elias (1931) described them ' as due to the presence of hairs or bristles or scales '. Elias (1931) also commented that " nevertheless these striae are not equivalents of the veins or nerves, because they are so densely spaced that there is no room for soft tissue or parenchyma between the would be veins ". But the authors failed to recognize any significance of this structure. Walkom (1916) remarked that these transverse markings appear to be something more than a lithological character, but are not sufficiently definite to be regarded as venation. Walton (1936) and Abbott (1958) suggested that they were caused by some unexplained structure of cellular dimensions, possibly internal. Schmalhausen (1879), Zalessky (1918), Thomas (1911) and Neuburg (1964) suggested the nature, as lamellate mesophyll but they could even represent internal fibre or a transfusion tissue. Rigby (1966b) also hold view of ' lamellate mesophyll ' nature as in the leaf of *Umbellaphyllites*. Pant and Nautiyal (1967) regarded them as transversely placed internal fibre-like bands in the lamina of *Raniganjia*.

This type of fibres are only known in living gymnosperms, as in *Ephedra vulgaris*. Haberlandt (1914, p. 111) mentioned similar type of structures and stated " possibly the network of delicate external ridges which is so frequently developed on epidermal surface — usually owing to corrugation of the cuticle ".

We presume that these striae were internal fibre-like structures as in *Raniganjia*. With the presence of this structure it can be assumed that the plants experienced a warmer climate. The fibre-like bands were developed possibly to check the extra evaporation of water from the leaf.

DISCUSSION

In 1880, Feistmantel discovered two fragmentary leafy equisetalean shoots from the Lower Gondwana Formation of Rajmahal Hills, Bihar. According to him the stems were articulated and striated. Leaves were broad-lanceolate arranged in whorls and 10-14 per whorl. He also noted " . . . their bases are decurrent on internode, and from several of the whorls it appears that the bases of the leaves are jointed to a sheath, but the nature of this cannot be more closely stated . . .". While dealing with this species Arber (1905) stated " the union of the leaves into sheath, near their attachment to the node is not very obvious in the figure given by Feistmantel. If this plant is correctly assigned to the genus *Phyllotheca*, the comparatively broad character of the free segments easily distinguishes it from the other phyllothecas belonging to the Glossopteris flora ". The broad character of Arber — the free segments of *Phyllotheca robusta* have made many confusions among the workers and many of them have referred it to *Annularia*. Since the recorded specimens of *P. robusta* Feistmantel show distinct morphological features it was separated by Surange and Prakash (1962) under a new genus *Stellotheca*. They described the leaves as ' only united at the base '. The restudy shows that the leaves are free right upto the base. Hence, a emended diagnosis is given here.

Emended Generic Diagnosis

Leaf bearing branches slender, articulated and ribbed; ribs are continuous beyond the node (*Paracalamites*-type); leaves arranged in star-shaped whorls, free upto base without any union, fairly broad a little away from base and gradually narrowed to an acute apex; vein solitary, strong and extends upto apex.

Emended Specific Diagnosis

Leafy branches slender with robust looking verticillate leaf whorls; leaves linear-lanceolate to lanceolate, free upto base, 2-14 in number and spread out horizontally in a single plane like a star; transverse thickening-like structure on lamina; vein solitary, stout and extends upto apex.

Walkom (1922) said " there seems room for doubt as to whether *Phyllotheca* is the genus to which this species (*P. robusta*) should be referred. It seems more probable that it should be referred to *Annularia* ". According to Townrow (1955) *P. robusta* Feistmantel closely resembles *Annularia* and *Lobatoannularia*. However, the northern

genera *Annularia* and *Asterophyllites* agree closely to *Stellotheca*. *Annularia* has linear-lanceolate to lanceolate leaves which are arranged in whorl like a star but are united at the base. In *Asterophyllites*, leaves are free right upto base but differ from *Stellotheca* having needle-shaped leaves which are ascending, forming 60° angle with the stem. Thus, *Stellotheca* stands in between the above mentioned genera in leaf characters. The major difference from *Asterophyllites* and *Annularia* lies in fact that they are borne on calamitean stems whereas *Stellotheca* has *Paracalamites* type of stem.

The other articulate genera *Phyllotheca*, *Umbellaphyllites*, *Raniganjia* and *Annulina* also show some affinity with *Stellotheca*. *Stellotheca* differs from *Phyllotheca* by the robust looking whorls, slender stem and the absence of adpressed leaf sheath and the presence of transverse thickening-like structure on leaf. *Annulina* differs in having small, oblique, cup-like sheath. *Raniganjia* and *Umbellaphyllites* share many characters common with *Stellotheca*. Pant and Nautiyal (1967) compared *Raniganjia* with *Stellotheca* on the basis of minute or non-existent leaf sheath and the presence of transverse striae. On the basis of above mentioned characters *Umbellaphyllites* can also be compared with. But they are distinct in having large number of long leaves which unite most part of their length.

Halle (1927) described *Annularia*-type of leaves from China which differ from *Stellotheca* in possessing (i) leaves united for some distance, (ii) leaf whorls form gaps on lower portion, and (iii) leaves are shorter on the side of the gap. Moreover, the information regarding its stem is lacking. Halle's *Annularia* from the description and the figures appears to be similar to *Lobatoannularites*.

A large number of species are occasionally referred to *S. robusta*. Surange and Prakash (1962) mentioned Walkom's *Annularia stellata* (?), which Walkom thought to represent a similar type of *P. robusta*. The description of *A. stellata* (?) given by Walkom (1916) differs from *S. robusta* only by the union of leaves to form a narrow basal collar; they are upto 3 mm in breadth and 2 cm in length. But this description does not tally with the photograph given by him. Moreover, the 2 cm long basal collar seems to be a mistake in place of 2 mm. Even though it can be remarked that *A. stellata* (?) appears very close to *S. robusta* from the photograph.

Both Ethridge (1891) and Arber (1905) expressed same opinion regarding *Annularia* (?) *australis* Feistmantel which according to them "free, lanceolate segments approximate more closely to leaf whorls to certain Indian species of *Phyllotheca* (cf. *P. robusta*) than to *Annularia*." Rigby (1966a) however, merged *A. stellata* (?) Walkom and *Annularia* (?) *australis* Feistmantel with *S. robusta* Surange and Prakash.

Elias (1931) referred an Angara form *Phyllotheca stschurowskii* Schmalhausen which is comparable with *P. robusta* of India. The similarity was also noted by Feistmantel. Arber (1905) also remarked that "Schmalhausen's specimens are too imperfect to justify a correlation". While Elias (1931) was comparing this (*P. stschurowskii*) with *Annularia zalesskii* mentioned that "leaves have only longitudinal striations and have no transverse or feather-like striation. Furthermore, midvein is not very prominent." But the photographs (pl. 24, figs. 1, 3-6; pl. 25, figs. 5-7a; pl. 26, figs. 2, 4; pl. 38, fig. 2; pl. 53, figs. 1, 1a) of Zalessky's Atlas (1918) of the species clearly demonstrate the presence of transverse striations with prominent midrib. However, we could not recognize the longitudinal striations in the photograph of his holotype as mentioned by him. Boureau (1964) has transferred *Phyllotheca schstschurowskii* to *Stellotheca* as *S. schtschurowskii*. *S. schtschurowskii* differs from *S. robusta* (from photograph) having more linear and large number of long leaves (about 30 in a whorl). In some (young) branches, leaves are 8 in number and are lanceolate as in young branches of *S. robusta*. It may be pointed out that both Arber and Elias spelled *P. stschurowskii* wrongly for *P. schtschurowskii*.

Phyllotheca brookvalensis, a species described by Townrow (1955) can also be referred to *S. robusta*. Townrow doubtfully referred this species to *Phyllotheca*. Pant and Kidwai (1968) also noted this similarity on the basis of leaf sheath. The common character in between *P. brookvalensis* and *S. robusta* are (i) *Paracalamites* stem, (ii) width of swollen node, and (iii) number of leaves per whorl. The significant differences between them are (i) the length of leaf

which is more than double than the leaves of *S. robusta*, (ii) the absence of transverse striae, and (iii) extremely minute collar of tissues (about 0·2 mm wide). Thus *P. brookvalensis* Townrow could be a member of *Stellotheca*, which can only be said after examining the type specimen.

Rigby (1966a) drew attention on the similarity between *Annularia jerunakovensis* Neuberg and *P. robusta* of India. According to Neuberg (1948), *A. jerunakovensis* differs from Indian specimens by the absence of longitudinal striations on the surface of the leaf. According to Rigby (1966a) she had made wrong interpretation of Feistmantel's description. There are no such longitudinal striations on the leaves of Indian specimens. The striations have been described on the midrib region by Feistmantel (1880). Rigby (1966b) also mentioned similarity between *Stellotheca* and *Gamophyllites* Radczenko, but the latter differs in having cylindrical sheath.

In 1960, Archangelsky described *Annularia kurtzii* from Argentina. Rigby (1966a) emphasized the similarity between *A. kurtzii* and *S. robusta* on the basis of leaf shape. He stated that " illustrated leaves in whorls of *A. kurtzii* appear to be rigid whereas over half of the leaves in some whorls of *S. robusta* are so bent as to appear lax. *A. kurtzii* was borne on stems with ribs that alternated at internodes whereas ribs were opposite, i.e. in juxtaposition, on the stems of *S. robusta*."

Rigby (1966a) illustrated one isolated fragmentary whorl in the name of *Stellotheca* sp. He described the leaves as broad and did not taper gradually towards apex as in *S. robusta*. Moreover, the midrib is visible from ventral surface only. He was not sure about the leaf sheath and apex of leaf but only by analogy he put it in *Stellotheca*. It is very difficult to comment on this fragmentary specimen on the basis of photographs.

In 1969, Rigby commented that *Annularia americana* reported from Brazil was possibly a *Stellotheca*. At present there is no information, except one photograph given by Dolianiti (1948). From the illustration it can be said that *A. americana* compares morphologically with the young branches of *S. robusta*.

Walkom (1938) mentioned some affinities between *P. robusta* and *Annularites sinensis* Halle. But *A. sinensis* is very similar to *Lobatannularia* than *Stellotheca*.

Huard-Moine (1964) reported one ill preserved specimen from Rhodesia in the name of *Annularia* sp. He compared his specimen with *Annularia* cf. *pseudostellata* Potonié (see Halle, 1927, pl. 5, fig. 4). The Rhodesian specimen appears close to *Stellotheca* except the shape of the leaf which seems to be uniformly broad at the basal region and nature of attachment of leaves at the node. In 1966, Lacey and Huard-Moine reported *Annularia* sp. (? *Stellotheca* sp.) and remarked that though the specimen, tentatively assigned to the genus *Annularia*, agrees very much with *Stellotheca*. In the end they concluded that " if the leaves of the present specimen could be shown to be united at the base, it would certainly be referred to *S. robusta* (Feistmantel) Surange and Prakash ". From their photograph it is not possible to examine the nature of leaves at the point of attachment on the node. The length and breadth of leaf and the number of leaves in a whorl agrees with our specimens representing the middle-apical part of shoot.

Habit

Rigby (1966a) stated that " the branching is decussate, two branches arise at each node. Except in one specimen, branches are unbranched ". Townrow (1955) mentioned that there were no leaf in the nodes of basal region. A few of our specimens also support this finding. The internodes have almost same length and width as the above leafy portion and nodes are swollen.

Rigby (1966a) said " the most likely reconstruction would be identical with branches of *Calamites carinatus* Sternburg, particularly the one shown by Krystofovich (1957, text-fig. 156) or the ultimate branches shown by Hirmer (1927, fig. 537)." But we think different from that reconstruction though morphologically they may look similar. *Stellotheca* differs with that reconstruction by the following characters (i) plant is not very robust, (ii) branches are not more than two per node, (iii) branches are opposite, (iv) branches arise at 40°-45° from the stem, (v) leaves at the node from where branches appear spreading and not ascending, and (vi) branches rarely bifurcate

once. Therefore we presume that the plants were erect herbaceous in nature.

Rigby (1969) while drawing the Lower Gondwana scene, has shown that *Stellotheca*, *Raniganjia* and *Umbellaphyllites* were growing in water and along the shore too. We do not think that this plant was of aquatic habit, because it shows (i) stout, erect stem, (ii) the stem appears to be woody, (iii) thick leaves nearly coriaceous, (iv) stout vein, and (v) transverse thickening on the leaves. Most probably the plant was growing in land in dry conditions.

Affinities

Stellotheca with its free uninerved leaves and without any sheath form a unique group. So far no other group of plants can be mentioned having such combination of characters. The whorled linear-lanceolate leaves of *Raniganjia* with single median vein and minute or non-existent leaf sheath indicated possible affinity with *Stellotheca*. Furthermore, the presence of transverse thickening-like structure in both the genera is also important. But *Raniganjia* differs by the fusion of leaves for most part of their length.

On the basis of free nature of leaf, *Trizygia* and its allied genera indicate relationship with *Stellotheca*. The *Trizygia* group of plants having constant number of leaf throughout the plant and the broad leaves with large number of dichotomizing vein precludes the possibility of both of them being member of the same phyletic series.

However, it can be said on the basis of gross morphological features that *Raniganjia* and *Stellotheca* could be the member of same stock and developed independently from their very inception.

Nomenclature — Maheshwari (1972) rejected the name *Stellotheca* Surange & Prakash and proposed a new name *Lelstotheca* considering the name homonym to *Stellatheca* Danzé, 1956. According to article 64 of International Code of Botanical Nomenclature (1966, p. 5) " A name is illegitimate and must be rejected if it is a later homonym, that is, if it is spelled exactly like a name previously and validly published for a taxon of same rank based on different types ". In accordance to this the name *Stellotheca* cannot be rejected because it has a different spelling from *Stellatheca*. Moreover, the former genus has been proposed for arthrophytes and the later genus for ? osmundaceous fertile frond.

In article 75, " when two or more generic names are so similar that they are likely to be confused, because they are applied to related taxa or for any other reason they are to be treated as variants, which are homonym, when they are based on different types ". Further it has been clarified such names should not be confused: *Symphyostemon* and *Symphostemon*. According to this article it is clear that no confusion exists in between two generic names because both of them have been used for two entirely different taxa. Therefore, there seems no justification for the institution of a new name for *Stellotheca*, which has been widely used by different workers. Hence, we propose to continue the use of name *Stellotheca* for the Lower Gondwana *Annularia*-like forms.

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*Not seen the original.

EXPLANATION OF PLATES

Stellotheca robusta Surange & Prakash emend.

PLATE 1

1. A part of stem showing continuous nature of ridges and grooves. × 3; No. 40/474.

2, 4. Abaxially preserved leaf whorls showing leaves free upto base. × 3; No. 35270.

3. An adaxially preserved leaf whorl shows cup-like depression from top view. × 3; No. 35270.

PLATE 2

5. A small branch showing ascending young leaves and their free nature. × 6; No. 35271.

6. Three abaxially preserved leaf whorls showing the nature of leaves. Two leaves at the lower whorl detached from the whorl. × 2; No. 35270.

7. A slender stem with opposite ridges and grooves at the internodes. × 2; No. 35273.

8. A part of leaf whorl showing thickening-like structure transverse to the stout veins. × 4; No. 40/474.

9. A broad stem showing two possible branch scar like depressions. × 2; No. 35274.

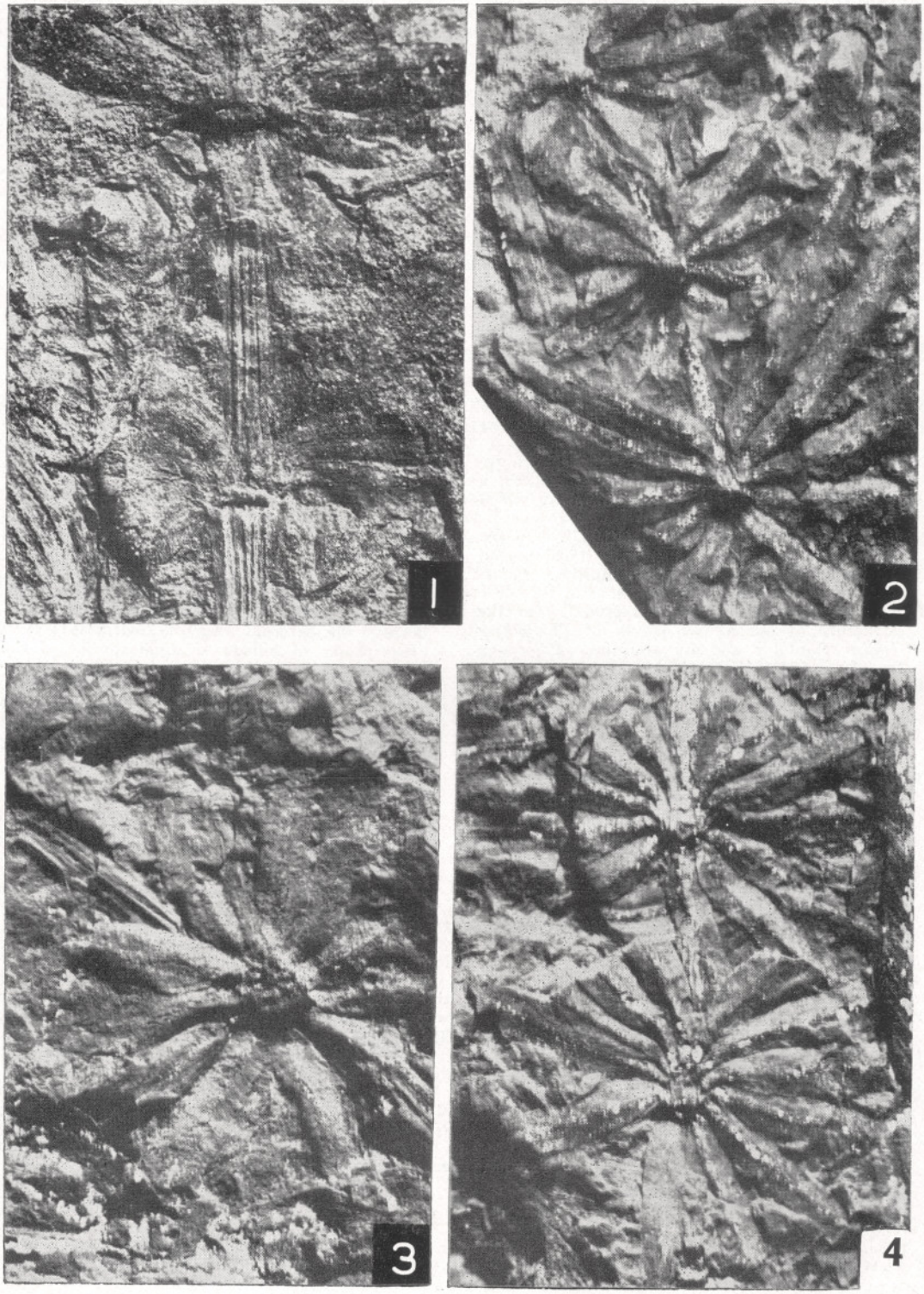
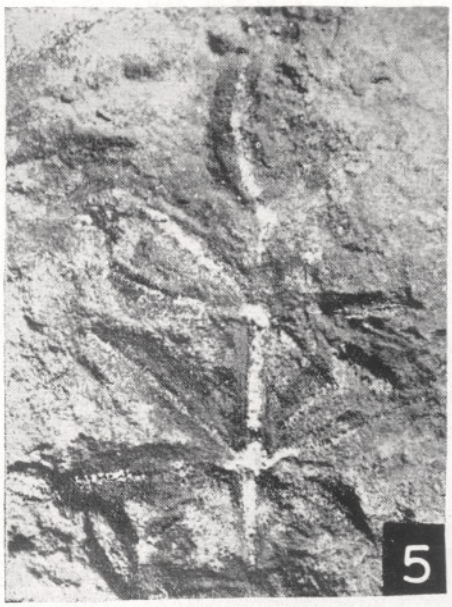


PLATE 1



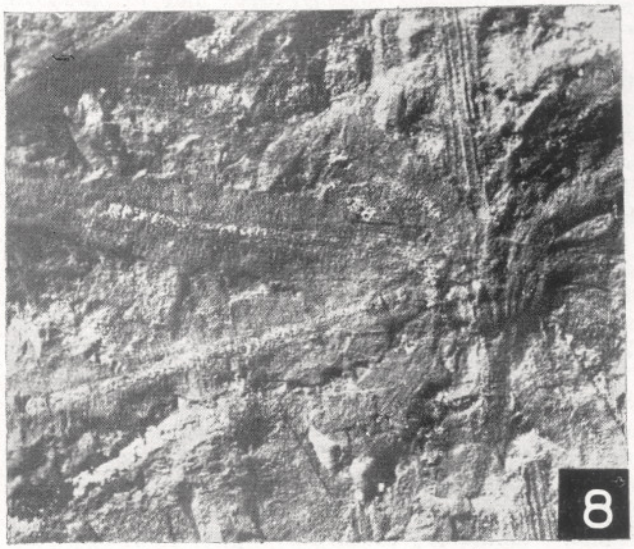


PLATE 2