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ON *NEUROPHYLLUM KOREANICUM* GEN. ET SP. NOV. FROM THE LOWER PERMIAN BEDS OF NORTHERN TYÔSEN (KOREA)

By

Enzô KON'NO

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I. Introduction

This paper[1] describes a strange plant belonging to the class ARTICULATAE, collected from the Zidô Series in the western marginal region of the Heizyô coal-field, northern Tyôsen.

I wish to express here my hearty thanks to Profs. T. KATO and T. KOBAYASHI and Dr. Y. OTUKA, all of the Geological Institute of the Imperial University, Tôkyô; Prof. S. NAKAMURA and Mr. N. KOBATAKE of the Geol. Inst. of the Imp. Univ., Kyôto; Prof. K. SUGI and Assistant Prof. T. MATUMOTO of the Geol. Inst. of the Imp. Univ., Kyūsyū; Prof. S. OISHI of the Geol. Inst. of the Imp. Univ., Hokkaidô, and others, who so kindly extended me numerous facilities and made helpful suggestion in connexion with the present study. The writer is also greatly indebted to Prof. G. KOIDZUMI of the Botanical Inst. of the Imp. Univ., Kyôto; Profs. A. SEWARD, W. J. JONGMANS, T. G. HALLE, M. HIRMER, and other foreign authorities on palaeobotany, for much information derived from a perusal of their valuable works.

II. Diagnosis, and Remarks on Genus *Neurophyllum* nov.

Genotype:—*Neurophyllum koreanicum* gen. et sp. nov.

Generic Definition:—Axis regularly articulated. Surface of in-

* Dedicated to the memory of the late S. KAWASAKI, the former Director of the Geological Survey, Government-General of Tyôsen.

[1] 本研究及び其の出版の費用の一部は文部省自然科學研究奬勵金による,特記して謝意を表す.

ternode traversed by fairly distinct ribs and grooves, which do not alternate at nodes, but run straight on from one internode to the next. Leaves broadly linear in form, borne in whorl at node, more than four times as long as internode, separated from base, and not fused into sheath, with lamina traversed by several parallel veins which are simple throughout their whole course. Branch inserted in the axil of leaf-segment, immediately above node. Strobilus bears alternating whorls of long sterile bracts and compound sporangiophore-complexes, each of the latter consisting of numerous sporangiophores. Each sporangiophore bears four ovoid sporangia, grouped around their common circular attaching center.

Remarks:—The new genus resembles, to some degree, *Asterocalamites* SCHIMPER on the one hand and *Phyllotheca* BRONGNIART on the other, but the former differs from the latter two in the following characters: the leaf-segment is usually traversed by several veins which are always simple and never forked; the strobilus consists of alternating whorls of long sterile bracts and sporangiophore-complexes, the latter of which is composed of more than 10 sporangiophores.

III. Description of *Neurophyllum koreanicum* gen. et sp. nov., and Remarks

Specific Definition:—Plant herbaceous. Stem hollow, comparatively slender, divided regularly into nodes and internodes. Surface of internodes traversed by ridges and shallow grooves which do not alternate in successive internodes, but run straight on through the nodes. Leaf broadly linear in form, traversed apparently by three parallel veins, each of which is persistent and simple throughout its whole length. Leaves more than four times as long as internode, about 14 in each whorl, equal in form as well as in size, separated from base and not fused into sheath, attached obliquely to and given off in all direction from node. Primary branches emerge from immediately above node, attached obliquely to stem and arranged in whorl at every node of axis; both axis and leaves of each branch repeat, though in smaller size, almost all the characters of those of stem. Strobilus long and narrow, contracted at base, inserted laterally and obliquely to that stem which bears vegetative branches and leaves. Axis of cone bears

regularly alternating whorls of long sterile bracts and sporangiophore-complexes. Each sporangiophore-complex composed of intimate groupings of more than 10 sporangiophores, each of which bears 4 ovoid sporangia around their common circular attaching center.

Type specimen: shown in Fig. 1, Pl. I, which is to be preserved in the museum of the Geol. Instit. Kyūsyū Imp. University, Hukuoka-si, Japan.

Locality: Anzyô-ri(2), Daidô District, South Heian-dô, Tyôsen.

Geological formation and age: Zidô Series, Lower Permian.

Results of numerical measurements and general descriptions of individual specimens shown in the annexed plates:

The specimen shown in Fig. 1, Pl. I is the type specimen of this new species and, consequently, that of the present new genus. The main axis, most probably the main stem, attains to more than 75 mm in length, with breadth at node measuring 5.5 mm in the lower and 3.0 mm in its upper region. This axis is divided into 18 internodes in all, each 4 mm long in its proximal and 3.25 mm long in its distal part. The surface of the internode is usually traversed by about 7 broad rigdes. The leaf-segment, lying on the left side of the lowermost node of this axis, is more than 27 mm long, about 1.5 mm broad at base, and about 2 mm wide near its middle, and inserted at about half a right angle into the axis. Each leaf is traversed by comparatively fine parallel veins, of which there are usually 3, as a rule about 0.7 mm apart from one another, and slightly covergent toward the base. A primary branch is seen in this specimen, being preserved as it was originally connected to the stem at its lowermost node, arising immediately above the nodal line at an angle of about 35° from the stem. Its axis is more than 27 mm long and about 2 mm broad, divided into many internodes, each of which usually attains to 3.5 mm in length, while in both the basal and apical regions, they measure only about 2.5 mm. The surface of the internode is also regularly ribbed, there being seen about 7 ribs on the fossil surface. The secondary leaves are abundantly preserved in this specimen; each about 10 mm long, with a broadly linear lamina, having the ap-

(2) 朝鮮平安南道大同郡安靜里.

pearance of a slight dentation at the apical margin. A linear strobilus is attached to the stem of this type specimen at an angle of about 25°. It is narrow linear in form with a suddenly contracted base, about 7 mm wide at its broadest and more than 30 mm long, and covered more or less densely with numerous linear sterile bracts of more than 6.5 mm long.

In the specimen shown in Fig. 2, Pl. I, as much as 47 mm of the axis is preserved, and this is divided into 6 internodes, all of which are nearly equal in length, measuring about 8 mm, with 1.3 mm breadth at node. The leaves are linear, about 35 mm long and 2 mm broad, that lying on the left side of the lowermost nodal line being given off at an angle of about 40° from the axis. There are usually 3 veins in each leaf, comparatively fine, but well-marked, from 0.08 to 0.1 mm across on the fossil surface, usually 0.5 mm apart from one another, and slightly convergent toward both ends, but more gradually toward the apical one than the basal. The lamina is generally entire, at any rate for the largest part of it, although very rarely showing some traces of shallow longitudinal splitting, most probably of secondary mechanical origin, not primary.

The specimen shown in Fig. 3, Pl. I is an example of a thick shoot with an axis attainning to about 9 mm in breadth, traveresed by from 8 to 9 longitudinal ribs. Although this axis contains 3 internodes, it is only the central one that shows a full internodal length, mearing about 8 mm. In the upper region of this specimen we find preserved several leaf-segments attached directly to the nodal line, each of which is only 1 mm broad at the base, and evidently traversed by 3 veins, showing very clearly one of their characteristics, which is that the vein is always simple even at the very base of lamina.

Fig. 4, Pl. I shows an imperfect specimen of an axis bearing 2 characteristic leaf-segments on its right side. The axis is more than 70 mm long and 4.5 mm broad. It divides into many internodes, each measuring usually from 7 to 8 mm in length.

Although the specimen shown in Fig. 5, Pl. I is also very poorly preserved, it also still retains several characteristic leaf-segments, which most probably represent those of the secondary order. Such secondary leaves are seen in the lower region of the specimen, being preserved tightly appressed upon the axis, which last is

about 6 mm broad with a length of more than 70 mm, divided into 5 internodes, each attainning to from 11.5 mm to 13.0 mm in length.

Some detailed observations and remarks on individual organs:

1). Axis.—What seems to claim our first attention is that in the type specimen, the internodes of the stem as well as those of the primary branch are very short, compared with those of all the other specimens. Actual measurements of the internode follow:

No. of specimens shown in Pl. 1		Breadth (mm)	Length (mm)
Fig. 1	Stem	3.0–5.5	3.25–4.0
	Primary branch	2.0	2.5 –4.0
Fig. 2a		1.3	8.0
Fig. 3		9.0	8.0
Fig. 4		4.5	7.0 –8.0
Fig. 5		6.0	10.0 –11.5

Except in the type specimen, the axis of the present species may be said to have an internode of from 7 to 8 mm long in general, attainning sometimes to as much as 11.5 mm, while its breadth varies widely between 1.3 and 9.0 mm, whence it follows that the internode of this type specimen must be regarded as representing a special case of this plant. As will be described later, the sporangia in the cone attached to this type specimen are exceptionally small, their longer diameter being only 1/6 mm or less. Moreover, in the primary branch of the same specimen, its secondary leaf-segments are inserted crowdedly and highly inclined to the axis, with an appearance that suggests some bud stage of this branch. In view of all these fact, this type specimen appears to represent an example of a shoot in its very young stage of development.

On the surfaces of some of the internodes, such, for example, as in the specimen shown in Fig. 5, Pl. I are often seen innumerable very fine longitudinal striations, separated by only from 1/20 to 1/30 mm and less from one another. These fine striations remind us at once similar surface ornamentations on the epidermis of the axis of the recent *Equisetum*. Upon examining fossil internodes under the highest possible magnification, I found there numerous highly elongated polygonal meshes of various sizes with their walls nearly

straight and their elongation-direction strictly parallel to one another, but could find no such special meshes as would suggest the presence of stomata on the axis. Undoubtedly, these internodes with their characteristic striations exhibit the true characters of the natural surface of the axis of the present species, thus indicating that the grooves on the internode were not so deep in our present axis as in that of the recent *Equisetum hymale* L. In some internode, however, such, for example, as those near the the base of the cone in the type specimen, the grooves are often very deep and the ridges highly projected, and with the breadth of the former almost equal to that of the latter. Since these deeply grooved internodes do not show any trace of such fine longitudinal striations as seen in the specimen just mentioned, they might suggest some inner features, probably below the epidermal layer of the axis. It is also notable that in all the specimens now in hand, the axes are always preserved in a very flattened state and actually provided with flattened hollows at some nodes, suggesting the hollowness and the absence of the solid massive core of wood inside them.

2). The vegetative leaf.—We shall examine first the venation, which is one of the most important characteristics of the present species. There occur, in each leaf, usually 3 parallel veins that are simple and all of the same thickness. Each single vein is relatively fine, from 0.1 to 0.05 mm across on the fossil surface, and much thinner than those in any single-veined leaf of *Annularia*, *Asterophyllites*, *Neocalamites*, *Equisetites*, and the allies of Equisetales. It is known that there occur in some fossil leaves of certain Equisetinean plants, a number of longititudinal striations in place of the midrib, as seen, for example, in *Asterophyllites longifolius* STERNBERG Forma *striata* WEISS sp.[3], *Neocalamites hoerensis* (SCHIMPER), and others. As a matter of fact, as mentioned in my previous paper[4], in *Neocalamites hoerensis* from the Korean Mesozoic, a thick midrib is seen in leaves of good preservation, while in many of their cast it is replaced by numerous fine longitudinal striations, the midrib being quite invisible.

[3] JONGMANS, W. J., Anleitung zur Bestimmung der Karbonpflanzen West-Europas. Bd. 1, 1911: pp. 222–224.

[4] KON'NO, E., A new *Chiropteris* and other fossil plants from the Heian System, Korea. Jap. Jour. Geol. Geogr., Vol. XVI, Nos. 1–2, 1939: p. 112.

That is to say, in this Korean *Neocalamites*, these fine striations on the lamina are nothing more than mere surface ornamentations, most probably of the epidermis of the leaf. The vein of our present leaf is much thicker, more regular in its course, and more clearly defined than in those striations just mentioned. Moreover, in our leaf also, such longitudinal striations are often visible, although they are finer and more crowded together (usually separated by 0.05 mm or slightly less) than those in both *Asterophyllites longifolius* and *Neocalamites hoerensis* from Korea. Thus the vein in our leaf must be the true vein, corresponding to the vascular bundle of the leaf. All the 3 veins of the leaf are clearly seen under the microscope to be quite simple, even in the proximal region of the lamina.

In the lobes of *Schizoneura*, consisting of many linear uninerved leaf-segments, there is usually one suture line[5][6][7] in the lamina between every two true veins. No such suture line occurs in our present leaf, as will be seen also from the fact that its lamina does not show any profound splitting in usual.

We must determine next the number of leaf-segments that were naturally grouped together in a whorl at each node. None of the specimens now in hand are sufficiently well preserved to enable us to do so, by means of the leaves actually preserved in them. As will be fully described later, the number of leaf-segments at one node appears to agree with the branches at that node, it being possible to count the latter by means of their basal casts lefts on the axis, with the result that each leaf-whorl in the type specimen must have had about 14 leaf-segments altogether. It is also certain that these leaf-segments in a whorl were arranged not in a plane, but on the surface of an inverted cone around the shoot-axis, and that they were not fused into any sheath-like form, but separated entirely from one another even in their proximal regions. Besides, there is nothing to show that leaf-segments in a whorl were not the same in form as well as in size.

3). Branches and branching habit.—As just said, there is

[5] Feistmantel, O., The fossil flora of the Gondwana System, III, 2, Mem. Geol. Surv. India, (Ser. XII.) Vol. III, 1881: p. 59, Pls. 1A-xA.

[6] Schimper, W. P., Traité de Paléontologie végétale. Vol. I, 1869: pp. 280, 281 Atlas, Pl. XIV.

[7] Kawasaki, S. and Kon'no, E., The Flora of the Heian System Pt. 3. Bull. Geol. Surv. Chosen, Vol. VI, No. 3, 1932: pp. 33, 34. Figs. 14-17.

preserved in the type specimen a primary branch in it original connexion with the stem, and since this branch measures only 2 mm across on the fossil surface, it may be said to be exceedingly narrow, compared with the stem on which it sits. Upon examining the basal end of this branch with a microscope, we find a circular diaphragm-like impression left on the stem. As many as 14 similar branch-scars are observable, arranged in a whorl just above the nodal line, whence this primary branch gives off. It is surprising to find that, in the type specimen, similar whorls of branch-scars are recognizable at every node of the stem. The branch-scar, which as a rule very complex in structure, and measures about 2 mm in diameter, usually consists of two parts, the one the central circular depression with numerous radiant spokes and the other the peripheral elevated ring. Closer examination of this peripheral elevated part showed that it consists of many rounded knobs of from 0.3 to 0.5 mm in diameter, grouped in intimate contact with one another, and that in each of these 0.3–0.5 mm scars the central depression is surrounded by numerous still finer circular scars (generally of 0.05 mm in diameter) around it. These scars of from 0.3 to 0.5 mm diameter are believed to be the basal scars of the secondary branches of this shoot, because scars similar to them in form as well as in size are also visible very clearly at every node of the primary branch, actually preserved in the type specimen. Moreover, around each scar of these secondary branches, we find numerous hair-like organs given off in all directions, which strongly suggest the presence there tertiary leaf-segments. Similar characters in the nodal region are observable always at every node of the axes of all the other specimen besides the type specimen. In that shown in Fig. 2a, Pl. I, for example, the main axis bears a whorl of branch-scars of from 0.7 to 1.0 mm diameter, each having more than 10 still finer round scars of from 0.7 to 1.0 mm diameter. These scar in Fig. 2a, Pl. I, therefore, of the primary as well as of the secondary order of dimentions, are slightly smaller in size, compared with those of the type specimen. In the specimen shown in Fig, 3, Pl. I, the larger branch-scars attain to about 1.5 mm in diameter, and the smaller ones usually to about 0.5 mm. It is difficult to ascertain by examining the fossil surface alone, whether these branch-scars of the successive nodes are arranged in vertical rows in super-

position or in alternation, although it is most probably the former. There is no doubt that since each branch-scars is disposed in each axil of the leaf-segment, the branches must have corresponded in both number and position on the axis to the leaves at each node. To see all as a whole, the stem must have been upright in nature, monopodial, repeatedly branched, with whorls of both long-developed leaf-segments and branches at each node, every branch being inserted in the axil of the leaf-segment.

4). Strobilus.—Although there is only one example of the cone now in hand, its original connexion to the stem is fortunately preserved, together with various vegetative organs. As most of them are preserved as casts, it was not possible to separate the cone substance from the matrix in order to prepare it for the microscope. As, however, the rock-matrix is very fine, some of the detailed features of the cone could be made out by examining the fossil surface under magnifications of 20, 62, and more in strong reflected light. This cone is evidently inserted laterally to the stem, replacing the sterile primary branch at the node. Since the cone-base lies very near the node, there is no doubt that it was attached to the stem either in sessil or by a very short pedicel. As to which of these two methods of attachment was actually the case, it is hardly possible to tell, although most probably it was the latter. The strobilus consists of crowded, alternating whorls of long linear bracts and of semi-spherical sporangiophore-complexes. About 20 sporangiophore-complexes are seen arranged in a lateral row in the main part of its fossil surface, so that there must have been about 40 of them in a whorl encircling the cone-axis. Each sporangiophore-complex measures from 0.7 to 0.8 mm in diameter, consisting of more than 10 sporangiophores in a group. A sporangiophore bears 4 sporangia, grouped together around a common circular attaching center, from which common center radiate numerous simple veins covering the whole surface (probably the upper one) of these 4 sporangia in a group. The sporangium is either obovate or oblong in shape, with its longer diameter of from 1/7 to 1/6 mm. The surface of the individual sporangium is often seen to be divided into several concertric areas, the one the certral oblong or circular area and the others the concentric rings surrounding the first. Besides, each of these peripheral ring-formed area is frequently seen clearly divided by

many transverse walls into numerous minute rectangular sections. These surface ornamentations of the sporangium seem to represent the cell-structure of the outermost layer of its sporangial wall. It is evident that our present sporangiophore does not show such a thick pelta at its upper end as that commonly seen in most Equisetacean cones. There are, however, as described above, numerous radiant veins covering the 4 sporangia in a group, these radiant veins appearing strongly to suggest that there might have been a very thin (neither thick nor of special shape) peltate lamina also in our present sporangiophore, the lamina of which was wasted away by subsequent decay, leaving only its tissues behind.

A fact that seems to be worth our special notice, is that the sporangium in this cone is always too small in size, usually from 1/7 to 1/6 mm even in its longer diameter, to be regarded as a fully ripened example of it. It is certain that these small sac-like organs, which I considered to be sporangia, can not be regarded as being either macro- or microsporangia, judging from its sac-like nature, its oblong form, the usual grouping of every 4 of them in one plane around a circular attaching center, and other features just described. Moreover, each sporangiophore-complex, consisting of more than 10 groups of 4 each of these small sacs, shows no enveloping organ that corresponds in any way to the sporangial wall. Recalling a remark made in a preceding page, concerning the vegetative organs of the present species, namely, "this type specimen", to which this cone attaches, "appears to repesent an example of a shoot in its very young stage of development", this cone must also have been in a stage of very young growth, so that the minute size of the sporangium in this cone must be explained as being due to its immaturity. It is true that more than 10 sporangiophores are grouped together into a single, well-defined, semi-spherical body. But the detailed inner structure of this composite body could not be ascertained, and the manner of branching of these sporangiophores in a group from their common axis, if present, are so far unknown to me, for which reason it is preferable at present to call this composite body, provisionally, a sporangiophore-complex. In this cone, these sporangionphore- complexes are arranged in longitudinal direction, evidently in supperposition.

We shall now examine the sterile bracts and their relation to the sporangiophore-complexes. A naked eye inspection of this cone

shows many apparently simple longitudinal striations covering its entire surface. Some of them are seen under the microscope to be only irregular grooves between two neighbouring longitudinal rows of the sporangiophore-complexes, but most of them are evidently either true solid veins or their casts. The vein is always simple, more than 6 mm long and from about 0.03 to 0.05 mm across on the fossil surface, every 3 of which are set in a group, with their courses strictly parallel, and with distance of from 0.1 to 0.15 mm separating them. Between every two contiguous veins in a group, there are often seen numerous every fine longitudinal striations, usually 0.025 mm apart, which remind us at once of similar fine striations on the lamina of the vegetative leaves as described above. There is therefore no doubt that every three of these parallel veins in a group represent a single sterile bract of this cone. In the central, marginal region of this cone are seen a number of successive bracts, showing clearly some of their original features. These bracts emerge there at an angle of about 65° from the cone-axis, gradually turning upwards to become eventually strictly parallel to the latter, each bract embracing one sporangiophophore-complex on the adaxial side of its curved basal part. It is true that every one whorl of the sporangiophore-complexes is placed at every space between two successive whorls of bracts, but no further relationship between these two organs is known for certain at present.

IV. Comparisons of *Neurophyllum koreanicum* with others

The class ARTICULATAE is usually subdivided into five orders[8][9][10], namely, Hyeniales, Pseudoborniales, Sphenophyllales, Cheirostrobales, and Equisetales. Of these, Hyeniales occurs in the middle Devonian and Pseudoborniales in the upper Devonian, all plants under these two orders being too remote in age as well as in characters to be compared with our present plant.

So far as our present knowledge is concerned, the 3rd order Sphenophyllales includes only one well-defined genus, the *Sphe-*

(8) HIRMER, M., Handbuch der Palaeobotanik Bd. I, 1927: p. 344.

(9) KOIDZUMI, G., Brief Synopsis of the Class Pteridophyta with special reference to the New Class Palaeophyllariae. (in japanese). Acta Phytotaxonomica et Geobotanica Vol. VII, No. 1, 1938: p. 4.

(10) DARRAH, W. C., Principle of Palaeobotany, 1939: p, 70.

nophyllum, including *Sphenophyllostachys*. *Sphenophyllum* occurs in beds from upper Devonian to early Triassic, most commonly in the late Carboniferous and the early Permian. Although in Korea, it[11] occurs also in the Kobôsan Series, it is in the Zidô Series (lower Permian) that *Sphenophyllum* occurs most abundantly, from the latter of which our present specimens were also obtained. In this BRONGNIART genus and the present species there are some characters in common as, for example, that they are both herbaceous in nature; the ribs on the axis do not alternate in successive internodes, but run straight on through the nodes; the leaf-segments in a whorl are entirely independent of one another and do not fuse into a sheath. In fructification, too, these two plants show some resemblance, because their cones are alike in being composed of regular alternating whorls of simple or compound sporangiophores and sterile bracts. The vegetative leaf moreover is traversed in both plants by several fine veins instead of by a single midrib. Although our present plant undoubtedly has some resemblance to *Sphenophyllum*, there seem to be some more important distinctions between them. For example in *Sphenophyllum* the leaf-segments are usually wedge-shaped, characterized by such venation that "An[12] der Basis ein oder doch nur wenige Hauptnerven, welche sich dichotom verzweigen", while in our present species, they are linear in shape, being traversed by simple parallel veins, apparently three in number; each sporangiferous appendage generally bears one or two sporangia in the former strobilus[13], instead of four in the latter; the sterile bract differs in many respects from the vegetative leaf in the former, while in the latter it retains almost all its characters unchaged. The distinction between these two plants is emphasized by the fact that the stem of our plant is hollow in the center, whereas in *Sphenophyllum* it is solid in the certer, provided with a solid strand of wood without pith. All these distinctions indicate that the plant in question had no direct affinity with any species of Sphenophyllaceae.

We shall next examine the 4th order, Cheirostrobales, which

(11) KAWASAKI, S., The Flora of the Heinan System. Pts. 1–5, Bull. Geol. Surv. Chosen, Vol. IV. 1927, 1931, 1932, 1934, 1939.

(12) JONGMANS, W. J., Op. cit., 1911: p. 367.

(13) HIRMER, M., Op. cit., 1927. pp. 355–361, 468–474.

contains only one species, the *Ch. pettycurensis*, from the lower Carboniferous of Scotland. This genus was first described by Prof. SCOTT on a single cone, and nothing is known regarding the vegetative organs on which it was borne. This cone is characterized by such features that "the[14] members of sucessive whorls were accurately superposed in vertical series, ——. —— each sporophyll was subdivided in two planes; immediately above its base it branched into an inferior and superior lobe, while at the same time both lobes subdivided, in a palmate manner, into segments. —— three superior segments were the fertile sporanphores, while the three inferior members were sterile bracts. —— sporangiophores had each a thick peltate lamina, bearing four sporangia on its inner side. —— the sterile lamina was itself a complex structure, for it divided into two apical prongs, directed almost vertically upwards, while it was prolonged below into two shorter and stouter outgrowth." As to the cone of our present plant, we find resemblances to SCOTT's genus in that the members of successive whorls of the former are most probably in superposition, the sterile bract of the former being traversed apparently by three simple veins which in a certain sense are comparable to each three sterile bracts of a group in the latter; each of its sporangiferous appendage also bears four sporangia. Thus our cone seems to have a little more in common with Cheirostrobus than with any type of the *Sphenophyllostachys*. There are, however, in our plant, many other characters that differ essentially even from the SCOTT's genus. For example, the sterile bract of the former shows no such intimate connexion with the sporangiferous appendages as found in the latter; the lamina and veins of our sterile bract are not forked; the peltate lamina in ours seems to be very thin, if at all present. Moreover, our stem is evidently hollow, while in the axis of *Cheirostrobus* "there[15] was no pith, the wood extending to the center of the stele."

We shall next examine the various families under the 5th order Equisetales. This order is generally subdivided into three families, namely, Asterocalamitaceae, Calamitaceae, and Equisetaceae.

Asterocalamitaceae[16][17] comprises such genera as *Astero-*

[14] SCOTT, D. H., Studies in Fossil Botany. Vol. I 3rd edit., 1920: pp. 104, 105.
[15] SCOTT, D. H., Op. cit. 1920: p. 107.
[16] JONGMANS, W. J., Op. cit. 1911: pp. 32–34.
[17] HIRMER, M., Op. cit. 1927: pp. 377–381.

calamites, *Pothocitopsis*, *Autophyllites*, and *Sphenasterophyllites*, of which the former two occur in the lower Carboniferous and the latter two in the upper Carboniferous of Europe. This family differs from our present plant in that the "Pflanzen[18] —— mit mehrfach gabelig geteilten Blättern; Blüten in wesentlichen nur aus Quirlen von schildförmigen Sporophyllen gebildet, deren Reihen nur gelegentlich von einem Quirl steriler Blätter unterbrochen werden." Undoubtedly, our present plant would have been too distinctive to be placed in Astrocalamitaceae. It is, however, also true that our plant bears some characters in common with genus *Asterocalamites* at any rate, because in the latter "die[19] zahlreichen um die zentrale Markhöle ringsum angeordneten Gefässbündel in den aufeinanderfolgenden Sprossgliedern (Internodien) nicht alternieren und demzufolge auch an den Knoten durchlaufen. Blätter an den Knoten zu ebensovielen im Quirl, als Leitbündel vorhanden; —— und bis zur Basis frei. Blüten —— mit Einschaltung eines Laubblattquirls nach einer mehr minder grossen Serie von Sporophyllen. Glieder aller Quirle in Superposition, wenigstens solange Zahlengeleichheit vorhanden. Sporophylle ——, mit vier Sporangien." Moreover, in regard to the figure of *Asterocalamities* (*Pothocites*) *scrobiculatus* SCHLOTHEIM sp., after STUR, reproduced in Fig. 454, in HIRMER's Handbuch, we find a good example of the sporangiferous appendage on the uppermost region of that specimen, in which four sporangia are seen attached in stellate arrangement around a small circular depression, the peltate lamina appearing rather very thin, having "the[20] expanded portion little developed." All these features in the single sporangiophore of SCHLOTHEIM sp. are also seen in the same organ of our present cone. Thus it is quite surprising to find that this very ancient (lower Carboniferous) plant, the *Asterocalamites*, bore these numerous important characters in common with our present plant of lower Permian age.

The Calamitaceae is defined by HIRMER as follow: "Pflanzen[21] von Equisetineencharakter mit unzerteilten Blättern. Glieder der Quirle der vegetativen Sprosse regelmässig alternierend (*Calamites*)

[18] HIRMER, M., Op. cit. 1927: p. 377.
[19] HIRMER, M., Op. cit. 1927: p. 377.
[20] SCOTT, D. H., Op. cit., 1920: p. 62.
[21] HIRMER, M., Op. cit., 1927: pp. 381–382.

oder nur teilweise und ohne bestimmte Regelmässigkeit alternierend, teilweise noch superponiert (*Mesocalamites*). Meist beträchtliche Holzbildung. Blüten nur von *Calamites* bekannt, meist aus abwechselnd aufeinander folgenden Sporangiophor- und Brakteenquirlen bestehend." From this HIRMER's definition, our present plant differs essentially, because in ours, the ribs on the internode usually show a straight course through the nodes; the leaves and branches are evidently superposed in vertical series; the leaf-segment is always traversed by several simple veins, instead of by a single midrib in the *Calamites*; the sporangiferous appendages stand on the axis not singly, but in groups. Thus our present plant clearly differs in morphology from Calamitaceae, and most probably still more widely from Asterocalamitaceae. It is also true that the distinction between our specimen and Calamitaceae is less marked than that between ours and either Cheirostrobaceae or Sphenophyllaceae, because the former two are common in having the hollow stem provided with leaf-segments characterized by lamina and a vein that is not bifurcate. In the habit of venation, however, our present plant resembles neither Calamitaceae nor Sphenophyllaceae, because in the former known family the leaf-segment is traversed by a single midrib, and in the latter by several bifurcate veins. Lady I. BROWNE says, as to her *Calamostachys magnae-crucis*, as follows[22]; "at the level of the nodes each bundle," (of internode of the cone-axis), "probably gave off traces to about three bracts." Evidently in her case, every one of the three bracts in a group receives a trace from the one mother vascular bundle of the internode, passing out into the simple midrib of each uninerved bract. If so, then there does not appear to be any fundamental distinction between the two types of the nervation of the BROWNE's cone-bracts and the leaf-segments of our present plant. Apart from the question whether such the conclusion is in order or not, there is no doubt that in the habit of venation, our plant comes nearer to Calamitaceae than to Sphenophyllaceae, because the leaves of both ours and Calamitaceae have a vein of simple and undivided course.

We shall next discuss the 3rd family, the Equisetaceae, comparing it with the plant now in question. This family is the youngest

[22] BROWNE, I. M. P., Notes on the Cones of the *Calamostachys*--type in the RENAULT and ROCHE Collection. Ann. Bot. Vol. 39. 1925: p. 328, Tex-fig. 1.

of the class ARTICULATAE, occurring from upper Carboniferous to Recent. Of the Palaeozoic and the Mesozoic Equisetacean plants, it is only in the *Equisetites* and *Phyllotheca* that their membership in this family has been fully established by evidences of the reproductive organs. The *Equistites* occur in beds of upper Carboniferous and later, most frequently, in those of the Triassic, so that some species of it at least must have been contemporaneous with our present plant. It is odd that in the characters of our present plant we can find virtually nothing in common with those of Equisetites, excepting that our stem is hollow in the center.

As to the genus *Phyllotheca*, matters appear to be somewhat different. *Phyllotheca* occurs in beds from the upper Carboniferous up to Wealden, with special frequency in regions of *Glossopteris* flora. This genus differs from ours in that the leaf-segments are always uninerved and shorter than the internode, cohering basally into funnel-shaped sheaths; every six sporangia being borne on a single sporangiophore with a thick peltate lamina. All these distinctions being essential, it is certain that our present plant was never congeneric with *Phyllotheca*. Nevertheless, in our plant we find some important characters in common with the latter such as that the leaf-segments are evidently superposed in vertical rows, the ribs on the successive internodes run straight through, and not alternately, at the nodes. On the fructification of the *Phyllotheca deliquescens* GOEPPERT, from the Permian in Siberia, SOLMS-LAUBACH writes[23]: "striated axis with sheaths thoroughly like those of *Phyllotheca* bears on the internodes between the sheaths in a lateral position certain small organs, which are exactly like the sporangiferous disks of our Equiseta. They lie indeed in numbers all round the axis in the interval between every two sheaths." Prof. GOTHAN[24] reported other example of the similar fructification of this genus, which he named *Ph. uluguruana*, from the Karoo Formation in 1927. Prof. HIRMER wrote, in connexion with his revised definition of *Phyllotheca*: "Die[25] Blüten, (bekannt von *Ph. delinquescens* und *Ph. uluguruana*) unterscheiden sich von

[23] SOLMS-LAUBACH, H. Graf zu, (Translated by GARNSEY, H. E. F.), Fossil Botany, 1891: p. 181, Fig. 17_B.

[24] GOTHAN, W., Fossilpflanzen aus der Karruschichten der Umgebung des Ulu gurugebirges in Deutsch-Ost-Afrika. Palaeotogr. Suppl. 7, 1927: p. 150, Pl. XVIII, Figs. 6–8.

[25] HIRMER, M., Op. cit., 1927: p. 461.

denen der Gattungen *Equisetites* und *Equisetum* im wesentlichen nur dadurch, dass mehrmals hintereinander eine grössere Folge von Sporophyllquirlen von einem sterilen Blattquirl unterbrochen ist." We thus know that the cone of our present plant agrees with those of *Phyllotheca* in having numerous polysporangiate sporangiophores between every two whorls of sterile bracts. In the former, however, the sporangiophores are grouped into compound sporangiophore-complexes, while in the latter they stand singly and independently on the axis. That is to say, in each interval between two successive whorls of sterile bracts, there is only one whorl of sporangiophore-complexes in our present cone, while in that of *Phyllotheca* there are many whorls of simple independent sporangiophores.

We shall next compare *Schizoneura* SCHIMPER, the famous member of the *Glossopteris* flora, with our present plant. This SCHIMPER genus has been provisionally classified into Equisetaceae, although the evidences, especially in regard to its fructification, are still inadequate. *Schizoneura* appears to have a slight resemblance to our plant, in that these two are common in the following respects, namely, the stem is hollow with ribs not alternate at node, the leaf-segments are longer than the internodes and are arranged vertically in juxtaposition. SCHIMPER et MOUGEOT give an excellent explanatory figure of Sch. paradoxa in their work, published in 1844[26], which shows very clearly that every node of the axis gives off several vegetative branches in a whorl, being superposed in vertical rows on the axis. If this is generally the case, *Sch. paradoxa* may be said to agree also in the branching habit with our present plant. In *Schizonenra*, however, the leaf-segments are always uninerved, those in one whorl being united together into two loose coherent lobes, and the axis traversed by much more ribs than the leaf-segments in a whorl at a node. On the fructification of *Schizoneura*, our present knowledge is still extremely meagre. ETHERIGE[27] has reported an example in which the leaf-bearing axis terminates in a pair of compact strobili of 2–2.5 cm length, each of which shows no trace of sterile bract. Our

[26] SCHIMPER, W. P. et MOUGFOT, A., Monographe des plantes fossiles du grès bigarré de la chaine des vôsges. 1844: pp. 50, 51, Pl. XXIV, Fig. 1.

[27] See ARBER, E. A. N., Catalogue of the fossil Plants of the *Glossopteris* flora in the Department of Geology, British Museum (Nat. Hist.), 1905: p. 9, Text-fig. 4.

present plant therefore differs in its essential characters, even from *Schizoneura*.

Lastly, as to *Neocalamites* HALLE, which occurs abundantly in the older Mesozoic beds throughout the world, it appears to differ considerably from our present plant, seeing that in this Mesozoic genus, the leaf-segments are always uninerved and, moreover, their number in a whorl is generally much less than that of the ribs on the axis. Of the characteristics of the HALLE genus, the followings may be worth remembering:—"Blätter[28] in Wirteln, ——, vollkommen frei von einander.", and "die[29] Leisten an den Noden unregelmässig, indem sie bald alternieren, bald in unveränderter Richtung die Nodial-Linie durchqueren." These, together with other characteristics, may play some rôle in the solution of the problem of the systematic relation between *Neocalamites* and our present plant. Since nothing is known about the fructification of *Neocalamites*, the problem can only be left open at present.

V. Conclusion

In view of all that has been said, we naturally conclude that there is no family known at present to which our plant can satisfactorily assigned, taxonomically. For this reason I propose here to designate our present plant by a new name, *Neurophyllum koreanicum*, because of the character of the leaf-segment traversed by several simple parallel veins. I wish further to establish a new family, Neurophyllaceae, according to the following diagnosis: "Stem monopodial, hollow, regularly articulated; longitudinal ribs on axis run straight through nodes; both leaf-segments and branches superposed in vertical rows on axis; leaf-segments linear in form, much longer than length of internode, provided with several simple and parallel veins; strobilus consists of alternating whorls of long sterile bracts and sporangiophore-complexes, the latter of which composed by intimate assemblage of numerous polysporangiate sporangiophores."

There now remains the problem—To which order does this new family belong? Unfortunately, the available evidence now in

[28] HALLE, T. G., Zur Kenntnis der mesozoischen Equisetales Schwedens. K. Svenska Vetensk. Akad. Hdlg. 43. 1908: p. 6.

[29] HALLE, T. G., Op. cit. 1908: p. 9.

possession is quite inadequate to furnish answer to the question. Many important characters, such, for example, as the anatomy of the axis, details of the fructification, and other matters, are still in doubt. All we can do therefore at present is to assume that this new family belongs to the order Equisetales, to judge from its characters, namely, the stem is hollow, bearing linear leaf-segments with both the lamina and the veins being not bifurcated at all.

As pointed above, *Neurophyllum koreanicum* appears to be comparable to a certain degree either to *Phyllotheca* or to *Asterocalamites*, both of the latter belonging to Equisetales. *Phyllotheca* seems, however, to be much more modern in aspect when compared with our present plant, because it closely resembles the recent *Equisetum* in having either its sporangiophore with six sporangia on its well-defined peltate lamina, or the leaf-segments in a whorl, which are shorter than the internode and adhere basally to a well-defined sheath. It is odd that it is not possible to detect affinity between these two plants, *Phyllotheca* and *Neurophyllum*, which thrived almost at the same time, namely the lower Permian, although the former did so chiefly in the Gondwana land. *Asterocalamites*, on the contrary, occurs mainly in the lower Carboniferous, so that it is very remote in age from our present plant, but these two have various charaeters in common as mentioned above. In short, our present plant is separated widely in aspect from any other families ever known, and shows characters of a purely Palaeozoic affinity on the whole.

Explanation of Plate I

Fig. 1. General view of the type specimen; × 1.

Fig. 1a. View of basal region of a leaf-segment lying on the left-hand extremity of the 5th nodal line of the main axis of the type specimen; × 10.

Fig. 1b. View of 3 simple veins in the basal region of a leaf-segment, emerging from the 6th node of the main axis of the type specimen; × 10.

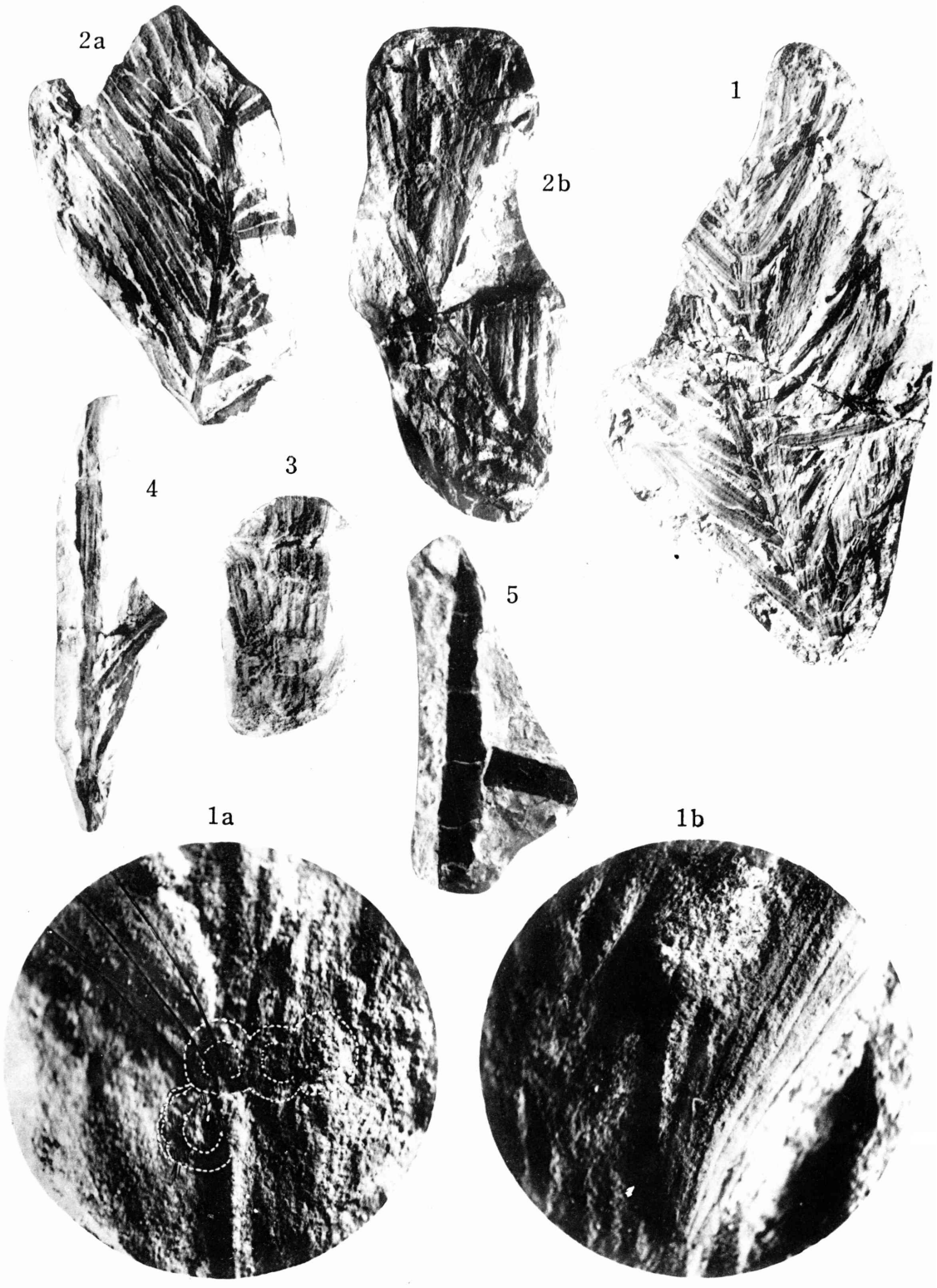
Fig. 2a. A slender axis shows 6 internodes, traversed by several ribs which run straight on through nodes; × 1.

Fig. 2b. Cast of the specimen shown in Fig. 2a; × 1.

Fig. 3. Comparatively thick axis: several highly elevated longitudinal ridges are seen on its central internode, at the lower extremity of which is shown the inner hollow of this axis; × 2.

Fig. 4. Ribs on this axis are seen to be not alternate but continuous at nodes from one internode to the next; × 1.

Fig, 5. Axis bears the characteristic branch-scars on every node; × 1.



C. UEKI Photo.

PLATE

Explanation of Plate II

Fig. 1c. View of scars of the primary branches on the left-hand region of and immediately above the 2nd nodal line of the type specimen; × 10.

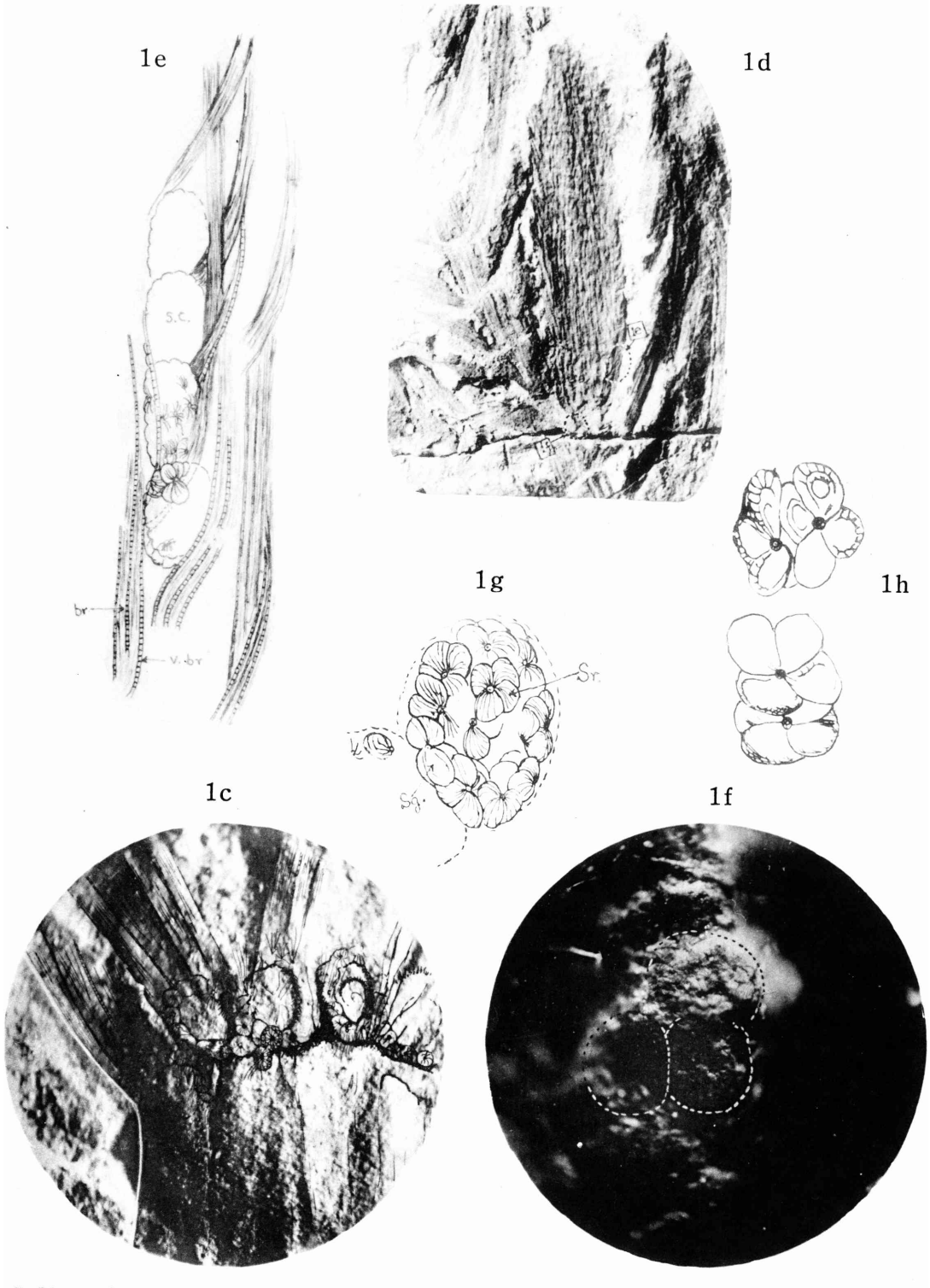
Fig. 1d. Enlarged photogragh of the strobilus; × 2.

Fig. 1e. Sketch of the basal right-hand portion of the cone, showing 4 sporangiophore-complexes (s. c.) in superposition and trinerved bracts (br.; v. br.: vein of bract); × about 18.

Fig. 1f. View of 3 sporangiophor-complexes, lying on the basal left-hand extremity of the cone; × 20.

Fig. 1g. Sketch of a single sporangiophore-complex, out of the 3, photographed in Fig. 1f. (Sr., sporangiophore. Sg., sporangium.); × 40.

Fig. 1h. Sketch of 4 sporangiophores; × about 60.



C. UEKI Photo.