Permian Sphenopsids From Antarctica

GEOLOGICAL SURVEY PROFESSIONAL PAPER 613-F

Permian Sphenopsids From Antarctica

By J. F. RIGBY

CONTRIBUTIONS TO PALEONTOLOGY

GEOLOGICAL SURVEY PROFESSIONAL PAPER 613-F

Descriptions and distribution of species of the fossil plant genera Phyllotheca, Schizoneura, Paracalamites, *and* Umbellaphyllites

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1969

UNITED STATES DEPARTMENT OF THE INTERIOR

WALTER J. HICKEL, *Secretary*

GEOLOGICAL SURVEY

William T. Pecora, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price 45 cents (paper cover)

CONTENTS

	Page
Abstract	F1
Introduction	1
Acknowledgments	1
Previous investigations	1
Descriptions of flora	2
Paracalamites	2
Phyllotheca	7
Schizoneura	7
Description of flora—Continued	
Umbellaphyllites	F9
Sphenopsid leaves	10
Plant organs, parallel-veined or parallel-ribbed fragments	10
Conclusions	11
References cited	11
Index	13

ILLUSTRATIONS

[Plates follow index]

PLATE 1. *Paracalamites australis* Rigby.
2. *Umbellaphyllites ivini* (Walkom) Rigby, *Phyllotheca, Paracalamites australis* Rigby, and *Schizoneura gondwanensi* Feistmantel.
3. Sphenopsid leaves, plant organs, and *Paracalamites australis* Rigby.

	Page
FIGURES 1, 2. Diagrammatic representations of:	
1. Nodal rib pattern in *Paracalamites australis*	F5
2. Irregularities in rib pattern in part of upper node of *Paracalamites australis*	6

TABLES

	Page
TABLE 1. Dimensions of leaf whorls of some specimens of *Umbellaphyllites* and *Raniganjia*	F9
2. Distribution of Gondwanaland sphenopsid genera by continents	11

CONTRIBUTIONS TO PALEONTOLOGY

PERMIAN SPHENOPSIDS FROM ANTARCTICA

By J. F. Rigby

ABSTRACT

Sphenopsids in the Permian of Antarctica are represented almost entirely by leafless stems of *Paracalamites australis* from 23 localities distributed throughout all areas of known Lower Gondwana sedimentary deposits. These stems are abundant in a few localities where they represent almost all the plant remains available. *P. australis* stems are characterized by adjacent and apposing ribs that are interconnected at the nodes.

Leaf remains are rare; they are known from eight localities. *Schizoneura gondmanensis* and *Umbellaphyllites irini* are each known from one locality. Remains at other localities are specifically or generically indeterminate: *Phyllotheca* sp. represents the only other leaf definitely recognized. *Umbellaphyllites irini* is restricted to the Lower Permian Greta Coal Measures; the other species are long ranging and widely distributed. No precise stratigraphic age determinations are therefore possible from recognition of these sphenopsid species.

INTRODUCTION

The distribution of sphenopsids in Antarctica has already been indicated by Rigby and Schopf (1969). Leafless stems of *Paracalamites australis* represent almost the entire fossil record of sphenopsids in the Permian of Antarctica. These stems are identical with stems found elsewhere in Lower Gondwana deposits. Other remains include determinable and indeterminable leaf whorls and leaves. These are limited to only a few localities and each determinable species is restricted to a single locality. It is striking that sphenopsid stems are common and foliage is rare in Antarctica.

The only other part of Gondwanaland where this type of preservation is also as striking is in the Perth and Collie Basins of Western Australia, where stems are fairly common, but leaves are restricted to *Umbellaphyllites minima* known only from a single locality. Species of *Phyllotheca* form a significant part of the flora in many parts of Gondwanaland; *Schizoneura* is less common, and other genera are rare.

Occurrences of nonfoliaceous stems are usually accompanied by leaves of either *Phyllotheca* or *Schizoneura.* These two genera apparently occur within different strata at any particular locality. Other sphenopsid genera based on leaves also appear to occur alone within any particular stratum. These rarely found genera are *Stellotheca*, *Umbellaphyllites*, and *Raniganjia.*

The genus *Sphenophyllum* is common only in India, but it is known from elsewhere in Gondwanaland. Its habit is uncertain, but *Sphenophyllum* appears to have been different from other ancient herbaceous and arborescent forms that had a habit similar to the extant *Equisetum*. The reconstruction of *Sphenophyllum multirame* given by Darrah (1968) may also be typical for this genus in Gondwanaland.

Within the present report, fossils are discussed in the following order: stems, identifiable leaves, nonidentifiable leaves, and other remains.

ACKNOWLEDGMENTS

Studies of Antarctic paleobotany and palynology have been supported by the Office of Antarctic Research, National Science Foundation (project AG–12, formerly GA 177). This particular report was completed with funds generously provided by Ohio State University, through the Institute of Polar Studies, for a period of 2 months after funds provided by the National Science Foundation had been exhausted. In addition, thanks are due to U.S. Naval Support Squadron VX 6, which was responsible for logistic aid in fieldwork. The assistance of those who provided materials for the collections, as specifically indicated in the text, is also gratefully acknowledged.

PREVIOUS INVESTIGATIONS

The only previous reports of sphenopsid remains in the Permian of Antarctica have been made by Plumstead (1962) and Rigby and Schopf (1969).

Plumstead (1962) recorded specimens of sphenopsids from the Theron Mountains. Her single specimen of *Annularia* sp. is now considered to be a possible record of *Schizoneura* sp. Her specimens of *Phyllotheca* sp. cf. *P. australis*, which were leafless stems, are now included in *Paracalamites australis.*

Rigby and Schopf, (1969) listed regions of Antarctica where sphenopsids occur; their distribution is extensive. The present report is a detailed discussion of the sphenopsids referred to by Rigby and Schopf (1969).

DESCRIPTIONS OF FLORA

Genus PARACALAMITES Zalessky

Paracalamites australis Rigby

Plate 1, figures 1–9; plate 2, figures 6–8; plate 3, figures 4–8; text figures 1, 2

1861. *Phyllotheca indica* Bunbury. Geol. Soc. London Quart. Jour., v. 17, p. 335–338 [part only], pl. 10, figs. 6, 9; pl. 11, figs. 1, 2.

1879. Equisetaceous stalks. Feistmantel, India Geol. Survey Mem., Palaeontologica Indica, v. 3 (Fossil Flora Gondwana System), pt. 1, p. 8, pl. 1, figs. 4, 5.

1880. *Schizoneura gondwanensis* Feistmantel, India Geol. Survey Mem., Palaeontologica Indica, v. 3 (Fossil Flora Gondwana System), pt. 2, p. 63, pl. 5A, fig. 3; pl. 7A, fig. 1a; pl. 9A, figs. 1–7.

1881. Equisetaceous stalk. Feistmantel, India Geol. Survey Mem., Palaeontologica Indica, v. 3 (Fossil Flora Gondwana System), pt. 1 (supp.), p. 52, pl. 30, fig. 1.

1882. Equisetaceous stem. Feistmantel, India Geol. Survey Mem., Palaeontologica Indica, v. 4 (Fossil Flora Gondwana System), pt. 1, p. 23, pl. 11, fig. 5.

1890. *Phyllotheca australis* Brongniart. Feistmantel, Uhlonosne Utvary V Tasmanii [spisuw poctenych jubilejni cenoukral. c. spolecnosti nauk v. Praze.] v. 3, p. 90, pl. 7, figs. 2, 15 only.

1890. Rachis of ferns(?) Kidston *in* Foord, Geol. Mag., ser. 3, v. 7, p. 102, figs. 6, 6a.

1895. *Phyllotheca*? sp. Etheridge, New South Wales Geol. Survey Records, v. 4, pt. 4, p. 149 (stems), pl. 18, figs. 1, 2.

1900. Schizoneura?. Potonie, H., Deutsch Ost-Afrika, *in* Palaont. Ergebnisse W. Burnhardt, pt. 2. Berlin, D. Reimer (E. Vohsen). v. 7, p. 502, text fig. 28.

1902. *Schizoneura gondwanensis* Feistmantel [probably]. Zeiller, Palaeontological Indica, new ser., v. 2, pt. 1, p. 27 [only], pl. 6, figs. 2–4.

1904. *Archaeocalamites scrobiculatus* (Schlotheim) Stur. Chapman, Royal Soc. Victoria Proc., v. 16, p. 315, pl. 27, figs. 8–9.

1905. *Schizoneura gondwanensis* Feistmantel. Arber, British Mus. (Nat. History) Catalogue Fossil Plants *Glossopteris* Flora, p. 5–12 [part only], text fig. 3.

1905. *Phyllotheca australis* Brongniart. Arber, British Mus. (Nat. History) Catalogue Fossil Plants *Glossopteris* Flora, p. 19–20 [part only]; stem casts and impressions only.

1905. *Phyllotheca indica* Bunbury. Arber, British Mus. (Nat. History) Catalogue Fossil Plants *Glossopteris* Flora, p. 22, stem casts only.

1905. *Phyllotheca deliquescens* (Goeppert) Schmalhausen. Arber, British Mus. (Nat. History) Catalogue Fossil Plants *Glossopteris* Flora, p. 22–24.

1905. *Phyllotheca zeilleri* Etheridge. Arber, British Mus. (Nat. History) Catalogue Fossil Plants *Glossopteris* Flora, p. 28–29 [part only].

1905. *Phyllotheca* sp. Arber, British Mus. (Nat. History) Catalogue Fossil Plants *Glossopteris* Flora, p. 29–30, specimen V3620 only.

1908. *Phyllotheca* sp. White, D., *in* White, I. C., Coal Measures, Associated Rocks, South Brazil, Rept., pt. 3, p. 420–423, 428–433, pl. 5, figs. 3–5.

1911. *Phyllotheca australis* Brongniart. Halle, Uppsala Univ. Geol. Inst. Bull., v. 11, p. 163–166 [part only], pl. 1, figs. 12–14.

1911. *Phyllotheca* cf. *deliquescens* (Goeppert) Schmalhausen. Halle, Uppsala Univ. Geol. Inst. Bull., v. 11, p. 166–167 [part only], pl. 1, fig. 26.

1921. *Phyllotheca* sp. Kurtz, Cordoba Acad. Nac. Ciencias Acta [Argentina], v. 7, pl. 11, fig. D and possibly others; pl. 26, fig. 364.

1922. *Phyllotheca* sp. Walkom, Queensland Geol. Survey Pub. 270, p. 7, pl. 1, fig. 2.

1923. ?*Phyllotheca* sp. Glauert, Royal Soc. Western Australia Jour., v. 10, pt. 3, p. 8.

1923. cf. *Phyllotheca australis* Bronguiart. Seward and Walton, Geol. Soc. London Quart. Jour., v. 79, p. 318, pl. 19, fig. 6.

1929. *Phyllotheca* sp. Walton, Southern Rhodesia Geol. Survey Bull., 15, p. 64, pl. A, fig. 1.

1934. Tallos de equisetales. Harrington, Mus. La Plata [Argentina] Revista, v. 34, p. 320, pl. 4, figs. 3–5.

1935. Tiges ou rameaux—Equisetales. Carpentier, Madagascar Geol. Serv. des Mines Annales, v. 5, p. 10, pl. 2, figs. 1–3.

1935. Diaphragme d'Equisetinee. Carpentier, Madagascar Geol. Serv. des Mines Annales, v. 5, p. 10, pl. 4, fig. 1.

1935. Rameau d'Equisetinee. Carpentier, Madagascar Geol. Serv. des Mines Annales, v. 5, p. 10, pl. 5, fig. 1.

1941. *Phyllotheca* sp. Read, Brasil Div. Geol. Mineralogia Mon. 12, p. 90–91, pl. 3, figs. 4–6.

1943. *Schizoneura* sp. Teixeira, Soc. Geol. Portugal Bol., v. 2, pt. 1, p. 7, pl. 2, figs. 8–10; and, Teixeira, Anais Junta Invest. Coloniais [Portugal], v. 2, no. 2, 1947, p. 18, 26, pl. 15, figs. 3–5.

1954. *Phyllotheca* sp. Mendes, Univ. Sao Paulo [Brazil], Fac. Filos. Cienc. Letras. Bol. 175, Geol. 10, p. 69, pl. 1, figs. 6, 7.

1956. Stems. Surange, Palaeobotanist, v. 4, p. 83, pl. 1, figs. 1–3; text fig. 1.

1959. *Calamites*. Teixeira and Goncalves, Garcia de Orta, v. 7, pt. 4, pl. 7, figs. 4–6.

1960. Equisetaceous stems. Høeg and Bose, Mus. Royal Congo Belgique, 8°, Annales, Sci. Geol., v. 32, p. 29–30, pl. 1, fig. 1; pl. 2, fig. 1; pl. 3, figs. 1, 2; pl. 4, fig. 4.

1961. Equisetalean stem. White, Australia Bur. Mineral Resources Geology and Geophysics Bull., v. 60, p. 300, pl. 2, fig. 2.

1962. *Phyllotheca* sp. cf. *P. australis* Brongniart. Plumstead, London, Trans-Antarctic Expedition, 1955–1958, Sci. Rept., Geol., no. 9, p. 63, pl. 17, figs. 3–6.

1962. Equisetaceous stem. Saksena, Palaeobotanist, v. 10, p. 94, pl. 2, figs. 25, 26.

1965. Equisetalean stem. Maheshwari and Prakash, Palaeobotanist, v. 13, no. 2, p. 118, pl. 1, fig. 4.

1966. *Phyllotheca* stems. Surange, Indian fossil Pteridophytes, Council for Scientific and Industrial Research, Bot. Mon., no. 4, p. 38–40, figs. 19, 20.

1966. Equisetalean stems. Maithy, Paleobotanist, v. 14, p. 54, pl. 1, fig. 7.

1966. *Paracalamites* sp. A. Rigby, *in* Symposium on floristics and stratigraphy of Gondwanaland, Palaeobot. Soc. India, Spec. Session. Lucknow, Dec. 1964, Proc., p. 52, pl. 1, fig. 5.

1966. *Paracalamites* sp. B. Rigby, *in* Symposium on floristics and stratigraphy of Gondwanaland, Palaeobot. Soc. India, Spec. Session. Lucknow, Dec. 1964, Proc. p. 53, pl. 1, fig. 6.

1966. *Paracalamites australis* Rigby, Palaeontographica, v. 118, sec. B, pts. 4–6, p. 123, pl. 32, fig. 19; pl. 33, figs. 20, 23.

Diagnosis (*amended, from Rigby, 1966b*).—Articulate stem having ribs of pith cast opposite at nodes; ribs alternate only to accommodate changes in number of ribs between adjacent internodes. Rib vascular bundles continuous from one internode to the next without break; also vascular bundles branch and recombine with vascular bundles of adjacent ribs at nodes. Ribs and furrows sometimes finely striated. Ribbing on node of external cast weak. Internodes substantially longer than stem diameter, except in thick trunks.

Discussion.—The form genus *Paracalamites* is used here in the same way as it has been used previously in New South Wales (Rigby, 1966a), Western Australia (Rigby, 1966b), and Antarctica (Rigby and Schopf, 1969), to describe sphenopsid stems of unknown affinity that have ribs in apposition, not alternating, at nodes. The specimens may have represented stems of any of the following Lower Gondwana genera:

Phyllotheca Brongniart
Schizoneura Schimper and Mougeot
Stellotheca Surange and Prakash
Umbellaphyllites Rasskazova
Raniganjia Rigby

Almost all these stems have been placed in the species *Paracalamites australis* Rigby. Nothing indicates that any of the isolated sphenopsid stems from Antarctica should be included in any other species, and these stems should not be regarded differently from stems described previously under this epithet.

Paracalamites has also been used as a generic name to designate the stems of the following genera from Angaraland:

Phyllotheca Brongniart
Annularia?
Annulina Neuburg
Koretrophyllites Radczenko
Neokoretrophyllites Radczenko
Umbellaphyllites Rasskazova
Gamophyllites Radczenko

Very few of these genera have known fructifications. The only genus common to both Gondwanaland and Angaraland has fructifications that differ in each region. Thus, *Phyllotheca australis* from Gondwanaland bore fructifications of the *Gondwanostachys* type, and *Phyllotheca* spp. from Angaraland bore the *Tschernovia* spp. type of fructifications.

The method used to name Gondwana sphenopsids is herein reconsidered. I propose that the stems be known as *Paracalamites*, though leaves may be attached in many specimens. Previous practice has been to prefer the specific name based on features of the leaf whorl, and to identify stems devoid of leaves according to the features of leaves accompaning such stems. Such stems were thus given a possibly erroneous designation. A typical example was given by Feistmantel (1880, p. 63); he referred most nonleafy stems associated with leafy stems of *Schizoneura gondwanensis* in the Damuda Series, India, to *Schizoneura*. He mentioned that the stems were generally designated as *Phyllotheca* in India at the time.

My suggested nomenclature was used in designating species from collection H3–75 from the Ohio Range, Antarctica. The collection includes many rock fragments, which are so broken that it is impossible to determine how many fragments have counterparts. These fragments bear many broken stems of *Paracalamites australis.* A few stems have partial leaf whorls typical of *Schizoneura gondwanensis*, which are described under the apropriate heading (p. F7). Collection H3–75 includes 118 plant fragments—99 fragments of leafless stems, eight fragments of stems that have partial leaf whorls (see pl. 2, figs. 11, 12), and 11 fragments of solitary or grouped single leaf fragments. (See pl. 2, figs. 9, 10.)

Specimens of leafless stems are designated *Paracalamites australis.* Stems that have partial leaf whorls are best designated as leaves of *Schizoneura gondwanensis* borne on stems of *Paracalamites australis.* Isolated leaves are specimens of *Schizoneura gondwanensis.* These stems have internodes 25–40 mm long, and ribs 1.3–2.0 mm apart. The widest stem is 29 mm wide and has 19 ribs across its diameter.

In this system, the use of a generic name based on leaf remains automatically indicates that specimens of leaves are present. The fact that no discernible difference exists between the stems of many of the Gondwana sphenopsid genera that are based on characters of leaves is acknowledged by the use of the specific name *Paracalamites australis* for these various stems. If any species distinguished by features of leaves should prove to have a distinctive type of stem, then a separate species of *Paracalamites* might be proposed.

Most Antarctic specimens do not appear to have any features significantly different from others referred to in the synonomy. However, the specimens discussed herein have distinctive aspects worthy of separate comment. Typically, the stems occur in thin beds or along bedding planes and lie parallel to or closely parallel to bedding. Orientation appears to be random (pl. 1, fig. 9).

Specimen E 54 (pl. 2, fig. 6) is the broadest sphenopsid stem from Antarctica that I have seen. The apparent bend in the stem has been caused by two stem fragments being closely pressed together.

Dimensions of specimen E 54:
- Stem width, 57 mm.
- Length of internodes (top to bottom of figure), ?, 26 mm, 26 mm.
- Spacing of ribs, 10 per 19 mm.
- Average spacing of ribs, 1.9 mm.

A second specimen, E 56, has some fragments of stems of similar dimensions. Ribs are spaced at 10 per 23 mm. Internode length and stem breadth are unknown, but stem breadth exceeds 55 mm. Another similar fragment, specimen E 44a (pl. 3, fig. 5), has four ribs spaced at three ribs per 8 mm. Internode length is 20 mm.

Specimen H4w–13c (pl. 2, figs. 7, 8) is part of a small, slender stem that has closely spaced nodes. The stem is swollen at the nodes. The shape of the preserved remains suggests that the lower 1.5 nodes (below the diagonal fracture) represent the front surface of the original specimen. The upper part of the specimen (above the fracture) represents the back surface of the original specimen. The lowest internode has been crumpled, which gives its adjacent nodes an unduly swollen appearance.

Dimensions of specimen H4w—13c:

	Length (mm)	Diameter (mm)	Number of ribs on exposed surface
Top:			
Fractured internode	?	?	9
Top node		2. 6	
Internode	2. 3	2. 1	9
Node		3. 3	
Internode	3. 0	2. 0	11
Node		2. 9	
Internode with diagonal fracture	3. 9	2. 1	11
Node		3. 0	
Internode	3. 4	?	11(?)
Bottom:			
Fractured node		?	

Although this specimen has very small overall dimensions, its features indicate that it probably was from a plant having a stem similar to that of *Paracalamites australis*. If this stem had been found associated with a single very distinctive type of foliage, however, it might have been identified as a separate species.

Specimens QM 10 and QM 11 B, both from the same horizon, bear impressions of *Paracalamites australis* preserved indistinctly. Mineral matter is deposited along the ribs and nodes and all dimensions given are approximate.

Specimen QM 10 (pl. 3, fig. 8) bears three fragments identified as *Paracalamites australis*. One is a broad stem that has four expanded nodes spaced at 15, 14, and 12 mm. The diameter of the stem at the nodes is 35 mm. Ribs are spaced at 2 mm. The stem represents the lower part of a trunk.

Specimen QM 11 B (pl. 3, fig. 7) bears a stem of *P. australis* with a thick branch. The main stem is of unknown breadth, but the nodes are 20 mm apart. Ribs are spaced at five or six per 10 mm. The branch has a diameter of 11 mm. at the point of contact with the stem. The axis of the branch is slightly (about 1 mm.) above the plane of the node. From the appearance of the specimen, the branch was probably twice as thick somewhat above its base than at its base. There are eight ribs per 10 mm in the branch.

The size of the branch indicates that plants having stems of the *Paracalamites australis* type grew to a significant height, but the actual height can only be surmised. No known *P. australis* stems are as large as some specimens of *Calamites*, which have a trunk diameter of as much as 50 cm (Eggert, 1962) and a height of 20–30 m (from Boureau, 1964) as estimated by Grand-'Eury. Based on these figures, the largest diameter stem of *P. australis* reported herein (diameter of 57 mm) may have belonged to a plant 2–3 m high. It must be assumed that a plant of this height was rare, as very few known stems from Gondwanaland have a diameter greater than 30 mm.

Specimen QM 177d (pl. 1, fig. 8) is a narrow stem with swollen nodes. Slender branches arise at two nodes. The branches are ribbed. This specimen is typical of some stems that have short internodes and are more slender. Some crumpling is present in the internodes.

Specimen QM 29 (pl. 1, fig. 1) has a small branch arising from a rather broad stem. The unevenness of the specimen, combined with its lack of contrasting color and the granularity of the rock, made photographic reproduction very difficult.

Dimensions of specimen QM 29:
- Diameter of node of main stem where branching occurs, 16 mm.
- Length of one internode on the main stem (not figured), 65 mm.
- Length of first internode of branch, 2 mm.
- Diameter of first node of branch, 4 mm.
- Length of second internode of branch, 11 mm.
- Diameter of second node of branch, 4 mm.
- Length of third internode of branch, >14 mm.

The first internode of the branch is triangular; the apex of the triangle connects with the main stem.

Specimen H4w–15c (pl. 3, fig. 6) shows the triangular basal section of a branch from a stem. There are three internodes below the level at which the stem diameter becomes relatively constant. The ribbing begins a few millimeters above the base.

Triangular basal sections of branches are indicative of pith casts in calamitalean remains.

Dimensions of specimen H4w–15c:

	First internode-first node	Second internode-second node	Third internode-third node	Fourth internode-fourth node
Diameter at base ____mm__	4	________	________	________
Length of internode__mm__	6	2. 5	3	4
Diameter at node____mm__	8	11	15	________
Number of ribs below node_	8	10	10	12

Specimen E 59 (pl. 1, fig. 7) is part of a stem; the figure is an enlarged view showing two adjacent nodes. The ribs dichotomize at each node. Each rib in the lower node branches and recombines as shown in figure 1. Originally it was thought that ribs in *Paracalamites* from Gondwanaland branched and combined in a manner similar to that figured and described by Surange (1956, p. 84, text fig. 1; Rigby, 1966a). Specimen E 59 shows that some fibers are continuous between apposed ribs of adjacent internodes.

The fibers continuous between apposing ribs in the upper node of the figured specimen are not as distinct as those in the lower node. On many ribs, fibers appear to be lacking. The ribs broaden and flatten as they approach the nodes. There is a small depressed area or pit between each apposing rib on the axis of the node. The pit probably represents the point of attachment of a leaf trace. The continuous transverse fibers pass across the bottom of the pit.

Pant and Kidwai (1968) have described leafy stems of *Phyllotheca indica* from the Lower Gondwana of Bihar, India, that showed similar fibers. Their plate 32, figure 18, and text figures 4D and 5A show tracheid strands passing around the pit to give continuity of fibers between apposing ribs, as well as branching and combination between adjacent ribs. Their stems appear identical with the one described here. Our reconstruction of the rib pattern (fig. 1) differs only in that continuity of fibers between apposing ribs is shown, and the gap in the center of each internodal rib was not seen.

Specimen E 44a (pl. 3, figs. 4, 5) has a similar pattern of fibers at each node. Both figured nodes have irregularities where the number of ribs, hence rib spacing, alters at the node. The new rib forms by fusion of fibers arising from the lower adjacent ribs. The rib arrangement of the upper node of specimen E 44a is shown diagrammatically in figure 2. The diagram suggests that increase in rib number is brought about by dichotomous splitting of the vascular strands.

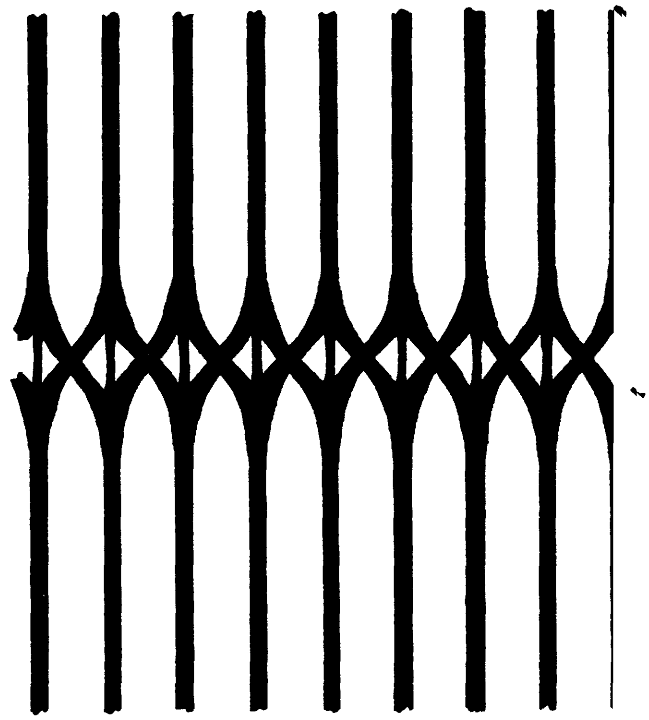


FIGURE 1.—Nodal rib pattern in *Paracalamites australis*, based on specimen E 59 (pl. 1, fig. 7).

Some stems have fine striations parallel to the ribs. These striations uniformly cover both ribs and the region between ribs. The enlarged view of specimen P4–92 (pl. 1, fig. 5) shows these striations; there are approximately 25 per millimeter. All other specimens in the same collection (P4) have similarly striated stems. In all stem fragments from this collection that have nodes, the node is not as clearly marked as is usual for the species (pl 1, figs. 4, 6). Previously, I (Rigby, 1966b, p. 125, pl. 33, fig. 20) figured a similar specimen, which I thought represented an external cast. I now believe that all these represent internal casts (pl. 1, fig. 4) and molds (pl. 1, fig. 6).

Specimens QM 33–1 and QM 33–2 consist of medium- to coarse-grained sandstone and contain several flattened gray argillaceous lenses. Four of these lenses have the general appearance of plant axes. One lens on specimen QM 33–1 appears to represent a stem with longitudinal ribbing (ribs about 15 mm apart) similar to that of *Paracalamites.* Finer striations are also present. This stem has one or possibly two nodes. The other three axes look similar but do not have clear diagnostic features. The three indistinct specimens are recorded as *Paracalamites*?, and the distinctive specimen, as *Paracalamites australis*?.

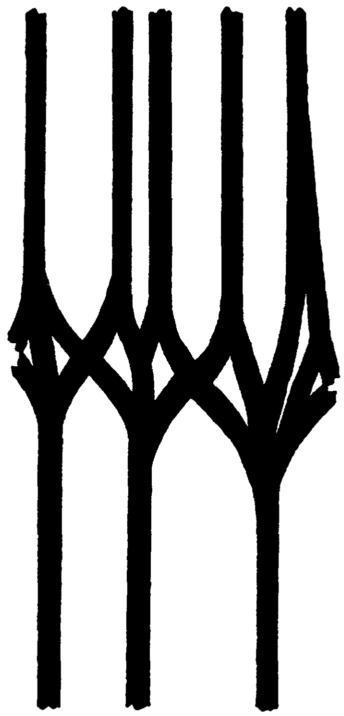


FIGURE 2.—Irregularities in rib pattern in *Paracalamites australis* in part of upper node of specimen E 44a (pl. 3, figs. 4, 5).

The only previous report of *Paracalamites australis* from Antarctica was given by Plumstead (1962) as *Phyllotheca* sp. cf. *P. australis*. She described the preservation of her specimens as poor. She considered her plate 17, figure 3, to be impressions of a leaf sheath, but the figured impressions are so dubious that I am hesitant to accept them on the basis of her photograph.

Sphenopsid nodal diaphragm (pl. 1, figs. 2, 3).—A single elliptical sphenopsid nodal diaphragm—in part specimen E 61 and its counterpart, specimen E 62—was found in a collection associated with several stems of the *Paracalamites* type.

The diaphragm is elliptical and has a major axis 9 mm long and a minor axis slightly greater than 7 mm long. The diaphragm was apparently ornamented by about 30 radial thickenings or ribs. The precise number of ribs cannot be determined because of damage to the specimen.

Specimen E 62 has lost a small part of the central part of the disk. This missing part is occupied by a small tubercle or thickening about 0.8 mm diameter in the counterpart, specimen E 61. The nodal diaphragm described by Lele (1962, p. 71, pl. 1, fig. 4) is almost identical.

Distribution of Paracalamites *in Antarctica*.—The distribution is given as follows.

Allan Nunatak, near location MS–11 of Gunn and Warren (1962): SR 109a–86 and SR 109a–109.

Allan Nunatak, about half a mile east of the above locality: SR 143–6(?).

Robison Peak, ANT 67–0–66c.

Mount Feather, ANT 67–6–27 and ANT 67–6–28.

Queen Maud Range, Cape Surprise: 34–1.

Nilsen Plateau, section 14 of Long (1968): QM 311.

Nilsen Plateau, section 4 of Long (1968): QM 10 and QM 11B.

Nilsen Plateau, section 5 of Long (1968): QM 29 and QM 33–1, (*Paracalamites*?), QM 33–2(?).

Nilsen Plateau, section 6 of Long (1968): QM 341.

Nilsen Plateau, section 13 of Long (1968): QM 177d.

Mount Weaver: Sigma 728, Blackburn collection.

Mount Weaver, upper part of Weaver Formation: H4w–13c, H4w–15a, H4w–15c, H4w–16d.

Ohio Range, Mercer Ridge of Mount Schopf: H3–517J, H3–522J, H4w (Leaia Ledge).

Ohio Range, Terrace Ridge of Mount Schopf: H2–46(2) and H3–271.

Ohio Range, ridge east of Terrace Ridge of Mount Schopf: H3–75.

Pecora Escarpment, Brown Nunatak: P4–2, P4–3, P4–4, P4–6, P4–13, P4–54, P4–73, P4–91, P4–92, P4–99; SR 63–1, SR 63–2, SR 63–3, SR 63–4, SR 63–5, SR 63–6, SR 63–7, SR 63–8, SR 69–9, SR 63–10 SR 63–11, SR 63–12, SR 63–13, SR 63–14, SR 63–15, SR 63–16, SR 63–17, SR 63–18.

Theron Mountains, Upper Horizon. Unnumbered chips, reported by Plumstead (1962) as *Phyllotheca* sp. cf. *P. australis*.

Sentinel Range, Polarstar Peak, Unit 2 of Craddock and others (1965): ANT 67–3–19; E 25, E 27, E 28, E 29, E 30, E 31, E 32, E 33, E 35, E 36a, E 36b, E 37, E 38, E 39, E 44, E 45, E 46, E 47, E 48, E 49, E 50, E 51, E 52, E 53, E 54, E 55, E 56, E 57, E 58, E 59, E 60, E 61, E 62, E 64, E 65.

Sentinel Range, Polarstar Peak, Unit 3 of Craddock and others (1965): ANT 67–3–22 and ANT 67–3–23.

Sentinel Range, Polarstar Peak, Unit 4 of Craddock and others (1965): ANT 67–3–25, ANT 67–3–26, ANT 67–3–27 (?), ANT 67–3–28, ANT 67–3–31.

Sentinel Range, Polarstar Peak, Unit 6 of Craddock and others (1965): E 428.

Distribution elsewhere.—Leafless stems of *Paracalamites australis* have been reported from all major areas of Gondwanaland. These stems are found throughout the entire Lower Gondwana epoch. Some species of form genera have limited vertical or horizontal distribution, but *P. australis* has neither. Its presence in any Gondwana deposit indicates only that the deposit is

Lower Gondwana; no more definite age determination can be made.

The presence of *P. australis* demonstrates that arborescent sphenopsids grew in Gondwanaland at about the same time that the arborescent *Calamites* and its relatives flourished in the Northern Hemisphere. The Gondwana arborescent sphenopsids probably developed from a *Phyllotheca*-like herbaceous plant, because the larger stems of *Paracalamites* have a rib pattern indistinguishable from that of *Phyllotheca*. *Paracalamites* does not appear to be closely allied to *Calamites* or to *Asterocalamites*.

Genus PHYLLOTHECA Brongniart

Phyllotheca sp.

Plate 2, figure 4

The figured specimen formed part of a leaf whorl; 13 leaves are preserved. These leaves have been flattened into a 110° sector, hence the entire whorl may have contained approximately 40 leaves.

Dimensions of the figured specimen:
- Length of leaf sheath, 5.0–5.5 mm.
- Width of fused part of whorl, 3–4 mm.
- Maximum length of free part of any leaf, 13 mm (the leaf apex may not have been retained).

This fragment differs only slightly from the whorls of several other species of *Phyllotheca* known from various parts of Gondwanaland, but it most closely resembles *Phyllotheca indica*. The leaves in each do not taper, but *P. indica* has a shorter sheath (3 mm) and a lesser proportion of the length of the leaves fused in a whorl of similar dimensions.

This fragment differs from whorls of *Phyllotheca australis* by having leaves that do not taper. Dimensions agree with those of figured specimens of *P. australis* (for example, Townrow, 1955, p. 41, fig. 1c).

This fragment resembles some specimens of *Phyllotheca griesbachi*, which differ only by having a significantly shorter sheath, usually 1.5–2mm long. The close resemblance is shown in some specimens figured by Surange (1956, particularly pl. 3, figs. 12, 14).

Phyllotheca muelleriana has very much smaller whorls and a proportionately longer sheath.

Distribution.—Upper Bowden Neve, west side, small nunatak out from cliff edge, Survey station J of New Zealand Geological Survey, at lat 83°51′ S.; long 162° 38′ E. Specimen B 812/11 of collection V–42–NZ.

Phyllotheca? sp.

Plate 2, figure 5

A second, more fragmentary part of a leaf whorl appears to be referable to *Phyllotheca sp.* Only eight leaves and part of the sheath are preserved. The upper part of each leaf tapers to a point; the middle part is parallel sided, and the lower part is fused. Individual leaves lose their identity in the fused part of the whorl. The sheath may have been either cup or cone shaped. This fragment differs from the previous fragment by having tapering leaves. Comparisons are not warranted with such a small fragment.

The sheath is 2.0 mm long; the fused part of the whorl, 3.0 mm long; and the free part of the whorl, 9.5–10.0 mm long. The greatest width of leaf is 1 mm.

Distribution.—Upper member, Weaver Formation, Tillite Ridge, Wisconsin Range. Specimen H4w–134.

Genus SCHIZONEURA Schimper and Mougeot

Schizoneura gondwanensis Feistmantel

Plate 2, figures 9–12

1876. *Schizoneura gondwanensis* Feistmantel, India Geol. Survey Record, v. 9, pt. 3, p. 66, 69.

1876. *Schizoneura gondwanensis* Feistmantel, Asiatic Soc. Bengal Jour., v. 45, pt. 2, no. 4, p. 345–346, pl. 16, figs. 1–3.

1879. *Schizoneura* sp. Feistmantel, India Geol. Survey Mem., ser. 12, v. 3, pt. 1, p. 8, pl. 1, fig. 1.

1879. *Schizoneura* comp. *meriani.* Feistmantel, India Geol. Survey Mem., ser. 12, v. 3, pt. 1, p. 8, pl. 1, figs. 6–7.

1879. *Schizoneura gondwanensis* Feistmantel, India Geol. Survey Mem., ser. 12, v. 3, pt. 1, pl. 1, figs. 2–3.

1880. *Schizoneura gondwanensis* Feistmantel, India Geol. Survey Mem., ser. 12, v. 3, pt. 2, p. 61–64, pls. 1A–4A, 5A, figs. 1, 2, 4, 5; pls. 6A–8A, 9A, figs. 5, 6; pl. 10A.

1882. *Schizoneura gondwanensis* Feistmantel, India Geol. Survey Mem., ser. 12, v. 4, pt. 1, p. 21–22, pl. 11, fig. 8; pl. 13, fig. 1; pl. 20, fig. 6.

1886. *Schizoneura gondwanensis* Feistmantel, India Geol. Survey Mem., ser. 12, v. 4, pt. 2, pl. 21–22.

1893. *Schizoneura? australis* Etheridge, New South Wales Geol. Survey Records, v. 3, pt. 3, p. 74–77, pl. 13.

1898. *Schizoneura gondwanensis* Feistmantel. Seward, Fossil Plants, v. 1, p. 292–294, fig. 69.

1902. *Schizoneura gondwanensis* Feistmantel. Zeiller, India Geol. Survey Mem., new ser., v. 2, pt. 1, p. 26–27, pl. 6, fig. 1.

1903. *Schizoneura australis* Etheridge, New South Wales Geol. Survey Records, v. 7, pt. 3, p. 234–235, pls. 48–49.

1905. *Schizoneura gondwanensis* Feistmantel. Arber, British Mus. (Nat. History) Catalogue Fossil Plants *Glossopteris* Flora, p. 5–12, text figs. 1, 2, 4,

1910. *Schizoneura gondwanensis* Feistmantel. Arber, Geol. Soc. London Quart. Jour., v. 66, p. 238.

1932. *Schizoneura gondwanensis* Feistmantel. Du Toit, South African Mus. Annals, v. 28, pt. 4, p. 373–374, pl. 40, figs. 1–2.

1962. *Schizoneura gondwanensis* Feistmantel. Lele, Palaeobotanist, v. 10, p. 71, pl. 1, fig. 3.

1965. *Schizoneura gondwanensis* Feistmantel. Maheshwari and Prakash, Palaeobotanist, v. 13, no. 1, p. 118, pl. 1, fig. 4.

1966. *Schizoneura gondwanensis* Feistmantel. Surange, Council for Scientific and Industrial Research, India, Bot. Mon., no. 4, p. 30–34, figs. 14–16.

Probably the same species:

1852. Fossil plant. Hooker, Geol. Soc. London Trans., ser. 2, v. 7, p. 227, pl. 28, fig. 1.

1889. *Schizoneura* (?) *africana* Feistmantel, Böhm. Gesell. Wiss., [Prag] abh., ser. 7, v. 3, p. 41–42.

1902. *Schizoneura* (?). Arber, Geol. Mag., ser. 4, v. 9, p. 347.

1905. *Schizoneura* (?) *africana* Feistmantel. Arber, British Mus. (Nat. History) Catalogue Fossil Plants *Glossopteris* Flora, p. 13–14.

1908. *Schizoneura africana* Feistmantel. Seward, Geol. Soc. London Quart. Jour., v. 64, p. 89–90, fig. 2.

Record of *Schizoneura*? sp.:

1962. *Annularia* sp. Plumstead, London, Trans-Antarctic Expedition 1955–1958, Sci. Rept., Geol. no. 9, p. 62, pl. 17, figs. 1–2.

Discussion.—The records of *Schizoneura africana* are included here because this species seems to have no difference worthy of specific differentiation from *S. gondwanensis*. Seward (1908) expressed this opinion, though Du Toit (1953) and Boureau (1964) have retained each as a distinct species.

Feistmantel (1889) differentiated *Schizoneura africana* from *S. gondwanensis* only on the basis of differences in leaf size and thickness and the number of leaf segments per whorl; his description was based on the figure given by Hooker (1852). Arber (1902) reexamined Hooker's specimen and noted that the figure was "largely a restoration." Apparently, the species *S. africana* was erected on very weak grounds, though the discovery of better material may justify its retention.

Leafless stems that may or may not have belonged to *Schizoneura* have been described under *Schizoneura*?, *Schizoneura* sp., *S. gondwanensis*?, or other similar names. These stems are now placed in the genus *Paracalamites*.

Collection H3–75 includes many stem fragments of *Paracalamites australis* in a pale-gray siltstone that bleaches to buff on weathering. Bedding is not apparent, but stems lie in almost the same plane though orientation varies. Most stems have two or more nodes; some have remains of leaf whorls at the nodes. The leaves appear to be free and lax. It was impossible to find any connection between leaves to form a united whorl, as the plane of fracturing of the specimen is at right angles to the plane of the whorl. There is no evidence of branching in the stems. The specimens are identical with some specimens of *Schizoneura gondwanensis* figured by Feistmantel (1880, pl. 8A, figs. 3–4; pl. 9A, figs. 5, 6) from the Raniganj Group of India.

The stems were slightly compressed during burial, as the sides are concave between nodes. It is the outer surface of the stem that is visible, for the leaf attachment can be seen.

Dimensions of the figured specimen (pl. 2, fig. 11) from bottom to top are:

Node diameter, 22 mm.
Internode length, 28 mm.
Node diameter, 18 mm (Node with leaf).
Internode length, 26 mm.
Node diameter, 17 mm (Node with leaf 23 mm long).

The incomplete leaf on this specimen appears to be finely striated longitudinally. There are suggestions of leaves attached to some other stem fragments. Apparent vein dichotomies are caused by superposition of adjacent leaves during compression. Each leaf contains a single longitudinal vein. The leaf fragments indicate that these stems of *Paracalamites australis* had leaves of *Schizoneura gondwanensis* attached to them.

Some isolated leaves (pl. 2, figs. 9, 10) were also found in this collection. The figured leaf is typical. It is almost linear, tapering only slightly from base to apex. The asymmetry is only apparent and was caused by folding or tearing during life or burial. This leaf is distinctly longitudinally striated, about 20 striations per millimeter. This specimen, the longest leaf from this locality, is 42 mm long, 4 mm wide at the broad end and 3 mm wide at the narrow end. There is no reason to suspect that this and other similar leaves represent anything other than detached leaves of *Schizoneura gondwanensis*.

Specimen H3–552J includes a stem of *Paracalamites australis* and several closely associated linear leaf fragments similar to those described above. None of the leaf fragments is connected to the stem, but some lie across the stem. The leaves have a midrib; they are 1.0–0.8 mm wide and at least 6 mm long. They appear to be typical isolated leaves of *Schizoneura gondwanensis*.

Plumstead (1962) identified a specimen from Theron Mountains as *Annularia* sp. She expressed some doubt as to the correct generic placement of the specimen. She compared it with leaf whorls of other Gondwana plants previously assigned to *Annularia*, *Schizoneura wardii*, *S. gondwanensis*, and some *Phyllotheca* species. She preferred a comparison with the specimen described as *Annularia* sp. by Archangelsky (1958), largely because of the apparent rigidity of the leaves in both. Surange (1966) compared Plumstead's figure with Indian specimens of *Schizoneura gondwanensis* and *S. wardii*. He thought (1966, p. 34) the Antarctic *Annularia* sp. "* * * may very well be placed nearer to *S. gondwanensis* than to *Annularia*, * * *" The specimen is fragmentary, and under the circumstances no precise determination can be made. It is recorded as *Schizoneura* sp. with reservation.

Distribution in Antarctica.—*Schizoneura gondwanensis* Feistmantel, Ohio Range, ridge east of Terrace

Ridge of Mount Schopf, H3–75; Ohio Range, Mercer Ridge of Mount Schopf, Leaia Ledge, H3–522J. *Schizoneura* sp., Theron Mountains; based on specimen recorded by Plumstead (1962) as *Annularia* sp.

Genus UMBELLAPHYLLITES Rasskazova

Umbellaphyllites ivini (Walkom) Rigby

Plate 2, figures 1–3

1941. *Annularia ivini* Walkom, Australian Mus. Records, v. 21, no. 1, p. 43–44, pl. 8, figs. 1–4.
1966. *Umbellaphyllites ivini* (Walkom) Rigby, Palaeontographica, v. 118, sec. B, p. 118–121, pl. 31, figs. 10–16.

Six fragments of whorls, some with counterparts, were found on rock specimens E 279, E 280, E 281, and E 323 in a single bed at Polarstar Peak, Sentinel Range.

One whorl on specimen E 280 (see pl. 2, figs. 1, 3), counterpart on specimen E 279, is almost complete; 24 leaves are visible, and from two to four leaves are probably missing at a crack on the rock. The longest preserved leaf is 16 mm in length. Two of the leaves at 120° to each other are forked; the veins branch at slightly less than half-leaf length from the center of the whorl. In one forked leaf there is a distinct vein dichotomy, and the leaf boundary commences 1.5 mm above the dichotomy. In the other forked leaf the vein is roughly two parallel touching veins below the apparent dichotomy, and the leaf boundary commences 3.5 mm above the dichotomy. No significance can be attached to this abnormality. The whorl of leaves is depressed near the node forming a distinct leaf sheath.

Specimen E 281 (see pl. 2, fig. 2) and its counterpart, E 323, bear a partial whorl attached to a slender stem. The stem is faintly longitudinally ribbed. At a node 15 mm below the whorl, the stem is 2 mm in diameter. There appear to be five ribs on the stem near the node. Maximum preserved length of any leaf in the whorl is 13 mm. A few leaves are complete except for the mucronate tip.

All leaves are wrinkled, as described by Rigby (1966b). *Umbellaphyllites ivini* probably represents one form of foliage correlated with stems of the *Paracalamites australis* type. Both species occur at this locality, where they are the only sphenopsid remains.

This species has been reported previously only from a single locality at Murulla, New South Wales (Walkom, 1941), where it forms a rare component in the flora of the Greta Coal Measures of Early Permian age.

Discussion.—Meyen (1967) and Pant and Nautiyal (1967) have suggested that Gondwana species of *Umbellaphyllites* may actually belong to *Raniganjia*. The distinguishing features between various species of these two genera, on both generic and specific levels, are not great. Rigby (1966b, table 1) has tabulated several features that differ or are similar. Pant and Nautiyal (1967) have shown that one character used to distinguish the genera is not valid; leaves of both have similar transverse wrinkling. Pant and Nautiyal (1967) have also shown that *Raniganjia indica* is a synonym of *R. bengalensis*. The few measurements and ratios given on table 1 indicate close similarity between these two genera.

TABLE 1.—*Dimensions of leaf whorls of some specimens of Umbellaphyllites and Raniganjia*

[All dimensions are in millimeters. Ratios are approximate. Tabulation based on measurements of leaves from Antarctica, and on data and photographed specimens given by Walkom (1941), Srivastava (1955), Rasskazova (1961), Rigby (1962, 1963, 1966b), and Pant and Nautiyal (1967)]

	U. annularioides	*U. ivini*	*U. minima*	*R. bengalensis*
Node diameter	4–7	0.8–1.2	1.5–2.3	0.75–5
Sheath length	3–6	2.0	1.6	0
Ratio ÷ $\frac{\text{Node diameter}}{\text{Sheath length}}$	1+/1	1/2	1+/1	------------
Whorl diameter	32–48	20–38	16–21	26–86
Node diameter	4–7	.8–1.2	1.5–2.3	.75–5
Ratio $\frac{\text{Whorl diameter}}{\text{Node diameter}}$	8/1	20/1–30/1	10/1	18/1–60/1
Number of leaves	32–40	20–34	14–19	10–80+
Whorl diameter	32–48	20–38	16–21	26–86
Ratio $\frac{\text{Number of leaves}}{\text{Whorl diameter}}$	1/1	1/1	1/1	1/1–5/2
Ratio $\frac{\text{Length of leaf attached}}{\text{Length of leaf}}$	<1/2	4/5	4/5	<1/2–3/4
Leaf apex	Acute	Mucronate	Acuminate	Mucronate

The principal generic difference is in the sheath, which is short and cylindrical in *Umbellaphyllites* and absent in *Raniganjia*. The absence of a sheath in *Raniganjia* may have been due to the mode of preservation of the material examined and reported on in publications from India and Australia.

Apparently, the inclusion or exclusion of the species *U. ivini* and *U. minima* in *Umbellaphyllites* must ultimately depend on characters of the plant not shown by sterile leaf whorls. Fertile structures, which may be decisive, have not been observed in Antarctic material.

An essential requirement in the definition of *Raniganjia* before *U. ivini* and *U. minima* could be included in it would be the recognition of a cylindrical leaf sheath in *Raniganjia*. The leaf sheath in the Gondwana species of *Umbellaphyllites* is small—2.0 mm long or shorter; hence, a similar leaf sheath in species of *Raniganjia* might be either overlooked or masked during burial. Specimens of *Raniganjia* figured by Srivastava (1955), Rigby (1962, 1963), and Pant and Nautiyal (1967, pl. 10, fig. 3) do not appear to have anything resembling a sheath; instead, leaves are fused to a small annulus at the node, as in *Annularia*.

The principal difference between the Angara species of *Umbellaphyllites*, *U. annularioides*, and the Gondwana species *U. ivini* and *U. minima* lies in the proportion of leaf length fused in the leaf whorl. *U. annularioides* has leaves fused for less than half of their length, but both *U. ivini* and *U. minima* have leaves fused for four-fifths of their length (table 1).

Another distinguishing feature between the Angara species and the Gondwana species depends on size, which may be significant, but size also depends on growth conditions and the leaves in the individual specimen.

Ratios given in table 1 indicate a very close relationship among these four species. However, the present collections yield no significant additional data to suggest that either the two genera might be merged (Boureau, 1964) or *U. ivini* and *U. minima* might be better included in *Raniganjia* (Meyen, 1967; Pant and Nautiyal, 1967). Including *U. ivini* and *U. minima* in *Raniganjia* would give a geographical separation of the genera—*Umbellaphyllites* in Angaraland and *Raniganjia* in Gondwanaland. This arrangement is attractive, but present evidence is insufficient to justify this separation.

Distribution.—Sentinel Range, Polarstar Peak, Unit 6 of Craddock and others (1965). Specimens E 279, E 280, E 281, E 323.

Sphenopsid leaves

Plate 3, figure 1

A few isolated leaf fragments that appear to have belonged to sphenopsid plants were found at one locality. These are linear and generally less than 1 mm in width (widest 1.3 mm). The longest may have been 12 mm long. All fragments are broken at both ends. None has a midrib, but each leaf is longitudinally striated and has as many as the equivalent of 30 striations per millimeter. Apparent dichotomies in the striations have resulted from minute irregularities during compression.

The figured leaves appear to have grown in either a whorl or in a tightly packed clump, but they are neither radiating from a single point nor in a single plane as fossilized. The leaves may have been fairly rigid as they were not bent during burial.

A few specimens of *Arberiella* are associated with the leaves. The striations on the *Arberiella* have the same spacing as those on the leaves. This is probably only a coincidence.

Distribution.—Pecora Escarpment, Brown Nunatak. SR 72–99.

Plant organs, parallel-veined or parallel-ribbed fragments

Plate 3, figures 2, 3

Nearly identical fragments were found at two widely separated localities—Queen Alexandra Range and Mount Fleming.

Collection V–46–NZ (specimens B 819/1–B 819/14) includes hundreds of stemlike fragments ornamented with parallel ribbing. Each of five fragments has what appears to be a single node, but some or all may be only folds in the specimen. The fragments generally lie along bedding planes; however, orientation is random (pl. 3, fig. 2). The fragments have two forms, differentiated by the spacing of the ribs (pl. 3, fig. 3). Those with broadly spaced ribs are not common and are termed "broad-ribbed" specimens below.

Dimensions:
- Rib spacing on most fragments, 11–18 ribs per 10 mm.
- Rib spacing on broad-ribbed fragments, 7 ribs per 10 mm.
- Width, broad- and narrow-ribbed fragments, 10 mm or less.
- Widest fragment, which is a narrow-ribbed fragment, 19 mm.
- Length, broad- and narrow-ribbed fragments, average, 30–40 mm.
- Maximum length, narrow-ribbed fragment, 87 mm.
- Maximum length, broad-ribbed fragment, 65 mm.

Broad-ribbed fragments were more broken during transport and burial than the narrow-ribbed fragments. Almost all specimens are straight, and ribbing is parallel throughout. The longest specimen, a narrow-ribbed fragment, is curved over an arc subtending an angle of 75°, and no distortion is visible. Other fragments on the same rock slab are completely straight.

Carbonified fragments were macerated for 20 hours in sodium hypochlorite solution until transparent. Neither cuticle nor cellular detail in cross section was preserved.

Collection AMF–221B (specimens ANT–67–5–7a, ANT–67–5–7b) contains numerous narrow-ribbed fragments, which tend to be larger than, but not as well-preserved as, the narrow-ribbed fragments in collection V–46–NZ. The host rock of this collection is not as fine grained as that of collection V–46–NZ, and some specimens of this collection are distorted.

Dimensions:
- Rib spacing on fragments, 16–20 ribs per 10 mm.
- Width, average, 10–12 mm.
- Width, widest, 16 mm.
- Length, average, 40–60 mm.
- Length, longest, 138 mm.

These fragments also show some evidence of fine longitudinal striations, both on the ribs and between them; 20 striations per millimeter were counted on one specimen. No suggestion of a node was found on any specimen.

Specimens ANT–67–5–8a and ANT–67–5–8b in collection AMF–222 (from the same horizon as AMF–221B) contain part and counterpart of a fragment of a sphenopsid stem, though no node is visible. The rock has fractured so that the upper and lower outer surfaces of the stem are exposed. These specimens also contain a small part of a ribbed plant organ (length 16, width 8 mm, rib spacing 10 per 8 mm) identical with the remains discussed above. This fragment is also longitudinally striated—13 striations per 5 mm.

These remains might best be considered as sphenopsid remains, as they are found within strata equivalent to strata near the top of the Permian section in nearby localities. This occurrence may be too early for them to represent fragments of cycad leaves such as *Nilssonia* and other similar leaf forms. Also, leaves of cordaites such as *Noeggerathiopsis* always have some evidence of vein dichotomy or divergence of veins along a leaf fragment.

Distribution.—Mount Fleming, collection AMF–221B, specimens ANT–67–5–7a, ANT–67–5–7b; collection AMF–222, specimens ANT–67–5–8a, ANT–67–5–8b. Queen Alexandra Range, Upper Bowden Nevé, Prebble Glacier, second spur end on right, collection V–46–NZ, specimens B 819/1 to B 819/14.

CONCLUSIONS

No reliable stratigraphic age determinations can be made from the recognition of these sphenopsid species. These species either range throughout Early Gondwana time or they are so rarely found that their occurrence within a stratum cannot be used to determine the age of the stratum. *Umbellaphyllites ivinii* is the only example of a rarely found species. It occurs in one locality at Polarstar Peak, Ellsworth Mountains, and at a second locality at Murulla, New South Wales, in the Lower Permian Greta Coal Measures.

Stems of *Paracalamites australis* as much as 57 mm wide were found at Polarstar Peak and are evidence that sphenopsids in Gondwanaland grew to treelike proportions. Remains of sphenopsids of diameter sufficient to support a plant of arborescent size also have been recorded from Australia (Rigby 1966a, b). In the Antarctic specimens, the node diameter exceeds the internode length. No evidence as to actual height has been found yet.

Sphenopsid distribution in Gondwanaland is indicated in table 2.

TABLE 2.—*Distribution of Gondwanaland sphenopsid genera by continents*

	Antarctica	Africa	Australia	India	South America	Elsewhere [1]
Phyllotheca	×	×	×	×	×	×
Sphenophyllum	----	×	×	×	×	×
Schizoneura	×	×	×	×	----	×
Paracalamites	×	×	×	×	×	×
Stellotheca	----	----	×	×	----	----
Umbellaphyllites	×	----	×	----	----	×
Raniganjia	----	----	×	×	----	----

[1] Genera known from areas outside Gondwanaland. Well-preserved specimens are always specifically distinct between Gondwanaland and other areas, except in *Sphenophyllum*.

REFERENCES CITED

Arber, E. A. N., 1902, On the distribution of the *Glossopteris* flora: Geol. Mag., ser. 4, v. 9, p. 346–349.

Archangelsky, Sergio, 1958, Estudio geologico y paleontologico del Bajo de La Leona (Santa Cruz): Acta Geol. Lilloana, v. 2, p. 5–133, 56 figs.

Boureau, Edouard, 1964, Traité de Paléobotanique: Paris, Masson et Cie., v. 3, 544 p., 436 figs.

Craddock, Campbell, Bastien, T. W., Rutford, R. H., and Anderson, J. J., 1965, *Glossopteris* discovered in West Antarctica: Science, v. 148, no. 3670, p. 634–637, 3 figs.

Darrah, E. L., 1968, A remarkable branching *Sphenophyllum* from the Carboniferous of Illinois: Palaeontographica, v. 121, sec. B, p. 87–101, pls. 19–29.

Du Toit, A. L., 1953, The geology of South Africa: 3d ed., New York, Hafner Publishing Co., 611 p., 41 pls., 73 figs., 1 map.

Eggert, D. A., 1962, The ontogeny of Carboniferous arborescent Sphenopsida: Palaeontographica, v. 110, sec. B, p. 99–127, pls. 17–24.

Feistmantel, Ottokar, 1880, The flora of the Damuda-Panchet Division (1st half): India Geol. Survey Mem., Palaeontologica Indica, ser. 12, v. 3, pt. 2, p. 1–77, pls. 1A–16A.

——— 1889, Die Karoo-Formation und die dieselbe unterlagernden Schichten, Pt. 1, *in* Übersichtliche Darstellung der geologisch-palaeontologischen Verhältnisse Süd-Afrikas: Böhm. Gesell. Wiss [Prag] Abh., Math.-Natur. Cl., ser. 7, v. 3, no. 6, 89 p., 4 pls.

Gunn, B. M., and Warren, Guyon, 1962, Geology of Victoria Land between the Mawson and Mulock Glaciers, Antarctica: New Zealand Geol. Survey Bull. 71 n.s., 157 p., 48 figs., 3 tables, 2 maps.

Hooker, J. D., 1852, Note on a fossil plant from the Fish River, South Africa: Geol. Soc. London Trans., ser. 2, v. 7, p. 227, pl. 28, fig. 1.

Lele, K. M., 1962, Plant fossils from the South Rewa Gondwana Basin, pt. 2 *of* Studies in the Indian Middle Gondwana flora: Palaeobotanist, v. 10, p. 69–83, pls. 1–4, 10 figs.

Long, W. E., 1969, Stratigraphy of the Nilsen Plateau, Queen Maud Mountains, Antarctica: Geol. Soc. American Bull. (In press.)

Meyen, S. V., 1967, New data on relationship between Angara and Gondwana Late Paleozoic floras [abs.], *in* Resumenes de trabajos presentados a las sesiones, Internatl. Symposium Stratigraphy adn Paleontology of the Gondwana, 1st, Mar del Plata, Oct. 1–4, 1967: Buenos Aires, Assoc. Geol. Argentina, p. 13–14.

Pant, D. D., and Kidwai, P. F., 1968. On the structure of stems and leaves of *Phyllotheca indica* Bunbury, and its affinities: Palaeontographica, v. 121, sec. B, p. 102–121, pls. 30–33.

Pant, D. D., and Nautiyal, D. D., 1967, On the structure of *Raniganjia bengalensis* (Feistmantel) Rigby with a discussion of its affinities: Palaeontographica, v. 121, sec. B. p. 52–64, pls. 10–13.

Plumstead, E. P., 1962, Fossil floras of Antarctica: London, Trans-Antarctic Expedition 1955–1958, Sci. Rept., Geol., no. 9, p. 1–154, 28 pls., 2 figs., 6 tables.

Rasskazova, E. S., 1961, [Sphenopsida of the Upper Paleozoic from the Tungusska Basin]: Nauchno-Issled. Inst. Geologii Arktiki, Sbornik Statey po Paleontologii i Biostratigrafii. v. 23, p. 35–74, pls. 1–10, (in Russian).

Rigby, J. F., 1962, The taxonomic position of *Actinopteris indica* Srivastava: Linnean Soc. New South Wales Proc., v. 86, p. 299–304, pl. 10A.

——— 1963, On a collection of plants of Permian age from Baralaba, Queensland: Linnean Soc. New South Wales Proc., v. 87, p. 341–351, pls. 11–12.

——— 1966a, Some Lower Gondwana articulates from New South Wales, *in* Symposium on floristics and stratigraphy of Gondwanaland [Palaeobot. Soc. India, Spec. Session, December 1964]: Lucknow, Birbal Sahni Inst. Palaeobotany, p. 48–54.

——— 1966b, The Lower Gondwana flora of the Perth and Collie Basins, Western Australia: Palaeontographica, v. 118, Sec. B., p. 113–152, pls. 30–36.

Rigby, J. F., and Schopf, J. M., 1969, Stratigraphic implications of Antarctic paleobotanical studies, *in* Internat. Symposium Stratigraphy and Paleontology of the Gondwana, 1st. Mar del Plata, Oct. 1–4, 1967, Proc.: Buenos Aires, Asoc. Geol. Argentina. (In press.)

Seward, A. C., 1908, On a collection of fossil plants from South Africa: Geol. Soc. London Quart. Jour., v. 64, p. 83–108, pls. 2–8.

Srivastava, P. N., 1955, Studies in the *Glossopteris* flora of India; 1. Some new fossil plants from the Lower Gondwanas of the Raniganj Coalfield, India: Palaeobotanist, v. 3, p. 70–78, pls. 1–3.

Surange, K. R., 1956, Studies in the *Glossopteris* flora of India; 2. Equisetales from the Raniganj Coalfield: Palaeobotanist, v. 4, p. 83–88, pls. 1–3, 1 fig.

——— 1966, Indian fossil pteridophytes: New Delhi, Council for Scientific and Industrial Research Bot. Mon. no. 4, 209 p., 101 figs., 2 tables.

Townrow, J. A., 1955, On some species of *Phyllotheca:* Royal Soc. New South Wales Jour. and Proc., v. 89, pt. 1, p. 39–63, pl. 1, 5 figs.

Walkom, A. B., 1941, On a new species of *Annularia* from New South Wales: Australian Mus. Rec., v. 21, no. 1, p. 43–44, pl. 8.

INDEX

[Italic numbers indicate descriptions and major references]

Page

africana, Schizoneura F8
Angaraland 3
Annularia 3, 8, 9
  ivini 9
  sp 1, 8, 9
annularioides, Umbellaphyllites 9, 10
Annulina 3
Arberiella 10
Archaeocalamites scrobiculatus 2
Asterocalamites 7
australis, Paracalamites 1, *2*, 3, 4, 5, 6, 7, 8, 9, 11; pl. 1
  Phyllotheca 2, 3, 6, 7
  Schizoneura 7

bengalensis, Raniganjia 9

Calamites 2, 4, 7

deliquescens, Phyllotheca 2
Descriptions of flora *2*

Equisetaceous stalks 2
Equisetaceous stem 2
Equisetalean stem 2
Equisetum 1

Flora, descriptions 2

Gamophyllites 3
Gondwana deposits, Lower 1
Gondwana sphenopsids 3
Gondwanaland 1, 3, 4, 6, 7
gondwanensis, Schizoneura F2, *7*, 8; pl. 2
Gondwanostachys 3
griesbachi, Phyllotheca 7

indica, Phyllotheca, 2, 7
  Raniganjia 9
Investigations, previous *1*
ivini, Annularia 9
  Umbellaphyllites *9*, 11; pl. 2

Koretrophyllites 3

minima, Umbellaphyllites 1, 9, 10
muelleriana, Phyllotheca 7
multirame, Sphenophyllum 1

Neokoretrophyllites 3
Nilssonia 11
Noeggerathiopsis 11

Paracalamites *2*, 3, 5, 6, 7, 8, 11; pl. 1
  australis 1, *2*, 8, 9, 11; pls. 1-3
  sp. A 2
  sp. B 2
Phyllotheca 1, 3, 7, 8, 11; pl. 2
  australis 1, 2, 3, 6, 7
  deliquescens 2
  griesbachi 7
  indica 2, 7
  muelleriana 7
  zeilleri 2
  sp 1, 2, 3, 6, 7, 8; pl. 2
Plant organs, parallel-veined or parallel-ribbed fragments F*10*; pl. 3

Rachis of ferns 2
Raniganjia 1, 3, 9, 10, 11
  bengalensis 9
  indica 9

Schizoneura 1, 2, 3, 7, 8, 11
  africana 8
  australis 7
  gondwanensis 2, 3, *7*; pl. 2
  meriani 7
  wardii 8
  sp 1, 2, 7, 8, 9
scrobiculatus, Archaeocalamites 2
Sphenophyllum 1, 11
  multirame 1
Sphenopsid leaves *10*; pl. 3
Stellotheca 1, 3, 11

Tschernovia sp 3

Umbellaphyllites 1, 3, *9*, 10, 11; pl. 2
  annularioides 9, 10
  ivini *9*, 11; pl. 2
  minima 1, 9, 10

wardii, Schizoneura 8

zeilleri, Phyllotheca 2

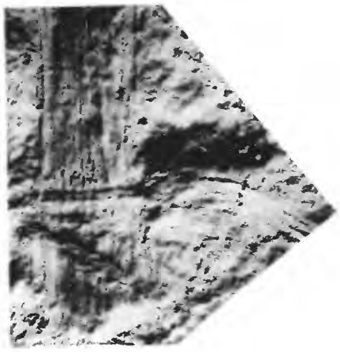
PLATES 1–3

PLATE 1

[Orientation of the figure on the plate is not intended to suggest any particular orientation during life]

FIGURES 1–9. *Paracalamites australis* Rigby (p. F2).

1. Stem with attached branch. Note the thinning of the branch toward the contact with the main stem, which is typical of the calamites and indicates that this specimen is a pith cast. Specimen QM 29 about 2,270 feet above basement on south side of Roaring Valley, about 18 miles southeast of Mount Helmer Hansen summit, Queen Maud Range, Antarctica. Collected by W. E. Long, Institute of Polar Studies.
2. Nodal diaphragm of a stem. Shows size; shape has been determined by irregular fracturing in the rock. Specimen E 62, near middle of Upper Polarstar Unit, East Ridge, Polarstar Peak, Sentinel Range, Antarctica. Collected by Campbell Craddock and associates, Minnesota.
3. Enlarged view (× 2½) of fig. 2 to show details of radial ribbing.
4. Internal cast of stem. Specimen P4–54, Brown Nunatak, Pecora Escarpment, southern Pensacola Mountains, Antarctica. Collected by A. B. Ford, U.S. Geological Survey.
5. Fragment, enlarged view (× 2½) to show detail of fine longitudinal striations on ribs and spaces between ribs. Specimen P4–92, from same locality as fig. 4.
6. Mold showing detail of inner surface of stem. Specimen P4–73, from same locality as fig. 4.
7. Enlarged view (× 4) of fragment to show details of fiber distribution at nodes. Text fig. 1 is based on details of nodes in this specimen. Specimen E 59, from same locality as fig. 2.
8. Slender stem that has what appear to be branches arising at most nodes. Specimen QM 177d, 1,750 feet above basement on South Ridge—about 34 miles south-southeast of Mount Helmer Hansen, Queen Maud Range, Antarctica. Collected by W. E. Long, Institute of Polar Studies.
9. Matted stem fragments randomly oriented, lying approximately along bedding planes. This attitude is typical for these stems when preserved as impressions. Specimen E 36, from same locality as fig. 2.



1

4

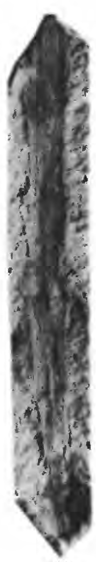
5

2

3

6

7



8

9

PARACALAMITES AUSTRALIS RIGBY

PLATE 2

[Orientation of the figure on the plate is not intended to suggest any particular orientation during life]

FIGURES 1–3. *Umbellaphyllites ivini* (Walkom) Rigby (p. F9).

1. Almost complete leaf whorl; enlarged view (× 2½) to show forking of leaf midribs—more distinct with complete fusion of veins in upper center, less distinct with two veins separate but almost touching in lower right. Specimen E 280, near middle of Upper Polarstar Unit, East Ridge, Polarstar Peak, Sentinel Range, Antarctica. Collected by Campbell Craddock and associates, Minnesota.
2. Partial leaf whorl attached to a slender stem. A node occurs at the lower end of the straight section of the stem. The curved part follows a fracture in the rock. Specimen E 281, from same locality as fig. 1.
3. Same specimen and view as fig. 1, natural size. The free apical part of the leaf may be seen on some leaves along the lower edge.

4. *Phyllotheca* sp. (p. F7).

Partial leaf whorl showing typical fused leaves becoming free toward the apex. Specimen B 812/11 of collection V–42–NZ; nunatak 2 miles southeast of Dawson Peak summit, Painted Cliffs district, Queen Elizabeth Range, west side, Upper Bowden Nevé, Antarctica. Collected by R. I. Walcott, New Zealand Geological Survey.

5. *Phyllotheca*? sp. (p. F7).

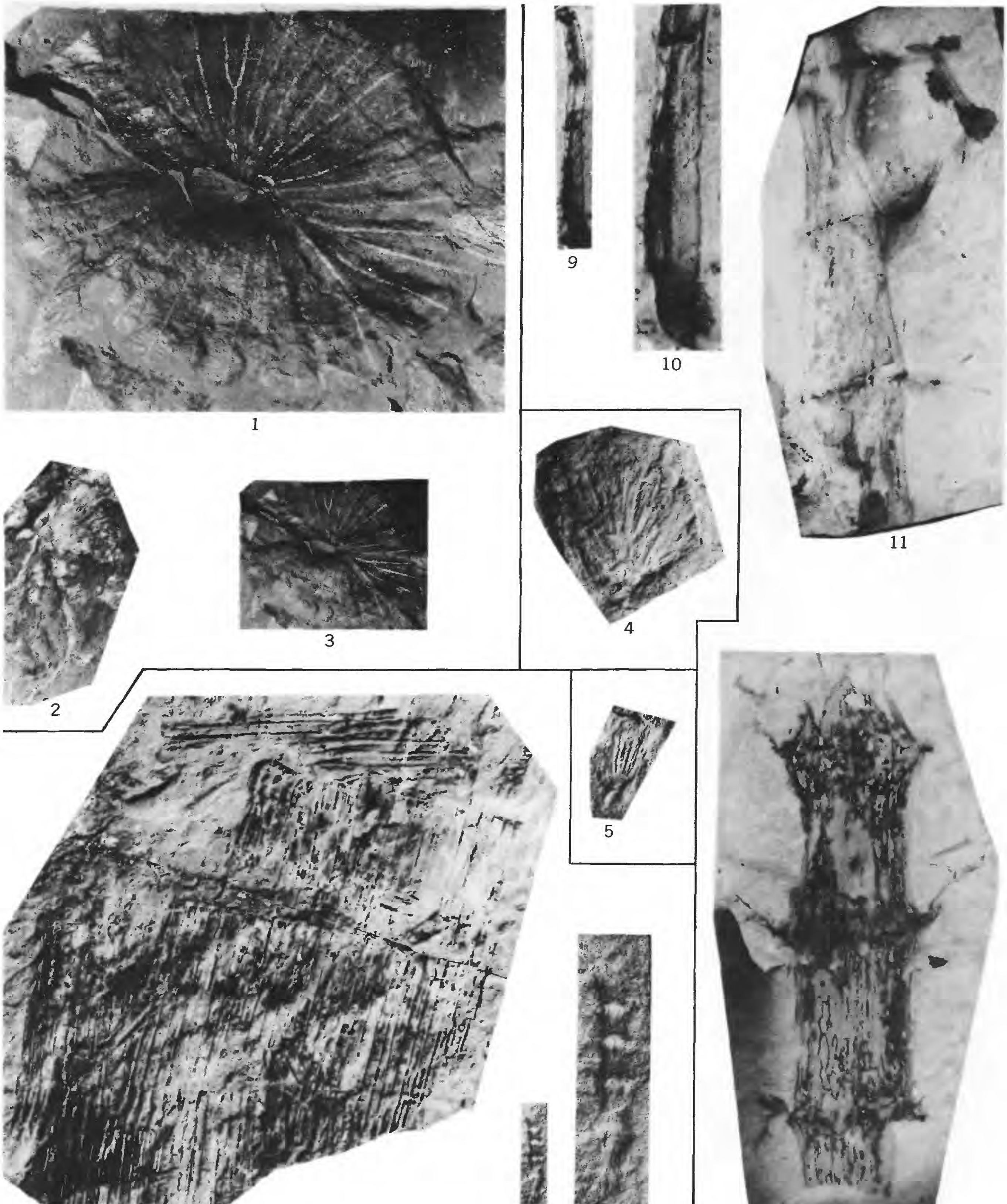
Very fragmentary leaf whorl that appears to be typical of *Phyllotheca*. Specimen H4w–13d; uppermost shale, Weaver Formation, Tillite Ridge, Wisconsin Range, Antarctica. Collected by V. H. Minshew, Institute of Polar Studies.

6–8. *Paracalamites australis* Rigby (p. F2).

6. Broadest stem found. The bend is apparent only, being caused by a second stem fragment being pressed into the first. Specimen E 54, from same locality as fig. 1. See p. F4 for dimensions.
7. Small slender stem with nodes close together. Narrowest stem found. Specimen H4w–13c, from same locality as fig. 5.
8. Enlarged view (× 2½) of fig. 7 to show details of ribbing and swelling at nodes.

9–12. *Schizoneura gondwanensis* Feistmantel (p. F7).

9. Isolated leaf showing single midrib. Apparently, neither base nor apex are preserved. Specimen H3–75; about 985 feet below diabase cap on ridge 1 mile northeast of Terrace Ridge, Mount Schopf, Ohio Range, Antarctica. Collected by W. E. Long, Institute of Polar Studies.
10. Enlarged view (× 2½) of part of isolated leaf of fig. 9 to show longitudinal striations.
11. Leaves attached to a distorted stem of *Paracalamites australis* Rigby. The longest attached leaf is at upper right; other leaves occur at the two lower nodes. Specimen H3–75; same locality as in fig. 9.
12. Fragmentary leaves attached to a stem of *Paracalamites australis* Rigby. Specimen H3–75; same locality as in fig. 9.



UMBELLAPHYLLITES IVINI (WALKOM) RIGBY, *PHYLLOTHECA*, *PARACALAMITES AUSTRALIS* RIGBY, AND *SCHIZONEURA GONDWANENSIS* FEISTMANTEL

PLATE 3

[Orientation of the figure on the plate is not intended to suggest any particular orientation during life]

FIGURE 1. Sphenopsid leaves (p. F10).

These very small organs appear to be arranged in a whorl. Specimen (× 5) SR 72–99; 15 feet below thick coal bed in upper part of section, Brown Nunatak, Pecora Escarpment, Pensacola Mountains area, Antarctica. Collected by J. M. Schopf and J. F. Rigby, U.S. Geological Survey.

2, 3. Plant organs (p. F10).

2. Strips of plant material which appear to be leaves. Most fragments shown on this specimen have no apex, base, or sides preserved. Specimen B 819/12 of collection V–46–NZ; spur on south side Prebble Glacier, about 3½ miles north-northwest of Mount Falla summit, Queen Alexandra Range, Antarctica. Collected by R. I. Walcott, New Zealand Geological Survey.

3. Strips of plant material. Two forms are shown. A single fragment of the form that has broadly spaced ribs lies along the upper right; this form resembles a stem rather than a leaf. The remaining fragments are of the form that has closely spaced ribs. Specimen B 819/14 of collection V–46–NZ; same locality and collector as for fig. 2

4–8. *Paracalamites australis* Rigby (p. F2).

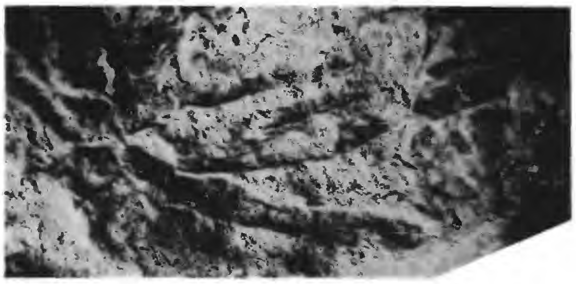
4. Stem that has irregular rib arrangement at nodes. Specimen E 44a, near middle of Upper Polarstar Unit, East Ridge, Polarstar Peak, Sentinel Range, Antarctica. Collected by Campbell Craddock and associates, Minnesota.

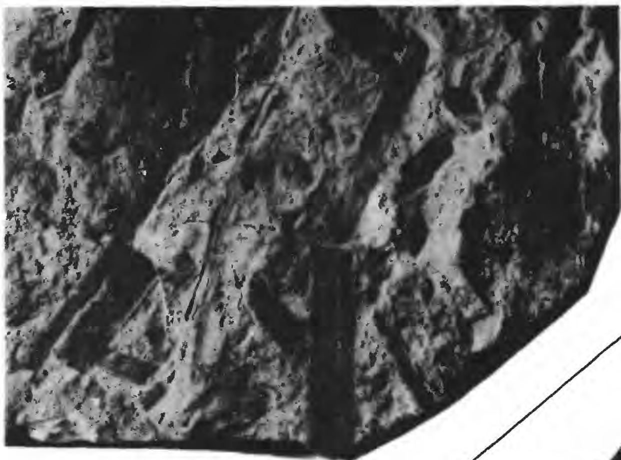
5. Enlarged view (× 2½) of fig. 4 to show arrangement of fibers entering and crossing nodes. Text fig. 2 shows the fiber arrangement at the right-hand side of the upper node.

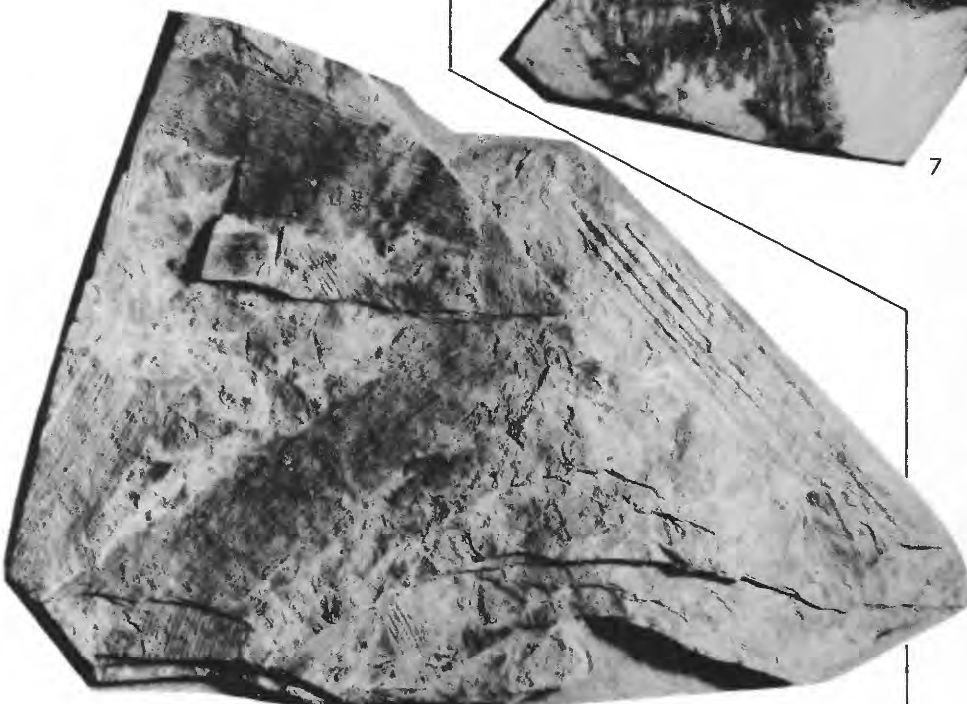
6. Internal cast of base of a stem showing very short internodes and rapidly expanding diameter of the stem away from the base. Specimen H4w–15c, shale at top of Mount Weaver Formation, Tillite Ridge, Wisconsin Range, Antarctica. Collected by V. H. Minshew, Institute of Polar Studies.

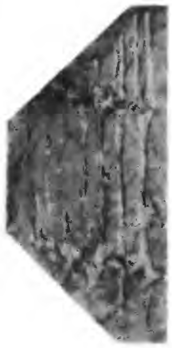
7. Poorly preserved stem bearing a branch apparently similar to branch in fig. 6. Specimen QM 11B; 1,785 feet above basement at head of Wildcat Canyon, about 17 miles southeast of Mount Helmer Hansen summit, Queen Maud Range, Antarctica. Collected by W. E. Long, Institute of Polar Studies.

8. Poorly preserved broad stem; internodes very much shorter than stem width. This form is typical of the lower parts of trunks. Specimen QM 10; same locality as in fig. 7, but about 20 feet higher in the section.


1

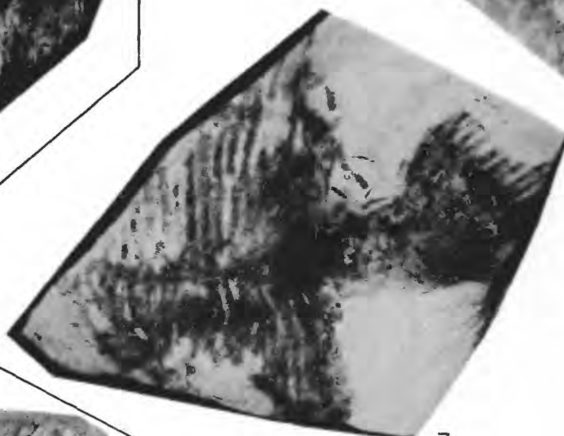

2


3


4


5


6


7


8

SPHENOPSID LEAVES, PLANT ORGANS, AND *PARACALAMITES AUSTRALIS* RIGBY

Contributions to Paleontology 1968

GEOLOGICAL SURVEY PROFESSIONAL PAPER 613

This volume was published
as separate chapters A–F

UNITED STATES DEPARTMENT OF THE INTERIOR

WALTER J. HICKEL, *Secretary*

GEOLOGICAL SURVEY

William T. Pecora, *Director*

CONTENTS

[Letters designate the separately published chapters]

(A) An early *Reticuloceras* Zone fauna from the Hale Formation in northwestern Arkansas, by Mackenzie Gordon, Jr.
(B) *Teiichispira*, a new Early Ordovician gastropod genus, by Ellis L. Yochelson and Clive R. Jones.
(C) Early Pennsylvanian ammonoids from southern Nevada, by Mackenzie Gordon, Jr.
(D) Ferns from the Chinle Formation (Upper Triassic) in the Fort Wingate area, New Mexico, by Sidney R. Ash.
(E) Carboniferous megafaunal and microfaunal zonation in the northern Cordillera of the United States, by William J. Sando, Bernard L. Mamet, and J. Thomas Dutro, Jr.
(F) Permian sphenopsids from Antarctica, by J. F. Rigby.

U.S. GOVERNMENT PRINTING OFFICE: 1969 O—357-071