

A STUDY OF SOME CARBONIFEROUS
MARATTIALEAN FRUCTIFICATIONS

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Ratan K. Mohta
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Gilbert A. Leisner
Approved for Major Department

James W. Bryan
Approved for Graduate Council

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TABLE OF CONTENTS

	Page
Introduction	1
Methods and Materials	7
Description	8
<u>Scolecoperis minor</u>	8
<u>S. latifolia</u>	16
<u>Cyathotrachus altissimus</u>	24
Discussion	29
Summary	35
Literature Cited	36

LIST OF TABLES

	Page
I. Comparison of various species of <u>Scolecoperis</u>	4-5
II. Comparison of various species of <u>Cyathotrachus</u>	6
III. <u>Scolecoperis minor</u> : A comparison of the findings of different workers	32

LIST OF FIGURES

	Page
1. Portion of a frond of <u>Scolecoperis minor</u>	9
2. Transverse section of pinna axis of <u>S. minor</u>	9
3. Pinnule of <u>S. minor</u> sectioned in a plane parallel to the surface of the lamina	10
4. Tracheids of <u>S. minor</u>	10
5. Transverse section of pinna axis of <u>S. minor</u> with one pinnule	11
6. Longitudinal section of young sporangia of <u>S. minor</u>	11
7. Transverse section of pinnule of <u>S. minor</u>	13
8. Pinnule of <u>S. minor</u> sectioned parallel to the surface of the lamina showing synangia	13
9. Pinnule of <u>S. minor</u> sectioned in a plane parallel to the lamina surface showing veins	14
10. Pinnule of <u>S. minor</u> sectioned in a plane parallel to the lamina surface showing lateral veins on one side and synangia on the other side	14
11. Transverse section of two synangia of <u>S. minor</u> each containing three sporangia	15
12. Transverse section of a synangium of <u>S. minor</u> with six sporangia	15
13. Transverse section of a pinnule of <u>S. minor</u> showing inflexed margins	17
14. A multicellular hair of <u>S. minor</u> attached to the pinnule midrib	17
15. Transverse section of a synangium of <u>S. minor</u> showing dehiscence of sporangia and outer thick wall	18
16. Spores of <u>S. minor</u>	18
17. Transverse section of pinna of <u>S. latifolia</u> with two pinnules sectioned in part	20
18. Transverse section of pinna axis of <u>S. latifolia</u>	20

LIST OF FIGURES CONTINUED

	Page
19. Single pinnule of <u>S. latifolia</u> sectioned in a plane parallel to the lamina surface	21
20. Transverse section of a pinnule of <u>S. latifolia</u>	21
21. Longitudinal section of a synangium of <u>S. latifolia</u>	22
22. Longitudinal section of a synangium of <u>S. latifolia</u>	22
23. Tangential section of pinnule of <u>S. latifolia</u> showing sporangia and marginal lobes	23
24. Portion of pinnule of <u>S. latifolia</u> sectioned in a plane parallel to the lamina surface	23
25. Spores of <u>S. latifolia</u>	25
26. A single synangium of <u>C. altissimus</u> consisting of nine sporangia sectioned transversely through distal portion where central column is absent	26
27. A single synangium of <u>C. altissimus</u> consisting of eight sporangia sectioned transversely through distal portion where central column is absent	26
28. Three synangia of <u>C. altissimus</u> each with six sporangia cut in transverse section	27
29. A single synangium of <u>C. altissimus</u> cut in longitudinal section	27
30. A single sporangium of <u>C. altissimus</u> cut longitudinally showing spores	28
31. Cordate pollen grains that filled the sporangia of <u>C. altissimus</u> shown in Fig. 26	28

INTRODUCTION

The order Marattiales, consisting of six living genera and several extinct forms, is characterized by exannulate eusporangia borne, free and grouped into elongate sori or united into synangia, on the abaxial surface of fronds. The fructifications that we refer to the Carboniferous Marattiales are usually borne on Pecopteris type foliage, on the abaxial side in the form of radially symmetrical sori.

Mamay (1950) included seven genera of fern sporangia in the extinct Marattiales, limited mainly to strata of Pennsylvanian age. General characteristics of these genera are as follows:

1. Acitheca Schimper: Synangia sessile; sporangia attached at their bases to a central column, with distal portions free; sporangial apices long and bristle-like. Based mainly on petrifications.
2. Asterotheca Presl: Synangia sessile; sporangia attached to a receptacle, but free distally with long axes of the sporangia parallel to the plane of the pinnule. Based mainly on compressions.
3. Cyathotrachus Watson, emend. Mamay: Synangia pedicellate; sporangia enclosed in a continuous synangial sheath; basal portion of synangium with central column; apical portion hollow and cup-like. Based on petrifications.
4. Eoangiopteris Mamay: Sori linear; sporangia arranged in two rows along fleshy receptacle; sori located along lateral veins; sporangia free; monotypic. Based on petrifications.
5. Ptychocarpus Weiss: Synangia pedicellate; sporangia enclosed in a continuous synangial sheath, and fused to a central column

extending through the entire length of the synangium. Based mainly on compressions.

6. Scolecoperis Zenker: Synangia pedicellate; sporangia attached to a central receptacle but free distally. Based mainly on petrifications.
7. Sturiella Weiss: Synangia pedicellate; sporangia basally fused but free above; annulus - like structure present. Based mainly on petrifications.

These genera are separated from each other on the following criteria:

1. Sori radial or linear.
2. Synangia pedicellate or sessile.
3. Sporangia free above or enclosed in a continuous synangial sheath.
4. Central column present or absent in synangia. If present, extends through the entire length of the synangium or not.

The species are recognized on the basis of size of sporangia, structure of sporangial wall, number of sporangia in the sorus, arrangement of synangia on pinnules, spore dimensions and sculpturing, and pinnule dimensions and margins.

Mamay proposed that the Marattiales have been derived from coenopterid ferns through a "phyletic slide." He considered the coenopterid genus Chorionopteris as a possible progenitor for the asterotheceous fructifications, with this evolution supposedly coming about by means of a "phyletic slide" from marginal or terminal sori to superficial ones. He also proposed that Cyathotrachus and Ptychocarpus (with fused sporangia) are allied to the living genera Danaea, Christensenia, and Marattia; and Scolecoperis, Asterothea and Eosangiopteris (with free sporangia) are allied to the

living genera Angiopteris, Archangiopteris, and Macroglossum.

Scolecopteris

The genus, founded by Zenker in 1837, based upon silicified material from the Lower Permian of Saxony, includes the following 12 species and one variety:

- S. elegans Zenker, *Linnaea* II: 509. 1837.
- S. subelegans Grand'Eury, *Acad. Sci. Inst. France Mem.* 24:72-73. 1877.
- S. ripariensis Grand'Eury, *Ibid.*, pp. 73.
- S. minor Hoskins, *Bot. Gaz.* 82:427-436. 1926.
- S. oliveri Scott, *Journ. Linnean Soc. London, Botany*, 49:1-12. 1932 and pp. 309-321. 1933.
- S. latifolia Graham, *Bot. Gaz.* 95:456-458. 1934. Emend Mamay, *Ann. Missouri Bot. Gard.* 37:425-428. 1950.
- S. radforthii Andrews, *Ann. Missouri Bot. Gard.* 30:435-437. 1947.
- S. iowensis Mamay; *Ibid.*, 37:429-431. 1950.
- S. minor Hoskins var. parviflora Mamay, *Ibid.*, pp. 431-432.
- S. incisifolia Mamay, *Ibid.*, pp. 433-436.
- S. major Mamay, *Ibid.*, pp. 436-439.
- S. monothrix Ewart, *Ibid.*, 48:277-280. 1961.
- S. illinoensis Ewart, *Ibid.*, pp. 281-283.

The main characteristics of these species are summarized in Table I.

Table I. Comparison of various species of Scolecopteris.

	Average dimensions of sporangia (length x width mm)	Number of sporangia per synangium	Nature of sporangial walls	Dimensions of pinnules (length x width mm)	Pinnule margin	Arrangement of synangia	Spore dimensions; sculpturing
<u>S. elegans</u> Zenker	0.90 x 0.40	Usually 5	Thickened outer surface; inner surface thin	3.50-4.00 x 1.50-1.70	Entire	Single series on each side midvein	10 μ diameter; triradial scars, smooth exines
<u>S. oliveri</u> Scott	1.32-1.40 x 0.44	Usually 4 sometimes 3 or 5	---Do---	6.00 x 2.70	Minutely toothed	---Do---	Bilateral with greatest dimensions 18 μ ; exine rugose
<u>S. latifolia</u> Graham	0.90-1.20 x 0.34-0.39	3 or 4	No thickening of outer surface	3.80 x 2.00	Deeply incised	---Do---	35 μ diameter, triradial scars, smooth exines
<u>S. radforthii</u> Andrews	0.70 x 0.25	3 or 4	?	3.00 x 2.00	Entire	---Do---	32 μ diameter, triradial scars, smooth exines
<u>S. minor</u> Hoskins	0.70 x 0.28	Usually 4 or 5 rarely 6	Thickened outer surface; inner surface thin	6.00-7.00 x 3.30	---Do---	---Do---	17 μ diameter, no markings
<u>S. minor</u> var. <u>parviflora</u> Hamay	0.50 x 0.35	Usually 4 or 5 rarely 6	---Do---	3.00 x 1.75	---Do---	---Do---	15 μ diameter, triradial scars, smooth exines

Table I. Comparison of various species of Scolecopteris.

	Average dimensions of sporangia (length x width mm)	Number of sporangia per synangium	Nature of sporangial walls	Dimensions of pinnules (length x width mm)	Pinnule margin	Arrangement of synangia	Spore dimensions; sculpturing
<u>S. iowensis</u> Mamay	0.90 x 0.35	4, 5, usually 6	---Do---	7.00 x 3.5	---Do---	Single or double series on each side of midvein	65-80 μ diameter; triradial scars, reticulate exines
<u>S. major</u> Mamay	2.10-2.90 x 0.50	Usually 4, rarely 5	---Do---	?	?	?	45-55 μ diameter; triradial scars, irregularly reticulate exines
<u>S. incisifolia</u> Mamay	0.75 x 0.33	3, usually 4	---Do---	5.00-6.00 x 2.00	Deeply incised	Single series on each side of midvein	Bilateral 22 x 14 μ , smooth exines
<u>S. monothrix</u> Ewart	1.8 x 0.35	4 or 5 rarely 3	?	6.00 x 2.5	---Do---	---Do---	12 x 9 μ , smooth exines, thick walls
<u>S. illinoensis</u> Ewart	0.65 x 0.31	5 or 6	Outer wall thick, lateral walls thin	5.5 x 2.2	Minutely toothed	---Do---	15 μ diameter; crescent shaped indentation in exine

CYATHOTRACHUS
Cyathotrachus

This genus, founded by Watson in 1906 based upon material from the Lower Coal Measures of England and emended by Mamay (1950), includes the following three species.

C. altus Watson, Roy. Micr. Soc. Journ. 1906:1-3. 1906.

C. bulbaceus Graham, Bot. Gaz. 95:459-461. 1934.

C. altissimus Mamay, Ann. Missouri Bot. Gard. 37:420-423. 1950.

The main characteristics of these species are summarized in Table II.

Table II. Comparison of Various Species of Cyathotrachus.

		Sporangial dimensions (length x width mm)	Number of sporangia per synangium	Spores
<u>C. altus</u>	Watson	0.70 x 0.20	4-7	Ovoid, 12.5 x 15 μ
<u>C. bulbaceus</u>	Graham	0.65 x 0.30-0.35	4-6	Round, 18 μ in diameter
<u>C. altissimus</u>	Mamay	1.50 - 1.80 x 0.20 - 0.45	5-9	Bilateral, 12 x 20 μ

This paper summarizes a study of these two genera, Scolecopteris and Cyathotrachus, plus attached pinnules when present, in representative coal balls in the paleobotanical collection of Kansas State Teachers College. These coal balls were collected at various sites in Kansas and Illinois.

METHODS AND MATERIALS

A total of 16 coal balls were studied in the present investigation. These coal balls were collected from different sites in Kansas and Illinois: #1103 and 5250 were collected at the Western Coal and Mining Company Mine, approximately one mile northeast of Cherokee, Kansas; Weir-Pittsburg Coal, Cherokee Group, Desmoinesian Series, Middle Pennsylvanian. Numbers 90, 599, 701, 2965, 3855, and 3887 were collected at the Pittsburg and Midway Coal Company Mine #19, two miles northwest of Hallowell, Kansas; Mineral or Fleming Coal, Desmoinesian Series, Middle Pennsylvanian. Numbers 3778, 3796, 4139, and 4553 were collected at the Sahara Mine, approximately four miles northwest of Carrier Mills, Illinois; Herrin #6 coal, Kewanee Group, Middle Pennsylvanian. Numbers 2669, 2686, 2801, and 2810 were collected at the Palmer Mine located three miles northeast of Arma, Kansas; Bevier Coal, Desmoinesian Series, Middle Pennsylvanian.

The cellulose acetate peel technique was followed in the study of this material. In a few instances serial sections were obtained by making successive peels at close intervals. From these the reconstructions of the pinnules and the way in which the sporangia were attached were made.

DESCRIPTION

Scolecopteris minor - Although specimens of this species were found in many Kansas coal balls, those in balls #701, 1103, 2810, 3480, 3887, 4139 and 5250 were excellently preserved and were selected for critical study.

The fructifications are born on Pecopteris - type pinnales which are arranged alternately upon the pinna axis as shown in Fig. 1. The pinna trace, when viewed in cross section is U - shaped (Fig. 2). The smallest xylem cells are located at the tips of the trace and the tips are slightly involute (Fig. 2). Tracheids show spiral thickenings in longitudinal section (Fig. 4). Surrounding the xylem are three to four rows of thin - walled cells. Many of the large cells beneath the trace show dark contents and are probably tannin or mucilage cells. A band of sclerenchyma extends from between the tips of the trace towards the upper epidermis (Fig. 2). Multicellular hairs are present on the lower side of the pinna axis and the pinnales (Figs. 2, 13, 14).

The section in Fig. 3 has been cut in a plane parallel to the surface of the lamina. The pinna axis with the pinnule midvein departing from it can be seen very clearly. The pinnule midvein is prominent and extends almost to the tip giving off three to five lateral veins at angles of about 70° (Figs. 9, 10). As seen in Fig. 1, the pinnules vary in size in the same frond being smaller towards the apex. The apex and the margins of the pinnule are strongly inflexed (Figs. 5, 13) and form a sort of semi - chamber enclosing the fructifications. The pinnules measured at the "shoulders" are 2.20 to 3.20 mm in length and 1.50 to 1.80 mm in width, averaging 2.70×1.60 mm. If flattened, they would measure up to

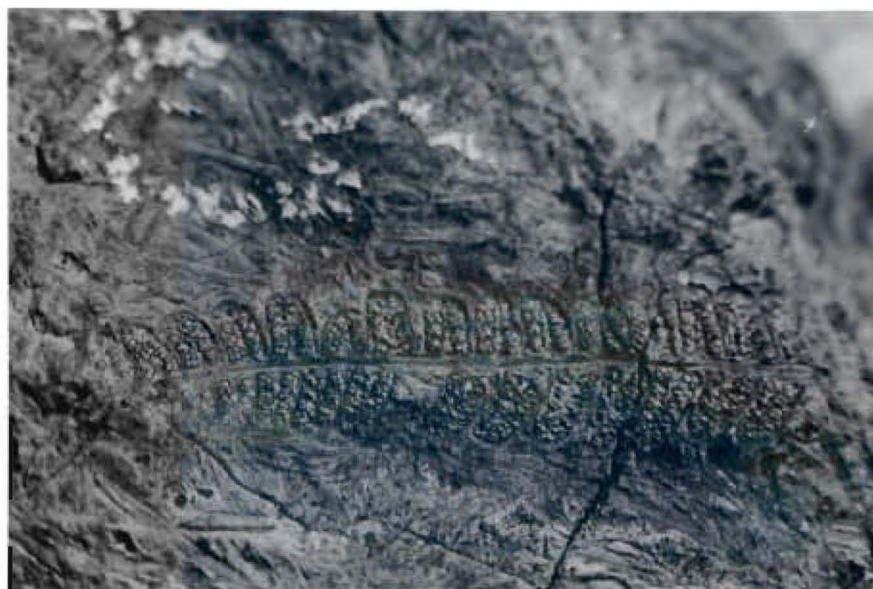


Fig. 1. Portion of a frond of S. minor showing the arrangement of pinnules on the pinna axis. Specimen #5250, X3.5.

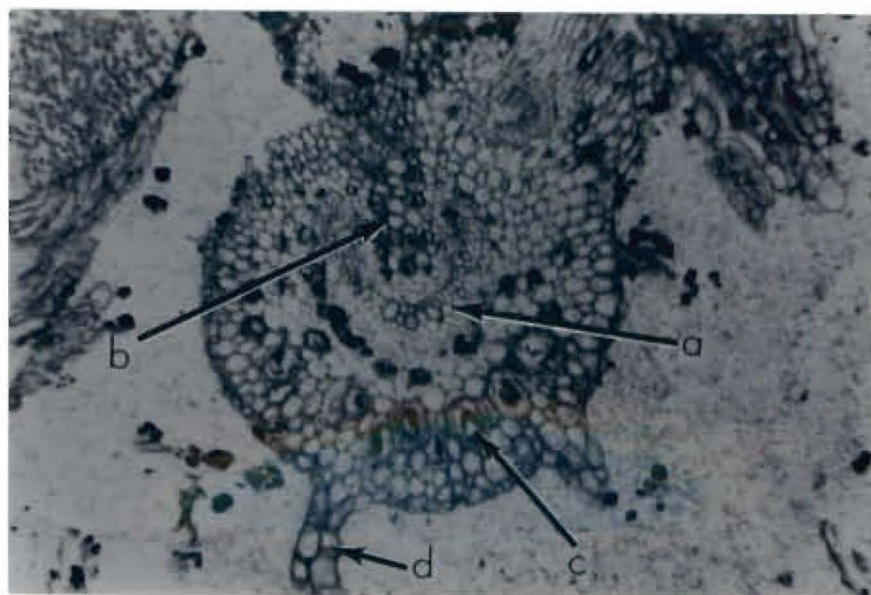


Fig. 2. Transverse section of pinna axis of S. minor. a. U-shaped vascular bundle; b. band of sclerenchyma; c. large cells with dark contents; d. multicellular hair. Slide #3778B(I)Bottom1-1, X67.

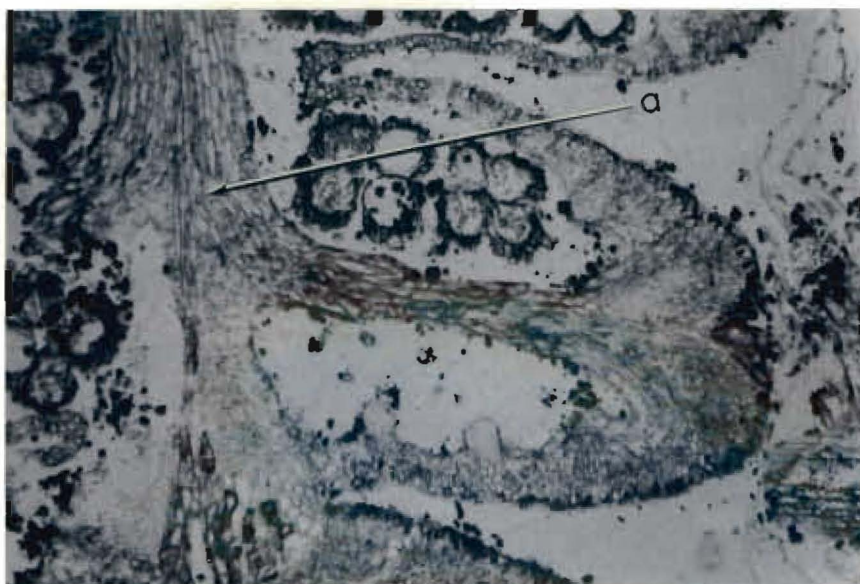


Fig. 3. Pinnule of S. minor sectioned in a plane parallel to the surface of the lamina. a. pinnule midvein departing from the pinna axis. Slide #701A(4)1-1, X35.

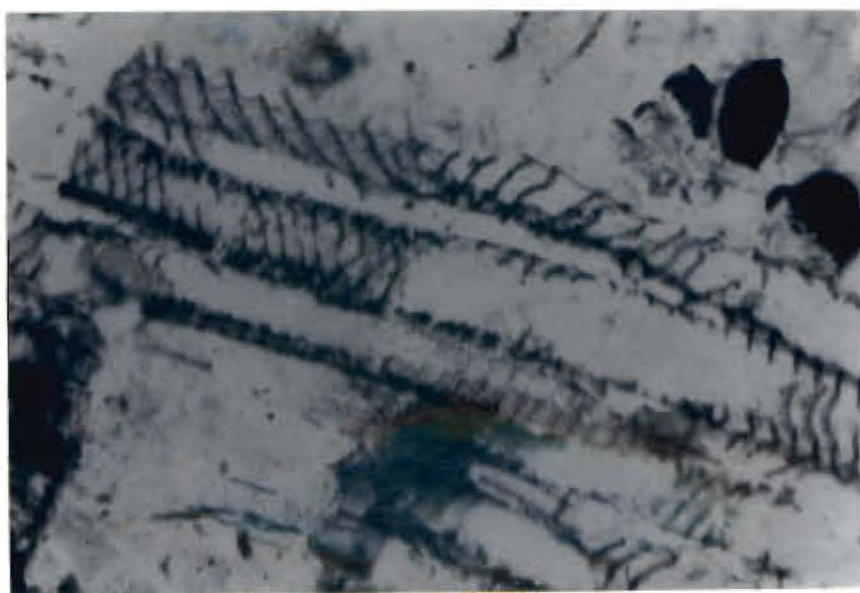


Fig. 4. Tracheids of S. minor showing spiral thickening. Slide #4139B1-3, X350.

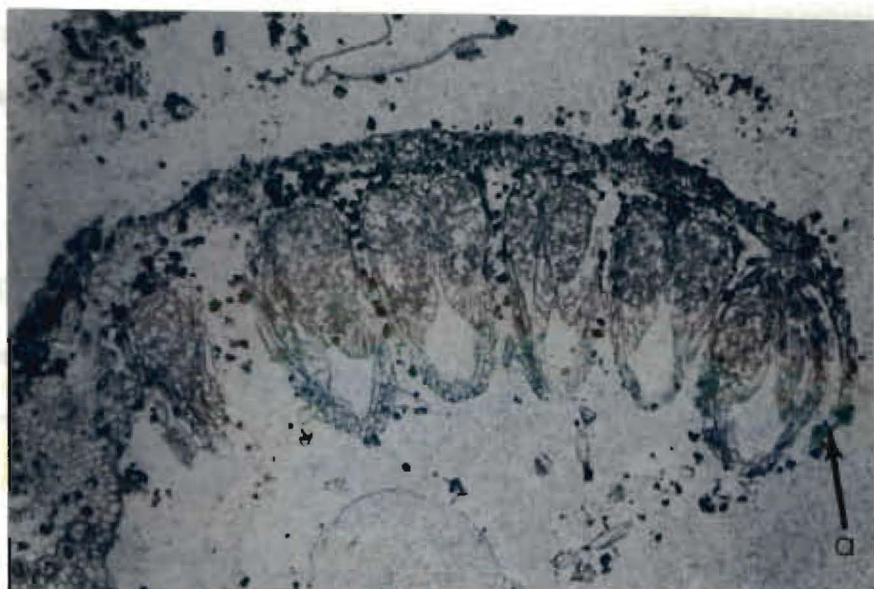


Fig. 5. Transverse section of pinna axis of S. minor with one pinnule. a. recurved pinnule apex. Slide #3480B(I)Bottom1-1, X35.

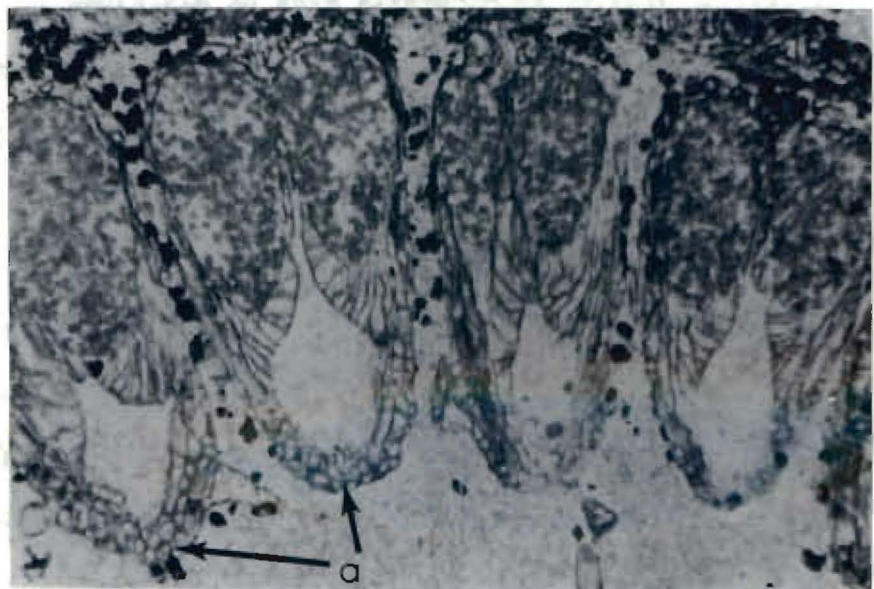


Fig. 6. Longitudinal section of young sporangia of S. minor. a. fused apices. Slide #3480B(I)Bottom1-1, X67.

5.20 mm in length and 3.50 mm in width, with the average being 4.50×3.20 . The margins of the pinnules are entire.

The pinnules in transverse section show one or two rows of large thick-walled cells beneath the upper epidermis (Fig. 7). In a number of specimens a very well - preserved palisade layer is seen beneath these thick - walled cells (Fig. 7). In other cases thin - walled cells are seen in this region. No stomatal structures can be identified. The midvein of the pinnule consists of a small circular group of tracheids surrounded by thin - walled cells. Tracheids again have spiral thickenings like those in the pinna axis. The synangia are supplied by the lateral veins.

Sporangia occur in pedicellate synangia, which are inserted in a single series on each side of the midvein on the lower side of the pinnule. With the exception of a few with three (Fig. 11) or six (Fig. 12), the number of sporangia in each synangium is usually four or five, with four-sporangiate synangia being most common. It is not uncommon to find adjacent synangia on the same pinnule varying in the number of sporangia (Fig. 8).

The synangia average 0.85 mm in diameter and 0.70 in length, excluding the pedicel. In transverse section the synangium appears to be star-like with extremely obtuse points.

The sporangia, basally attached to a common pedicel, appear closely appressed to each other in immature synangia. An individual sporangium in cross section is roughly circular, with the sides adjacent to neighboring sporangia being slightly flattened. In longitudinal section the sporangial cavity is ovoid in shape, with longer axis at a right angle to the pinnule. The distal ends of the sporangia are prolonged considerably

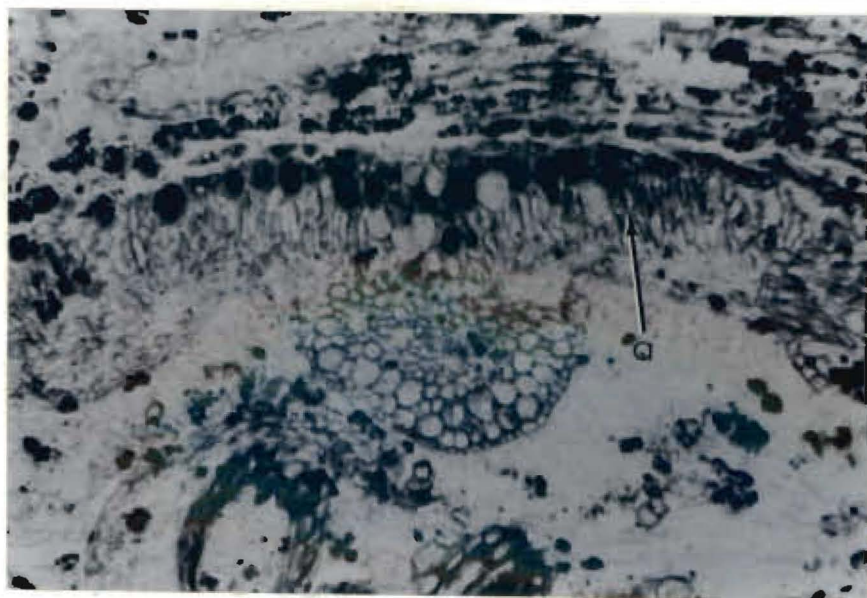


Fig. 7. Transverse section of pinnule of *S. minor*.
a. palisade layer. Slide #1103C Top1-5, X67.

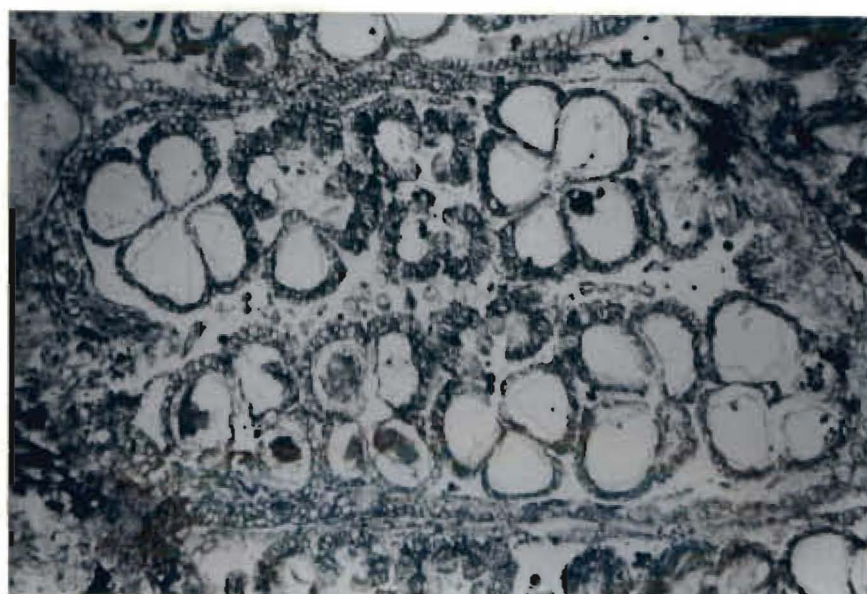


Fig. 8. Pinnule of *S. minor* sectioned parallel
to the surface of the lamina. Slide #4139(A)1-1,
X35.

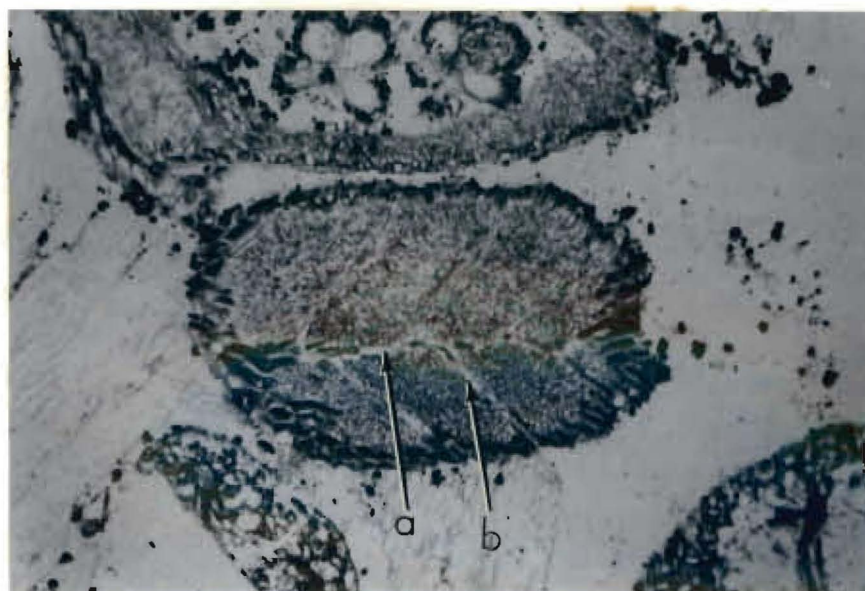


Fig. 9. Pinnule of *S. minor* sectioned in a plane parallel to the lamina surface. a. pinnule midvein b. lateral veins. Slide #701A(4)1-8, X35.



Fig. 10. Pinnule of *S. minor* sectioned in a plane parallel to the lamina surface showing lateral veins departing from the pinnule midvein on one side and synangia on the other side. Slide #701A(4)1-8, X35.

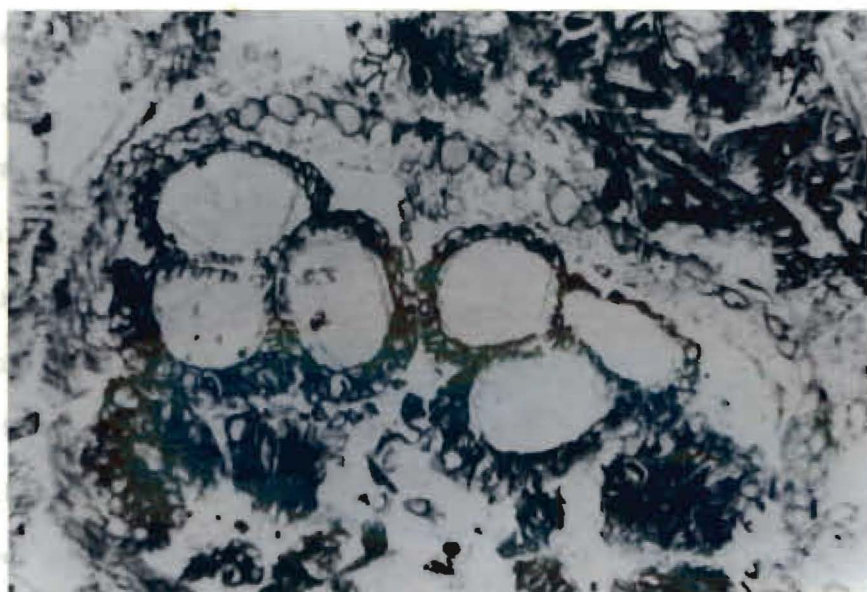


Fig. 11. Transverse section of two synangia of S. minor each containing three sporangia. Slide #4139(B)1-3, X67.

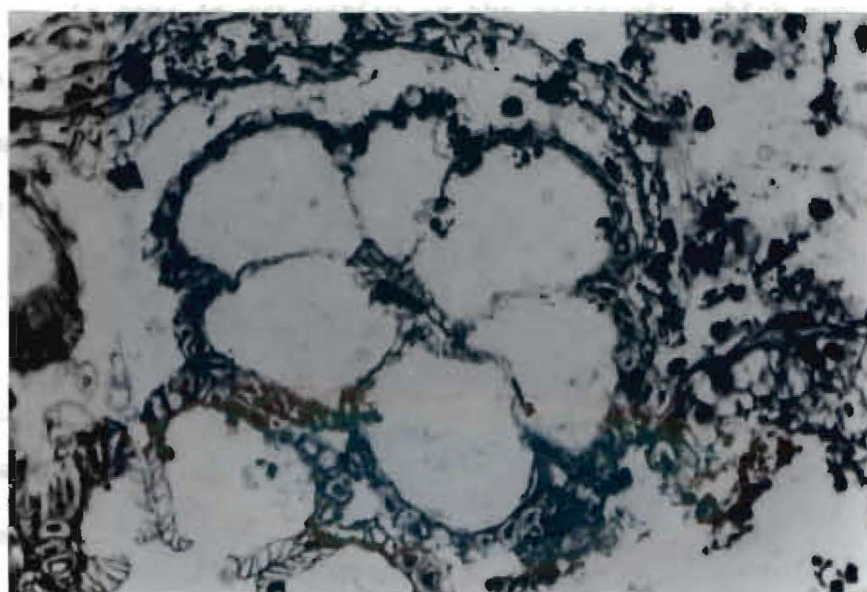


Fig. 12. Transverse section of a synangium of S. minor with six sporangia. Slide #3887B(1) 1-10, Top, X86.

beyond the sporangial cavity to form bluntly pointed apices which are usually curved towards the center of the synangium and touch each other (Figs. 5, 6). In many specimens the apices are missing and the ends of the sporangia appear to be capped by a layer of thick - walled cells.

The outer wall of the sporangium is thicker than the inner one and its cells are also larger (Fig. 15). Usually the sporangial wall is one layer thick but occasionally additional layers of cells have also been seen on the outer wall. The cells of the lateral sides are smaller and have thin walls in comparison to the outer cell walls. The smallest cells occur at the very innermost part of the sporangium where dehiscence occurs by means of a longitudinal cleft (Fig. 15).

Maximum elongation of the wall cells is seen at the distal end of the sporangium where they form the apex. The cells are twice as long as wide. A gradation is seen in maturation of the sporangia, which proceeds from the base of the pinnule to the apex.

Spores are well preserved in many of the specimens. They are spherical in shape and vary in diameter from 15 to 17 μ . Triradiate markings can be seen on the smooth exines (Fig. 16).

Scolecopteris latifolia - Graham emend Mamay: These fructifications were studied in coal balls #90, 599, 3778, 3796 and 4139. This species occurs much less commonly than S. minor and preservation is usually poor.

The sori are borne again on Pecopteris - type foliage, with the pinnules being arranged alternately on the pinna axis. Structure of the pinna axis is very much like that of S. minor. The vascular trace is U - shaped, surrounded by thin - walled cells and the tracheids show spiral

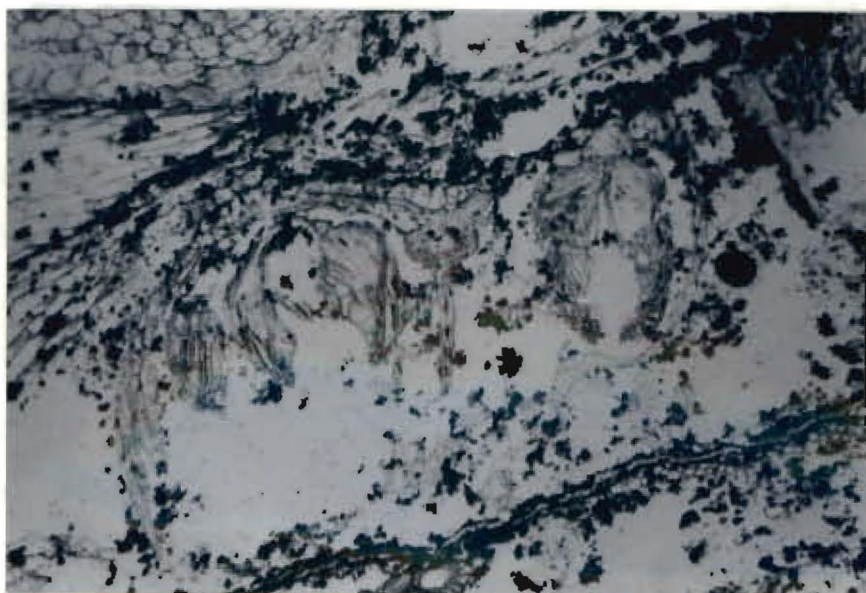


Fig. 13. Transverse section of a pinnule of S. minor showing inflexed margins. Slide #3778(C)1-3, X35.



Fig. 14. A multicellular hair of S. minor attached to the pinnule midrib. Slide #3778(C)1-3, X86.

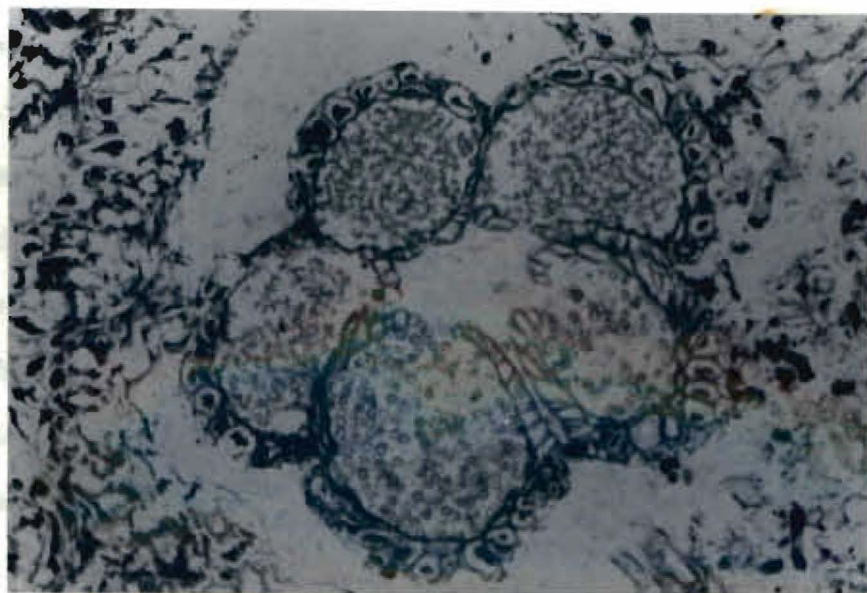


Fig. 15. Transverse section of a synangium of *S. minor* showing dehiscence of sporangia and outer thick wall. Slide #3887B(1)1-4, X86.

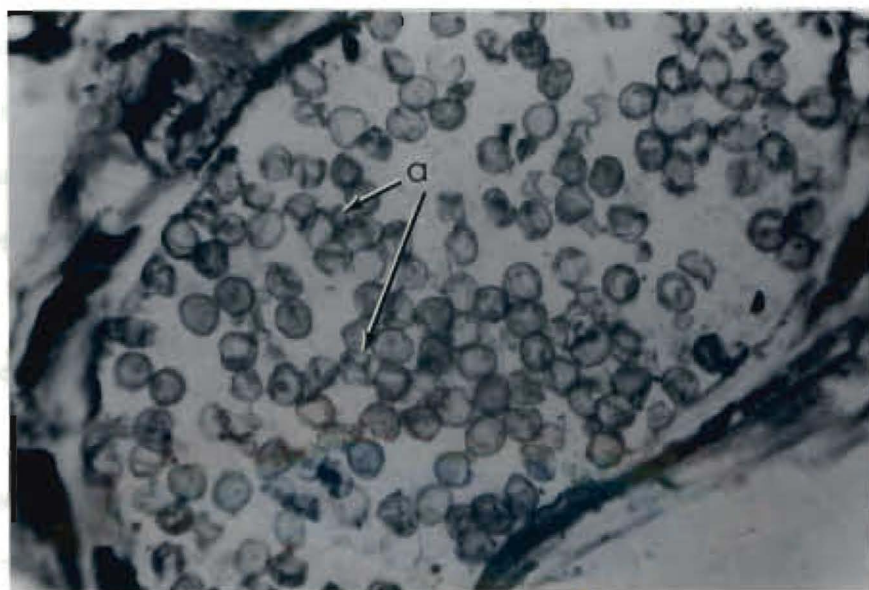


Fig. 16. Spores of *S. minor* a. triradiate markings. Slide #3887A(4)1-6, X350.

thickenings (Figs. 17, 18). A band of sclerenchyma can be seen near the tips of the trace. Many large cells with dark contents are seen beneath the trace (Fig. 18). The pinnule midveins, departing from the pinna rachis, can be seen in sections cut in a plane parallel to the lamina surface. The lateral veins in the pinnule correspond to the number of the marginal lobes.

The pinnules have very strongly inflexed margins and slightly recurved apices. In sections cut in a plane parallel to the surface of the lamina, the pinnules average 2.40 mm in length and 1.70 mm in width. When unrolled the length, including the recurved apex, measures 3.80 mm and the width, including the margins, is 7.20 mm. The internal structure of the pinnule is not well preserved. The edge of the outer epidermis with inflexed margins can be seen in Fig. 20. The cells of the epidermis contain dense contents. The margins of the pinnules are deeply incised and have crescent - shaped lobes with dense cellular contents. The lobes measure 0.50 mm in length and 0.15 mm in width with their convex surface directed towards the mid-vein of the pinnule. Multicellular hairs measuring up to 0.36 mm in length are present on the lobes (Figs. 23, 24).

Sori occur in a single series on each side of the pinnules. They appear to be inserted very close to the bases of the marginal lobes (Fig. 19), below and near the apices of the lateral veins. The synangia in this species contain three or four sporangia. The groups of three are more abundant than those with four and adjacent synangia may vary in number of sporangia in the same pinnule. The synangia average 0.70 mm in diameter and 0.9 to 1.20 mm in length, excluding the pedicel.

Individual sporangia vary from 0.90 - 1.20 mm in length and 0.20 to 0.34 mm in width. They are widest at the base and taper gradually towards

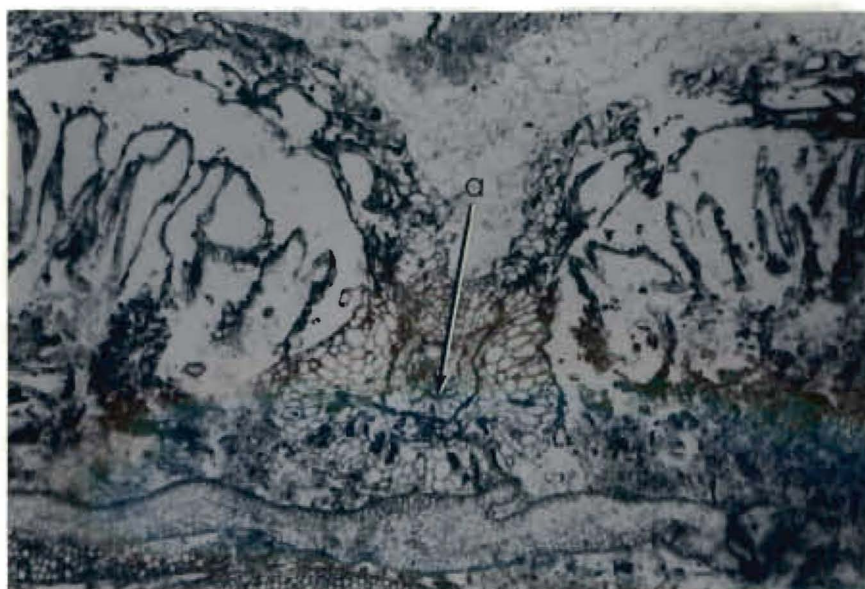


Fig. 17. Transverse section of pinna of S. latifolia with two pinnules sectioned in part. a. U-shaped vascular bundle. Slide #4139(C) 1-4, X35.

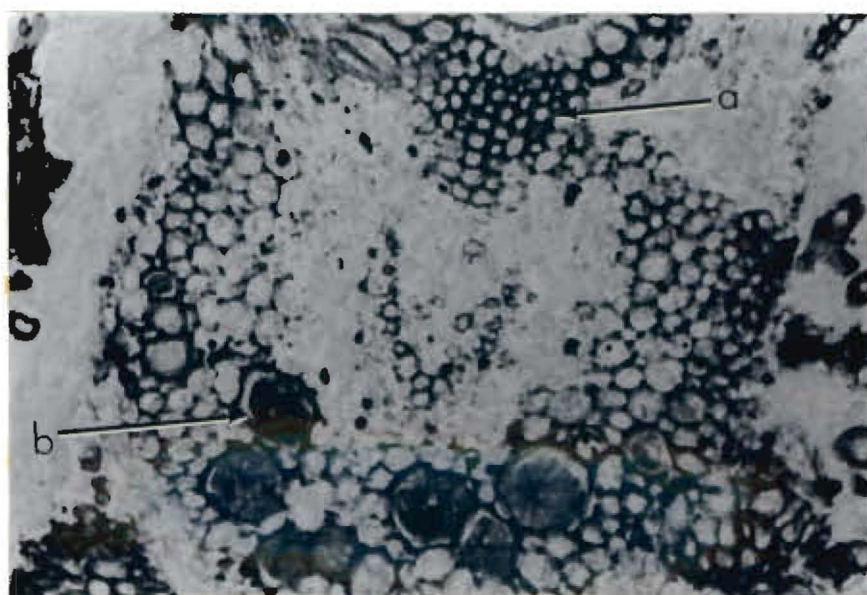


Fig. 18. Transverse section of pinna axis of S. latifolia. a. sclerenchyma; b. large cells with dark contents. Slide #599(A)6-1, X86.

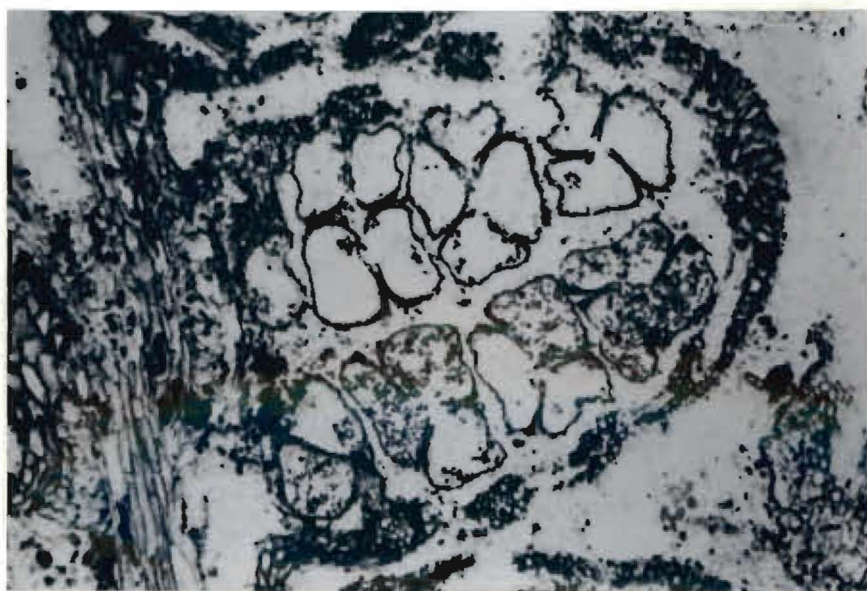


Fig. 19. Single pinnule of *S. latifolia* sectioned in a plane parallel to the lamina surface. Slide #90(A)1-1, X35.



Fig. 20. Transverse section of a pinnule of *S. latifolia*. a. strongly inflexed margins. Slide #3796A(1)1-1, X35.

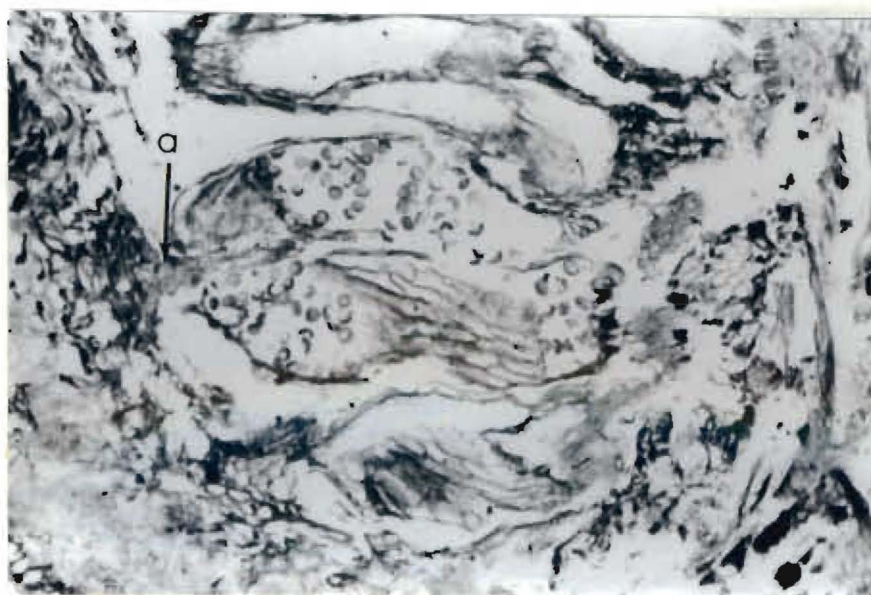


Fig. 21. Longitudinal section of a synangium of *S. latifolia*. a. pedicel. Slide #4139(C)1-4, X86.

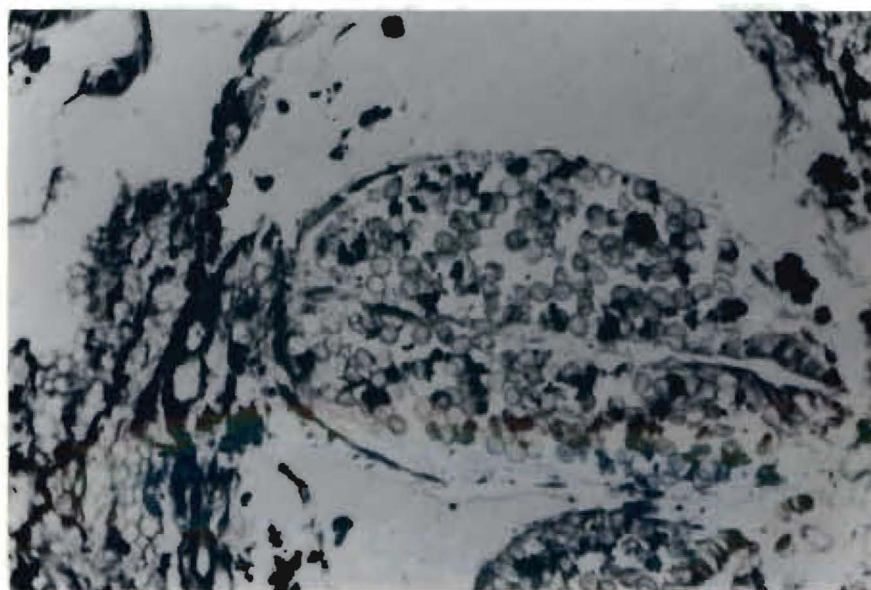


Fig. 22. Longitudinal section of a synangium of *S. latifolia*. Slide #3775(E)1-1, X86.



Fig. 23. Tangential section of pinnule of *S. latifolia* showing sporangia and marginal lobes. Slide #3814B(1)1-1, X67.

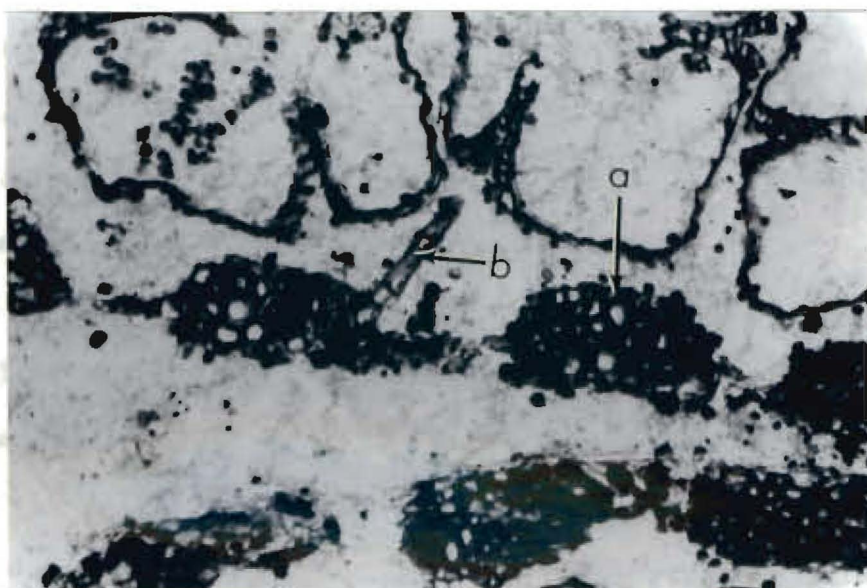


Fig. 24. Portion of pinnule of *S. latifolia* sectioned in a plane parallel to the lamina surface. a. lobe; b. multicellular hair. Slide #90(A)2, X86.

the distal end forming an acute apex (Figs. 21, 22). The outer walls of the sporangia are not very thick in contrast to S. minor. Dehiscence occurs by means of a longitudinal cleft along the innermost surface of the sporangia, as is the case in all the species of the genus Scolecopteris.

Spores are very well preserved and show clear trilete markings (Fig. 25). In one specimen monolete spores have also been seen. The maximum diameter attained by the spores is 35 μ and the exines are smooth.

Cyathotrachus altissimus: The fructifications of C. altissimus are seen, isolated and attached to poorly - preserved pinnules, in coal balls #2065, 2801, 2686 and 2669.

Sori are inserted on the lower side of the pinnule, with the number of sporangia per synangium varying from five to nine. The central column is seen clearly in a transverse section of the synangium (Fig. 28) and measures 0.15 - 0.20 mm in diameter. No vascular elements are present in it. Figs. 26 and 27 show transverse sections of the synangia through the distal portion where the central column is absent. The outer surface of the synangium is enclosed by a continuous layer of thin - walled cells. The synangia vary from 0.65 to 1.80 mm in diameter. Individual sporangia vary from 0.8 to 1.7 mm in length (Fig. 29) and 0.20 to 0.46 mm in width. The sporangial walls are only one layer thick and the cells are thin - walled. Dehiscence occurs by means of a longitudinal slit along the inner walls of the sporangia.

The spores are smooth - walled, bilateral, with monolete markings, and average 9 x 15 μ in dimension. Although general spore preservation is poor, a few spores appear bean - shaped (Fig. 30). In one case the sporangia are inexplicably filled with cordate pollen grains (Fig. 31).

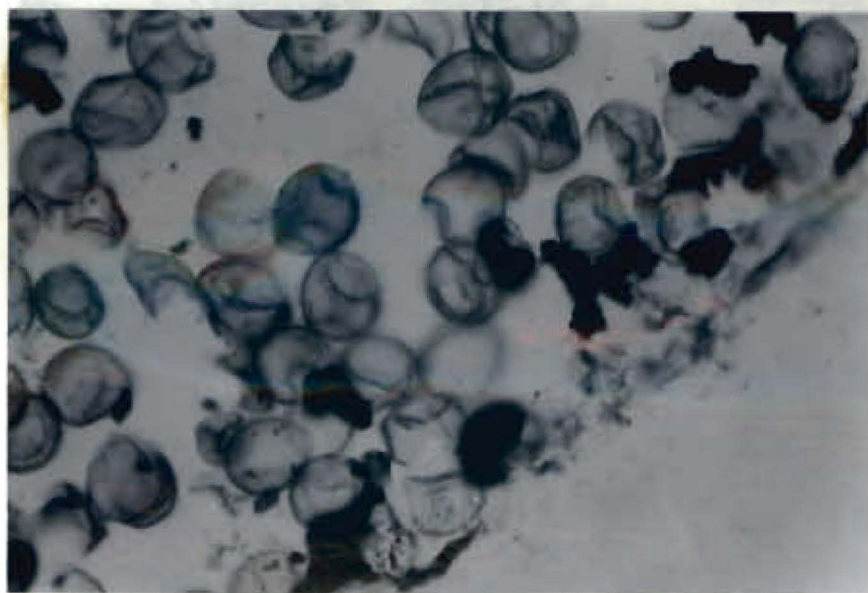


Fig. 25. Spores of S. latifolia. Slide #3778
(E)1-1, X350.

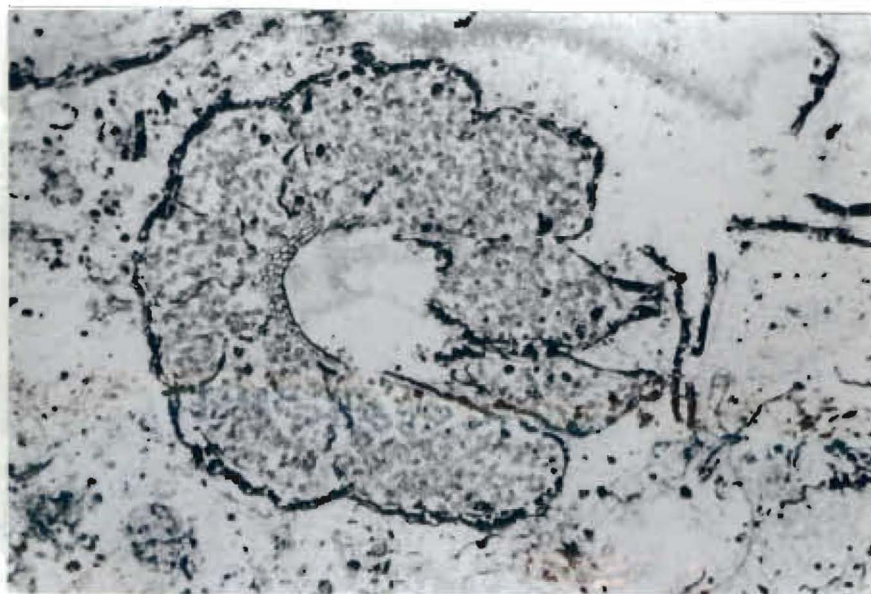


Fig. 26. A single synangium of *C. altissimus* consisting of nine sporangia sectioned transversely through distal portion, where central column is absent. Slide #2965A1-1, X35.

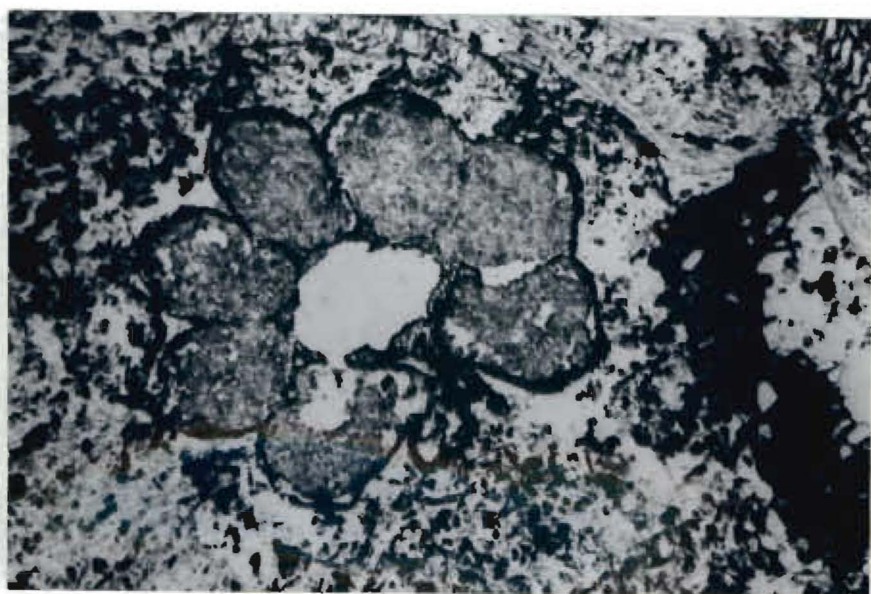


Fig. 27. A single synangium of *C. altissimus* consisting of eight sporangia, sectioned transversely through distal portion where central column is absent. Slide #2686B(6)1-1, X35.

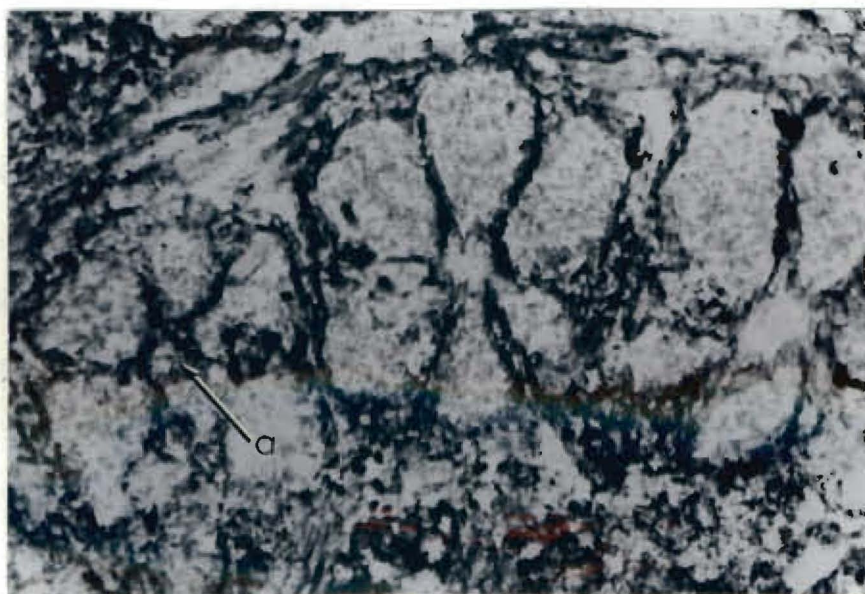


Fig. 28. Three synangia of C. altissimus each with six sporangia, cut in transverse section. a. central column. Slide #2669B(5)3-1, X86.

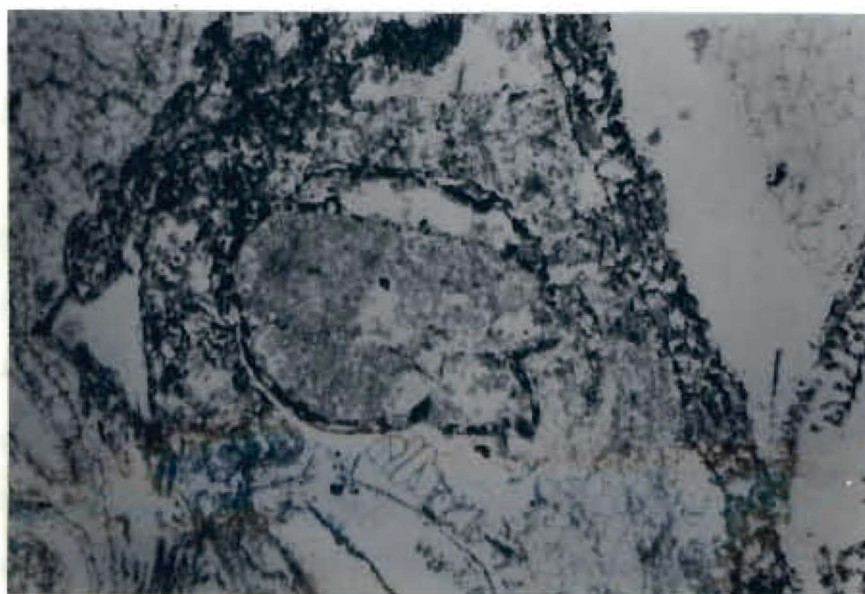


Fig. 29. A single synangium of C. altissimus cut in longitudinal section. Slide #2801B(3) 1-1, X35.

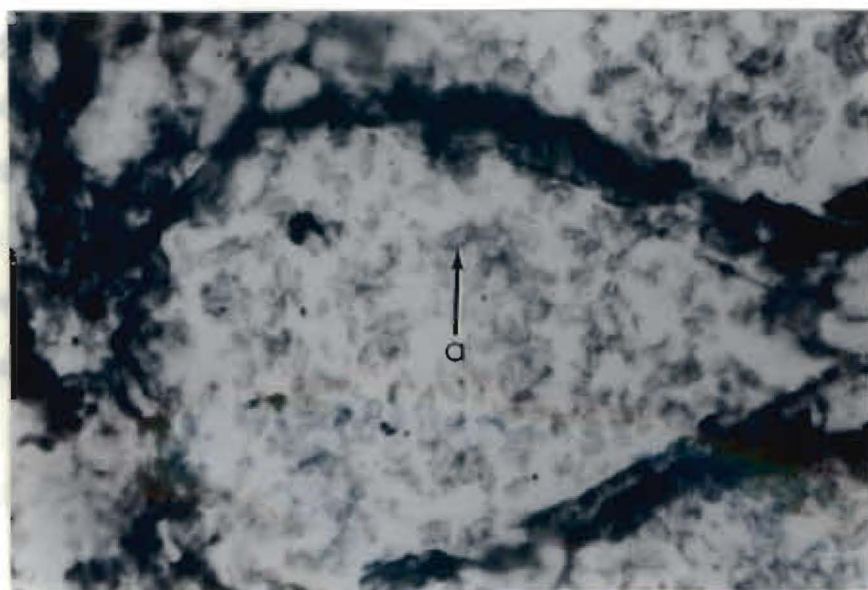


Fig. 30. A single sporangium of C. altissimus cut longitudinally. a. bean shaped spore.
Slide #2669B(5)3-1, X350.



Fig. 31. Cordaites pollen grains that filled the sporangia of C. altissimus shown in Fig. 26.
Slide #2965A1-1, X165.

DISCUSSION

Scolecoperis minor, founded by Hoskins in 1926, was based upon fossil specimens from the Pennsylvanian of Illinois and was given the following distinctive features:

1. Sori composed of four or five, rarely six sporangia, attached by short pedicels to the lower surface of the pinnules of Pecopteris type, in a single series on each side of the midvein.

2. Pinnules about 6-7 mm in length and 3.30 mm in width and furled so that their edges approach the lower side of the midvein.

3. Sporangia ellipsoidal, roughly circular in transverse section, with adjacent sides slightly flattened and attached laterally at their bases. Distal ends extended into slightly concrescent bluntly pointed apices by the elongation of the sporangial wall cells. Sporangia about 0.28 mm in diameter and 0.70 mm in length. Dehiscence occurs through a vertical cleft on the innermost wall of the sporangia.

4. Spores averaging $17\ \mu$ in diameter with smooth exines.

Graham (1936) described S. minor from the same strata. The dimensions of pinnules in his specimens averaged 2.80 mm in length and 1.70 mm in width and those of sporangia, 0.57 mm in length and 0.24 in diameter. He attributed these dimensional variations as having been induced by varying climatic conditions.

Mamay (1950) established a tentative new variety of S. minor based upon the specimens from the Pennsylvanian of Iowa. The characteristics of S. minor var. parviflora Mamay are as follows:

1. Syngonia borne in a single series on each side of the midrib and consisting of four or five sporangia.

2. Sporangia ovate, with blunt apices averaging approximately 0.58 mm in length and 0.35 mm in width, closely appressed at the bases, but entirely separate for the greater part of their length; outer surface of the walls thickened, inner surface thin; dehiscence by means of a longitudinal cleft along the innermost surface of the sporangial wall.

3. Pinnules with strongly inflexed margins, averaging 3.00 mm in length and about 1.75 mm in width, but 2.60 mm if unrolled.

4. Spores round, averaging 15 μ in diameter, walls with triradiate scars and otherwise smooth exines.

The criteria for recognizing this variety are smaller dimensions of the pinnules, sporangia, and spores. It is evident that the specimens described by Graham (1934), as summarized above, would be included in this taxon. From the work of Hoskins, it appears that the pinnule dimensions described by him included the inflexed margins and the recurved apices. Mamay did include the inflexed margins in his measurements but possibly did not take notice of the recurved apices of the pinnules. If this is true, and there is no evidence in his paper to prove or disprove this, the varietal differences could have been greatly minimized. In the present study, the pinnules, when flattened, averaged about 4.50 mm in length and 3.20 in width. This length is intermediate to the lengths described by Hoskins (6-7 mm) and Mamay (3 mm) while the width is about equal to that of Hoskins (3.3 mm).

It is well-known that in ferns pinnule dimensions vary considerably on the same frond. In general, pinnules on near-apical axes are smaller than those near the base of the frond. In addition, pinnule size can vary on the same pinna from base to apex. Though Graham attributed this

variation to environmental conditions, I feel that this variation in pinnule dimensions (Table III) is a characteristic feature of all fern fronds.

In the measurements of sporangia, I fear, Mamay may have lost sight of one very important point, namely the considerably prolonged apices. These appear to be missing in his sections (Fig. 33, Mamay, 1950). Longitudinal sections of sporangia frequently fail to show the extreme tips of the apices, which could either be due to their loss before petrification or during the cut. What Mamay feels to be the "blunt apices" are actually the decapitated ends with caps of large thick-walled cells. When sporangia without tips were measured in the present study, the average obtained was 0.59 mm in length and 0.32 mm in width, dimensions which are almost identical to Mamay's varietal diagnosis. On the other hand, a measurement of complete sporangia varied from 0.43 - 0.89 mm in length and from 0.20 to 0.34 mm in width averaging 0.70 mm in length and 0.28 mm in width, dimensions which are absolutely identical to those of Hoskins.

Sporangia, when young, are elongated, relatively close together, with their tips curved towards the center of synangium and fused with each other. During maturation, the fused tips split open and the sporangia separate from each other and look, comparatively, wider than the younger ones and in many cases appear to have lost their apices. Consequently, depending upon the stage of maturation, considerable variation may occur in length and width.

Another reason for this variation can be the amount of mechanical pressure exerted on the material at the time of preservation. A comparison of findings of different workers on S. minor (Table III) shows that sporangia in Hoskin's specimens were greater in length than those in Mamay's

Table III. Scolecoperis minor: A comparison of the findings of different workers.

	Average dimensions of sporangia (Length x width mm)	Number of sporangia per synangium	Dimensions of pinnules (length x width mm)	Spore dimensions (diameter μ) and sculpturing
Hoskins	0.70 x 0.28	4 or 5 rarely 6	6-7 x 3.30	17; no markings
Grahan	0.57 x 0.24	4 or 5 rarely 6	2.80 x 1.70	18; triradiate markings
Mamay	0.50 x 0.35	4 or 5 rarely 6	3.00 x 1.75	15; triradiate markings
Present study	0.70 x 0.28	4 or 5 rarely 3 or 6	4.50 x 3.20 (when flattened)	15-17; triradiate markings

material but the width in the former case was smaller. This could be possibly due to varying amounts of pressure.

Spore dimensions have varied in all the specimens studied by different workers. In the present study spore diameter varied from 15 - 17 μ , bore clear trilete markings and thick walls, leaving no doubt about their maturity. Certainly the small difference in spore size between the species (17 μ) and the variety (15 μ) is well within the range of normal variability.

A new variable is found in this study in the instance of the number of sporangia per synangium. So far examples of four, five and six have been reported, but this investigation adds a new variable with three.

All these findings make me to feel that these variations are not trustworthy criteria for building up taxonomic distinctions. All these specimens should be referred to S. minor Hoskins, and there is no need for recognizing a distinct variety.

Scolecopteris minor Hoskins. Structure of Pennsylvanian plants from Illinois. Bot. Gaz. 82:427-436. 1926.

Scolecopteris minor Hoskins. Pennsylvanian flora of Illinois as revealed in coal balls I. Bot. Gaz. 95:456-458. 1934.

Scolecopteris minor Hoskins var. parviflora Mamay. Some American Carboniferous fern fructifications. Ann. Mo. Bot. Gard. 37:431-432. 1950.

Emended diagnosis:

Synangia borne in a single series on each side of the midvein on the abaxial surface of the pinnules and consisting of four or five sporangia, rarely three or six. Sporangia ovate with considerably prolonged bluntly

SUMMARY

pointed apices and averaging 0.70 mm in length and 0.28 mm in width; outer surface of the walls thickened, inner surface thin; dehiscence by means of a longitudinal cleft along the innermost surface of the sporangial wall. Pinnules with strongly inflexed margins and slightly recurved apices, vary from 4.50 mm to 7.00 mm in length and from 2.60 to 3.50 mm in width when unrolled. Spores round, vary from 15 - 18 μ in diameter; walls with triradial markings and smooth exines.

Occurrences: correspond very closely with those of Hopkins. However several McLeansboro Group in Illinois; Desmoinesian Series in Indiana and Kansas and Shore, Lancashire, England.

The study on S. latifolia and Cyathotrachus altissimus does not have anything new to add but does support Mamay's findings.

The specific diagnosis

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SUMMARY

Scolecoperis and Cyathotrachus fructifications, present in the coal balls from the Pennsylvanian of Kansas and Illinois, have been studied. Two species of Scolecoperis, S. minor Hoskins and S. latifolia Graham emend. Mamay, are common in these coal balls. Cyathotrachus is represented by one species, C. altissimus, only.

S. minor Hoskins is the more common of the two species. In general, the findings correspond very closely with those of Hoskins. However several new observations have been made in this study. Pinnules showed very distinct layer of palisade cells and measured 4.50 - 5.20 mm in length and 3.20 - 3.50 mm in width, when flattened. Synangia consisting of three sporangia have also been found in a few specimens. The spores have very clear trilete markings and vary from 15 - 17 μ in diameter.

The specific diagnosis has been emended and it is suggested that the varietal segregation recognized by Mamay is not necessary and the specimens described by him as S. minor var. parviflora be referred to S. minor Hoskins.

No new information has been added in the study of S. latifolia and C. altissimus. The observations made are in very close agreement with those of Mamay.

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III. Bot. Gard. 42: 1-12.

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