

# Proceedings of the Iowa Academy of Science

---

Volume 83 | Number

Article 4

---

1976

## Two Species of Alethopteris From Iowa Coal Balls

Mary Ann Reihman  
*University of Iowa*

J. T. Schabilion  
*University of Iowa*

Copyright ©1976 Iowa Academy of Science, Inc.

Follow this and additional works at: <https://scholarworks.uni.edu/pias>

---

### Recommended Citation

Reihman, Mary Ann and Schabilion, J. T. (1976) "Two Species of Alethopteris From Iowa Coal Balls," *Proceedings of the Iowa Academy of Science*, 83(1), 10-19.

Available at: <https://scholarworks.uni.edu/pias/vol83/iss1/4>

This Research is brought to you for free and open access by the Iowa Academy of Science at UNI ScholarWorks. It has been accepted for inclusion in Proceedings of the Iowa Academy of Science by an authorized editor of UNI ScholarWorks. For more information, please contact [scholarworks@uni.edu](mailto:scholarworks@uni.edu).

## Two Species of Alethopteris From Iowa Coal Balls

MARY ANN REIHMAN and J. T. SCHABILION<sup>1</sup>

REIHMAN, MARY ANN, and J. T. SCHABILION (Department of Botany, University of Iowa, Iowa City, Iowa 52242). Two Species of *Alethopteris* from Iowa Coal Balls. Proc. Iowa Acad. Sci. 83(1): 10-19, 1976.

SYNOPSIS: Petrified specimens of *Alethopteris sullivanti* (Lesquereux) Schimper and *Alethopteris lesquereuxi* Wagner, species of Pennsylvania seed fern leaves, were found in coal balls from the Lovilia locality in south central Iowa. The morphology and anatomy of these leaves are described and are compared with findings of previous workers (Leisman, 1960; Baxter and Willhite, 1969).

It is generally accepted that *Alethopteris* is a foliage type of the Pennsylvania peridosperm, *Medullosa* (Scott, 1899; Steidtmann, 1944). Evidence cited to support this includes the attachment of seeds to *Alethopteris* foliage (Halle, 1927), the common association of the genus with *Myeloxylon*, *Dolerotheca*, *Pachytesta*, and other organ genera of medullosan affinity, and the anatomical similarities of the leaves with *Myeloxylon* petioles (Leisman, 1960; Ramanujam et al., 1974).

The genus, *Alethopteris*, was established by Sternberg in 1825 to describe a

fern-like compression foliage. Most subsequent studies of the genus have been confined to compression material. A summary of this work is found in Wagner's comprehensive monograph (1968). *Alethopteris sullivanti* (Lesquereux) Schimper and *Alethopteris lesquereuxi* Wagner are the only Pennsylvanian species of which the details of internal anatomy are known from petrified coal ball material (Leisman, 1960; Baxter and Willhite, 1969).

Wagner (1968, pp. 16-17) believes that the classification of Carboniferous fern-like foliage into natural genera must be based on several different features. These are 1) the general morphology of the frond and its pinnae, 2) epidermal characteristics as preserved in cuticles, 3) fructifications, 4) pinnule morphology and ontogenetic pattern. Wagner feels that ultimately studies of cuticles will be particularly useful in establishing natural genera.

This paper describes the morphology and anatomy of *Alethopteris sullivanti* and *A. lesquereuxi* leaves found in Iowa coal balls. It also includes a study of the cuticles of these species.

INDEX DESCRIPTORS: Paleobotany; fossil plants; *Alethopteris*; coal balls; Iowa Pennsylvanian.

## MATERIALS AND METHODS

The petrified specimens used in this study were found in coal balls collected from the Lovilia locality in south central Iowa. This locality is believed to be stratigraphically equivalent to the Summon (No. 4) coal of Illinois and the Bevier coal of Kansas (Schabilion et al., 1974).

Upon sectioning the Lovilia coal balls hundreds of alethopteroid pinnules were found. Splitting coal balls along their internal bedding planes, as outlined by Leisman (1960), revealed the external morphology of the pinnules. This made possible comparison of the pinnules with compression specimens and allowed correlation of petrified and compression specimens. The internal anatomy of the pinnules was studied by using standard cellulose acetate peels (Steward and Taylor, 1965).

The cuticle and epidermis of petrified pinnules was studied by macerating coal ball fragments with a dilute HCl solution. If pyrite obscured the cuticles, they were cleared with Schultz's solution (Brown, 1960). The cuticles were then mounted on microscope slides in Piccolyte.

The specimens and slides illustrated in this paper are housed in the paleobotanical collections of the University of Iowa.

## ALETHOPTERIS SULLIVANTI

EXTERNAL MORPHOLOGY — The specimens found by splitting Iowa coal balls (Fig. 7) are comparable to compression specimens of *Alethopteris sullivanti* (Lesquereux) Schimper (Fig. 9). The specimens shown in figures 7 and 9 exhibit the characteristics of the species as outlined by Wagner (1968): Typically the pinnules are obliquely inserted and broadly confluent at the base. They are strongly decurrent on the basioscopic side and generally are constricted at the acrosopic side. The pinnules range from 12-24 mm long by 7-12 mm wide.

Closer examination of a single pinnule (Fig. 8) obtained from an Iowa coal ball shows the venation characteristic of *Alethopteris sullivanti* (Fig. 1). The density of secondary veins is 22-25 veins per

cm at the pinnule border. The secondary veins depart from the midrib at acute angles and dichotomize once or twice as they arc to the margin. The midrib is present only in the basal two-thirds of the pinnule and appears slightly decurrent at its attachment to the rachis (Fig. 7, 9). Several subsidiary veins enter the basioscopic side of the pinnule (Fig. 1, 8).

As has been noted by other workers (White, 1899; Leisman, 1960), the basal pinnules differ slightly in morphology from the more apical ones. The basal pinnules are constricted at the base having a neuropteroid-type attachment to the rachis (Fig. 10). These pinnules measure 28 X 12 mm.

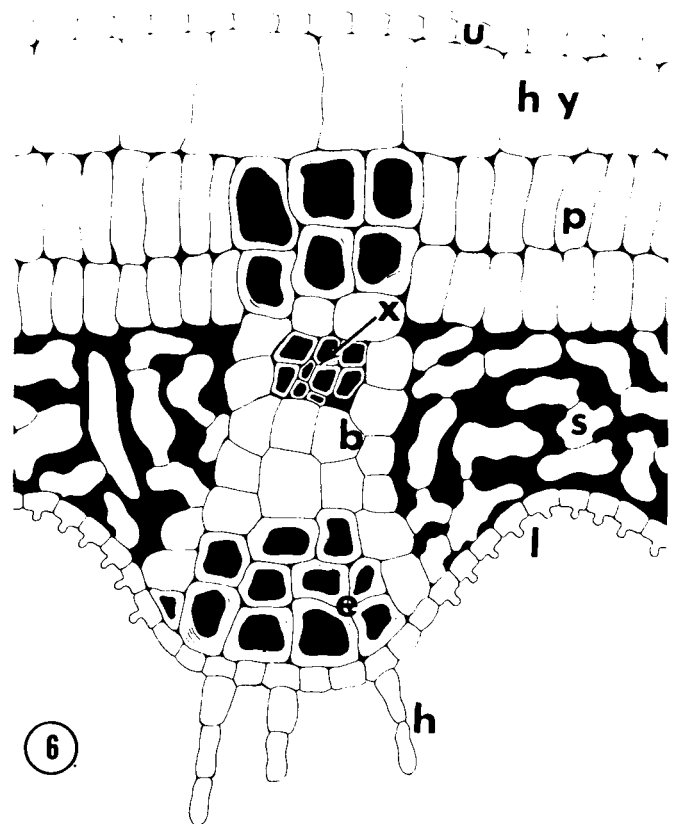
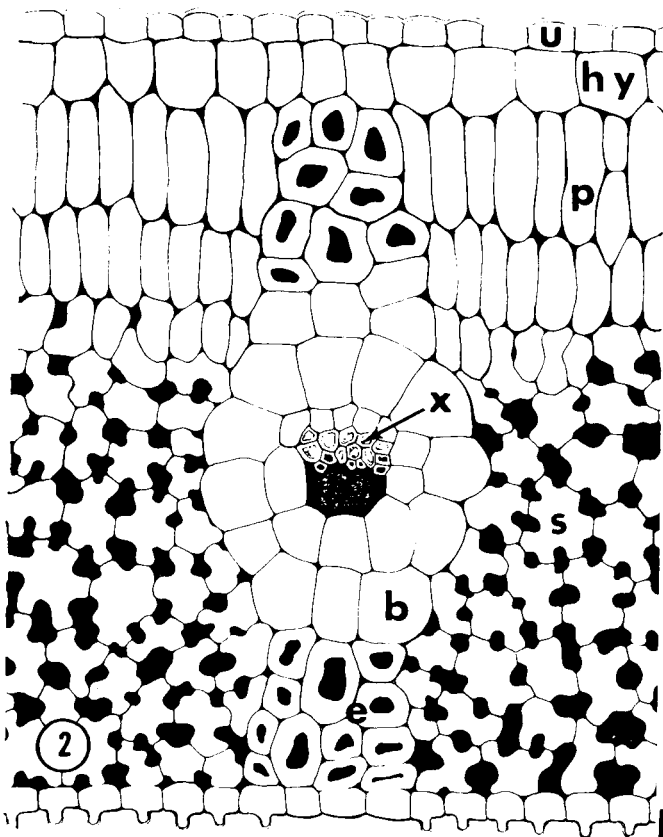
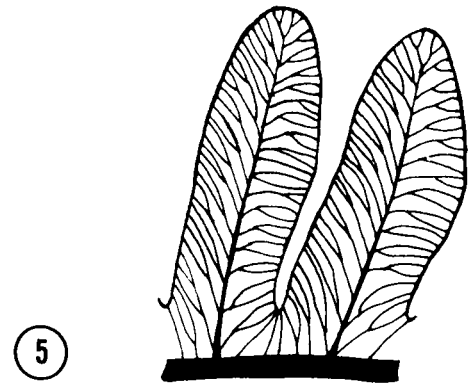
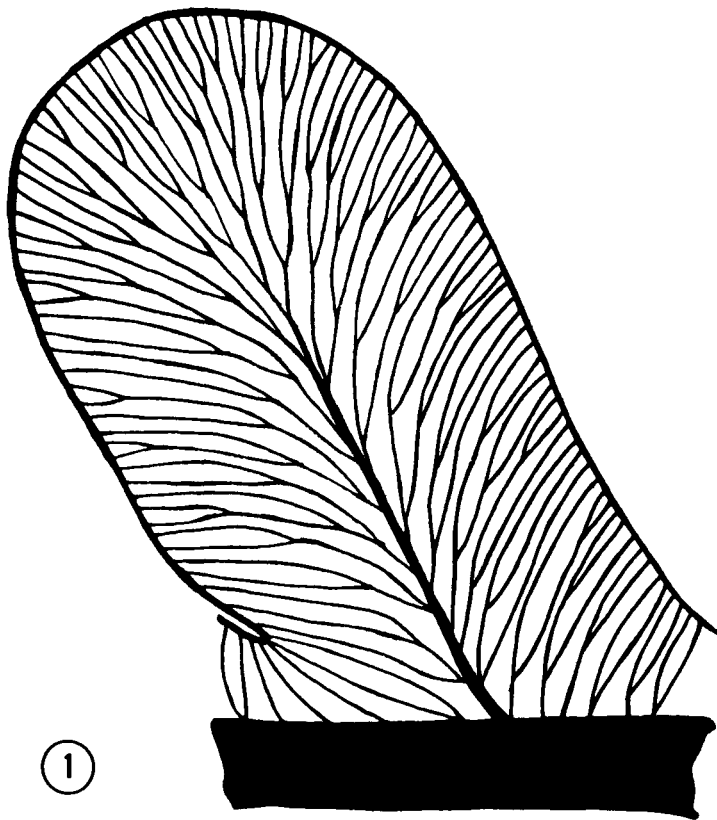
INTERNAL ANATOMY — In transverse section the pinnules of *Alethopteris sullivanti* are relatively flat (Fig. 3, 11). The general outline of the pinnule is smooth, and the only ridge on the lower surface is that of the midrib which, as has been noted, is present only in the basal two-thirds of the pinnule. In the flat portion of the blade the pinnules average 537  $\mu$  in thickness, while in the midvein area they average 888  $\mu$  in thickness.

A thick cuticle ( $\cong 5 \mu$ ) covers the upper surface of the pinnule. The upper epidermis is composed of small rectangular cells which average 19  $\mu$  X 25  $\mu$  (Fig. 2, 12). A hypodermis of large, squarish cells (41  $\mu$  X 39  $\mu$ ) underlies the epidermis. The mesophyll of the pinnule consists of both palisade and spongy parenchyma (Fig. 2,

Key to Labeling: *b*, bundle sheath; *c*, secretory canal; *e*, bundle sheath extension; *g*, guard cell; *h*, multicellular hair; *hb*, hair base; *hy*, hypodermis; *l*, lower epidermis; *m*, midrib; *p*, palisade parenchyma; *pa*, papillae; *r*, rachis; *s*, spongy parenchyma; *sc*, sclerenchyma; *st*, stoma; *u*, upper epidermis; *v*, vein; *vb*, vascular bundle; *x*, xylem.

Fig. 1-6 — Fig. 1. Diagram of a single pinnule of *Alethopteris sullivanti* (redrawn from Wagner, 1968) X5. — Fig. 2. Diagram of *A. sullivanti* in transverse section showing a single vascular bundle and the anatomical features of the pinnule. X200. — Fig. 3. Outline of *A. sullivanti* in transverse section drawn from fig. 11. X5. — Fig. 4. Outline of *A. lesquereuxi* in transverse section drawn from fig. 27. X5. — Fig. 5. Diagram of pinnules of *A. lesquereuxi*. (redrawn from Wagner, 1968) X5. — Fig. 6. Diagram of *A. lesquereuxi* in transverse section showing a single vascular bundle and the anatomical features of the pinnule. X200.

<sup>1</sup>Department of Botany, University of Iowa, Iowa City, Iowa 52242



12). The palisade parenchyma consists of 2, possibly 3, layers of cells which often contain a dark material. The palisade cells are vertically elongated, each averaging  $72 \mu \times 27 \mu$  (Fig. 13). As Leisman noted, approximately one-third of the mesophyll layer consists of palisade cells. The remaining two-thirds is spongy parenchyma. The spongy parenchyma cells are irregular in shape and have "arms" extending in various directions. This gives the cells a stellate appearance. Numerous air spaces are present in the tissue (Fig. 14). The lower epidermis is composed of a single layer of small rectangular cells averaging  $18 \mu \times 27 \mu$  (Fig. 2, 12). These observations are similar to those made by Leisman (1960).

In the basal portion of the pinnule, the midrib is quite prominent (Fig. 16). Most of the cells in the midrib are large and thin-walled. Leisman suggested that these cells may represent a proliferated bundle sheath. A crescent-shaped band of sclerenchyma 2-3 cells thick borders the entire abaxial margin of the midrib; there is a square-shaped area of sclerenchyma approximately 4 cells thick at the adaxial margin. In the center of the midrib a horizontally elongated cluster of tracheids is present. The smaller, protoxylem tracheids are located in the abaxial portion of the cluster. The phloem elements probably were located abaxially to the xylem. However, the tissue of this region was poorly preserved in the *Lovilia* material. Generally papillae are not present on the lower epidermis of the midrib.

There are many secondary veins in the blade portion of the pinnule. Each is enclosed in a very prominent bundle sheath which is composed of large, thin-walled cells ( $57 \mu \times 39 \mu$ ) (Fig. 2, 15). In paradermal section, the bundle sheath cells are elongated parallel to the direction of the vein and measure  $64 \mu$  long (Fig. 17). Bundle sheath extensions of sclerenchyma are present. These extend to the hypodermis and to the lower epidermis. A small cluster of tracheids is present within the bundle sheath cells (Fig. 2, 15). The smaller, protoxylem elements are located more toward the abaxial portion of the pinnule. The tissue immediately below the tracheids is not well preserved. This was probably the location of the phloem.

The rachis is mainly composed of large, thin-walled cells which average  $86 \mu \times 133 \mu$  (Fig. 20). These cells are somewhat smaller in the adaxial region of the rachis and in the area surrounding the vascular tissue but do not appear to be thick-walled as Leisman (1960) has suggested. There are 3-7 discrete vascular bundles in the rachis which are arranged in an adaxially flattened ring. The protoxylem is in the centrifugal position (Fig. 21). A pinnule trace can be seen departing from one of the more adaxial vascular bundles in figure 20. Secretory canals are often present in the rachis. Along the periphery of the abaxial portion of the rachis are small, thick-walled cells averaging  $21 \mu \times 30 \mu$ . These sclerenchyma cells appear to be arranged in a 2-3 layered border extending around the entire abaxial portion of the rachis. Sclerenchyma is also present in the adaxial portion of the rachis (Fig. 20).

**DETAILS OF THE CUTICLE** — Examination of macerated cuticles (Fig. 18) showed that the upper epidermal cells located between the veins have slightly wavy walls. The cells which are located directly over the veins are more rectangular and are elongated parallel to the vein. A dark material is often present in these cells. The upper epidermis has no stomata, trichomes, or papillae.

The lower epidermis, however, is covered with papillae (Fig. 19). Papillae occur in the interveinal areas and on the peripheral portions of the secondary veins but do not occur on the midrib or on the secondary veins near the midrib. Stomata are abundant on the lower surface of the pinnule in the interveinal areas (Fig. 19). They are sunken and are surrounded by an overhanging ring of papillae. Each of the 4-9 subsidiary cells has a single papilla (Fig. 22, 23). The cells in the interveinal areas have a wavy outline, while the cells lying directly below the veins are rectangular and are elongated in the direction of the vein. Also present on the lower epidermis are

areas which are believed to be the bases of multicellular hairs which have broken off (Fig. 24). These occur most commonly on the midrib and on the secondary veins proximal to the midrib. The hair bases are quite large and cover 1, 2, or 3 lower epidermal cells.

### ALETHOPTERIS LESQUEREUXI

**EXTERNAL MORPHOLOGY** — The fractured surface of coal balls revealed the external morphology of *Alethopteris lesquereuxi* pinnules (Fig. 25, 26). These pinnules fit the species description given by Wagner: The pinnules have a pectopteroid aspect. They are inserted almost at right angles to the rachis, fairly widely spaced, and narrowly confluent at the base. They are elongate-triangular in shape and range 6-20 mm long by 4-5 mm wide. The margins of the pinnules are fairly straight and taper to an "obtusely acuminate apex".

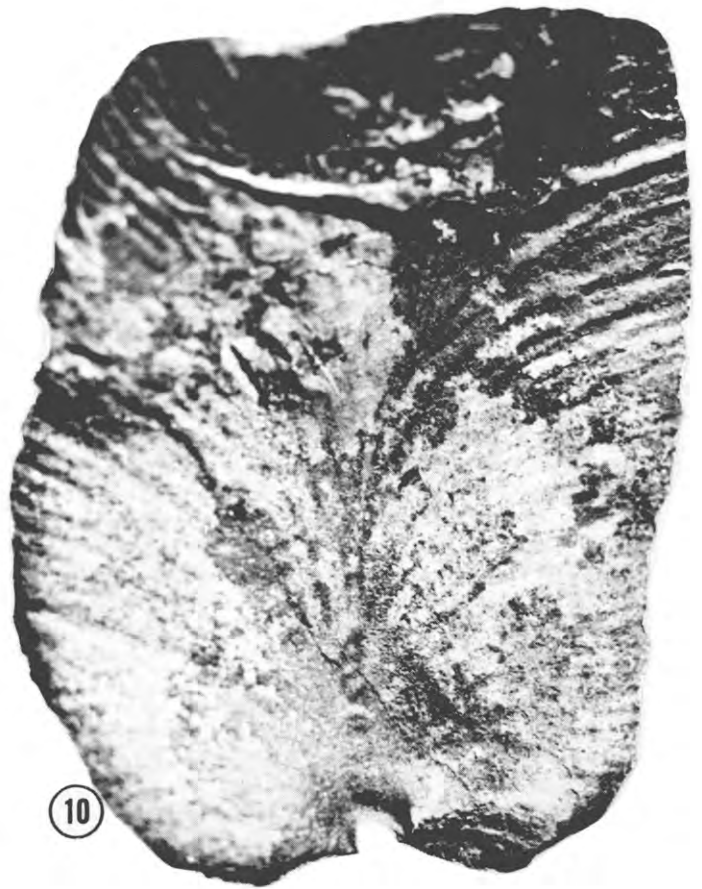
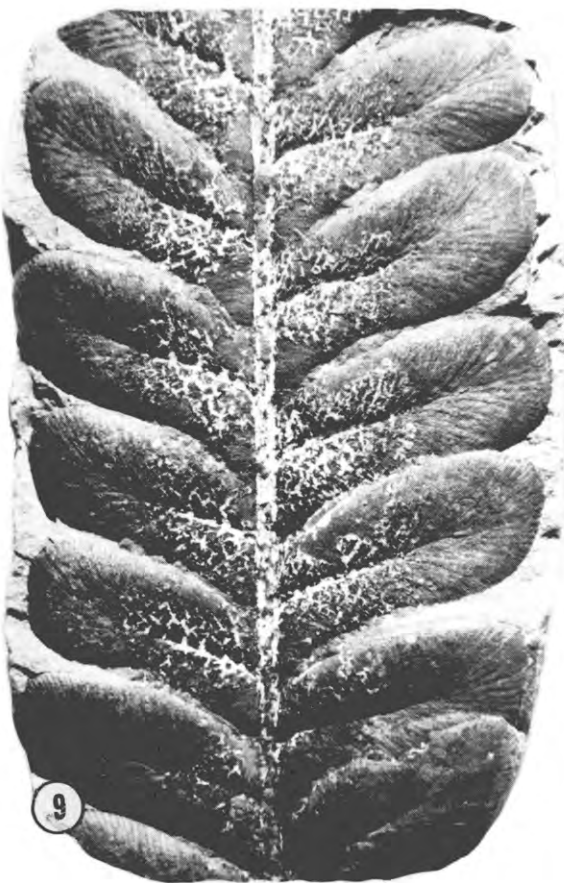
The midrib is sunken on the upper side of the pinnule lamina and extends nearly to the apex of the pinnule. In the *Lovilia* specimens, there are 32-36 secondary veins per cm at the margin of the pinnule (Fig. 5, 26). This is within the range of the species (30-35 veins per cm) as reported by Wagner. The secondary veins depart from the midrib at a shallowly acute angle and follow an oblique but straight course to the margin. They usually dichotomize once before reaching the margin. Subsidiary veins enter the pinnule directly from the rachis.

**INTERNAL ANATOMY** — In contrast to *Alethopteris sullivanti*, *Alethopteris lesquereuxi* has a markedly inrolled margin. Also, each of the secondary veins forms a ridge on the lower surface (Fig. 4, 27). In transverse section the pinnules of *Alethopteris lesquereuxi* measure  $725 \mu$  thick in the region of the midrib and  $490 \mu$  thick in the blade portion of the pinnule. Figures 3 and 4 show the size difference of the two species of *Alethopteris*. Also note that figures 1 and 5, and 2 and 6 are drawn to the same scale.

A thick cuticle ( $\cong 3.5 \mu$ ) covers the upper surface of *A. lesquereuxi*. Small, rectangular cells ( $20 \mu \times 38 \mu$ ) form the upper epidermis (Fig. 6, 28). A hypodermis of extremely large cells ( $96 \mu \times 76 \mu$ ) underlies the epidermis. The mesophyll of the pinnule is comprised of both palisade and spongy parenchyma. The palisade parenchyma consists of 1-2 rows of vertically elongated cells averaging  $73 \mu \times 24 \mu$  (Fig. 6, 28, 29). These cells generally contain a dark material. Approximately one-third of the mesophyll is palisade parenchyma. The remainder is spongy parenchyma which consists of cells which are irregular in shape but which lack the almost stellate appearance of the spongy mesophyll of *A. sullivanti* (Fig. 6, 30). The cells of the lower epidermis are small and rectangular ( $14 \mu \times 24 \mu$ ). These measurements and observations are similar to those made by Baxter (1969).

As has been noted previously, the midrib of *A. lesquereuxi* extends nearly to the apex of the pinnule. The ground tissue of the midrib consists of large, parenchymatous cells (Fig. 31). Two rows of sclerenchyma cells border the abaxial margin of the midrib. Though preservation is often poor, the adaxial margin is bordered by 2-3 rows of hypodermal cells. The vascular strand of the midrib consists of a crescent-shaped cluster of tracheids (Fig. 31). The protoxylem is located in the abaxial portion of the cluster. Due to poor preservation of the tissue, it is difficult to ascertain the position of the phloem, but it seems likely that it occupied the region abaxial to the tracheids. Several secretory canals are present in the midrib (Fig.

Fig. 7-10. — *Alethopteris sullivanti* — Fig. 7. Portion of a frond from an Iowa coal ball. X3 — Fig. 8. Single pinnule from an Iowa coal ball. X7. — Fig. 9. Portion of a frond from a Mazon Creek nodule. X3. — Fig. 10. Single pinnule from an Iowa coal ball showing a neuropteroid base. X9.



31). Large multicellular hairs are a prominent feature of the midrib.

Many secondary veins are present in the blade portion of the pinnules. Each is enclosed in a prominent bundle sheath which is composed of large, thin-walled cells ( $38 \mu \times 33 \mu$ ) (Fig. 6, 32). In paradermal section the bundle sheath cells are elongated parallel to the vein and measure  $129 \mu$  long (Fig. 33). Bundle sheath extensions of sclerenchyma extend to the hypodermis and to the lower epidermis where they form the ridges on the lower surface of the pinnule (Fig. 6, 32). Multicellular hairs are present on the ridges (Fig. 6, 28). A small cluster of tracheids is present within the bundle sheath. The smaller protoxylem tracheids are in the more abaxial portion of the cluster indicating the development of the xylem was exarch. The position of the phloem was probably abaxial to the tracheids.

The ground tissue of the rachis is composed of large, thin-walled cells ( $48 \mu \times 37 \mu$ ) (Fig. 34). The cells are smaller in the region of the vascular tissue and in the adaxial portion of the rachis. There are 3-5 separate vascular bundles in the rachis which are arranged in a circle similar to that of *A. sullivanii*. Several secretory canals are present in the rachis (Fig. 34). The abaxial margin of the rachis is bordered by a layer of sclerenchyma which occurs immediately within the epidermis. Large multicellular hairs are attached to the rachis (Fig. 34).

**DETAILS OF THE CUTICLE** — Examination of cuticles revealed that stomata and papillae are present in the interveinal areas of the lower epidermis. They do not occur on the midrib or on the secondary veins. The stomata are sunken and are surrounded by a ring of 6-7 papillae. Each subsidiary cell gives rise to one papilla. Papillae seem to be present only in association with stomata (Fig. 35).

As has been noted previously, the large multicellular hairs are present on the midrib and on the secondary veins (Fig. 36). The hairs average  $272 \mu$  long and generally consist of 4-5 cells (Fig. 38). The hair bases cover 1, 2, or 3 cells as do those of *A. sullivanii*.

Unlike the lower epidermis, the upper epidermis does not have stomata, papillae, or hairs (Fig. 37). There is little difference between cells in interveinal areas and those cells which lie over the veins. Those on the veins are only slightly elongated.

## DISCUSSION

As has been suggested by Baxter and Willhite (1969), there are several similarities between the two species of *Alethopteris* which have been described from coal balls. These include 1) a prominent hypodermal layer, 2) a mesophyll composed of both palisade and spongy parenchyma, 3) a parenchymatous bundle sheath with sclerenchymatous sheath extensions, 4) numerous vascular bundles in the rachis, 5) presence of multicellular hairs on the lower epidermis. To this list of similar features can be added 1) the presence of papillae on the lower epidermis, 2) the presence of secretory canals in both the rachis and midrib, 3) a similar stomatal structure, 4) hair bases which cover 1, 2, or 3 epidermal cells.

Despite the numerous similarities, these two species of *Alethopteris* exhibit distinctive differences in morphology, anatomy, and venation. The pinnules of *Alethopteris sullivanii* are larger and slightly thicker than those of *A. lesquereuxi*. In *A. lesquereuxi* the midrib extends nearly to the apex of the pinnule, while in *A. sullivanii* it extends only 2/3 of the length of the pinnule. The margins of *A. lesquereuxi* are inrolled, and the secondary veins form ridges on the lower surface. The pinnules of *A. sullivanii* are smooth and flat in outline. The vein density in *A. lesquereuxi* is 32-36 veins per cm at the pinnule margin; that of *A. sullivanii* is 22-25 veins per cm. *A. lesquereuxi* has a proportionately thicker hypodermis than *A. sullivanii*. Also, in *A. lesquereuxi*, the papillae of the lower epidermis occur only between the veins and only in association with stomata. In *A. sullivanii* all the lower epidermal cells are papillate with the exception of those on the midrib and on secondary veins in the region adjacent to the midrib.

The overall dimensions and basic anatomical features of the *Alethopteris* pinnules described in this paper are in general agreement with the findings of Leisman (1960) and Baxter and Willhite (1969). We have, however, observed a difference in the relative abundance of the two species. Baxter and Leisman reported that in Kansas coal balls *Alethopteris* pinnules with inrolled margins (such as *A. lesquereuxi*) were abundant while *A. sullivanii* was represented by only occasional specimens. In Lovilia coal balls both species are present, but *A. sullivanii* clearly predominates.

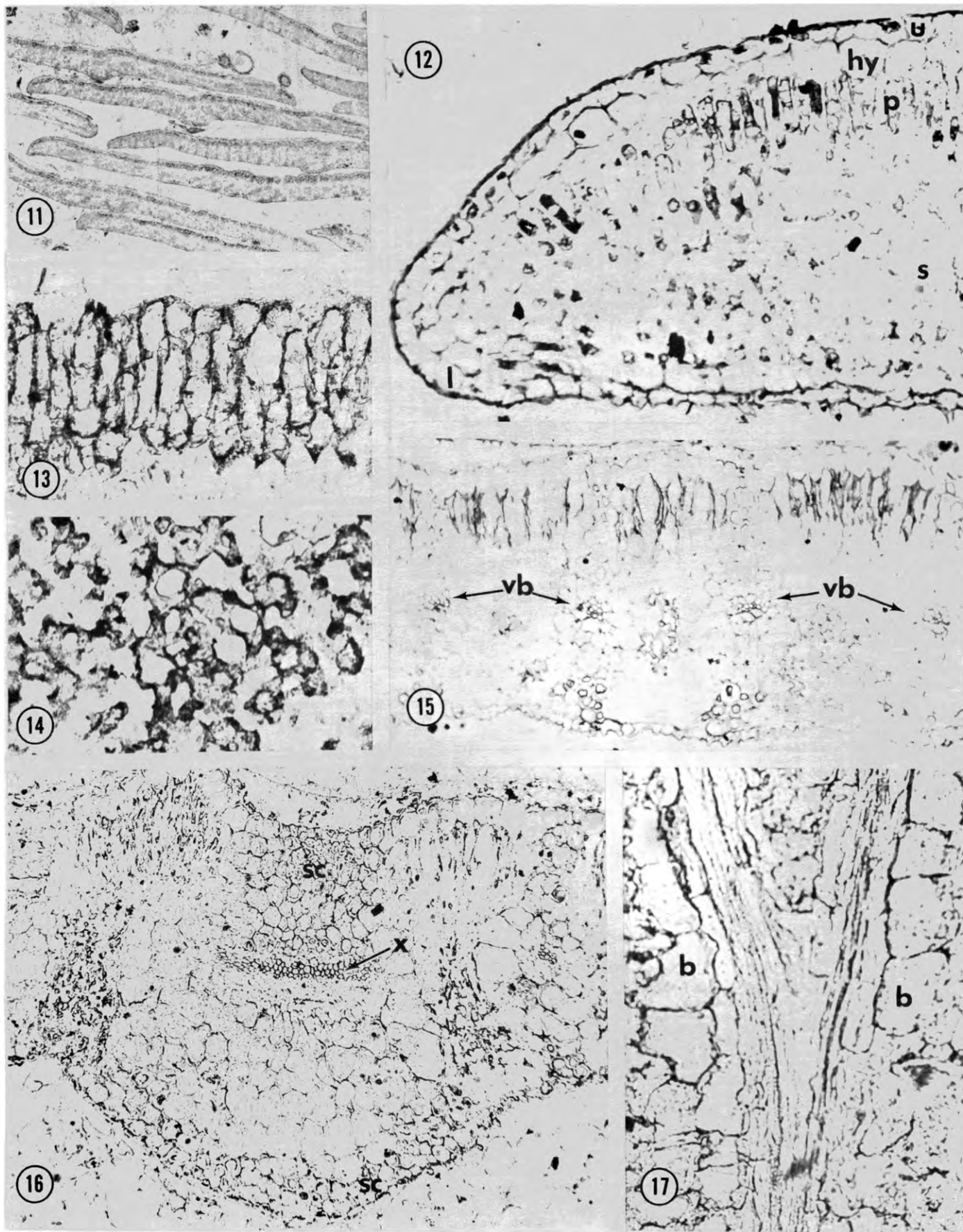
A detailed comparison of the anatomy of *A. sullivanii* specimens from Lovilia with those described by Leisman (1960) shows some differences. Leisman reported that the midrib of *A. sullivanii* has thick-walled ground tissue. In the specimens of *A. sullivanii* from Lovilia the ground tissue of the midrib appears to be parenchymatous with sclerenchyma present only in the adaxial and abaxial regions. In the Lovilia material the ground tissue of the rachis is parenchymatous with thick-walled cells confined to a continuous band around the periphery. Leisman had reported that the peripheral sclerenchyma was arranged in discrete hypodermal bundles. These differences in the amount and arrangement of sclerotic tissue may well reflect differences in the degree of maturation or portion of the foliage sectioned. Leisman reported an endarch development of the xylem in the vascular bundles of *A. sullivanii*. In the specimens from Lovilia the protoxylem of the pinnules occupies an abaxial (exarch) position. Leisman also suggested that the entire abaxial surface of the pinnule was covered with multicellular hairs. The specimens from Lovilia have hairs present only on the midrib and on the secondary veins near the midrib.

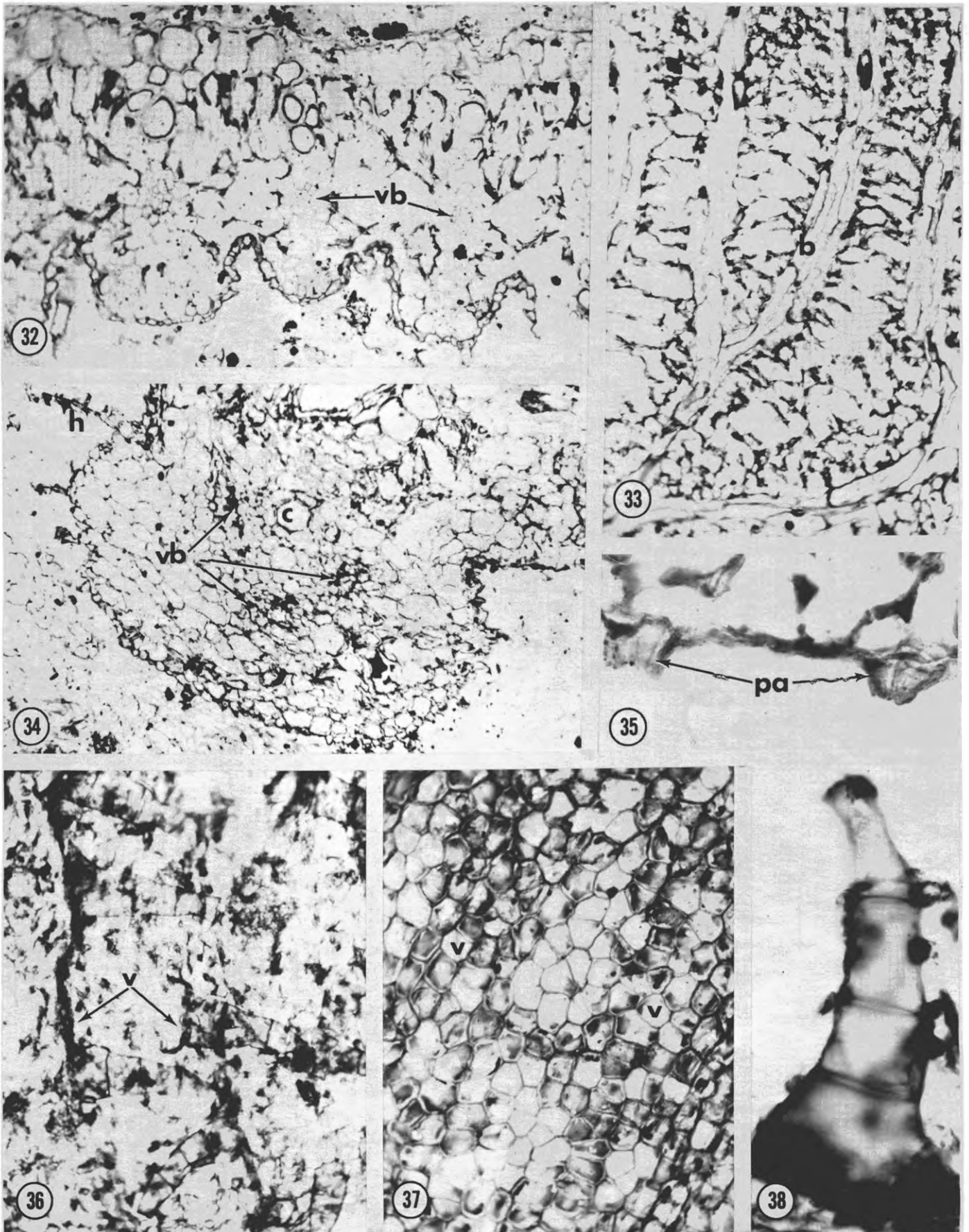
Exceptionally well-preserved specimens of *A. lesquereuxi* from Lovilia have provided additional anatomical information. Baxter was not able to clearly see features of the lower epidermis of *A. lesquereuxi*, but he suggested that it was nonpapillate with stomata located between veinlet ridges. The *A. lesquereuxi* specimens from Lovilia clearly show a papillate lower epidermis with stomata located in the grooves between secondary veins.

It has been noted by several workers that *Alethopteris* pinnules exhibit xeromorphic characteristics (Schopf, 1939; Franks, 1963; Cridland, 1968; Baxter and Willhite, 1969). If an inrolled margin, protected stomata, abundance of hairs, and prominent hypodermal layer are indications of xeromorphic adaptations, then, as has been noted by Baxter and Willhite (1969), *A. lesquereuxi* is more highly modified than *A. sullivanii*. It has also been pointed out that *Alethopteris* pinnules show features similar to those of plants found in swamps (Schopf, 1930) or bogs (Cridland 1968). Features which are attributed to bog plants by Warming (1909), i.e. plants growing in acid, humus-rich soil in a temperate or cold climate; seem to correlate well with features noted in *Alethopteris* pinnules. These features included 1) presence of hairs, 2) papillae, 3) a thick cuticle, 4) sclerophylly, 5) secretory structures, and 6) a hypodermis.

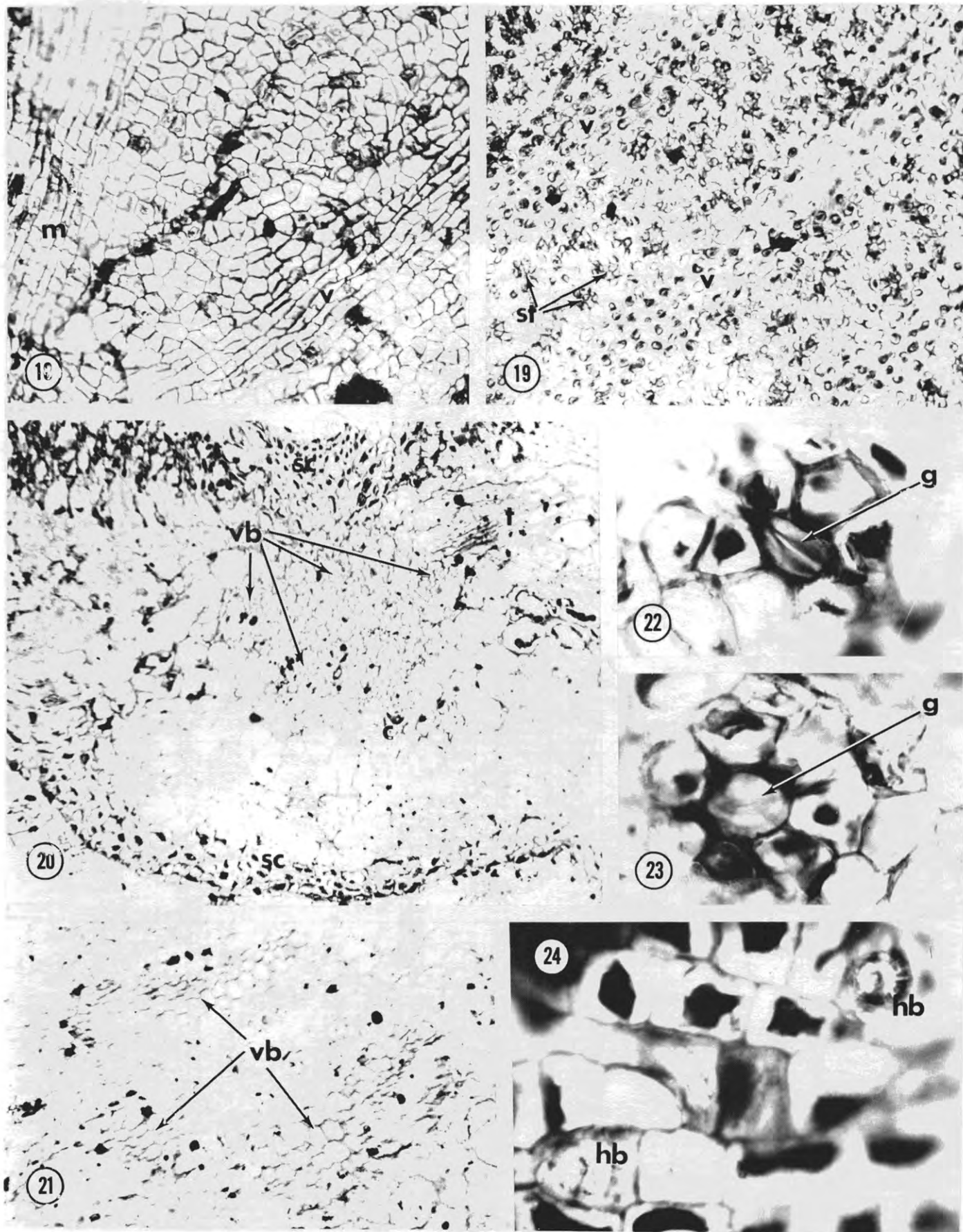
The stratigraphic range established by Wagner (1968) for *A. lesquereuxi* is upper Westphalian D to Stephanian A. Baxter and Willhite (1969) reported *A. lesquereuxi* from the Fleming coal of Kansas which they regarded as being stratigraphically equivalent to the upper Westphalian D of Europe. The Lovilia coal of Iowa is believed to be stratigraphically equivalent to the Summon no. 4 coal of Illinois and to the Bevier coal of Kansas (Schabillon et al, 1974; Brotzman, 1974).

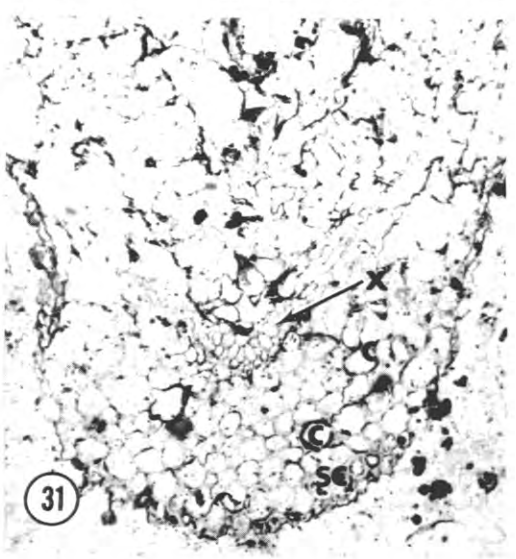
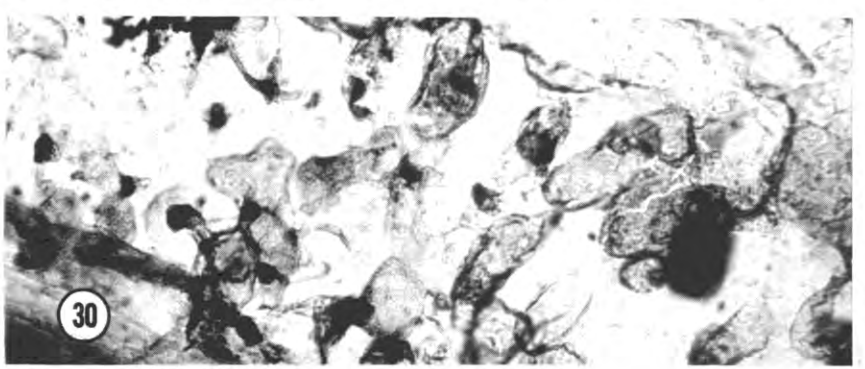
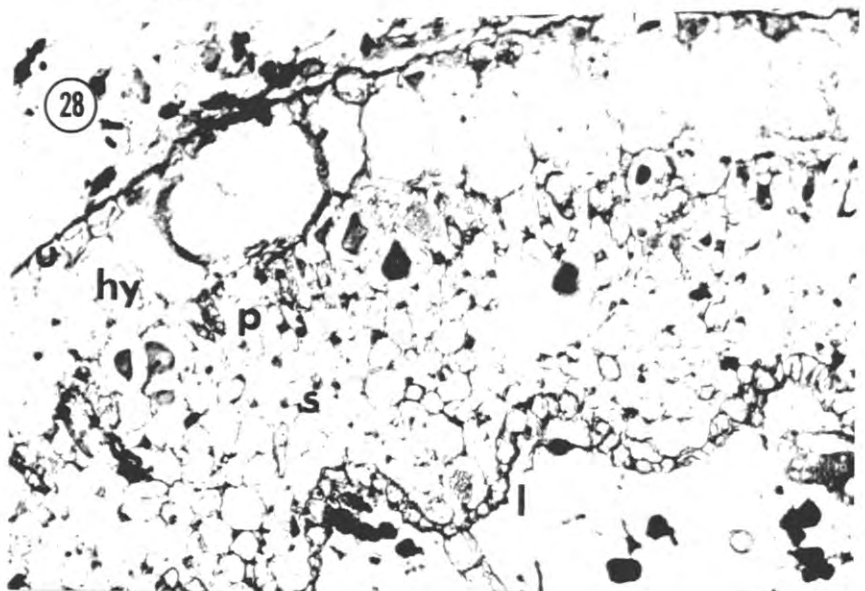
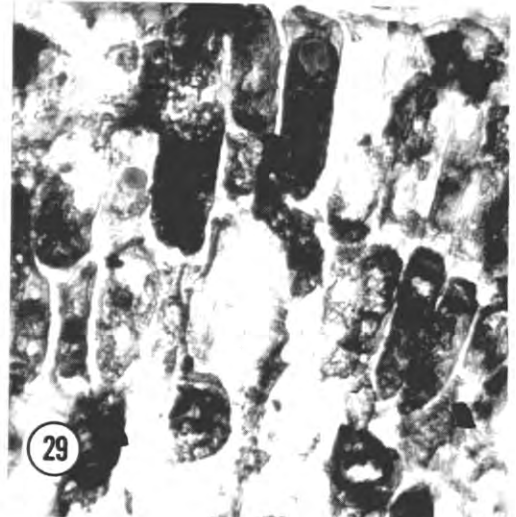
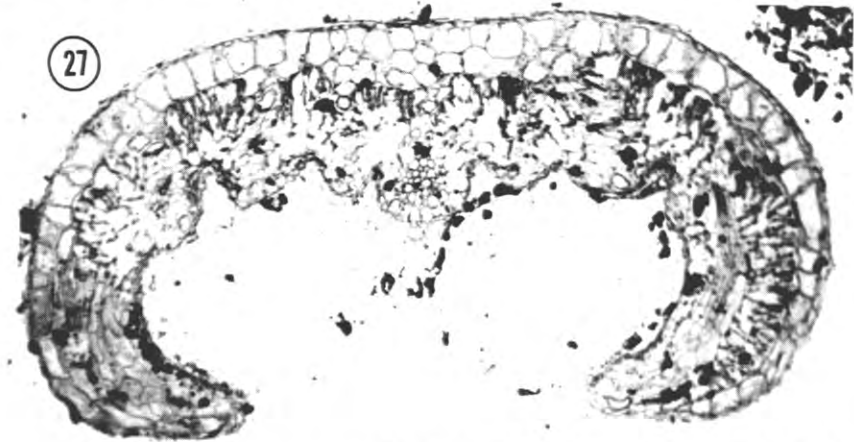
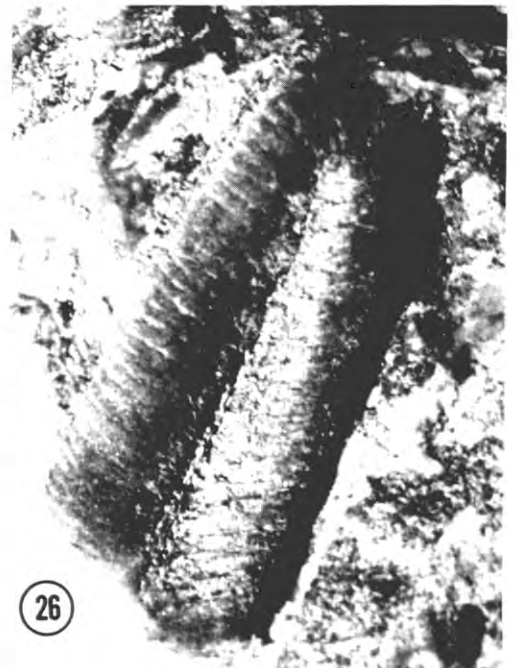
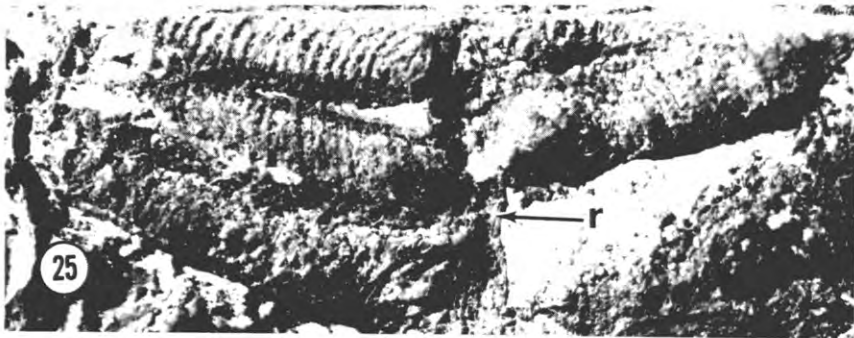
Fig. 11-17. — *Alethopteris sullivanii* from Iowa Coal Balls — Fig. 11. Transverse sections of pinnules. X6. — Fig. 12. Transverse section of a pinnule margin showing tissue types. X210. — Fig. 13. Palisade parenchyma. X310. — Fig. 14. Spongy parenchyma. X270. — Fig. 15. Transverse section showing the vascular bundles of several secondary veins. X100. — Fig. 16. Transverse section of the midrib region. X80. — Fig. 17. Paradermal section of a secondary vein enclosed in the bundle sheath. X136.











## ALETHOPTERIS FROM COAL BALLS

Fig. 18-24. — *Alethopteris sullivanti* from Iowa Coal Balls — Fig. 18. Cuticle of the upper epidermis. X98. — Fig. 19. Cuticle of the lower epidermis. Note extreme abundance of papillae. X98. — Fig. 20. Transverse section of a rachis. X83. — Fig. 21. The several vascular bundles of the rachis. X111. — Fig. 22. Single stoma showing the guard cells. X510. — Fig. 23. Single stoma showing the overhanging papillae. X510. — Fig. 24. Hair bases on the lower epidermis. X500.

Fig. 25-31. — *Alethopteris lesquereuxi* from Iowa Coal Balls — Fig. 25. Portion of a frond from an Iowa coal ball showing several pinnules attached to the rachis. X8. — Fig. 26. Single pinnule from an Iowa coal ball. X10. — Fig. 27. Transverse section of a single pinnule near the apex. X37. — Fig. 28. Transverse section showing tissue types. X110. — Fig. 29. Palisade parenchyma. X375. — Fig. 30. Spongy parenchyma. X386. — Fig. 31. Transverse section of midrib region. X105.

Fig. 32-38. — *Alethopteris lesquereuxi* from Iowa Coal Balls — Fig. 32. Transverse section showing the vascular bundles of several secondary veins. X130. — Fig. 33. Paradermal section showing bundle sheath cells. X80. — Fig. 34. Transverse section of a rachis. X94. — Fig. 35. Two stomata showing the surrounding ring of papillae. X375. — Fig. 36. Cuticle of the lower epidermis showing the multicellular hairs which are present on the secondary veins. X150. — Fig. 37. Cuticle of the upper epidermis. X100. — Fig. 38. Multicellular hair. X400.

nv

The Bevier coal is stratigraphically somewhat higher than the Fleming coal (Baxter and Hornbaker, 1965). Therefore, the *Lovilia* material of *A. lesquereuxi* appears to fall within the stratigraphic range Wagner established for the species.

The stratigraphic range established by Wagner for *A. sullivanti* is middle Westphalian C to upper Westphalian D. The *A. sullivanti* specimens from Lovilia, and those reported by Leisman from the Fleming coal fall within this stratigraphic range. Leisman, however, also reported *A. sullivanti* from the What Cheer mine of Iowa. This locality is believed to be stratigraphically equivalent to the Westphalian B of Europe (Schabillion, 1974; Brotzman, 1974). The occurrence of *A. sullivanti* from the What Cheer locality, therefore, appears to extend the range of *A. sullivanti* downward to the Westphalian B.

## ACKNOWLEDGMENTS

The authors wish to thank Dr. H. L. Dean for assistance with photography and Dr. Nancy L. Brotzman for assistance with the drawings.

## LITERATURE CITED

- BAXTER, R. W. and M. R. WILLHITE, 1969. The Morphology and Anatomy of *Alethopteris Lesquereuxi* Wagner. The University of Kansas Science Bulletin. XLVIII: 767-783.
- BAXTER, R. W. and A. L. HORNBAKER, 1965. Pennsylvanian Fossil Plants from Kansas Coal Balls. A Field Conference Guidebook for the Annual Meetings. The Geological Society of America and Associated Societies, Kansas City.
- BROTZMAN, N. L. C., 1974. North American Petrified Cordaitan Ovules. Ph.D. Thesis. The University of Iowa.
- BROWN, C. A., 1960. Palynological Techniques. C. A. Brown, publisher. Baton Rouge, Louisiana.
- CRIDLAND, A. A., 1968. *Alethopteris ambigua* Lesquereux, a Pennsylvanian pteridosperm from Missouri. U.S.A. J. Linn. Soc. (Bot.). 61: 107-111.
- FRANKS, J. W., 1963. On some Alethopteroid pinnules from the Permian of Autun. Annals of Botany, N. S. 27: 447-452.
- HALLE, T. G., 1927. Palaeozoic plants from central Shansi. Palaeontologia Sinica (A). 2: 1-316.
- LEISMAN, G. A., 1960. The morphology and anatomy of *Callipteridium sullivanti*. Amer. J. Bot. 47: 281-287.
- RAMANUJAM, G. G. K., G. W. ROTHWELL and W. N. STEWART, 1974. Probable attachment of the *Dolerotheca campanulum* to a *Myeloxylon-Alethopteris* type frond. Amer. J. Bot. 61: 1057-1066.
- SCHABILION, J. T., N. L. BROTZMAN, and T. PHILLIPS, 1974. Two coal ball floras from Iowa. (Abstr.) Amer. J. Bot. 61: 19.
- SCHOPF, J. M., 1939. *Medullosa distellica*, a new species of the Anglica group of *Medullosa*. Amer. J. Bot. 26: 196-207.
- SCOTT, D. H., 1899. On the structure and affinities of fossil plants from the paleozoic rock, III, On *Medullosa Anglica*, a new representative of the Cycadofilices. Philos. Trans. R. Soc. London. 191 B: 81-126.
- STEIDTMAN, W. E., 1944. The anatomy and affinities of *Medullosa Noei* Steidtmann, and associated foliage, roots and seeds. Michigan University Museum of Paleontology Contributions. 6: 131-166.
- STEWART, W. N. and T. N. TAYLOR, 1965. The Peel Technique. In B. Kummel and D. Raup (ed.), Handbook of Paleontological Techniques. W. H. Freeman and Company, San Francisco.
- WAGNER, R. H., 1968. Upper Westphalian and Stephanian species of *Alethopteris* from Europe, Asia Minor, and North America. Uitgevers-Maatschappij "Ernest Van Aelst". Maastricht, Netherlands.
- WARMING, E., 1909. Oecology of Plants. An Introduction to the Study of Plant-Communities. Clarendon Press, Oxford.
- WHITE, D., 1899. Fossil flora of the lower Coal Measures of Missouri. U.S. Geol. Surv. Monogr. 37: 1-467.