CONTRIBUTIONS FROM THE MUSEUM OF PALEONTOLOGY

UNIVERSITY OF MICHIGAN

VOL. VII, No. 9, pp. 131–269 (34 pls., 2 figs., 2 maps) DECEMBER 29, 1949

FOSSIL FLORA OF THE MICHIGAN COAL BASIN

BY

CHESTER A. ARNOLD

UNIVERSITY OF MICHIGAN PRESS
ANN ARBOR

UNIVERSITY OF MICHIGAN

Director: LEWIS B. KELLUM

The series of contributions from the Museum of Paleontology is a medium for the publication of papers based entirely or principally upon the collections in the Museum. When the number of pages issued is sufficient to make a volume, a title page and a table of contents will be sent to libraries on the mailing list, and also to individuals upon request. Correspondence should be directed to the University of Michigan Press. A list of the separate papers in Volumes II–VI will be sent upon request.

VOL. I. The Stratigraphy and Fauna of the Hackberry Stage of the Upper Devonian, by C. L. Fenton and M. A. Fenton. Pages xi+260. Cloth. $2.75.

VOL. II. Fourteen papers. Pages ix+240. Cloth. $3.00. Parts sold separately in paper covers.

VOL. III. Thirteen papers. Pages viii+275. Cloth. $3.50. Parts sold separately in paper covers.

VOL. IV. Eighteen papers. Pages viii+295. Cloth. $3.50. Parts sold separately in paper covers.

VOL. V. Twelve papers. Pages viii+318. Cloth. $3.50. Parts sold separately in paper covers.

VOL. VI. Ten papers. Pages viii+336. Paper covers. $3.00. Parts sold separately.

(*Continued on inside back cover*)

VOL. VII, No. 9, pp. 131-269 (34 pls., 2 figs., 2 maps) DECEMBER 29, 1949

FOSSIL FLORA OF THE MICHIGAN COAL BASIN

By CHESTER A. ARNOLD

CONTENTS

INTRODUCTION

FOSSIL plants in the coal-bearing rocks of Michigan were first noticed in the vicinity of Jackson. In his report to the state geologist, dated January 20, 1840, Columbus C. Douglass (in Houghton, 34) mentioned impressions of *Lepidodendron*, *Stigmaria*, and *Calamites*, "together with thin masses of carbonaceous matter" in the quarries north and south of that town. The next year Bela Hubbard reported (in Houghton, 34) similar finds in the sandstones between the "upper" and the "lower" coals in Jackson, Ingham, Eaton, Calhoun, Clinton, Shiawassee, and Genesee counties. Hubbard appears to have made the first collections that were kept, some of the specimens having been given to the University of Michigan. Except for its historical significance this material is of little value because it consists mostly of sandstone casts that show few diagnostic features. A few of the better-preserved specimens collected by Hubbard are illustrated with slight reduction in size in Plate I. These are in collections of the University of Michigan. In the first biennial report of the state geologist in 1861 Alexander Winchell (70) alluded to fern leaves in the shales associated with the coals, and reported expressed readiness on the part of Dr. J. S. Newberry, leading American paleobotanist of the time, to undertake the study of the fossil flora. There is no record, however, that Newberry received any of the Michigan plants. Some of the specimens collected by Winchell are still in the collections of the University Museums. Lesquereux described no Michigan plants in his *Coal Flora* (46), although he mentioned (46, p. 635) specimens of *Stigmaria* received from Rominger.

No systematic studies of the Michigan coal flora were recorded until 1902 when Lane (43, pp. 43–44) published a list of some thirty plants determined by David White from the mines near Saginaw, Grand Ledge, Owosso, and St. Charles. In 1906 Cooper (18, p. 188) gave a list of thirteen plants, also determined by White, from the United City Mine at West Bay City. Then, in 1908 Lane (44, p. 19) referred to a plant resembling *Neuropteris Desorii* from the Wolverine Mine No. 3 in Bay County, and in 1909 he (45, pp. 87–88) listed a number of species from the Verne. The plants of all of these collections, except those collected at Grand Ledge, are in the Museum of Paleontology of the University of Michigan, having been deposited there by the Geological Survey of Michigan some years ago. The plants which White identified from the Standard Mine, the United

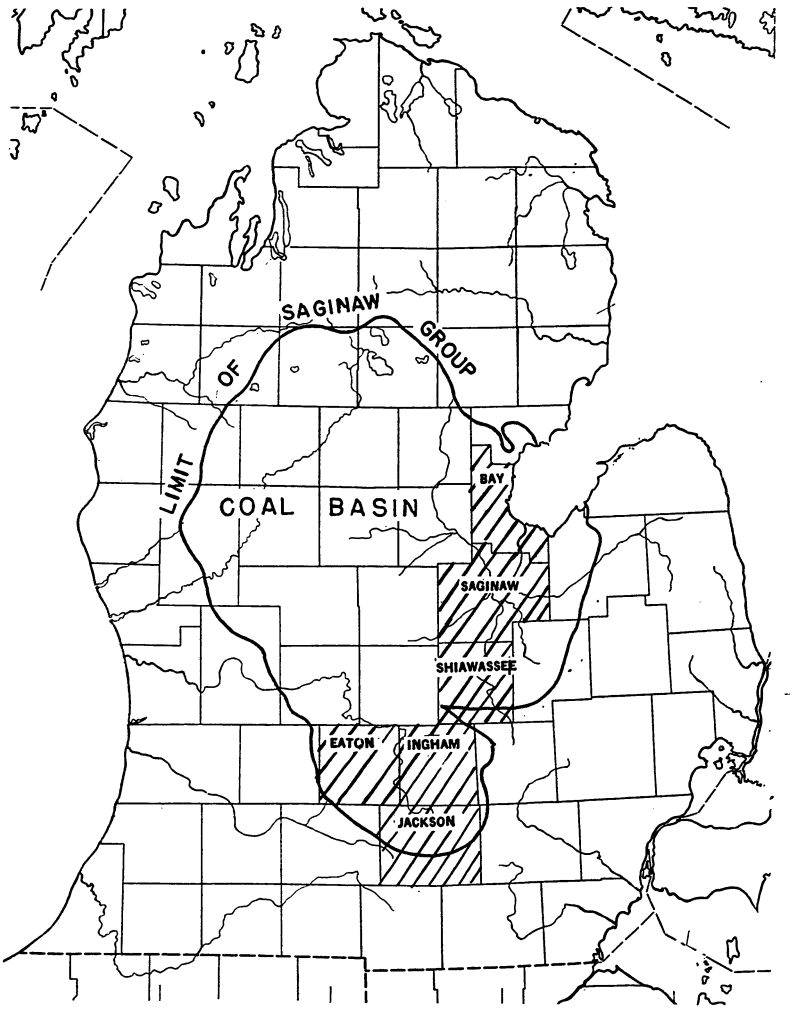
City Mine, and the Owosso Coal Company can be recognized by small numbers scratched in the matrix (presumably by White himself) which correspond to the sequence in the lists of Lane and Cooper. The specimens from St. Charles were not marked, and the accompanying labels have become interchanged. It is impossible, therefore, to be sure of the exact identity of all of the specimens originally secured from there.

The present study is based in part upon the plants mentioned in the foregoing paragraphs and in part upon additional ones collected at other times. While making a comprehensive study of the Pennsylvanian system in Michigan, W. A. Kelly collected plants in the vicinities of Grand Ledge and Corunna, which he submitted in 1929. Of other collections, that made by S. H. Perry in 1889 at Grand Ledge was noteworthy. The bulk of the material used in the present study was collected by the author between 1929 and 1945. In 1934 a preliminary account (5) was published in which about forty plants were listed, some being reported from the state for the first time. In 1937 a highly productive plant bed was discovered in two of the quarries at Grand Ledge, and soon afterward considerable additional material was found in a mine near St. Charles. These later discoveries have made notable additions to the Michigan Coal flora, and a number of species heretofore unknown in the state have been added. In his account of the Pennsylvanian system in Michigan, Kelly (40) listed fifty-six plants identified by White, Arnold, and himself, and cited localities. Recent studies have added about forty more, and the total number of plants from the coal basin of the state now on record is more than ninety. Future investigations will certainly add to the list.

LOCALITIES

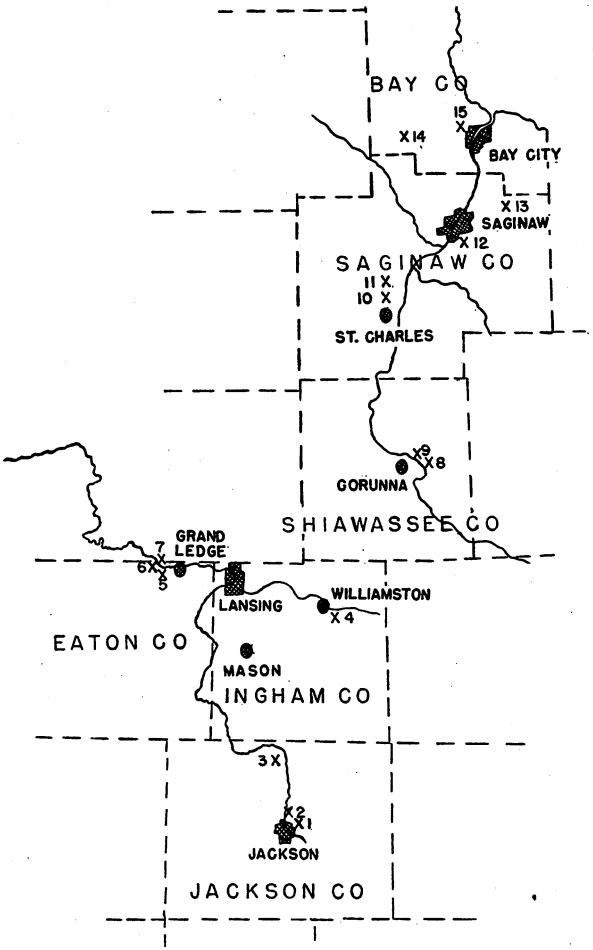
It is impossible to list all of the places in Michigan where fossil plants have been found, but the most productive localities are near Jackson, Saginaw, St. Charles, Bay City, Corunna, Williamston, and Grand Ledge (Map 1). Productivity of any locality varies greatly with the quarrying and coal-mining activities that happen to be under way at any particular time.

JACKSON.—In the collections of the Museum of Paleontology of the



MAP 1. The Lower Peninsula of Michigan showing the location and extent of the coal basin. The counties in which fossil plants have been collected are shaded. Specific locations are listed on Map 2.

University of Michigan are parts of the original collections of Hubbard and Winchell (Pl. I), but most of the specimens are featureless



MAP 2. Fossil-plant localities in Bay, Shiawassee, Eaton, Ingham, and Jackson counties

1. Woodville Mine at northeastern city limits of Jackson. 2. The state prison farm. 3. Unnamed strip mine in sec. 16, T. 1 S., R. 1 W. 4. Quarry of the Michigan Clay Products Company east of Williamston. 5. Quarry of the American Vitrified Products Company south of the Grand River at Grand Ledge. 6. Quarry of the Grand Ledge Clay Products Company. 7. Quarry of the Grand Ledge Face Brick Company north of the Grand River. 8. Quarry of the New Corunna Brick Company. 9. Mine dumps of the Owosso Coal Company. 10. Big Chief No. 8 Mine north of St. Charles. 11. St. Charles-Garfield Mine at Eastwood (Garfield on some maps). 12. Standard Mine. 13. Uncle Henry Mine. 14. Wolverine Mine. 15. United City Mine.

casts of no value. There is no evidence, either from literature or from recent observations, of well-preserved leaf compressions ever having been found in quantity near Jackson, although considerable coal was mined there during the latter part of the last century. During the course of the present investigation three visits were made to Jackson County, but the dumps of the abandoned mines and the unworked quarries yielded little material of value. A few years ago a fine display of upright casts could be seen in a strip mine (Map 2, locality 3) about ten miles north of the center of the city of Jackson and two and two-thirds miles east of Rives Junction (sec. 16, T. 1 S., R. 1 W.) Mr. R. E. Hodges, of Jackson, has removed several of these casts, some of which are nearly six feet long. Some taper gradually from a diameter of about six inches at the base to two inches at the top and probably represent whole or nearly whole trunks of *Calamites*. They lack the longitudinal ribs that characterize the pith casts of this genus, but there is a suggestion of the segmented construction, and short lengths of typical calamitean pith casts are scattered about in the same quarry. Mr. Hodges has also found Pennsylvanian plants in the glacial drift in the southeastern corner of the state prison farm (Map 2, locality 2) north of Jackson (Arnold and Stanley, 9). The plants are in pieces of clay ironstone nodules which are identical with those in cyclical formation "A" in the quarries at Grand Ledge (Kelly, 39). Since these nodules have been found in place only at Grand Ledge, the assumption is that they were carried by the ice from near there to the Jackson site. From the nodules found at Jackson the following plants were tentatively determined:

Sphenopteris sp.
Corynepteris coralloides?
Eremopteris sp. (aff. *E. artemisaefolioides*)
Neuropteris gigantea?
Neuropteris sp. (cf. *N. obliqua*)
Neuropteris tenuifolia
Megalopteris Kellyi
Cordaites principalis
Cardiocarpon reniformis

The specimens of *Lepidodendron clypeatum* from Jackson that are listed by Lane (44, p. 19) are believed to represent *L. Rhodeanum*.

In a piece of dark shale collected by Winchell at the old Woodville Mine (Map 2, locality 1), the following have been described (Arnold, 8):

Physostoma Winchellii
Sphenopteris sp. (cf. *S. obtusiloba*)
Spermatites reticulatus

SAGINAW AND ST. CHARLES.—All of the plant material examined from the vicinity of Saginaw is believed to be from the Saginaw coal horizon and hence is somewhat lower stratigraphically than that from other places. Although Lane (43) assigned the coal beds at St. Charles also to the Saginaw Coal, that from the Big Chief No. 8 Mine is probably higher. Material from six mines has been examined.

Lane (44, p. 43) listed ten plants from the Standard Mine (Map 2, locality 12) in the northeast quarter of section 6 in Bridgeport Township as follows:

1. *Sphenophyllum bifurcatum*
2. *Neuropteris*
3. *Calamites ramosus*
4. *Stigmaria verrucosa*
5. *Caulopteris*
6. *Sphenophyllum cuneifolium*
7. *Calamites* sp.
8. *Cardiocarpon?*
9. *Asterophyllites* cf. *longifolius*
10. *Lepidodendron obovatum*

This collection was deposited at the University of Michigan, but *Sphenophyllum bifurcatum* (1), *Asterophyllites* cf. *longifolius* (9), and *Lepidodendron obovatum* (10) cannot be located. The *Neuropteris* (2) is a fragment of *N. Schlehani*, a species characteristic of the Saginaw coal horizon in Michigan. There is no reason to question the determination of *Calamites ramosus* (3) but the name *C. carinatus* has priority and is assumed to be correct. The two fragments labeled *Caulopteris* (5) are hardly sufficient even for determination to genus. *Sphenophyllum cuneifolium* (6) is represented by fragments showing a few characteristic leaves. The specimen labeled *Calamites* sp. (7) is a fragment showing a long internode, but the nodes are not present. The supposed *Cardiocarpon* fragment (8) is more likely an arthropod, probably an eurypterid. *Calamites undulatus* and *Annularia asteris* have subsequently been identified from the Standard Mine.

From one of the near-by Marquette Mines some fragmentary plant fossils have been received.[1] These include *Neuropteris Schlehani*, *Sphenopteris artemiseafolioides*, and *Diplothmema obtusiloba*.

[1] Pere Marquette Mine No. 1 was situated in the NW. ¼ of sec. 32 of Buena Vista Township. Whether the plants came from this mine or from the No. 2 mine (location unrecorded) is unknown.

Considerable plant material was collected from the dump of the Big Charles between 1929 and 1931, before the mine ceased operation. Chief No. 8 Mine (Map 2, locality 10) about one mile north of St. The collections from there include:

Sphenophyllum saxifragaefolium
S. cuneifolium
Asterophyllites equisetiformis
Annularia sp. (*A. asteris*)
Asolanus camptotaena
Lepidocystis (*Lepidocarpon*) sp.
Neuropteris dilitata
Neuropteris (*Cyclopteris*) sp.
N. cf. *tenuifolia*
Alethopteris decurrens
A. Helenae
Mariopteris nervosa
"Trigonocarpus" Noeggerathi
Lepidodendron ophiurioides
L. aculeatum
L. Brittsii
L. vestitum
Lepidostrobus sp.

The following microfossils have also been described from this mine (Arnold, 8):

Physostoma Winchellii
Trigonocarpolithus typicus
Spermatites reticulatus
Spermatites globosus
S. cylix

Lane (43, p. 44) listed the following plants from various shafts near St. Charles:

1. *Lepidodendron modulatum*
2. *L. dichotomum*
3. *Lepidophyllum cultriforme*
4. Fragments with spores and slickensides probably representing collapsed fleshy fruits
5. *Calamites* cf. *cistiiformis* and *C. Suckowii*
8. *Lepidophyllum cultriforme*
9. *Lepidostrobus* axis
10. *Lepidostrobus* apex
11, 12, 16. *Lepidodendron ophiurus*
13, 15. *Lepidodendron rhombicum*
14. *Lepidophloios?*
7, 17, 18, 25. *Stigmaria verrucosa*
26. *Pseudopecopteris* cf. *obtusiloba*

Of the above, Nos. 1, 2, 3, 8, 9, and 10 are correctly determined. Nos. 4 and 14 are indeterminable. Nos. 11, 12, and 16 belong to other

species. No. 26 is possible but uncertain, and Nos. 5, 13, and 15 cannot be located.

A highly productive mine was the St. Charles-Garfield Mine (Map 2, locality 11) at Eastwood (sometimes called Garfield), three miles north of St. Charles (NW. corner of sec. 21, T. 11 N., R. 3 E.), which ceased operation about 1942. The following were collected from the dump:

Neuropteris Schlehani
N. saginawensis
N. obliqua
N. tenuifolia
Aulacotheca Campbelli
Rhabdocarpus multistriatus
Cordaites sp.
Calamites undulatus
"Trigonocarpus" Noeggerathi
Bothrodendron punctatum
B. minutifolium
Alethopteris decurrens

The only mine in Saginaw County (other than the Big Chief No. 8 Mine) that has yielded plants from a horizon higher than the Saginaw Coal is the Uncle Henry Mine No. 2 (Map 2, locality 13), seven miles northeast of Saginaw. A specimen of *Megalopteris Southwellii* was found there (Arnold, 5).

BAY COUNTY.—The entire collection of plants reported by Cooper (18, p. 188) is at hand for examination. The thirteen species determined by White from the United City Mine (Map 2, locality 15) at West Bay City are the following:

1. *Mariopteris muricata*
2. *Pseudopecopteris* cf. *avoldensis*
3. *Sphenopteris* (*Crossotheca*), sp. nov.
4. *Sphenopteris* (*Palmatopteris*) sp. indet.
5. *Heterangium?* stem fragment
6. *Pecopteris dentata?*
7. *Neuropteris rarinervis* (var.)
8. *Calamites ramosus*
9. *Sphenophyllum emarginatum*
10. *Bothrodendron minutifolium*
11. *Lepidodendron aculeatum*
12. *Stigmaria verrucosa*
13. *Cordaites* sp.

The first species on the list above bears a closer resemblance to *M. acuta* than to *M. muricata*, but the specimen is too small to allow ac-

curate identification. The specimen listed as *Pseudopecopteris* cf. *avoldensis* is described on a subsequent page of this study as *Sphenopteris Bradfordii*, sp. nov. The *Sphenopteris* (*Crossotheca*), sp. nov., is indeterminable, as is also *Sphenopteris* (*Palmatopteris*) sp. Both are sphenopterid fragments but little can be said about them. The supposed *Heterangium* stem fragment is not exactly characteristic of that genus, and the specimen identified questionably as *Pecopteris dentata* looks more like a poorly preserved fragment of *Pecopteris plumosa*. There are several specimens of *Neuropteris rarinervis* which are believed to be correctly determined, but there is no obvious reason except for their somewhat small size for giving them varietal rank. *Calamites ramosus* (*C. carinatus*) is represented by several pieces showing branch scars. *Sphenophyllum emarginatum* is correctly determined, but the identification of *Bothrodendron minutifolium* is doubtful. The faintly indicated crowded leaf cushions are suggestive of the *Lepidophloios laricinus* type. *Lepidodendron aculeatum* is represented by a fairly well-preserved specimen. *Stigmaria verrucosa* is a synonym of *S. ficoides*, and the several fragments of *Cordaites* leaves are identified as *C. principalis*. In addition to the plants listed above, a fragment of *Megalopteris* resembling *M. Southwellii* is present on a block bearing *Sphenophyllum emarginatum*, and there is a seed fragment of the *Cardiocarpon* type.

The only other mine in Bay County on record as having yielded fossil plants is the Wolverine Mine No. 3 (Map 2, locality 14) in the eastern part of Williams Township. From the roof of the coal, assumed to be upper Verne, David White (in Lane, 44, p. 19) identified *Lepidodendron aculeatum*, *Lepidostrobus variabilis*, and a plant similar to *Neuropteris Desorii*. The last is described in this account under that name.

CORUNNA.—In 1902 Lane (1943, p. 44) listed the following plants from the mine of the Owosso Coal Company (Map 2, locality 9):

1. *Cordaites*, probably *C. Robbii*
2. *Cardiocarpon ovale*
3. *C. bicuspidatum* var. *ohioense*

The above-named plants are on a piece broken from a shaly nodule. None of the determinations is positive because of the fragmentary nature of the material.

In 1929 Kelly (40, pp. 197–198) collected plants in the sandstone lentil of Bed "2" of formation "B" in the quarry of the New Corunna Brick Company (Map 2, locality 8). Although precise determinations are difficult because of the fragmentary nature of the material, the following may be listed:

Megalopteris Dawsoni
M. Kellyi
Zeilleria stellata
Neuropteris sp.
N. obliqua
Palaeopteridium Reussi
Annularia sphenophylloides
Samaropsis Newberryi
Cardiocarpon sp.
Cordaites sp.

Zeilleria stellata was described by me in 1937 (6).

The presence of two species of *Megalopteris* and of *Samaropsis Newberryi* at this locality points to a similarity in age with Kelly's Cycle "A" of the Grand Ledge section. The plants from the two beds are so much alike that it is difficult to interpret them as anything but synchronous.

WILLIAMSTON.—The only plant material in addition to undescribed microfossils from Williamston consists of a few lycopod remains from the quarry of the Michigan Clay Products Company on the south side of the highway just east of the town (Map 2, locality 4). None of the plants was found in place, consequently they cannot be located within the Williamston section given by Kelly (40, p. 201). The following have been identified:

Lepidodendron dichotomum
L. obovatum
Lepidostrobus sp.
Lepidocarpon linearifolium

GRAND LEDGE.—The quarries northwest of Grand Ledge have provided the best fossil-plant collecting of any of the localities within the state, and a couple of them have yielded continuously over a period of several years (Map 2, localities 5–7). Lane (43, p. 44) listed the following:

Lepidodendron lycopodioides
L. obovatum
Cordaites borassifolius
Cardiocarpon Cuyahogae
Neuropteris flexuosa
Neuropteris cf. *Harrisi*
Asterophyllites sp.
Diplothmema sp.
Pseudopecopteris or *Mariopteris* sp.

As this collection has not been located little can be said concerning

it. *Lepidodendron lycopodioides* and *Cardiocarpon Cuyahogae* have not been observed by me at Grand Ledge. *Neuropteris Harrisi* cannot be identified from the very brief and unsatisfactory description of the species, and *N. flexuosa*, if it is present at Grand Ledge, has so far escaped notice. There are other species waiting to be identified at that place when more complete specimens are available. It can be emphatically asserted that Lane's list does not adequately represent the Grand Ledge flora as it has been revealed by later collections.

Of the eight cyclical formations that Kelly (39) has designated at Grand Ledge, four have yielded identifiable plants, and it is likely that they occur in all of them. Cycles "A" and "F" are the most productive of the named and measured cyclical formations, although the most prolific plant bed is in an undesignated formation immediately below Cycle "A." This plant bed was first noticed by me in the autumn of 1937 at the bottom of the quarry of the Grand Ledge Face Brick Company (Map 2, locality 7), which is in Section 3 on the east bank of the Grand River about a quarter of a mile south of the county line. At the time of the discovery the bed yielded large numbers of detached leaflets of *Neuropteris Scheuchzeri* and the small flask-shaped seed of *Cordaianthus ampullaceus*. About a year later the same bed with a similar assortment of plants was uncovered in the bottom of the quarry of the Grand Ledge Clay Products Company (Map. 2, locality 6) directly across the river from the other locality. This locality continued to yield good plant fossils as long as quarrying operations were carried on there. The following plants have been identified by me below Cycle "A":

Calamites Suckowii
C. carinatus
C. Cistii
Sphenophyllum cuneifolium
S. majus
Asterophyllites vernensis
A. equisetiformis
Discinites delectus
D. Jongmansi
Sigillaria (*Rhytidolepis*) sp.
Pecopteris Miltoni
Neuropteris Scheuchzeri
Neuropteris tenuifolia
Eremopteris michiganensis
Rhabdocarpus multistriatus
R. Mansfieldi
Cordaites palmaeformis
C. principalis
Ginkgophyllum grandifolium
Cordaianthus devonicus
C. ampullaceus
Cardiocarpon late-alatum
C. annulatum
Cordaites (*Artisia*) sp.

This list would be longer if all the undetermined fragments could be identified, but as it stands it is the largest assemblage from any stratigraphic unit at a single locality in the state. Two features that stand out are the abundance of cordaitean remains and the scarcity of lycopods. *Calamites* and *Sphenophyllum* are scattered throughout the bed but most of the other species, *Neuropteris Scheuchzeri* in particular, often occur in pockets which soon become exhausted when quarrying operations are prolonged. During 1937 and 1938 thousands of leaflets of this plant were seen, but they soon disappeared completely, even though large quantities of other plants continued to be unearthed by the power shovels. A collector at either of the two sites in 1939 would probably have failed to find even a fragment of this interesting species. Because of the limited vertical and horizontal distribution of many species in the Michigan Coal Basin, repeated visits to the mines and quarries being actually worked are necessary. A sample of everything that is to be had at any one place can usually be secured within a couple of hours, but another visit a week later is likely to result in the discovery of something else. This statement is true of all the plant localities in Michigan, but especially so of the two quarries under consideration at Grand Ledge.

The revised list of plants from Cycle "A" embraces the following:

Asterophyllites equisetiformis
Odontopteris sp.
Megalopteris Dawsoni
M. Kellyi
Neuropteris sp. (cf. *N. heterophylla*)
Neuropteris caudata
N. obliqua
Trigonocarpus sp.
Rhabdocarpus multistriatus
R. mamillaris
Samaropsis Newberryi
Cordaites sp.

The plants most worthy of note in Cycle "A" are the two species of *Megalopteris* which occur in the clay ironstone nodules below the layer designated by Kelly (39) as the "lower *Lingula* layer." The nodules are hard and break irregularly, and mention has already been made of their occurrence in the glacial drift near Jackson by Arnold and Stanley (9). In addition to *Megalopteris* there are seeds and pieces of *Neuropteris* leaves which are generally too fragmentary for accurate determination. Some of the larger nodules consist almost entirely of compressed leaves of *Cordaites*.

In the west wall of the quarry of the Grand Ledge Clay Products

Company, between the coal of Cycle "B" (the Grand Ledge Coal) and the coal of Cycle "E," plants occur in the light gray shale that is at present being removed. It has not been possible to locate the plants in the section more exactly because they have not been found in place. In Cycle "E" well-preserved imprints of *Sigillaria scutellata* and leafy twigs of *Bothrodendron minutifolium* were found several years ago in the north wall of the quarry of the Grand Ledge Face Brick Company.

Cycle "F" has been fairly productive of plant material, the following having been identified (Arnold, 5):

Calamites Suckowii
Sphenophyllum emarginatum
Annularia sphenophylloides
Bowmanites sp.
Calamites sp. (fructification)
Neuropteris rarinervis
Alethopteris decurrens

No plants have been secured from Cycle "G," but in Cycle "H," once known as the Woodville sandstone but later designated as Eaton by Kelly (40), a few plants have been taken which consist mostly of stem and root casts. There has been a tendency to assign any fossil specimen preserved in light-brown or light-gray sandstone from Grand Ledge to the Eaton, but, as this has probably resulted in some errors, it seems best not to attempt a list of plants from the Eaton sandstone at present.

From time to time specimens have been received at the Museum of Paleontology from Grand Ledge, which were either unaccompanied by stratigraphic data or were collected in places where the exact position was undetermined. Owing to the short lateral extent of many of the beds n the quarries where one or more of the cyclical formations may disappear within a short distance, the position of much newly discovered plant material is frequently uncertain. The following species came from unknown horizons but for the most part above the Grand Ledge Coal (Cycle "B"):

Annularia asteris
Calamites schützeiformis
Lepidodendron aculeatum
L. obovatum
L. lanceolatum
Lepidostrobus Bartlettii
Cordaites michiganensis
C. crassinervis
Alethopteris decurrens
Palmatopteris furcata
Neuropteris sp.
Sigillaria sp. (cf. *S. mamillaris* Brongniart)

REVISED LIST OF PLANTS

The following is a revised list of fossil plants known to occur in the Michigan Coal Basin:

Lycopodiales
- *Lepidodendron aculeatum* Sternberg
- *L. obovatum* Sternberg
- *L. ophiurioides* Arnold, sp. nov.
- *L. Brittsii* Lesquereux
- *L. vestitum* Lesquereux
- *L. dichotomum* Sternberg
- *L. modulatum* Lesquereux
- *L. Rhodeanum* Sternberg
- *Lepidostrobus Bartlettii* Arnold
- *Lepidostrobus* sp.
- *Lepidocarpon linearifolius* (Lesquereux) Schopf
- *L. cultriforme* (Lesquereux), comb. nov.
- *Bothrodendron minutifolium* Boulay
- *B. punctatum* Lindley and Hutton
- *Asolanus camptotaena* (Wood) Wood
- *Sigillaria scutellata* Brongniart
- *Sigillaria* sp. (cf. *S. mamillaris* Brongniart)
- *Sigillaria* (*Favularia*) sp.
- *Stigmaria ficoides* Brongniart

Calamitales
- *Calamites Suckowii* Brongniart
- *C. undulatus* Sternberg
- *C. approximatus* Brongniart
- *C. Cistii* Brongniart
- *C. carinatus* Sternberg
- *C. schützeiformis* Kidston and Jongmans
- *Asterophyllites equisetiformis* (Schlotheim) Brongniart
- *A. vernensis* Arnold, sp. nov.
- *Annularia sphenophylloides* (Zenker) Unger
- *A. radiata* Brongniart
- *A. asteris* Bell
- *A. stellata* Schlotheim
- *Palaeostachya* sp.
- *Macrostachya* sp.

Sphenophyllales
- *Sphenophyllum emarginatum* Brongniart
- *S. cuneifolium* Sternberg
- *S. saxifragaefolium* Sternberg

S. majus Bronn
Bowmanites sp.
Filicales and Pteridospermae
Pecopteris Miltoni Artis
P. plumosa Artis
Alethopteris decurrens Artis
A. Helenae Lesquereux
Alethopteris sp.
Neuropteris Scheuchzeri Hoffman
N. saginawensis Arnold, sp. nov.
N. Desorii Lesquereux
N. caudata White
N. rarinervis Bunbury
N. obliqua (Brongniart) Zeiller
N. tenuifolia (Schlotheim) Zeiller
N. cf. *heterophylla* Brongniart
N. Schlehani Stur
N. dilitata (Lindley and Hutton) Lesquereux
N. gigantea? Sternberg
Odontopteris sp.
Megalopteris Southwellii Lesquereux
M. Kellyi Arnold
M. Dawsoni Hartt
Sphenopteris obtusiloba (Brongniart) Stur
Caulopteris sp.
Zeilleria stellata Arnold
Aulacotheca Campbelli (White) Halle
Rhabdocarpus multistriatus (Presl) Lesquereux
R. Mansfieldi Lesquereux
R. mamillaris Lesquereux
"Trigonocarpus" Noeggerathi (Sternberg) Brongniart
Samaropsis Newberryi (Andrews) Seward
Trigonocarpolithus typicus Arnold
Physostoma Winchellii Arnold
Seminae Incertae Sedis
Spermatites reticulatus Arnold
S. globosus Arnold
S. cylix Arnold
Noeggerathiales
Discinites delectus (Arnold), comb. nov.
D. Jongmansi Hirmer and Guthörl
Palaeopteridium Reussi (Ettingshausen) Kidston
Eremopteris michiganensis Arnold, sp. nov.
Cordaitales
Cordaites palmaeformis (Goeppert) Weiss

C. principalis (Germar) Geinitz
C. crassinervis Heer
C. michiganensis Arnold
Ginkgophyllum grandifolium (Lesquereux), comb. nov.
Cordaicladus sp. (cf. *Cordaites principalis* (Germar) Geinitz)
Cordaicladus intermontanus Arnold, sp. nov.
Cordaianthus devonicus (Dawson) Stopes
C. ampullaceus (Bell), comb. nov.
Cardiocarpon annulatum Newberry
C. late-alatum Lesquereux
Cordaites (*Artisia*) sp.

The names of twenty-five species which occur in older lists have been omitted from those given above for one of the reasons indicated below.

(*a*) No referable material has been seen during the course of the present study.

Lepidodendron rhombicum
Lepidostrobus variabilis
Asterophyllites cf. *longifolius*
Neuropteris flexuosa
N. cf. *Harrisi*
Pecopteris dentata
Sphenopteris trifoliolata

(*b*) Identification is believed to be incorrect.

Lepidodendron clypeatum
L. lycopodioides
L. ophiurus
Sphenophyllum myriophyllum
Mariopteris muricata
Pseudopecopteris cf. *avoldensis*
Ps. cf. *obtusiloba*
Cardiocarpon Cuyahogae

(*c*) Material is too poorly preserved to allow accurate identification.

Mariopteris cf. *inflata*
Sphenopteris (*Crossotheca*) sp.
Heterangium sp.
Cardiocarpon ovale
C. bicuspidatum ohioense

(*d*) Use of other names is preferred on account of priority.

Sphenophyllum bifurcatum
Stigmaria verrucosa
Calamites ramosus
Cordaites borassifolius
C. cf. *Robbii*

CHARACTERISTICS AND COMPOSITION OF THE PENNSYLVANIAN FLORA OF MICHIGAN

The number of species found in Michigan is large in proportion to the extent of the coal basin and the total amount of material that has

been collected from it. Even though the plants are fragmentary, preservation is often good. Whether the Michigan coal swamps were completely isolated or whether they were connected with those of neighboring areas throughout all or part of their existence is unknown, but they constituted, nevertheless, an isolated unit consisting of numerous small swamps of relatively short duration and frequently changing boundaries. Within this area local environmental conditions shifted with the changes in the boundaries of the swamps, and these changes are everywhere reflected by abrupt changes in the flora. This accounts for the limited distribution of many species, such as *Neuropteris Scheuchzeri*. There was a luxuriant growth of this plant in a restricted area, but subsidence followed by inflow of salt water eradicated it permanently. A similar account could be given of several other species. The sporadic occurrence of many of the components of the flora limits their value considerably as guide fossils, both in local correlation and in attempts to correlate the Saginaw group with contemporaneous deposits in other states.

The chief constituents of the flora of the Michigan Coal Basin are arborescent lycopods and calamites, sphenophylls, ferns, seed ferns, and gymnosperms of the cordaitean complex. It is typical in every essential respect of upper Carboniferous floras elsewhere.

During the course of the study it became apparent that at least two and probably three floral zones are to be distinguished within the Michigan Coal Basin. These zones represent deposition intervals separated by periods of nondeposition during which the swamps diminished in size. Between these intervals of deposition some species disappeared from the scene, and others replaced them. Many species survived from the beginning to the end.

In the Saginaw Coal, the lowest coal horizon yielding plants in Michigan, there are distinctive species that do not extend into the Verne cyclical formations at Grand Ledge and similar formations in other parts of the state. Species that characterize the Saginaw Coal are *Neuropteris Schlehani* (Pl. XXIV, Figs. 7–10), *N. saginawensis* (Pl. XXI, Figs. 1–2, 5–6), *Aulacotheca Campbelli* (Pl. XXIV, Figs. 4–6), *Sphenopteris artemisaefolioides* (Pl. XXVI, Fig. 4), and *Diplothmema obtusiloba* (Pl. XXVI, Figs. 1–3). If any of these plants occur at higher levels they are rare, but they are often abundant in the mines in the Saginaw Valley. For convenience, the Saginaw Coal flora will

be referred to as the "lower" flora. At Grand Ledge and Corunna, in the lower of the cyclical formations assigned by Kelly to the lower Verne, there is present the largest assemblage of plants yet discovered in Michigan. This, to be referred to as the "intermediate" flora, contains as representative species *Sphenophyllum cuneifolium* (Pl. XVIII, Figs. 1, 3, 6, 9), *Neuropteris tenuifolia* (Pl. XXII, Figs. 5–10), *N. Scheuchzeri* (Pl. XX), *Eremopteris michiganensis* (Pl. XXVII), *Megalopteris Dawsoni* and *M. Kellyi* (Pl. XXV, Figs. 1, 4), *Sigillaria scutellata* (Pl. X, Figs. 1, 5), and *Cordaianthus ampullaceus* (Pl. XXXIII, Figs. 2–6). The "intermediate" flora intergrades with the "lower" flora and with an "upper" flora, which is represented in the higher cyclical formations at Grand Ledge and the coal mines in Bay County. The formations exposed in the mines in Bay County are assigned by Lane and Cooper to the upper Verne. The "upper" flora contrasts with the "lower" and "intermediate" floras by the disappearance of *Sphenophyllum cuneifolium*, *Neuropteris tenuifolia*, and *Eremopteris michiganensis*, and by the initial appearance of *Sphenophyllum emarginatum* (Pl. XVIII, Fig. 4), *Palmatopteris furcata* (Pl. XXVI, Figs. 7–8), *Annularia radiata* (Pl. XVII, Fig. 3), *A. stellata* (Pl. XVII, Fig. 1), *A. sphenophylloides* (Pl. XVI, Fig. 4), *Neuropteris rarinervis* (Pl. XXII, Figs. 1–4), and *N. Desorii* (Pl. XXIV, Figs. 1–3). The "intermediate" flora appears to be confined mainly to Cycle "A" and the plant bed immediately below it, but it may also extend into Cycle "B." There are many species that extend throughout the entire sequence of these three zones. The similarity between the "intermediate" and the "upper" floras is more pronounced because they have more species in common. The significance of this apparent zonation will be discussed in connection with the age of the flora.

The exact position of the plant bed in the Big Chief No. 8 Mine at St. Charles must for the present be held in abeyance. Lane (43) assigned the coal seams at St. Charles to the Saginaw Coal, but the plants from this mine are different from those from this horizon elsewhere. The occurrence in the Big Chief No. 8 Mine of *Asolanus camptotaena*, *Neuropteris* cf. *tenuifolia*, and *Alethopteris decurrens* suggests proximity to the lower Verne cyclical formations.

Maceration of the coals and coaly shales in the Saginaw group reveals a variety of spore types, many of which presumably represent

lycopodiaceous genera. A notable contribution to fossil spore literature is Bartlett's paper (10) on spores in coal pebbles from the glacial drift at Ann Arbor. Bergquist (15) discovered a thin seam of spore coal at Williamston which consists mostly of large spores. Descriptions of the spores from the Michigan coals are being reserved for a later report.

AGE OF THE FLORA

(Table I, p. 159)

One of the objects of the present study was to secure more information than has previously been available on the exact age of the Saginaw group. The coal-bearing rocks of Michigan were assigned to the Carboniferous at an early date, and White (in Lane, 43, p. 44) stated that the plants he examined from Owosso point to the Sewanee zone of the upper Pottsville, and he suggested comparison with the Mercer group. White believed that the plants from the Standard Mine came from somewhere between the Homewood sandstone and the Sharon Coal, and that they can hardly be later than Kanawha. Regarding the plants collected by Cooper, White said (in Lane, 44) that they certainly are not older than Mercer and could be as young as the Clarion Coal. Kelly (40) confirmed White's conclusions concerning the lower Pennsylvanian age of the Michigan Coal and made the significant statement that the extension of the embayment outside Michigan was toward the west and southwest rather than in the direction of Ohio. Preliminary observations on the early Pennsylvanian flora of Illinois and adjacent parts of Kentucky tend to support this conclusion, and further research may show the flora of the Saginaw group to be more closely related to the late Caseyville and Tradewater floras than to floras of comparable age in Ohio. The general resemblance between the Michigan flora and the Yorkian flora of Great Britain has been noted (Arnold, 5). Moore and coauthors (48), the most recent commentators on the subject, said that the Pennsylvanian rocks of Michigan are older than Missourian, and they referred to the faunas of the Saginaw group as Desmoinesian or Lampasan, and equivalent to the Kanawha or Allegheny.

None of these commentators possessed enough fossil material to enable him to pass judgment upon one very important matter, and

that is, whether the Saginaw group represents continuous and uninterrupted deposition all within one stage, or whether parts of it may be correlated with various stages of Pennsylvanian deposition. With respect to the latter possibility, it is interesting to note that Lane (43, p. 46) correlated the Saginaw Coal with the Sharon Coal of Ohio; the "Middle Rider" with the Connoquenessing stage; and the coal seams in Bay County, at Grand Ledge, Owosso, and Jackson with the upper and lower Mercer. He then correlated that of the "Upper Rider" with the Homewood sandstone. While Lane's correlation was not based upon the most conclusive evidence, it nevertheless agrees in regard to the length of time encompassed with conclusions independently reached from the study of the fossil flora. The flora indicates a slightly higher position for the whole Saginaw group, and it is believed that the Saginaw Coal was laid down after deposition of the Sharon Coal rather than contemporaneously with it.

The study of such a flora as that of the Michigan Coal Basin is made difficult by the extremely unsatisfactory and sketchy condition of the knowledge of Pennsylvanian floras elsewhere in the eastern United States. Not only are the floras of many of the important coal horizons virtually unknown, but the existing information is too often of little value for comparison with other floras. Up-to-date descriptions of the bulk of the plant types in the coal formations of the Appalachian area are lacking, and for most of the species, the *Coal Flora* of Lesquereux (46) is the only source of reference. Some of the species named by White subsequent to the publication of the *Coal Flora* were not figured, or if they were figured, only small fragments were illustrated. It is necessary, therefore, to resort to the more ample and more copiously illustrated literature on European coal floras, especially that from Great Britain, Belgium, Holland, France, and Germany. The superbly illustrated works of Kidston and his successors, Bertrand, Corsin, Renier, Stockmans, Jongmans, and Gothan are by far the most satisfactory modern sources of information on Carboniferous plants. The disadvantages of being forced to rely so heavily upon foreign literature are apparent. It not only reflects the serious lag in the development of American paleobotany, but it renders the task of correctly interpreting the smaller and more isolated American floras unduly difficult. There are many plant forms in the American

Carboniferous that closely resemble contemporary European forms but which, if critically examined, would be recognized as specifically different. Moreover, comparison of American plants with European types tends to exaggerate the differences between floras of neighboring areas.

Most of the Michigan Coal flora seems to resemble the Westphalian B flora as closely as it does floras of comparable age in West Virginia and Ohio, but its relation to the floras of these states is probably closer than is apparent. The "lower" or Saginaw Coal flora seems to approximate rather closely that of the "Zone of *Mariopteris pygmaea*" (Zone 3 of Read, 54) of the Appalachian region. *M. pygmaea* has not been found in Michigan, but on the basis of Read's (53) correlation of this zone with a Pottsville flora in central Colorado, the Saginaw Coal can also be correlated with it. The Saginaw Coal would, therefore, be equivalent to the upper Lee of the eastern United States, floral zone "D" of South Wales (Dix, 22), the Assise de Vicoigne of France, and the Baarlo-Wilhelmina group of Limburg, Holland (Table I). *Neuropteris Schlehani* is of particular interest in the Saginaw Coal flora, for it is believed to be a derivative of *N. pocahontas*, which characterizes part of the very early Pottsville. *N. Schlehani* and some of the other species in the Saginaw Coal hark back to more ancient types, which suggests that the "lower" flora is the derivative of a still older one and that the sediments up to and including the Saginaw Coal represent a distinctly earlier stage of deposition than the cyclical formations at Grand Ledge and other places in Michigan.

The "intermediate" flora most certainly, because of the prevalence of species that at other places extend into the Allegheny, is of upper Kanawha age, and probably belongs for the most part to the "Zone of *Neuropteris tenuifolia*" (Zone 5 of Read, 54). The occurrence of *Megalopteris* at several localities in Michigan might point to placing it in the "Zone of *Cannophyllites*" (Zone 4 of Read, 53) were it not for the fact that at Grand Ledge such species as *Neuropteris tenuifolia*, *N. caudata*, and *N. Scheuchzeri* occur below the ironstone nodules of Cycle "A." Although in Ohio and West Virginia *Megalopteris* is said to characterize the Connoquenessing stage (the Zone of *Cannophyllites*), the range of the plant has never been clearly set forth, and in Michigan it seems more reasonable to assume that in the coal swamps *Megalop-*

teris persisted into late Kanawha time than to postulate an extraordinarily early occurrence of several types that elsewhere characterize the late Kanawha (or Pottsville) and the early Allegheny. The former assumption would also bring the Verne cyclical formations into line with the upper Mercer Coals of Ohio and West Virginia and the upper Tradewater of Illinois. It is unfortunate that practically nothing has been published on the flora of the Mercer Coal. In a brief note White (68) remarked upon the occurrence in the Mercer of late Pottsville and Allegheny forerunners (the exact situation in Michigan), but the species making up the Mercer flora were not listed.

The possibility must be considered that the "upper" flora may be in part of lower Allegheny age, although the view is taken here that it is not later than latest Kanawha. The occurrence in the "upper" flora of *Neuropteris Desorii*, *N. rarinervis*, and other plants of Allegheny aspect, combined with the replacement of *Sphenophyllum cuneifolium* and *S. saxifragaefolium* by *S. emarginatum*, all point toward a transition to an Allegheny flora.

An intimate relation to the Allegheny is further shown in White's (65, p. 149) list of species from the Clarion Coal, which he regarded as early Allegheny. Of his list of twenty-five species the following occur in Michigan:

Neuropteris Desorii
N. rarinervis
N. Scheuchzeri
Annularia stellata
A. sphenophylloides
Sphenophyllum emarginatum
Lycopodites Meekii (*Bothrodendron minutifolium*)
Lepidodendron dichotomum
Sigillaria (*Rhytidolepis*) sp.
Rhabdocarpus multistriatus

The first seven species in the list above occur in the "intermediate" and "upper" floras of the Saginaw group. In the Appalachian region *N. Desorii* has not been recorded below the Kittaning Coal (Hendricks and Read, 32).

At Tipton, Blair County, Pennsylvania, White (67) listed twelve species from a coal horizon assigned by him to the Kittaning group. The following five of the species also occur in Michigan:

Pecopteris Miltoni
Neuropteris Scheuchzeri
Asterophyllites equisetiformis
Sphenophyllum emarginatum
Rhabdocarpus mamillatus

From the Hazard Coal (No. 6) at the Blue Diamond Mine, Perry County, Kentucky, twenty species have been identified by me but not published, of which the following occur in Michigan:

Asterophyllites equisetiformis
Sphenophyllum cuneifolium
Lepidodendron obovatum
L. Brittsii?
Bothrodendron minutifolium
Ulodendron (Bothrodendron) punctatum
Neuropteris rarinervis
N. tenuifolia
Diplothmema obtusiloba

This assemblage bears more resemblance to the "intermediate" flora of the Saginaw group than to the "higher," and it contains some elements of the "lower."

The possibility of a connection between the Michigan coal swamps and those to the west and southwest has been mentioned. Although published information on the flora of the Tradewater group is meager, plants from a few Tradewater localities are listed by Jongmans and Gothan (38). Of eleven species from twenty-five feet below the Curloo limestone near Crofton, Christian County, Kentucky, the following occur in Michigan:

Neuropteris cf. *tenuifolia*
N. rarinervis
Mariopteris nervosa
Sphenophyllum cuneifolium
S. majus
Calamites carinatus
Annularia sphenophylloides
A. radiata

Jongmans and Gothan also reported *Neuropteris Scheuchzeri* from the coal above the Babylon sandstone near Pleasantview, Illinois, at the base of the so-called Pottsville in that region.

Although comparisons between the floras of the Saginaw group and those of other places in the eastern United States have to be based to a considerable extent on assumptions, all evidence points toward upper Lee or upper New River age for the Saginaw Coal, and an age no older than late Kanawha for the highest floras in the Saginaw group (Table I).

The recent work by Bell (12, 13, 14) on the fossil floras of Nova Scotia, is by far the most extensive of any recent attempts to evaluate American Carboniferous floras and is the most satisfactory in making comparative studies.

From the Riversdale group of Nova Scotia, Bell (14, pp. 25–26) listed

a total of forty-nine species of which the following have been identified in the Saginaw group:

Diplothmema obtusiloba
Neuropteris Schlehani
Alethopteris decurrens
Calamites Suckowii
C. ramosus (*C. carinatus*)
C. undulatus
Asterophyllites equisetiformis
Sphenophyllum cuneifolium
Cordaites principalis

Bell regarded the Riversdale as probably of early Namurian age and compared the flora with that of the Flora C of Dix (22, 23) in South Wales and the Baarlo group of Holland. It has several features in common with the flora of the Saginaw Coal, particularly in the occurrence in both of *Calamites undulatus*, *Neuropteris Schlehani*, and *Diplothmema obtusiloba*, species that in Michigan have never been found as high as the Verne cyclical formations.

In the Cumberland group, which is higher, Bell (14, p. 27) listed the following species that occur also in Michigan:

Diplothmema furcatum
D. obtusiloba
Mariopteris nervosa
Neuropteris Schlehani rectinervis
N. tenuifolia
Alethopteris decurrens
Pecopteris plumosa
Megalopteris Kellyi
Annularia stellata longifolia
A. asteris
Calamites Suckowii
C. Cistii
C. ramosus (*C. carinatus*)
Sphenophyllum cuneifolium
Sphenopteris artermisaefolioides (*S. valida*)
Lepidodendron aculeatum
L. dichotomum
L. obovatum?
Sigillaria scutellata
S. mammillaris
Cordaites principalis

The Cumberland flora is larger than the Riversdale flora (Bell listed ninety-one species from it), and it is believed to be early Westphalian B (early Kanawha) in age. Although *Neuropteris Schlehani* occurs in the Cumberland group, it is rare and disappears in the upper part. Bell regarded its survival into the Cumberland as less significant as an age determiner than the presence of such species as *Asterophyllites equisetiformis*, *Neuropteris tenuifolia*, and *Lepidodendron dichotomum*.

In the higher beds of Nova Scotia, the Morien, Bell (12) listed the

following that have been found in Michigan:

a) *Lonchopteris* zone (twenty-four species)

Diplothmema furcatum
Neuropteris tenuifolia
N. Scheuchzeri angustifolia
Asterotheca Miltoni
Calamites Suckowii
Annularia radiata
A. sphenophylloides
Asterophyllites equisetiformis
Cordaites principalis

b) *Linopteris obliqua* zone (eighty-eight species)

Neuropteris tenuifolia
N. Scheuchzeri
N. rarinervis
Mariopteris nervosa
Asterotheca Miltoni
Calamites Suckowii
Asterophyllites equisetiformis
Annularia radiata
A. stellata
A. sphenophylloides
Sphenophyllum emarginatum
S. cuneifolium
Lepidodendron dichotomum
Cordaites principalis
Samaropsis ampullacea

c) *Ptychocarpus unitus* zone (eighty-four species)

Neuropteris tenuifolia
N. Scheuchzeri
N. rarinervis
Mariopteris nervosa
Asterotheca Miltoni
Calamites Suckowii
Asterophyllites equisetiformis
Annularia radiata
A. sphenophylloides
A. stellata
Sphenophyllum emarginatum
S. majus
Lepidodendron dichotomum
Asolanus camptotaena
Cordaites principalis

Bell regarded the *Lonchopteris* zone as late Westphalian B (equivalent to late Kanawha), the *Linopteris obliqua* zone as Staffordian, and the *Ptychocarpus unitus* zone as Radstockian (upper Allegheny and Conemaugh).

After examining the lists of species common to the floras of Nova Scotia and Michigan the following conclusions have been drawn:

a) The Riversdale flora shows several features in common with the Saginaw Coal flora (herein referred to as the "lower" flora), particularly in the occurrence in both of *Calamites undulatus*, *Neuropteris Schlehani*, and *Diplothmema obtusiloba*, species that in Michigan have not been recognized as high as the Verne cyclical formations.

b) The Cumberland group has several of the Saginaw Coal elements as well as a number of forms from the Verne cyclical formations at Grand Ledge and formations certainly of similar age at Corunna. Except for the occurrence of *Neuropteris Scheuchzeri* below Cycle "A" at Grand Ledge, the flora of Cycle "A" and the plant bed below it closely resembles that of the Cumberland group. *Megalopteris* is common to both floras.

c) The *Lonchopteris* zone of the Morien series and the two succeeding zones contain species common to the "intermediate" and the "upper" floras of the Saginaw group. The *Lonchopteris* zone marks the initial appearance of *Neuropteris Scheuchzeri* in Nova Scotia, and the *Linopteris obliqua* zone marks the earliest appearance of *N. rarinervis*. Neither *Lonchopteris* nor *Linopteris* have been found in Michigan.

d) From the situation as revealed in Nova Scotia the Saginaw Coal flora is either Riversdale or early Cumberland, more likely, it seems, the former. The "intermediate" flora is undoubtedly Cumberland, and the "upper" flora in all likelihood extends into the early Morien and is, therefore, equivalent to the late Kanawha and late Yorkian (Westphalian B).

e) The "upper" flora cannot be regarded as a true Allegheny flora, because of the absence of the kinds of pecopterids which characterize such floras as those of Mazon Creek, Illinois, and Henry County, Missouri, and the presence of a goodly number of pre-Morien species. Among typical Allegheny or post-Cumberland species that are absent are *Neuropteris ovata*, *N. flexuosa*, *Alethopteris Serlii*, *Callipteridium Sullivantii*, species of *Oligocarpia*, and such pecopterids as *Pecopteris unitus*, *P. dentatus*, and *P. pennaeformis*.

f) The plant-bearing part of the Saginaw group embraces a time interval approximately equivalent to the upper Lee (upper Westphalian A) and the Kanawha (Westphalian B). It is approximately equivalent to the Yorkian of Great Britain, although less fully developed.

The peculiar distribution of some of the plants of the Saginaw group presents obstacles to correlating it with other floras. The red ironstone nodules at Grand Ledge, which bear *Megalopteris* and *Samaropsis Newberryi*, are assigned by Kelly (40) to Cycle "A." On the basis of the presence of these plants, that part of the Saginaw group con-

taining Cycle "A" could be placed with full confidence in the Connoquenessing stage of the Pottsville. Below Cycle "A" at Grand Ledge, however, there is a very productive plant bed which has yielded large numbers of specimens of *Neuropteris Scheuchzeri*, *N. tenuifolia*, and *Cordaianthus ampullaceus*, which in Nova Scotia have been found only in the *Linopteris obliqua* zone of the Morien series. *Neuropteris tenuifolia* is rare in the Cumberland group, but *N. Scheuchzeri* has not been reported anywhere as occurring below *Megalopteris*, as it does at Grand

TABLE I

RELATION OF THE FLORAS OF THE SAGINAW GROUP TO THOSE OF THE EASTERN UNITED STATES, THE MARITIME PROVINCES, AND WESTERN EUROPE

Michigan	Eastern United States	Maritime Provinces	Western Europe
"Upper Flora" Bay City area and higher cyclical formations at Grand Ledge	Latest Kanawha, Upper Tradewater	Early Morien and late Cumberland	Late Yorkian, late Westphalian B, Assise d'Anzin, Mauritz Group
"Intermediate Flora" Cycle "A" and below at Grand Ledge and Corunna	Late Kanawha, Upper Tradewater	Cumberland	Late Yorkian, etc.
"Lower Flora" Saginaw Coal horizon	Upper Lee	Late Riversdale	Early Yorkian, Upper Westphalian A, Assise de Vicoigne, Baarlo - Wilhelmina Group.

Ledge. More information is needed on the stratigraphic range of many species such as *Neuropteris Scheuchzeri* and *Megalopteris*. In Nova Scotia *N. Scheuchzeri* has not been found as low as the Cumberland. The sequence of the two plants in Michigan is just the reverse of what it is elsewhere. *N. Scheuchzeri* does occur as low as the Rock Island Coal in the Tradewater of Illinois, and Read (54) listed it among plants from Cannelton, Indiana, which he places in his Zone 5 (the zone of *Neuropteris tenuifolia*).

LYCOPODIALES

The prevalence of *Stigmaria* in the Saginaw group is ample testimony of the abundance of arborescent lycopods in the ancient swamps. Here, as elsewhere, it is often the only plant fossil to be found, but

when it occurs with other plants, it may be the only lycopod remains. This manner of occurrence has caused much discussion concerning the nature of this rootlike organ. When it is the only lycopod present, the assumption is that it was produced by vegetation rooted in the deposits in which other plants had previously become entombed and consequently represents later vegetation. Under these circumstances the foliage and stems that belonged to it would not be preserved in the same bed.

The arborescent lycopods in the Michigan Coal basin that can be recognized from trunk characteristics are *Lepidodendron*, *Bothrodendron*, and *Sigillaria*. Sporophylls of *Lepidocarpon* occur and a few fragments of the little known *Asolanus* have been found. *Lepidodendron* is the most common genus. *Lepidophloios* has not been observed with certainty. *Sigillaria* is not common, but both the *Favularia* and and *Rhytidolepis* forms occur. *Bothrodendron* is not easy to recognize because of the lack of raised leaf cushions. The only remains attributable to this genus in Michigan are the specimens (Pl. IX, Fig. 1) showing the large branch scars and leafy twigs that were once referred to *Lycopodites* (Pl. VII, Fig. 2).

The Michigan species of *Lepidodendron* are difficult to identify because of the scarcity of satisfactory figures and descriptions of members of the genus from other places in North America. The only authors that have given them more than casual mention are Wood (71), Lesquereux (46), White (64), and Bell (12, 13, 14). Wood, in many instances, did not cite the source of his specimens, and most of his specific names are synonyms. White described only a few species, and Lesquereux's figures are for the most part crude and lacking in essential diagnostic details. Bell has recognized ten species of *Lepidodendron* in Nova Scotia in a flora greatly exceeding the Michigan flora in size. Because of the general inadequacy of American literature on *Lepidodendron*, reliance has to be mainly upon European authors for descriptive material.

Lepidodendron aculeatum Sternberg

(Pl. II, Figs. 1, 3–4)

A few specimens believed to represent the small branches of *Lepidodendron aculeatum* came from the Big Chief No. 8 Mine at St. Charles, and from an unrecorded locality in Ingham County.

The Ingham County specimen (Pl. II, Figs. 3–4) is the imprint of a slender branch in light-brown micaceous sandstone. From the appearance of the block it is believed to have come from the glacial drift, so that the original source is unknown. The foliar cushions, which are a little more than 4 mm. wide and about 15 mm. long, including the long tapering ends, are identical in shape and surface markings with authentic figures of *Lepidodendron aculeatum*, although they are smaller than those usually representing this species. There is a close resemblance to the smaller of Lesquereux's figures of *L. modulatum* (46, Atlas, Pl. LXIV, Fig. 13), but it does not show the diagonal border markings which characterize this form. Most authors believe that *L. aculeatum* and *L. modulatum* represent very similar if not identical plants.

The material from St. Charles (Pl. II, Fig. 1) has cushions which are slightly larger than those from Ingham County, but aside from this it appears to be the same.

Lepidodendron aculeatum is the most widely spread and commonly encountered species of the genus and can be readily recognized. It has previously been reported from Grand Ledge (5), West Bay City (18), and the Wolverine Mine No. 3 (44).

Lepidodendron obovatum Sternberg

(Pl. III, Figs. 1–2)

Material of *Lepidodendron obovatum*, in addition to that previously reported from Michigan, has been procured from the pit of the Michigan Clay Products Company at Williamston.

One specimen from the Williamston pit is the imprint of a single leaf cushion which by some means or other had become detached from the trunk (Pl. III, Fig. 2). Another specimen (in the *Aspidaria* condition) consists of a fair-sized part of a trunk surface from which the projecting portions of the cushions had been removed, probably by abrasion rather than decay, and which shows little except the arrangement and outline of the cushions (Pl. III, Fig. 1). The cushion outlines on this specimen are 17 mm. wide and 45 mm. long, and they are widest at the middle and taper about equally at top and bottom. The lateral angles are rounded and in the middle or very slightly above is the vertically elongated print of the leaf trace. A similarly preserved specimen of *L. obovatum*, figured by Stur under the name of *L.*

dichotomum (61, Pl. XIX, Fig. 4), shows cushions bearing surface features like those on the imprint of the detached cushion from Williamston. Feistmantel (26, Pls. XXXIX and XL) shows material preserved in this way from Bohemia.

Lepidodendron ophiurioides, sp. nov.

(Pl. III, Fig. 4; Pl. IV, Figs. 1–3, 5?)

Branches slender, forking by equal or slightly unequal dichotomies. Leaves up to 3 cm. long, slender, spreading at the base and nearly straight or upwardly arched, attached to rhomboidal cushions. Cushions distinct, separated by slight furrows, nearly three times as long as broad; lateral angles rounded; upper and lower extremities acute and slightly curved; broadest slightly above the middle. Leaf scar an equilateral triangle situated two-thirds of the distance from the lower extremity of the cushion; on smaller branches one-half as wide as the cushion at that level, often obscure. Parichnos and trace prints not visible. Surface of lower part of cushion ornamented with a low keel bearing rather coarse but short transverse marks. Upper surface smooth and without distinct keel, and bearing a small ligule scar at upper angle of leaf scar. Lateral lines departing from angles of leaf scar and joining margin of cushion at its broadest place.

From the characteristics, as set forth in the diagnosis and as seen on Plates III and IV, the resemblance to *Lepidodendron ophiurus* is obvious, so that it was only after considerable deliberation that the species was described as new. The reason for not referring the material to *L. ophiurus* is that there is much confusion in the literature as to just what the specific characters of *L. ophiurus* actually are, and how it is to be distinguished from *L. lycopodioides*. *L. ophiurioides* is also close to those specimens of *L. elegans* and *L. lycopodioides* which has been set apart as *L. simile*. Arber (3), however, claimed that more than one species was lumped into *L. simile* and refused to accept the species as a valid one, and Jongmans (36) has grouped *L. simile*, *L. lycopodioides*, and *L. elegans* into *L. ophiurus*.

Brongniart's original figures of *L. ophiurus* (Brongniart, 17) are not clearly diagnostic, and the same is true of Sternberg's figures (58) that are supposed to represent the original specimen of *L. lycopodioides*.

(*L. elegans*, it seems, was a name substituted by Sternberg for *L. lycopodioides*.) It is impossible to make any satisfactory distinction between *L. ophiurus* and *L. lycopodioides* on the basis of original figures or to refer other material to these species. Probably the oldest figures of *L. ophiurus* that accurately portray the characters of the species are those of Zeiller (72, Pl. LXVIII). Although Zeiller did not specifically state that he had examined Brongniart's type specimen, he gave pertinent information which leads to that belief, and his figures may therefore be considered authentic.

In comparison with *Lepidodendron ophiurus*, as defined by Zeiller, the material under consideration here differs in at least one important respect and in one or two lesser ones. The pair of lines that curve downward from the lateral angles of the leaf scar merge with the margin instead of running parallel to it to the lower tip of the cushion; the inferior keel is marked with cross lines which are generally said to be absent from *L. ophiurus*; and the cushions stand out in low relief and are not as prominently projecting as in typical specimens of the European species.

Regardless of the fact that Sternberg's original figures are not suitable for species determination, the name *L. lycopodioides* has been widely employed, and the confusion that has resulted is at once apparent when the synonymies of Zeiller, Kidston, Jongmans, and others are compared. Consequently, our material would be called *L. lycopodioides* by some authors but not by others. Crookall (20) described and figured *L. lycopodioides* as having a leaf scar shaped like a vertical angular slit and twigs clothed with short leaves. If Crookall accurately portrayed *L. lycopodioides* it cannot be confused with the Michigan form in spite of a marked similarity in shape of leaf cushion and in the presence in both of transverse marks on the lower keel.

It is evident from the above statement that neither *Lepidodendron ophiurus* nor *L. lycopodioides* are suitable specific designations for the Michigan material and that, since the status of *L. simile* is not clear of doubt, the only satisfactory procedure is to establish a new name.

The specimen shown in Figures 1 and 2 of Plate IV has been designated the holotype, although the leaves are better preserved on some of the syntypes (Pl. IV, Fig. 3).

The holotype is the imprint of a branch about 10 mm. broad. The

leaf cushions are a trifle more than 2 mm. wide and 6 mm. long. The deltoid leaf scar, which is slightly above the middle, is about 1 mm. across (Pl. IV, Fig. 1). Although the cushions project only very slightly from the stem surface, they are distinctly defined by the shal-

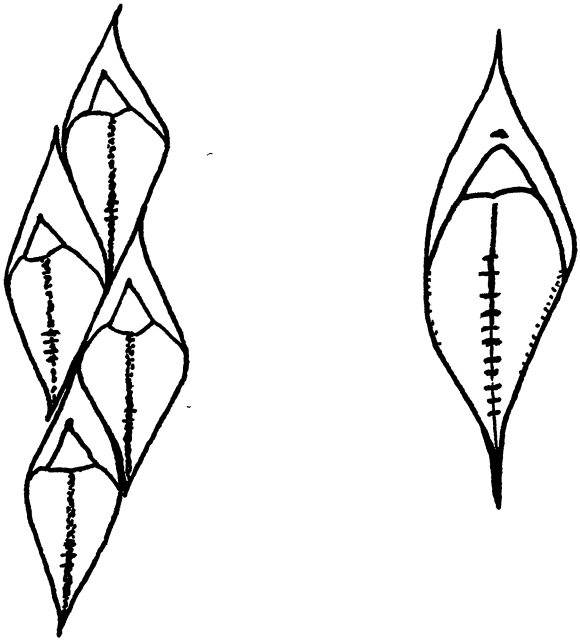


Fig. 1. *Lepidodendron ophiurioides* sp. nov.

A. The form and arrangement of the small leaf cushions of the holotype. × 6

B. The form of the larger cushions. × $3\frac{3}{4}$

low groove which completely separates the adjacent ones in the lengthwise series.

The smaller leafy twigs are straight and slender, and one specimen 3.5 mm. in diameter shows no curvature over a distance of 19 cm. (Pl. IV, Fig. 3).

The description is based principally upon twigs with leaf cushions less than 10 mm. long, but on the same slabs with them are larger stems having cushions as much as 6 mm. broad and 17 mm. long. The ends

of these longer cushions are somewhat attenuated and the main part of the body is only about 12 mm. long. Except for their larger size, these cushions are indistinguishable from the smaller ones, although the lateral lines slope downward more abruptly and continue the slope of the sides of the scar (Fig. 1). Surface features of the scar are nowhere visible.

The larger cushions of *Lepidodendron ophiurioides* bear a closer resemblance to authentic figures of *L. ophiurus* than do the smaller ones, and there can be little question but that they are closely related, if not varieties of the same species. Cones associated with *Lepidodendron ophiurioides* resemble those figured by Brongniart and Kidston for *L. ophiurus* (Pl. VIII, Fig. 1).

Most of the material upon which the new species is based came from the Big Chief No. 8 Mine at St. Charles. A specimen that appears indistinguishable from the larger form of this species was found many years ago at an unrecorded locality at Grand Ledge (Pl. IV, Fig. 5).

Lepidodendron lanceolatum Lesquereux

(Pl. V; Pl. VI, Figs. 4–6)

Several specimens from Grand Ledge having rather long leaf cushions with tapering extremities are believed to represent *Lepidodendron lanceolatum*, described by Lesquereux in the *Coal Flora* (46, p. 369). A large specimen showing a branch and bearing a few leaves is in the S. H. Perry collection (Pl. V). One, according to the accompanying label, was found by F. M. Paine in 1869, and several fragments were recently secured from the quarry of the Grand Ledge Clay Products Company between the Grand Ledge Coal and the coal of Cycle "E" (Pl. VI, Figs. 4–5). On the fragments some details of the leaf cushions are shown more distinctly than on the material in the older collections.

Most of the specimens have cushions which vary from 3 to 4 mm. in width and 14 to 16 mm. in length (Pl. V; Pl. VI, Figs. 4–5). They are broadest slightly above the middle and the upper and lower extremities taper to slender points, the lower being more acute than the upper (Pl. VI, Fig. 5). The leaf scar is situated about three-fourths of the distance from the bottom to the top and above the widest part of the scar. No distinct scar surface is visible because it is either very small or no well-defined abscission layer was produced. The point of

attachment of the leaf is determinable only by the divergence of the lateral lines from a point some distance below the upper end of the cushion, and a rather abrupt sloping of the cushion surface from this point toward the tip. The leaf was situated on the most elevated part as in other species of *Lepidodendron*. No ligule scar or other surface markings are present above the point of leaf attachment. As the two lateral lines diverge, they curve downward, but instead of merging with the margin at the widest place on the cushion, they continue downward adjacent to the margin to the tip. These lines form a distinct edge along the inferior part of the cushion and set this part off sharply from the furrow which separates it from the adjacent cushions. This is a feature possessed in common with *Lepidodendron ophiurus*.

Extending down the mid-part from the point of leaf attachment to the lower extremity is a low but distinct median ridge without cross striations. No parichnos prints or ligule scars are visible, but their apparent absence may be the result of faulty preservation.

Figure 6 on Plate VI shows a specimen slightly different from the others in which the cushions are broader in proportion to their length, and the ends are less tapering. The place of leaf attachment is near the upper extremity of the cushions, and the pronounced furrows separating the cushions are conspicuous.

One of the stems bears leaves which, though rather indifferently preserved, are about 3 mm. wide and at least 4 cm. long (Pl. V). They are nearly straight and stand out from the stem at an angle of about 45 degrees. The cones shown in Plate VII, Figures 1 and 3, are believed to belong to this species.

The criterion for referring the specimens to *Lepidodendron lanceolatum* is the long slender cushion with the leaf scar situated rather high, and the rather coarse foliage, much coarser than that usually shown attached to stems determined as *L. ophiurus*, *L. lycopodioides*, or *L. simile*. Lesquereux's description of *L. lanceolatum* (46, p. 369) is brief, and the figures (46, Atlas, Pl. LXIII, Figs. 3–5a) are not good, so that it cannot be absolutely certain that this form is different from others which bear such names as *L. scutatum*, *L. fusiforme*, and *L. marginatum*.

In 1899 White (64) identified material from Missouri as *Lepidoden-*

dron lanceolatum. The name had also been used for *Lepidodendron* material from Great Britain, but Arber (3) concluded that the British form was identical with *L. lycopodioides.* Then Jongmans (36) placed it in *L. ophiurus* and designated most of the older figures as "Unbestimmbar." Bell (14), has backtracked and readopted Lesquereux's name for material from the Riversdale, Cumberland, Morien, and Stellarton groups of Nova Scotia and said (14, p. 88): "Until satisfactory criteria are advanced for the separation of *Lepidodendron lycopodioides* Zeiller (? non Sternberg), or *L. simile* Kidston, from *L. lanceolatum* Lesquereux the writer prefers to retain Lesquereux's species." I am in essential agreement with this statement. As is pointed out in the discussion of *L. ophiurioides*, however, the original figures of *L. ophiurus* and *L. lycopodioides* are not clear, and *L. simile* designates vaguely defined forms, so it is doubtful whether the situation would be clarified to any extent by adopting as a substitute for these, another equally obscure. As long as the rules of nomenclature require the retention of names based upon ill-defined types, perpetual confusion can be circumvented only by describing well-preserved material as new species (as is done here with *L. ophiurioides*) even at the risk of having the names later reduced to the status of synonyms. Nevertheless, the Michigan material of *L. lanceolatum* seems sufficiently close to Lesquereux's figures and descriptions to justify reference to it.

All of the material collected so far came from Grand Ledge, and the specimens from the S. H. Perry collection probably came from the Eaton sandstone.

Lepidodendron Brittsii Lesquereux

(Pl. II, Fig. 2)

One specimen from the Big Chief No. 8 Mine at St. Charles seems referable to this species. Lesquereux's brief description (46, p. 368, Pl. LXIII, Figs. 1–2) has been greatly augmented by White (64) who set forth its characters clearly. The usually slender or acuminate leaf cushions lack a median keel, and the rounded surface both above and below the broad crescentic leaf scar is marked with coarse irregular transverse wrinkles.

In the St. Charles specimen the leaf cushions are nearly identical in shape with the cushion figured by White (64, Pl. LII, Fig. 3a) from

Clinton, Missouri. The main body of the cushion is rhomboidal-oval with the indistinct leaf scar just above the middle. The lower right margin of the cushion is concave and the corresponding margin on the left is convex, thus imparting to the slender tip a rather pronounced flexuous aspect. Some of the cushions are connected with those above and below by their tips. The cushions are about 5 mm. broad by approximately 14 mm. long. The leaf scar, though generally indistinct, shows faintly in some places as a transverse print with a curved upper border and a straight or nearly straight lower one. It is about one-half as broad as the diameter of the cushion at that level.

Lepidodendron vestitum Lesquereux

(Pl. II, Fig. 5)

Two specimens from the Big Chief No. 8 Mine at St. Charles and one from the St. Charles-Garfield Mine at Eastwood are tentatively determined as *Lepidodendron vestitum*. Although Lesquereux's figure (46, Atlas, Pl. LXIV, Fig. 15) is lacking in some of the essential details, the pronounced angularity of the low leaf cushions and the location of the leaf scar in the apex of the upper angle are features so strikingly similar in both the figure and the specimens that the likelihood of identity cannot be ignored.

Of the two specimens from St. Charles, one is a flattened cast about 4 cm. wide and 22 cm. long which bears two branches. Only the form of the leaf cushion is visible on this specimen; the more detailed surface markings have disappeared. The other specimen is a negative counterpart which has also lost some of its surface, but the form and position of the leaf scar and the keel are retained (Pl. II, Fig. 5).

The distinctly rhomboidal cushions as represented by both specimens are separated by narrow but rather sharply impressed straight furrows that extend as diagonal parallel lines across the surface. At places the cushions are equilateral and in vertical series with the lower extremity of one cushion lying in vertical alignment with the apex of the cushion next below it as shown in Figure 15 on Plate LXIV of the *Coal Flora* (46). Elsewhere, they take on a more oblique form with the extremities of adjacent ones in a series off-lapping by as much as a quarter of their length. All four sides of the cushions are straight and the angles are distinct, there being very little or no rounding of the

lateral ones. The cushions measure approximately 12 mm. long by 6.5 mm. in width. Details of the leaf scar are not well exhibited except in that it is a triangular mark fitting into the apical angle leaving no sloping surface between it and the tip. The two lines that bend downward from the lateral angles of the cushion of most species of *Lepidodendron* are not conspicuous in this because of their proximity to the edge. The keel is a straight low ridge extending from the lower margin of the scar to the lower tip of the cushion. No transverse striations are visible, although they are illustrated in Lesquereux's *Coal Flora* sketch. Although in some places there appear to be faint indications of parichnos scars below the leaf scar, their presence cannot be demonstrated with certainty, and no surface marks on the leaf scar itself are retained.

From the material at hand it would seem that this species of *Lepidodendron* is sufficiently distinctive to merit recognition, although Jongmans (36) claims on the basis of Lesquereux's inexact figure that it is similar to *L. aculeatum* and *L. obovatum*. Judgment concerning the accuracy of Lesquereux's figure cannot be passed without examining the original specimen. When first examined, the specimens from St. Charles were thought to represent medium-sized to small examples of *L. obovatum*, but there is a strong tendency in *obovatum* for the small cushions to be somewhat broader in proportion to their length, and generally there is a little more space between the leaf scar and the apex of the cushion.

Lepidodendron dichotomum Sternberg

(Pl. VI, Figs. 2–3)

Several specimens found in the pit of the Michigan Clay Products Company at Williamston are believed to represent the kind of plant originally figured by Sternberg (58, Pl. II) under this name in 1825. The specimens consist of small stem fragments having the tissues compressed to thin coaly layers about a millimeter thick but retaining on the surface the distinct pattern of the cushions and leaf scars.

The nearly equilateral cushions measure about 4.5 mm. in breadth and 5 mm. in length. The leaf scar, which is situated near the upper angle, is about 3 mm. wide, and its lower margin is slightly curved. No markings are preserved on the scar. Extending from the lower

edge of the scar to the lower angle of the cushion is a distinct but unstriated keel which becomes more sharply defined as it approaches the lower angle (Pl. VI, Fig. 3).

Lepidodendron dichotomum is one of the most confusing species of the genus, as the name has often been used when that of a species of *Lepidophloios* or some other name would have been more appropriate. The distinctions between *L. dichotomum* and species of *Lepidophloios*, especially *L. acerosus*, are not always clear because of the tendency of some of the leaf cushions to be broader than long. *L. dichotomum* is probably closely related to *L. obovatum* as is indicated by the similarity of the smaller cushions. What the larger cushions on a trunk of *L. dichotomum* were like is uncertain because Sternberg's figures are not clear on this point. Large cushions believed by Stur (61) to belong to this species are indistinguishable from those of *L. obovatum*.

Associated with the carbonized stems at Williamston is a flattened cone measuring nearly 2 cm. by 10 cm. with small closely imbricated bracts. It bears a striking resemblance to a cone figured by Lesquereux in the *Coal Flora* (46, Vol. III, Pl. CVII, Fig. 2) as attached to a stem similar to *L. dichotomum* but identified as *L. Sternbergii*, a name substituted by Brongniart for *L. dichotomum*.

Lepidodendron modulatum Lesquereux

(Pl. III, Fig. 3)

One specimen from the mine dump at Eastwood is identified as belonging to the species described by Lesquereux as *Lepidodendron modulatum* (46, p. 385, Pl. LXIV, Fig. 14). Considered by most authors merely a form of *L. aculeatum*, *L. modulatum* is one of the most easily recognized types of *Lepidodendron*. The cushions, which in themselves are indistinguishable from those of *L. aculeatum*, are separated by half-round borders about 2 mm. wide which are obliquely striated on the surface so as to resemble loosely twisted cord.

According to White (64) *Lepidodendron modulatum* is one of the common species in the Pennsylvanian series, but at that time it was unknown below the Allegheny. White (65) later recorded it from the Twin Coal of the southern anthracite coal field in Pennsylvania, regarded by him as late Pottsville but now considered early Allegheny and probably equivalent to the lower Kittanning Coal of western Pennsylvania and Ohio.

When the range of the various lepidodendroids in the American Carboniferous becomes better known, *L. modulatum* may be found to be more restricted than *L. aculeatum*, but now its claim to at least varietal distinction seems well founded.

Lepidodendron Rhodeanum Sternberg

(Pl. IV, Fig. 4; Pl. VI, Fig. 1)

Two specimens from an unrecorded locality at Jackson are tentatively assigned to *Lepidodendron Rhodeanum* on the basis of Stur's figures in the *Culm-flora* (61, Pl. 24, Figs. 1–3). They had previously been determined as *L. clypeatum*, probably from their general resemblance to Figure 16 on Plate LXIV of Lesquereux's *Coal Flora* (46). There is no certainty, however, that this figure represents *L. clypeatum*, because it differs somewhat from the original figure of this species in Rogers' *Geology of Pennsylvania*.[2] It seems not unlikely that the *Coal Flora* figure shows *L. Rhodeanum* instead. At least the specific identity of the two figures of Rogers and Lesquereux requires verification.

The so-called *Lepidodendron clypeatum* of the *Coal Flora* is probably identical with *L. ichthyolepis* of Wood (71, Pl. 5, Fig. 5), but Wood's figure is that of a partly decorticated specimen on which many of the diagnostic features are lost. In the *Coal Flora* figure the foliar cushions are slightly broader than long and reminiscent of *Lepidophloios*, but otherwise they are typical of *Lepidodendron*.

On the larger of the two specimens here identified as *Lepidodendron Rhodeanum* (Pl. VI, Fig. 1) the foliar cushions, which are broadly limuloid in outline, are nearly symmetrical and vertically aligned. The upper margin is rounded and entire and is not apically prolonged or continuous with the inferior prolongation of the cushion next above it. The cushions stand out in low relief and slope gradually from the apical margin to the basal point. In marked contrast to the rounded upper margin, the lower margins are convex, due to the crowding of the cushions which alternate with it in the adjacent series. The cushions measure approximately 12 by 17 mm. in breadth and length, and the dome-shaped upper portion occupies slightly less than half of the length.

[2] H. D. Rogers, *The Geology of Pennsylvania* (Harrisburg, 1858).

The transversely elongated leaf scar measures about 3 by 7 mm. in height and width, and is situated at a distance about equal to its height from the apex of the cushion. Directly above the truncated apex of the scar is a small ligule print, and on the scar surface itself and situated slightly below its transverse axis are the three small prints representing the leaf trace and the two parichnos strands.

The keel is unornamented and weakly developed, and on either side of it just below the scar the two oval superficial prints, present only on some species of *Lepidodendron*, show rather clearly.

On the smaller of the two specimens (Pl. IV, Fig. 4), in which the vertical and lateral dimensions of the cushions are about one-half those of the specimen described above, the usual oblique alignment is exhibited.

Although *Lepidodendron Rhodeanum* may bear considerable resemblance to *L. obovatum*, the specimens described here appear distinct from any of the forms so far identified as *L. obovatum*. Many authors have united the two species. Since no species of *Lepidodendron* is represented in the Michigan Coal Basin by anything more than fragments, it is possible that those determined as *L. obovatum* and *L. Rhodeanum* are different stages of development of plants of the same species. Nevertheless, until the actual connections between these various growth forms is revealed, it is necessary to describe them separately.

The form of the leaf scar and the more or less strict vertical alignment of the cushions of the larger of our specimens are features rather strongly suggestive of *Lepidodendron Volkmannianum* to which the *L. Rhodeanum* type is possibly related. The main difference, however, lies in the confluence of the cushions in vertical series in the former species.

Lepidostrobus sp.

(Pl. VII, Figs. 1, 3–4)

The proper specific designations for several compressions of *Lepidostrobus* found in Michigan remain an open question, and to refer them arbitrarily to previously named species, without evidence of their identity with these species, would serve no purpose.

In the S. H. Perry collection are two incomplete lepidophytic cones which evidently belong to stems identified as *Lepidodendron lanceola-*

tum. One represents the apical part of a slender cone (Pl. VII, Fig. 1) and the other the basal (Pl. VII, Fig. 3), but they are probably not parts of the same cone. The basal part is terminal on a short length of leafy stem. When the two pieces are placed together, as in Figures 1 and 3, they give a fairly accurate idea of the complete organ. There is some resemblance to *Lepidostrobus Bartlettii* (Arnold, 4), previously described from Grand Ledge, but the spores in the two are different.

Several spores of the *Lagenicula rugosa* type (Pl. VII, Fig. 4) were recovered from the flattened and partly carbonized tissue of the part of a cone shown in Figure 3 on Plate VII. These spores are nearly round, measure 516 microns in diameter, and have smooth or slightly granular walls 14.5 microns thick. The trilete sutures are 175 microns long, and the distal extremities are joined by distinct arcuate ridges which delimit smooth contact surfaces. The apical crest is a conspicuous structure about 125 microns high.

Lepidostrobus sp.

(Pl. VIII, Fig. 1)

The compression of a complete cone 2 cm. wide and 13 cm. long came from the Big Chief No. 8 Mine at St. Charles. It was associated with *Lepidodendron ophiurioides*, but there is no direct evidence that it belongs to this species. The cone axis is about 3.5 mm. in diameter, and the stipitate part of the sporophyll is about 5 mm. long. The sporophylls are inclined slightly upward and the terminal bracts, which are bent toward the apex at a steep angle, are nearly 1 cm. long. No other structural details are in evidence.

Lepidostrobus sp.

(Pl. VIII, Fig. 2)

The specimens illustrated were found by W. A. Kelly in a shale pit on the south bank of the Grand River about one-fourth of a mile north of the Grand Ledge Face Brick Company. The horizon is undetermined, but it is probably high in the Grand Ledge section. The matrix is a hard, very dark gray shale in which the form of the cones is distinctly impressed. The substance of the cones had become altered into a brittle anthracitic material heavily infilterated with mineral matter.

These cones are specifically distinct from any others found at Grand

Ledge, but in the absence of associated vegetative parts affinity other than with the genus *Lepidostrobus*, as broadly interpreted, is not clear. They are about 2 cm. broad, with parallel sides and rounded bases. None is complete. The largest part preserved is 12.5 cm. long, and since they taper little if at all, the original cone was probably considerably longer. It was a slender organ. The axis is about 4 mm. broad, and the stipitate part of the sporophyll is about 8 mm. long. The sporophylls are compactly arranged on the axis at intervals 2–2.5 mm. apart. The stipitate part is nearly horizontal to the axis, and the apical bracts are short, seldom more than 5 mm. long. No spores have been found.

Lepidocarpon linearifolium (Lesquereux) Schopf

(Pl. IX, Figs. 2–3)

Detached lycopod sporophylls of the *Lepidocarpon* type were found in the quarry of the Michigan Clay Products Company on the eastern outskirts of Williamston in Ingham County. The horizon from which the fossils came is unknown, but the matrix is a black moderately fissile shale containing numerous minute flecks of mica.

The conspicuous feature of *Lepidocarpon linearifolium* is the long slender terminal bract which, in most of the specimens, extends outward in a horizontal position along the line of the pedicellate part of the sporophyll and at right angles to the strobilar axis. In a few specimens there is an upward inflection of as much as 45 degrees. The longest bracts measured are 55 mm. but are incomplete. The appearance of the cone must have been that of a bottle brush, and measured from the extremities of the bristle-like bracts, the cone probably had a total diameter of 20 cm. or more. It is the *Ortholepidostrobus* type of cone of Arber (3).

The specimen originally figured by Lesquereux (46, Atlas, Pl. LXIX, Fig. 39) consisted merely of the terminal bract and a fragment of the pedicel, the sporangiocarp being entirely lacking. The types were re-examined by Bassler (11), who portrayed more complete specimens and assigned them with several related forms to the genus *Cantheliophorus*. Schopf (55) has recently shown that Bassler's genus was founded upon the compressed megasporophylls of *Lepidocarpon* and consequently *Cantheliophorus* must be discarded as a valid generic name.

So close is the resemblance between the Williamston specimens and those figured by Bassler that no detailed description is necessary. It must be borne in mind that Bassler misinterpreted the morphology of the fossil; he believed that the sporophylls have two saclike sporangia on short sporangiophores arising from a plate of sterile tissue which ascended from the vertical mid-line of the pedicel. What Bassler took to be the sporangia was in reality a huge megaspore contained within a thin-walled megasporangium attached to the upper surface of the pedicel and protected by two lateral outgrowths of the pedicel which meet along the top but leave a crevice-like micropylar opening. It was probably the micropylar line that Bassler mistook for the median plate to which he believed two lateral sporangia were attached.

The sporangiocarps of the Williamston specimens measure about 7 mm. in height and about 20 mm. in length. The ligule has not been preserved, and the heel shows only as a low rounded hump just beneath the distal end of the pedicel. On several specimens the outline of the megaspore is visible as an elongated object lying in the lower part of the sporangiocarp and parallel to the pedicel. No complete megaspores have been isolated, and their size can be determined only from the outlines on the compression surfaces. They appear to be rather large, 4 or 5 mm. in diameter and nearly 15 mm. long. The end adjacent to the strobilar axis is rounded, and the end toward the terminal bract is somewhat tapered. Fragments subjected to maceration show the fibrous structure characteristic of lepidocarp megaspores.

Lepidocarpon linearifolium has been recorded elsewhere only from strata of supposed Allegheny age, equivalent to the lower Kittanning Coal. Its range is not known.

Lepidocarpon cultriforme (Lesquereux), comb. nov.

Lepidophyllum cultriforme Lesquereux, 1884, p. 785; Pl. CVII, Figs. 13–14; Pl. CVIII, Fig. 2.

White (in Lane, 43, p. 44) identified *Lepidophyllum cultriforme* from St. Charles. The specimens, which are not very well preserved, are in black shale that apparently came from the Black Pearl Mine.

The general similarity of the detached sporangium-bearing sporophylls to *Lepidocarpon linearifolium* is obvious, but they are considerably smaller. The main body of the sporangium is about 4 mm. high by 7 mm. long. These dimensions are only about one-half those given

by Lesquereux (46, p. 785) for this species. It is difficult to determine the length of the terminal bract because in no observed specimen is it complete. It is at least 2 cm. long, and unattached bracts in the matrix among the sporangia are longer. Some of the attached bracts bend rather abruptly upward at the distal end of the sporangia.

Although these sporophylls represent the *Lepidocarpon* type beyond all reasonable doubt, the specific assignment is retained only in deference to White's judgment.

The specimens from St. Charles are too poorly preserved to photograph satisfactorily.

Bothrodendron minutifolium Boulay

(Pl. VII, Fig. 2)

Leafy lycopodiaceous twigs resembling those previously found at Grand Ledge (Arnold, 5) have been collected at the St. Charles-Garfield Mine at Eastwood. There are no superficial characters whereby this material can be distinguished from the so-called *Lycopodites Meekii* of lower Allegheny age in Illinois or the *Lycopodites carbonaceus* of Europe. They all probably represent related if not identical plants.

Bothrodendron punctatum Lindley and Hutton

(Pl. IX, Fig. 1)

Several large carbonized trunk fragments bearing *Ulodendron* scars have been collected on the mine dumps near St. Charles. These scars are 9–12 cm. in diameter. In some the scars are low domes, in others they are depressions, depending upon whether the specimen is the original or the counterpart. Situated slightly at one side of the center is the so-called "umbilicus," or vascular-bundle scar, which consists of an adhering mass of brittle coaly substance. One slab bears two such scars 7.5 cm. apart and another two with an intervening distance of 5.5 cm. On all of the specimens except one, the stem surface around the scars is unornamented, probably the result of decay. On this one, there are on the surface at the sides of the scars small punctations arranged in quincuncial pattern. Between the scars are shallow rather indistinct markings resembling partly erased cushions of *Lepidophloios*.

Fossils commonly included under the name of *Bothrodendron punctatum* probably represent more than one kind of plant. It is probably a form species rather than a clearly defined natural species.

Sigillaria scutellata Brongniart

(Pl. X, Figs. 1, 5)

Sigillaria scutellata is the only member of *Sigillaria* that has been identified with absolute certainty to species in Michigan. Until its discovery about 1930 the genus had not been reported within the state. Several specimens have been found in some of the old collections, but most of them represent trunk portions that have suffered considerable effacement of the surface features previous to the deposition of the enclosing sediments. Specific identification of such material is usually impossible.

Figures 1 and 5, Plate X, show specimens from an unrecorded locality but presumably Grand Ledge, which are believed to be variants of *Sigillaria scutellata*. Figure 1 represents an area near the base of the tree where the ribs had become broadened from secondary growth. Figure 5 is probably from the upper part of the tree just below the leaf-bearing crown. The large leaf scars situated upon the relatively narrow ribs produce the zigzag course of the furrows. The intermediate form of this species has been figured elsewhere (Arnold, 5, Plate IV, Fig. 1).

Although originally reported only from Cycle "F," *Sigillaria scutellata* has since been found at a level that may be as low as Cycle "B."

Sigillaria sp. (cf. *S. mamillaris* Brongniart)

(Pl. X, Fig. 2)

One specimen from an unknown horizon in the quarry of the Grand Ledge Clay Products Company resembles *Sigillaria mamillaris*, but the surface is not sufficiently preserved for positive determination. The leaf cushions are situated upon prominent rounded ribs separated by deep furrows. The cushions are closer together and stand out more prominently than in representative specimens of *S. scutellata*. As the outermost tissue had disappeared the only remaining figure on the leaf scar surface is a small circular print.

Sigillaria sp. (*Favularia* type)

(Pl. X, Figs. 3–4)

A sigillarian imprint on a slab of black coaly shale from an unrecorded locality at Jackson seems to represent some rare or unknown species, but preservation is hardly sufficient to permit a full description. The prints of the leaf cushions are shallow depressions which are separated from each other on all six sides by fine raised lines. The transversely elongated cushion prints are about 4.5 mm. high and 13 mm. wide to the apices of the lateral angles. Opposite sides are straight and parallel, there being no appreciable rounding of the lateral margins. The leaf scar is obscure, although at places an ellipsoidal print is dimly outlined which covers one half or more of the surface of the cushion (Pl. X, Fig. 4). The surface markings of the scars are not distinct, but on some there is a short, slightly bent transverse mark slightly above the mid-line of the cushion. The scar itself is broadest near the middle, but the upper margins curve inward somewhat less abruptly than do the inferior ones. Extending inward from each lateral cushion angle, and bisecting it, is a low transverse keel. On some cushions this keel is short and barely perceptible; on others it is faintly visible as far as the edge of the cushion. The keel is never conspicuous and is almost invisible except by examination with a low-power lens and oblique illumination. Casual examination of the specimen reveals only the regularly arranged, transversely elongated, parallel-sided, nearly contiguous low leaf cushions showing few surface features.

This specimen is a sigillaria of the *Favularia* type, and is closely related to, though readily distinguishable from, *S. elegans* and *S. elegantula* from which it differs by its less protruding and broader cushions. No other specimen of this type has so far been discovered in the Michigan Coal Basin.

Stigmaria ficoides Brongniart

(Pl. XI, Figs. 1–2)

The exceptionally fine specimen shown in Figure 1 of Plate XI is in a boulder from the glacial drift near Jackson. It was discovered by Mr. R. E. Hodges. The position of the vascular cylinder is shown where

the cast is broken transversely. The central pith cavity has become filled with the sandy matrix, and the enclosing woody cylinder is represented by a circular space. Radiating outward from the main rootstock are several lateral rootlets still in their original position.

Figure 2 shows a well-preserved compressed rootstock with appendages. This specimen came from the St. Charles-Garfield Mine at Eastwood.

Asolanus camptotaena (Wood) Wood

(Pl. XI, Fig. 3)

Fragments identified as *Asolanus camptotaena* have been found at St. Charles and at Grand Ledge. A specimen in the S. H. Perry collection (Pl. XI, Fig. 3) represents the *Knorria* stage of preservation, but shows to good advantage the fine striations that extend diagonally between the trace scars.

CALAMITALES

The uncertainties attending the identification of species of *Calamites* is emphasized by the small number of forms described by Lesquereux, White, and other authors, even though the remains are exceedingly common and often present in large numbers.

The fragmentary condition of specimens of *Calamites* is partly the result of the fragile construction of the plant body. The branches readily became detached and they broke apart freely at the nodes. The wood and cortical tissues decayed rapidly, and were it not for the numerous characteristic pith casts the genus would be considered a rare one.

On the basis of the position of the branch scars on the pith casts the genus *Calamites* has been subdivided into three subgenera: (1) *Stylocalamites*, branching irregular and sparse; (2) *Calamitina*, whorls of branches at certain nodes with the internodes varying greatly in length; and (3) *Eucalamites*, branches at every node, the internodes often rather long. Specimens may occasionally be found that do not fit into this scheme, but it is nevertheless useful in classifying calamitean pith casts when determination to species is not possible. All three types occur in Michigan. *Stylocalamites* is represented by *Calamites Suckowii* and *C. Cistii*, *Calamitina by C. undulatus*, *C.*

schützeiformis, and *C. approximatus*, and *Eucalamites* by *C. carinatus*. Foliage of the *Annularia* and *Asterophyllites* types is common, and detached compressed fructifications (*Palaeostachys* and *Macrostachya*) are frequently encountered.

Calamites Suckowii Brongniart

(Pl. XII, Fig. 1)

The excellent specimen of *Calamites Suckowii* figured on Plate XII came from the shale above the Grand Ledge Coal in the quarry of the Grand Ledge Clay Products Company. It is a typical cast of this species which is characterized by the bluntly rounded angles formed by the upper ends of the ribs and the rather conspicuous tubercles situated upon them. Branch scars are rarely seen in *Calamites Suckowii*, for this species branched sparsely and irregularly. The figured specimen is the lower end of a branch, and the tapered lower end represents the narrow pith where it departed from the main stem.

Calamites Suckowii is one of the most widely distributed of Carboniferous plant fossils, and within this series it has little stratigraphic significance.

Calamites approximatus Brongniart

(Pl. XII, Fig. 2; Pl. XIII, Fig. 1)

A cast from a strip mine about ten miles north of Jackson (Pl. XIII, Fig. 1) seems to resemble Brongniart's figures of *Calamites approximatus*. The specimen, which measures 15 cm. in length, has eight internodes which vary but slightly in length. One of them bears a series of branch scars. The cast is slightly constricted at each node, and instead of having parallel sides it narrows from a width of slightly more than 5 cm. at the middle to less than 4 cm. at each extremity. The ribs are much finer than in the more typical *C. schützeiformis* casts, in which there are about 10 per cm., and rather few of them alternate at the nodes. No leaf or infranodal scars are visible on the ribs, but this apparent lack may be due to the small size of the ribs and the coarseness of the sandy matrix.

Another specimen (Pl. XII, Fig. 2) came from the quarry of the Grand Ledge Clay Products Company. It is from one of the higher beds of the Saginaw group at Grand Ledge, but the exact horizon is unknown.

Calamites schützeiformis Kidston and Jongmans

(Pl. XIII, Fig. 2)

The name *Calamites schützeiformis* designates a group of calamitean casts belonging to the subgenus *Calamitina* of Weiss in which there are a number of internodes between the nodes which bear branches. Many of the internodes are very short. Kidston and Jongmans (42) have designated three forms. In forma *typicus* the internodes range from 6 to 36 mm. in length and in forma *waldenburgensis* the range is from 3 to 10 mm. Forma *intermedius* is intermediate between these extremes. The readiness with which the forms can be distinguished is doubtful in the great majority of instances, so all of the Michigan casts with short internodes are lumped together under the general name.

Specimens of the *Calamites schützeiformis* type have been found at Grand Ledge in formations probably representing Cycle "C" or "D."

Calamites Cistii Brongniart

(Pl. XIV)

Calamites Cistii, with *C. Suckowii* and *C. cistiiformis*, represent the subgenus *Stylocalamites* of Weiss. Branching is irregular and sparse, and the ribs are straight. *C. Cistii* is not always easy to distinguish from *C. Suckowii* if preservation is not good, but generally *Suckowii* has coarser ribs which are rounded instead of angular at their upper extremities. *C. Cistii* has been recognized in the lowest plant bed at Grand Ledge and at Corunna.

Calamites carinatus Sternberg

(Pl. XV, Fig. 1)

Calamites carinatus typifies a subgroup of the subgenus *Eucalamites* of Weiss which is characterized by a whorl of branches at each node. This subgroup has two opposite branches at each node as opposed to the *C. cruciatus* subgroup in which the whorl contains several branches. The internodes of *C. carinatus* are usually long; on one cast found at Grand Ledge having a width of about 7 cm., the distance between successive nodes is 24 cm. Usually the casts are oriented in such a position that only one branch scar is visible at the node, the opposite one being on the lower side.

Calamites carinatus is rather abundant below cyclical formation "A" at Grand Ledge, and many of the undetermined cast fragments seen at other places probably belong to this species. It is one of the most common species of *Calamites* in Europe and probably in North America. Bell (12, 13) reported it from the Riversdale, Cumberland, and Morien groups of Nova Scotia, but it seems to be most common in the Cumberland.

Calamites undulatus Sternberg

(Pl. XVI, Fig. 1)

Calamites undulatus, previously reported from the Standard Mine (Arnold, 5), has since been found at Eastwood. It is a rare species in Michigan and so far is known only from the Saginaw Coal horizon.

Calamites sp.

(Pl. XII, Fig. 3)

One specimen from the plant bed below Cycle "A" at Grand Ledge shows a portion of the external surface of a calamitean trunk. The exterior plainly reveals the nodal construction of the stem but the surface ribs, which are separate from those of the pith casts, are less pronounced. The specimen bears some resemblance to those often described as *Calamites Goeppertii* or *C. Sachsi*, but lacking branch scars it cannot be identified closer than to the genus.

Asterophyllites vernensis, sp. nov.

(Pl. XVI, Figs. 6–9)

Stem delicate; internodes about 4 mm. long. Leaves in whorls, as many as 12, tapering basally and apically, apex sharp, about 5 mm. long and 0.5 mm. broad at middle; of equal length and spreading, straight or very slightly curved.

The material consists of a number of small stem fragments from the plant layer below Cycle "A" at Grand Ledge. The plant is of delicate appearance, and upon casual observation might be mistaken for a species of *Annularia* of the *A. galioides* or *A. minuta* type. Careful examination reveals that the leaves of a whorl are all nearly of the same length and that they are pressed laterally and forward to form an open cup, which is typical of the genus *Asterophyllites*. The leaves are some-

what broader in proportion to their length than they are in most species of *Asterophyllites* and resemble those of *Annularia*, but the arrangement seems to be more like that of the former genus.

The leaf whorls of this species agree in size with those of *Asterophyllites grandis* as originally figured by Sternberg (58, Pl. XLIX, Fig. 1), but differ in the leaves being broader.

Asterophyllites equisetiformis (Schlotheim) Brongniart

(Pl. XVII, Figs. 2, 4–5)

Asterophyllites equisetiformis probably represents a group of similar forms rather than a single biological species. In Michigan as elsewhere a very common fossil, it is especially abundant in the plant-bearing shales of Cycle "A" and the Saginaw Coal. One specimen (Pl. XVII, Fig. 5) shows a part of a stem bearing three lateral branches on one side and five on the opposite side. On another fragment (Pl. XVII, Fig. 4) a branch tip bears the lower part of a cone.

Annularia asteris Bell

(Pl. XVI, Fig. 5)

Annularia sp. (small form). Arnold, 1934, p. 187, Pl. I, Figs. 2, 4.

This small *Annularia* was mentioned and figured in my preliminary account (5) of the flora of the Michigan Coal Basin, but was not determined to species. Bell (14) distinguished *A. asteris* from *A. galioides* on the basis of its more delicate, narrower, less elliptical, and straight-sided leaves with acuminate tips. With Bell's figures and description the Michigan specimens seem to be in essential agreement. Bell recorded *A. asteris* from the Cumberland and Riversdale groups of Nova Scotia.

In Michigan *Annularia asteris* occurs in the Saginaw Coal and in the Verne cyclical formations at Grand Ledge.

Annularia radiata Brongniart

(Pl. XVII, Fig. 3)

The presence of *Annularia radiata* in the light-colored clays above the Grand Ledge Coal is attested by a branch portion bearing eight whorls of leaves. The leaves, which are about 15 mm. long, are widest

at the middle and taper to an acute point. This species is not common in Michigan.

Annularia stellata (Schlotheim)

(Pl. XVII, Fig. 1)

Annularia stellata appears not to have been previously recognized in Michigan, and in the recently made collection there is but a single leaf whorl that appears referable to this well-known form. The specimen figured came from the shales between Cycles "B" and "E" in the quarry of the Grand Ledge Clay Products Company.

Palaeostachya sp.

(Pl. XVI, Figs. 2–3)

Although calamitean fructifications are frequently encountered in the Saginaw group, they are seldom well preserved. The most common type is that shown in Figures 2 and 3 of Plate XVI, which appears to represent the organ genus *Palaeostachya*. To attempt to assign these remains to some particular species would serve no useful purpose.

The two specimens figured were selected from a large number of fragments from the plant bed below Cycle "A" at Grand Ledge.

Macrostachya sp.

(Pl. XV, Fig. 2)

The fructification shown in Figure 2 on Plate XV was briefly described before (Arnold, 5, p. 188) but not assigned to any particular genus. It is evidently a species of *Macrostachya* as indicated by its size. It came from Cycle "F" at Grand Ledge.

SPHENOPHYLLALES

In the preliminary report on the fossil flora of Michigan (Arnold, 5) five species of *Sphenophyllum* were included. The more recent collections have confirmed the identifications of all of these except *S. myriophyllum*, which must be removed from the list of Michigan plants. The material originally assigned to this species was found upon more critical examination to be a poorly preserved slender-leaved species of *Annularia*.

Sphenophyllum emarginatum (Pl. XVIII, Fig. 4) recorded only from Cycle "F" at Grand Ledge, had previously been collected by Cooper (18) at West Bay City. Its occurrence there in association with *Neuropteris rarinervis* is quite in accord with the late Pottsville aspect of the upper Verne beds. *S. majus*, of which a single leaf was originally found, is represented in later collections by several typical leaves (Pl. XVIII, Fig. 7). *S. cuneifolium* and *S. saxifragaefolium* differ only with respect to the depth of the incisions of the leaves. Some authors merge the two, and others retain *saxifragaefolium* as a varietal name. The figures on Plate XVIII give a fair idea of the variety of form represented by material that seems to fall within *S. cuneifolium*. Rather typical leaf whorls are shown in the upper corner of Figure 1, and in Figures 3 and 6. Figures 1 and 9 show a form with rather narrow leaves. Figure 8 shows a very slender form that resembles the *saxifragaefolium* type (Pl. XVIII, Fig. 5), except that each leaf generally shows but one bifurcation which does not extend more than one-third of the length of the leaf. The filiform aspect of the leaves is rather suggestive of *S. trichomatosum*. The slender form shown in Figures 1, 8, and 9 occurs rather abundantly below Cycle "A" at Grand Ledge.

Associated with *S. cuneifolium* at Grand Ledge are numerous but rather poorly preserved fructifications believed to belong to it (Pl. XVIII, Fig. 2). Such detached sphenophyllaceous fructifications are assigned to the organ genus *Bowmanites*.

FILICALES AND PTERIDOSPERMAE

As it is not practical to try to separate the numerous fernlike leaf types into ferns and seed ferns in a flora of this kind, the customary practice will be followed of treating them together.

Members of the form genus *Pecopteris* are rare in Michigan, and those that have been found are isolated and poorly preserved fragments of wide-ranging forms. Although a few pecopterids extend into the lower part of the Pennsylvanian system, they are never prominent elements of the flora anywhere below the Allegheny series. In the Allegheny, as at Mazon Creek, Illinois, and in Henry County, Missouri, many are present. The scarcity of pecopterids in the Saginaw group is evidence in favor of pre-Allegheny age.

Alethopteris, a common leaf type in Pennsylvanian rocks, is also rare in Michigan. A few fragments identified as *Alethopteris decurrens* and *A. Helenae* have been collected. *A. Serlii*, a species one would expect in Michigan, is not known to occur there.

Several species of *Neuropteris* are present in the Saginaw group, but their distribution is patchy, as shown by *Neuropteris Scheuchzeri*. Their range through the coal basin is unknown because of the uncertainty in identifying the small fragments. Only those which can be identified from pinnule characteristics can be positively determined, whereas many species of the genus can be separated from others solely on features of the fronds. The neuropterids are important guide fossils in the Pennsylvanian, especially in the lower part. More information on the distribution and identity of the neuropterids in Michigan would furnish data useful in correlation.

Megalopteris (Pl., XXV, Figs. 1, 4) is represented in Michigan by three species; one (*M. Kellyi*) has been described as new. Specimens have been found at four places, at the Uncle Henry Mine near Saginaw, at Corunna, at the United City Mine at West Bay City, and in the clay ironstone nodules of Cycle "A" at Grand Ledge. At Grand Ledge it seems to be limited to these nodules, and no additional specimens have been found in them since first reported (Arnold, 5).

The *Sphenopteris* complex is represented in the Saginaw group by several forms, but the material, for the most part, is too fragmentary for satisfactory determination. Three species have been identified in addition to one each of *Palmatopteris* and *Zeilleria*. Only a few fragments representing one or possibly two species of *Mariopteris* have been found. It is very rare in Michigan.

Seeds apparently belonging to the seed ferns are abundant at places, but none has been found attached to vegetative parts. *Rhabdocarpus* and *Trigonocarpus* are believed to represent the seeds and *Alethopteris* and *Neuropteris* the foliage of a large seed fern of the genus *Medullosa*, parts of the trunks, petioles, and roots of which are often found in the petrified condition in coal balls. Evidence supplied by association makes it seem probable that the pollen-bearing organ, *Aulacotheca Campbelli*, the seed identified as *"Trigonocarpus" Noeggerathi*, and the frond fragments of *Neuropteris Schlehani*, all found on the dump of the St. Charles-Garfield Mine at Eastwood, represent one plant.

The association of the broad-winged seed *Samaropsis Newberryi* and *Megalopteris* has been commented upon elsewhere (Arnold, 5).

Pecopteris plumosa Artis

(Pl. XXVI, Fig. 5)

The only specimen referable to this species is a pinna fragment from the United City Mine which White had questionably identified as *Pecopteris dentata* (Cooper, 18, p. 188). Kidston (41, p. 384) merged *P. dentata* with *P. plumosa* and claimed that on the large and well-preserved fronds from the British Coal Measures both *dentata* and *plumosa* types are present as variants of different parts of the same frond. Kidston's interpretation seems to be generally accepted, but in recent practice whenever the *dentata* type has been distinguished, it is referred to as *Pecopteris plumosa* forma *dentata.* The Michigan specimen is a mere fragment, but seems on comparison with Kidston's excellent figures to resemble the typical *plumosa* rather than the *dentata* form. Preservation, however, leaves considerable to be desired, and reference to this species must for the present remain tentative.

The small tongue-shaped pinnules are more or less oblique and slightly arcuate and are attached to the rachis by the entire width of the base. They broaden slightly at the base. The margins appear to be very shallowly crenulate, and the apex is rounded. The midrib of the pinnule extends to the apex, and the lateral veins fork once with a single veinlet terminating in each marginal crenulation.

Pecopteris plumosa is a wide-ranging species which in North America first appears in the Pottsville in the Sewanee zone, but it is most abundant above the Pottsville. In Great Britain it ranges throughout the entire upper Carboniferous, although it is rare below the Yorkian.

Pecopteris Miltoni Artis

(Pl. XIX, Figs. 1–3)

Several fragments of this wide-ranging species were found in the shale below Cycle "A" of the quarry of the Grand Ledge Face Brick Company. Because of the intimate association of the fragments, it is possible that they all came from the same plant. Its known distribution in Michigan is limited to this one occurrence.

Although the pinnae and pinnules of the fragments from Grand Ledge fall well within the size range of this species as given by Kidston and other authors, they are somewhat smaller and of finer texture than the typical Allegheny members of *Pecopteris Miltoni*. The alternately arranged pinnae seldom exceed 3 cm. in length and 1.2 cm. in width. They are broadly linear with nearly parallel sides up to near the apex where they taper rather abruptly. They are close together on the rachis, but do not overlap. The broadly linear and blunt-tipped pinnules stand out from the pinna rachis at nearly right angles from it, although some of them are slightly oblique. The largest are about 7 mm. long and 3 mm. broad. The midrib is distinct, but the veinlets are difficult to observe. This obscurity is apparently due to the hairy covering possessed by the pinnules of this species. The margins of the pinnules are parallel and entire except in one small fragment which shows marginal crenulations of the *Pecopteris vestita* type, formerly considered a distinct species.

The stratigraphic range of *Pecopteris Miltoni* in North America is probably similar to that in western Europe. In Great Britain it is the most widely distributed species of *Pecopteris*, ranging throughout the Yorkian, Staffordian, and Radstockian series. It is characteristic, however, of the Yorkian. Its occurrence on the continent is similar. White (66, p. 824) reported it from the roof shales of the Twin Coal at Pottsville Gap which he arbitrarily established as the basal member of the "Productive Coal Measures" (Allegheny). This is hardly to be regarded as its lowest occurrence, because *Sphenopteris pilosa*, which Stopes (60, p. 42) has shown to be the same as *Pecopteris Miltoni*, is reported from the Lykens Coal Nos. 2 and 3, and from the Sewell formation. Stopes also reported it from St. Johns, New Brunswick, and Bell (12, p. 72) found it extending upward from the upper part of the *Lonchopteris* zone of the Morien series in the Sydney coal field. *P. Miltoni* is the most common plant fossil in the Mazon Creek flora. It also occurs abundantly in Henry County, Missouri.

Alethopteris Helenae Lesquereux

(Pl. XIX, Figs. 5–6)

A few pinna fragments, one with a terminal pinnule, were collected several years ago from the Big Chief No. 8 Mine at St. Charles. The

pinnules which are rather small sometimes exceed 15 mm. in length; they are broadest at the mid-position, from which they taper gradually to a rounded tip. Each pinnule diverges from the rachis at an angle of about sixty degrees, is decurrent at the base, and has gently curved margins. The narrowing toward the base is very slight except for the abrupt notch in the upper angle, which sometimes extends halfway to the midrib. The midrib is fairly pronounced. The lateral veins are somewhat close; they bend abruptly outward immediately after departure from the midrib and follow an almost horizontal course to the margin. There are one or two divisions in the lateral veins, the first occurs soon after the veins separate from the midrib, and the second somewhere between that point and the margin. The terminal pinnule is more slender than the lateral ones and is both longer and narrower.

The identification of the pinna fragments with *Alethopteris Helenae* is based upon the resemblance to the specimen illustrated in the *Coal Flora* Atlas (Pl. XXX, Fig. 3) of Lesquereux. The fragments resemble this figure more closely than they resemble the other figures, but Lesquereux remarked (46, p. 180) that in Figures 1 and 2 the delineation of the pinnule bases is not correct. The terminal pinnule in Lesquereux's Figure 3 is less slender than in the Michigan specimen, but the range of individual variation is unknown. The lateral pinnules of the Michigan form are shorter and broader in proportion to their length than in typical specimens of *A. lonchitica*, and are, as Lesquereux said, more like those of *A. Grandini*. The form does not belong, however, to that species for it has pinnules which are characteristically more blunt.

Alethopteris Helenae differs from *A. decurrens* (Pl. XIX, Fig. 7) in having broader and shorter pinnules, and in having pinnules of a less pronounced linear form.

Neuropteris Scheuchzeri Hoffman

(Pl. XX)

Large detached pinnules of *Neuropteris Scheuchzeri* were present in abundance below Cycle "A" in the bottom of the quarry of the Grand Ledge Face Brick Company during 1937 and 1938. This plant appears to be localized, because it was only during the few months fol-

lowing the discovery that many were found, even though excavations were continued long afterward in the same bed. Thousands of specimens were seen during this brief period, the shale slabs often being covered with torn and broken pinnules.

The pinnules, all of which are detached, range up to 11 cm. in length and 3.5 cm. in breadth. In outline they are lanceolate, inequilateral, and somewhat irregular. The apex is acute to acuminate. The base varies from oblique to auriculate or cordate, or sometimes the opposite sides are straight and taper unequally. Small oval or elliptical basal pinnules are sometimes present. Below the tapering apical portion of the main pinnule the sides are parallel. The veins are fine, arched, and fork four or five times with about thirty to a centimeter at the margin. The midvein consists of the coalesced basal part of the smaller veins and continues with diminishing prominence nearly to the apex. The lower surface is adorned with scattered coarse hairs.

The discovery of this particular species of *Neuropteris* at Grand Ledge is of considerable interest because of its general occurrence in the Allegheny and beds of similar age in both North America and Europe. Up to the end of the last century it was unknown in beds older than Allegheny in North America, but it has since been found to extend as low as the Mercer group. There is one report of it in southern Illinois in shales questionably assigned to the Caseyville formation and probably equivalent in age to the lowermost upper Pottsville (Jongmans and Gothan, 38). In the Orion Quadrangle, Rock Island County, Illinois, it occurs in the Tradewater, at a horizon believed to be the Rock Island Coal. In Great Britain it is a common species in the Staffordian and Radstockian although it is on record as very rare in the Lanarkian and fairly rare in the Yorkian. Bell (12) has recently reported the atypical *N. Scheuchzeri* form *angustifolia* in the upper part of the *Lonchopteris* zone of the Morien series of Nova Scotia, which is equivalent to late Pottsville or earliest Allegheny. Higher in the Morien series the more typical form occurs and White (64) in discussing its presence in Henry County, Missouri, assumed that form *angustifolia* is the early expression of the species. The presence of the regular form in Michigan does not support this generalization because its pinnules are larger, and aside from such minor differences as a slightly greater degree of asymmetry, the pinnules are quite typical of the species.

The early forms were as large as the later ones, but show a strong tendency to be more oblique at the base and more asymmetrical and to have sharper apices. It is likely that some of these persisted into the Allegheny and were contemporaneous with the more symmetrical forms common at Mazon Creek and other places.

There is considerable variation among the pinnules that were collected at Grand Ledge, probably more than would ordinarily be expected in so restricted a locality. Most of the pinnules exhibit a tongue-shaped form with parallel sides below the acuminate terminal part. Some are rather small and slender and not greatly unlike those of *angustifolia* variety, but the majority are large, and except for the slight differences mentioned, they resemble the typical upper Carboniferous members of the species. Probably the most pronounced difference among the specimens is the asymmetry exhibited by most of them. With only a few exceptions the acuminate apical part, which constitutes one-third to one-half of the length of the pinnule, is lunately curved so that one margin along this part is slightly concave (Pl. XX, Fig. 5).

Considerable variation is also shown by the base. The base is always oblique, but in some specimens the obliquity is so great that the basal lobe on the adaxial margin has been suppressed and the midvein in the lower part passes close to the margin (Pl. XX, Fig. 4). In others, probably where the basal lobes have been completely cut off as a pair of pinnules, the base is broadly and unequally cuneiform (Pl. XX, Fig. 2). In the most symmetrical specimens the midvein is straight as far as the curved apical part, but in others it arches for its full length.

Only a few examples were observed with the basal pinnules attached (Pl. XX, Fig. 1), but several bear a large basal lobe which is partly separate (Pl. XX, Fig. 2). Scattered among the large pinnules on the slabs are numerous small rounded or elliptical specimens, identical in appearance with the attached basal lobes, which furnish evidence that these were produced in quantity.

The long stiff hairs that are often prominently displayed by *N. Scheuchzeri* are not always conspicuous on the material under discussion. On many leaves they cannot be detected at all, which is probably due to the state of preservation.

Whatever differences are manifest between the Grand Ledge form

and typical members of *N. Scheuchzeri* are entirely differences of degree. Although the epidermal hairs may be somewhat less conspicuous and there seems to be a greater tendency toward the development of large basal lobes and fewer basal pinnules, its identity with *N. Scheuchzeri* seems unquestionable.

Concerning possible affinities with other neuropterids little need be said. *Neuropteris Gilmani*, described by Sellards (56) from the Cherokee shales of Kansas, is similar to our form, but it is probably a variant of *N. Scheuchzeri* derived from the *angustifolia* variety. *N. Scheuchzeri* differs from *N. Clarksoni* by its weaker midvein; from *N. inflata* by its more pointed apex; and from the *impar* form of *N. obliqua* by its greater size, closer venation, and less triangular outline. The same differences apply to *N. acuminata*, as shown by Zeiller (72, Pl. XLI, Fig. 4). Lesquereux's *N. anomala* (*Coal Flora* Atlas, 46, Pl. VII, Fig. 1) has large pinnules, but the plant illustrated properly belongs to *Linopteris* and is referable to *L. Muensteri*.

Neuropteris saginawensis, sp. nov.

(Pl. XXI, Figs. 1–2, 5–6)

This species, from the St. Charles–Garfield Mine, is described as new only after some hesitation. The specific diagnosis is as follows:

Frond unknown. Ultimate pinnae linear, 2–3 cm. broad, terminating in an elongated pinnule; rachis narrow, with 2 or 3 longitudinal ribs on the exposed surface. Pinnules 12–17 mm. long, straight or rarely very slightly curved, thin, pointing forward at an angle of from 45 to 70 degrees from the rachis, tapering to a blunt apex, not at all overlapping or very slightly so at the bases, attached by a short decurrent stalk. Pinnule base oblique, acute above and rounded below. Midvein weak but prolonged beyond the middle of the pinnule. Lateral veinlets arising at a steep angle and passing to the margin with slight curvature, once or twice forked and spaced about 0.5 mm. apart along the margin. Terminal pinnule about 23 mm. long, slender, slightly asymmetrical, broadest one-third the distance above the base; terminal part narrowly tapering; basal part acute, partly coalescent with uppermost lateral pinnule.

The features which distinguish this species are the tapering, nonoverlapping or only very slightly overlapping pinnules with the steeply

ascending veinlets. Some of the veinlets, especially those above the lowermost ones, bend very little, and after the initial arching immediately after departure from the midvein may pass to the margin in almost a straight line. The forking is somewhat irregular. It may occur near the midrib, near the margin, or anywhere between. The lowermost veins curve more than the higher ones, and those of the basal anterior part of the pinnule may bend rather sharply. These lowermost veins appear to enter directly from the short attachment stalk, having split off from the pinnule trace below the lamina. In some of the forwardmost pinnules where the blade is partly attached by the lower margin to the rachis, the basal veins pass into the rachis, *Mixoneura* or *Neurodontopteris* fashion. The weakly developed midvein, and the decurrent attachment stalk from which the lowermost veins are directly derived, are suggestive of an approach to the *Odontopteris* condition.

Neuropteris saginawensis is close to *N. callosa*, but the two seem to be distinguishable by the more tapering and less oval pinnules and by the somewhat less arched veins of the former. When first noticed it was thought to be *N. obliqua*, from which it differs by the greater amount of separation of the pinnule blade from the rachis. In *N. saginawensis* only the forwardmost pinnules are to any extent decurrent upon the rachis, and then mostly on the lower side.

Neuropteris caudata White

(Pl. XXI, Figs. 3–4, 7)

Fragments of this distinctive species occur in the red nodules of Cycle "A" at Grand Ledge. It has previously been reported only from Jasper County, Missouri (White, 62), the McAlester-Lehigh coal field of Oklahoma (White, 63), and the Cherokee shales at Lansing, Kansas (Sellards, 56). The pinnules of this species have been described in detail by White (62, pp. 87–91). The distinguishing feature is the acuminate spurlike prolongation of the lower basal angle by means of which it is easily recognized even when in an extremely fragmentary condition.

Since the horizons from which *Neuropteris caudata* has been previously reported are undoubtedly younger than the Saginaw group, its occurrence at Grand Ledge extends its range somewhat.

Neuropteris rarinervis Bunbury

(Pl. XXII, Figs. 1–4)

Neuropteris rarinervis is fairly abundant in the Verne cyclical formations, having been previously reported from Cycle "F" at Grand Ledge (Arnold, 5) and from the United City Mine by White (in Lane, 44, p. 188). A few fragments apparently representing this species came from the plant bed below Cycle "A" at Grand Ledge, but it is believed not to be as abundant here as at higher levels.

White apparently regarded the material of *Neuropteris rarinervis* from the United City Mine as a distinct variety, but he gave no varietal name to it nor any reason for believing it to be distinct. I see no reason for regarding it as atypical. The only feature that might be used as a basis of distinction is the small size of the pinnules, which are somewhat less than a centimeter in length, but such specimens are not uncommon elsewhere, and the small size of the pinnules is one of the distinguishing features of the species.

Both Bertrand (16) and Stockmans (59) advocated abandoning the name *rarinervis*. Bertrand maintained that Bunbury's figure of the type specimen from Nova Scotia is inadequate for the determination of European material and Stockmans discarded the name in favor of *N. attenuata* of Lindley and Hutton. Bell (12) has recently figured several specimens from the Sydney coal field, however, which show unmistakably the specific identity of the Nova Scotian and European forms.

Neuropteris tenuifolia (Schlotheim) Zeiller

(Pl. XXII, Figs. 5–10)

In the quarries at Grand Ledge and elsewhere in the Michigan Coal Basin are numerous fragments of *Neuropteris*, which it is evident belong to the *Neuropteris heterophylla* group as defined by Bertrand (16), but more exact identification is uncertain. Among the more readily identified members of this group is *N. rarinervis*, which is characterized among the Michigan species by its smaller pinnules and coarser venation. A large proportion of the fragments are believed to represent the highly variable *N. tenuifolia*. This species and *N. heterophylla* closely resemble each other. Some authors question the

propriety of regarding the two as distinct and maintain that all material referred to them merely represents different parts of large variable fronds. Stockmans (59), who has given the most detailed description of the two species, claimed that they are distinct but that fragments alone cannot be satisfactorily assigned. He leaves some doubt as to just what the distinguishing characters are, but the fact that the resemblances are much more pronounced than the differences becomes evident when one compares his figure of the terminal part of a pinna of *N. heterophylla* (59, Pl. I, Fig. 2b) with a similar part of *N. tenuifolia* (59, Pl. III, Fig. 1b). In general the pinnules of *tenuifolia* tend to be more tapering and less rounded or elliptic than those of *heterophylla*, but they vary so much on different parts of the same frond that unless large portions are preserved they are quite inseparable. In both species the terminal pinnules of the secondary pinnae vary from acuminate to oblong-elliptical with blunt apices, and they are almost always larger than the lateral pinnules immediately below.

Among the Grand Ledge specimens are frond parts apparently representing the terminal portions of both the primary and the secondary pinnae. The primary pinnae are characterized by their triangular form and the small slender terminal pinnule (Pl. XXII, Fig. 8). The lateral pinnules are for the most part rather distantly spaced and seldom overlap at the margins. The longest ones are about 20 mm. long and 6 mm. broad at the slightly cordate base from which they taper gradually to the rounded apex. The secondary pinnae have the same general form but are narrower and more acute, and the terminal pinnules are somewhat larger and broader (Pl. XXII, Figs. 6, 7, 9). The pinnules are much shorter than those of the primary pinnae but nearly as broad. They are well spaced, broadest at the base, and stand out from the rachis at right angles or are slightly inclined forward.

The four specimens previously figured from Grand Ledge and identified as *Neuropteris rarinervis* (Arnold, 5, Pl. III. Figs. 1–2, 5, 7) are believed to represent secondary pinnae of *N. tenuifolia*. *N. rarinervis* is present in the same beds but at that time was not figured.

Neuropteris tenuifolia marks a stratigraphic zone in the upper three-quarters of the Kanawha series of the eastern United States

and the mid-continent region (Read, 54) and in the upper Yorkian of Great Britain. In eastern North America it occurs with *N. gigantea*, *N. missouriensis*, *Alethopteris grandifolia*, and species of *Eremopteris*, *Zeilleria*, and *Megalopteris*. In South Wales *N. tenuifolia* is associated with *N. callosa*, *N. gigantea*, *Asolanus Camptotaena*, and *Lepidodendron simile* as a constituent of "Flora F," a flora that is similar to that of the Maurits group of Holland and the lower Gasflammkohle of western Germany (Dix, 24). In the Saar Basin it characterizes the Assise de Charbon Gras, and in the Bassin du Nord of France it is present in the Assise de Bruay of Westphalian C age (Corsin, 19).

Neuropteris obliqua (Brongniart) Zeiller

(Pl. XXIII, Figs. 1–4)

The occurrence of *Neuropteris obliqua* in the Michigan Coal Basin is adequately attested by several small but well-preserved specimens. There appears to be no previous record of this species in the United States, but it has been reported from several places in eastern Canada (Bell, 13–14) where it occurs in the Cumberland group.

Neuropteris obliqua is a member of a group of imparipinnate neuropterids related to *N. heterophylla* and *N. tenuifolia*, but at the same time transitional between *Neuropteris* and *Mixoneura*. It is placed by some authors in the last-named genus. The distinctive feature is the mixoneuroid character of the pinnules near the tips of the pinnae. For some distance back from the terminal pinnule the lower side of the pinnules is decurrent, and in this region the veins enter directly from the rachis. In *N. heterophylla* and *N. tenuifolia* a similar situation exists in the forwardmost pair or pairs of pinnules, but the mixoneuroid condition does not extend as far back as in *N. obliqua*. In one of the Michigan specimens at least six pairs of pinnules are strongly mixoneuroid. The upper sides of the pinnules are more or less separate from the rachis. As the midvein bends rather abruptly upon entering the pinnule base it passes near the distal basal margin, giving the pinnules a decidedly asymmetrical appearance.

The midrib and ultimate veins of the pinnule are quite distinct. Along the central part the venation is somewhat open, but it becomes

denser and more crowded toward the margin as a result of two or more divisions of the veins. The midrib can be followed about two-thirds of the distance to the apex before it loses its identity. Some of the veinlets are slightly flexuous but not strongly so.

Among the specimens collected in Michigan are both the *obliqua* (Pl. XXIII, Figs. 2–3) and the *impar* forms (Pl. XXIII, Fig. 1). The *impar* forms consist of larger pinnules and were originally designated a separate species by Weiss. That both represent the same species has been fully demonstrated by Stockmans (59, Pl. XI, Fig. 1) in a specimen from the Westphalian B of Belgium.

Material of *Neuropteris obliqua* was found on the dump of the St. Charles-Garfield Mine at Eastwood, in the red ironstone nodules from Cycle "A" at Grand Ledge, and at Corunna.

In North America exclusive of Michigan, *Neuropteris obliqua* is confined to the Cumberland and equivalent series in eastern Canada. In Europe including Great Britain it is a fairly common species in the middle part of the upper Carboniferous.

Neuropteris sp. (cf. *N. heterophylla* Brongniart)

A fairly large terminal pinnule and five adjacent lateral pinnules from an ironstone nodule of Cycle "A" at Grand Ledge previously figured as *Neuropteris* sp. (Arnold, 5, p. 193, Pl. VII, Fig. 2), is now believed to be a fragment of *N. heterophylla.* No additional material except a few isolated and incomplete terminal pinnules from Corunna has been found since the figured specimen was collected.

In size and general appearance the Grand Ledge specimen bears some resemblance to *Neuropteris missouriensis,* but differs in having finer venation, ill-defined midribs, and pinnules which are less rounded at the base. There is a closer resemblance to the specimen from Mazon Creek, Illinois, which Lesquereux described (46, Atlas, Pl. VII, Fig. 1) as *N. capitata,* except that the terminal pinnule is more acutely tapering and has a more blunt tip. Janssen concluded (35, p. 46) that the type of *N. capitata* belongs to *N. heterophylla.*

The fragmentary nature of the remains makes positive identification impossible, but the resemblance to *N. heterophylla* seems closer than resemblance to any other species.

Neuropteris Desorii Lesquereux

(Pl. XXIV, Figs. 1–3)

In 1907 David White (see Lane, 44) assigned several fragments from shaft No. 3 of the Wolverine Mine in Bay County to the *Neuropteris Desorii* group. Re-examination of the material and comparison with the description and figures of *N. Desorii* by Lesquereux, furnish no obvious reason for not assigning it to this species. The species is not particularly well-known, but Lesquereux's figures of it are more adequate than for many of the species figured by him. In the *Coal Flora* (46, p. 713) he listed *N. Desorii* from the Salem and Gate veins near Pottsville, from the Blakely vein near Archbald, and from Wilkes-Barre and Cannelton, all in Pennsylvania. These occurrences are apparently high in the Pennsylvanian, and Sellards (56) has more recently identified it in the LeRoy and Lawrence shales and the Chase formations of Kansas. White (66) listed it without further remarks from the upper intermediate division of the type section of the Pottsville. *N. Desorii* ranges widely in the Pennsylvanian.

There is little to be added to the descriptions of *N. Desorii* by Lesquereux and Sellards and it is not certain whether some of the smaller pinnae on the slabs are merely variants or belong to a distinct species. White in his letter to Lane (44, p. 19) stated his belief that all apparently belonged to the same species. This seems unlikely because in some of the smaller forms the venation is more suggestive of *N. rarinervis*.

The pinnae on the more typical specimens are linear-lanceolate with subopposite attached pinnules which are slightly arched forward and stand out from the rachis at an angle of about sixty degrees. The pinnules are up to 7 mm. in breadth and 17 mm. in length, and are, as Lesquereux described them, generally lanceolate, gradually narrowed to an obtuse apex, and undulate or lobed (Pl. XXIV, Fig. 1). The lobing varies considerably. Many of the pinnules are quite entire, while others show shallow marginal undulations which are sometimes most pronounced at the pinnule base. Frequently the lobing is sufficiently deep to cut the lamina into small obtusely rounded segments, with each segment supplied by the branches of a single veinlet arising from the midvein of the pinnule. The veinlets depart from the midvein at a steep angle, and pass upward and outward with but

slight outward curvature to a line about halfway between the midvein and the margin. They then curve outward, but during the latter part of their course pass nearly straight to the margin at an angle of about thirty degrees from the horizontal. Where lobing occurs, the number of veinlets to depart from the midvein is equal to the number of lobes. On some of the pinnae the lobing of the pinnules persists into the tapered apical portion, whereas in others it is almost completely repressed even in the broader basal parts.

According to Hendricks and Read (32), *Neuropteris Desorii* does not occur below the Allegheny, and in the Appalachian coal fields not below the Kittaning Coal group.

Neuropteris Schlehani Stur

(Pl. XXIV, Figs. 7–10)

Material of this rather distinctive type has been found at three places in Michigan; at one of the Marquette mines at Saginaw, at the St. Charles-Garfield Mine at Eastwood, and at the Standard Mine. None of the specimens shows more than parts of the ultimate pinnae, although some bear the characteristic terminal pinnule. At Eastwood the detached pinnules are copiously scattered over the surface of the thin shale slabs, and except for the ubiquitous *Stigmaria* this species is probably the most frequent plant fossil at this locality.

Although *Neuropteris Schlehani* is known to vary considerably and to intergrade with other forms in numerous instances, the material collected in Michigan conforms well to the more typical examples of the species as illustrated by Stur, Potonié, and others. The following description applies strictly to the Michigan material. The maximum breadth of the largest pinna fragments measured is 32 mm. It is quite possible that larger ones exist. The pinnae taper evenly to a point, without any pronounced curvature of the margins. Surmounting the pinna is a small linear terminal pinnule in which the midrib is a continuation of the pinna rachis (Pl. XXIV, Fig. 10). The terminal pinnule is 2 mm. or less in width and less than 10 mm. long. The lateral pinnules are linear to elongate-oval with blunt apices and sides that curve slightly. Most of them are straight and point slightly forward, but a few are slightly curved. The longest ones may exceed 17 mm. in length, but at a distance of 30 mm. or more below the base

of the terminal pinnule they gradually shorten toward the tip. The base of the pinnule is slightly oblique and is more rounded on the upper than on the lower margin. Attachment is by a short stalk which is usually obscured by the matrix. They may be slightly separated laterally, or there may be some overlapping.

The midrib of the pinnule is strongly developed and is marked on the upper surface by a distinct furrow which extends to within 1 or 2 mm. of the apex. The lateral veins, which are also distinct, arise steeply from the midrib, arch away from it, divide once or twice, and pass to the margin at nearly right angles to it. The deeply depressed midrib and the thick carbonaceous residue of the compressions suggest that the pinnules were of coriaceous texture with a heavily reinforced epidermis. The fragmentary nature of the plants makes it seem probable that they were carried some distance from where they grew.

Neuropteris Schlehani is one of a group of forms which because of certain resemblances to *Alethopteris* has been designated the "neuralethopterids." At some places transitional forms between *N. Schlehani* and *Alethopteris* have been reported. In the Michigan material the pinnules are typically neuropterid regardless of their form and texture and, except for the last one or two pairs of pinnules at the extreme apex of the pinnae, they are consistently constricted at the base and attached by a portion no broader than the midrib.

No plants have so far been found in the Michigan Coal Basin with which *Neuropteris Schlehani* might be easily confused, but elsewhere in North America similar or identical species have been described under different names. In the so-called Weber shales of Pottsville age in central Colorado, Read (53, p. 83) has identified a "neuralethopterid" as *N. Dluhoschi*, a species described by Stur (61, II, p. 187) from the Ostrauer Schichten. It is very similar to *N. Schlehani* and both species are figured on the same plate by Stur (Taf. 11). Both his figures represent fragments without terminal pinnules and the only distinguishing features shown are that *N. Dluhoschi* has a broader pinna rachis and pinnules which are slightly more distant and more tapering. Otherwise, the two illustrated specimens appear much the same, and several authors, including Zeiller (72, p. 280) and Potonié (52, Lief. V-99) have united the two species under *N. Schlehani*. *N. Elrodi* was described by Lesquereux in the *Coal Flora* (46, pp. 107, 735),

but White (66, p. 894) believed that material from the roof of the Sewanee Coal of Tennessee included in *N. Elrodi* is identical with *N. Schlehani.* Jongmans (37) has reported *N. Schlehani* from the upper part of the Pocahontas series in West Virginia, and in the overlying New River series he identified *N. rectinervis* which British authors believe to be a form of *N. Schlehani.* Differences between *N. Dluhoschi, N. Elrodi, N. rectinervis,* and what may be considered the more typical forms of *N. Schlehani* are not great, and the probabilities are that if all the facts pertaining to the normal variations were at hand most of the forms assigned to these would be found to represent one or at most two large and diversified species.

In Europe *Neuropteris Schlehani* is regarded an important horizon marker in the Lower Coal Measures. In South Wales Dix (23) has shown that *N. Schlehani* and *Lyginopteris Hoeninghausi* constitute a well-marked floral zone (Flora C) which includes the uppermost beds of the Millstone Grit near Swansea. It diminishes rapidly at higher levels. This zone can be traced throughout the other coal fields in Great Britain and on the Continent finds a counterpart in the Faisceau d'Olympe in France, the Assise de Chatelet of Belgium, the Mager Coal of Westphalia, the Baarlo Group of Holland, and in the division characterized by Flora III in the Donetz Basin. These are included mostly within Westphalian A.

In eastern North America *Neuropteris Schlehani* and its relatives range from the middle Pocahontas beds to the New River series, all of which are included in the lower Pottsville. In the Pocahontas beds it appears to intergrade with some forms of *N. pocahontas,* but in the New River group it approaches the *N. rectinervis* type, which seems to differ somewhat from the Michigan material in having longer and more linear pinnules.

Megalopteris Dawson

(Pl. XXV, Figs. 1, 4)

Except for a small fragment resembling *Megalopteris Southwellii* in Cooper's collection of plants from West Bay City, no new material of *Megalopteris* has been found in Michigan since the publication of the preliminary study in 1934 (Arnold, 5).

The Saginaw group has yielded three species of *Megalopteris* (Arnold,

5), one of which, *Megalopteris Kellyi*, was described as new. It is distinguished by the course of the lateral veins. After leaving the midrib at a steep angle, the veins bend abruptly outward, and pass to the margin at right angles to it. In *M. Dawsoni* the veins pass to the margin, either straight or with slight curvature, at an angle of about forty-five degrees to the midrib. In *M. Southwellii* the condition is intermediate between *M. Kellyi* and *M. Dawsoni*. Bell (13) has found *M. Kellyi* in the Cumberland series of the Pictou coal field of Nova Scotia.

Diplothmema obtusiloba (Brongniart) Stur

(Pl. XXVI, Figs. 1–3)

Abundant though fragmentary remains of this species have recently been collected on the dump of the St. Charles-Garfield Mine at Eastwood. It had previously been reported from the Marquette Mine (Arnold, 5, p. 197), and White (in Lane, 43, p. 44) questionably identified it from the J. H. Somers No. 2 shaft at St. Charles.

At Eastwood the fragments occur in a medium gray fissile shale which weathers rapidly and, although the carbonaceous residue stands out prominently in the compressions, the preservation except for small pieces is not good. It has not been possible to observe any of the divisions of the frond larger than the secondary or penultimate pinnae, although on a number of specimens the essential features of the pinnae are plainly revealed.

Diplothmema obtusiloba was first described by Brongniart as *Sphenopteris obtusiloba*. The name was given to a frond fragment of unknown source, distinguished by the triangular form of the secondary pinnae, the thin texture of the tissue, and the rounded to triangular form of the ultimate (tertiary) pinnae, which were divided into three more or less equal lobes, the lower ones of which were themselves bilobed or trilobed. Like most other Carboniferous fernlike leaf types this leaf shows many variations which have received different names by authors. Stur (61, p. 124), for example, on the basis of the divisions of the frond, included this species within his genus *Diplothmema* and Lesquereux (46, p. 753) placed it in *Pseudopecopteris*, where it was retained by White (64, pp. 24–27). The generic assignments of these fernlike leaf forms are largely a matter of definition.

Several other specific names have been given forms identical with or closely resembling *Sphenopteris obtusiloba*, some of which at times have been synonymized with it. Among them are *S. striata*, *S. irregularis*, *S. latifolia*, and *Diplothmema Schumannii*. Bell (12, p. 20) has described a form from the Morien series of Nova Scotia and New Brunswick which is close to the material here, as *S. Whitii*. This species, as described by Bell, differs from *S. obtusiloba* in having smaller pinnae and more coriaceous pinnules with immersed veins. When Bell's figures of *S. Whitii* are compared with Brongniart's figure of *S. obtusiloba* the differences he cited are somewhat in evidence, but it seems justifiable to hesitate in accepting them as sufficiently pronounced to indicate a different species. Variations in the prominence of the venation could readily be due to differences in preservation. The ultimate pinnae of *S. Whitii* seem to be more triangular and the terminal pinnule more pointed, but among the fragments from the St. Charles-Garfield Mine both conditions are present so it seems probable that this feature is merely a normal variation and not a specific difference. Furthermore, whereas the pinnules of the Michigan form agree well in size with those of *S. Whitii*, the shape of the pinnae is more like that in Brongniart's figure, and the pinnules, as indicated by the absence of a compression border, seem to be very thin. All that remains of the tissue is a delicate film of brownish black cutinized substance which sometimes peels from the shale. The veins are obscure, and the microscopic rugosity ascribed to *S. Whitii* is lacking. This may be the result of differences in preservation for most of the internal tissues of the pinnules have disappeared.

Kidston believed *Sphenopteris striata* to be identical with *S. obtusiloba* and considered that the striated appearance of the rachis was the result of preservation.

In continental Europe *Sphenopteris obtusiloba* is an important fossil in the middle part of the middle upper Carboniferous, but is rare in the upper part. In Great Britain it occurs in the Lanarkian, Yorkian, and Staffordian series, but is least common in the last. It is generally accompanied by *S. striata* and related forms. In North America it has been reported from Henry County, Missouri, from the Scott shale of Tennessee (White, 69), and from several places in Illinois in horizons higher than the Pottsville. The specimens figured from Illinois

have pinnules which are much larger than any of those from Michigan, Great Britain, or continental Europe have, and their identity with this species may be questioned.

Sphenopteris Bradfordii, sp. nov.

(Pl. XXIII, Figs. 5–6)

Pseudopecopteris cf. *avoldensis* White (non Stur) in Cooper, 1906, p. 188.

A single specimen from the United City Mine, identified by White as *Pseudopecopteris* cf. *avoldensis*, appears to represent a new species. It is described as follows: Outer tissues of rachis (outer cortex) with longitudinal fibrous strands, inner tissues (inner cortex) with transverse sclerotic plates, glandular. Pinnae linear-lanceolate, up to 1 cm. broad at base and 3 cm. long, borne at right angles to rachis or directed very slightly forward, with no apparent overlapping. Pinnules alternate, those on lower parts of pinnae oblong and consistently five-lobed (two pairs of subopposite lobes and an unequilaterally divided terminal lobe), 2.5 mm. broad and 5 mm. long, becoming trilobate, bilobate and simple toward the terminal portions. Lobes round, 1 mm. in diameter, short-stalked and decurrent, fleshy, veins immersed and obscure. Frond characters unknown.

This species is distinguished by the small size of the round thick pinnule lobes. It appears very similar to and may be identical with *Sphenopteris Marrati*, described by Kidston (41, p. 47) from the Staffordian and Westphalian (Yorkian) of Great Britain. Kidston stated that *S. Marrati* is rare in both series but especially so in the Staffordian. It seems advisable to describe the Michigan form as new, especially as only small pieces of *S. Marrati* are figured.

That *Sphenopteris Bradfordii* belongs to the lyginopterid group of pteridosperms is indicated by the structure of the cortical tissues of the rachis and by the presence of trichomes (probably glands) along the rachises of the pinnae. Coarse longitudinal striations on the rachis where the outermost tissues are preserved indicate subepidermal fibrous strands, and the cross striations visible where the deeper portions are exposed is suggestive of the transverse type of sclerotic plate present in the inner cortical tissues of *Heterangium*. The presence of trichomes on the pinna rachis is indicated by numerous small openings in the epidermis surrounded by small epidermal cells. Capitate glands

are conspicuous features of *Sphenopteris Hoeninghausi*, the leaf of *Lyginopteris oldhamia*, but whether the trichomes of *S. Bradfordii* are of the same nature is unknown. Their presence with the cortical features mentioned indicates affinities with both *Lyginopteris* and *Heterangium*.

The inflated appearance of the small round pinnule lobes at first led to the belief that they were fructifications, but transfer mounts clearly reveal their vegetative nature. In life the lobes were probably quite thick with a strongly convex upper surface.

The specimen of *Sphenopteris Bradfordii* is one of several plant-bearing slabs collected by the Michigan Geological Survey from the United City Mine. No information concerning the horizon accompanies the specimens, but Cooper (18, p. 188) stated that in this mine plants occur in a three-foot layer of gray shale above a coal seam believed to be upper Verne. It is probable that this plant is from that source. It is named after Mr. George Bradford who, according to Cooper, made a collection of plants from this horizon in 1904.

Palmatopteris furcata (Brongniart) Potonié

(Pl. XXVI, Figs. 7–8)

One specimen referable to this rather readily recognizable species came from the soft gray shales of the quarry of the Grand Ledge Clay Products Company. The exact level from which it was derived is uncertain, but coming from above the Grand Ledge Coal, it must be from one of the cyclical formations above "B" and not higher than "E."

Although the form and division of the dissected pinnules are adequate for ready identification, the specimen as a whole is not well preserved. Only a small part of the rachis is present, and the remains consist mostly of torn fragments scattered rather indiscriminately over the irregular surface of the shale block.

The systematic treatment of Carboniferous plants with dissected sphenopteroid pinnules has been handled differently by authors with inevitable confusion as a result. For the type of plant under consideration many well-known writers (Stur, 61; Zeiller, 72; Kidston, 41; Bell, 12, 14) have used Stur's genus *Diplothmema*, but White (69) presented a good case for Potonié's genus *Palmatopteris*.

Little is known of the distribution of *Palmatopteris furcata* in North America outside of Nova Scotia, where Bell (12, 14) reported it from the Cumberland, Pictou, and Morien groups. It is listed but not figured by Lesquereux (46, p. 282), and a fragment from Braidwood, Illinois, is figured by Noé (51, p. 45, Fig. 1). In Great Britain it occurs in the Lanarkian and Westphalian but is not abundant. On continental Europe it is sometimes abundant in the middle part of the middle upper Carboniferous.

Mariopteris nervosa (Brongniart) Zeiller

(Pl. XXV, Figs. 2–3)

A few fragments from the red ironstone nodules from cyclical formation "A" at Grand Ledge and from the Big Chief Mine No. 8 at St. Charles are referred to this species rather than to *M. muricata* because of the more tapering or triangular form of the pinnules and apparent suppression of lateral lobes. The fragments agree well with *M. nervosa* as illustrated by Kidston (41) and Corsin (19). They are not strikingly different from *M. pottsvillea*, described by White (69) from the roof of the Castle Rock Coal of the Lookout formation of Georgia, but since the Castle Rock Coal is much older than anything yet recognized in the Michigan Coal Basin, and *M. pottsvillea* is not known to extend into any of the Pennsylvanian formations above the approximate level of the Lookout formation, it is considered advisable to refer our material to the other species.

Fragments of *Mariopteris* have been encountered at several places in the Michigan Coal Basin, but seldom in sufficient quantity or in large enough pieces to enable one to be absolutely certain as to the specific identity.

Mariopteris sp.

A fragment of the subterminal part of a pinna from the United City Mine at West Bay City has been identified by White as *Mariopteris muricata* (Cooper, 18, p. 188). The horizon is given as upper Verne. The pinnules are tapering, pointed, and rather strongly decurrent, and the venation is somewhat obscure. The margins are provided with shallow, sawlike, forwardly pointing lobes or teeth.

Caulopteris sp.

(Pl. XXIX, Fig. 1)

A piece of sandstone cast 15 cm. wide and 34 cm. long, bearing on the surface the imprint of a row of nearly circular leaf scars, furnishes evidence of the existence of ferns of the *Psaronius* group in the Paleozoic forests of Michigan. The specimen is not well preserved and only the gross features of the scars are visible. The label states that it came from Grand Ledge, apparently having been collected by F. H. Day about 1901. It had been identified as "*Stemmatopteris cyclostigma*," a plant described by Lesquereux (46, p. 341) but not figured. It is not known why the specimen was referred to that species.

The scars are 6.5 cm. wide by 5.5 cm. high, and equidistantly spaced in vertical series 3 cm. apart. Only one row is visible, there being no evidence of the quincuncial order mentioned by Lesquereux. Markings on the surface of the scars are not clear. Covering the whole surface of the specimen are longitudinal and slightly oblique striations having a width of about 2 or 3 mm. which probably resulted from exposure of the sclerenchyma strands after removal of the surface cells.

The data concerning the horizon from which the specimen was obtained are illegible, but it was probably derived from the sandstones of the Grand River group which overlies the Saginaw group.

The only other reference to *Caulopteris* from Michigan is in White's list (in Lane, 43, p. 43) of plants from the Standard Mine.

Aulacotheca Campbelli (White) Halle

(Pl. XXIV, Figs. 4–6)

The shales of the mine dump at Eastwood have yielded a number of elongate spore-bearing organs of the type described by Halle (29) as *Aulacotheca*. They are very similar to and believed to be specifically identical with the fossil that White (66, p. 905) described from the Pottsville of the Appalachian region as *Whittleseya Campbelli*. At that time the fructifications now known as *Aulacotheca* and *Whittleseya* were supposed to be leaves. Halle not only revealed their true structure, but distinguished between the two forms. He mentioned a resemblance between *Aulacotheca* and *Whittleseya Campbelli*, but

being entirely dependent upon White's figures for comparison, was unable to do more than comment upon their similarity. The sporocarp of *Aulacotheca* is elongate, cylindrical or narrowly club-shaped, and ornamented with strong parallel ribs and furrows which extend from the tapering base to the more or less rounded apex. That of *Whittleseya* is a campanulate body. The surface ribs of both types represent cylindrical spore cavities which are arranged in a circle within the tissue around a supposedly hollow interior.

There is some variation in size among the sporocarps collected at Eastwood, but most of them range from 2 to 3.5 mm. in width and 11 to 16 mm. in length. There is no evidence that more than one species is represented, and the size differences are no greater than may be accounted for by normal variation. The compression surface bears three or four longitudinal ribs which in turn are marked with very fine lengthwise striations. At the abruptly rounded apex each rib terminates in a slightly inwardly curved tooth. The margins of the compression converge very slightly downward, and in the lower portion they round off to a taper-pointed base which merges gradually into a filamentous attachment stalk. Many of the specimens contain spores which adhere together as long bands of several hundred spores each, which extend nearly the entire length of the sporocarp. These spore bands may be separated from the enclosing tissue by maceration with Schultze's reagent followed by ammonium hydroxide. Each sporocarp contains six spore masses which measure about 0.9 by 13 mm. The spores themselves are broadly oval bodies averaging 135 by 176 micra and have smooth walls except for a single lengthwise mark (Pl. XXIV, Fig. 4).

None of the sporocarps found at Eastwood were attached, but they are intimately associated with *Neuropteris Schlehani* and the testae of large, oval, longitudinally furrowed seeds. This association supports the current belief that *Aulacotheca* is the microsporangiate organ of certain members of the Medullosaceae.

Several specimens of *Aulacotheca Campbelli* from the Sewell formation of West Virginia are available for comparison with the Eastwood material. Because the West Virginia specimens have lost their spores, comparisons are confined to external features which show no apparent differences other than size. Size differences are not great. The Sewell

sporocarps range from 2 to 3.75 mm. in width and from 13 to 20 mm. in length as compared with 2–3.5 mm. by 11–16 mm. for the others. While this slight difference in size may possess some stratigraphic significance, it is not sufficient when taken alone to indicate a specific difference.

The dimensions given by White for *Aulacotheca Campbelli* are closer to those of the sporocarps from Eastwood than to those from the Sewell formation. However, he said that there is considerable variation, some being slightly smaller than the average and others considerably larger. The smaller sporocarps occur more generally in the lower horizons of the Pottsville, and the larger ones near the top. A very large form was found 450 feet below the top of the series in Pottsville Gap.

Jongmans (37, pp. 398, 400, 402, 403) listed *Aulacotheca* from two localities in the Pocahontas series and from one in the New River series of West Virginia. He remarked upon the general resemblance of the sporocarps to *A. Campbelli*, but assigned the first two to European species. The smaller ones which come from the lower horizon (Seam 3 of the Pocahontas) he compared to *A. Hemingwayi*, and the larger ones from Seams 4–6 are compared with *A. elongata*. Jongmans gave no measurements, but his figures show that the older one (assigned by him to *A. Hemingwayi*) is the smaller. Halle in his description of the two species, said that *A. Hemingwayi* is larger than *A. elongata*, sometimes reaching a maximum length of 30 mm., whereas the other is about 15 mm. (or more) in length. Less is known about the size range of *A. elongata* because only a few specimens were available. Before Halle separated them, *A. elongata* and *A. Hemingwayi* had both been included under the name *Holcospermum elongatum*. External dimensions alone probably do not furnish reliable clues to the specific identity of different species of *Aulacotheca*, but it seems more likely that the form which Jongmans found in Seam 3 of the Pocahontas should be referred to *A. elongata* and the form from the higher seams should be compared with *A. Hemingwayi*. Both of these are from horizons low in the Pottsville group, and the size difference cannot be correlated with stratigraphic position.

Final analyses of the specific relation of the different forms of *Aulacotheca* in the Pottsville group, or a decision as to whether White may have included more than one species in *A. Campbelli*, cannot be

made until a complete series of specimens from different horizons is assembled and the specimens critically compared. In the meantime it seems preferable to apply the specific name proposed by White to all of them. A notable omission in our knowledge of all of the sporocarps from the Appalachian region is lack of data on sizes of the spores and the spore groups. Since the spores are preserved in the Michigan material, it is possible to compare it very satisfactorily with *A. elongata* and *A. Hemingwayi.* Comparative data can conveniently be presented in tabular form as follows:

Species	Size of Sporocarp	Size of Spores	Size of Spore Bands	Number of Spore Bands
A. Campbelli (Eastwood)....	2–3.25 × 11–16 mm.	135 × 176	0.9 × 13 mm.	6
A. Campbelli (Sewell formation).....	2–3.75 × 13–20 mm.	.....	.....	6 (?)
A. Campbelli (after White)..	2.25–5 × 12–22 mm.	.....	.....	6 (?)
A. elongata (after Halle).....	3.5–4 × 15 (or more) mm.	90–100 × 140–150	0.5–0.7 mm. in breadth	8–9
A. Hemingwayi (after Halle).	4.5–5.5 × 28–30 mm.	120–170 × 170–220	.....	9
A. Dixiana (after Dix).....	4.5 × 25 mm.	150 × 170	.....	.....
A. Hallei (after Hemingway).	3.5 × 16 mm.	73 × 113	.....	6 (?)

From this table it may be seen that *A. Hallei* has the smallest spores and that those of *A. Campbelli* from Eastwood are larger, but they are not as large as those of *A. Hemingwayi.* In size the sporocarps of *A. elongata, A. Hallei,* and *A. Campbelli* are close, so were it not for a more pronounced difference in spore size it is doubtful whether any good reason could be found for keeping them separate. In *A. Dixiana* the spores are about the same size as those of *A. Campbelli,* but the sporocarp more closely approaches *A. Hemingwayi. A. Dixiana* is associated with *Neuropteris rectinervis* (Hemingway, 31), and the close association of *A. Campbelli* and *N. Schlehani* at Eastwood indicates the occurrence of similar if not identical plants in Great Britain and Michigan. Jongmans reported a sporocarp similar to *A. Campbelli*

associated with *N. rectinervis* from the New River formation in West Virginia. *N. rectinervis* is close to *N. Schlehani*, and both have probably been derived from *N. pocahontas*. In this connection it should be noted that *Aulacotheca* occurs in intimate association with all of the frond types of these three species of *Neuropteris*.

Since *Aulacotheca* extends throughout the entire vertical extent of the Pottsville group in the Appalachian region, its use as a horizon marker within the Pottsville is limited, although White's comment that the sporocarps in the higher beds usually are larger than those found at lower levels may be based upon genuine differences. When the sporocarps from Eastwood are compared with those from the Sewell formation they are found to be very slightly smaller. White said that the oldest sporocarps are not over 13 mm. long, and these apparently occur in the lower coals of the Lykens group. They attain their normal size in the Clark and Quinnimont divisions and near the horizon of Lykens Coal No. 4. It would seem that the Eastwood sporocarps, being only slightly if at all below normal in size, might correspond to those of the above-named division. Unfortunately, *Aulacotheca* has been found at only one locality in Michigan, so that nothing is known concerning its possible size range within the Saginaw group.

Rhabdocarpus multistriatus (Presl) Lesquereux

(Pl. XXIX, Figs. 4–6)

Until recently this seed had been recognized in the Michigan Coal Basin only in the form of crystal-filled casts from the ironstone nodules of Cycle "A" at Grand Ledge (Pl. XXIX, Figs. 4–5), but it is now believed that certain compressions from the dump of the St. Charles-Garfield Mine at Eastwood represent the same species (Pl. XXIX, Fig. 6). At Eastwood the seed is preserved in two forms, one showing the external features and the other the interior. Were it not for the fact that the collection contains a sufficient number of specimens to show the connection between the two forms, one would be inclined to place them in distinct species or even genera.

The compression showing the exterior is an ovate body 5 cm. long and approximately 2.7 cm. wide (Pl. XXIX, Fig. 6). Extending lengthwise of the seed are six or seven broad low ridges which converge

toward the apex and base, but which flatten out before reaching either. The distance between the crests of adjacent ribs along the broadest portion is about 5 mm. Whether these ribs are surface features or are due to sclerotic bands in the testa is not clear.

Rhabdocarpus multistriatus is very similar to the somewhat larger *R. Mansfieldi* (Pl. XXIX, Fig. 2), but probably of more significance than the rather slight difference in size is that *Mansfieldi* has a slightly broader and more rounded apex and the furrows separating the ribs appear to be more distinctly impressed, with flatter bottoms and steeper sides. Such a small difference as this could readily be the result of preservation.

The compressions showing the internal parts of the seed are oval or barrel-shaped bodies either rounded or slightly truncated at the ends. They are fairly uniform in size, being about 2 cm. wide and 3 cm. long with slight variation in both dimensions. They are ornamented with surface ridges similar to those on compressions showing the exterior but which in most instances are less distinct. In some specimens they are visible only with side lighting. The markings that show on this part of the seed seem to correspond to the ridges on the surface and they may or may not have existed in life. It is quite possible that the surface of the nucellus was nearly smooth and that the present surface markings are the result of pressure against the ribbed testa.

Some of the compressions of the internal part of the seed show a rather distinct compression border which resulted from the flattening of the testa around the margin. This border is approximately 5 mm. in width and is interpreted as representing the original thickness of the testa. The total width of the interior and the compression border (in specimens where it is shown) is usually a little less than 3 cm., a measurement which agrees well with the external measurement of the seed.

The agreement in the appearance of the surface ribs and the dimensions of the specimens appears to constitute satisfactory evidence that the two compression types under consideration are different preservation forms of the same seed. In common with many other Paleozoic seeds the nucellus of *Rhabdocarpus multistriatus* was probably free from the surrounding integument (testa) except for the basal attachment, and occupied the large cavity in the lower part. A rather

obvious feature of some of the specimens is that the curvature of the ribs is not such that they meet at the base and apex but at a point beyond what would correspond to the base and apex of the seed. This indicates that one of the oval or barrel-shaped compressions represents the inside part of which the other type represents the outside surface of the same seed.

The seeds described here are assigned to *Rhabdocarpus multistriatus* on the basis of Lesquereux's figures in the *Coal Flora* (46, Pl. LXXXV, Figs. 22, 23) and on a figure by Arber (2, Pl. VI, Fig. 10) of a specimen from the Transition Coal Measures of North Staffordshire. Although many authors have objected to further use of the name *Rhabdocarpus* on grounds that it cannot be explicitly applied, it is felt that for the fossils under consideration nothing would be gained by the use of an other name than the one used by Lesquereux for seeds of this type.

It is believed that *Rhabdocarpus carinatus* (Newberry, 50, p. 376, Pl. 44, Fig. 3) from the shale over the Sharon Coal of Ohio is identical with *R. multistriatus*.

Rhabdocarpus Mansfieldi Lesquereux

(Pl. XXIX, Fig. 2)

This seed is represented by a nearly complete specimen and fragments of two others from the shales below Cycle "A" at Grand Ledge, which appear to be identical with one from Cannelton, Pennsylvania, which Lesquereux attributed to *Cordaites Mansfieldi*.

The most complete of these specimens is the compression of an egg-shaped seed 3 cm. wide, slightly below the middle, and 6 cm. long. Extending the length of the seed are four or five flat-surfaced ribs about 4 mm. broad separated by shallow but plainly marked furrows about 2 mm. wide. The substance of the compression consists of a thick layer of carbonaceous material. Another seed, of which only the basal part is preserved, was probably about 7 cm. long, and a third was about 4 cm.

The nomenclature of *Rhabdocarpus Mansfieldi* is somewhat confused owing to the fact that Lesquereux attributed it to *Cordaites*. He used the name on page 18 of the *Coal Flora* Atlas, where Plate LXXXV, Figure 21, is cited, but on page 539 of the text he referred to the same figure as *Cordaicarpus Mansfieldi*, and on Plate LXXXVII (between

pp. 560–61) he called a similar object *Cordaites Mansfieldi*. This object Lesquereux believed to be attached to a stem fragment associated with leaves of *Cordaites Mansfieldi* which he deemed belonged to the stem.

For several reasons it is extremely improbable that this seed belongs to *Cordaites Mansfieldi*. In the first place Lesquereux's figure does not supply definite proof of attachment to the underlying stem fragment, and in the second, he gave no convincing evidence that it is a cordaitean twig. It seems likely that the position of the seed with respect to the twig is accidental. Furthermore, the seed itself is not of the type now known to be borne by any of the Cordaitales, and its attachment (if actually attached as Lesquereux believed) is not to a cordaitean inflorescence. There is thus no satisfactory evidence that *Rhabdocarpus Mansfieldi* is a cordaitean seed. For the present its affinities must remain unknown, but the probabilities are that it was borne by one of the pteridosperms.

The seed of *R. Mansfieldi* is larger than that of *R. multistriatus*, which is also from Grand Ledge, and slightly broader and more rounded apically. The two are probably closely related seeds and distinguishing between smaller specimens of *R. Mansfieldi* and larger ones of *R. multistriatus* might be difficult.

"Trigonocarpus" Noeggerathi (Sternberg) Brongniart

(Pl. XXIX, Fig. 3)

This seed appears to be represented in the Michigan Coal Basin by several flattened objects from the mine dump at Eastwood which seem to consist of casts of the inner or sclerotic layer of the integument. Typical examples are oval and measure approximately 1.5 cm. in width and about 2.5 cm. in length. The presence of a compression border around some of the flattened casts is the sole evidence of the existence of any surrounding tissue. The exposed surface of these seeds is smooth, and the only markings are rather prominent ribs which are characteristic of this genus. Since all the Eastwood specimens are flattened, none of them shows all three ribs, and most of them have the ribs pressed so flat as to be scarcely noticeable. One specimen which does show a rib rather plainly is split at the apex in a manner similar to that often figured for this and other species of *Trigonocarpus*.

At Eastwood the material identified as "*Trigonocarpus*" *Noeggerathi* is associated with *Neuropteris Schlehani* and *Aulacotheca Campbelli.* This species has been rather frequently reported from the middle and upper Westphalian of Great Britain and continental Europe but so far its known occurrences in North America are few.

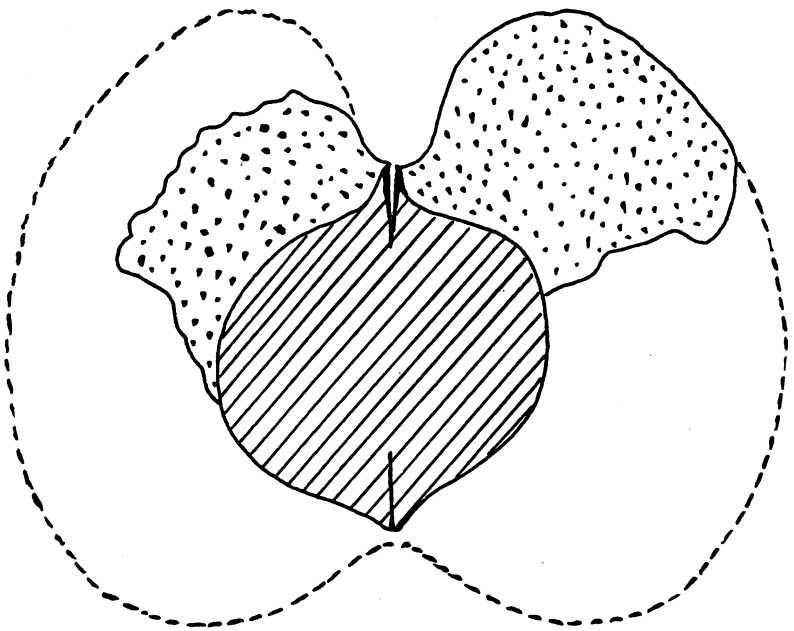


Fig. 2. *Samaropsis Newberryi.* Restoration to show the breadth of the wing. × 2

Samaropsis Newberryi (Andrews) Seward

(Fig. 2)

The broad-winged seed identified as *Samaropsis Newberryi* from the clay ironstone nodules at Grand Ledge (Arnold, 5) was transferred to *S. ingens* by Bell (13) on the grounds that the wing of *S. Newberryi* is broader than in the specimens figured. Since the preliminary account of the Michigan Coal flora was written a few additional specimens of the seed in question have been found which throw more light

on the problem of identity, and Andrews' type specimen of *S. Newberryi*, which is in the geological collection of Marietta College, has been examined.

The specimen of *Samaropsis Newberryi* figured by Andrews (1, Pl. XLVI, Fig. 2) is a rather poorly preserved seed with an incomplete wing of which the margin shows at only one place, but at the horizontal mid-line of the seed the wing is approximately 12 mm. wide. On one of the newly found fragments the wing is at least this wide, and at one place between the mid-line and the micropylar notch it is 18 mm. wide (Fig. 2). Lesquereux said that the wing of *S. ingens* is 5 mm. wide at the middle but that it widens toward the apex. His figures (46, Atlas, Pl. LXXXV, Figs. 34–35) show that at no place the wing is more than 6 mm. wide. On the basis of the width of the wing the Michigan seed is unquestionably closer to Andrews' species than to the other. Furthermore, neither Andrews' specimen nor those from Michigan show the pronounced cordate base depicted by Lesquereux for *S. ingens*. In the specimens originally figured from Grand Ledge the full width of the border is not shown, but there is ample evidence that it is much broader than in *S. ingens*.

NOEGGERATHIALES

The discovery of *Discinites* in the Saginaw group is the first recognized occurrence of the Noeggerathiales in the Pennsylvanian of North America. The only other record of this group in the American Paleozoic is Darrah's (21) account of *Tingia* in the late Paleozoic Wichita group of Texas. *Tingia* and *Discinites* are quite different. Because of the verticillate arrangement of the sporophylls, *Discinites* may be readily confused with fructifications of the Sphenopsida, and perhaps for this reason noeggerathialean fructifications in the Pennsylvanian have been overlooked. Although none of the numerous fragments of *Discinites delectus* or *D. Jongmansi* found in Michigan are in organic union with other plant parts, intimacy of association gives ground for the belief that one of them at least was connected with *Eremopteris michiganensis*. *Eremopteris* has not been mentioned in connection with any of the European species of *Discinites*, but there is an evident similarity between the foliage displayed by *Eremopteris* and that commonly attributed to the Noeggerathiales. *Saaropteris*, the leaf of

Saarodiscites, was described by Hirmer and Guthörl (33) from the Saar area; it is similar to *Eremopteris*, but differs mainly in having shorter and slightly more obtuse pinna lobes. The venation and general shape of the leaf is similar in the two forms.

Eremopteris michiganensis, sp. nov.

(Pl. XXVII)

Eremopteris elegans Lesquereux, 1880, pp. 294–95; 1879, Pl. LIII, Fig. 7.

This species is locally very abundant in the shales below Kelly's Cycle "A" in the quarries west and northwest of Grand Ledge. Its formal diagnosis is as follows: Frond at least bipinnate; penultimate pinnae long, slender, straight, gradually tapering; rachis slender, straight, coarsely striate; ultimate pinnae alternate, spreading at an angle of 35–45 degrees from the rachis, decurrent, lanceolate, separated or slightly overlapping; lateral pinnules alternate, regular, strongly decurrent, slender, spreading from pinna rachis at an angle of twenty degrees or less; outward curvature slight, apex rounded or with one or two small but acute notches on the outer margin just below the apex; terminal pinnule often coalescent with the adjacent lateral pinnule for one-half or more of its length; venation dichotomous, fine, obscure.

Eremopteris michiganensis so closely resembles *E. artemisaefolia* that it could easily be confused with it, but when the numerous fragments of *michiganensis* are carefully examined and compared with illustrations of *artemisaefolia*, certain differences become so evident that the two are not difficult to separate. Some of the differences are well illustrated by Lesquereux's figures (46, Atlas, Pl. LIII) in the *Coal Flora*. In Figures 5 and 6 the more open habit of *E. artemisaefolia* is shown. The pinnules show a greater tendency to curve away from the pinna rachis than in the Michigan form, and they display considerable irregularity in shape and extent of lobing. The basal inferior pinnule in particular is deeply incised into three or more segments, and the whole pinnule stands out somewhat from the others. Figure 7 on the same plate which Lesquereux labeled *Eremopteris elegans* is obviously that of *E. michiganensis*. It shows the more strict form of the pinnae (as contrasted with *E. artemisaefolia*) and the slender and less deeply cut pinnules which are only shallowly notched. The basal inferior pinnule is not different from the others.

Lesquereux was correct in placing his specimen in *Eremopteris*, but the species assignment was wrong. Ettingshausen's figures (25, Pls. III, IV) of *Asplenites elegans* that Lesquereux used for identification show that the main rachis bears large narrowly rhomboidal pinnules which are deeply cut into numerous, narrow, pointed segments. The pinnules stand out from the rachis at a wide angle. The original *Asplenites elegans* of Ettingshausen is not an *Eremopteris* and was made the type of the genus *Rhacopteris* by Schimper.

Of the several accounts in the literature of *Eremopteris artemisaefolia*, that given by Kidston (41, pp. 407–11) is probably the best. He showed that the main rachis of the large frond forks by dichotomy into two equal divisions and that the ultimate pinnae fork similarly but sporadically. Although one is not justified in assuming that the frond of *E. michiganensis* is simple throughout, no branching of the main rachis other than the normal production of pinnae has been observed. The largest specimen collected at Grand Ledge is part of a penultimate pinna 40 cm. long; another is 36 cm. long and several are 20 cm. long. All are unbranched.

In view of the distinctive characters there seems to be ample justification for describing the Grand Ledge *Eremopteris* as a new species and to include the specimen figured by Lesquereux (46, Atlas, Pl. LIII, Fig. 7) as *E. elegans* in it. There is little possibility of confusing *E. michiganensis* with any species of the genus except *E. artemisaefolia* and the differences that have been pointed out are distinctive.

The leaf of *Eremopteris* probably represents one of the ancient cuneiform leaf types such as was expressed in the early Carboniferous by *Triphyllopteris* and in the late Devonian by *Archaeopteris*. The genus is not often mentioned in literature pertaining to the Carboniferous flora of continental Europe, but Kidston (41) reported that it is widely scattered in Great Britain, though rare in the Lanarkian and Yorkian, where two species, *E. artemisaefolia* and *E. zamioides*, occur. In North America several species have been described from the Pottsville of the Appalachian region (White, 66, 69) and from the lower Allegheny in Henry County, Missouri (White, 64). Lesquereux listed seven species in the *Coal Flora*, but the genus is broadly defined and includes some that would ordinarily be placed in *Sphenopteris* and *Rhacopteris*. He gave four localities for *E. artemisaefolia* but did not cite the localities for the figured specimens, so his account is not satis-

factory from the standpoint of the distribution of that species. The stratigraphic distribution of *Eremopteris* in North America probably closely parallels that of Great Britain. It is mainly a Pottsville type but some species extend into the lower Allegheny.

Palaeopteridium Reussi (Ettingshausen) Kidston

(Pl. XXVI, Fig. 6)

A pinna fragment collected by W. A. Kelly from the quarry of the New Corunna Brick Company seems referable to this species. The pinna, which lacks the apex and base, is linear and about 10 mm. in width. The obovate alternate pinnules are equal in size, touch or slightly overlap, and are attached obliquely to the rachis. The adaxial basal margin touches the rachis for about one-third of its length. Each pinnule is about 4.5 mm. wide and 8 mm. long. The rounded apex is finely serrate with a veinlet terminating in each tooth. There is no midvein, but the single vein which enters the pinnule at the base divides dichotomously. Subsequent divisions produce the veinlets which pass straight to the margin.

While the specimen from the Corunna quarry fits well into the genus *Palaeopteridium* as defined by Kidston (41), the species reference must be considered tentative pending the discovery of more complete portions of the plant. Of the three specimens figured by Kidston on his Plate LV, the agreement is closest to his Figures 1 and 3. Figure 2 shows more slender lax pinnules and those at the base of the pinnae are larger and with lacinate margins. Our specimen is insufficient to demonstrate either the presence or absence of pinnules of such type.

In Lesquereux's *Coal Flora* the nearest approach to the *Palaeopteridium Reussi* type is *Pseudopecopteris decipiens* (46, p. 214; Atlas, Pl. LII, Figs. 9–10) from the Pottsville of Arkansas, Alabama, and Pennsylvania. Lesquereux has probably included more than one species under this name, and the specimen showing the closest resemblance to *Palaeopteridium Reussi*, as far as pinna and pinnule form is concerned, is figured as having odontopteroid venation (46, Pl. LII, Figs. 9–9a). White (69) in his more recent treatment of the genus *Diplothmema* transferred the specimen shown in Figures 9 and 9a of the *Coal Flora* to his new species, *Diplothmema morrowensis*, which is different from the Michigan specimen.

Palaeopteridium Reussi is a rare species. Only one fragment has

been recognized in Michigan, and in England it is restricted to the Blue Measures above the Brooch Coal which is in the upper part of the Westphalian (Yorkian) section in the South Staffordshire coal field.

The discovery of this leaf fragment in the Saginaw group is of special interest, because in Europe *Palaeopteridium* is believed to be the leaf of a plant bearing the *Discinites* type of fructification and hence a member of the Noeggerathiales. No *Discinites* fructifications have been found at Corunna.

Discinites delectus (Arnold), comb. nov.

(Pl. XXVIII, Figs. 1, 4–7)

Bowmanites delectus Arnold, 1944.

The fructifications that are assigned here to Feistmantel's genus *Discinites* were originally placed in *Bowmanites* (Arnold, 7), and described as heterosporous members of that genus. That they belong to *Discinites* instead seems certain, as may be seen by comparing the figures on Plate XXVIII with those of *Discinites* by Němejc (49) and Hirmer and Guthörl (33).

The specific description of *Discinites delectus* as originally given, is as follows:

Strobili large, about 1.70 cm. in diameter and at least 10 cm. long, linear; sporangia ovoid; 1.75 × 2.50 mm., borne in pairs and in whorls spaced at intervals of 5 mm. on the axis, numerous (60 or more to a whorl) and closely packed; heterosporous; megasporangia and microsporangia similar except for spore contents and produced in the same whorls; microspores numerous, 75–90 microns in diameter, smooth; megaspores spherical or slightly ovoid, thin walled, smooth, 660–750 micra in greatest diameter, about 16 to a sporangium; a few aborted megaspores having about one-third the diameter of the mature ones; perispore probably present; tetrad scar conspicuous on both types.

To the foregoing description nothing need be added except to remark that the supposed pairing of the sporangia may be nothing more than an appearance resulting from compression.

Discinites delectus is similar in size to *D. Jongmansi*, but it is markedly smaller than the Bohemian forms described by Němejc which range from 2.50–4.00 cm. in diameter. In all species where the spores are known, heterospory exists with pronounced differences in size between the microspores and megaspores.

The fructification described and figured in the *Coal Flora* (46, Vol. III, Pl. CVII, Fig. 1) as *Lycopodites Lacoei* may belong to a species of *Discinites*. The horizontally arranged tubercles resemble the sporangia of *Discinites* as does also the slender form of the whole fructification.

Discinites delectus has been found only in the plant bed below Cycle "A" at Grand Ledge.

Discinites Jongmansi Hirmer and Guthörl

(Pl. XXVIII, Figs. 2–3)

The material assigned to *Discinites Jongmansi* is associated with *D. delectus*. The two species are distinguished by the outward appearance of the fructifications. In *D. delectus* the form of the sporophylls is not evident; only the whorled and neatly tiered sporangia constitute the external features. In *D. Jongsmani* the shield-shaped sporophylls show on the compression surfaces. These structures are a little less than 2 cm. in diameter and are spaced at intervals of approximately 5 mm. apart on the axis. The sporangia and spores have not been observed.

Since the two forms occur together in the same plant bed and are similar in size, the question arises whether the differences are the result of preservation.

Discinites Jongmansi was described by Hirmer and Guthörl (33) from the upper part of the Hendrik Group (upper part of lower Westphalian B) of Limburg, Holland.

CORDAITALES

To judge from the prevalence of the foliage and seeds throughout the Saginaw group, the environment at the time of deposition of the sediments must have been exceedingly favorable for the growth of *Cordaites*. From the Saginaw Coal to the Eaton sandstone the long ribbon-like or lanceolate leaves are present sometimes almost to the complete exclusion of other plants. Some of the clay ironstone nodules at Grand Ledge are made up mostly of compacted masses of these leaves lying either in contact or separated from each other by thin layers of clay. In the bed below Cycle "A" a few nearly complete leaves have been obtained.

The abundance of *Cordaites* leaves in the Coal Measures and the comparative scarcity of stem material has led to the supposition that the trees did not grow in the swamps but occupied higher ground some distance away. This may have been true for some species but certainly not for all, and the abundance of the leaves at some places indicates nearly pure stands of cordaitean trees in the swamps.

Specific determinations of cordaitean foliage have been founded upon a rather variable set of characters, that is, the outline of the leaf combined with the arrangement of the coarse and fine striations on the surface. It is not always possible to piece enough fragments together to determine the shape of the leaf, and venation characters distinguish only a few types. With leaves as large as these, size variation on a single tree must have been considerable. Five subgenera of *Cordaites* have been proposed by various authors (White, 64, p. 257) on differences expressed by size, form, shape of apex, and venation. These subgenera may have served to classify the specimens upon which they were based, but they are not especially useful for the reception of cordaitean leaves in general.

The difficulties attending the identification of cordaitean foliage are mainly responsible for the widespread neglect of them on the part of paleobotanists. They are often ignored in floristic studies or only casual reference is made to them. More care in collecting these leaves, with special effort to piece together whole specimens, and more attention given to associated seeds and inflorescences, would in time produce clearer information in regard to their classification. When the leaves are preserved in fine shales, the epidermis is sometimes retained and can be studied microscopically.

There is no infallible method for distinguishing the detached seeds of the seed ferns from those of the Cordaitales, although in general the oval radially symmetrical types (*Trigonocarpus*, *Rhabdocarpus*, *Pachytesta*, etc.) belong to seed ferns and the flat, winged, or samara type to the Cordaitales. There are no known instances of the seeds of the seed ferns having been borne in strobili, but the young ovules in *Cordaites* are situated between adpressed bracts of conelike inflorescences. Most of those seeds placed in the organ genera *Cardiocarpon* and *Cordaicarpus* are cordaitean. Those with a very broad wing are

usually assigned to *Samaropsis*. Some seed ferns, however, also have flat seeds.

Cordaites principalis (Germar) Geinitz

(Pl. XXX, Figs. 1–3; Pl. XXXI, Fig. 1)

This species is distinguished by the fine striations, one to five in number, present between each pair of coarser striations on the surface of the leaf. The fragments found at a number of localities in Michigan indicate that the complete leaves were large. None has been found complete, but one specimen from the shales below Cycle "A" at Grand Ledge is 46 cm. long and 4.2 cm. broad, with only a small part of the base missing (Pl. XXX, Figs. 1–2). Other pieces are slightly broader and were probably proportionally longer. The leaves are broadest at the middle and the margins taper gradually toward the apex and base. They are less obtuse and more pointed than those of most previously described members of this species.

The fragments from the United City Mine at Bay City listed by Cooper (18, p. 188) as *Cordaites* sp. show the characteristic surface striations when the compressions are examined with a lens. The specimen from the Owosso Coal Company mine which White (in Lane, 43, p. 44) determined as "*Cordaites*, probably *C. Robbii* Dn" is apparently the same.

This species is present in the ironstone nodules of Cycle "A" at Grand Ledge as well as in the shales below. Its distribution is probably wide in Michigan.

Cordaites palmaeformis (Goeppert) Weiss

(Pl. XXXI, Fig. 2)

Cordaites palmaeformis, identified so far only from the plant bed below Cycle "A" at Grand Ledge, has the veins of the leaves of equal size and close together. All of the specimens from Michigan that are assigned to this species are long lanceolate organs that must have been large. One specimen from the plant bed below Cycle "A" at Grand Ledge, which represents the lower middle portion of the leaf, is 45 cm. long, and widens from 4.5 cm. to 7.0 cm. from the basal portion forward. The complete leaf was probably a meter or more long. In

other fragment the apex tapers from a width of 2.3 cm. to a point over a length of 13 cm. The veins are approximately 0.25 mm. apart.

Cordaites crassinervis Heer

(Pl. XXX, Fig. 4)

A few fragments in the Eaton sandstone at Grand Ledge appear to be identical with *Cordaites crassinervis* described by Heer (30) from Switzerland. This form is characterized by the extreme coarseness of the venation. The veins (which were probably strongly fortified with sclerenchyma) are about 1 mm. broad and 2 mm. apart. There are no finer veins between them. Nothing is known of the size or shape of the leaves as all specimens that have been observed are small and incomplete.

Ginkgophyllum grandifolium (Lesquereux), comb. nov.

(Pl. XXXI, Fig. 3)

Cordaites grandifolius Lesquereux, 1880, p. 530; 1879, Pl. LXXVII, Figs. 1–2a.
Cordaites grandifolius White, 1899, p. 904.

Fragments of large wedge-shaped leaves were found in the plant bed below Cycle "A" at Grand Ledge. These are the same as the leaves described by Lesquereux in the *Coal Flora* under the name of *Cordaites grandifolius*, but should be placed in Saporta's genus *Ginkgophyllum* as defined by Gothan and Kukuk (27).

Small parts of the leaves of *Ginkgophyllum grandifolium* are easily confused with those of the genus *Cordaites*. This resemblance would explain why it has not been more often recognized in the late Pottsville, where it is may be more prevalent than generally realized.

The largest specimen found at Grand Ledge is 28 cm. long, and broadens from a width of about 1.3 cm. at the base to 12 cm. at the forward end. Neither the basal nor apical parts are complete. Another specimen 22 cm. long is 1 cm. broad at the base which appears to be the point of attachment to the stem. All of the specimens are split apically into narrow ribbon-like segments 2–6 cm. wide, and some of the segmentations extend nearly to the base. None of the specimens are sufficiently well-preserved to show the apex, but in the original account of the species Lesquereux (46, p. 530) says that the tip is rounded or truncate.

The complete length of any of the Grand Ledge leaves is unknown, but Lesquereux states that one specimen from Pittston, Pennsylvania, is 38 cm. long. Ours were no doubt fully as large. The venation is fairly coarse. All of the veins appear to be about the same size and are 0.5–0.6 mm. apart. No smaller veins are visible between these but very small deeply embedded strands may be present, although not seen. Lesquereux said that there is often an indistinct intermediate vein. The leaf becomes more coarsely striate in the narrow basal portion. The specimen illustrated (Pl. XXXI, Fig. 3) is a fragment of a large leaf. Originally, the specimen must have been at least twice as long, with the fan-shaped apical part probably split irregularly into segments of varying widths.

In addition to the "Sub-conglomerate" at Pittston, Pennsylvania, *Ginkgophyllum grandifolium* has been found in the upper Lykens division of the Pottsville in the southern anthracite coal field (White, 66, p. 904). It is also known to be rather common in the Pottsville of the eastern interior coal field at a level nearly equivalent to the Connoquenessing stage in Ohio, the stage which is characterized by the presence of *Megalopteris.*

Cordaicladus sp. (cf. *Cordaites principalis* (Germar) Geinitz)

(Pl. XXXI, Fig. 4; Pl. XXXII, Fig. 2)

A few carbonized stem fragments of *Cordaites* having the characteristic transversely elongated leaf scars were found in the quarries at Grand Ledge. At least two species are present and the one which comes from the shales below Cycle "A" appears to be identical with the stem identified by Seward (57, p. 232, Fig. 466C) as *C. principalis.*

The scars are 5 to 7 mm. broad and slightly curved, and the low cushions upon which they are situated are decurrent for a distance of about one centimeter. The sloping surface is ornamented with vertical striations. The scars within a spiral are about 18 mm. apart, and those within adjacent spirals alternate.

At Grand Ledge this stem is intimately associated with the foliage of *Cordaites palmaeformis* and *C. principalis* and with that of *Ginkgophyllum grandifolium.*

Cordaicladus intermontanus, sp. nov.

(Pl. XXXII, Fig. 1)

The specimen on which the following description is based came from the shales above the Grand Ledge Coal in the quarry of the Grand Ledge Clay Products Company. The exact horizon is unknown but presumably it is from Cycle "C" or "D."

Stem large; leaf scars oval and transversely placed and situated upon low, only slightly decurrent cushions, in spiral sequence, distant; surface of scar ornamented with transverse row of bundle scars slightly above the middle; surface of stem between scars covered with vertical striations; inflorescence scar a circular print on stem above leaf scar.

This species differs markedly from the previously described stem (*Cordaicladus* sp.) in the scars being larger, more oval, and more distantly spaced. The oval prints are 8 mm. high and 14 mm. broad and occupy the summit of low elevations which are only very slightly raised above the surface of the stem. Judging from the shape of the scar, the leaf was attached by a thickened base. Scars within the same spiral are 25 to 28 mm. apart. The inflorescence scar is about 5 mm. in diameter and is situated one or two millimeters above the leaf scar. The vertical striations on the stem are fine, there being about 12 to a centimeter. They follow a perfectly straight course without curvature.

Cordaicladus intermontanus has not been found associated with recognizably cordaitean foliage. It seems to represent a distinct type of stem in the Michigan Coal Basin and so is described as a new species.

Cordaianthus devonicus (Dawson) Stopes

(Pl. XXXIII, Fig. 1)

Fragments of spikelike cordaitean inflorescences occur among the leaf and seed remains in the shales at Grand Ledge. Specific determinations of these fossils are difficult; there appear to be at least two forms, distinguishable principally by size. The smaller of the two bears the seed that has been described as *Samaropsis ampullacea* (Bell, 12), and may appropriately receive the designation *Cordaianthus ampullaceus* (see following description). The larger inflorescence has not been found with seeds attached but is associated with *Cardiocarpon late-alatum.*

The larger inflorescence type is assigned to *Cordaianthus devonicus* on the basis of the description and figures of Stopes (60, p. 85, Pl. XXII, Fig. 57; Pl. XXV, Fig. 66). In the most complete specimen the central stalk is 12 cm. long and tapers from 4 to 2 mm. from the base to the tip. The spikelets, which are 7 mm. broad and 10 mm. long, are suboppositely arranged and are spaced from 10 to 12 mm. apart. The acicular bracts subtending each of the spikelets are seldom preserved but they are at least 22 mm. long. Exclusive of the bracts, the whole inflorescence is about 2 cm. broad. The material bears considerable resemblance to the inflorescence which Lesquereux described from the "Sub-conglomerate" at Pittston, Pennsylvania, as *Cordaianthus spicatus* (46, p. 802, Pl. CIX, Fig. 1), but differs in having a more slender stalk and in lacking the distinct lengthwise ridge which Lesquereux figures on the surface of the structure he calls the "seed." In interpreting the scaly dwarf shoot of the inflorescence as a nutlet or seed Lesquereux was mistaken concerning its morphology. As the seeds have usually been shed previous to fossilization they are rarely observed attached, and the overlapping fibrous scales sometimes present the deceptive appearance of the outer protective layers of a seed or an achene-like fruit.

Another species to which the Grand Ledge material bears a close resemblance is *Cordaianthus femina* which was described by Grand-'Eury from France (28, p. 279, Pl. XXXIII, Fig. 1). Lesquereux mentioned the resemblance between this species and his *C. spicatus* but concluded that they were different. His decision concerning distinctive characters of *C. spicatus* was probably the result of his misinterpretation of the morphology of the spikelets. Whatever resemblances there might be between *C. devonicus*, *C. femina*, and *C. spicatus*, the first specific name has priority as it was proposed by Dawson in 1868 on the assumption held at that time that the plant-bearing beds at St. John were of Devonian age. The type specimen of *C. devonicus* (according to Stopes) is not well preserved, the plant substance being reduced to a film of graphite in which many of the details are obliterated. The general resemblance between the St. John species and the Michigan material is strong and is believed to be sufficient to indicate specific identity.

Cordaianthus devonicus bears considerable resemblance to the inflorescences that are usually assigned to *C. Pitcairniae*. The original

figures of this species by Lindley and Hutton (47, Pl. 82) are crude and do not serve well as a basis for comparison, but one of them shows a stout stalk bearing rather large spikelets. *C. Pitcairniae* is said to have borne the rather small seed known as *Samaropsis acuta* which has not been recognized in the Michigan Coal Basin.

Cordaianthus ampullaceus (Bell), comb. nov.

(Pl. XXXIII, Figs. 2–6)

Under this name are included the smaller of the cordaitean inflorescences, and the distinctive flask-shaped seed described by Bell (12, p. 104) from the Morien series of Nova Scotia as *Samaropsis ampullacea*. This seed is characterized by the elongated micropylar beak which includes about one-third of the length of the body. It has been encountered in large numbers in the shales below Cycle "A" in the quarries at Grand Ledge, and in several instances hundreds were observed strewn over the surfaces of the slabs. Although apparently local in its distribution, the number of specimens seen of this seed exceeds that of any other plant fossil in the Michigan Coal Basin.

The seeds vary slightly in size but the majority of them are from 9 to 10 mm. in width and from 17 to 21 mm. in length. Bell says the Nova Scotia specimens attain a width of 12 to 14 mm. and a length of 20 mm., but no individuals have been observed in Michigan which are quite as broad. Bell apparently gives the maximum dimensions of his seeds, and it is believed that the difference in size is not sufficiently great to be important. The nucule, or central portion of the seed, is rounded or slightly indented at the base and pointed above. The nucule is surrounded by a flattened winglike border about 2 mm. wide. It is nearly uniform in width around the body of the seed but diminishes gradually toward the tip of the neck.

In one instance a seed was found attached by a stalk 7 mm. long to the axillary dwarf shoot of an inflorescence of the *Cordaianthus* type, thus proving its identity with the Cordaitales (Pl. XXXIII, Fig. 4). The fructification to which the seed was attached is smaller than *C. devonicus* and less well preserved.

In *Cordaianthus ampullaceus* the slender inflorescence axis bears its dwarf seed-bearing shoots at intervals of about 5 mm. Each dwarf shoot with its complement of small overlapping scales is an oval struc-

ture about 6 mm. long and is situated within the axil of a long slender bract which was 1.5 cm. or more in length (Pl. XXXIII, Figs. 2–3). The inflorescence is similar to many that are often casually inferred to be *C. Pitcairniae*, but because of the distinctive character of the seeds it is regarded as different from anything that has previously been referred to that species.

The seed which White (in Lane, 43, p. 44) determined as *Cardiocarpon cuyahoga* belongs to this species.

Cardiocarpon late-alatum Lesquereux

(Pl. XXXIV, Fig. 2)

This seed occurs at Grand Ledge in association with that of *Cordaianthus ampullaceus*, but differs from it in lacking the pronounced micropylar prolongation and in having the wing slightly broader at the apex than at the base. In *C. ampullaceus* the wing is nearly of constant width all the way around. *C. late-alatum* is a round-ovate seed 9–11 mm. broad and about 11 mm. long. The nucule is nearly circular, shows no indentation at the base, and is very obtusely pointed at the apex. The apex of the seed is also obtusely pointed but not as much so as the nucule due to the slight broadening of the wing along the micropyle above the nucule. There is a slight indentation at the base of the seed where the slender stalk was attached.

The seeds from Grand Ledge are assigned to this species on the basis of their identity with the seeds from Pittston, Pennsylvania, figured by Lesquereux (Atlas, Pl. LXXXV, Figs. 46–47) for *Cardiocarpon late-alatum*. His figures are apparently the only ones of this seed ever published, and after allowing for an inevitable range of variation, the Michigan specimens agree well with the description. White stated (66, p. 908) that in the Sewanee zone of the Pottsville *C. late-alatum* intergrades with *C. elongatum*, which Newberry (50, p. 373, Pl. 43, Fig. 5) described from the Sharon Coal of Ohio. The specimens from Grand Ledge are similar to the single seed figured by Newberry, but are distinguishable from it by the broader and less elongated form. It seems not improbable that *C. minus*, also described by Newberry from the Sharon Coal, may be a variant of the *C. late-alatum* group, although it is slightly larger than typical examples and the wing is narrower in proportion to the size of the nucule.

While *Cardiocarpon late-alatum* may have been borne on the inflorescence described here under the name *Cordaianthus devonicus*, there is no evidence of their connection other than that of association.

Cardiocarpon annulatum Newberry

(Pl. XXXIV, Figs. 1, 3)

This rather distinctive species is represented by a number of specimens in the shales below Cycle "A" in the quarries at Grand Ledge. These seeds, which are nearly circular in outline, measure about 20 mm. in diameter. The central part, or nucule, is also nearly circular but very slightly beaked at the apex and shallowly indented at the base. The thin border-like wing is about 5 mm. wide, and maintains about the same width all the way around the seed. The outlet of the micropyle is marked by a shallow notch, and there is no prolongation of the wing at the apical end of the seed.

Several specimens have been found, but *Cardiocarpon annulatum* is not as abundant as *"Samaropsis" ampullacea* or *Cardiocarpon late-alatum*, and is more local in occurrence. It appears to be a cordaitean seed, although it has not been found attached to such a fructification and is considerably larger than the seeds that have been found attached. As with the other plant groups of the Carboniferous, the complete range of form among the Cordaitales in either the vegetative or reproductive organs is unknown, so these large seeds may represent certain of the more unusual or less frequent cordaiteans that differ somewhat from the better-known forms. The association of *Cardiocarpon annulatum* with *Ginkgophyllum grandifolium* at Grand Ledge should be emphasized, because the seeds produced by a tree bearing this unusual leaf probably also differed from the more typical cordaitean seeds. *Ginkgophyllum grandifolium* and *Cardiocarpon annulatum* also occurred together in the "Interconglomerate" at Pittston, Pennsylvania (46, p. 856).

Cardiocarpon annulatum was first described by Newberry (50, p. 374) from the shale over the Sharon Coal. It has also been reported from the "Sub-conglomerate" of Arkansas (46, p. 854) and from the Upper Intermediate division of the Pottsville in the type section (White, 66, p. 801). Its stratigraphic range, therefore, appears to be from the roof of the Sharon Coal (believed by White to be ap-

proximately equivalent to the Lykens Coals Nos. 2 and 3) to near the top of the Pottsville series.

Artisia sp.

(Pl. XXXIV, Fig. 4)

A cordaitean pith cast from Grand Ledge resembles *Artisia approximata* except for the presence of low tubercles which apparently represent the position of branches. These tubercles show a spacing similar to the leaf scars on compressions of the *Cordaicladus* believed to represent *Cordaites principalis*. The specimen represents an unusual condition, because in most cordaitean stems the branches were more distantly spaced, as in Recent conifers, and did not arise from buds situated in the axils of all the leaves.

LITERATURE CITED

1. ANDREWS, E. B. 1875. Descriptions of Fossil Plants from the Coal Measures of Ohio. Rept. Geol. Surv. Ohio, Paleontol., 2.
2. ARBER, E. A. N. 1914. A Revision of the Seed Impressions of the British Coal Measures. Ann. Bot., 28, pp. 81–108.
3. ——— 1922. Critical Studies of Coal-Measure Plant Impressions. Journ. Linn. Soc. London, Bot., 46, pp. 171–217.
4. ARNOLD, C. A. 1930. A Petrified Lepidophyte Cone from the Michigan Coal Basin. Amer. Journ. Bot., 17, pp. 1028–32.
5. ——— 1934. A Preliminary Study of the Fossil Flora of the Michigan Coal Basin. Contrib. Mus. Paleontol. Univ. Mich., 4, pp. 177–204.
6. ——— 1937. The Seeds of Alethopteris, and Other Pteridosperms from North America. Compt. rend. 2ème congr. strat. carb. Heerlen, 1935, 1, pp. 41–45.
7. ——— 1944. A Heterosporous Species of Bowmanites from the Michigan Coal Basin. Amer. Journ. Bot., 31, pp. 466–69.
8. ——— 1948. Some Cutinized Seed Membranes from the Coal-bearing Rocks of Michigan. Bull. Torrey Bot. Club, 75, pp. 131–46.
9. ——— and STANLEY, G. M. 1947. Pennsylvanian Plants from the Glacial Drift near Jackson, Michigan. Papers Mich. Acad., 31, pp. 247–50.
10. BARTLETT, H. H. 1929. Fossils of the Carboniferous Coal Pebbles of the Glacial Drift at Ann Arbor. Papers Mich. Acad., 9, pp. 11–28.
11. BASSLER, H. 1919. A Sporangiophoric Lepidophyte from the Carboniferous. Bot. Gaz., 68, pp. 73–108.
12. BELL, W. A. 1938. Fossil Flora of the Sydney Coalfield. Canada Dept. Mines and Res., Geol. Surv. Mem., 215.
13. ——— 1940. The Pictou Coalfield, Nova Scotia. *Ibid.*, 225.

14. ——— 1944. Carboniferous Rocks and Fossil Floras of Northern Nova Scotia. *Ibid.*, 238.
15. BERGQUIST, S. G. 1939. The Occurrence of Spore Coal in the Williamston Basin, Michigan. Journ. Sed. Petrol., 9, pp. 14–19.
16. BERTRAND, P. 1930. Bassin houiller de la Sarre at de la Lorraine. I. Flore Fossile. Fasc. 1. Neuropteridées. Étude gîtes minér. France. Paris.
17. BRONGNIART, A. 1922. Sur la classification et la distribution des végétaux fossiles en general, et sur ceux terraines de sediment superieur en particulier. Mém. mus. d'hist. nat., 8, pp. 203–40.
18. COOPER, W. F. 1906. Geological Report on Bay County. Rept. State Bd., Geol. Surv. Mich., 1905. Lansing.
19. CORSIN, P. 1932. Guide paleontologique dans le terrain houiller du nord de la France. Trav. et mém. l'univ. Lille, Fasc. 5. Lille.
20. CROOKALL, R. 1929. Coal Measure Plants. London.
21. DARRAH, W. C. 1938. The Occurrence of the Genus Tingia in Texas. Harvard Univ. Bot. Mus., Leaflet 5, pp. 173–88.
22. DIX, E. 1933. The Succession of Fossil Plants in the Millstone Grit and the Lower Portion of the Coal Measures of the South Wales Coal Field (near Swansea) and a Comparison with Other Areas. Palaeontographica, 78 B, pp. 158–202.
23. ——— 1934. The Sequence of Floras of the Upper Carboniferous with Special Reference to South Wales. Trans. Roy. Soc. Edinburgh, 57, pp. 789–838.
24. ——— 1937. The Succession of Fossil Plants in the South Wales Coal Field with Special Reference to the Existence of the Stephanian. Compt. rend. 2ème congr. strat. carb. Heerlen, 1935, 1, pp. 159–84.
25. ETTINGSHAUSEN, C. VON. 1852. Die Steinkohlenflora von Stradonitz in Böhmen. Abh. K. K. Geol. Reichsanst. Bd. I. Abt. 3. Wein.
26. FEISTMANTEL, O. 1874–76. Die Versteinerungen der böhmischen Ablagerungen. Palaeontographica, 23.
27. GOTHAN, W., and KUKUK, P. 1933. Ueber das sogenannte "Psygmophyllum" delvali Cambier und Renier. Sitzb. Gessell. naturf. Freunde, 1933, pp. 66–77.
28. GRAND'EURY, C. 1877. Mémoire sur la flore carbonifère du département de la Loire et du centre de la France. Mém. l'acad. sci., de l'inst. nat. France, 24.
29. HALLE, T. G. 1933. The Structure of Certain Fossil Spore-bearing Organs Believed to Belong to Pteridosperms. Kungl. Svenska Vetenskapsakad., Handl. III, 12(6).
30. HEER, O. 1877. Flora fossilis Helvetiae. Die Vorweltiche Flora der Schweiz. Zürich.
31. HEMINGWAY, W. 1941. On the Coal Measure Plant, Aulacotheca. Ann. Bot., n. s., 5, pp. 197–201.
32. HENDRICKS, T. A., and READ, C. B. 1934. Correlation of Pennsylvanian

Strata in Arkansas and Oklahoma Coal Fields. Amer. Assn. Petrol. Geol. Bull., 18, pp. 1050–58.

33. HIRMER, M., and GUTHÖRL, P. 1940. Die Karbonflora des Saargebietes. Noeggerathiineae. Palaeontographica, Suppl. 9.
34. HOUGHTON, D. 1840. Geological Reports, 1837–1845. (Republished.) Lansing: Mich. Hist. Comm. 1928.
35. JANSSEN, R. 1940. Some Fossil Plant Types of Illinois. Ill. State Mus. Sci. Paper, 1. Springfield.
36. JONGMANS, W. J. 1929. Fossilium Catalogus II: Plantae. Lycopodiales II. Berlin.
37. ——— 1937. Comparisons of the Floral Succession in the Carboniferous of West Virginia with Europe. Compt. rend. 2ème congr. strat. carb. Heerlen, 1935, 1, pp. 393–415.
38. ——— and GOTHAN, W. 1933. Florenfolge und vergleichende Stratigrafie des Karbons der östlichen Staaten Nord-Amerika's. Geol. Bur. Heerlen (Holland), pp. 17–44.
39. KELLY, W. A. 1933. Pennsylvanian Stratigraphy near Grand Ledge, Michigan. Journ. Geol., 41, pp. 77–89.
40. ——— 1936. The Pennsylvanian System of Michigan. Ann. Rept. Mich. Geol. Surv., Div., Publ. 40, Geol. Ser. 34, pp. 155–226.
41. KIDSTON, R. 1923, 1923–25. Fossil Plants of the Carboniferous Rocks of Great Britain. Mem. Geol. Surv. Great Brit., Palaeontol., 2(1), 1923; 2(2), 1923–25.
42. ——— and JONGMANS, W. J. 1915, 1917. A Monograph of the Calamites of Western Europe. Mededeel. Rijksops. Delfst., No. 7. The Hague. Atlas, 1915; text, 1917.
43. LANE, A. C. 1902. Coal in Michigan. Mich. Geol. Surv., 8(2). Lansing.
44. ——— 1908. Ninth Annual Report of the State Geologist. Rept. State Bd., Geol. Surv. Mich., 1907. Lansing.
45. ——— 1909. Tenth Annual Report of the State Geologist. *Ibid.*, 1908.
46. LESQUEREUX, L. 1879, 1880, 1884. Description of the Coal Flora of the Carboniferous Formation in Pennsylvania and Throughout the United States. Second Geol. Surv. Pennsylvania. Rept. Progress P, Harrisburg. Atlas, 1879; Vols. 1 and 2, 1880; Vol. 3, 1884.
47. LINDLEY, J., and HUTTON, W. 1833–35. The Fossil Flora of Great Britain. II. London.
48. MOORE, R. C., and others. 1944. Correlation of Pennsylvanian Formations of North America. Bull. Geol. Soc. Amer., 55, pp. 657–706.
49. NĚMEJC, F. 1941. Weitere Fructifikationen vom Typus *Discinites* nebst einigen Bemerkungen über die *Archaeopteriden* der mittelböhmischen Kohlenbecken. Mitteil. Tschech. Akad. Wiss., 1941, pp. 1–13.
50. NEWBERRY, J. S. 1873. Descriptions of Fossil Plants from the Coal Measures of Ohio. Rept. Geol. Surv. Ohio, 1(2).
51. NOÉ, A. C. 1925. Pennsylvanian Flora of Northern Illinois. Ill. Geol. Surv. Bull., 52.

52. POTONIÉ, H. 1907. Abbildungen und Beschreibungen fossiler Pflanzen-Reste. Küngl. Preuss. Geol. Landesanst., Lief. V. Berlin.
53. READ, C. B. 1934. A Flora of Pottsville Age from the Mosquito Range, Colorado. U. S. Geol. Serv., Prof. Paper 185–D.
54. ——— 1947. Pennsylvanian Floral Zones and Floral Provinces. Journ. Geol., 60, pp. 271–79.
55. SCHOPF, J. M. 1941. Notes on the Lepidocarpaceae. Amer. Midl. Nat., 25, pp. 548–63.
56. SELLARDS, E. H. 1908. Fossil Plants of the Upper Paleozoic of Kansas. Univ. Geol. Surv. Kansas, 9, pp. 386–480.
57. SEWARD, A. C. 1917. Fossil Plants. Vol. III. Cambridge Univ. Press.
58. STERNBERG, K. GRAF VON. 1825. Versuch einer Geognostisch-Botanischen Darstellung deren Flora der Vorwelt.
59. STOCKMANS, F. 1933. Les Neuropteridées des bassins houillers Belges. Mém. mus. roy. d'hist. Nat., 57. Brussels.
60. STOPES, M. C. 1914. The "Fern Ledges" Carboniferous flora of St. John, New Brunswick. Canada Dept. Mines and Res. Geol. Surv. Mem., 41.
61. STUR, D. 1877. Die Culm-Flora der ostrauer und Waldenburger Schichten. Akad. K. K. Geol. Reichsanst., 8(2).
62. WHITE, D. 1893. Flora of the Outlying Carboniferous Basins of Southwestern Missouri. U. S. Geol. Surv. Bull., 98.
63. ——— 1897–98. Report on Fossil Plants from the McAlester Coal Field, Indian Territory, collected by Messrs. Taft and Richardson in 1879. Nineteenth Ann. Rept. U. S. Geol. Surv., 3, Econ. Geol., pp. 457–534.
64. ——— 1899. Fossil flora of the Lower Coal Measures of Missouri. U. S. Geol. Surv. Monogr., 37.
65. ——— 1900. Relative Ages of the Kanawha and Allegheny Series as Indicated by the Fossil Plants. Bull. Geol. Soc. Amer., 11, pp. 145–78.
66. ——— 1900. The Stratigraphic Succession of the Fossil Floras of the Pottsville Formation of the Southern Anthracite Coal Field. Twentieth Ann. Rept. U. S. Geol. Surv., II.
67. ——— 1903. Age of the Mercer group. Science, n. s., 17, p. 942.
68. ——— 1913. The Fossil Flora of West Virginia. Geol. Surv. W. Va., 5(2), pp. 390–453.
69. ——— 1943. Lower Pennsylvanian Species of Mariopteris, Eremopteris, Diplothmema, and Aneimites from the Appalachian Region. (ed. C. B. Read). U. S. Geol. Surv., Prof. Paper 197-C.
70. WINCHELL, A. 1861. First Biennial Rept. Mich. Geol. Surv. Lansing.
71. WOOD, H. C. 1866. A Contribution to the Knowledge of the Coal Period in the United States. Trans. Amer. Phil. Soc., 13, pp. 341–49.
72. ZEILLER, R. 1886, 1888. Flore fossile du bassin houiller Valenciennes. Étude gîtes minér. France. Atlas, Paris, 1886; Texte, Paris, 1888.

PLATE I

Fossil plants from the Bela Hubbard and Alexander Winchell collections.

1. Pith cast of *Cordaites* (*Artisia*). No. 24913
2. Indeterminate stem fragment. No. 24914
3. Pith cast of *Calamites*. No. 24915
4. Imprint of *Calamites* node. No. 24916
5. Imprint of decorticated *Lepidodendron* stem (cf. *L. aculeatum*). No. 24917

PLATES AND DESCRIPTIONS

PLATE I

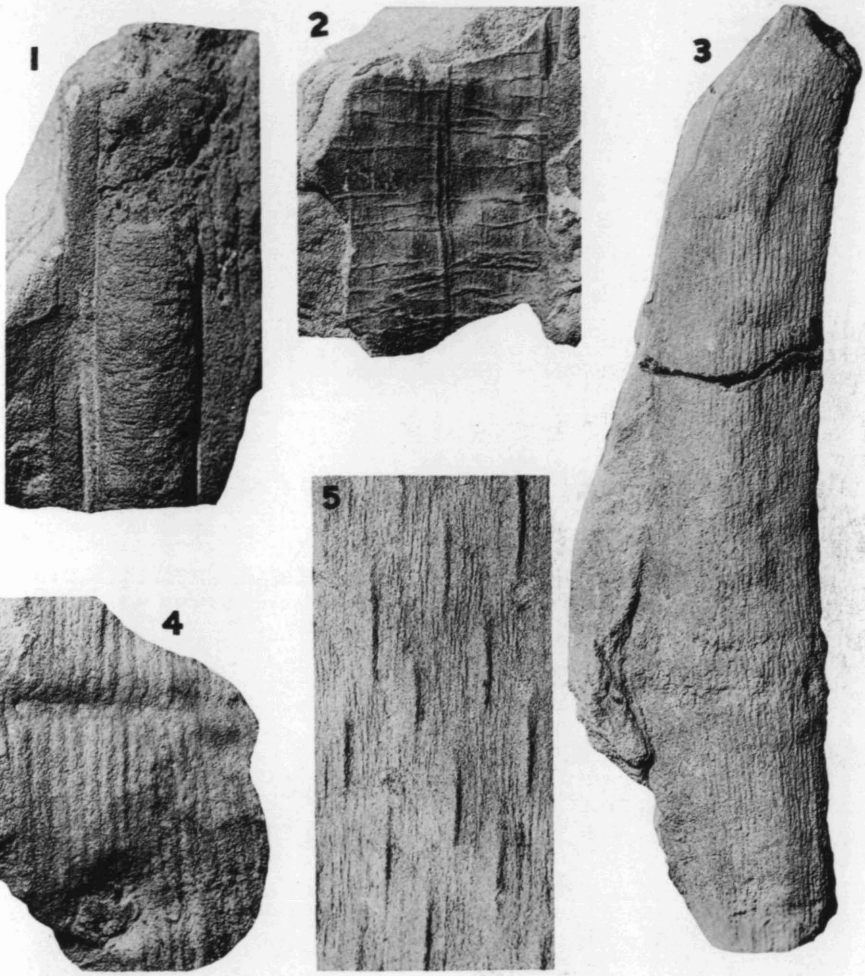
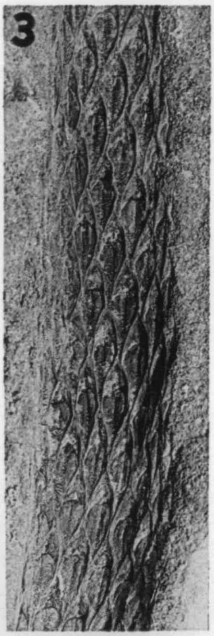


PLATE II


1


2


3


4


5

PLATE II

1. *Lepidodendron aculeatum.* Big Chief No. 8 Mine, St. Charles. No. 24918
2. *Lepidodendron Brittsii.* Big Chief No. 8 Mine, St. Charles. No. 24920
3. *Lepidodendron aculeatum.* Mason, Ingham County. No. 24921
4. Specimen shown in Fig. 3, enlarged
5. *Lepidodendron vestitum.* Big Chief No. 8 Mine, St. Charles. No. 24922

PLATE III

1. *Lepidodendron obovatum.* Williamston. No. 24923
2. *Lepidodendron obovatum.* Williamston. No. 24924
3. *Lepidodendron modulatum.* Standard Mine. No. 24925
4. *Lepidodendron ophiurioides*, sp. nov. Big Chief No. 8 Mine, St. Charles. No. 24929

PLATE III

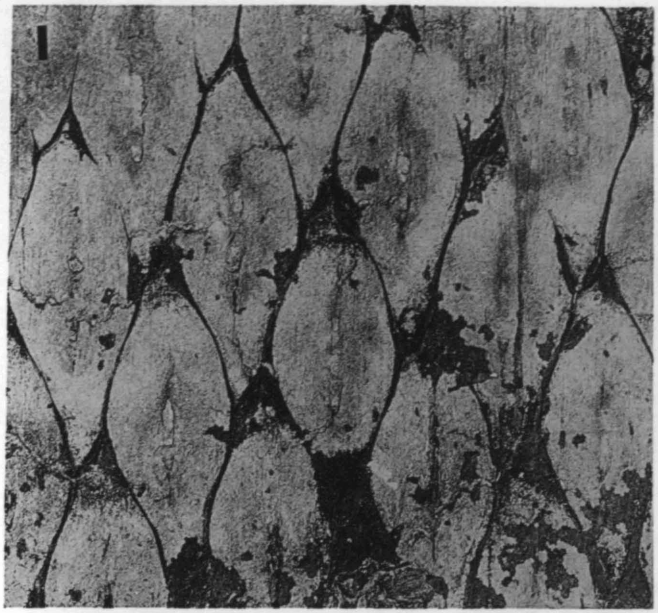


PLATE IV

PLATE IV

1. *Lepidodendron ophiurioides*, sp. nov. Part of specimen shown in Fig. 2, enlarged
2. *Lepidodendron ophiurioides*, sp. nov. Big Chief No. 8 Mine, St. Charles. Holotype. No. 24930
3. *Lepidodendron ophiurioides*, sp. nov. Big Chief No. 8 Mine, St. Charles. No. 24931
4. *Lepidodendron Rhodeanum*. Jackson. No. 11313
5. *Lepidodendron ophiurioides?* Grand Ledge. No. 24933

PLATE V

Lepidodendron lanceolatum. Grand Ledge. S. H. Perry Collection. No. 24934

PLATE V

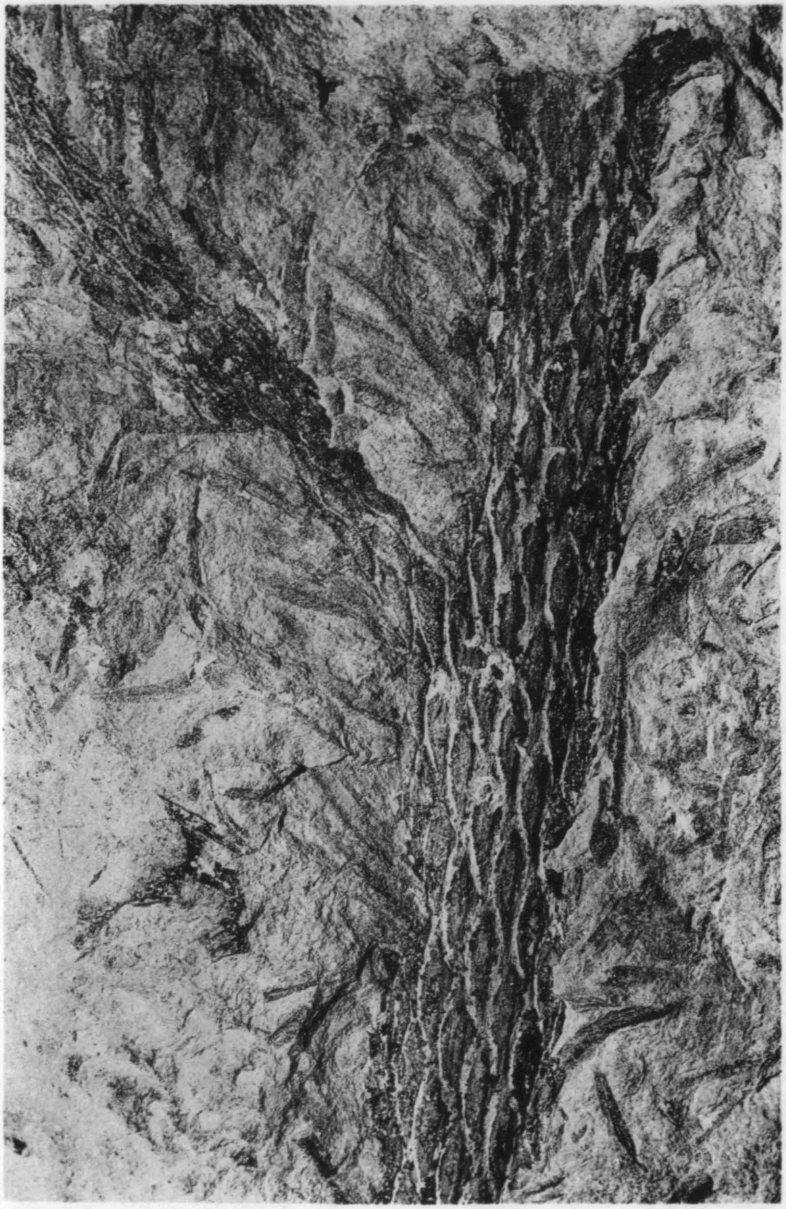


PLATE VI

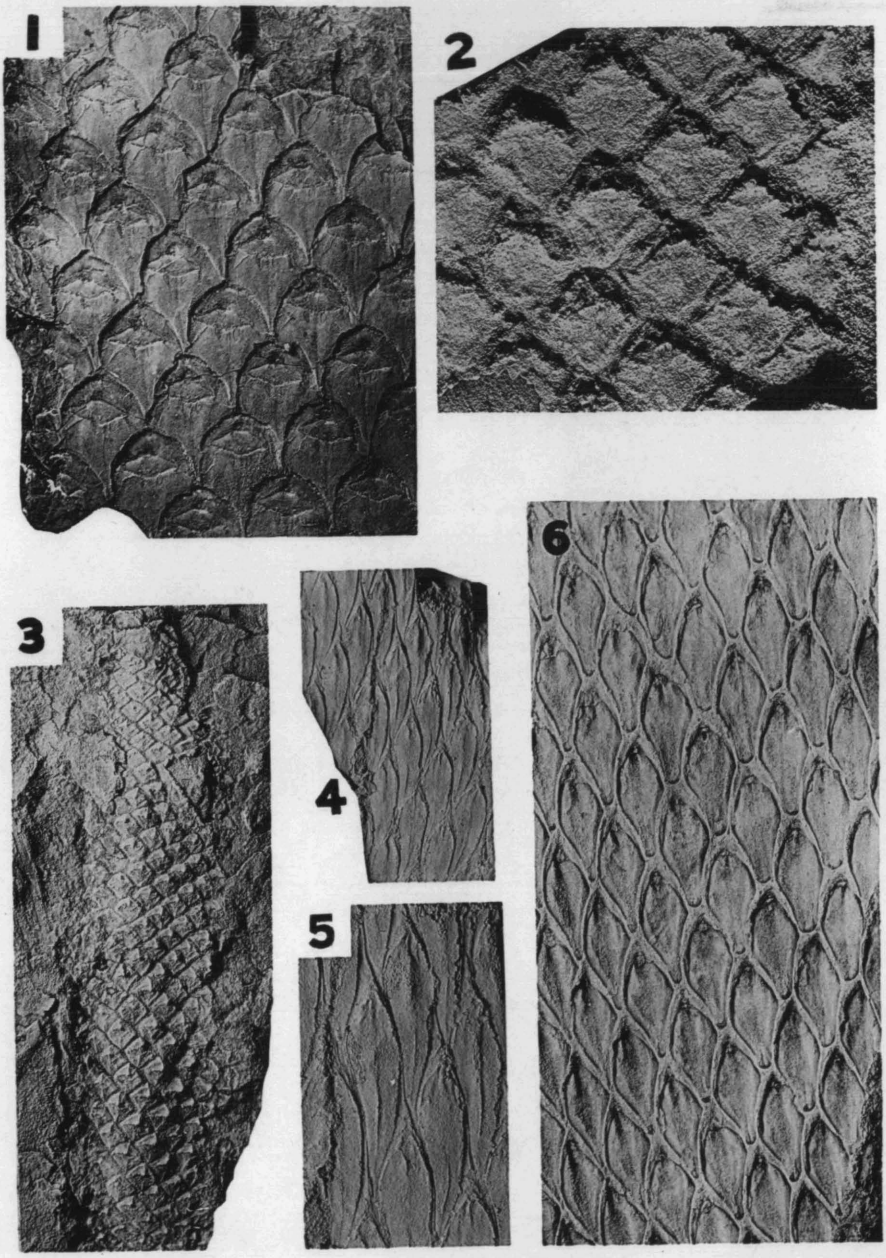


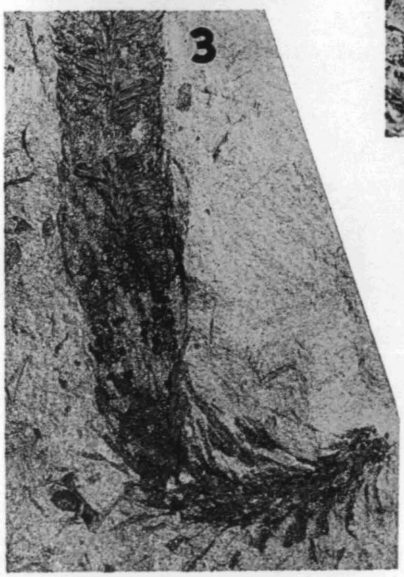
PLATE VI

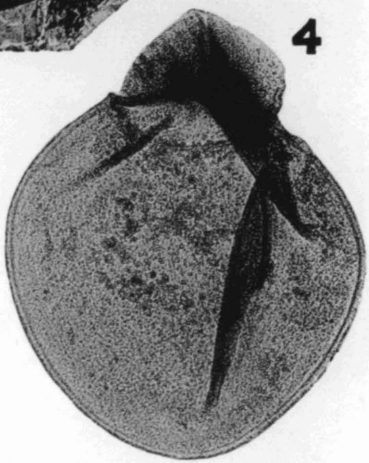
1. *Lepidodendron Rhodeanum.* Jackson. No. 11313
2. *Lepidodendron dichotomum.* Specimen shown in Fig. 3, enlarged
3. *Lepidodendron dichotomum.* Williamston. No. 24928
4. *Lepidodendron lanceolatum.* Quarry of Grand Ledge Clay Products Company. No. 24937
5. Specimen shown in Fig. 4, enlarged
6. *Lepidodendron lanceolatum.* Grand Ledge. No. 24940

PLATE VII

1. *Lepidostrobus* sp. Grand Ledge. S. H. Perry Collection. No. 24942
2. *Bothrodendron minutifolium*. Big Chief No. 8 Mine, St. Charles. No. 24943
3. *Lepidostrobus* sp. Grand Ledge. S. H. Perry Collection. No. 24942
4. Megaspore (*Lagenicula* type) from *Lepidostrobus* sp. shown in Fig. 3. ×75. No. 24958

PLATE VII






1

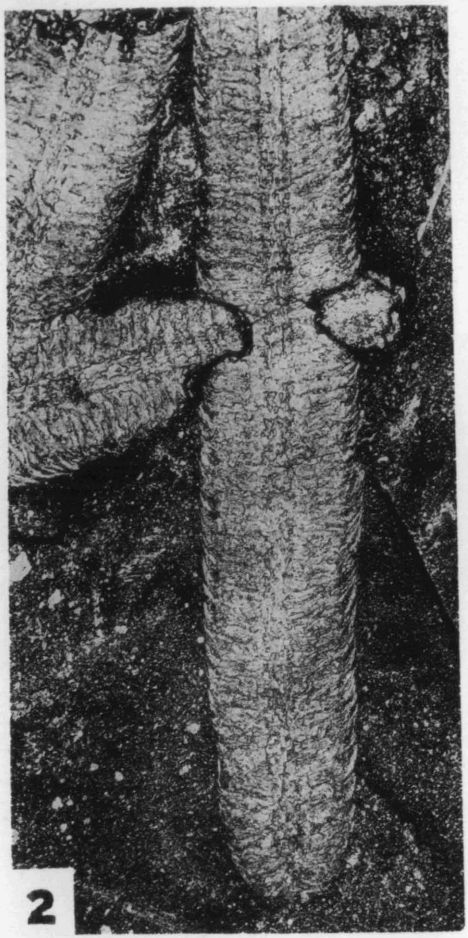

2

PLATE VIII

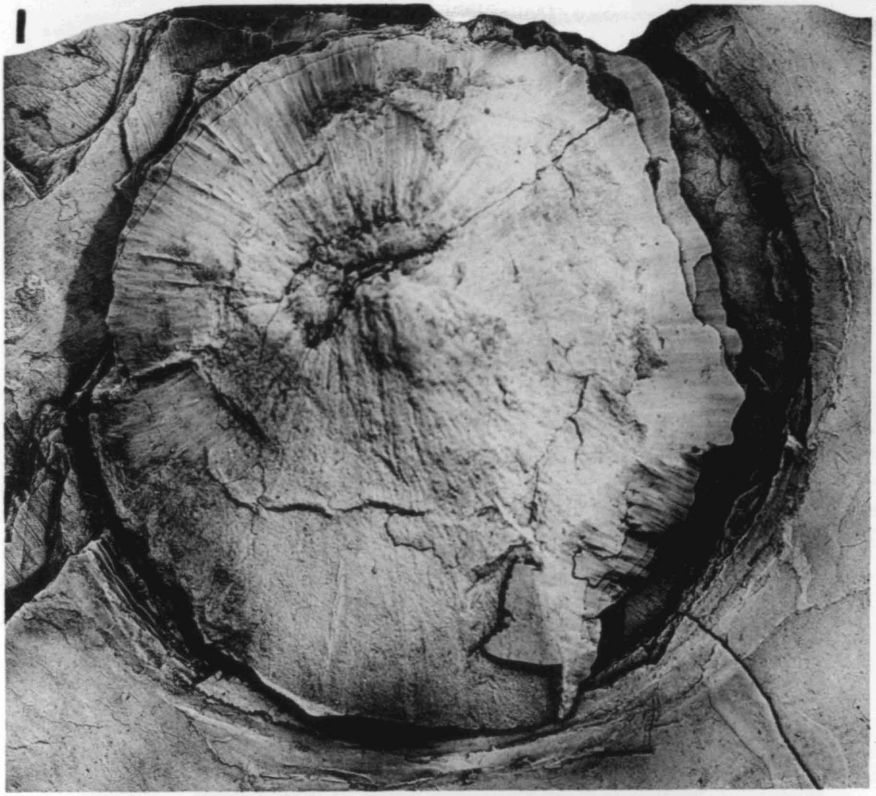
1. *Lepidostrobus* sp. Big Chief No. 8 Mine, St. Charles. No. 24944
2. *Lepidostrobus* sp. Grand Ledge, south bank of Grand River, one-half mile north of quarry of Grand Ledge Face Brick Company. Collected by W. A. Kelly. No. 24945

PLATE IX

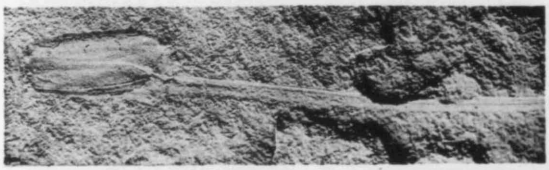
1. *Bothrodendron punctatum.* St. Charles-Garfield Mine, Eastwood. No. 25088
2. *Lepidocarpon linearifolium.* Williamston. No. 24946
3. *Lepidocarpon linearifolium.* Specimen shown in Fig. 2, enlarged

PLATE IX

1

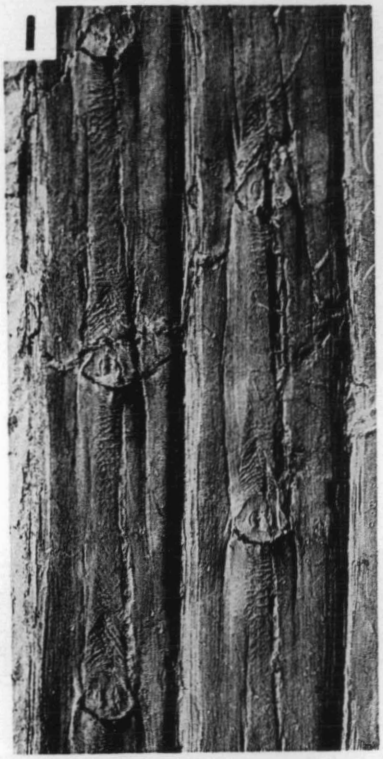


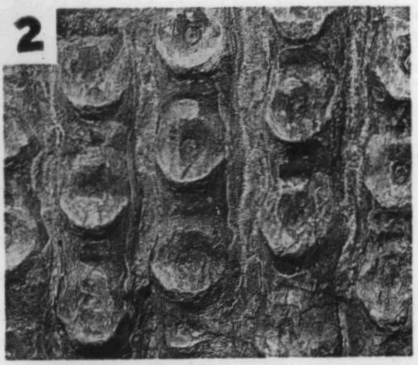
2

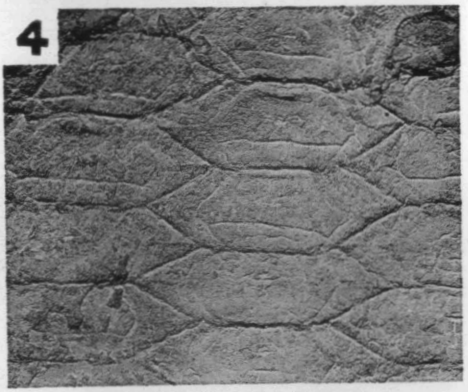


3

PLATE X







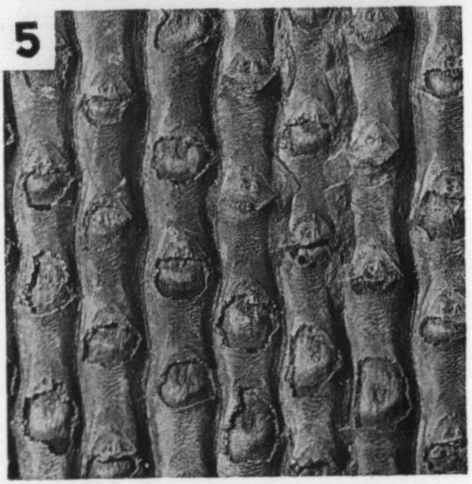


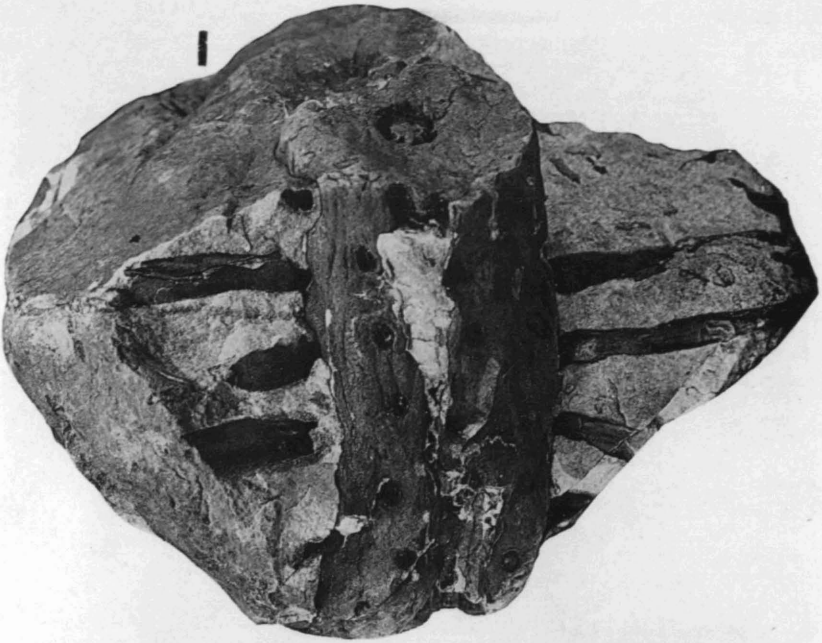
PLATE X

1. *Sigillaria scutellata.* Grand Ledge. No. 24947
2. *Sigillaria* sp. (cf. *S. mamillaris*). Quarry of Grand Ledge Clay Products Company. No. 24952
3. *Sigillaria* sp. (*Favularia* type). Jackson. No. 24953
4. Specimen shown in Fig. 3, enlarged
5. *Sigillaria scutellata.* Grand Ledge. No. 24948

PLATE XI

1. *Stigmaria ficoides.* Glacial drift, Jackson. No. 24954
2. *Stigmaria ficoides.* St. Charles-Garfield Mine, Eastwood. One-half natural size. No. 24955
3. *Asolanus camptotaena.* Grand Ledge. S. H. Perry Collection. No. 24956

PLATE XI



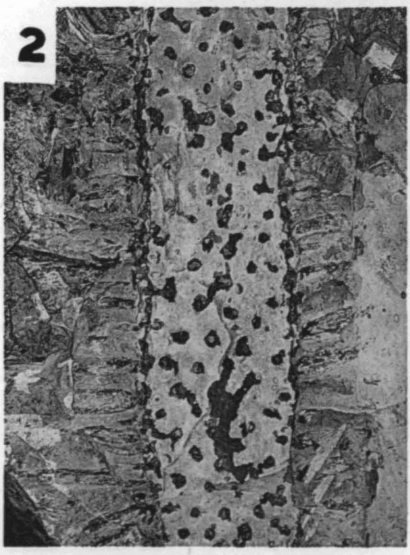


PLATE XII

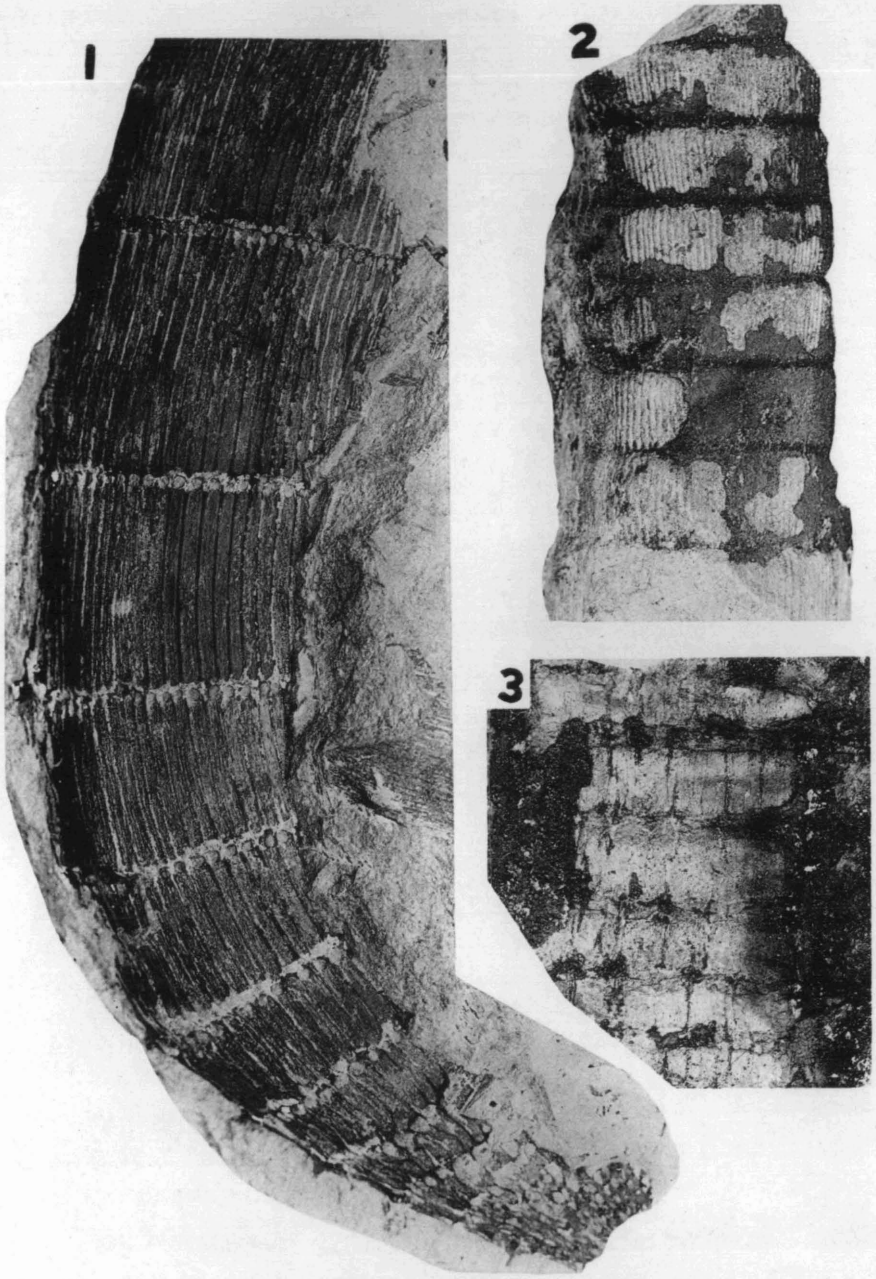


PLATE XII

1. *Calamites Suckowii.* Quarry of Grand Ledge Clay Products Company. No. 24959
2. *Calamites approximatus.* Quarry of Grand Ledge Clay Products Company. No. 24960
3. *Calamites* sp. Stem surface. Quarry of Grand Ledge Clay Products Company. No. 24961

PLATE XIII

1. *Calamites approximatus.* NW. corner sec. 15, Rives Township, Jackson County. No. 24962
2. *Calamites schützeiformis.* Quarry of Grand Ledge Clay Products Company. No. 24963

PLATE XIII

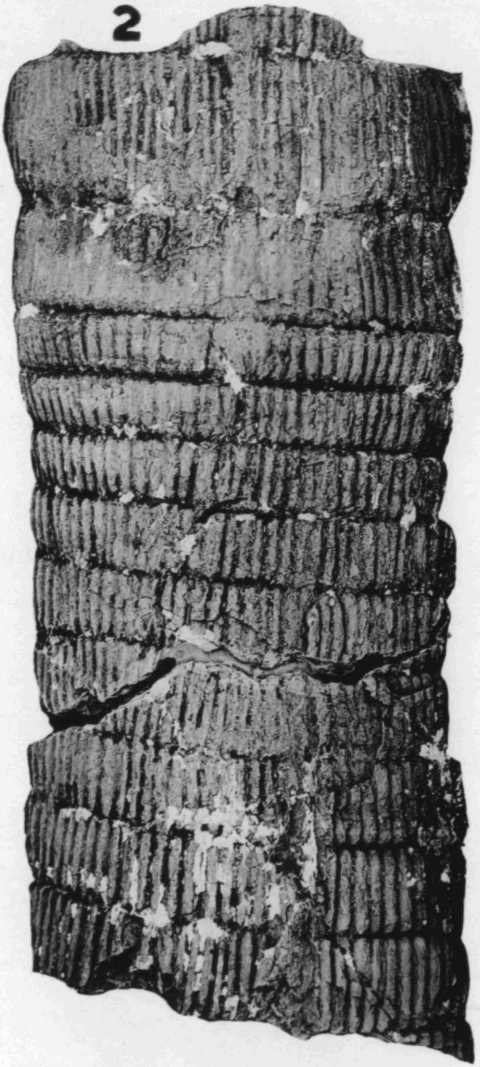


PLATE XIV

PLATE XIV

Calamites Cistii. Below Cycle "A," Grand Ledge. No. 24964

PLATE XV

1. *Calamites carinatus*. Below Cycle "A," Grand Ledge. No. 24965
2. *Macrostachya* sp. Grand Ledge. No. 15429

PLATE XV

1

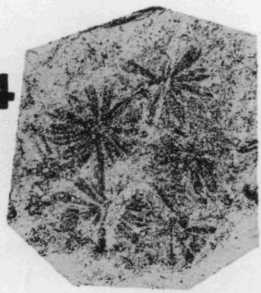
2

PLATE XVI


1


2


3


4


5


6


7


8


9

PLATE XVI

1. *Calamites undulatus.* St. Charles-Garfield Mine, Eastwood. No. 24966
2–3. *Palaeostachya* sp. Below Cycle "A," Grand Ledge. No. 24973
4. *Annularia sphenophylloides.* Cycle "F," Grand Ledge. No. 14802
5. *Annularia asteris.* Grand Ledge. No. 14799
6. *Asterophyllites vernensis,* sp. nov. Specimen shown in Fig. 7, enlarged.
7. *Asterophyllites vernensis,* sp. nov. Below Cycle "A," Grand Ledge. Holotype. No. 24974
8–9. *Asterophyllites vernensis,* sp. nov. Below Cycle "A," Grand Ledge. Paratypes. No. 24975

PLATE XVII

1. *Annularia stellata.* Quarry of Grand Ledge Clay Products Company. No. 24977
2. *Asterophyllites equisetiformis.* Quarry of Grand Ledge Clay Products Company. No. 24978
3. *Annularia radiata.* Quarry of Grand Ledge Clay Products Company. No. 24979
4. *Asterophyllites equisetiformis.* Branch bearing terminal fructification. Quarry of Grand Ledge Clay Products Company. No. 24980
5. *Asterophyllites equisetiformis.* Quarry of Grand Ledge Clay Products Company. No. 24981

PLATE XVII

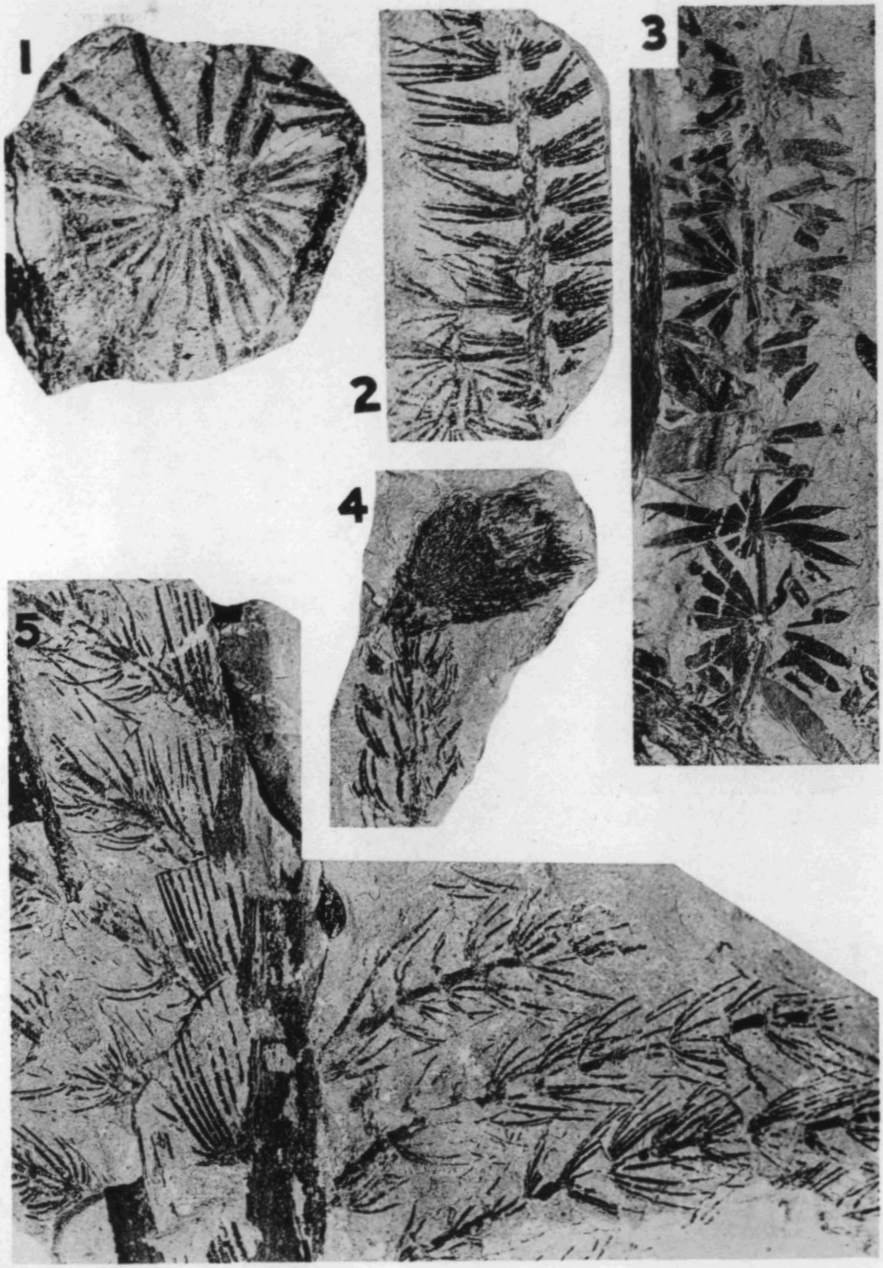
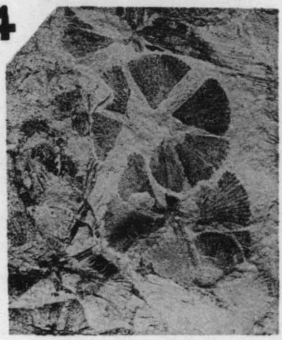


PLATE XVIII


1

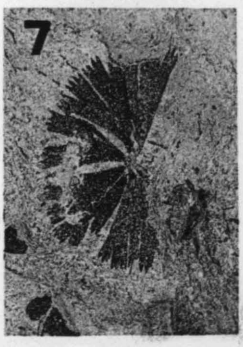

2


3


4


5


6


7


8


9

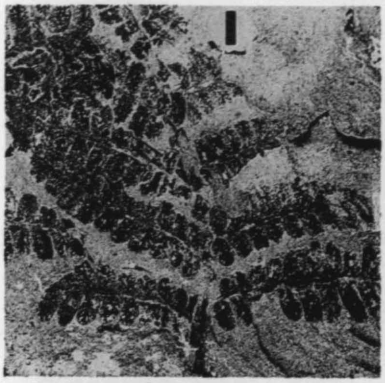
PLATE XVIII

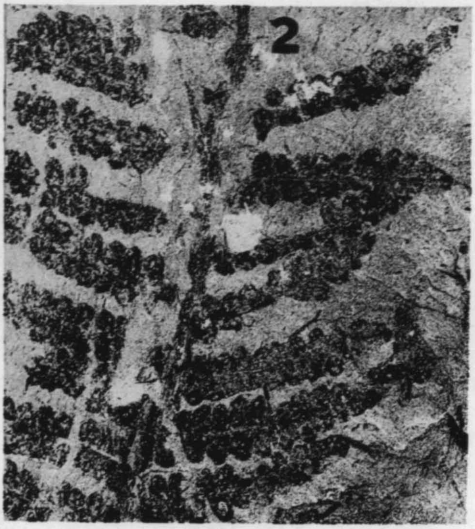
1. *Sphenophyllum cuneifolium.* Below Cycle "A," Grand Ledge. No. 24982
2. *Bowmanites* sp. Below Cycle "A," Grand Ledge. No. 24983
3. *Sphenophyllum cuneifolium.* Below Cycle "A," Grand Ledge. No. 24984
4. *Sphenophyllum emarginatum.* Cycle "F," Grand Ledge. No. 14783
5. *Sphenophyllum saxifragaefolium.* Big Chief No. 8 Mine, St. Charles. No. 14784
6. *Sphenophyllum cuneifolium.* Below Cycle "A," Grand Ledge. No. 14785
7. *Sphenophyllum majus.* Below Cycle "A," Grand Ledge. No. 24986
8. *Sphenophyllum saxifragaefolium.* Below Cycle "A," Grand Ledge. No. 24987
9. *Sphenophyllum cuneifolium.* Below Cycle "A," Grand Ledge. No. 24988

PLATE XIX

1–3. *Pecopteris Miltoni*. Below Cycle "A," Grand Ledge. No. 24989
4. *Alethopteris decurrens*. St. Charles-Garfield Mine, Eastwood. No. 24990
5–6. *Alethopteris Helenae*. Big Chief No. 8 Mine, St. Charles. No. 24992
7. *Alethopteris decurrens*. Cycle "F," Grand Ledge. No. 14809

PLATE XIX





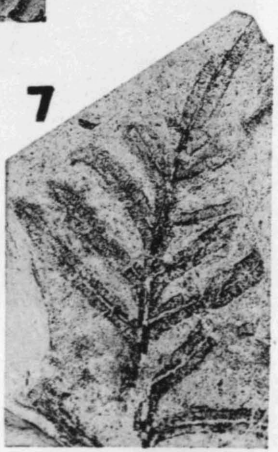


PLATE XX

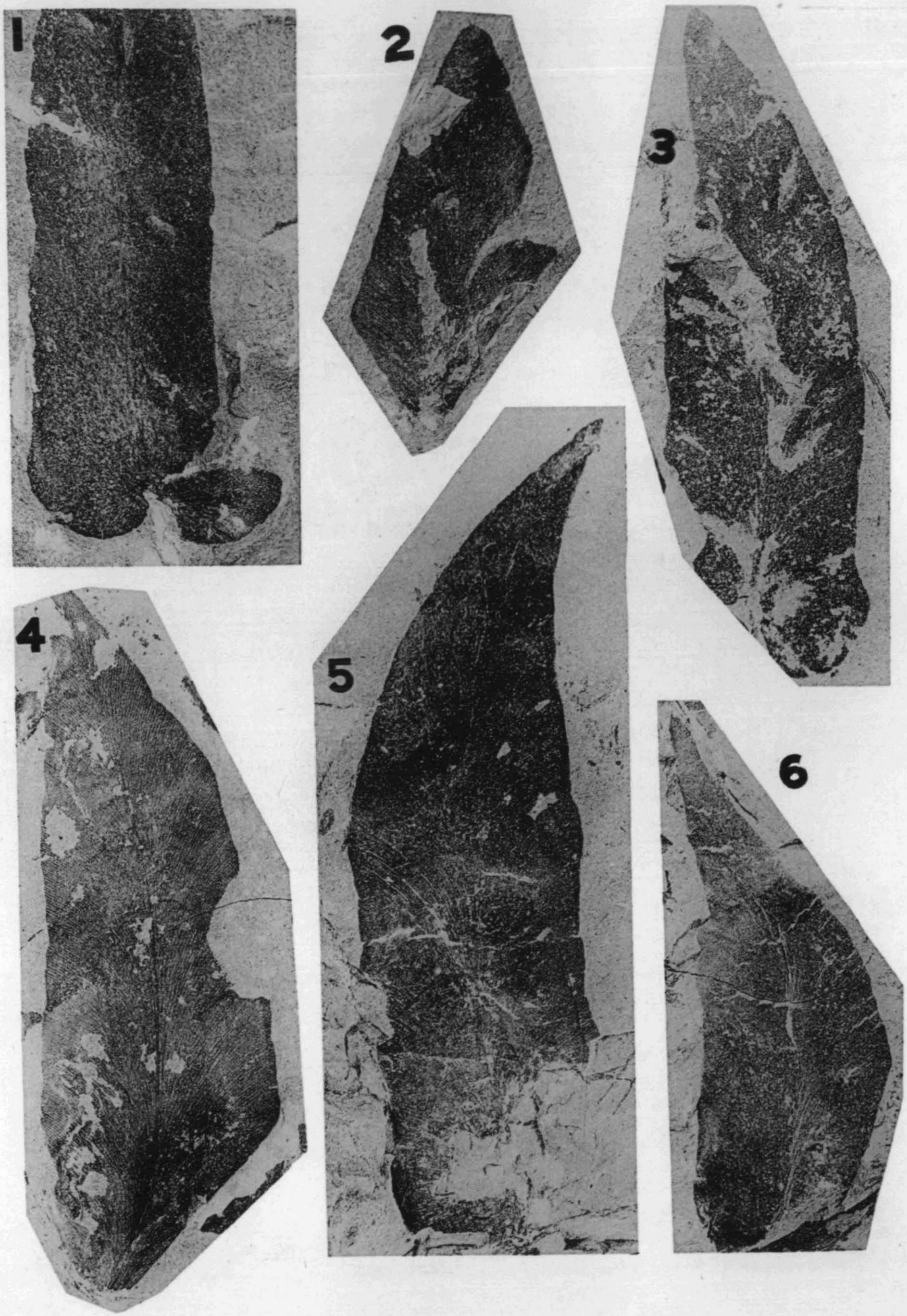


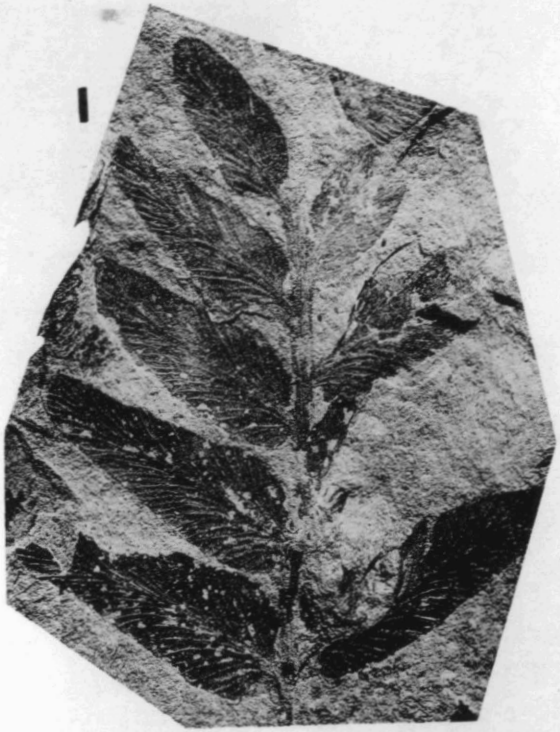
PLATE XX

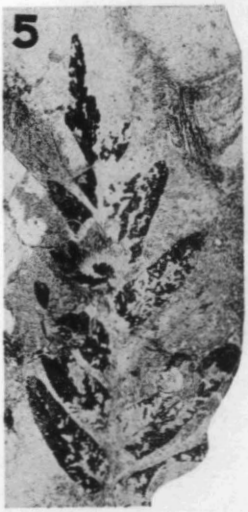
1–6. *Neuropteris Scheuchzeri.* Below Cycle "A," Grand Ledge. No. 24993

PLATE XXI

1. *Neuropteris saginawensis*, sp. nov. Specimen shown in Fig. 2, enlarged. × about 3
2, 5–6. *Neuropteris saginawensis*, sp. nov. Syntypes. St. Charles-Garfield Mine, Eastwood. No. 24995
3–4. *Neuropteris caudata*. Cycle "A," Grand Ledge. No. 24997
7. *Neuropteris caudata*. Specimen shown in Fig. 4, enlarged to show pinnule characteristics. × about 3

PLATE XXI





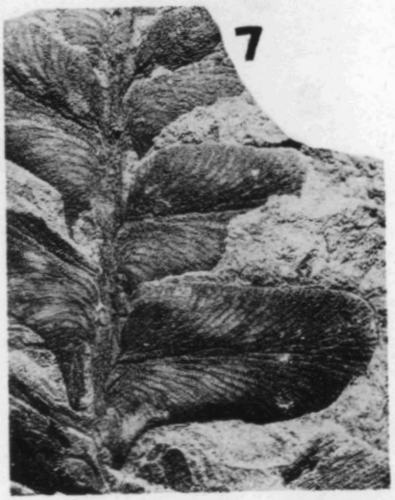


PLATE XXII

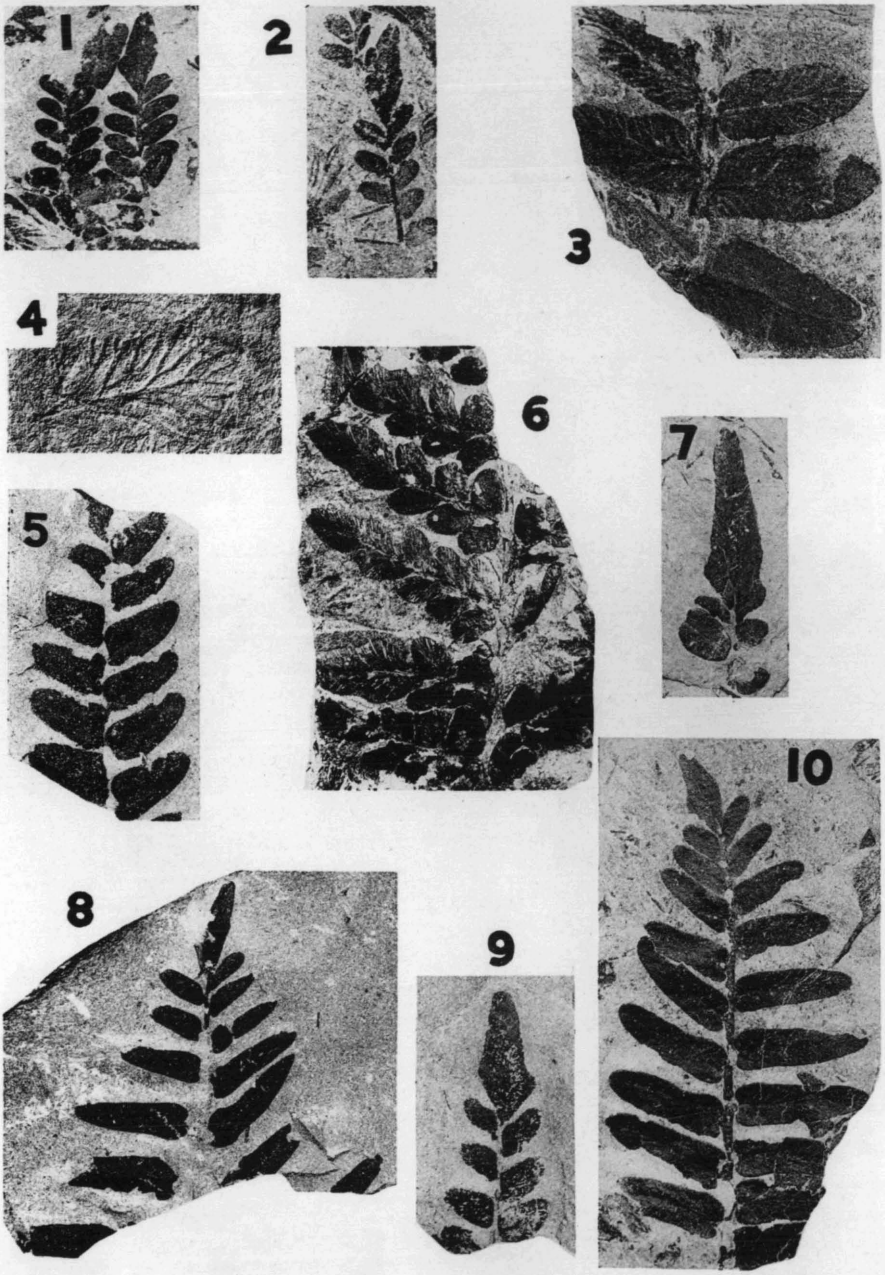


PLATE XXII

1–2. *Neuropteris rarinervis.* Below Cycle "A," Grand Ledge. No. 24999

3. *Neuropteris rarinervis.* Single pinnule of specimen enlarged to show venation. × about 3

4. *Neuropteris rarinervis.* Single pinnule enlarged to show venation. United City Mine. × about 3. No. 25068

5–6, 8–10. *Neuropteris tenuifolia.* Below Cycle "A," Grand Ledge. No. 25000

7. *Neuropteris tenuifolia.* St. Charles-Garfield Mine, Eastwood. No. 25002

PLATE XXIII

1. *Neuropteris obliqua. Impar* form. St. Charles-Garfield Mine, Eastwood. No. 25004
2–3. *Neuropteris obliqua.* St. Charles-Garfield Mine, Eastwood. No. 25005
4. Specimen shown in Fig. 2, enlarged
5. *Sphenopteris Bradfordii*, sp. nov. Specimen shown in Fig. 6, enlarged.
6. *Sphenopteris Bradfordii*, sp. nov. United City Mine. Holotype. No. 25007

PLATE XXIII

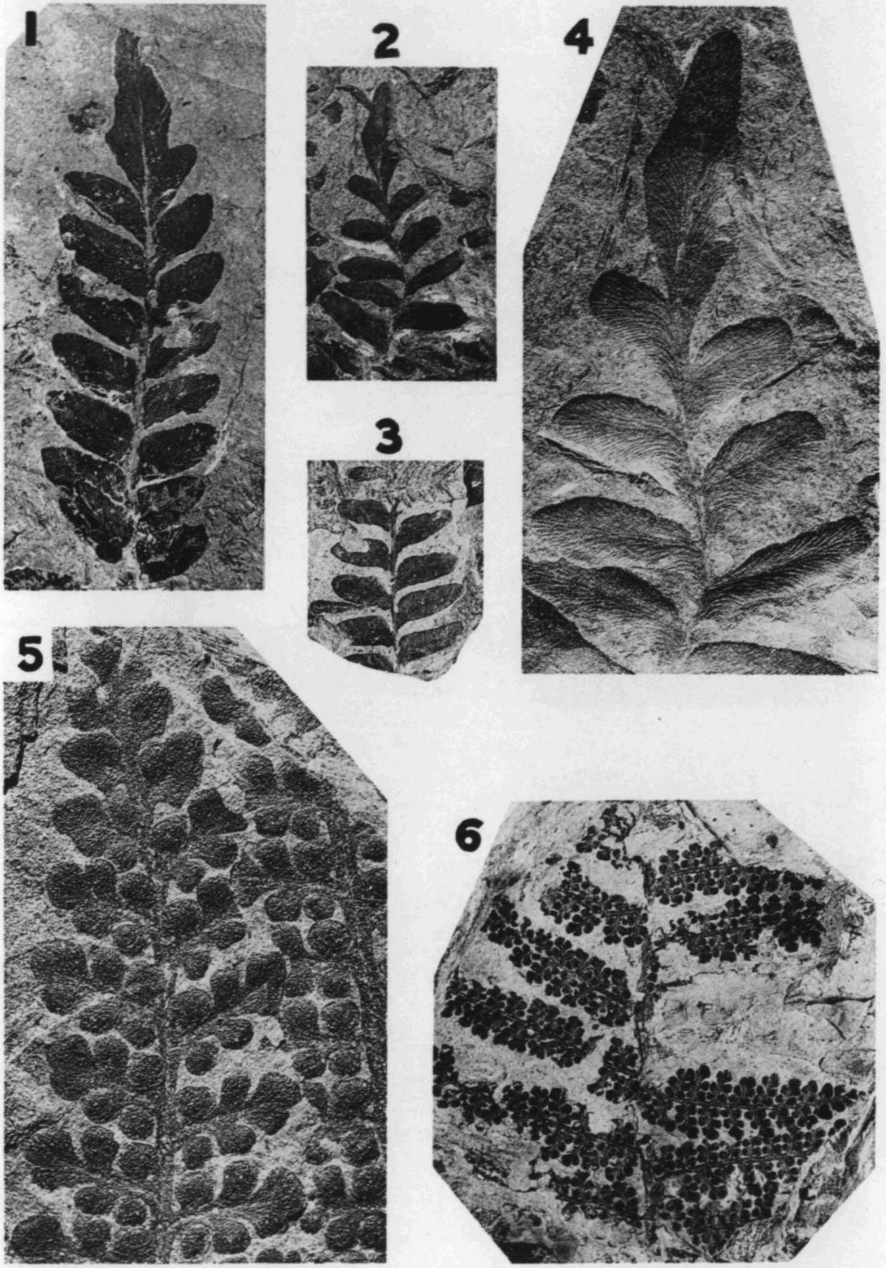


PLATE XXIV

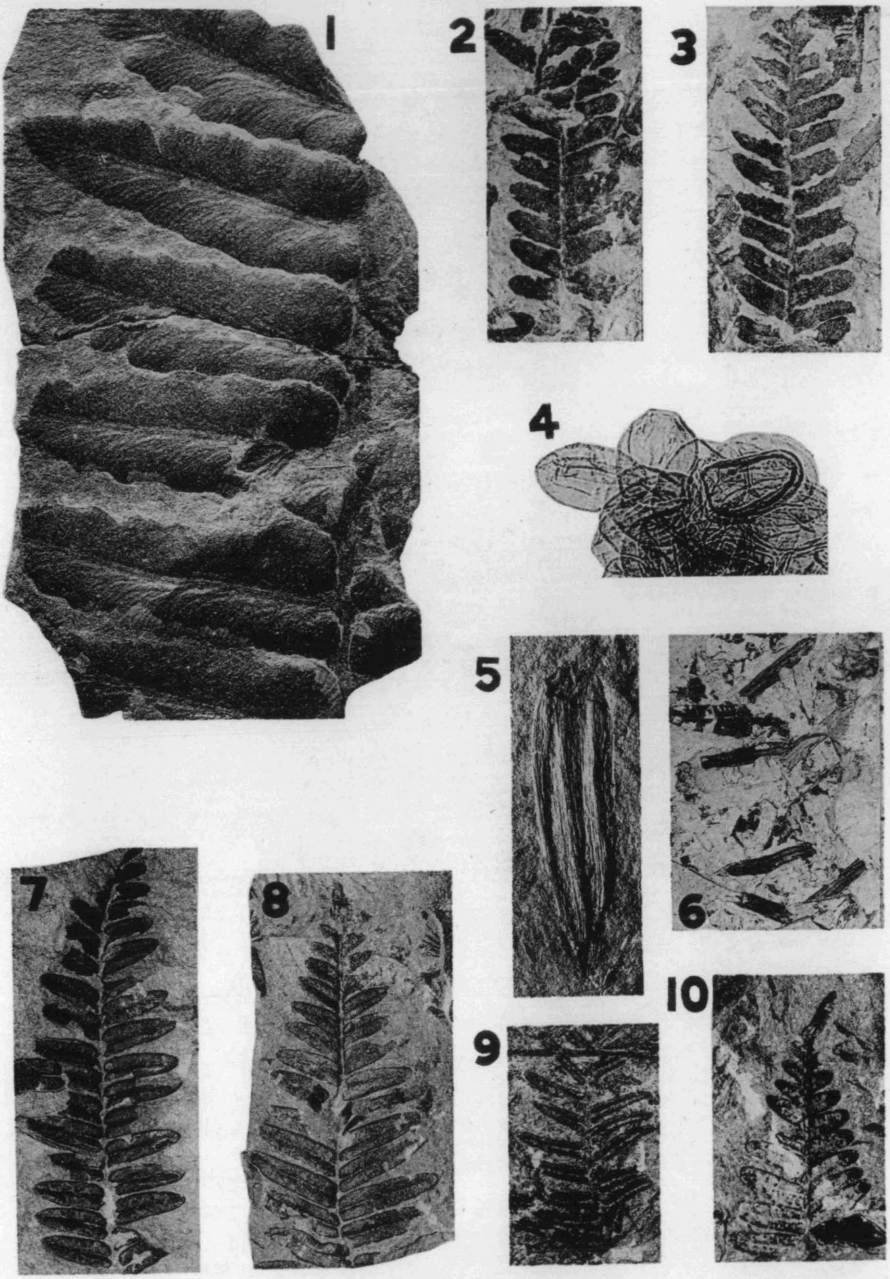


PLATE XXIV

1. *Neuropteris Desorii.* Wolverine Mine No. 3. Enlarged. No. 25009
2–3. *Neuropteris Desorii.* Wolverine Mine No. 3. No. 25010
4. *Aulacotheca Campbelli.* Spores. × 70. No. 25014
5. *Aulacotheca Campbelli.* Sporocarp, enlarged. No. 25013
6. *Aulacotheca Campbelli.* Sporocarps, natural size. St. Charles-Garfield Mine, Eastwood. No. 25015
7–9. *Neuropteris Schlehani.* St. Charles-Garfield Mine, Eastwood. No. 25017
10. *Neuropteris Schlehani.* Marquette Mine. No. 25016

PLATE XXV

1. *Megalopteris Dawsoni*. Cycle "A," Grand Ledge. No. 14766
2–3. *Mariopteris nervosa*. Big Chief Mine No. 8, St. Charles. No. 25019
4. *Megalopteris Kellyi*. Cycle "A," Grand Ledge. No. 14805

PLATE XXV

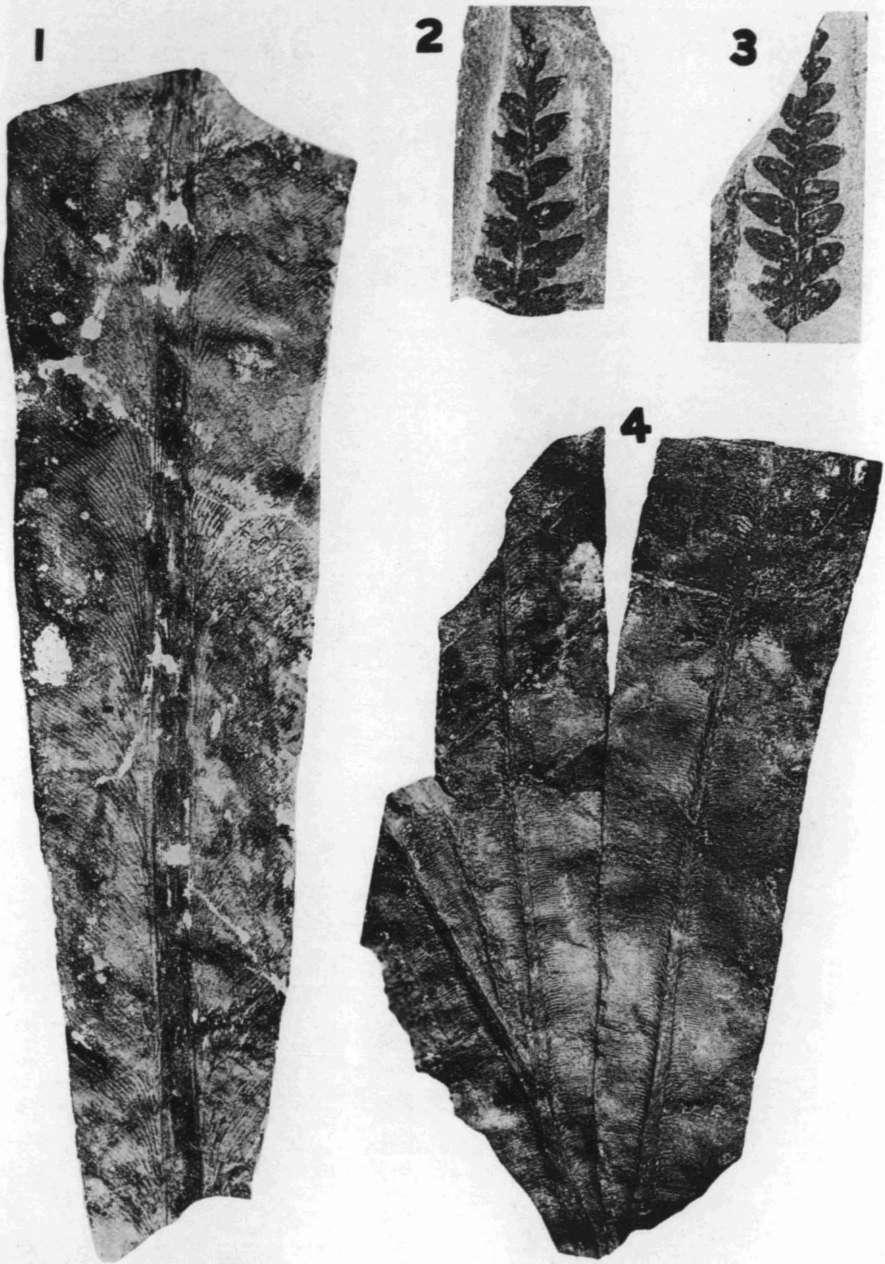
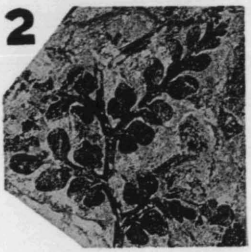


PLATE XXVI


1


2


3


4


5


6


7


8

PLATE XXVI

1. *Diplothmema obtusiloba.* St. Charles-Garfield Mine, Eastwood. No. 25020
2. *Diplothmema obtusiloba.* Marquette Mine. No. 14770
3. *Diplothmema obtusiloba.* St. Charles-Garfield Mine, Eastwood. No. 25020
4. *Sphenopteris artemisaefolioides.* Marquette Mine. No. 14801
5. *Pecopteris plumosa.* United City Mine. No. 25021
6. *Palaeopteridium Reussi.* Corunna. No. 25022
7. *Palmatopteris furcata.* Quarry of Grand Ledge Clay Products Company. No. 25023
8. *Palmatopteris furcata.* Specimen shown in Fig. 8, enlarged

PLATE XXVII

1–4. *Eremopteris michiganensis*, sp. nov. Syntypes. Below Cycle "A," Grand Ledge. No. 25025


1


2

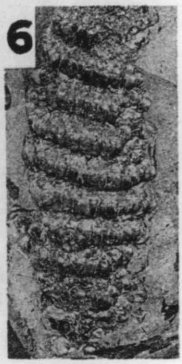

3

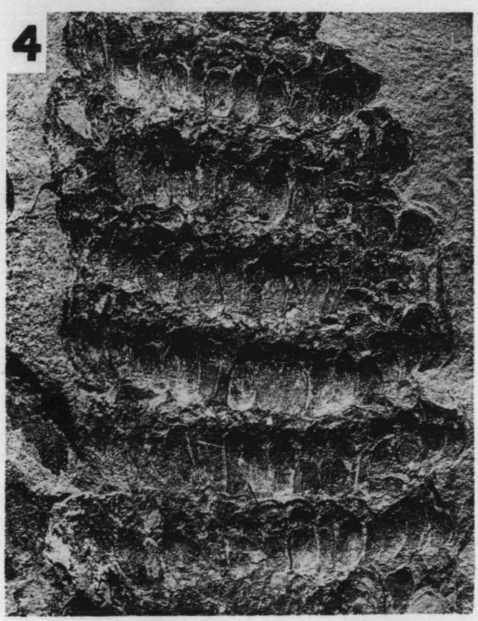

4


1


2


3


6


4


5

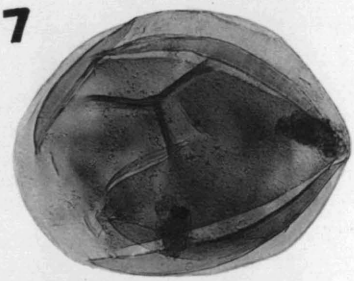

7

PLATE XXVIII

1. *Discinites delectus*, comb. nov. Below Cycle "A," Grand Ledge. Paratype. No. 25027
2–3. *Discinites Jongmansi*. Below Cycle "A," Grand Ledge. No. 25030
4. *Discinites delectus*, comb. nov. Specimen in Fig. 6, enlarged.
5. *Discinites delectus*, comb. nov. Microspores. × 64. No. 25029
6. *Discinites delectus*, comb. nov. Holotype. Below Cycle "A," Grand Ledge. No. 23415
7. *Discinites delectus*, comb. nov. Megaspore. × 64. No. 25029

PLATE XXIX

1. *Caulopteris* sp. Grand Ledge. No. 25031
2. *Rhabdocarpus Mansfieldi.* Below Cycle "A," Grand Ledge. No. 25032
3. *"Trigonocarpus" Noeggerathi.* St. Charles-Garfield Mine, Eastwood. No. 25033
4. *Rhabdocarpus multistriatus.* Base of cast showing vascular strands. Cycle "A," Grand Ledge. No. 14775
5. *Rhabdocarpus multistriatus.* Side view of specimen shown in Fig. 4
6. *Rhabdocarpus multistriatus.* Compression of seed. St. Charles-Garfield Mine, Eastwood. No. 25035

PLATE XXIX


1


2


3


4


5


6

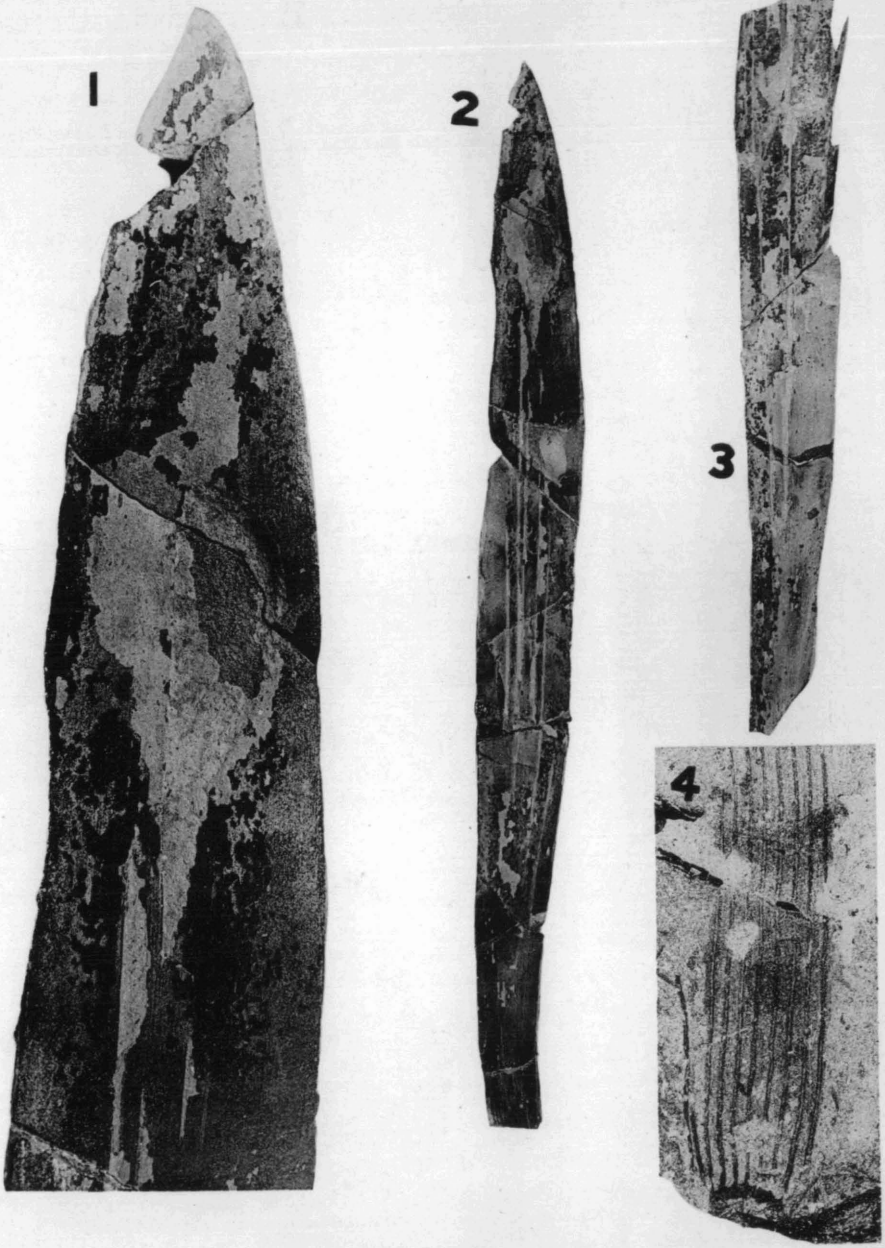

1
2
3
4

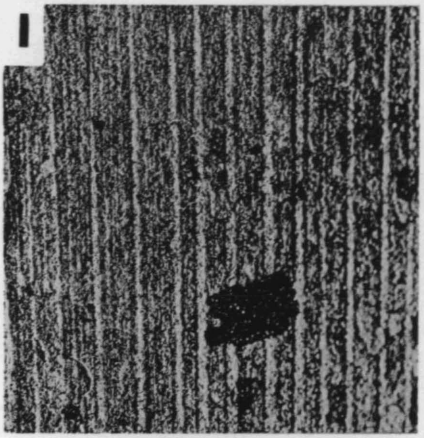
PLATE XXX

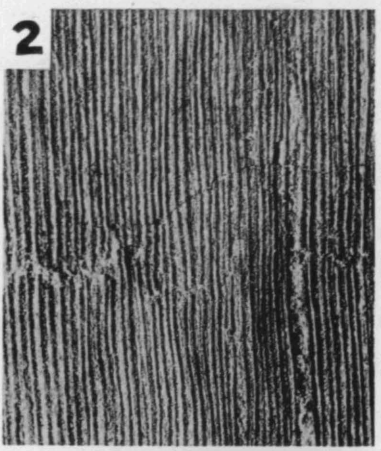
1. *Cordaites principalis.* Apex of leaf shown in Fig. 2, natural size. No. 25036
2–3. *Cordaites principalis.* Reduced. No. 25036
4. *Cordaites crassinervis.* Grand Ledge. No. 25037

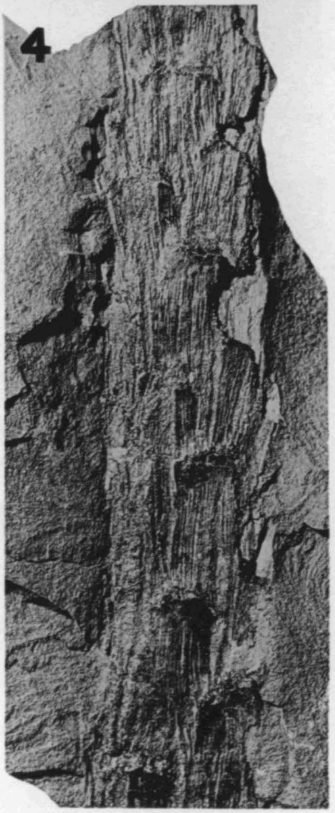
PLATE XXXI

1. *Cordaites principalis.* Surface of leaf enlarged to show specific characters. No. 25036
2. *Cordaites palmaeformis.* Surface of leaf enlarged to show specific characters. Below Cycle "A," Grand Ledge. No. 25039
3. *Ginkgophyllum grandifolium*, comb. nov. Below Cycle "A," Grand Ledge. No. 25042
4. *Cordaicladus* sp. (cf. *Cordaites principalis*). Below Cycle "A," Grand Ledge. No. 25044

PLATE XXXI








1


2

PLATE XXXII

1. *Cordaicladus intermontanus*, sp. nov. Quarry of Grand Ledge Clay Products Company. Holotype. No. 25041
2. *Cordaicladus* sp. (cf. *Cordaites principalis*). Below Cycle "A," Grand Ledge. No. 25044

PLATE XXXIII

1. *Cordaianthus devonicus*. Below Cycle "A," Grand Ledge. No. 25045
2. *Cordaianthus ampullaceus*, comb. nov. Portion of inflorescence, enlarged. Below Cycle "A," Grand Ledge. No. 25047
3. *Cordaianthus ampullaceus*, comb. nov. Specimen shown in Fig. 2, natural size
4. *Cordaianthus ampullaceus*, comb. nov. Fragment of fructification with seed attached. Below Cycle "A," Grand Ledge. No. 25048
5. *Cordaianthus ampullaceus*, comb. nov. Seed. Below Cycle "A," Grand Ledge. No. 25050
6. *Cordaianthus ampullaceus*, comb. nov. Enlargement of seed shown in Fig. 5

PLATE XXXIII

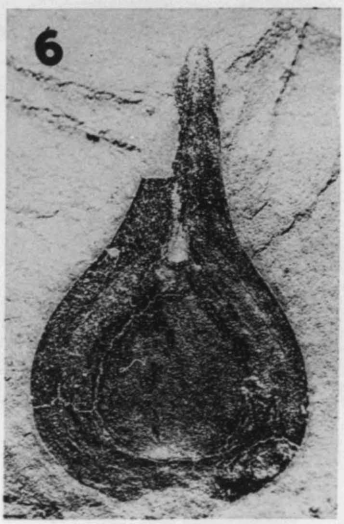
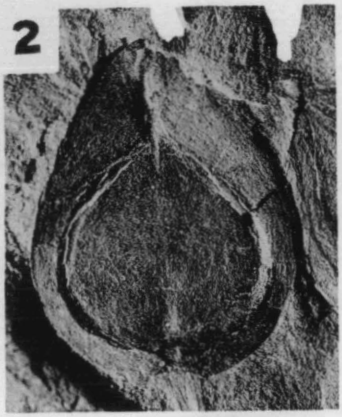


PLATE XXXIV

1

2



3

4

PLATE XXXIV

1. *Cardiocarpon annulatum.* Below Cycle "A," Grand Ledge. × 2. No. 25056
2. *Cardiocarpon late-alatum.* Below Cycle "A," Grand Ledge. × 3½. No. 25053
3. *Cardiocarpon annulatum.* Below Cycle "A," Grand Ledge. No. 25057
4. *Artisia* sp. Grand Ledge. No. 14804

VOLUME VII

1. The Priority of Dana, 1846–48, versus Hall, 1847, and of Rominger, 1876, versus Hall, 1876 (?1877), by Erwin C. Stumm. Pages 1–6. Price $.25.

2. Lower Middle Devonian Species of the Tetracoral Genus *Hexagonaria* of East-Central North America, by Erwin C. Stumm. Pages 7–49, with 14 plates. Price $1.25.

3. A Revision of the Aulacophylloid Tetracoral Genus Odontophyllum, by Erwin C. Stumm. Pages 51–61, with 2 plates. Price $.35.

4. Pleistocene Stratigraphy and Paleontology of Meade County, Kansas, by Claude W. Hibbard. Pages 63–90, with 1 plate. Price $.75.

5. Pliocene Saw Rock Canyon Fauna in Kansas, by Claude W. Hibbard. Pages 91–105. Price $.40.

6. *Tremarctotherium* from the Pleistocene of Meade County, Kansas, by George C. Rinker. Pages 107–112, with 1 plate. Price $.25.

7. New Uncoiled Gastropods from the Middle Devonian of Michigan and Manitoba, by Aurèle La Rocque. Pages 113–122, with 3 plates. Price $.30.

8. Corals of the Devonian Traverse Group of Michigan. Part I, *Spongophyllum*, by George M. Ehlers and Erwin C. Stumm. Pages 123–130, with 3 plates. Price $.30.

9. Fossil Flora of the Michigan Coal Basin, by Chester A. Arnold. Pages 131–269, with 34 plates. Price $3.00.