KENTUCKY GEOLOGICAL SURVEY
UNIVERSITY OF KENTUCKY, LEXINGTON
Donald C. Haney
State Geologist and Director

PENNSYLVANIAN PLANTS OF EASTERN KENTUCKY: A FLORA FROM THE BREATHITT FORMATION NEAR GRANNIES BRANCH AND ROCKY BRANCH OF GOOSE CREEK, CLAY COUNTY, KENTUCKY

Paul A. Spurgeon
and
James R. Jennings

REPORT OF INVESTIGATIONS 3
SERIES XI, 1985

ISSN 0075-5591

KENTUCKY GEOLOGICAL SURVEY
UNIVERSITY OF KENTUCKY, LEXINGTON
Donald C. Haney
State Geologist and Director

PENNSYLVANIAN PLANTS OF EASTERN KENTUCKY: A FLORA FROM THE BREATHITT FORMATION NEAR GRANNIES BRANCH AND ROCKY BRANCH OF GOOSE CREEK, CLAY COUNTY, KENTUCKY

Paul A. Spurgeon
and
James R. Jennings

REPORT OF INVESTIGATIONS 3
SERIES XI, 1985

CONTENTS

ILLUSTRATIONS

PENNSYLVANIAN PLANTS OF EASTERN KENTUCKY: A FLORA FROM THE BREATHITT FORMATION NEAR GRANNIES BRANCH AND ROCKY BRANCH OF GOOSE CREEK, CLAY COUNTY, KENTUCKY

Paul A. Spurgeon
and
James R. Jennings

ABSTRACT

This study of fossil plants is intended to provide a basis for more detailed biostratigraphic dating of Pennsylvanian-age strata. The determination of biostratigraphic correlations based upon fossil plants will assist in the correlation of coal beds in eastern Kentucky.

A flora collected from strata associated with a coal described as the Jellico coal, in Clay County, Kentucky (Ogle 7 1/2-minute quadrangle) consists of *Lepidodendron* cf. *L. aculeatum*, *Lepidophylloides longifolium*, *Lepidostrobophyllum lanceolatum*, *Lepidostrobus ornatus*, *Bothrodendron minutifolium*, *Ulodendron minus*, *Asolanus* sp., *Calamites cisti*, *C. undulatus*, *Annularia galioides*, *Asterophyllites longifolius*, *A. charaeformis*, *Paleostachya* sp., *Sphenophyllum cuneifolium*, *Bowmanites* sp., *Pecopteris* cf. *P. plumosa*, *Alethopteris decurrens*, *Alethopteris* cf. *A. lonchitica*, *Neuropteris* cf. *N. tenuifolia*, *N. heterophylla*, *N. gigantea*, *Mariopteris nervosa*, *Eremopteris gracilis*, *Sphenopteris amoena*, *Sphenopteris* sp., *S. obtusiloba*, and *Trigonocarpus* sp.

Correlative strata were examined in several areas, and each area yielded substantially different plant assemblages. Vertical and lateral changes in floral assemblages in the study area, often accompanied by shifts in lithofacies, suggest that sedimentological factors influenced fossil plant distribution significantly. The magnitude of lateral variation in the flora underscores the importance of collecting at a number of sites at a given stratigraphic horizon in order to obtain a representative flora and in order to derive more reliable paleobotanical correlations.

INTRODUCTION

Purpose of the Study

The correlation of coal beds is important for both exploration and reserve evaluations. Rapid lateral facies changes and the paucity of invertebrate fauna in many Pennsylvanian rocks of North America make the biostratigraphic dating of these strata difficult. Fossil plants may provide an important tool for dating terrigenous clastic rocks, especially in coal basins, if sufficient detailed work is done upon which to base stratigraphic correlations.

Although paleobotanical research has been carried on in the United States since the middle of the nineteenth century, knowledge of the Pennsylvanian floras of North America is incomplete, specifically with respect to eastern Kentucky. Fossil plants in many areas have not been described, and the stratigraphic ranges of most plant species remain unclear. Furthermore, very little is known about the effects of environment, transportation, and deposition on fossil plant distribution.

This first detailed study of the fossil plant compressions of eastern Kentucky was initiated to locate fossil plant material with potential biostratigraphic significance, to determine the plant types present, and to evaluate the extent of lateral variations that must be considered before meaningful correlations can be made. This report can be used as a basis for more complete dating of Pennsylvanian strata and for facilitating correlations of coal beds in eastern Kentucky and elsewhere.

Location of the Study Area

Four exposures of strata described as the Jellico coal zone in the Ogle 7 1/2-minute quadrangle, Clay County, Kentucky (Ping and Sergeant, 1978), were chosen for the study (Fig. 1). The outcrops are exposed around abandoned coal-mine adits situated in the hills above Grannies Branch and Rocky Branch of Goose Creek; they are designated EKP-1 (17,750 feet from the western quadrangle boundary, 11,750 feet from the northern boundary), EKP-2 (17,750 feet from the western quadrangle boundary, 12,500 feet from the northern boundary), EKP-5 (15,750 feet from the western quadrangle boundary, 9,875 feet from the northern boundary), and EKP-6 (17,500 feet from the western quadrangle boundary, 13,875 feet from the northern boundary).

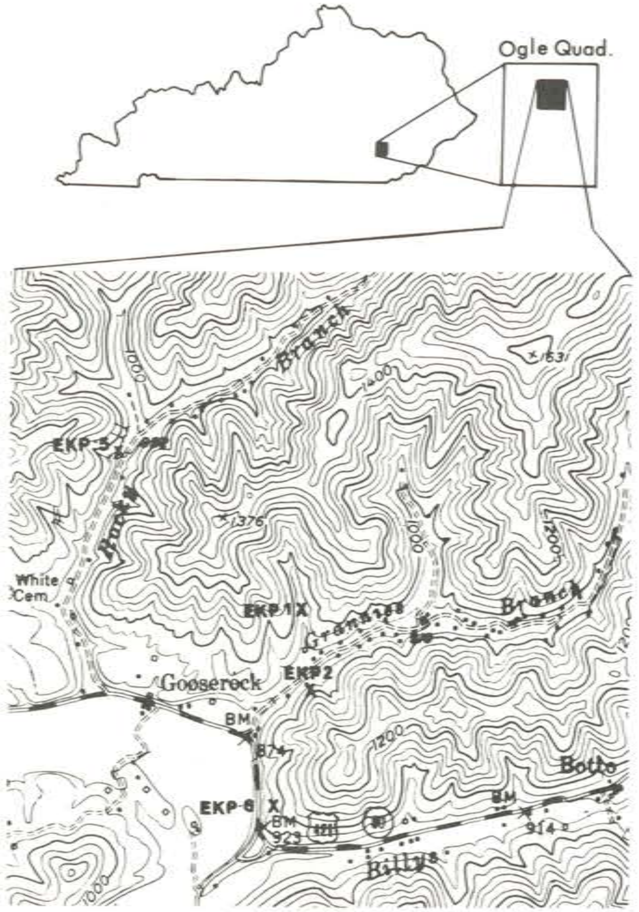

Figure 1. Location of study area.

Four localities were utilized in order to determine the extent of lateral variations in the flora in short distances. A small study area was maintained so that all four localities could be reliably correlated by standard lithostratigraphic methods.

Stratigraphy

General Stratigraphy

The Pennsylvanian rocks of eastern Kentucky form a terrigenous clastic wedge that thickens to the southeast. These sediments were derived from the Appalachian highlands to the east and southeast, and were deposited in a deltaic environment in a rapidly subsiding trough. Brackish-water and marine invertebrate fossils in shale and calcium carbonate deposits indicate the occurrence of several marine transgressions during the Pennsylvanian Period (Rice and others, 1979).

The lower part of the Pennsylvanian section in eastern Kentucky is dominated by the orthoquartzite of the Lee Formation, and the upper part is dominated by shale, siltstone, and subgraywacke of the Breathitt and Conemaugh Formations.

The Breathitt Formation, which contains the coal zone studied, reaches a maximum thickness of about 950 meters and is composed of clay-shale, siltstone, subgraywacke, and several relatively thin calcium carbonate beds. The 30 major coal beds in the formation make up most of the mineable coal in eastern Kentucky (Rice and others, 1979).

Although correlations are uncertain, geologic units possibly equivalent to the Breathitt Formation include the Kanawha Formation of West Virginia, the Upper Pottsville Series of Ohio and Pennsylvania, the Atokan Series of the mid-continent region, the Tradewater Formation of western Kentucky, and the Abbott and Lower Spoon Formations of Illinois (Moore and others, 1944). Jongmans and others (1937) believed that these Pennsylvanian strata are equivalent to the Westphalian B of Europe.

Jellico Coal Zone

The Jellico coal takes its name from the town of Jellico, Tennessee, where the coal has been mined extensively (Glenn, 1925). In northern Tennessee it marks the base of the Mingo Formation of the Breathitt Group, and occurs 100 to 140 feet above the Blue Gem coal (Englund, 1969).

In eastern Kentucky the Jellico coal occurs in the Breathitt Formation about 325 feet above the Lee Formation. It is situated 60 to 125 feet above the Blue Gem coal and about 300 feet below the Fire Clay coal. Coal at approximately this horizon appears to be present in Whitley, Knox, Bell, Clay, McCreary, and Laurel Counties (Huddle and others, 1963).

Huddle and others (1963) believed that the Howard coal of Rocky Branch in the Ogle Quadrangle (Hodge, 1918) is equivalent to the Jellico coal. According to Hodge (1918), two relatively thick coal beds, separated by 5 to 15 feet of strata, occur at this horizon south of Martins Creek in the Ogle Quadrangle. Huddle and others (1963) correlated the higher bed with the Jellico coal.

Rice and Smith (1979) correlated the Jellico coal zone with the following coals found in other parts of eastern Kentucky: the Mingo coal zone, the Huckleberry coal, the Harlan coal zone, the Rim coal, the Moss coal, the Upper Elkhorn No. 1 coal zone, the Upper Elkhorn No. 2 coal zone, the Grassy coal, the Alma coal zone, the Hopewell coal, and the Lacy Creek coal.

The fossil plants present in the strata studied at Grannies Branch and Rocky Branch are found above the main coal bed in an upward-coarsening sequence of shale, siltstone, and sandstone (Fig. 2). This sequence occurs at all of the study localities, although outcrops EKP-2 and EKP-6 generally consist of coarser grained rocks than EKP-1 and EKP-5.

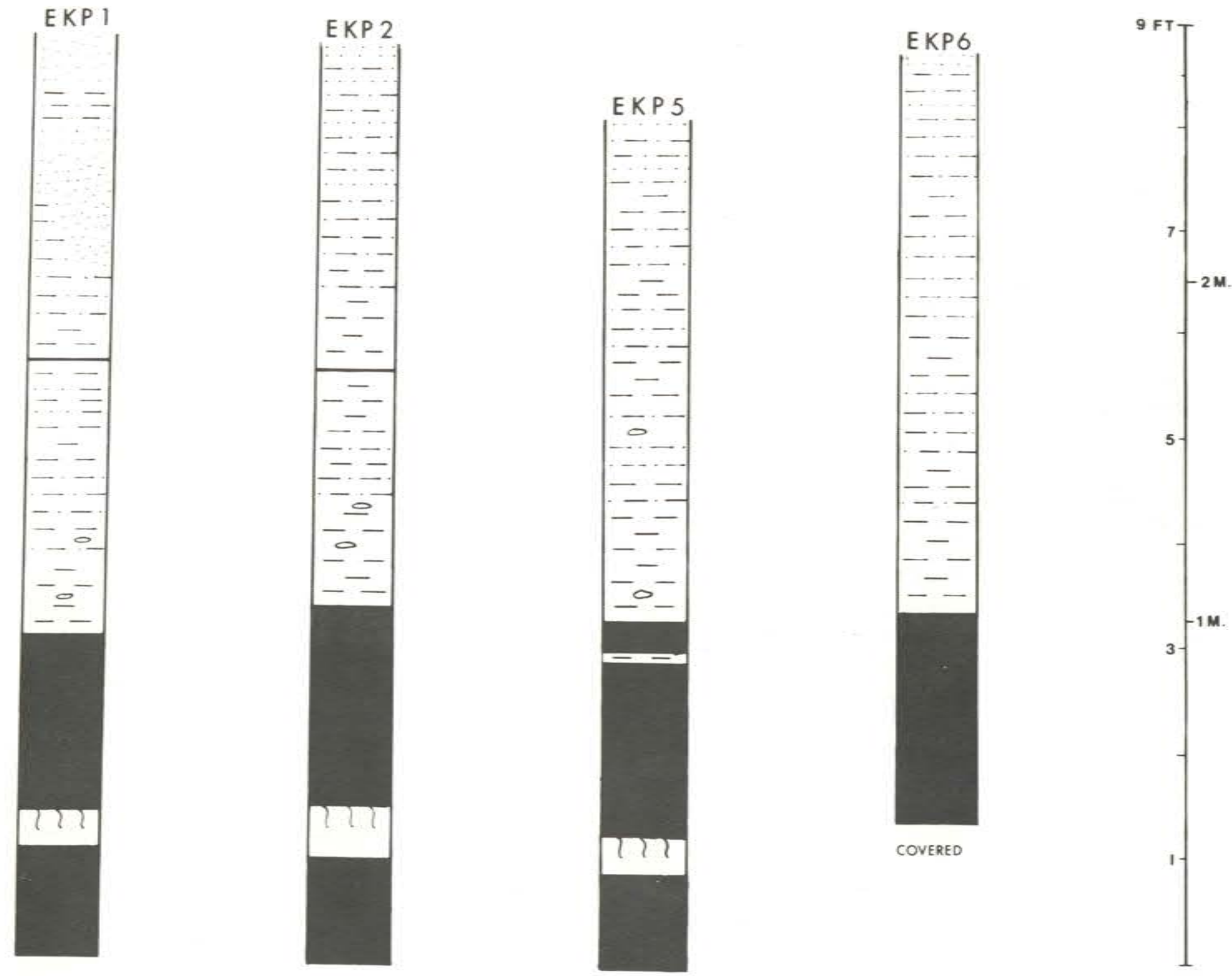

Figure 2. Generalized stratigraphic columns of outcrops in the study area.

Previous Investigations

Eastern North America

A major early work describing the fossil plants of Pennsylvania and other localities throughout the United States was published by Lesquereux (1879-84). Lesquereux also reported on the upper Carboniferous floras of Illinois (1870). Janssen (1940) updated the classification of some of the plant types from Illinois originally described by Lesquereux.

White (1899) did pioneering work on the Lower Pennsylvanian floras of Missouri and the fossil plants of the Pottsville Series from the anthracite region of Pennsylvania (1900a).

Summary volumes have been written on the Pennsylvanian plant fossils of the Eastern Interior Basin by Noe (1925), the Michigan Basin by Arnold (1949), and eastern Canada by Bell (1966).

Darrah (1969) published a monograph that deals primarily with plant fossils from Mazon Creek, Illinois, in an attempt to summarize and update the taxonomic classification of the Upper Pennsylvanian floras of the eastern United States.

Read and Mamay (1964) divided the upper Paleozoic strata of the United States into 15 zones based on the floral succession preserved in the rocks. Their floral zone 8 includes most of the Kanawha Formation and its equivalents and is indicated by the presence of *Neuropteris tenuifolia*.

A significant amount of biostratigraphic work has been done on the Kanawha Formation of West Virginia. The floral succession present in this formation was compared to European floras by Jongmans and others (1937). Like White (1900b), they divided the Kanawha strata into two floral zones, both of which were considered correlative with the Westphalian B of Europe.

Gillespie and Pfefferkorn (1976) marked the base of the Kanawha Formation of West Virginia by the disappearance of *Sphenopteris hoeninghausi* and *Mariopteris pottsvillea* and the appearance of *Neuropteris gigantea*. The first occurrence of *Neuropteris scheuchzeri* indicates the youngest Kanawha strata.

Cridland and others (1963) discussed the floral biostratigraphy of the Pennsylvania rocks of Kansas.

Eastern Kentucky

Few studies concerning the paleobotany of eastern Kentucky have been undertaken. Lesquereux (1861) listed the fossil plants associated with the coal beds in Bath, Powell, Montgomery, Morgan, Owsley, Floyd, Breathitt, Greenup, Carter, Lawrence, and Johnson Counties of eastern Kentucky. The coals were designated numerically and cannot be correlated with the names in use at the present time.

Seward (1933) described a pair of seed fern fossils from eastern Kentucky.

Work by David White on the foliar compressions of several genera of pteridosperms from the Appalachian Basin, including specimens from eastern Kentucky, was published posthumously in 1943.

In his short summary of the Pennsylvanian floras of the United States, Bode (1958) listed two floras from eastern Kentucky, one of which came from strata associated with a coal described as the Jellico coal, 1 1/2 miles west of Woodbine, Kentucky.

Methods of Study

Specimens were coated with polyvinyl chloride, and the matrix was dissolved in hydrogen fluoride. The preparations were then mounted on slides in Canada balsam so that the structure of the plants could be observed. The sphenophytes, ferns, and some of the pteridosperms yielded useful preparations.

Some of the carbonaceous material from the fossil cones was removed from the shale matrix and oxidized in a solution of nitric acid and potassium chlorate (Schulze's Solution) for 24 to 48 hours. Fossil spores were released by treating the oxidized material with potassium hydroxide for 10 minutes and ultrasonic vibration for 30 seconds. The macerated material was mounted on slides in Canada balsam.

SYSTEMATIC PALEONTOLOGY

The fossil plants were identified according to the original published descriptions of the appropriate species. Other references containing descriptions of these plant types are also given.

Division Lycophyta

***Lepidodendron* cf. *L. aculeatum* Sternberg, 1825**
Pl. 1, Figs. 1-6

1880. *Lepidodendron aculeatum* Lesquereux, p. 371, Pl. 64, Fig. 1.
1949. *L. aculeatum* Arnold, p. 237, Pl. 2, Fig. 1.
1969. *L. aculeatum* Darrah, Pl. 30, Fig. 1.
1978. *L. aculeatum* Gillespie and others, p. 46, Pl. 11, Fig. 1.

Description: The largest leaf cushions are S- shaped, and are 30 mm high and 10 mm wide at the middle. A diamond-shaped leaf scar is situated slightly above the center of the leaf cushion. A triangular ligule scar appears just above the leaf scar. Parichnos scars were not preserved. The keel is distinct but bears no transverse wrinkles.

Discussion: This species was found at outcrops EKP-1 and EKP-2, and may have borne the small, specifically unidentifiable branches that are so common in these rocks.

The length-to-width ratio of the leaf cushions and the absence of keel markings are characteristic of *L. lanceolatum* Lesquereux (Janssen, 1939), but the leaf cushions at Grannies Branch do not have notches above the leaf scar and are not as straight vertically as the form described by Lesquereux.

L. aculeatum is a common plant type in the Pottsville and Allegheny strata and equivalent rocks elsewhere in North America (Darrah, 1969).

***Lepidostrobus ornatus(?)* Brongniart, 1828**
Pl. 2, Fig. 9

1966. *Lepidostrobus ornatus* Crookall, Pl. 101, Figs. 2-5.

Description: This type of lycopod cone varies in length from 55 to 90 mm and is about 12 mm wide. The laminar part of the sporophyll is lanceolate and 2 to 4 mm long. The cones are terminally attached to small lycopod branches (Pl. 1, Fig. 2). Spores referable to the genus *Lycospora* Schopf, Wilson, and Bentall (1944) were found in the residue when the cones were macerated.

Discussion: Isolated lycopod cones are common to all of the study localities, especially EKP-1 and EKP-2. Several cones were found attached to branches bearing leaf cushions too small or too poorly preserved to identify with certainty, but having the general form of *Lepidodendron aculeatum* (Pl. 1, Figs. 1-2; Pl. 2, Fig. 9).

Lepidostrobus ornatus is known throughout the Carboniferous of Great Britain, but is most often found in upper Westphalian A to lower Westphalian C strata (Crookall, 1966). White (1900b) reported *L. ornatus* from the lower Kanawha Formation of West Virginia.

Several isolated cone fragments of a larger type, one reaching 30 mm in width, were also found in the study area. These large lycopod cones, *Lepidostrobus* sp. (Pl. 2, Fig. 10), are associated with spores referable to *Lycospora punctata* Kosanke (1950).

***Lepidostrobophyllum lanceolatum* Brongniart, 1828**
Pl. 2, Fig. 11

1939. *Lepidostrobophyllum lanceolatum* Janssen, p. 63, Fig. 46.

Description: These lycopod sporophylls average 50 mm in length, but may reach 70 mm. They are widest at the middle or just above the middle, measuring about 12 mm in breadth; they taper more rapidly toward the apex than toward the base.

Discussion: The sporophylls are abundant at all of the study localities. They are most noticeable at outcrop EKP-2, about 1 foot above the main coal, where the shale is more coarsely grained than the surrounding strata.

Lepidostrobophyllum lanceolatum is a common plant fossil in the Pottsville Series and its equivalents over much of eastern North America. It has been reported from Pennsylvania (Lesquereux, 1880), Illinois (Janssen, 1939), West Virginia (White, 1900b), and eastern Canada (Bell, 1966).

***Lepidophylloides longifolium* Brongniart, 1828**
Pl. 2, Fig. 8

1939. *Lepidophylloides longifolium* Janssen, p. 61, Fig. 44.
1978. *L. longifolium* Gillespie and others, Pl. 12, Fig. 1.

Description: These linear lycopod leaves are 3 mm wide and may reach 50 cm or more in length. Two thin furrows extend the length of the leaf.

Discussion: Lycopod leaves are common throughout the study area. *L. longifolium* has a wide stratigraphic range in the Pennsylvanian rocks of North America and Europe.

***Bothrodendron minutifolium* (Boulay) Zeiller, 1880**
Pl. 2, Figs. 1-3

1979. *Bothrodendron minutifolium* Jennings, p. 519-522.

Description: Several ultimate branches bearing leaves were found attached to part of a stem measuring about 8 cm in breadth. The branches divide dichotomously. Ultimate branches are reached very quickly away from the stem. Transversely elliptical leaf scars, 2 mm wide and 1 mm high, appear on the surface of the stem about 2 cm apart. Transversely oriented furrows are evident on the surface between the leaf scars. Leaf cushions are present on some of the small branches and are longitudinally elongate. The vascular and parichnos scars are oriented horizontally. The leaves are linearly lanceolate and are 3 mm long and 0.5 mm wide.

Discussion: *Bothrodendron* was observed only at the western end of locality EKP-1 in a zone about 6 inches above the main coal seam.

Bothrodendron minutifolium occurs from Westphalian A to C, peaking during Westphalian B, in Great Britain (Crookall, 1932, 1964). It also occurs in the Drury Shale Member of the Caseyville Formation of Illinois (Jennings, 1979). According to Jennings (1979), the occurrences of *Bothrodendron* reported by Reed (1926), White (1937), Janssen (1940), and Arnold (1949) do not contain the necessary diagnostic features for the correct identification of this plant. The occurrence of *Bothrodendron* in the Appalachian and Eastern Interior regions can now be confirmed.

***Ulodendron majus* Lindley and Hutton, 1831- 33**
Pl. 2, Figs. 4-6

1966. *Ulodendron majus* Crookall, p. 355-372.

Description: The stem surface has circular branch scars, approximately 35 mm in diameter, arranged in longitudinal rows, and has small, rhomboidal leaf cushions arranged helically. The large branches may branch dichotomously (Fig. 3). Several specimens bear attached leaves and have leaf cushions that are round, measure about 2 mm in diameter, and are slightly raised above the rest of the stem surface. A prominent indentation on some specimens represents the position of the vascular tissue. Parichnos scars were not identified on any of the leaf scars. The leaves are linearly lanceolate and are 2 to 3 mm long. Longitudinal furrows are frequently evident, and are about 2 cm apart.

Discussion: *Ulodendron* was found only at EKP-1 and EKP-5. Specimens here conform to the original figures of *Ulodendron minus*, which Crookall (1966) regarded as synonymous with *U. majus*. In the absence of the type specimen of *U. majus* (Crookall, 1966), we will treat all of the specimens in the collection as *Ulodendron majus*, which has priority, as suggested by Crookall (1966).

Figure 3. *Ulodendron majus.*

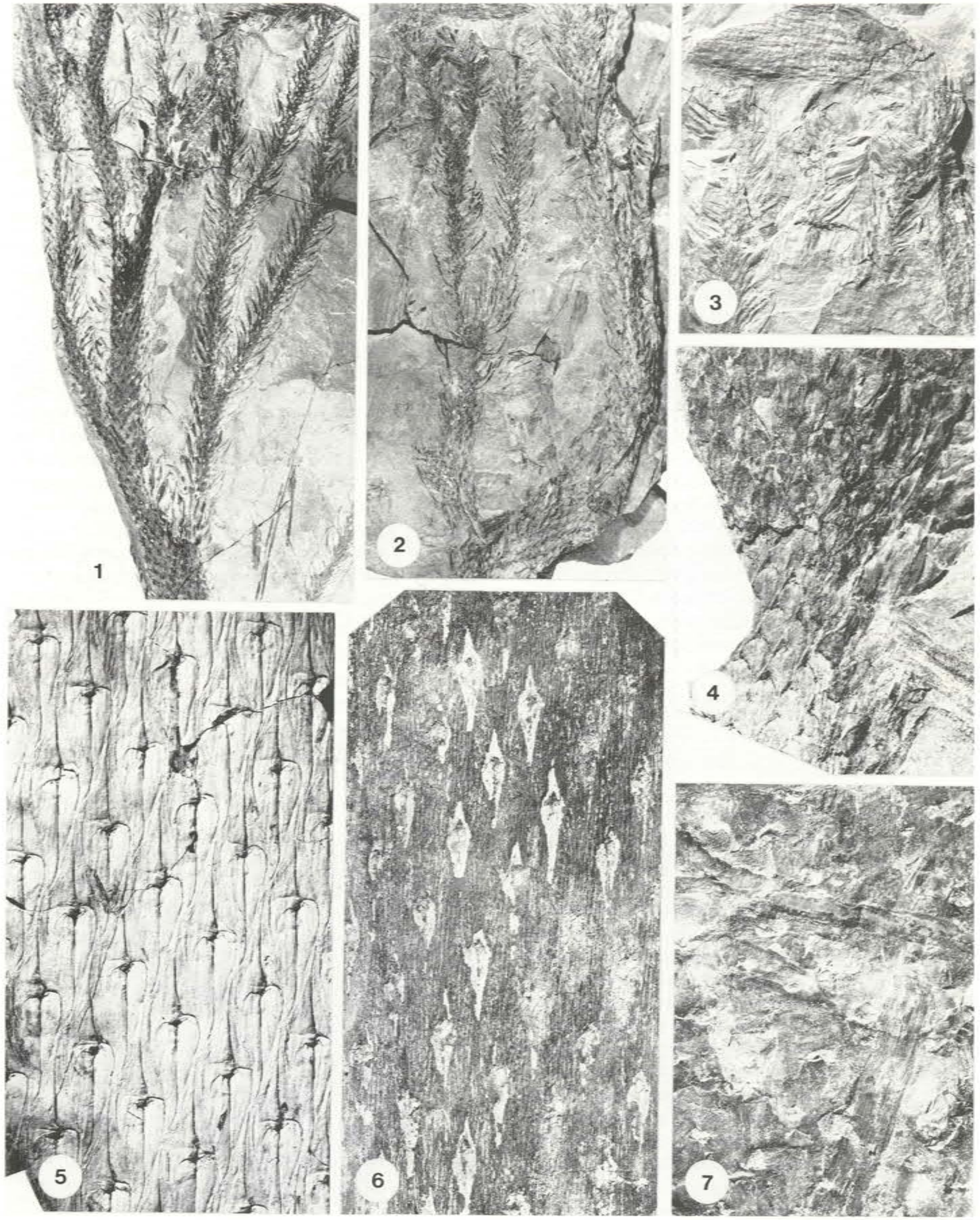

PLATE 1

Figure

1. *Lepidodendron* cf. *L. aculeatum*. Branches with attached leaves. EKP-1. X 0.5.

2. *Lepidodendron* cf. *L. aculeatum*. Branches with attached leaves and cone. EKP-1. X 0.5.

3. Detail of attached cone from Figure 2. X 2.

4. Detail of base of branch from Figure 2. X 2.

5. *Lepidodendron* cf. *L. aculeatum*. Stem surface. EKP-1.

6. *Lepidodendron* cf. *L. aculeatum*. EKP-1.

7. *Asolanus* sp. EKP-1.

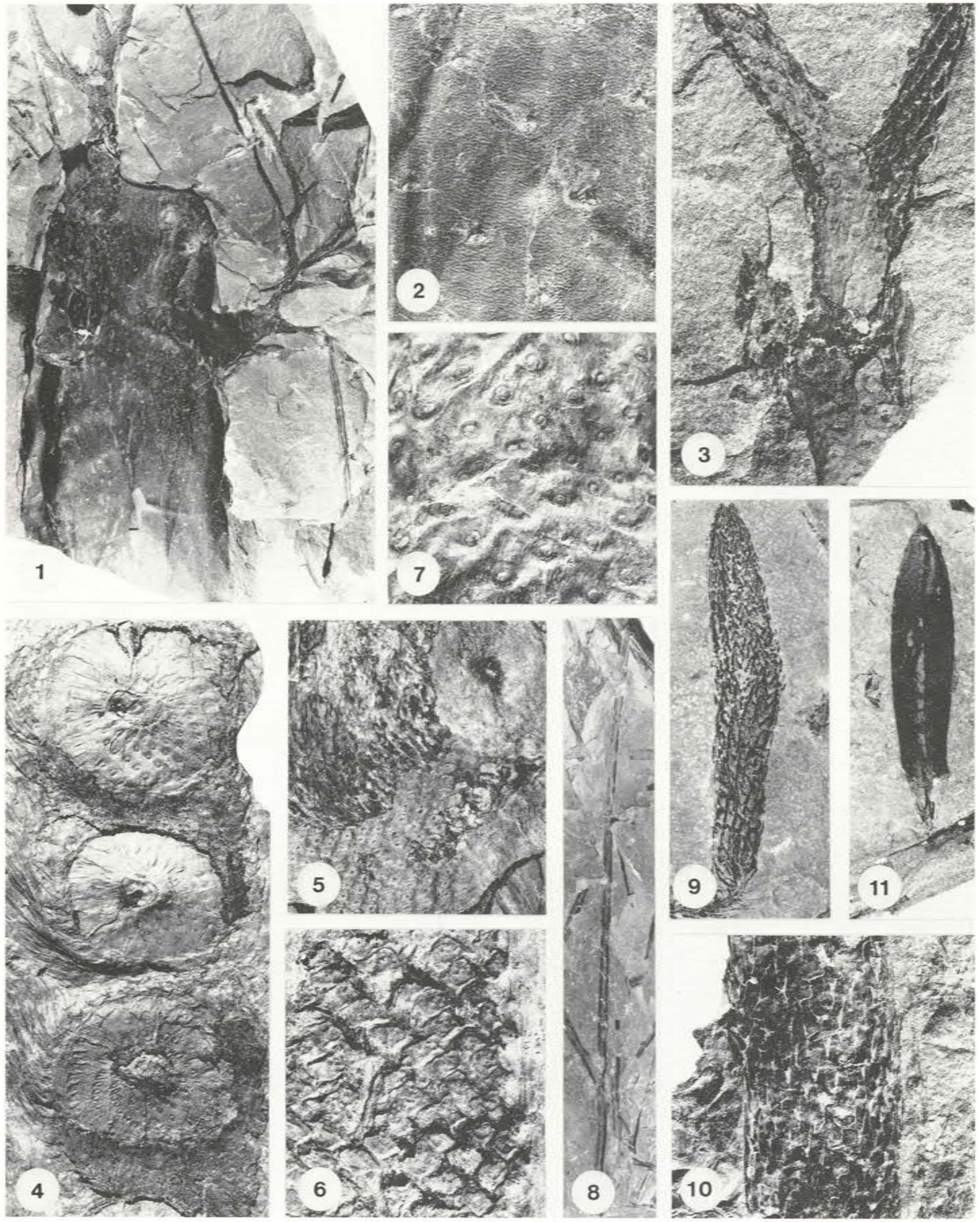

PLATE 2

Figure

1. *Bothrodendron minutifolium.* Branches with attached leaves. EKP-1. X 0.5.
2. *Bothrodendron minutifolium.* Stem surface. X 2.
3. *Bothrodendron minutifolium.* Detail of ultimate branch. EKP-1. X 3.2.
4. *Ulodendron minus.* EKP-1.
5. *Eulodendron minus.* EKP-1.
6. *Eulodendron minus.* Detail of stem surface. EKP-1. X 3.2.
7. *Stigmaria ficoides.* Pith cast. EKP-1.
8. *Lepidophylloides longifolium.* EKP-1. X 0.5.
9. *Lepidostrobus ornatus(?).* EKP-1.
10. *Lepidostrobus* sp. EKP-1.
11. *Lepidostrobophyllum lanceolatum.* EKP-2.

The large circular scars that are characteristic of *Ulodendron* are probably the result of the shedding of vegetative, or possibly cone-bearing, branches during the growth of the plant. Ulodendric-type branch scars have been observed on various species of *Lepidodendron* and *Bothrodendron* (*see* Crookall, 1966), but the form of the leaf scars and leaf cushions appears to be distinctive.

The specimens bearing attached leaves (Pl. 2, Fig. 5) are similar to material described by Schimper (1874) as *Ulodendron commutatum*.

Ulodendron majus occurs from the Namurian through Westphalian C in Great Britain.

Asolanus sp.
Pl. 1, Fig. 7

Description: *Asolanus* is represented in the flora by several large stem surfaces. This surface is nearly smooth, although it bears slightly raised, helically arranged, rhomboidal leaf scars. The leaf scars bear vascular and parichnos scars in a manner similar to *Lepidodendron*. There is no indication of leaf cushions.

Discussion: *Asolanus* sp. is a rare element in the flora and was found only at EKP-1.

This material may represent an anomalous form of *Lepidodendron*.

Asolanus has been reported from numerous horizons, and is not regarded as a very useful taxon for stratigraphic purposes.

Stigmaria ficoides Sternberg, 1825
Pl. 2, Fig. 7

1966. *Stigmaria ficoides* Crookall, p. 549-556, Pl. 104, Figs. 1-3, Pl. 105, Figs. 1-2, Pl. 106, Fig. 5.
1969. *S. ficoides* Darrah, Pl. 27, Fig. 3.
1978. *S. ficoides* Gillespie and others, Pl. 21, Figs. 3-5.

Description: The stigmarian pith casts have smooth surfaces with circular rootlet scars spaced about 1 cm apart. A small indentation can be seen in the center of some of the rootlet scars. The rootlet scars have a diameter of about 3 mm.

Discussion: Several pith casts of *Stigmaria ficoides* were found in the shale just above the main coal at EKP-1.

Stigmaria ficoides is extremely common throughout the Carboniferous of Europe (Crookall, 1966) and North America (Gillespie and others, 1978).

Division Sphenophyta
Calamites cisti Brongniart, 1828
Pl. 3, Fig. 3

1917. *Calamites cisti* Kidston and Jongmans, p. 122-128, Pls. 94-96, Pl. 106, Fig. 5, Pl. 158, Fig. 1, Text-Fig. 68.
1939. *C. cisti* Janssen, p. 80, Fig. 61.

Description: Internodal areas are longer than wide and vary in length from about 30 to 100 mm. The nodes constrict slightly. The ribs are straight, longitudinally striated, and 1 to 2 mm wide. They are rectangularly pointed at the node. When seen, the tubercles appear at the upper ends of the ribs and are longitudinally elliptical, measuring 1 to 3 mm high by 1 mm wide. Nodal diaphragms are preserved with several pith casts of this type collected at EKP-1.

Calamitean stem surface impressions found at EKP-1 (Pl. 3, Fig. 4) are smooth except for fine, longitudinal furrows and transverse striations 0.5 to 1 mm apart.

Discussion: Calamitean pith casts are the most abundant plant fossils found in the study area.

Calamites cisti is common in the Westphalian A, B, and lower C strata of Great Britain (Crookall, 1969). In North America, it is known from the upper Allegheny strata of West Virginia (White, 1900b) and the Caseyville Formation of Illinois (Jennings, 1974). It has also been found in eastern Canada (Bell, 1944), Michigan (Arnold, 1949), Missouri (Basson, 1968), and Ohio (Darrah, 1969).

Calamites undulatus Sternberg, 1825
Pl. 3, Figs. 1-2

1917. *Calamites undulatus* Kidston and Jongmans, Pls. 1-23.

Description: Internodes vary in length from 25 to 110 mm, but are most commonly about 70 mm. Internodes are shortest above nodes that bear branch scars. Ribs are straight or flexuous, longitudinally striated, and 2 to 3 mm wide. The ends of the ribs are rectangular or pointed where they alternate with supradjacent ribs. The ribs converge at the branch scars. Tubercles may be circular or oval; the largest measure 3 mm in height and 2 mm in width. Branch scars occur on the nodal line and range from 2 to 15 mm in diameter. The scars do not occur on each nodal line and may be singular or grouped.

Discussion: *Calamites undulatus* occurs in the Namurian and throughout the Westphalian Series of Great Britain. It is found most commonly from Westphalian A to lower C (Crookall, 1969). In North America it is present throughout the Pottsville Series and lower Conemaugh Formation (Darrah, 1969).

Annularia galioides Lindley and Hutton, 1831-33
Pl. 3, Figs. 6-7, Figs. 4-5

1969. *Annularia galioides* Crookall, p. 740-742, Pl. 127, Fig. 6.

Description: The whorls generally consist of nine to 12 leaves and occur about 6 to 11 mm apart on the ultimate branches. The leaves are fairly consistent in length, ranging from 4 to 8 mm long and 1 to 1.5 mm wide. The leaves are widest at the middle, or just above the middle, and taper both apically and basally. Some leaves are slightly spatulate with round apices. The mid-rib is relatively thin compared to other species of *Annularia*. The transfers of *A. galioides* show the presence of dark, centrally located, longitudinally elongate parenchyma cells. The lateral part of the leaf shows broad mesophyll cells extending at an acute angle toward the margin of the leaf.

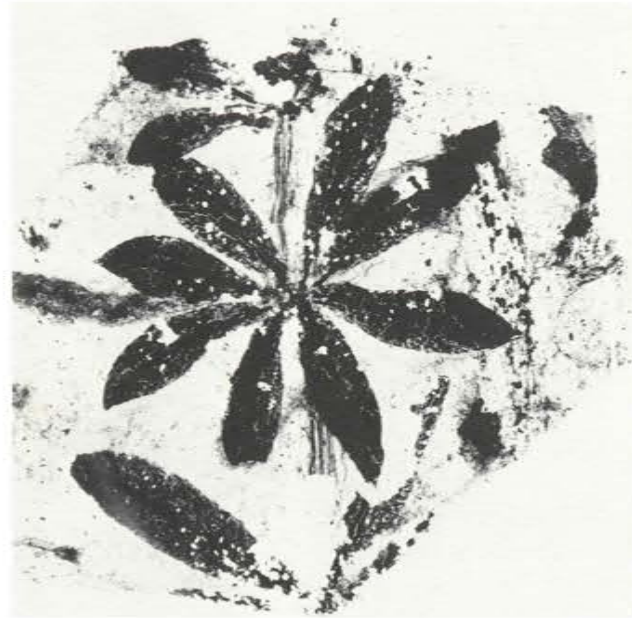

Figure 4. *Annularia galioides*. X 8.

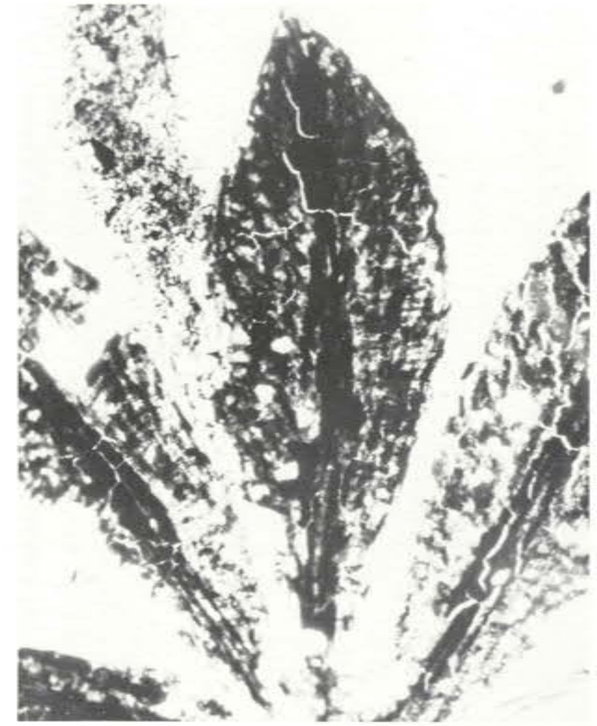

Figure 5. *Annularia galioides*. X 40.

Discussion: *Annularia galioides* is abundant at all of the study localities.

The leaves of *A. galioides* are intermediate in length between *A. asteris* Bell and *A. radiata* (Brongniart) Sternberg and are wider relative to their length than either of these species. The spatulate leaves resemble the type described by Walton (1936) as *A. jongmansi*. The species of *Annularia* from the study area conforms to the original description and figure of *A. galioides* (Lindlay and Hutton, 1831-33), but not the descriptions and figures referred to as *A. galioides* by Walton (1936) and Abbott (1958).

A. galioides is commonly present in the Westphalian B and less frequently in the Westphalian C and D of Great Britain (Crookall, 1969). Darrah (1969) reported *A. galioides* throughout the Pottsville and lower Allegheny rocks of North America.

Figure 6. *Asterophyllites longifolius*. X 8.

Asterophyllites longifolius (Sternberg) Brongniart, 1828
Pl. 3, Fig. 5, Figs. 6-7

1958. *Asterophyllites longifolius* Abbott, p. 384, Chart 1, Pl. 40, Fig. 53, Pl. 52, Fig. 60.
1969. *A. longifolius* Crookall, p. 704-707, Pl. 150, Fig. 2.
1978. *A. longifolius* Gillespie and others, Pl. 25, Fig. 5.

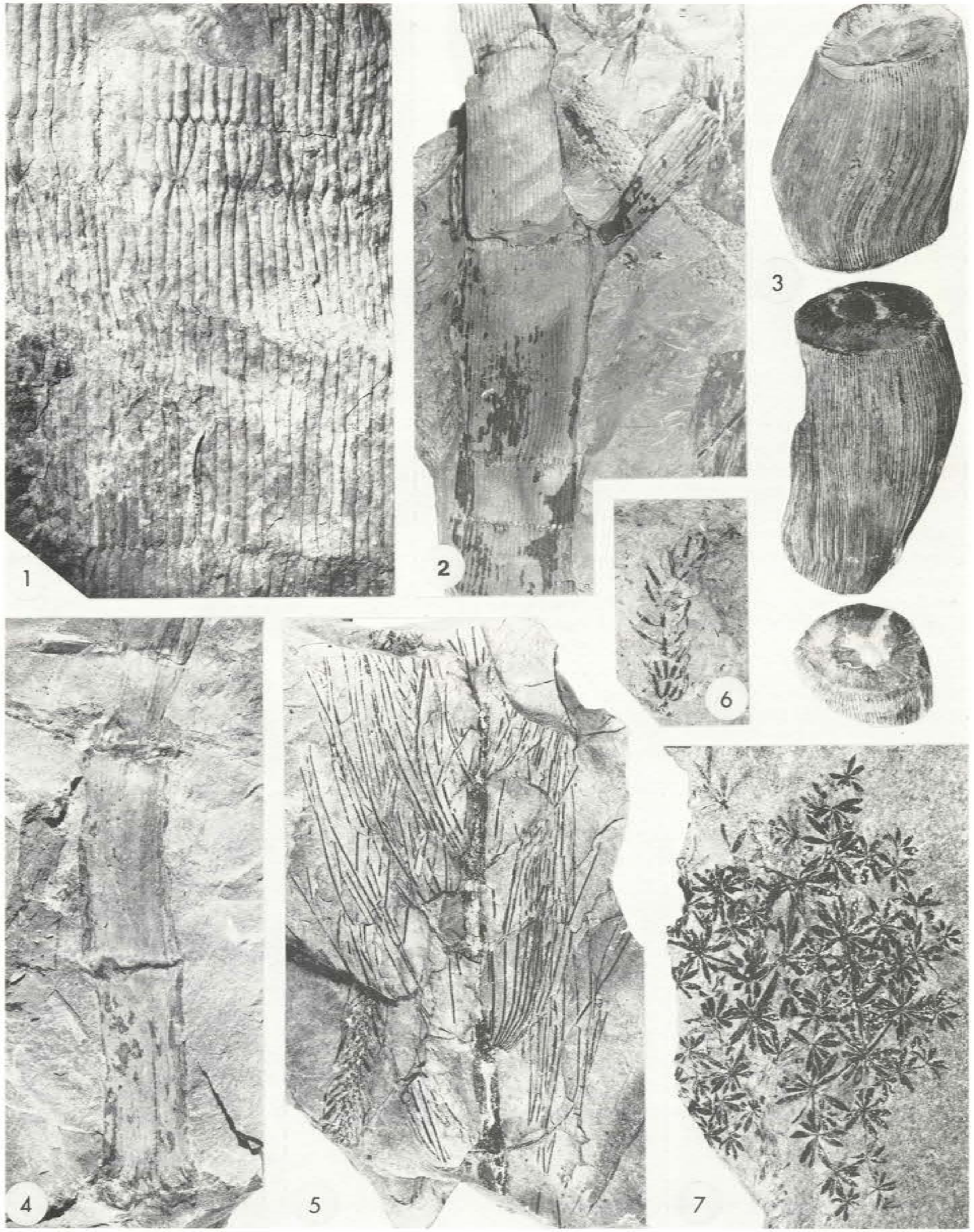

PLATE 3

Figure

1. *Calamites undulatus.* Pith cast. EKP- 1.
2. *Calamites undulatus.* Pith cast. EKP-1. X 0.5.
3. *Calamites cisti.* Pith casts with attached nodal diaphragms. EKP-1. X 0.32.
4. *Calamites* sp. Surface impression. EKP-1.
5. *Asterophyllites longifolius.* EKP-1.
6. *Asterophyllites charaeformis.* EKP-1. X 2.
7. *Annularia galioides.* EKP-1.

Figure 7. *Asterophyllites longifolius*. X 40.

Description: The nodes are approximately 10 mm apart on the small branches. The leaves are linear, and reach 60 mm in length and about 0.3 mm in width. The transfers show a large central zone of elongate parenchyma cells and a narrow zone of radiating mesophyll. The cells of the mesophyll are approximately perpendicular to the vascular strand.

A. longifolius is found in Westphalian A, B, and C strata in Great Britain (Crookall, 1969). It occurs from lower Pottsville to upper Allegheny rocks in Nova Scotia, throughout the Allegheny rocks of Pennsylvania and equivalent strata of Illinois, in the lower Allegheny equivalents of Missouri, and the upper Allegheny strata of Ohio (Abbott, 1958). Gillespie and others (1978) reported it throughout the Pennsylvanian strata of West Virginia.

Asterophyllites charaeformis Sternberg, 1825
Pl. 3, Fig. 7

1958. *Asterophyllites charaeformis* Abbott, p. 298, Chart 1, Pl. 35, Fig. 2, Pl. 48, Figs. 85-86.
1969. *A. charaeformis* Crookall, p. 709- 711, Fig. 206, Pl. 144, Fig. 3.
1978. *A. charaeformis* Gillespie and others, p. 70, Pl. 25, Figs. 1, 4.

Description: The leaves are narrow and arch upward in a whorl around the axis of the branch. The whorls are about 5 mm apart on the small branches. The leaves are 3 to 4 mm long and 0.5 mm wide.

Discussion: Specimens of *A. charaeformis* were observed only rarely at EKP-1.

This species has been reported throughout the Westphalian Series of Great Britain, but most commonly from the Westphalian B and lower C (Crookall, 1969) and throughout the Lower and Middle Pennsylvanian strata of West Virginia (Gillespie and others, 1978).

Sphenophyllum cuneifolium (Sternberg) Zeiller, 1880
Pl. 4, Figs. 3, 5

1958. *Sphenophyllum cuneifolium* Abbott, p. 337-339, Chart 3, Pl. 37, Fig. 22, Pl. 38, Fig. 36.
1969. *S. cuneifolium* Crookall, p. 783- 785, Figs. 160-162a, 171a, Pl. 107, Fig. 5, Pl. 109, Figs. 3-4.

Description: Approximately six wedge-shaped leaves comprise a whorl. The leaves are 8 to 10 mm long and 4 mm wide at the distal margin, where about eight triangular teeth are borne. Another leaf type, belonging to the same species (Pl. 4, Fig. 5), has four to eight acutely pointed lobes on the distal margin (Abbott, 1958). One vein enters each tooth at the distal margin. Nodes are 8 to 10 mm apart on the small branches.

Discussion: *S. cuneifolium* is common at all of the study area exposures except EKP-5, and is especially abundant at EKP-2, where it is generally restricted to the shale beds.

In Great Britain this plant is very common in the Westphalian A and B strata and rare in Westphalian C and D strata (Crookall, 1969). According to Abbott (1958), it is known from the Pottsville to upper Allegheny rocks of Nova Scotia, the Allegheny strata of Pennsylvania, the lower Carbondale Formation of Illinois, and the Allegheny to Monongahela beds of Ohio and equivalent strata in Kansas. Gillespie and Pfefferkorn (1976) noted it in the upper New River to lower Allegheny rocks of West Virginia.

Paleostachya sp.
Pl. 4, Fig. 2

Description: This calimitean cone is 14 mm long, and the central axis is 1 mm wide. The whorls of bracts arch upward and are 1.5 mm apart on the cone axis. The sporangia are oval and are attached to the axils of the bracts.

A specimen of another calamitean cone type is 5 cm long and 7 mm wide. The sterile bracts are 4 mm long and 1 mm wide and have pointed apices. The whorls of bracts are 4 mm apart on the cone axis. Since the mode of attachment of the sporangia to the cone cannot be seen, this cone is not assigned to a particular genus (Pl. 4, Fig. 1).

Discussion: Calamitean cones are not abundant, but occur throughout the study area. Only one specimen that could be positively identified as *Paleostachya* was collected.

Bowmanites sp.
Pl. 4, Fig. 4

Description: This cone specimen is 5.5 cm long and 1 cm wide. The bracts are fused along the margins to form a saucer-shaped structure around the cone axis. The sporangia were not found preserved with the specimen.

Discussion: One specimen of *Bowmanites* was collected at EKP-2 in the zone dominated by *Sphenophyllum cuneifolium* (Pl. 4, Fig. 4). A similar specimen was found at EKP-1.

Divisions Pterophyta and Cycadophyta
Pecopteris cf. _P. plumosa_ Artis, 1825
Pl. 4, Fig. 6, Fig. 8

1960. *Pecopteris plumosa-dentata* Dalinval, p. 53-64, Pls. 5-15.
1969. *P. plumosa* Darrah, Pl. 13, Fig. 4.

Description: The pinnules may be linear or triangular, with straight margins. The pinnules are 5 to 8 mm long and 2 to 4 mm wide at the base. The veins are fine and distant, with one or two branchings (Fig. 8).

Discussion: Pecopterid foliage is common at the western end of outcrop EKP-1, always in the form of isolated pinnae and almost exclusively in the sandy shale just below the thin rider coal.

Pecopteris plumosa has been found throughout the Westphalian Series of Europe (Dalinval, 1960). It is known from the middle Pottsville through Allegheny strata of Pennsylvania, West Virginia, Ohio, and Illinois; it also occurs in Indiana, Iowa, Missouri, and Kansas (Darrah, 1969). This plant has been reported from the Michigan Basin (Arnold, 1949) and from the Westphalian A of eastern Canada (Bell, 1966).

Sphenopteris amoena Stur, 1885
Pl. 4, Figs. 7-8, Figs. 9-11

Description: The pinnae are attached to a straight or slightly winged rachis. They usually bear four to six pairs of pinnules. The pinnules are most commonly quadrilobate with rounded or bluntly pointed lobes, and measure 2 to 5 mm long and about 2 mm wide. The veins, when preserved, are distant and rather coarse, and one vein extends to the margin of each lobe. Sporangia are small and nearly circular in outline (Fig. 11). They are borne on very short stalks (Fig. 10), and occur in aggregates at the margin of a pinnule where a vein is present. Since the sporangia are nearly opaque

Figure 8. *Pecopteris plumosa*. X 8.

Figure 9. *Sphenopteris amonea*. X 8.

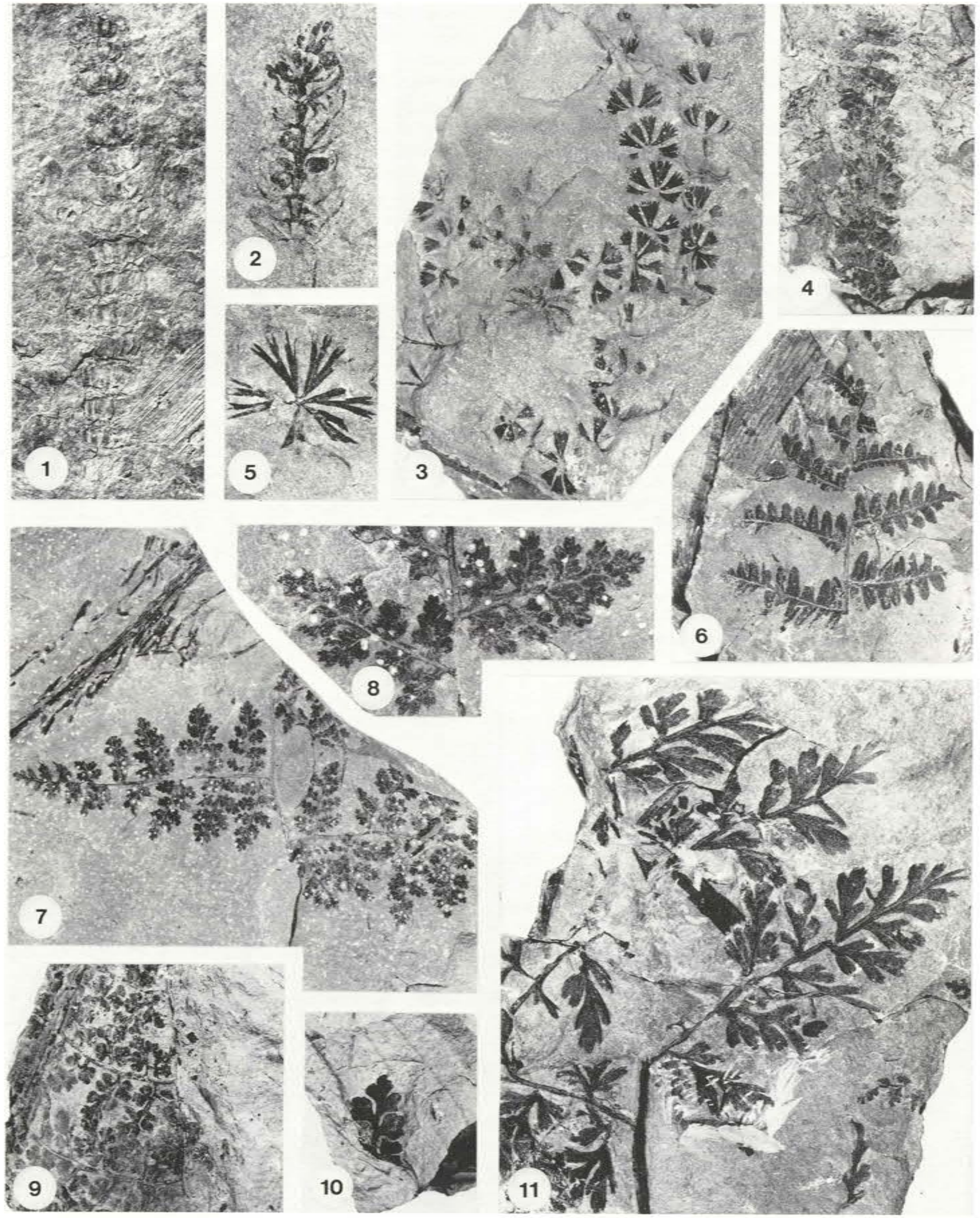

PLATE 4

Figure

1. Cone of *Calamites*. EKP-1. X 1.6.

2. *Paleostachya* sp. EKP-1. X 2.

3. *Sphenophyllum cuneifolium*. EKP-1.

4. *Bowmanites*. EKP-2.

5. *Sphenophyllum cuneifolium*. EKP-1.

6. *Pecopteris* cf. *P. plumosa*. EKP-1.

7. *Sphenopteris amoena*. EKP-1.

8. *Sphenopteris amoena*. Detail of pinnules from Figure 7. X 3.2.

9. *Sphenopteris obtusiloba*. EKP-2.

10. *Sphenopteris obtusiloba*. EKP-2.

11. *Eremopteris gracilis*. EKP-1.

and not well preserved, it was not possible to observe an annulus with certainty, although we believe that a small one may have been present.

Discussion: This plant is found at all of the study outcrops but is common only at EKP-1. It is usually restricted to the shale beds.

The shape of the pinnules varies, depending on the state of preservation, making specific identification difficult. The pinnules are smaller and more sharply pointed than *Sphenopteris footneri* Marrat, but not as sharply pointed as *S. schatzlarensis* Stur.

Sphenopteris amoena is found from the Westphalian A through C in Europe (Danze, 1956).

Sphenopteris obtusiloba Brongniart, 1829
Pl. 4, Figs. 9-10

1923. *Sphenopteris obtusiloba* Kidston, p. 29-33, Pl. 3, Figs. 1-4, Pl. 4, Figs. 4-5.
1949. *Diplothmema obtusiloba* Arnold, Pl. 26, Figs. 1-3.
1975. *Eusphenopteris obtusiloba* Van Amerom, p. 33-35, Pl. 6, Pl. 7, Figs. 1-8, Pl. 8, Pl. 10, Figs. 1-4, Pl. 12, Fig. 8, Pl. 15, Figs. 6, 11.

Figure 10. *Sphenopteris amonea.* X 50.

Description: The pinnules are often trilobate and are attached to a slightly flexuous rachis. They have rounded margins and are 3 to 5 mm long. The veins are fine and arcuate and have two or three divisions per vein.

Discussion: This plant is uncommon in the study area. Several specimens were collected at EKP-2, and one fragmented pinnule was observed at locality EKP-1.

Sphenopteris obtusiloba closely resembles the form called *S. trifoliolata* Artis, but has a denser mode of growth and more nearly wedge-shaped lobes on the pinnules.

S. obtusiloba is found in Westphalian A and B strata in Europe (Van Amerom, 1975) and in upper Pottsville to lower Allegheny rocks of Pennsylvania and equivalent strata in West Virginia, Tennessee, Illinois, and Missouri (Darrah, 1969). Arnold (1949) noted it in the Michigan Basin, also.

Sphenopteris sp.
Pl. 5, Fig. 5

Description: Pinnae lie perpendicular to the rachis, and are possibly reflexed in some cases. The pinnules are 10 mm long and 5 mm wide near the base. Pinnule apices are rounded. Commonly, a single lobe is developed near the base of the pinnule. Rarely, a lobe is developed on each side of the pinnule near the base. There is a weakly developed mid-vein that gives rise to closely spaced, arcuate lateral veins, which do not appear to fork into many smaller veins.

Figure 11. Sporangia of *Sphenopteris amonea.* X 50.

Discussion: This plant was found in a thin zone at outcrop EKP-5 in relative abundance. Several pinnules of this type observed at EKP-1 constitute the only other known occurrence of this plant in the study area.

This material closely resembles some of the material described by Van Amerom (1975) as *Eusphenopteris neuropteroides.*

Alethopteris decurrens Artis, 1825
Pl. 6, Fig. 4

1955. *Alethopteris decurrens* Crookall, p. 27-29, Pl. 2, Figs. 1-3, Pl. 6, Fig. 3.
1961. *A. decurrens* Buisine, Pls. 41-44.

Description: The pinnules range from 10 to 40 mm in length and 4 to 8 mm in width. Pinnule margins are parallel, the apex is bluntly pointed, and the base is confluent and decurrent. The pinnules are very lax. A strong mid-vein extends to the pinnule apex. The lateral veins are coarse, slightly flexuous, and branch once or twice. About 28 veins per centimeter can be counted along the pinnule margins.

Discussion: Several fragmented pinnae were found at locality EKP-5, and a few isolated pinnules were observed at EKP-6.

This species occurs in Westphalian A through C strata in Europe (Buisine, 1961). It is known from the New River and Kanawha Formations of West Virginia (Gillespie and others, 1978), the Westphalian A of eastern Canada (Bell, 1966), and from Michigan (Arnold, 1949).

Alethopteris cf. _A. lonchitica_ Zeiller, 1880
Pl. 6, Figs. 1-3, Fig. 12

Description: Pinnae lie oblique to the rachis. Pinnules are widely variable in size and shape, ranging from 7 to 20 mm long and 4 to 8 mm wide. The apex of the pinnule may be rounded, bluntly pointed, or acutely pointed, and the base is confluent and decurrent. Small pinnules have convex margins that become subparallel with larger pinnules. A strong mid-vein extends to the pinnule apex. Lateral veins curve strongly away from the mid-vein and reach the margin at about 90 degrees. The veins may be simple, may fork once (often near the mid-vein), or, rarely, branch twice (Fig. 12). Approximately 45 veins per centimeter can be counted along the pinnule margins.

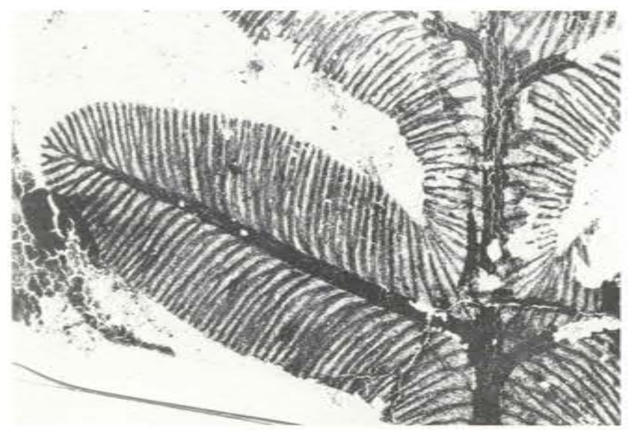

Figure 12. *Alethopteris* cf. *A. lonchitica.* X 50.

Discussion: This form of *Alethopteris* is commonly present at all of the study area exposures except EKP-5.

The form of the pinnules resembles *A. serli* Brongniart, but the veination of the Kentucky type is much denser, with simpler lateral veins. Pinnae bearing long, pointed pinnules may be compared to *A. lonchitica* Zeiller, although the veination of the study area type is slightly denser and simpler. Large pinnules with bluntly pointed apices and smaller pinnules with rounded apices from the study area also bear a strong resemblance to the European type *A. densinervosa* Wagner.

Neuropteris gigantea Sternberg, 1825
Fig. 13

1959. *Neuropteris gigantea* Crookall, p. 134-139, Figs. 47, 65f, 67e, Pl. 34, Pl. 35, Figs. 1-4, Pl. 49, Fig. 8.
1967. *Paripteris gigantea* Laveine, p. 252-257, Pls. 70-72.

Description: The pinnules average 25 mm in length and 10 mm in width. Although the veination is not well preserved, the veins were dense and oblique to the margins of the pinnules. The plant was identified on the basis of the sickle-shaped pinnules, which are typical of the species.

Discussion: One pinnule of this form was found at locality EKP-6.

Neuropteris gigantea is found throughout the Westphalian A and B strata of Europe (Laveine, 1967) and the Kanawha through lower Allegheny Formations of West Virginia (White, 1900b; Jongmans and others, 1937; Gillespie and Pfefferkorn, 1976).

Neuropteris cf. _N. tenuifolia_ Brongniart, 1828
Pl. 5, Figs. 1-2; Figs. 14-15

1949. *Neuropteris tenuifolia* Arnold, Pl. 22, Figs. 5-10.
1959. *N. tenuifolia* Crookall, p. 118-121, Figs. 42, 63f, 63k, Pl. 29, Figs. 1-4.
1967. *N. tenuifolia* Laveine, p. 167-172, Pls. 30-34.

Description: The pinnae lie oblique to the rachis. The pinnules are oblong-triangular or oval, and range in size from 5 to 20 mm long and 3 to 8 mm wide. The mid-vein is rather weak, and extends about three-fourths of the way to the pinnule apex. Lateral veins are fine and straight, arch slightly, and reach the pinnule margin at

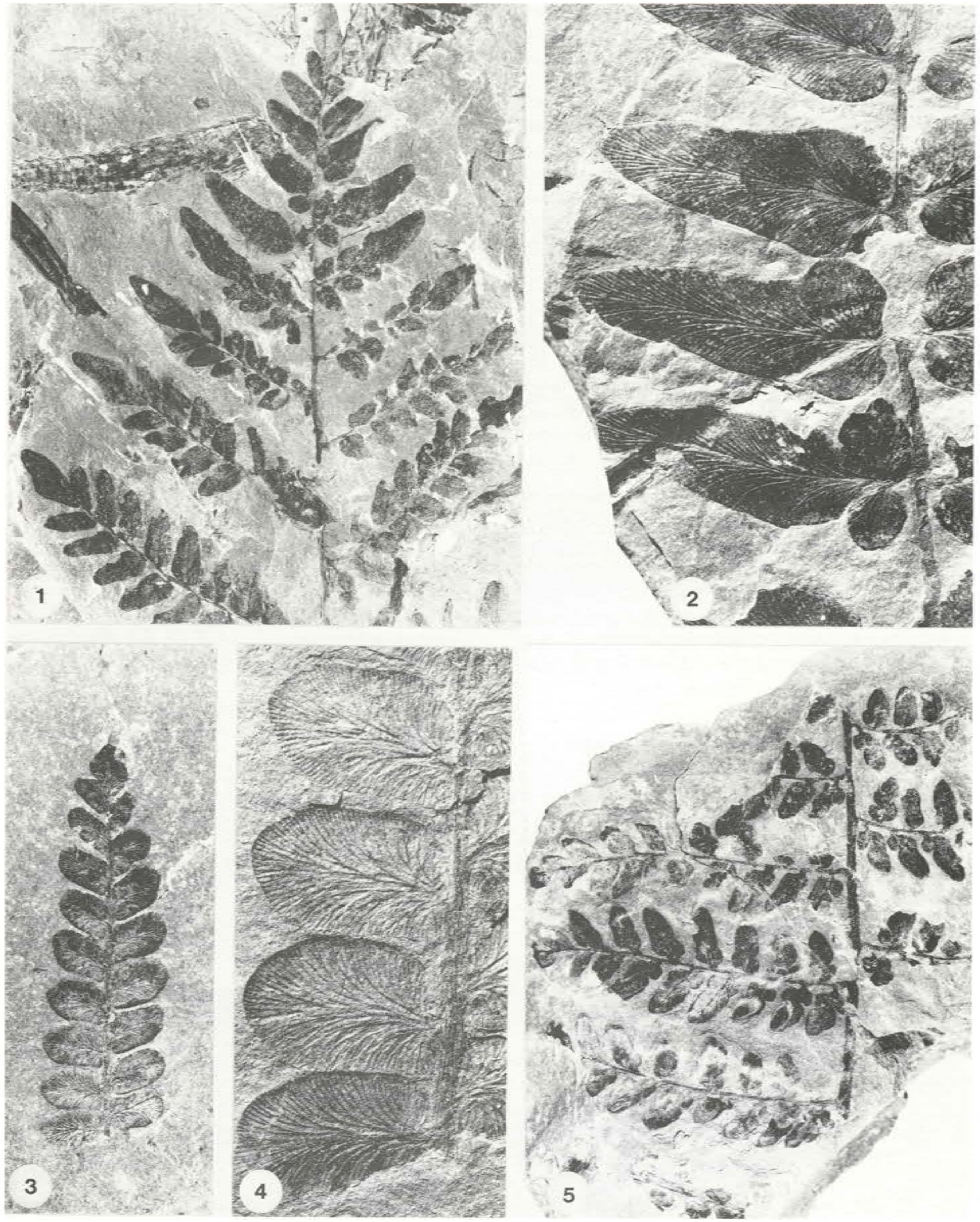

PLATE 5

Figure

1. *Neuropteris* cf. *N. tenuifolia*. EKP-1.

2. *Neuropteris* cf. *N. tenuifolia*. Detail from Figure 1. X 2.

3. *Neuropteris heterophylla*. EKP-1.

4. *Neuropteris heterophylla*. Detail from Figure 3. X 3.2.

5. *Sphenopteris* sp. EKP-5.

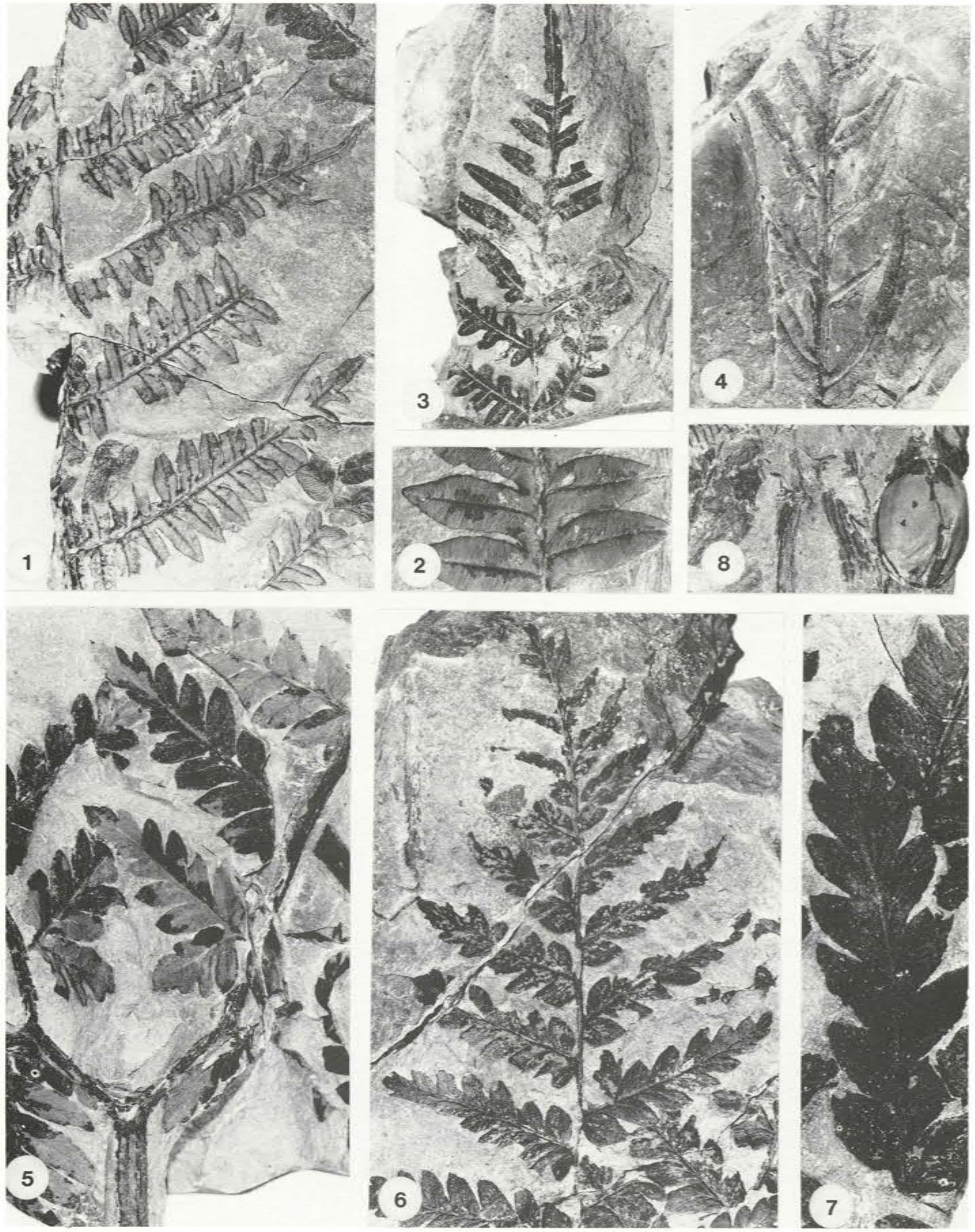

PLATE 6

Figure

1. *Alethopteris* cf. *A. lonchitica.* EKP-1.
2. *Alethopteris* cf. *A. lonchitica.* EKP- 1. X 2.
3. *Alethopteris* cf. *A. lonchitica.* EKP-2.
4. *Alethopteris decurrens.* EKP-5.
5. *Mariopteris nervosa.* EKP-1.
6. *Mariopteris nervosa.* EKP-1.
7. *Mariopteris nervosa.* Detail from Figure 6. X 2.
8. *Trigonocarpus* sp. EKP-1.

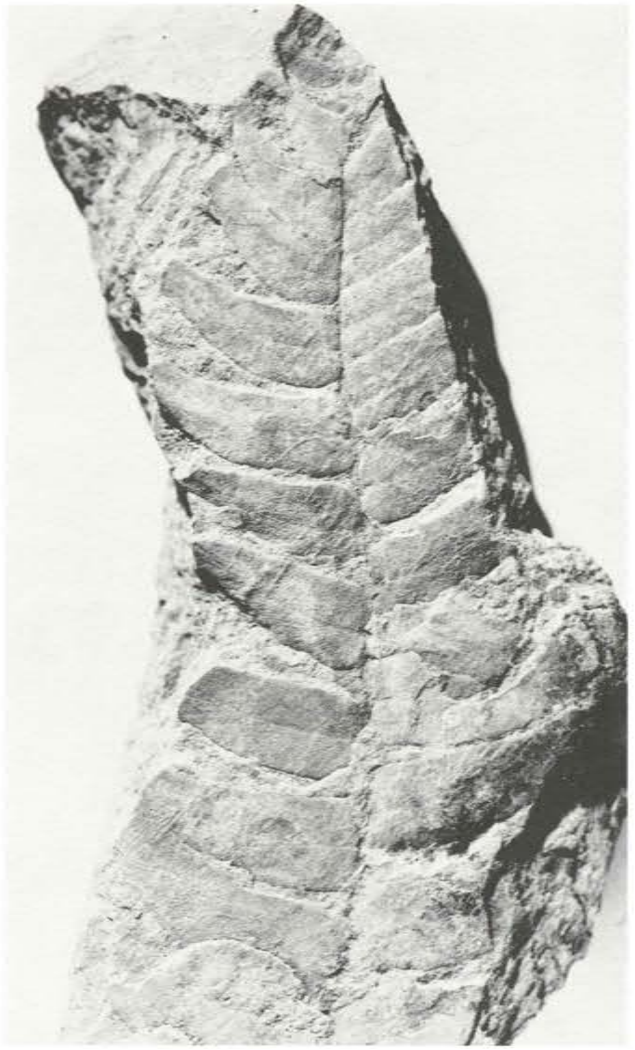

Figure 13. *Neuropteris gigantea*. X 1.

Figure 14. *Neuropteris tenuifolia*. X 8.

Figure 15. *Neuropteris tenuifolia*. X 40.

an oblique angle. At the margin, they arc sharply toward the apex, resulting in a dark border for the pinnule (Figs. 14- 15). They branch two to four times, and about 30 veins per centimeter can be counted along the pinnule margins. Small, dark areas lie between the veins and are perpendicular to them (Figs. 14-15). We believe these represent the position of sclerotic cells. They have not been observed, to date, in *N. heterophylla*.

Discussion: This form of *Neuropteris* is present at all of the study outcrops, usually in the form of isolated pinnules. Intact pinnae can be found in the shale beds at the eastern end of EKP-1.

The type of *Neuropteris* found in the study area is probably a member of the *N. heterophylla- tenuifolia* group (Crookall, 1959) and most resembles *N. tenuifolia*, although the pinnules of the study area type are often more nearly triangular than the specimens figured from Europe (Crookall, 1959; Laveine, 1967) and other parts

of North America (Arnold, 1949; Bell, 1966; Darrah, 1969).

The pinnules, especially the terminal pinnules, of *N. tenuifolia* are longer relative to their width than those of *N. heterophylla*. The shape of the small pinnules of the study area type resembles the undescribed type *N. tennesseeana* Lesquereux figured by Read and Mamay (1964), but since the veination of this form is unknown, a true comparison cannot be made. Although the shape of the pinnules of *N. callosa* Lesquereux is similar to *N. tenuifolia*, the veination of *N. callosa* is coarser, more distant, and not as straight as that of *N. tenuifolia*.

Neuropteris tenuifolia has been found from the Westphalian A through C, commonly Westphalian B and C, of Europe (Crookall, 1959; Laveine, 1967), and from the upper Pottsville to lower Allegheny strata of North America (Lesquereux, 1880; Arnold, 1949; Bell, 1966; Darrah, 1969).

Neuropteris heterophylla Brongniart, 1828
Pl. 5, Figs. 3-4, Figs. 16-17

1959. *Neuropteris heterophylla* Crookall, p. 98-104, Figs. 33-35, 63e, h, j, Pls. 25- 28, Pl. 29, Fig. 5, Pl. 32, Figs. 1-2, Pl. 49, Fig. 7, Pl. 54, Fig. 2, Pl. 55, Figs. 1-2.

1967. *N. heterophylla* Laveine, p. 141- 144, Pls. 11-13.

Description: The pinnules are most commonly oval but may be elongate, and average 7 to 12 mm in length and 7 mm in width. The lateral margins of the elongate pinnule form are roughly parallel. Adjacent pinnules often overlap. The mid-vein is very weak. Lateral veins are well arched and branch three or four times. About 40 veins per centimeter can be counted along the pinnule margins. While the veins may be slightly expanded at the margin of the pinnule, there is no indication of a border such as in *N. tenuifolia* (Figs. 16-17).

Discussion: Several fragmented pinnae of *N. heterophylla* were collected just above the rider coal at exposure EKP-1.

The veination of *N. heterophylla* is coarser and more arched than that of *N. tenuifolia*. Also, the pinnules of *N. heterophylla* are wider relative to their length than those of *N. tenuifolia*.

Neuropteris heterophylla is present from the Westphalian A through D of Europe, but occurs mostly in the Westphalian B (Crookall, 1959; Laveine, 1967). In North America it is mainly restricted to the upper Pottsville, but occurs rarely in the Allegheny equivalents (Darrah, 1969).

Mariopteris nervosa Brongniart, 1833
Pl. 6, Figs. 5-7, Figs. 18-19

1925. *Mariopteris nervosa* Kidston, p. 603-608, Figs. 88-89, Pl. 13, Figs. 3-4, Pl. 140, Fig. 1, Pl. 143, Figs. 1-2, Pl. 144, Figs. 1, 4-6, Pl. 153, Figs. 1- 7.

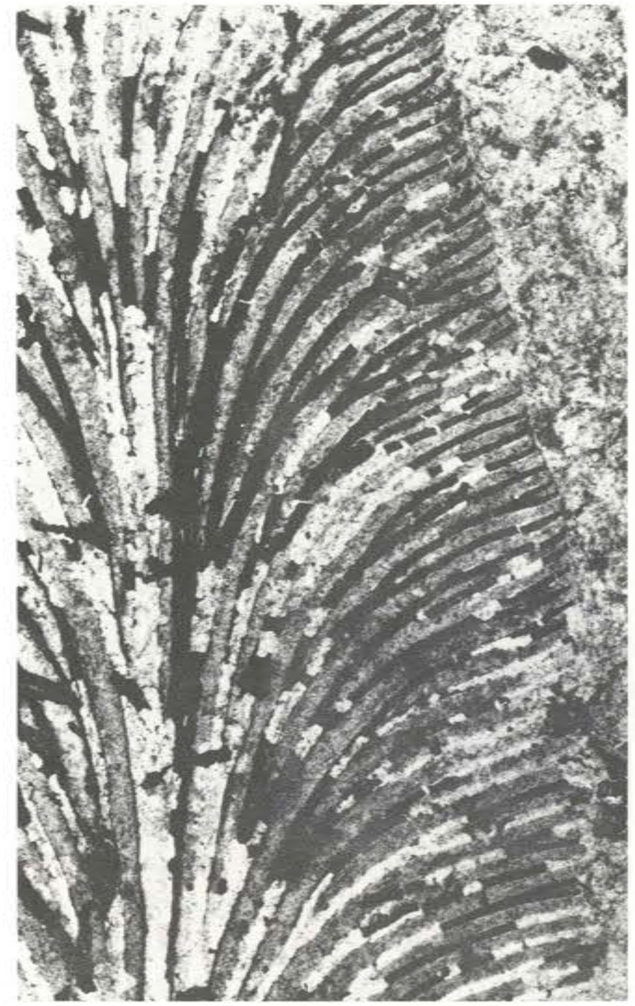

Figure 16. *Neuropteris heterophylla*. X 8.

Description: The petiole branches into two secondary rachises, which further divide distally. The pinnae lie oblique to the rachis and are present both above and below its forking. The pinnules are triangular, with slightly convex or straight margins, an acutely pointed or bluntly pointed apex, and a pecopteroid base. The pinnules are widely variable in size, and some form barely developed lobes. They range in size from 4 to 15 mm long, more commonly 8 to 10 mm, and 3 to 7 mm wide at the base. The mid-vein generally appears as a furrow, which extends almost to the apex of the pinnule. Lateral veins are distant and branch two or three times before reaching the margin of the pinnule. Dark areas on the transfers are small and numerous, rendering the preparations nearly opaque in some instances (Figs. 18-19).

Figure 17. *Neuropteris heterophylla*. X 40.

Discussion: *Mariopteris nervosa* is the most common pteridosperm found in the study area. It is especially abundant in the shale just above the main coal bed at the western end of EKP-1 and at locality EKP-2.

This plant can be differentiated from the similar species *M. muricata* Sternberg by the lack of dentate pinnule margins (Kidston, 1925).

Mariopteris nervosa occurs commonly throughout the Westphalian Series of Great Britain (Kidston, 1925). It has also been found in the Allegheny Series of Pennsylvania and Ohio, the Carbondale Formation of Illinois, and in Missouri and Kansas (Darrah, 1969). White (1900b) reported this plant from the upper Kanawha through upper Allegheny strata of West Virginia.

Eremopteris gracilis White, 1943
Pl. 4, Fig. 11, Figs. 20-21

Description: The pinnules are dissected into lobes with acute apices. There is a large central lobe at the apex of each pinnule. There are at least two lateral lobes, which may be further divided, especially in the large pinnules. The pinnules are 10 to 15 mm long and about 7 mm wide. The veination is distant, and each vein branches two or three times before reaching the pinnule margin. Many dark areas can be seen in transfer preparations and are arranged such that they give the appearance of transverse striations (Figs. 20-21).

Discussion: *Eremopteris gracilis* is not abundant in the study area, but does occur at all of the exposures except EKP-5.

Figure 18. *Mariopteris nervosa*. X 8.

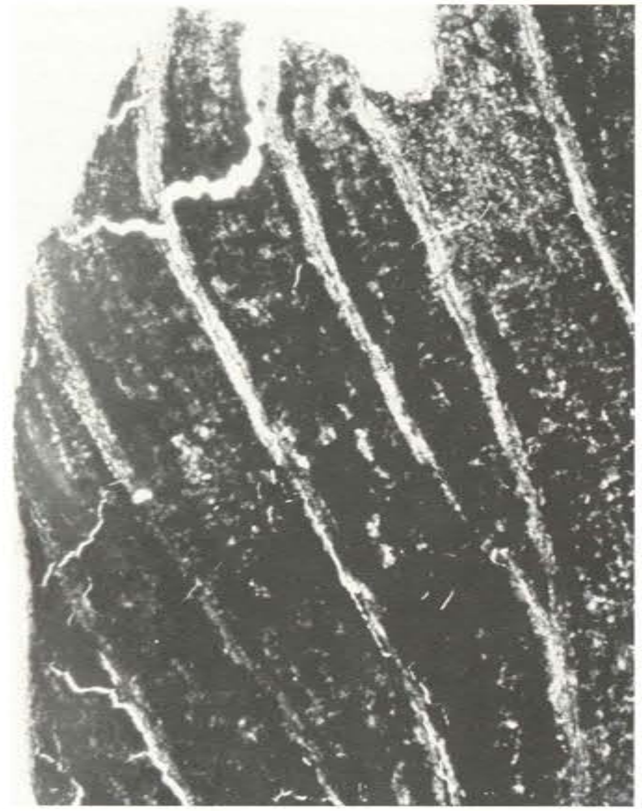

Figure 19. *Mariopteris nervosa*. X 40.

Figure 20. *Eremopteris gracilis*. X 8.

Several fragmented pinnae bearing pinnules with acutely pointed, strongly dissected lobes were observed. These may be referable to *E. lincolniana* White, but are probably a variation of the *E. gracilis* pinnule form.

White (1943) collected this plant from the North Jellico Mine near Grays Station, 7 miles southeast of Corbin, Kentucky.

***Trigonocarpus* sp.**
Pl. 6, Fig. 8

Description: Several impressions of the ovule type *Trigonocarpus* were collected at EKP-1. The seeds have an oval outline and average 3 cm in length and 2.5 cm in width. The surface of the impressions is smooth, and a suture ridge can usually be seen extending the length of the ovule.

Discussion: According to Darrah (1969), species of *Trigonocarpus* are found associated with *Alethopteris*, although no attached ovules of this form have been discovered.

DISCUSSION

The study area flora has six species in common with the Upper Lykens Coal Group (upper Pottsville) of Pennsylvania (White, 1900a): *Sphenophyllum cuneifolium*, *Neuropteris gigantea*, *N. tenuifolia*, *N. heterophylla*, *Mariopteris nervosa*, and *Sphenopteris obtusiloba*.

The lower Kanawha Formation of West Virginia contains several species also found in the study area (White, 1900b): *Bothrodendron* cf. *B. minutifolium*, *Lepidostrobus ornatus*, *Sphenophyllum cuneifolium*, *Calamites cisti*, *Pecopteris plumosa*, *Neuropteris gigantea*, *Alethopteris decurrens*, *Mariopteris nervosa*, and *Sphenopteris obtusiloba*.

Bode (1958) reported the occurrence of *Calamites cistisuckowi*, *Sphenophyllum cuneifolium*, *Neuropteris gigantea*, *Alethopteris decurrens*, *Neuropteris tenuifolia*, *N. heterophylla*, and *Pecopteris plumosa* from strata associated with a coal reported as the Jellico coal, west of Woodbine, Kentucky. In addition to these plants, he noted several types not found in the strata of the study area. Among the different plants are *Lepidophloios laricinus*, *Asterophyllites* cf. *A. equisetiformis*, *Linopteris obliqua*, *Mariopteris muricata*, *Palmatopteris furcata*, and *Cordaites principalis*.

The following fossil plants were collected by the authors from strata above a coal mapped as the Jellico (Puffett, 1963) in the same area studied by Bode: *Lepidodendron* sp., *Lepidostrobophyllum majus*

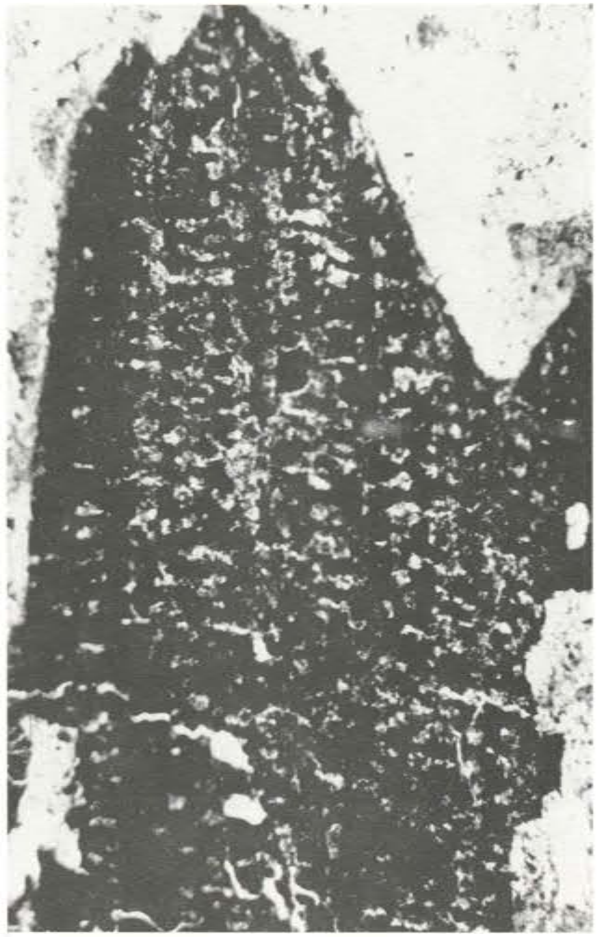

Figure 21. *Eremopteris gracilis*. X 40.

Brongniart, *Bothrodendron* cf. *B. minutifolium, Ulodendron minus, Calamites cisti, Sphenophyllum cuneifolium, Pecopteris plumosa, Alethopteris lonchitica* Zeiller, *Neuropteris heterophylla, Mariopteris muricata* Sternberg, *Sphenopteris trifoliolata* Artis, and *Sphenopteris* sp. Of these taxa, *Lepidodendron* sp., *Lepidostrobophyllum majus, Mariopteris muricata, Sphenopteris trifoliolata*, and *Sphenopteris* sp. were not found preserved in the study area. Also, the type of *Alethopteris,* which was collected near Woodbine, Kentucky, and identified as *A. lonchitica,* has a slightly more distant and more flexuous veination than the form present in the study area.

Preliminary collections were made from strata associated with coal beds correlated with the Jellico coal in two other localities in eastern Kentucky, not in the immediate vicinity of Grannies Branch. One of these sites is located in the Ogle Quadrangle, on Kentucky Highway 718, about 2.5 miles south of the junction of Kentucky Highway 718 and Kentucky Highway 421 (Ping and Sergeant, 1978). The flora from the Kentucky Highway 718 exposure is dominated by *Mariopteris pygmaea* White, and fragmented pinnae of *Mariopteris muricata* Sternberg, *Neuropteris heterophylla*, and a specifically indeterminate form of *Alethopteris* are also present. The *Alethopteris* resembles material collected from EKP-1.

Plant fossils collected from the Heidrick Quadrangle in a roadcut in Kentucky Highway 25E, 8 miles east of Corbin, Kentucky (Trimble and Smith, 1978), are similar to the study area flora, with the addition of *Annularia radiata* Brongniart.

CONCLUSIONS

The Pennsylvanian strata of eastern Kentucky contain abundant, well-preserved plant fossils that are valuable for biostratigraphic determinations.

The fossil plant types and their relative abundances change significantly both vertically and horizontally throughout the study area (Fig. 22). In the study area there appears to be no regular vertical succession of plant types in the strata over the coal.

In many instances the flora seems to vary as the texture of the rock matrix changes. This indicates that sedimentological factors influenced the floral assemblage preserved in a particular site. Factors such as the hydrodynamic and aerodynamic properties of the plants, the susceptibility of the plants to chemical and mechanical breakdown, the mode of transportation, and the environment of deposition must be taken into consideration before the paleoecology of these plants can be understood satisfactorily.

The lateral variation in the flora of the study area is great, and frequently two localities have fewer than half the species that are present in the flora in common (Fig. 23). This lateral variation underscores the importance of choosing a number of localities for paleobotanical sampling at a given horizon. A collection from only one locality is unlikely to yield a representative flora.

About half of the forms observed, such as *Alethopteris decurrens* and *Neuropteris gigantea,* occur only sporadically. The remaining half of the species appear consistently throughout the study area; however, even among these species, the relative abundance may change radically from one locality to another (Fig. 24).

Plants collected from several exposures associated with Jellico coal equivalents outside the study area are somewhat different on the specific level than the types preserved near Grannies Branch and Rocky Branch. This difference suggests that the floras probably are not exactly the same age or are derived from substantially different environments.

The flora of this study area contains several species that have been reported from the upper Pottsville Series of Pennsylvania and the lower Kanawha Formation of

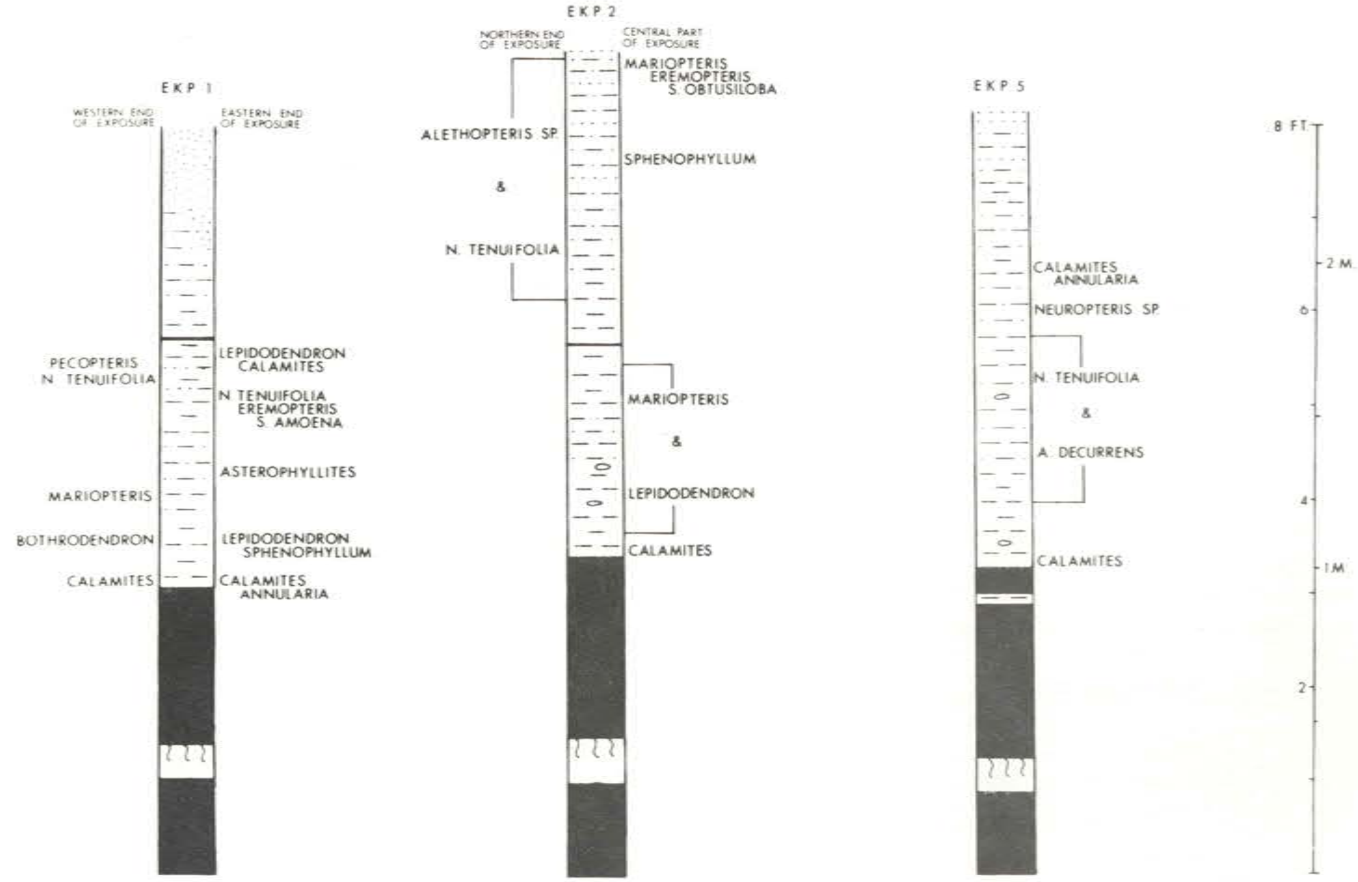

Figure 22. Stratigraphic columns illustrating where various plant types are abundant.

West Virginia. All of these plant types are present in the Westphalian B of Europe.

Additional studies must be undertaken in the future to establish the stratigraphic ranges of fossil plants preserved in eastern Kentucky, and to determine whether there are consistent relationships between the fossil plants and the surrounding strata. The geological processes that affect the distribution of fossil plants must be better understood before detailed correlations based solely on paleobotany can be made with certainty.

ACKNOWLEDGMENTS

The authors thank Dr. Norman C. Hester, Consolidated Resources of America, for help in locating a suitable study area; Drs. Charles T. Helfrich, S. S. Leung, and G. L. Kuhnhenn, Department of Geology, Eastern Kentucky University, for critical reading of the manuscript; and Mr. Galey Smith, Gooserock, Kentucky, for access to his property.

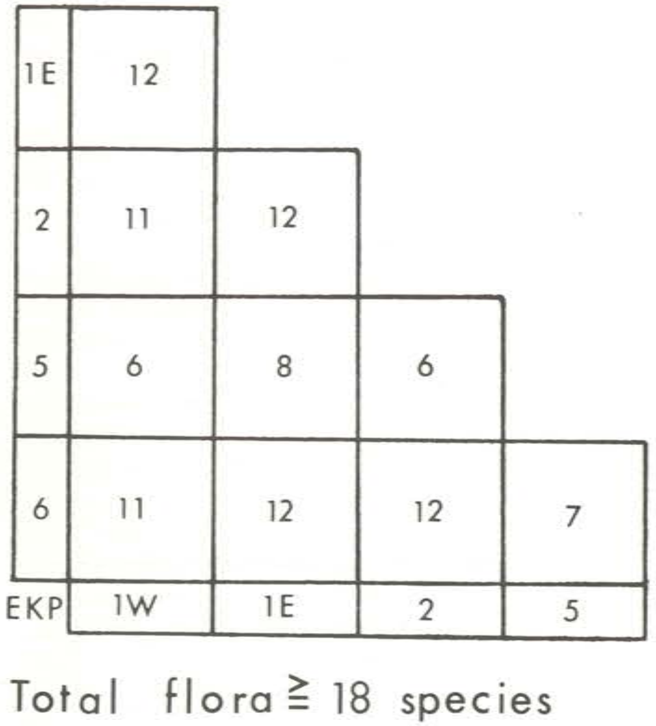

Figure 23. Chart showing the number of species in common between each pair of localities.

Figure 24. Abundance of different plant types at each locality.

REFERENCES CITED

Abbott, M. L., 1958, The American species of *Asterophylites, Annularia,* and *Sphenophyllum:* Bulletin of American Paleontology, v. 38, no. 174, p. 303-304, 337.

Aris, E. T., 1825, Antediluvian phytology, illustrated by a collection of the fossil remains of plants peculiar to the coal formations of Great Britain: London, J. Cumberland, 24 p.

Arnold, C. A., 1949, Fossil flora of the Michigan Basin: Michigan University Museum of Paleontology Contributions, v. 7, no. 9, p. 131-269.

Basson, P. W., 1968, The fossil flora of the Drywood Formation of southwestern Missouri: University of Missouri Studies, v. 44, p. 1-70.

Bell, W. A., 1944, Carboniferous rocks and fossil floras of northern Nova Scotia: Canada Geological Survey Memoir 238, 277 p.

Bell, W. A., 1966, Illustrations of Canadian fossils— Carboniferous plants of eastern Canada: Canada Geological Survey Paper 66-11, 76 p.

Bode, H., 1958, Die floristiche gliederung des oberkarbons der Vereinigten Staaten von Nordamerica: Zeitschrift der Deutschen Geologischen Gesellschraft, v. 110, p. 217-259.

Brongniart, M. A., 1828-37, Histoire des vegetaux fossiles: Paris, 2 v.

Buisine, Michel, 1961, Les Alethopteridees du nord de la France: Thèses présentees a la faculté des sciences, Lille, Douriez-Bataille, Lille, 317 p.

Cridland, A. A., Morris, J. E., and Baxter, R. W., 1963, The Pennsylvanian plants of Kansas and their stratigraphic significance: Paleontographica, v. 112B, p. 58-95.

Crookall, R., 1932, The relative value of fossil plants in the stratigraphy of the coal measures: Manchester Literary and Philology Society Memoirs and Proceedings, v. 76, p. 91- 122.

Crookall, R., 1955, Fossil plants of the Carboniferous rocks of Great Britain: Geological Survey of Great Britain Paleontology Memoirs, v. 4, pt. 1, 84 p.

Crookall, R., 1959, Fossil plants of the Carboniferous rocks of Great Britain: Geological Survey of Great Britain Paleontology Memoirs, v. 4, pt. 2, p. 85-216.

Crookall, R., 1964, Fossil plants of the Carboniferous rocks of Great Britain: Geological Survey of Great Britain Paleontology Memoirs, v. 4, pt. 3, p. 217-354.

Crookall, R., 1966, Fossil plants of the Carboniferous rocks of Great Britain: Geological Survey of Great Britain Paleontology Memoirs, v. 4, pt. 4, p. 355-571.

Crookall, R., 1969, Fossil plants of the Carboniferous rocks of Great Britain: Geological Survey of Great Britain Paleontology Memoirs, v. 4, pt. 5, p. 573-789.

Dalinval, A., 1960, Les *Pecopteris* du Bassin Houiller du nord de la France: Études Géologique Pour l'Atlas de Topographie Souterraine. Service Géologique des Houillères du Bassin du Nord et du Pas-de Calais, I flore fossile, p. 51- 69.

Danze, J., 1956, Les fougeres Sphenopteridiennes du Bassin Houiller du nord de la France: Études Géologique Pour l'Atlas de Topographie Souterraine. Service Géologique des Houillères du Bassin du Nord et du Pas-de Calais, I flore fossile, 2° fascicule, 568 p.

Darrah, W. C. 1969, A critical review of the Upper Pennsylvanian floras of the eastern United States, with notes on the Mazon Creek flora of Illinois: Gettysburg, Pennsylvania, privately printed, 220 p.

Englund, K. J., 1969, Geologic map of the Jellico West Quadrangle, Kentucky-Tennessee: U.S. Geological Survey Geologic Quadrangle Map GQ-855.

Gillespie, W. H., and Pfefferkorn, H. W., 1976, Plant fossils in early and middle parts of the proposed Pennsylvanian System stratotype in West Virginia, *in* Carboniferous stratigraphy of southwestern Virginia and southern West Virginia: Geological Society of America Field Trip Guidebook 3: American Geological Institute, Selected Guidebook Series, No. 1, 138 p.

Gillespie, W. H., Clendening, J. A., and Pfefferkorn, H. W., 1978, Plant fossils of West Virginia: West Virginia Geological and Economic Survey Educational Series, v. 3A, 172 p.

Glenn, L. C., 1925, The northern Tennessee coal field: Tennessee Division of Geology Bulletin 33-B, 478 p.

Hodge, J. M., 1918, The coals of Goose Creek and its tributaries: Kentucky Geological Survey, ser. 4, v. 4, no. 3, p. 1-78.

Huddle, J. W., Lyons, E. T., Smith, H. L., and Ferm, J. C., 1963, Coal reserves of eastern Kentucky: U.S. Geological Survey Bulletin 1120, 127 p.

Janssen, R. E., 1939, Leaves and stems from fossil forests, a handbook of the paleobotanical collections in the Illinois State Museum: Illinois State Museum Popular Science Series, v. 1, p. 40-43.

Janssen, R. E., 1940, Some fossil plant types of Illinois: Part I, A restudy of Lesquereux types in the Worthen Collection of the Illinois State Museum: Illinois State Museum Scientific Paper 1, 124 p.

Jennings, J. R., 1974, Lower Pennsylvanian plants of Illinois: I, A flora from the Pounds Sandstone Member of the Caseyville Formation: Journal of Paleontology, v. 48, no. 3, p. 466.

Jennings, J. R., 1979, Lower Pennsylvanian plants of Illinois: III, *Bothrodendron* from the Drury Shale: Journal of Paleontology, v. 53, no. 3, p. 519-522.

Jongmans, W. J., Gothon, W., and Darrah, W. C., 1937, Comparison of the floral succession in the Carboniferous of West Virginia with Europe: Congrès pour l'Avancement les Études de Stratigraphie Carbonifère, Deuxième, Heerlen, 1935, Compte Rendu, t. 1, p. 393-415.

Kidston, R., 1923, Fossil plants of the Carboniferous rocks of Great Britain: Geological Survey of Great Britain Paleontology Memoirs, v. 2, pt. 1, 109 p.

Kidston, R., 1925, Fossil plants of the Carboniferous rocks of Great Britain: Geological Survey of Great Britain Paleontology Memoirs, v. 2, pt. 6, p. 525-681.

Kidston, R., and Jongmans, W. J., 1917, Flora of the Carboniferous of the Netherlands and adjacent regions, a monograph of the *Calamites* of western Europe: Mededeelingen van de Rijksopsporing van Delfstoffen 7, v. 1, no. 1, p. 122-128.

Kosanke, R. M., 1950, Pennsylvanian spores of Illinois and their use in correlation: Illinois State Geological Survey Bulletin 74, 128 p.

Laveine, J., 1967, Les Neuropteridees du nord de la France: Études Geologique Pour l'Atlas de Topographie Souterraine. Service Géologique des Houillères du Bassin du Nord et du Pas-de-Calais, I flore fossile, 5° fascicule, 344 p.

Lesquereux, Leo, 1861, Report of the fossil flora and of the stratigraphic distribution of the coal in the Kentucky coal fields: Kentucky Geological Survey, ser. 1, v. 4, p. 331- 437.

Lesquereux, Leo, 1870, Report of the fossil plants of Illinois: Geological Survey of Illinois, v. 4, p. 375- 508.

Lesquereux, Leo, 1879-84, Description of the coal flora of the Carboniferous formations in Pennsylvania and throughout the United States: Pennsylvania Geological Survey 2nd Annual Report, v. 1-3, 977 p.

Lindley, J., and Hutton, W., 1831-33, The fossil flora of Great Britain: London, James Ridgeway and sons, v. 1, 223 p., v. 2, 208 p., v. 3, 207 p.

Moore, R. C., ed., 1944, Correlation of Pennsylvanian formations of North America: Geological Society of America Bulletin 55, chart 5.

Noé, A. C., 1925, Pennsylvanian flora of northern Illinois: Illinois State Geological Survey Bulletin 52, 113 p.

Ping, R G., and Sergeant, R. E., 1978, Geologic map of the Ogle Quadrangle, Clay and Knox Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-1484.

Puffett, W. P., 1963, Geology of the Corbin Quadrangle: U.S. Geological Survey Geologic Quadrangle Map GQ-231.

Read, C. B., and Mamay, S. H., 1964, Upper Paleozoic floral zones and floral provinces of the United States: U.S. Geological Survey Professional Paper 454-K, 34 p.

Reed, F. D., 1926, Flora of an Illinois coal ball: Botanical Gazette, v. 81, p. 460-469.

Rice, C. L., Sable, E. G., Dever, G. R., and Kehn, T. M., 1979, The Mississippian and Pennsylvanian (Carboniferous) Systems in the United States—Kentucky: U.S. Geological Survey Professional Paper 1110-F, p. F1-F28.

Rice, C. L., and Smith, H., 1980, Correlation of coal beds, coal zones, and key stratigraphic units in the Pennsylvanian rocks of eastern Kentucky: U.S. Geological Survey Miscellaneous Field Studies Map MF-1188.

Schimper, W., 1869-1874, Traite de paleontologie vegetale: Paris, J. B. Baillière et fils, v. 1, 740 p., v. 2, 968 p., v. 3, 896 p.

Schopf, J. M., Wilson, L. R., and Bentall, R., 1944, An annotated synopsis of Paleozoic fossil spores and the definition of generic groups: Illinois State Geological Survey Report of Investigations 91, 72 p.

Sternberg, K. M., 1825, Versuch einer geognostisch-botanischen darstellung der flora der vorwelt: Tentamen, Leipsig, and Prague, pt. 4, 48 p.

Stur, D., 1885, Die carbon-flora der schatzlarer schichten: Beitrage zur kenntniss der flora der vorwelt. Band II: Abhandlungên der Kaiserlich-Kōnglich Geologischen Reichsanstaft. XI Band Abteilungl, 418 p.

Trimble, D. E., and Smith, J. H., 1978, Geologic map of the Heidrick Quadrangle, Knox and Laurel Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-1501.

Van Amerom, H. W. J., 1975, Die Eusphenopteridischen pteridophyllen aus der sammlung des geologischen bureus in Heerlen, unter besonderer berucksichtigung ihrer stratigraphie bezuglich des sudlimburger kohlenreviers: Mededelingen Rijks Geologische Dienst, Serie C-II-1, v. 7, 208 p.

Wagner, R. H., 1968, Upper Westphalian and Stephanian species of *Alethopteris* from Europe, Asia Minor, and North America: Mededlingen van de Rijks Geologische Dienst, Serie C-III-1, v. 6, 319 p.

Walton, J., 1936, On the factors which influence the external form of fossil plants; with descriptions of the foliage of some species of the Paleozoic Equisetalean genus *Annularia* Sternberg: Philosophical Transactions of the Royal Society of London, v. 226, no. 535, p. 219-237.

White, C. D., 1899, Fossil flora of the lower coal measures of Missouri: U.S. Geological Survey Monograph 37, 567 p.

White, C. D., 1900a, The stratigraphic succession of the fossil floras of the Pottsville Formation in the southern anthracite coal field, Pennsylvania: U.S. Geological Survey 20th Annual Report, v. 2, p. 751-930.

White, C. D., 1900b, Relative ages of the Kanawha and Allegheny Series as indicated by fossil plants: Geological Society of America Bulletin, v. 11, p. 145-178.

White, C. D., 1937, Fossil flora of the Wedington Sandstone Member of the Fayetteville Shale, *in* Shorter contributions to general geology, 1936: U.S. Geological Survey Professional Paper 186-B, p. 12-41.

White, C. D., 1943, Lower Pennsylvanian species of *Mariopteris, Eremopteris, Diplothmema,* and *Aneimites* from the Appalachian region, *in* Shorter contributions to general geology, 1941-42: U.S. Geological Survey Professional Paper 197-C, p. 91.

Zeiller, R., 1880, Vegetaux fossiles du terrain Houiller de la France: Explication de la carte géologique de la France, Paris, 185 p.

APPENDIX 1
DESCRIPTIONS OF MEASURED SECTIONS

Thickness Feet	Thickness Meters	Description
		Measured Section EKP-1
15.00	4.50	Sandstone, buff, fine-grained, cross-bedded; interbedded siltstone and shale.
1.00	0.30	Siltstone, gray; grades into sandstone at top.
0.83	0.25	Shale, gray; grades into siltstone at top.
0.08	0.025	Coal.
2.67	0.80	Shale, gray; ironstone lenses, silty near top; interbedded siltstone.
1.67	0.50	Coal.
0.42	0.12	Underclay.
1.00	0.30	Coal.
		Measured Section EKP-2
2.50	0.75	Siltstone, gray, sandy; grades into sandstone at top.
0.67	0.20	Shale, gray; grades into siltstone at top.
0.08	0.025	Coal.
2.25	0.67	Shale, gray; ironstone lenses; interbedded siltstone.
1.92	0.57	Coal.
0.58	0.17	Underclay.
1.00	0.30	Coal.
		Measured Section EKP-5
2.00	0.60	Shale, gray, silty; sandy near top.
2.50	0.75	Siltstone, gray; interbedded shale.
1.42	0.42	Shale, gray; ironstone lenses; grades into siltstone at top.
0.17	0.050	Coal.
0.17	0.050	Shale, black, carbonaceous.
1.67	0.50	Coal.
0.50	0.15	Underclay.
0.75	0.22	Coal.
		Measured Section EKP-6
6.00	1.80	Siltstone, buff; interbedded shale, sandy, near top.
1.50	0.45	Shale, gray; ironstone lenses; grades into siltstone at top.
2.00	0.60	Coal.
		Covered.

Spurgeon and Jennings---PENNSYLVANIAN PLANTS OF EASTERN KENTUCKY--Ky. Geol. Survey, Ser. XI, 1985, Rpt. Inv. 3.