

FOSSIL PLANTS OF INDIANA

*by*  
JAMES E. CANRIGHT

Indiana Department of Conservation  
GEOLOGICAL SURVEY  
Report of Progress No. 14

1959

STATE OF INDIANA  
Harold W. Handley, Governor

DEPARTMENT OF CONSERVATION  
E. Kenneth Marlin, Director

GEOLOGICAL SURVEY  
John B. Patton, Acting State Geologist  
Bloomington

---

Report of Progress No. 14

---

FOSSIL PLANTS OF INDIANA  
by  
James E. Canright



Printed by authority of the State of Indiana

BLOOMINGTON, INDIANA

August 1959

---

For sale by Geological Survey, Indiana Department of Conservation, Bloomington, Ind.  
Price 75 cents

## SCIENTIFIC AND TECHNICAL STAFF OF THE GEOLOGICAL SURVEY

JOHN B. PATTON, Acting State Geologist  
13ERNICE M. BANFILL, Administrative Assistant to the State Geologist  
MARY BETH FOX, Mineral Statistician

### *COAL SECTION*

CHARLES E. WIER, Geologist and Head  
G. K. GUENNEL, Paleobotanist  
S. A. FRIEDMAN, Geologist  
HENRY H. GRAY, Geologist  
HAROLD C. HUTCHISON, Geologist  
RICHARD C. NEAVEL, Coal Petrographer  
LARRY LAWRENCE, Geological Assistant  
JAMES E. CANRIGHT, Field Party Chief,  
Summer, 1953-54

### *DRAFTING SECTION*

WILLIAM H. MORAN, Chief Draftsman  
ROBERT E. JUDAH, Geological Artist-Draftsman  
MICKY P. LOVE, Geological Draftsman  
JOHN E. PEACE, Senior Geological Draftsman

### *EDUCATIONAL SERVICES*

R. DEE RARICK, Geologist and Head

### *GEOCHEMISTRY SECTION*

R. K. LEININGER, Spectrographer and Head  
MAYNARD E. COLLER, Chemist  
LOUIS V. MILLER, Coal Chemist  
E. M. CRAIG, Geochemical Assistant

### *GEOPHYSICS SECTION*

MAURICE E. BIGGS, Geophysicist and Head  
ROBERT F. BLAKELY, Geophysicist  
CHARLES S. MILLER, Instrument Maker  
ALBERT J. RUDMAN, Geophysicist  
JOSEPH F. WHALEY, Geophysicist  
GLEN L. WORKMAN, Driller  
JERRY B. FOX, Assistant Driller  
ARTHUR WAYNE AYNES, Geophysical Assistant

### *GLACIAL GEOLOGY SECTION*

WILLIAM J. WAYNE, Geologist and Head  
W. HARRISON, Geologist

### *INDUSTRIAL MINERALS SECTION*

DUNCAN J. MCGREGOR, Geologist and Head  
GARY R. GATES, Geologist  
SEYMOUR S. GREENBERG, Petrographer  
JACK L. HARRISON, Clay Mineralogist  
NED M. SMITH, Geologist  
JACK A. SUNDERMAN, Geologist

### *PALEONTOLOGY SECTION*

ROBERT H. SHAVER, Paleontologist and Head

### *PETROLEUM SECTION*

T. A. DAWSON, Geologist and Head  
G. L. CARPENTER, Geologist  
OLIN R. HOLT, Geologist  
ANDREW J. HREHA, Geologist  
STANLEY KELLER, Geologist  
ARTHUR P. PINSAK, Geologist  
HOWARD SMITH, Geologist  
DAN M. SULLIVAN, Geologist  
FRANK H. WALKER, Geologist  
GEORGE ABBOTT, Draftsman  
JAMES CAZEE, Geological Assistant  
PHILLIP W. CAZEE, Geological Assistant

### *PHOTOGRAPHIC SECTION*

GEORGE R. RINGER, Photographer and Head

### *PUBLICATIONS SECTION*

GERALD S. WOODARD, Editor and Head

## CONTENTS

3

### Page

Abstract - - - - -	5
Introduction - - - - -	5
Purpose of the report - - - - -	6
Acknowledgments - - - - -	6
Significance of coal-forming plants - - - - -	7
Historical review of paleobotanical research in Indiana - - - - -	8
Kinds of fossilization and methods of study - - - - -	11
Petrifactions - - - - -	11
Compressions - - - - -	13
Casts - - - - -	13
Impressions - - - - -	14
Geology of the Indiana coal fields - - - - -	14
Classification of plants - - - - -	15
Pennsylvanian plants of Indiana - - - - -	19
Subphylum Lycopsidea; Order Lepidodendrales - - - - -	19
Subphylum Sphenopsida - - - - -	21
Order Equisetales - - - - -	21
Order Sphenophyllales - - - - -	23
Subphylum Pteropsida - - - - -	23
Orders Filicales and Cycadofilicales - - - - -	23
Fernlike foliage - - - - -	23
Seed ferns - - - - -	26
Order Cordaitales - - - - -	26
List of plant fossils from Indiana - - - - -	27
Collecting sites for plant fossils - - - - -	34
Literature cited - - - - -	42

(Plates follow Literature Cited)

Plate	1. Lepidodendrales	
	2. Lepidodendrales and Equisetales	
	3. Equisetales, Sphenophyllales, Filicales, and Cycadofilicales	
	4. Filicales and Cycadofilicales	
	5. Cycadofilicales and Cordaitales	
		Page
Text figure	1. Map showing coal basins in the Midwest -----	6
	2. Diagrams of median longitudinal sections of <i>Lepidostrobus</i> , <i>Calamostachys</i> , and <i>Palaeostachya</i> -----	22
	3. Map of southwestern Indiana showing collecting sites for plant fossils -----	35

## TABLES

		Page
Table	1. Geologic time scale and representative floras -----	9
	2. Stratigraphic chart of the Pennsylvanian System of Indiana -----	16
	3. Collecting sites for plant fossils -----	37

## FOSSIL PLANTS OF INDIANA

By James E. Canright

Plant fossils were first recorded in Indiana by David Dale Owen in 1843. Lesquereux's "Description of the Coal Flora of the Carboniferous Formation in Pennsylvania and Throughout the United States," published in 1880, listed 54 fossil plants from Indiana, and David White in 1896 identified 19 specimens from the whetstone beds of Orange County. Very little paleobotanical work has been done since then.

Stems, leaves, and cones of lycopsids and sphenopsids are common in the rocks associated with the coal beds of southwestern Indiana, and the seed ferns and Cordaitales are also found there. Fernlike foliage is abundant in the shales, and therefore a key to identify the common genera of fernlike leaves has been prepared for the lay reader.

The fossil plants found in southwestern Indiana at 93 collecting sites comprise 146 species assignable to 68 genera.

## INTRODUCTION

Indiana has been practically overlooked as a source of fossil plants. Only three small papers, those of Jackson (1914, 1916) and Benninghoff (1943), have appeared during the first half of this century. Much of the vast accumulation of fossil plant material and the knowledge derived from it stems from the coal-bearing rocks of the Pennsylvanian Period, or the Great Coal Age, as this geologic period is commonly called (table 1). Pennsylvanian rocks underlie southwestern Indiana, and because this area is on the east margin of the Eastern Interior Coal Basin, these coal-bearing strata are at or near the surface and thus are readily available to mining (text fig. 1). Fossils associated with these rocks therefore are easily obtained. In order to determine whether plant fossils were abundant, what their state of preservation might be, and what types of plant fossils could be found in Indiana, the Indiana Geological Survey sponsored a field project which covered two summer seasons. Extensive paleobotanical collections were made in the coal-bearing regions of Indiana during the years 1953 and 1954. The findings of this field and laboratory study are presented here.

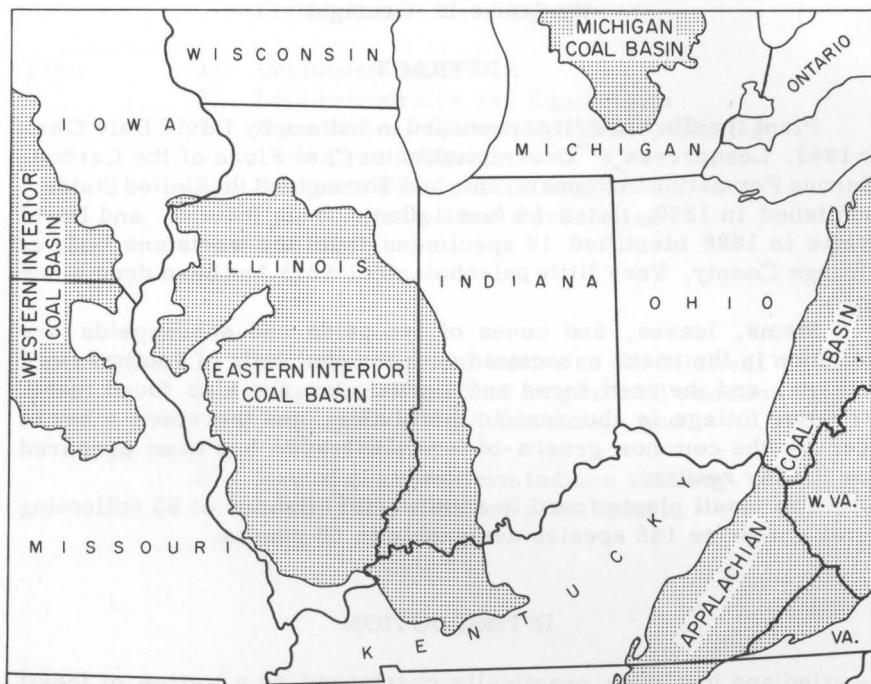


Figure 1.--Map showing coal basins in the Midwest.  
Modified from Siever, 1957, fig. 1.

#### PURPOSE OF THE REPORT

The immediate objectives of this paper are: (1) to review previous paleobotanical research in Indiana; (2) to outline the methods of plant fossilization and manner of preservation; (3) to explain the methods of naming fossil plant parts; (4) to relate Pennsylvanian plants to elements of the present-day floras; (5) to describe the more important floral members of Indiana's coal-bearing rocks; (6) to list the Pennsylvanian plants identified from Indiana; and (7) to list some of the better paleobotanical collecting sites in Indiana.

#### ACKNOWLEDGMENTS

The author wishes to express his appreciation to Joseph M. Wood and C. Francis Shutts for their invaluable assistance, both in the laboratory and in the field, and to G. K. Guennel, Paleobotanist, Indiana Geological Survey, for critically reading the paper and

offering many helpful suggestions. Thanks also are due the many mine operators in Indiana for permission to collect plant fossils on their property and for information regarding their coals. Dr. C. A. Arnold, of the University of Michigan, kindly assisted with various problems of identification; Drs. H. N. Andrews, Jr., of Washington University; W. N. Stewart, of the University of Illinois; and R. M. Kosanke, of the Illinois Geological Survey, contributed helpful information concerning coal-ball research. Dr. W. S. Benninghoff, University of Michigan, kindly loaned his records of early fossil plant collections in Indiana.

#### SIGNIFICANCE OF COAL-FORMING PLANTS

It is an acknowledged fact that coal has been derived from physically and chemically altered plant remains of past eras. Although a detailed discussion of the mode of origin of coal lies outside the scope of the present paper, persons interested in exploring this topic further are referred to the writings of White and Thiessen (1913) or to the recent textbook by Francis (1954).

Microscopic studies of coal (both from thin sections and from macerations) reveal a multitude of identifiable plant fragments, such as spores, sporangia, cuticles, resins, and woody particles. These microscopic plant materials, owing to their decay-resistant nature, are actually found within the coal itself; larger (macroscopic) plant fossils are commonly found only in the roof shales or the underclays of the coal seams. Therefore, research on the kinds of botanical materials in and around the various kinds of coal is fundamental in determining the specific characteristics of coal; for example, differences in physical properties, chemical composition, and combustion characteristics. Indeed, recent evidence (Schopf, 1948, p. 212) indicates that the rates and processes involved in coal formation (coalification) vary considerably among the various classes of botanical substances contributing to the coal bed.

Perhaps of lesser economic importance, but nevertheless pertinent, are paleobotanical studies on the kinds of vegetation which formed the prehistoric coal swamps. A thorough knowledge of these ancient floras provides the most reliable basis for concepts of climatic and ecologic conditions that existed during the coal-forming periods.

Within the past decade, careful analyses of the kinds and relative abundance of fossil plant spores in coal have made significant contributions to the stratigraphic correlation of coal seams in the United States (Wilson, 1946; Kosanke, 1947, 1950; Cross, 1950; Guennel, 1952, 1958). However, as these fossil spores are arti-

ficially classified (that is, without consideration of their botanical source or relationships), this method has certain shortcomings. In this connection, Schopf (1949, p. 511) stated: "An evaluation of the ecologic conditions that govern coal accumulation and origin will have to be based upon some understanding of the plants which have contributed to these coal beds. Furthermore, a greater reliance for stratigraphic and correlational purposes can be placed on forms that are understood botanically than on those having ranges and frequencies established on a more empirical basis."

Still largely unexplored in the United States is the value of plant macrofossils in correlating individual coal seams, although this method has been successfully applied by several European workers (Gothan, 1919; Bode, 1952). A few American paleobotanists (White, 1900; Elias, 1936; Read, 1947) have outlined floral zones (fossil plant assemblages of restricted stratigraphic distribution) for the rocks of Pennsylvanian age in the Appalachian and Western Interior Coal Basins of North America. Although similar types of paleobotanical investigations are desirable for the strata of the Eastern Interior Coal Basin, these must await more detailed information concerning the kinds of fossil plants in this region, as well as a better understanding of the geologic and geographic distribution of these macrofossils within this coal basin.

#### HISTORICAL REVIEW OF PALEOBOTANICAL RESEARCH IN INDIANA

The earliest published reference to fossil plants in the "Coal Measures" of Indiana is found in two brief papers by David Dale Owen in 1843. Owen, the Scottish-born first State Geologist of Indiana, described 20 to 25 stumps of fossil trees standing upright in a "slaty" clay 15 feet above a coal seam on the banks of Big Creek 12 miles from New Harmony, Posey County, Ind. Owen mistakenly referred these stumps to the palm family, a group that is not known from rocks older than the Triassic Period (table 1), which began approximately 45 million years later than the beds of Pennsylvanian age in which these stumps were found. Owen's interpretation of these stumps was given the stamp of authenticity when Sir Charles Lyell, the famous British geologist, visited the New Harmony site during a brief sojourn in America and concurred with Owen's identification. However, from Owen's description of the poorly preserved bark of these stumps (1843b, p. 271--"leaf scars longer horizontally than vertically, and parallel flutings absent"--it becomes apparent that these trees actually belonged to an ancient lycopod group. Lesquereux (1880, p. 507) later named these trunks

Table 1.—*Geologic time scale and representative floras*

[Modified from Eames, 1936, p. 308-309, and United States Geological Survey, 1958, p. 90]

Era	Period		Time (millions of years)	Dominant plant life and related events
Cenozoic	Quaternary		1	Glaciation; man appears; rise of modern herbaceous angiosperms.
	Tertiary		70	Angiosperms continue to spread; gymnosperms decline; herbaceous lycopods and horsetails almost extinct.
Mesozoic	No deposits in Indiana	Cretaceous	125	Rapid evolution and spread of angiosperms to world-wide dominance.
		Jurassic	150	Angiosperms rare; cycads and conifers dominant.
		Triassic	180	Higher gymnosperms on increase; seed ferns becoming extinct; first angiosperms appear?
		Permian	205	Decline and extinction of arborescent lycopods and horsetails.
Paleozoic	Not exposed at surface in Indiana	Pennsylvanian	230	Great coal-forming swamp forests; arborescent lycopods, horsetails, seed ferns, and gymnosperms, as well as true ferns, flourished in Indiana.
		Mississippian	255	Land floras well established.
		Devonian	315	Early land floras; rise of lycopods, horsetails, and seed ferns; gymnospermous tree ( <i>Calliatylon</i> ) common in late Devonian time; other plants rare in Indiana.
		Silurian	350	Appearance of land plants (psilopsids and lycopsids) in late Silurian time; not found in Indiana.
		Ordovician	430	Marine algae; rare in Indiana.
		Cambrian	510	Marine algae (coral-forming types); rare in Indiana.
		Precambrian	3,000	Primitive forms of algae and fungi, including bacteria; fossil record very sparse.
Proterozoic and Archeozoic				

*Didymophyllum (Sigillaria) Owenii*, but from the descriptions and illustrations he published (1879, pl. 74, fig. 10), it appears more probable that these stumps belong to the lycopod genus *Lepidophloios*. A cast of one of these stumps, measuring 2 feet high by 10 inches in diameter, was presented by David Owen to the museum of the Academy of Natural Sciences in Philadelphia.

In 1859-60 David Owen agreed to direct a "geological reconnaissance (sic) of Indiana" with the stipulation that one of his brothers, Col. Richard Owen, be in charge of the actual fieldwork.

The report of Richard Owen's geological survey of Indiana (1862) included an account of the geologic strata in the "Coal Measures" of Indiana by Leo Lesquereux, the Swiss-born "father of American paleobotany." The most important and lasting contributions of Lesquereux to the paleobotany of coal were his "Description of the Coal Flora of the Carboniferous Formation in Pennsylvania and Throughout the United States" (1880, 1884a) and his "Atlas to the Coal Flora," published in four volumes by the Pennsylvania Geological Survey (1879). These contained descriptions and, in some cases, illustrations of 54 species of fossil plants from the Pennsylvanian rocks of Indiana. Although many errors concerning nomenclature and interpretation of fossil plant organs have become apparent in Lesquereux's "Coal Flora" during the past 70 years, his publications on the coal flora of the United States undoubtedly are still the most-used references on this subject today.

In 1883 the State Geologist of Indiana, John Collett, asked Lesquereux to write a layman's guide to fossil plants. This was incorporated in the Thirteenth Annual Report of the Indiana Department of Geology and Natural History (1884b) as a sort of elementary textbook entitled "Principles of Paleozoic Botany."

David White (Kindle, 1896, p. 354-355) identified 19 specimens from the whetstone beds (Mansfield Formation) of Indiana. White used these fossils to correlate Indiana's whetstone beds with rocks of similar age in Pennsylvania. This was the first valid correlation of strata in Indiana with those of the Appalachian area on the basis of plant remains.

Since the turn of the century, the only papers on the coal flora of Indiana are those of Jackson (1914, 1916) and Benninghoff (1943). Jackson listed the plant fossils that he had identified from sandstones of Pennsylvanian age in the Bloomington Quadrangle, and Benninghoff described a coal-ball flora from a single mine near Petersburg in Pike County.

Recently, Guennel (1952, 1958) initiated an important line of research in which he differentiated Indiana's coal beds by means of their fossil-spore content. The use of macroscopic plant fossils for stratigraphic purposes in Indiana was briefly discussed by Wood

and Canright (1954) and Shutts and Canright (1955). For a more detailed account of the history of paleobotany in Indiana, the reader is referred to the recent paper by Canright (1958).

### KINDS OF FOSSILIZATION AND METHODS OF STUDY

Most plant fossils have been preserved by the burial of plant organs or fragments in mud or sand during sedimentation. In some places, however, especially in some western states, plants may have become entombed and been preserved by a very rapid deposition of volcanic ash. The degree of preservation of most plants depends on the amount of hard or waxy tissues present in the plant parts and on the rapidity of burial, which tends to restrict the normal processes of decay.

For all practical purposes, plant fossils may be divided into four main types based upon their manner of preservation. These types are: *petrifications*, *compressions*, *casts*, and *impressions*.

### PETRIFACTIONS

Petrifications are mineralized plant parts. This type of fossil is the most valuable to the paleobotanist, because not only is the more or less unaltered external form of the plant part retained, but also internal structure, including some of the original (though chemically modified) organic material, is well preserved. Probably the best known example of this type of fossilization found in the United States is the wood from the "Petrified Forests" of Arizona. About 160 million years ago these ancestors of some modern coniferous trees fell and were rapidly covered by stream-borne sediments which apparently had a high silica content. The silica, dissolved in the water, infiltrated the intercellular and intracellular spaces of the wood and was deposited there. Gradually, the organic cell wall substances were replaced by more silica, so that at the present time less than 5 percent by volume of the original wood remains. The striking color patterns in this wood were caused by oxides of iron and manganese. The minerals deposited in these logs have kept them beautifully preserved, despite the enormous pressures that were exerted later by 3, 000 feet or more of overlying sediments.

Though not as widely known as the Arizona examples, huge silicified logs (*Callixylon*) are found in a black shale of late Devonian age (table 1) in parts of Scott and Clark Counties in southeastern Indiana (Hoskins and Cross, 1952). Equally well preserved petri-

fied woods have been found associated with the coal seams of Indiana. Thin slices may be cut from such petrifications with a diamond edged saw and then may be ground down with carborundum powder until they are translucent. These thin sections, as they are called, then maybe mounted under a cover slip on a glass slide and studied under the microscope. The photomicrographs shown as figure 14, plate 5, were taken of such thin sections of *Callixylon*.

Of particular interest to those studying the botanical constituents of coal was the discovery of petrified masses of plant parts known as "coal balls. " Although not of common occurrence, this type of petrification has been found in 3 different coal seams at 18 different localities in southwestern Indiana. These coal balls, measuring from 2 inches to 3- feet in diameter, contain beautifully preserved plant parts in a calcareous matrix. Figure 14, plate 4, is a photograph of a cut and etched surface of half a coal ball. The cut and polished surface of the coal ball shows excellent preservation of *Psaronius* rootlets.

Perhaps the largest single aggregation of coal balls known was discovered in 1948 in the Wasson Coal Mining Corp. 's Big Creek No. 1 strip mine (now known as the Buckskin Mine), 3 miles south east of Lynnville, Warrick County, Ind. Approximately 30 tons of coal balls compacted together in one mass were uncovered here by stripping operations in Coal V.

Although coal balls have been known from England and Belgium as early as 1835, they were not discovered in this country until 1924, when Noe' reported coal balls from a mine near Harrisburg, 111. Since that time, coal balls have been found in other parts of Illinois, Missouri, Indiana, Iowa, and Kansas. Reports of coal-ball sites in other states are still in need of verification (Andrews, 1951, p. 442).

Walton (1928) devised the ingenious peel method of studying plant structures in calcareous coal balls. After a coal ball has been cut with a special saw, the cut surface is ground smooth with carborundum powder. The smooth surface is lightly etched with a dilute solution of hydrochloric acid. This process removes a thin layer of the calcareous matrix, but does not affect the organic material of the cell walls of the included plant parts, which, after etching, projects slightly above the surface of the coal ball. A nitro-cellulose solution is then poured over the leveled surface and allowed to dry. The resulting thin film, containing embedded plant material, is then stripped off and is ready for examination under a microscope. Besides being less time consuming and laborious, this peel method allows one to obtain many more sections of a plant organ than would ever be possible by the thin-section method mentioned above.

### COMPRESSIONS

In compressions the external form of the plant part has been more or less modified by the weight of overlying sediments. For example, a stem which was originally circular in transverse view may have become elliptical owing to lack of mineralization, which would have caused the stem to resist vertical compression. However, organs such as leaves, which were originally flat structures, have not been altered extensively during fossilization. The preservation of fine features of venation apparent in most of the leaf compressions is proof of this. Figures 8, 9, 10, and 11, plate 4, are examples of compressions that show beautifully preserved venation. Although some carbonaceous material remains in compressions, almost all internal structure has been destroyed.

In some parts of Indiana's coal fields, hard elliptical concretionary masses, termed "ironstones," are found bedded in the softer shales overlying certain coal seams. The iron content of these concretions causes them to turn red after exposure to weathering. When struck sharply with a hammer, the ironstones split in two, and many reveal enclosed plant fossils. One of the best known occurrences of fossils preserved in this manner is in the famous Mazon Creek region of northeastern Illinois. Here, literally thousands of these plant-containing concretions have been collected during the past 80 or 90 years.

Although the usual method of studying compression material is by reflected light under a low-power stereoscopic microscope, nitrocellulose peels may be made of flattened carbonized remains by using the techniques explained previously in connection with petrifications.

### CASTS

Casts contain neither organic material nor cellular structure. A cast is formed by the filling of a cavity left by the decay of the original plant material. Mud or sand gradually fills this cavity before much compaction of the sediments has occurred. After the mud or sand hardens in the cavity, the resulting fossil is termed a cast. Figure 12, plate 1, is an example of such a cast.

Some plants had naturally occurring hollow cavities inside their stems. Sedimentary material filled these cavities and hardened there, forming pith casts. Although the stem tissues later decayed, pith casts still reveal the internal form of the original stem (fig. 6, pl. 2). Certain seed types are also often preserved as internal casts (figs. 1, 3, and 4, pl. 5).

T h e c a s t s h o w s o n l y t h e i n t e r n a l

form of the seed; the external seed coats have rotted away.

### IMPRESSIONS

Impressions, like casts, contain no organic material. They are either mirror images of compressions or the mere imprints of plant organs, such as a tree trunk (fig. 6, pl. 1), on the surrounding sediments. Impressions are valuable fossils nevertheless. Much detail is visible in many impressions so that the external morphology of the plant part in question can be studied.

### GEOLOGY OF THE INDIANA COAL FIELDS

A portion of the Eastern Interior Coal Basin underlies at least parts of 24 counties in southwestern Indiana. As indicated by Wier and Wayne (1957, p. 8), this large basin probably began to form in Ordovician time (table 1), and the deepest part of the basin was in what is now southern Illinois. This coal basin is between the Appalachian and the Western Interior Coal Basins and lies southwest of the Michigan Basin (fig. 1). The geographic position of Indiana along the margin of the Eastern Interior Coal Basin allows ready examination of the various fossiliferous strata which come to the surface and are exposed in southwestern Indiana. In this area numerous coal beds and other sedimentary rocks of Pennsylvanian age dip to the southwest at an average rate of about 25 feet to the mile.

The proximity of these coal seams to the surface permits large-scale strip-mining operations in most of the Indiana coal fields. In this method of mining, the fossil-bearing rocks overlying the coal are removed by huge dragline shovels, some of which can remove 45 cubic yards in one "bite." This large-scale "scrambling" of the normal stratigraphy exposes many more plant fossils to the collector's eye than is ever possible by deep-mining methods. Although these piles of overburden are a nuisance to the mine operators and are referred to as spoil banks, it is here that the paleobotanist finds many of his choicest fossils. In addition, the erosional activity of rain, wind, and frost continually exposes more fossils on the surfaces of these spoil banks. This is especially true for the fossiliferous ironstones, which readily weather out of the softer shales which surround them.

Although coal has been formed in all major geologic periods since the Devonian (table 1), the Pennsylvanian was the greatest period of coal formation in the geologic history of the world. The

rocks of Pennsylvanian age in Indiana include shale, limestone, sandstone, coal, and clay totaling 1, 500 feet in thickness. The basal Pennsylvanian rocks rest unconformably on somewhat older strata of Mississippian age, whereas the top of the Pennsylvanian System is covered by much younger Pleistocene deposits (table 1).

The Pennsylvanian rocks of Indiana are classified in table 2. Most of the coal produced in Indiana is mined from beds in the Allegheny Series (middle Pennsylvanian). Although 25 coal beds in Indiana locally attain a thickness of 2 feet or more, only 7 to 10 seams are sufficiently widespread to be of great commercial importance. Coal V, averaging 5 feet in thickness and reaching locally a thickness of 11 feet, is the source of over 50 percent of the coal mined in Indiana.

It has been estimated that a vertical accumulation of perhaps 20 feet of peat is necessary in order to form 1 foot of coal. When one considers the enormous amounts of plant material needed to form a coal seam 11 feet thick, it staggers the imagination. Evidently the climate in Pennsylvanian time must have been much more favorable for the growth of vegetation than it is today, because the deepest existing peat bogs in Indiana are no more than 60 feet at their maximum depth.

For a more detailed report on the stratigraphy of Pennsylvanian rocks in Indiana, see the works of Ashley (1899, 1909) and Wier (1952).

Moore and others (1944) have summarized our knowledge of the correlation of the various Pennsylvanian formations in North America. This important contribution emphasizes the value of paleobotanical evidence for stratigraphic correlation, yet at the same time points out the inadequacy of our knowledge of successive Pennsylvanian floras. Read (1947, p. 274) has outlined his concepts of the Pennsylvanian floral zones in the Appalachian Coal Basin. However, the scarcity of information about the Pennsylvanian flora of Indiana prevents the correlation of our coals with those of the Appalachian area. Arnold (1949, p. 152) experienced the same difficulty in his studies of the fossil flora of the Michigan Coal Basin. Therefore, it is evident that the fossil floras of the important coal horizons in the Pennsylvanian of North America must be much better known before they can be utilized reliably for the purpose of stratigraphic correlation.

#### CLASSIFICATION OF PLANTS

All plants and animals, both living and fossil, are classified according to a system known as *binomial nomenclature*. Whenever a

Table 2.—*Stratigraphic chart of the Pennsylvanian System of Indiana*

Series	Formation	Principal coal beds
Conemaugh	New Haven Formation	
	St. Wendells Sandstone	
	Parkers Formation	
	Dicksburg Hills Sandstone	
	Hazelton Bridge Formation	
	Inglefield Sandstone	
	Ditney Formation	
	West Franklin Limestone	
	Shelburn Formation	
Allegheny	Dugger Formation	Coal VII Upper Millersburg Coal Lower Millersburg Coal Coal VI
	Petersburg Formation	Coal V Coal IVa
	Linton Formation	Coal IV Coal IIIa
	Staunton Formation	Coal III
Pottsville	Brazil Formation	Coal II Minshall Coal Upper Block Coal Lower Block Coal
	Mansfield Formation	

new biological organism is discovered, it is assigned two names that are derived from Greek or Latin. For example, the name of the American elm tree is *Ulmus americana*. The first name is that of the genus and the second that of the species. There are several kinds of elms; each has a particular species name, but all elms bear the name *Ulmus*. As it is evident that common names of plants and animals vary considerably from region to region, and especially internationally owing to language differences, any universal attempt to apply these common names (American elm, for example) would lead to a great deal of confusion and misunderstanding. This difficulty is avoided by the use of scientific names of Latin or Greek origin. In addition, for the purposes of reference, the name of the person who first described that particular plant is appended to the binomial; for example, *Ulmus americana* Linnaeus.

Although the task of identifying and classifying living plants according to their natural relationships is difficult, the problems involved in working with fossil plants are still more complex. The main difficulty encountered by paleobotanists stems from the fact that fossil plants are rarely preserved in their entirety. Therefore, the isolated organs or fragments, when first discovered, are each assigned a scientific name which is actually a form or organ genus and not a natural genus. Although these form genera are artificial and complex in usage, this system of nomenclature has been born of necessity, owing to the detached condition in which plants are normally preserved as fossils.

An example of this type of involved nomenclature is exhibited for the parts of a common tree which flourished during the Pennsylvanian Period:

Plant Part	Form Genus (name given to isolated organ)
trunk and wood	<i>Lepidodendron</i>
leaves - - - - -	<i>Lepidophyllum</i>
cone - - - - -	<i>Lepidostrobus</i>
sporophyll - - - - -	<i>Lepidostrobophyllum</i>
sporangia - - - - -	<i>Lepidocystis</i>
megaspores - - - - -	<i>Triletes</i>
root - - - - -	<i>Stigmaria</i>

Whenever organs which have previously been described separately are found to be parts of the same plant, the oldest published name is used to refer to the whole plant. Thus, in the case of the tree cited above, which has now been reconstructed in its entirety, the oldest generic name (*Lepidodendron*) is applied in referring to the whole plant. Nevertheless, for descriptive purposes, all the names

of the form or organ genera are still retained.

All plants can be separated into two large groups, Atracheophyta and Tracheophyta, depending on their lack or possession of vascular (conducting) tissue:

#### Nonvascular Plants (Atracheophyta)

#### Examples

##### Thallophyta

Algae - - - - - pond scums, sea weeds, diatoms

Fungi - - - - - bacteria, molds, yeasts, mushrooms

##### Bryophyta

Musci - - - - - mosses

Hepaticae - - - - - liverworts

#### Vascular Plants (Tracheophyta)

#### Examples

Psilopsida - - - - - psilophytes\*

Lycopsidea - - - - - club mosses, quillworts, lepidodendrids, \*  
sigillarias\*

Sphenopsida - - - - - horsetails, calamites, sphenophylls\*

##### Pteropsida

Filicineae - - - - - true ferns

Gymnospermae - - - seed ferns, \* cordaites, \* cycads, ginkgos, conifers

Angiospermae (flowering plants) - - - - - magnolias, grasses,  
roses, sunflowers, etc.

Because nonvascular plants are usually small and fragile, they are rarely found as fossils. Nevertheless, their early occurrence on earth can often be detected by traces of their former activity; for example, iron and sulfur deposited by certain types of bacteria, wood decay caused by certain fungi, and corallike rocks deposited by certain species of marine algae.

Remains of the oldest plants known, estimated as approximately 2 billion years old, were found in Precambrian rocks (table 1) on the north shore of Lake Superior (Tyler and Barghoorn, 1954). It is perhaps not surprising that these earliest plants were unicellular algae and simple forms of fungi, when one considers their great antiquity. Apparently plant life evolved slowly in the beginning (table 1), because the first reliable evidence of vascularized land plants did not appear in the fossil record until the end of the Silurian.

---

\*Now extinct; represented only by fossils.

Period, some 315 million years ago. Therefore, at least 80 percent of the geologic history of the earth had passed between the time of appearance of the first unicellular organisms and the evolution of the simple land plants of late Silurian time, the psilophytes.

Arborescent forms of club mosses and horsetails were the dominant elements in the coal-forming flora of the Pennsylvanian (table 1), but at the present time only small insignificant herbaceous species remain as representatives of these once-mighty groups. The lycopods and sphenopsids are both well on their way to extinction.

The ferns have a long geologic history dating back to Devonian time (table 1). They apparently were better equipped than the lycopsids and sphenopsids to survive adverse climatic changes and are still prominently represented in our present-day flora. Fossil wood of gymnosperms dates back to Devonian time. The cordaites and pteridosperms nearly rivaled the ferns, lycopsids, and sphenopsids in abundance during the coal-forming Pennsylvanian Period. Many families of gymnosperms are found among the plants making up the vegetation of today.

The geologic history of the angiosperms or flowering plants is comparatively brief. Palmlike plants were recently discovered in Triassic (table 1) beds of Colorado (Ladd and Brown, 1956). By mid-Cretaceous time numerous representatives of modern angiosperm families had appeared, and within the past 50 million years these have become widely distributed. Today the angiosperms represent the dominant vegetation of the earth.

#### PENNSYLVANIAN PLANTS OF INDIANA SUBPRYLUM LYCOPSIDA; ORDER LEPIDODENDRALES

Although the only living representatives of the Lycopsida are small herbaceous plants known as club mosses and quillworts, their Paleozoic ancestors were large trees which reached heights of more than 100 feet and whose trunk diameters averaged 2 to 3 feet.

There are three principal stem types in this group of arborescent lycopods; these are referable to the form genera *Lepidodendron*, *Sigillaria*, and *Lepidophloios*. Although all three were important in the formation of coal, *Lepidodendron* is undoubtedly the most abundant in the Pennsylvanian strata of Indiana. This fact is emphasized by Kindle's statement (1896, p. 350) with reference to the whetstone beds of Orange County that "the abundance of fossil *Lepidodendra* in this quarry has led to its abandonment. " So many casts of these trunks were found standing upright that it became impractical to continue whetstone quarrying operations in that quarry.

These trees were characterized by a relatively small amount of wood in comparison with modern trees. However, this structural weakness was remedied by the formation of an extremely thick layer of bark and by the persistence of closely aligned decay-resistant leaf bases. Trunk casts and impressions of *Lepidodendron* are readily distinguished from those of *Sigillaria* by the characteristic arrangement and shape of their persistent leaf bases. In *Lepidodendron* the diamond-shaped or rhomboidal leaf bases are spirally arranged, as can be seen in figures 1 to 6, plate 1, whereas the oval or hexagonal leaf bases of *Sigillaria* are arranged in vertical rows on the trunk (figs. 1 to 3, pl. 2). About 20 species of these 2 genera have been found in the Pennsylvanian rocks of Indiana.

In figure 1, plate 1, the larger diamond-shaped structures bearing transverse ridges are the leaf cushions. The smaller, oval scars at the top of the cushions mark the former points of attachment of the leaves in *Lepidodendron volkmannianum* Sternb. In *Lepidodendron obovatum* Sternb. (fig. 2, pl. 1) the cushions are more closely aligned and the leaf scars are more centrally located than is the case in *L. volkmannianum*. Wrinkled cortical tissue separates the leaf cushions of *L. modulum* (fig. 3, pl. 1).

*Sigillaria* stems that have lost their outside bark layer prior to fossilization are referred to the artificial genus *Syringodendron* (fig. 4, pl. 2). A similar situation is found in the lepidodendrid trunks; these casts have different appearances according to the depth of decay before fossilization. Successively deeper layers are given the names *Aspidiaria*, *Bergeria* (fig. 11, pl. 1), *Knortia*, and *Aspidopis*. Such names are of value only for descriptive purposes, because they may represent different stages of preservation of the same species of *Lepidodendron*.

The bark of *Lepidophloios* most closely resembles that of *Lepidodendron*; the two genera differ mainly in the shape of the leaf cushions; those of *Lepidophloios* are broader than they are long (fig. 13, pl. 1).

The rootlike organs which supported all three of these arborescent genera are indistinguishable and are referred to the form genus *Stigmaria*. These organs are characterized by spirally arranged rows of circular scars that mark the former points of attachment of the numerous rootlets (fig. 12, pl. 1). Casts of *Stigmaria ficoides* are abundant in most of the clays underlying many of our coal seams. Figure 14, plate 1, shows a rare variety of this species.

The leaves of *Lepidodendron* are referred to the form genus *Lepidophyllum*. Some of these leaves are grasslike and may reach a length of 3 feet (fig. 9, pl. 1); others are only a few inches long and are considerably broader (fig. 10, pl. 1). Leaves of *Sigillaria* are referred to the genus *Sigillariophyllum*, but these are difficult to distinguish from some species of *Lepidophyllum*, except when preserved

as petrifications.

The compact cones of these two trees are named *Lepido8ti-obu3* (text fig. 2; Arnold, 1947; and figs. 7 and 8, pl. 1) and *Sigillariostrobus* (fig. 5, pl. 2). These cones consist of numerous spirally arranged fertile leaves (sporophylls), which have spore-bearing structures (sporangia) on their upper surfaces (text fig. 2).

#### SUBPHYLUM SPHENOPSIDA

##### ORDER EQUISETALES

The modern representatives of the Equisetales are the horsetails or scouring rushes (*Equisetum*), which are small, stiff, ribbed plants bearing their branches and scalelike leaves in whorls at the nodes. During Pennsylvanian time, however, ancestors of the lowly *Equisetum* grew to 75 feet in height. Surprisingly enough, this size was attained despite the fact that these trees, like their modern descendants, had hollow stems, except for transverse plates of tissue at the nodes. Internal or pith casts of these trunks, belonging to the genus *Calamites* (fig. 6, pl. 2), are relatively common fossils in the roof shales or sandstones overlying Indiana coal beds.

Most fossil remains of the exterior surface of the stem, termed *Calamophyllites* (figs. 7 and 8, pl. 2), are rare elements of coal floras. This type of fossil, however, was found by the writer to be common in ironstone concretions in certain shales overlying the Lower Block Coal of Indiana. The calamite branch shown in figure 7, plate 2, has four cones (*Calamostachys*) attached to a node.

Whorled leaves of two types belong to the smaller branches of *Calamites*; these are named *Annularia* (figs. 1 to 4, pl. 3) and *Asterophyllite8* (fig. 7, pl. 3). As can be seen in these figures, the leaves of the latter genus are much more needlelike than those of the former.

Compressed calamite roots are usually referred to the form genus *Pinnularia* (fig. 9, pl. 2); however, it is probable that this artificial genus acts as a repository for almost any type of small compressed root.

Cones of *Calamites* are classified according to the manner in which their spore cases (sporangia) are attached to the cone axis. In *Palaeo8tachya* (text fig. 2) and fig. 11, pl. 2) the sporangiophores are attached in the axils of the bracts, but in *Calamostachys* (text fig. 2 and fig. 7, pl. 2) the sporangiophores are attached to the cone axis midway between the successive whorls of bracts. *Macro8tachya* (fig. 12, pl. 2) may be merely a larger type of the last named genus.

An extremely rare calamite fructification was discovered re-

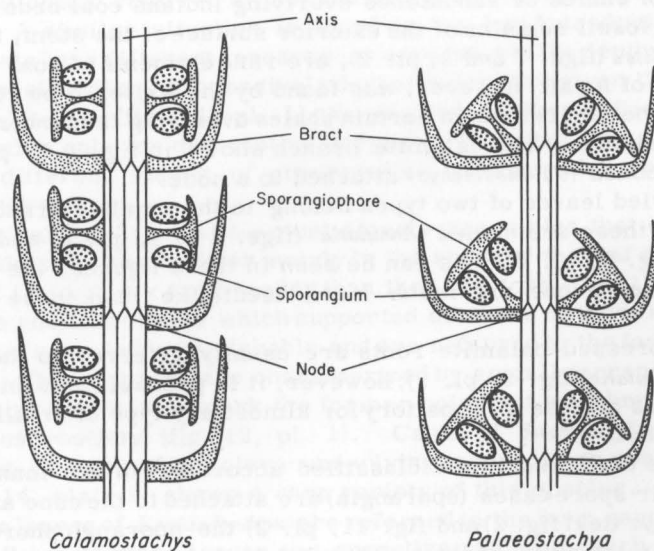
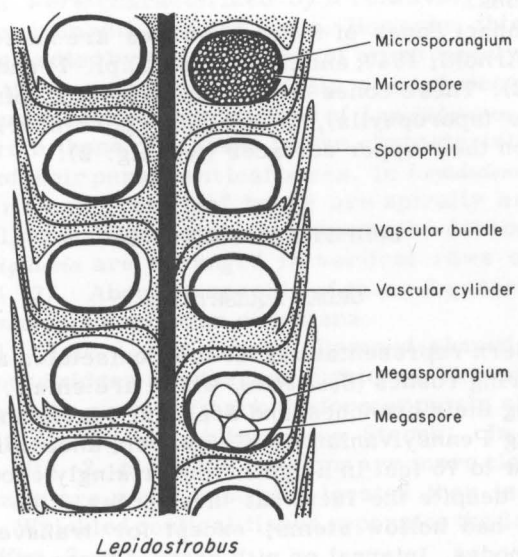


Figure 2. --Diagrams of median longitudinal sections of *Lepidostrobus*, *Calamostachys*, and *Palaeostachya*. Modified from Arnold, 1947.

cently in Indiana and has been tentatively assigned to the form genus *Cingularia* (fig. 10, pl. 2), a genus known previously only from European coal fields. In these cones the bracts are two lobed; the upper part is sterile, and the lower half bears pendant sporangia on their lower surfaces.

#### ORDER SPHENOPHYLLALES

*Sphenophyllum* (figs. 5 and 6, pl. 3) was a small herbaceous plant whose slender stem (not over 5 mm in diameter) bore whorls of 6 to 12 wedge-shaped leaves at each node. The cones (*Bowmanites*) were borne terminally. Numerous species of *Sphenophyllum* are distinguished, mainly on the basis of their variable leaf characters.

#### SUBPHYLUM PTEROPSIDA

##### ORDERS FILICALES AND CYCADOFILICALES

*Fernlike foliage.*—Normally it is impossible to distinguish the sterile fronds (leaves) of the Paleozoic ferns (Filicales) from those of the seed ferns (Cycadofilicales) which belong to the gymnosperms, a group of plants that bear naked seeds. If clusters of sporangia are found preserved on the lower surfaces of fern foliage, then these fern leaves obviously belong to the true ferns, the Filicales. This is true of such genera as *Acitheca* (fig. 16, pl. 3), *Asterotheca* (fig. 11, pl. 3), *Dactylothea* (fig. 15, pl. 3), *Renaultia* (fig. 9, pl. 3), *Senftenbergia* (fig. 12, pl. 3), and *Zeilleria* (fig. 8, pl. 3). The photograph of *Zeilleria* (fig. 8, pl. 3) shows large sporangia that have been impregnated with kaolinite, which makes them appear white. The same kind of fossilization is evident in the photograph of *Ptychocarpus* (fig. 14, pl. 3), which shows pectopterid pinnules that bear sporangia.

Seeds only rarely have been found attached to fernlike foliage. Figure 6, plate 5, shows a seed, *Holcospermum*, that seems to be attached to a pinna of *Odontopteris*, a fern leaf. Because these seeds are attached nakedly, the fossil leaves that bear them belong to the gymnosperm group and are known as Cycadofilicales. These seed ferns also are known by the name Pteridospermae. When fernlike foliage is found in the sterile condition (that is, without sporangia or seeds), it is extremely difficult to determine whether a leaf type belongs to the true ferns (Filicales) or the seed ferns (Cycadofilicales) because the same leaf genus (for example, *Pecopteris* and *Sphenopteris*) may belong to both groups.

Many of the species of leaf genera are of considerable value as indices of the age of Pennsylvanian strata in which they are found. Therefore, phrases such as "zone of *Mariopteris pottsvillea*" and "zone of *Neuropteris tenuifolia*" are used by stratigraphers to indicate definite horizons within rocks of Pennsylvanian age. Much of the foliage found in rocks is sterile, and, moreover, fertile leaves do not always yield well-preserved, identifiable sporangia or seeds. Artificial genera, based purely on leaf morphology, are useful in correlating strata. A key to help the lay reader identify the major types of fernlike leaves found in Indiana is given below. This key, purely artificial, is based on morphologic characters only, such as the shape of the leaflets (pinnules), their mode of attachment, and their venation (pattern of veins).

For further descriptions and illustrations of fernlike leaves the reader is referred to the works of Arnold (1947, p. 157-168), Bell (1938), Crookall (1929), Janssen (1939), Noe' (1925), Lesquereux (1879, 1880), and Zeiller (1886).

#### Key for Identifying Major Types of Fernlike Leaves Found in Indiana

##### I. Pinnules with a distinct midrib that continues to, or nearly to, apex.

A. Midrib of pinnules conspicuously thickened,  
protuberant on lower surface; pinnules over  
8 cm long - - - - - *Megalopteris* (fig. 7, pl. 4)

B. Midrib neither thickened nor protuberant;  
pinnules less than 5 cm long.

1. Margins of pinnules parallel, almost straight;  
secondary veins few in  
number - - - - - *Pecopteris* (figs. 11-17, pl. 3)

2. Margins of pinnules curved, not parallel, often tapering  
to apex; secondary veins many, closely  
spaced - - - - - *Alethopteris* (figs. 10, 11, pl. 4)

## II. Pinnules without midrib or an indistinct midrib that does not continue to the apex.

## A. Base of pinnules broadly attached, by entire width of pinnule.

1. Apex of pinnule rounded; basal pinnules unlobed ----- -  
*Odontopteris* (fig. 6, pl. 5)

2. Apex of pinnule pointed; most basal pinnules two lobed ----- -  
*Mariopteris* (figs. 1-3, pl. 4)

## B. Base of pinnules narrowly attached, not by entire width of pinnule.

## 1. Margins of pinnules entire.

## a. Pinnules tongue shaped or ovate.

## (1) Single vein enters base of pinnule.

- (a) Secondary veins form network - - - - -  
*Linopteris*  
(figs. 5, 6, pl. 4)

- (b) Secondary veins open to margin; do not  
form network - - - - - *Neuropteris*  
(figs. 8, 9, pl. 4)

(2) More than one vein enters base of  
pinnule - *Mizoneura* (fig. 12, pl. 4)

- b. Pinnules rounded or ear shaped - - - - - *Cyclopteris* (fig. 4,  
pl. 4)

## 2. Margins of pinnules lobed or dissected.

## a. Pinnules narrow only at base; lobed or toothed -

*Sphenopteris*, *Zeilleria*, and *Renaultia*  
(figs. 8, 9, pl. 3)

- b. Pinnules narrow throughout; deeply  
dissected *Diplothmema* (fig. 10, pl. 3)

*Psaronius* (figs. 13 and 14, pl. 4) refers to the trunks of certain tree ferns which are surrounded by a thick layer of adventitious roots. These roots grew out from the trunk and aided in support and probably absorption. The central vascular cylinder is shown on the right on figure 13, plate 4, and the numerous roots making up the characteristic "mantle" are seen arranged around it. Figure 14, plate 4, shows a cut and etched surface of a half of coal ball containing a number of petrified *Psaronius* rootlets.

*Seed ferns.-Trigonocarpus* (fig. 1, pl. 5) is a fairly large (2 to 5 cm long), oval seed which is believed to have belonged to the leaf genus *Alethopteris* (figs. 10 and 11, pl. 4) because it has often been found in association with it. The seed coat was divided into a soft matter husk and a hard inner coat; the latter was characterized by three distinct longitudinal ridges.

*Samaropsis* (fig. 2, pl. 5) includes rounded seeds which are surrounded by a flattened wing. This structure was part of the outer seed coat and probably helped in wind dissemination of these seeds. This type of seed may have belonged to both the Cordaitales and Cycadofilicales, for they have never been found attached.

*Holcospermum* (figs. 3 to 6, pl. 5) is a seed smaller than *Trigonocarpus* (fig. 1, pl. 5) when the outer husk is missing, the usual state of preservation. However, in the rare specimens in which the outer husk is preserved this seed may measure 5 cm (fig. 3, pl. 5). The hard inner coat of *Holcospermum* bears many distinctive longitudinal striations. This seed is believed to be associated with the foliage species *Neuropteris scheuchzenii* (figs. 8 and 9, pl. 4).

The seed ferns are believed to have become extinct some time during the Jurassic Period (table 1), whereas the descendants of certain of our Paleozoic ferns are numerous in the world's vegetation today.

#### ORDER CORDAITALES

An important arborescent group in the coal flora of Indiana is the order Cordaitales. The name *Cordaites* is usually applied to the stem and leaf remains of this tall (as much as 100 feet) slender gymnospermous tree. Although there is a superficial resemblance of the habit of these Paleozoic trees to that of certain of our modern conifers of the southern hemisphere, these groups are unrelated. The Cordaitales became extinct during the lower Triassic (table 1), but the first elements of our modern conifers did not appear until late Jurassic or early Cretaceous time.

The straplike leaves of *Cordaites* (fig. 7, pl. 5) measured 2 to 3 feet in length and approximately 2 to 3 inches in width. There is no midrib, but instead numerous linear veins run the full length of the

leaf, parallel to the leaf margins. Two other leaf form genera, *Dorycordaites* (fig. 8, pl. 5) and *Poacordaites* (fig. 9, pl. 5), are separated on the basis of their slightly different venation pattern, apex character, and narrower width.

*Artisia* (fig. 10i pl. 5) refers to the cylindrical pith casts of some cordaitalean stems. These casts show a number of closely aligned horizontal flutings, representing the former positions of softer tissue between the harder pith diaphragms, somewhat similar to the condition which appears in the pith of our modern walnut trees.

The known fructifications of the Cordaitales were borne on short stalks which were attached to the main branches up among the sessile leaves. Although it is quite certain that none of these fertile stalks ever bore both pollen sacs (male) and ovulate (female) structures, nevertheless, owing to the difficulty in distinguishing the two, both male and female reproductive branches are grouped under the form genus *Cordaianthus* (figs. 12 and 13, pl. 5).

As mentioned previously, some of the winged seeds known as *Samaropsis* undoubtedly belonged to the Cordaitales. In addition, certain heart-shaped or oval winged seeds (sometimes found attached to *Cordaianthus*) are usually assigned to the genus *Cordaicarpus* (fig. 11, pl. 5).

*Callixylon newberryi* (fig. 14, pl. 5) . although not a part of our coal flora, should be mentioned here because of its paleobotanical significance. Petrified trunks, measuring as much as 3 feet in diameter, have been found in Clark and Scott Counties. This genus has been an index fossil for upper Devonian rocks throughout the world. Although these trees are considered to be among the earliest representatives of the Cordaitales, nothing is known concerning their leaves or reproductive organs.

#### LIST OF PLANT FOSSILS FROM INDIANA

Most of the plant fossils in this list were collected by the author from rocks of Pennsylvanian age during 1953 and 1954 and are deposited in the collections of the Coal Section of the Indiana Geological Survey. The remaining specimens are deposited in the Indiana University Paleobotanical Collections in the Department of Botany. This list, comprising 68 genera and 146 species, does not include names of plant parts found in coal balls or names of spores isolated from coals. The scientific names of the plant fossils from Indiana, together with their proper position in the system of classification, are given below:

## Phylum TRACHEOPHYTA

## Subphylum Lycopsidea

## Order Lepidodendrales

*Stigmara ficoides* Bgt.  
*S. ficoides* var. *undulata* ( ? ) Goepp.  
*S. stellata* Goepp. <sup>1</sup>  
*Bergeria* Presl  
*Bothrodendron minutifolium* Boulay  
*Knorria* Sternb.  
*Lepidodendron aculeatum* Sternb.  
*L. clypeatum* Lx.  
*L. dichotomum* ( ? ) Sternb.  
*L. lanceolatum* Lx.  
*L. latifolium* ( ? ) Lx.  
*L. lycopodibides* ( ? ) Sternb.  
*L. modulatum* Lx.  
*L. obovatum* Sternb.  
*L. ophiurus* Bgt.  
*L. rhodeanum* Sternb.  
*L. rigens* Lx.  
*L. rimosum* ( ? ) Sternb.  
*L. vestitum* Lx.  
*L. volkmannianum* Sternb. <sup>1</sup>  
*L. wortheni* Lx.  
*Lepidophyllum* sp. Bgt.  
*L. affine* ( ? ) Lx.  
*L. incertus* ( ? ) Lx.  
*L. lanceolatum* Bgt.  
*L. longifolium* Bgt.  
*L. mansfieldi* Lx.  
*Lepidostrobus* sp. Bgt.  
*L. cf. geinitzi* Schimper  
*L. cf. lancifolius* Lx.  
*L. ornatus* ( ? ) Bgt.  
*L. ovatifolius* Lx.  
*L. variabilis* L. & H.  
*Lepidophloios* sp. Sternb.  
*L. laricinus* Sternb.  
*L. sigillarioides* ( ? ) Lx.  
*L. van ingeni* ( ? ) D. White  
*Sigillaria brardi* Bgt.

---

<sup>1</sup> Mississippian age.

## Phylum TRACHEOPHYTA- -Continued

## Subphylum Lycopsidea- -Continued

## Order Lepidodendrales --Continued

*Sigillaria elegans* Bgt.  
*S. cf. laevigata* Bgt.  
*S. mamillaris* Bgt.  
*S. orbicularis* Bgt.  
*S. ovata* Sauv.  
*Syringodendron* Sternb.  
*Sigillariophyllum* sp. Gr. 'Eury  
*Sigillariostrobus quadrangularis* (Lx. D. White

## Subphylum Sphenopsida

## Order Equisetales

*Annularia longifolia* Bgt.  
*A. radiata* Bgt.  
*A. sphenophylloides* (Zenker) Gutb.  
*A. stellata* Wood  
*Asterophyllites charaeformis* Sternb.  
*A. equisetiformis* (Schloth. ) Bgt.  
*A. grandis* Sternb.  
*A. longifolius* Bgt.  
*Calamites approximatus* Bgt.  
*C. cannaeformis* ( ? ) Schloth.  
*C. cisti* Bgt.  
*C. cruciatus* Sternb.  
*C. ramosus* Artis  
*C. suckowi* Bgt.  
*C. undulatus* Sternb.  
*Calamophyllites* sp. Gr. 'Eury  
*Calamostachys* sp. Schimper  
*C. charaeformis* Sternb.  
*C. elongata* (Presl) Weiss  
*C. germanica* ( ? ) Weiss  
*C. paniculata* Weiss  
*C. ramosa* Weiss  
*C. tuberculata* Sternb.  
*Cingularia* sp. ( ? ) Weiss  
*Palaeostachya* sp. Weiss  
*Pinnularia* sp. L. & H.

## Subphylum Sphenopsida- -Continued

## Order Equisetales- -Continued

Macrostachya sp. Schimper

Volkmannia sp. Sternb.

## Order Sphenophyllales

Bowmanites sp. Binney

Sphenophyllum cuneifolium Sternb.

S. emarginatum Bgt.

S. majus Bgt.

S. myriophyllum Crepin

S. saxifragaefolium Sternb.

## Subphylum Pteropsida

Orders Filicales and Cycadofilicales <sup>2</sup>

## "Alethopterids"

Alethopteris ambigua Lx.

A. decurrens Artis

A. grandini Bgt.

A. helenae Lx.

A. lonchita Schloth.

A. scalariformis ( ? ) Bell

A. serli Bgt.

A. valida Boulay

Callipteridium inaequale Lx.

C. membranaceum Lx.

C. pteridium ( ? ) Schloth.

---

<sup>2</sup> There is no reliable method of separating fern and seed-fern foliage unless fructifications are present. Therefore, fernlike foliage in the form genera listed here may belong to the Filicales (true ferns), Cycadofilicales (seed ferns), or to both groups. Furthermore, grouping under the subheadings "Alethopterids," "Sphenopterids," "Pecopterids," and "Neuropterids" is artificial and is based upon certain similarities of form alone. Accordingly, relationships among genera within these artificial subgroups are not implied.

## Subphylum Pteropsida- -Continued

## Orders Filicales and Cycadofilicales- -Continued

## "Alethopterids"- -Continued

*Callipteridium sullivanti* (Lx.) Weiss

## "Sphenopterids"

*Diplothmema fureatum* (Bgt. ) Stur  
*D. obtusiloba* ( ? ) (Bgt. ) Stur  
*D. zobeli* Goepp.  
*Eremopteris gracilis* ( ? ) D. White  
*Oligocarpia brongniarti* ( ? ) Stur  
*O. cf. missouriensis* D. White  
*Sphenopteris* (*Hymenotheca*) *broadheadi* D. W.  
*S. elegans* Bgt.  
*S. hoeninghausi* Bgt.  
*S. suspecta* D. White  
*Renaultia chaerophylloides* (Bgt.) Presl  
*Rhodea* sp. Presl  
*Zeilleria delicatula* Stemb.  
*Z. frenzli* Stur

## "Pecopterids"

*Acitheca polymorpha* Bgt.  
*Asterotheca abbreviata* Bgt.  
*A. arborescens* Schloth.  
*A. candolleana* Bgt.  
*A. crenulata* Bgt.  
*A. cyathea* Schloth.  
*A. hemitelioides* Bgt.  
*A. miltoni* Artie  
*A. oriopteridia* ( ? ) Schloth.  
*Dactylotheca aspera* Bgt.  
*D. plumosa* Artie  
*Dicksonites pluckeneti* Schloth.  
*Mariopteris hirta* ( ? ) Stur  
*M. lobata* D. White  
*M. muricata* Schloth.  
*M. nervosa* Bgt.  
*M. phillipsi* ( ? ) D. White

## Subphylum Pteropsida- -Continued

## Orders Filicales and Cycadofilicales --Continued

## "Pecopterids" - -Continued

*Mariopteris pottsvillea* D. White  
*M. pygmaea* D. White  
*Pecopteris clintoni* Lx.  
*P. pseudovestita* D. White  
*P. serpillifolia* Lx.  
*P. squamosa* Lx.  
*Ptychocarpus unitus* Bgt.  
*Senftenbergia pennaeformis* (Bgt.) Cords,

## "Neuropterids"

*Cyclopteris obliqua* Bgt.  
*C. trichomanoides* Sternb.  
*Linopteris obliqua* Bunbury  
*Megalopteris dawsoni* (Hartt) E. B. Andrews  
*M. southwellii* (?) Lx.  
*Mixoneura jenneyi* (?) D. White  
*M. ovata* Hoffm.  
*Neuropteris biformis* Lx.  
*N. clarksoni* Lx.  
*N. elrodi* Lx.  
*N. flexuosa* Sternb.  
*N. gigantea* Sternb.  
*N. heterophylla* Bgt.  
*N. macrophylla* Bgt.  
*N. microphylla* Bgt.  
*N. obliqua* Bgt.  
*N. plicata* Sternb.  
*N. rarinervis* Bunbury  
*N. scheuchzeri* Hoffm.  
*N. tenuifolia* Bgt.  
*Odontopteris alpina* (?) Gein.  
*O. subcuneata* Bunbury

## Miscellaneous Pteridophyll Organs

*Aphlebia* sp. Presl  
*Caulopteris* sp. L. & H.

## Subphylum Pteropsida- -Continued

## Orders Filicales and Cycadofilicales --Continued

## Miscellaneous Pteridophyll Organs- -Continued

Myeloxylon sp. Bgt.  
 Psaronius sp. Cotta  
 Ptychopteris sp. Corda  
 Spiropteris sp. Schimp.

## Cycadofilicalean Seeds

Calymmatotheca sp. Stur  
 Carpolithes sp. Sternb.  
 C. inflatus Lx.  
 Holcospermum mamillatus Nath.  
 H. sulcatum ( ? ) Sternb.  
 Lagenospermum sp. Nath.  
 Pachytesta sp. Bgt.  
 Rhabdocarpus mansfieldi ( ? ) Lx.  
 R. mamillatus Lx.  
 Trigonocarpus sp. Bgt.  
 T. adamsii ( ? ) Lx.  
 T. ampullaeformis Lx.  
 T. clavatus Sternb.  
 T. noeggerathi Sternb.

## Order Cordaitales

Artisia transversa (Artis) Sternb.  
 Callixylon newberryi Dawson<sup>3</sup>  
 Cardiocarpon annulatum Newb.  
 C. dilatatus Lx.  
 C. gutbieri Germ.  
 C. ingens Lx.  
 C. late-alatum Lx.  
 Cordaicarpon cordai ( ? ) Gein.  
 Cordaites sp. Unger  
 C. borassifolius Sternb.  
 C. crassinervis Heer

---

<sup>3</sup> Devonian age.

## Subphylum Pteropsida- -Continued

## Order Cordaitales- -Continued

*Cordaites principalis* Germ.  
*Dorycordaites palmaeformis* Goepp.  
*Poacordaites microstachys* Gold.  
*Samaropsis* sp. Goepp.  
*S. annulatus* Newb.

## COLLECTING SITES FOR PLANT FOSSILS

Most of the collecting sites for plant fossils reported in earlier publications can no longer be located, although some of these sites guided the author to general areas that proved productive. Plant fossils were collected from 93 sites during the 2 summers of fieldwork. These sites are shown in text figure 3 and table 3. Some of the most productive sites are described below in some detail.

Site No. 20 is the Dixie Bee Mine, which was abandoned in 1939. It is half a mile south of Pimento in Vigo County. Coal V was mined here at a depth of 285 feet. The roof shales on the mine dumps contain numerous petrifications and casts of *Lepidophloios*, *Lepidodendron*, and *Lepidostrobus*.

Site No. 22 is 3 miles east of Farmersburg in Sullivan County. Spoil banks of abandoned strip and drift mines contain ironstone nodules which were associated with Coal VII. *Asterophyllites*, *Sphenophyllum*, *Asterotheca*, and *Sytingodendron* are among the well-preserved fossils found here.

Site No. 28 is the abandoned strip mined of the Long and Price Coal Co. in Greene County near the intersection of State Routes 48 and 157. Lower Block Coal was mined here. Beautifully preserved plant fossils are found in abundance as ironstone concretions on the spoil banks. Representative genera are: *Calamites*, *Annularia*, *Asterophyllites*, *Dorycordaites*, *Palaeostachya*, *Calamostachys*, *Samaropsis*, *Holcospemum*, and *Zeilleria*.

Site No. 39- is approximately 2 miles west of Wheatland on United States Highway 50. The mine dumps of the White Ash Mine in Knox County contain argillaceous shales, associated with Coal VI, that yield a wide variety of well-preserved compressions of *Sigillaria*, *Sphenophyllum*, *Alethopteris*, and *Neuropteris*.

Site No. 43 is in the northeast corner of Daviess County about 1-21 miles northwest of Burns City. The spoil banks of an abandoned strip mine contain ironstone nodules in shale that overlay one of the block coals, *Lepidodendron*, *Lepidophyllum*, *Calamites*, and *Artisia* are

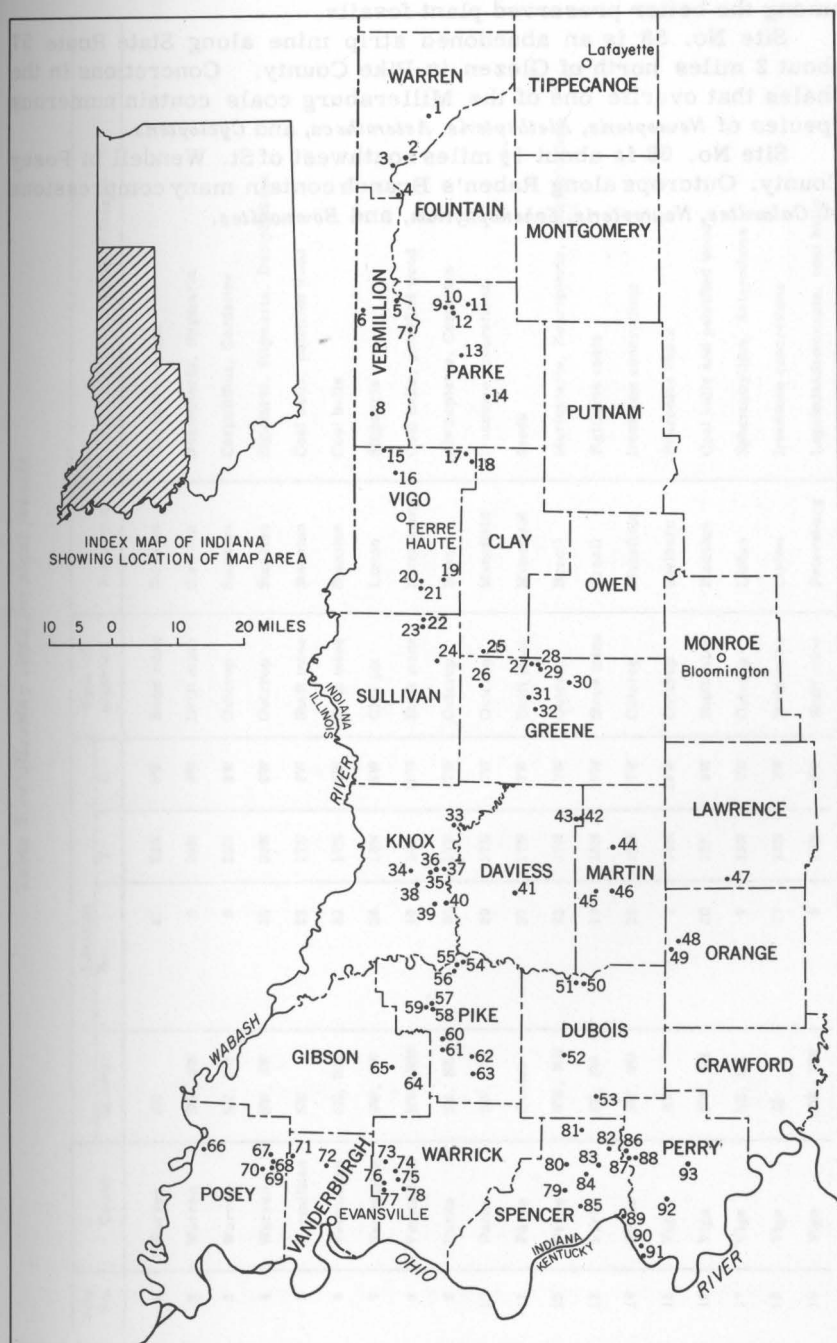


Figure 3. --Map of southwestern Indiana showing collecting sites for plant fossils.

among the better preserved plant fossils.

Site No. 58 is an abandoned strip mine along State Route 57 about 2 miles north of Glezen in Pike County. Concretions in the shales that overlie one of the Millersburg coals contain numerous species of *Neuropteris*, *Alethoptetis*, *Asterotheca*, and *Cyclopteris*.

Site No. 68 is about 121 miles southwest of St. Wendell in Posey County. Outcrops along Raben's Branch contain many compressions of *Calamites*, *Neuropteris*, *Sphenophyllum*, and *Bovmanites*.

Table 3.—Collecting sites for plant fossils

Site No.	County	Location				Type of exposure	Formation	Kinds of fossils
		Quarter	Sec.	T.	R.			
1	Warren	SE	21	22N	8W	Slope mine	Staunton	Cordaitea leaves
2	Warren	SW, SW	2	20N	9W	Drift mine	Staunton	Neuropteris, Stigmara
3	Warren	SE, NE	9	20N	9W	Outcrop	Staunton	Carpolithus, Cordaitea
4	Warren	SW, SW	35	20N	9W	Outcrop	Staunton	Sigillaria, Stigmara, Dactylothea
5	Vermillion	SW	22	17N	9W	Shaft mine	Staunton	Coal balls, petrified wood
6	Vermillion	SE, NE	32	17N	10W	Strip mine	Staunton	Coal balls
7	Vermillion	SW, SW	26	16N	9W	Clay pit	Linton	Stigmara
8	Vermillion	NW, NW	10	14N	10W	Shaft mine	Petersburg	Coal balls, petrified wood
9	Parke	SE, SE	30	17N	7W	Outcrop	Brazil	Alethopteris, Cordaitea
10	Parke	SW, SW	29	17N	7W	Outcrop	Mansfield	Ironstone concretions
11	Parke	Center	27	17N	7W	Drift mine	Mansfield	Seeds
12	Parke	NW, NW	32	17N	7W	Outcrop	Brazil	Mariopteris, Neuropteris, Sphenophyllum
13	Parke	SE, SW	17	15N	7W	Slope mine	Brazil	Sigillaria casts
14	Parke	SW, SW	29	17N	7W	Outcrop	Mansfield	Ironstone concretions
15	Vigo	NW	1	13N	10W	Outcrop	Shelburn	Psaronius casts
16	Vigo	NW, SE	20	13N	9W	Shaft mine	Staunton	Coal balls and petrified wood
17	Vigo	SE, SE	7	13N	7W	Outcrop	Linton	Sphenophyllum, Asterotheca
18	Vigo	S $\frac{1}{2}$	17	13N	7W	Strip mine	Linton	Ironstone concretions
19	Vigo	SW, NW	9	10N	8W	Shaft mine	Petersburg	Lepidodendron casts, coal balls

Table 3.—*Collecting sites for plant fossils*—Continued

Site No.	County	Location				Type of exposure	Formation	Kinds of fossils
		Quarter	Sec.	T.	R.			
20	Vigo	SE, SW	14	10N	9W	Shaft mine	Petersburg	Silicified wood, <i>Lepidostrobus</i>
21	Vigo	SW, SE	14	10N	9W	Shaft mine	Petersburg	<i>Lepidodendron</i> , <i>Lepidophloios</i> , coal balls
22	Sullivan	NW, NE	5	9N	8W	Drift mine	Dugger	<i>Calamites</i> , <i>Syringodendron</i> , <i>Asterophyllites</i> , <i>Sphenophyllum</i> , <i>Asterotheca</i>
23	Sullivan	NW, SE	5	9N	8W	Strip mine	Dugger	<i>Sphenophyllum</i> , <i>Asterophyllites</i>
24	Sullivan	S $\frac{1}{2}$	15	8N	8W	Strip mine	Dugger	<i>Asterotheca</i> , <i>Cordaites</i>
25	Clay	NE, NE	34	9N	7W	Strip mine	Petersburg	<i>Aspidaria</i> , <i>Lepidophloios</i>
26	Greene	SE, NW	27	8N	7W	Strip mine	Linton	Coal balls, petrified wood
27	Greene	NE, SW	12	8N	6W	Strip mine	Brazil	Ironstone concretions, variety of fossils
28	Greene	SW, NE	7	8N	5W	Strip mine	Brazil	Ironstone concretions that contain seeds, cones, pteridophylls, <i>Calamites</i> , <i>Stigmaria</i> , and <i>Lepidodendron</i>
29	Greene	NW, SE	7	8N	5W	Strip mine	Brazil	<i>Megalopteris</i> , <i>Mariopteris</i> , <i>Cordaites</i> , <i>Lepidodendron</i> , <i>Stigmaria</i>
30	Greene	NW, SW	23	8N	5W	Outcrop	Mansfield	<i>Calamites</i> , <i>Callipteridium</i> , <i>Cordaites</i> , <i>Neuropteris</i> , <i>Sphenophyllum</i> , <i>Annularia</i> , <i>Asterophyllites</i> , <i>Samaropsis</i>
31	Greene	SE, SW	35	8N	6W	Strip mine	Brazil	<i>Alethopteris</i> , <i>Cordaites</i> , <i>Neuropteris</i>
32	Greene	SE	13	7N	6W	Strip mine	Brazil	<i>Sphenophyllum</i> , <i>Annularia</i> , <i>Pecopteris</i> , <i>Cordaites</i>
33	Knox	SW, SE	34	5N	8W	Outcrop	Dugger	<i>Artisia</i> , <i>Calamites</i>
34	Knox	S $\frac{1}{4}$	Donation 74	4N	9W	Shaft mine	Petersburg	<i>Stigmaria</i>
35	Knox	NW, SW	Donation 125	4N	8W	Shaft mine	Petersburg	<i>Syringodendron</i>
36	Knox	Center	Donation 140	4N	8W	Shaft mine	Petersburg	Coal balls, <i>Trigonocarpus</i> , <i>Lepidodendron</i>

37	Knox	W $\frac{1}{4}$	Donation 241	4N	8W	Shaft mine	Petersburg	Coal balls, petrified wood
38	Knox	N $\frac{1}{4}$	Donation 68	3N	9W	Shaft mine	Dugger	Syringodendron
39	Knox	NW, NE	Donation 81	3N	8W	Shaft mine	Dugger	Asterotheca, Sphenophyllum, Neuropteris, Sigillaria, Lepidodendron, Syringodendron, Alethopteris, Cordaites
40	Knox	W $\frac{1}{4}$	Donation 110	3N	8W	Shaft mine	Petersburg	Lepidophloios, Syringodendron, Stigmara, Trigonocarpus
41	Daviess	NW, NW	22	3N	6W	Strip mine	Linton	Cordaites
42	Daviess	SE, NE	26	5N	5W	Strip mine	Brazil	Artisia, Cordaites, seeds
43	Daviess	SW, NE	25	5N	5W	Strip mine	Brazil	Lepidophyllum, Lepidostrobophyllum, Lepidostrobus, Lepidodendron, Asterophyllites, Annularia, Calamophyllites, cones, seeds
44	Martin	SE, NW	35	4N	4W	Outcrop	Mansfield	Lepidodendron, Calamites, Stigmara
45	Martin	NW	21	3N	4W	Outcrop	Mansfield	Bergeria, Aspidiaria
46	Martin	NE, NE	23	3N	4W	Outcrop	Mansfield	Calamites, Syringodendron
47	Lawrence	NW, SW	3	3N	1W	Outcrop	Bethel	Stigmara
48	Orange	SW, SE	32	2N	2W	Quarry	Mansfield	Lepidostrobus, Stigmara
49	Orange	NE, NE	6	1N	2W	Quarry	Mansfield	Mariopteris, Asterophyllites
50	Dubois	SE, SW	30	1N	4W	Outcrop	Mansfield	Stigmara, Artisia, Calamites
51	Dubois	NW, NE	25	1N	5W	Outcrop	Mansfield	Stigmara, Lepidodendron, Calamites
52	Dubois	NE, NW	9	2S	5W	Strip mine	Brazil	Megaspores
53	Dubois	SW, SW	20	3S	4W	Slope mine	Brazil	Megaspores, seeds
54	Pike	SE, NE	7	1N	7W	Slope mine	Petersburg	Coal balls
55	Pike	SE, NE	13	1N	8W	Slope mine	Petersburg	Coal balls
56	Pike	NW, NE	13	1N	8W	Strip mine	Petersburg	Coal balls, pyritized wood
57	Pike	NE, NW	9	1S	8W	Strip mine	Dugger	Nodules; Mixoneura, Mariopteris, Alethopteris, Pecopteris, Neuropteris

Table 3.—*Collecting sites for plant fossils*—Continued

Site No.	County	Location				Type of exposure	Formation	Kinds of fossils
		Quarter	Sec.	T.	R.			
58	Pike	SW, SE	9	1S	8W	Strip mine	Dugger	Neuropteris, Asterotheca, Pecopteris
59	Pike	NE, NW	8	1S	8W	Strip mine	Dugger	Cordaitea, Asterotheca, Mixoneura
60	Pike	SW, SW	2	2S	8W	Strip mine	Petersburg	Lepidodendron, Calamites, coal balls
61	Pike	SW, SE	11	2S	8W	Strip mine	Petersburg	Lepidodendron, Neuropteris, Pecopteris
62	Pike	SE, SE	33	2S	7W	Strip mine	Petersburg	Holcospermum
63	Pike	NW, NE	16	2S	7W	Strip mine	Petersburg	Artisia
64	Gibson	SE, SW	36	2S	9W	Shaft mine	Petersburg	Trigonocarpus, coal, pyritized wood
65	Gibson	NW, NE	26	2S	9W	Strip mine	Shelburn	Asterotheca, Cordaitea, Neuropteris
66	Posey	SW, SW	11	5S	14W	Outcrop	Parkers	Neuropteris, Calamites, Annularia, Sphenopteris, Cyclopteris
67	Posey	SE, SE	2	5S	12W	Outcrop	Parkers	Neuropteris, Cyclopteris, Asterotheca, Pecopteris, Pinnularia
68	Posey	SW, SE	11	5S	12W	Outcrop	Parkers	Calamites, Neuropteris, Pecopteris, Asterotheca, Syringodendron
69	Posey	SE	14	5S	12W	Outcrop	Parkers	Coal balls
70	Posey	SW, SE	22	5S	12W	Outcrop	Parkers	Neuropteris, Linopteris, Calamites, Asterotheca, Pecopteris, Cordaitea
71	Vanderburgh	NW	7	5S	11W	Outcrop	Parkers	Calamites, concretions
72	Vanderburgh	NE	13	5S	11W	Outcrop	Inglefield	Calamites
73	Warrick	SW	32	4S	9W	Slope mine	Dugger	Mariopteris, Dactylotheca, Calamites, Cordaitea, Sphenophyllum, Pecopteris, Asterotheca, Neuropteris, Linopteris, Calamostachys, Sigillaria

74	Warrick	SE, SE	10	5S	8W	Shaft mine	Petersburg	Coal balls
75	Warrick	SE	23	5S	8W	Slope mine	Petersburg	Coal balls
76	Warrick	NE, SW	20	5S	8W	Shaft mine	Petersburg	Psaronius, coal balls
77	Warrick	SE, SE	32	5S	8W	Shaft mine	Petersburg	Coal balls
78	Warrick	NE, SE	25	5S	8W	Shaft mine	Petersburg	Lepidodendron, coal balls
79	Spencer	S $\frac{1}{2}$	33	5S	5W	Strip mine	Staunton	Sphenopteris, Neuropteris
80	Spencer	SW, SE	9	5S	5W	Strip mine	Brazil	Lepidophloios, coal balls
81	Spencer	SE	12	4S	5W	Strip mine	Brazil	Megaspores
82	Spencer	NW, NW	26	4S	4W	Shaft mine	Mansfield	Stigmara
83	Spencer	SW, SE	9	5S	5W	Strip mine	Brazil	Coal balls, pyritized wood
84	Spencer	NW	18	5S	4W	Strip mine	Brazil	Sigillaria
85	Spencer	NE	1	6S	5W	Strip mine	Brazil	Neuropteris, Calamites, Sphenophyllum
86	Perry	NE, NE	30	4S	3W	Strip mine	Mansfield	Lepidodendron, Stigmara
87	Perry	NW, SE	30	4S	3W	Shaft mine	Mansfield	Stigmara, Cordaites, megaspores
88	Perry	SW, SE	29	4S	3W	Strip mine	Mansfield	Lepidodendron, Syringodendron
89	Perry	NW, SE	13	6S	4W	Outcrop	Mansfield	Stigmara
90	Perry	SE, SE	4	7S	3W	*	Mansfield	Lepidodendron, Lepidophloios
91	Perry	NW, NW	9	7S	3W	Outcrop	Mansfield	Lepidophloios, megaspores, Syringodendron, Calamites, Lepidodendron
92	Perry	SW, SE	31	5S	2W	Strip mine	Mansfield	Lepidostrobophyllum, Lepidophyllum, Lepidodendron, Sphenophyllum, Calamites
93	Perry	SE, NE	10	5S	2W	Outcrop	Mansfield	Lepidodendron, Stigmara

\*Abandoned mine.

## LITERATURE CITED

- Andrews, H. N., 1951, American coal ball floras: *Bot. Rev.* , v. 17, no. 6, p. 430-469, 11 figs.
- Arnold, C. A. , 1947, *An introduction to paleobotany*: 433 p. , 187 figs., New York, McGraw-Hill Book Co., Inc.
- 1949, Fossil flora of the Michigan Coal Basin: *Mich. Univ., Mus. Paleontology, Contr.* , v. 7, no. 9, p. 131-269, 34 pls., 2 figs.
- Ashley, G. H. , 1899, The coal deposits of Indiana: *Ind. Dept. Geology and Nat. Res., Ann. Rept. 23*, p. 1- 1573, 91 pls., 986 figs. , 7 maps.
- 1909, Supplementary report to the report of 1898 on the coal deposits of Indiana: *Ind. Dept. Geology and Nat. Res. , Ann. Rept. 33*, p. 13-150, 4 pls., 1 fig.
- Bell, W. A. , 1938, Fossil flora of Sydney coal field, Nova Scotia: *Canada Geol. Survey Mem. 215*, 334 p. , 107 pls. , 1 fig. (in 2 parts).
- Benninghoff, W. S. , 1943, Preliminary report on a coal ball flora from Indiana: *Ind. Acad. Sci. Proc.* , v. 52, p. 62-68, 1 pl.
- Bode, H. , 1952, Palaeobotanische Feinstratigraphie: *Cong. de Stratigraphie et de Geologie du Carbonifere*, 3d Heerlen, *Comptes rendus*, v. 1, p. 39-44.
- Canright, J. E. , 1958, History of paleobotany in Indiana: *Ind. Acad. Sci. Proc.* , v. 67, p. 268-273, 4 figs.
- Crookall, R. , 1929, *Coal measure plants*: 80 p. , 39 pls. , London, Edward Arnold Ltd.
- Cross, A. T. , 1950, Plant microfossils and the application of their study to coal stratigraphy: *Conf. on the Origin and Constitution of Coal*, Crystal Cliffs, Nova Scotia, *Proc.* , p. 49-74.
- Eames, A. J. , 1936, *Morphology of vascular plants, lower groups*. 433 p., 215 figs., New York, McGraw-Hill Book Co\_ Inc.

- Elias, M. K. , 1936, Elements of the Stephanian flora in the Midcontinent of North America: Cong. de Stratigraphie et de Geologie du Carbonifere, 2d Heerlen, Comptes rendus, p. 203-208.
- Francis, W. , 1954, Coal, its formation and composition: 567 p. , 203 figs. , London, Edward Arnold Ltd.
- Gothan, W., 1919, Das Alter der Karbonformation nordlich der Roehr und Allgerneines ueber Horizontierung im Karbon mit Hilfe der Flora: Glueckauf, v. 55, no. 26, p. 477-483.
- Guennel, G. K. , 1952, Fossil spores of the Alleghenian coals in Indiana: Ind. Geol. Survey Rept. Progress 4, 40 p. , 4 pls. , 9 figs.
- 1958, Miospore analysis of the Pottsville coals of Indiana: Ind. Geol. Survey Bull. 13, 101 p. , 6 pls. , 20 figs. , 11 tables.
- Hoskins, J. H. , and Cross, A. T. , 1952, The petrification flora of the Devonian-Mississippian Black Shale: Paleobotanist, v. 1, p. 215-238, 14 figs.
- Jackson, T. F., 1914, The paleobotany of the Bloomington, Ind. , Quadrangle: Ind. Acad. Sci. Proc. , v. 24, p. 395-398.
- 1916, The description and stratigraphic relationships of fossil plants from the lower Pennsylvanian rocks of Indiana. Ind. Acad. Sci. Proc. , v. 26, p. 405-428.
- Janssen, R. E. , 1939, Leaves and stems from fossil forests: Ill. State Mus. Pop. Sci. Ser. , v. 1, 190 p. , 165 figs.
- Kindle, E. M. , 1896, The whetstone and grindstone rocks of Indiana: Ind. Dept. Geology and Nat. Res. , Ann. Rept. 20, p. 328368, 1 map.
- Kosanke, R. M. , 1947, Plant microfossils in the correlation of coal beds: Jour. Geology, v. 55, no. 3, p. 280-284, 1 fig.
- 1950, Pennsylvanian spores of Illinois and their use in correlation: 111. Geol. Survey Bull. 74, 128 p. , 18 pls. , 7 figs.
- Ladd, H. S. , and Brown, R. W. , 1956, Fossils lift the veil of time: Nat. Geog. Mag., v. 109, p. 363-386.

- Lesquereux, Leo, 1879, Atlas to the coal flora of Pennsylvania and of the Carboniferous formation throughout the United States: Pa. 2d Geol. Survey Rept. Progress P, 85 pls.
- 1880, Description of the coal flora of the Carboniferous formation in Pennsylvania and throughout the United States: Pa. 2nd Geol. Survey Rept. Progress P. , v. 1 and 2, 694 p.
- 1884a, Description of the coal flora of the Carboniferous formation in Pennsylvania and throughout the United States: Pa. 2nd Geol. Survey Rept. Progress P. , v. 3, p. 695-977, 23 pls.
- 1884b, Principles of Paleozoic botany: Ind. Dept. Geology and Nat. History, Ann. Rept. 13, p. 6-106, 22 pls.
- Moore, R. C. , and others, 1944, Correlation of Pennsylvanian formations of North America: Geol. Soc. America Bull., v. 55, no. 6, p. 657-701, 1 chart.
- Noe', A. C. , 1924, Coal balls here and abroad: Ill. Acad. Sci. Trans.. v. 16, p. 179-180.
- 1925, Pennsylvanian flora of northern Illinois: Ill. Geol. Survey Bull. 52, 113 p. , 45 pls.
- Owen, D. D., 1843a, Fossil palm trees found in Posey County, Ind.: Am. Jour. Sci. , v. 45, p. 336-337.
- 1843b, On some fossil trees from New Harmony, Ind.: Acad. Nat. Sci. Philadelphia Proc. , v. 1, p. 270-271.
- Owen, Richard, 1862, Report of a geological reconnaissance of Indiana: 368 p. o 8 pls. , 21 figs. , 1 map, Indianapolis, Ind., H. H. Dodd and Co.
- Read, C. B. , 1947, Pennsylvanian floral zones and floral provinces: Jour. Geology, v. 55, p. 271-279.
- Schopf, J. M. , 1948, Variable coalification: the process involved in coal formation: Econ. Geology, v. 43, p. 207-225.
- 1949, Research in coal paleobotany since 1943: Econ. Geology, v. 44, p. 492-513.

- Shutts, C. F., and Canright, J. E. , 1955, Recent collections of Pennsylvanian plant fossils in Indiana: Ind. Acad. Sci. Proc.  
v. 64, p. 70-74, 2 figs.
- Siever, R. , 1957, Pennsylvanian sandstones of the Eastern Interior Coal Basin: Jour. Sed. Petrology, v. 27, no. 3, p. 227-250, 6 figs.
- Tyler, S. A. , and Barghoorn, E. S. , 1954, Occurrence of structurally preserved plants in Pre-Cambrian rocks of the Canadian Shield: Science, v. 119, no. 3096, p. 606-608, 4 figs.
- United States Geological Survey, 1958, Suggestions to authors of the reports of the United States Geological Survey: 255 p. , Washington, U. S. Govt. Printing Office.
- Walton, J. , 1928, A method of preparing sections of fossil plants: Nature, v. 122, p. 571.
- White, David, 1900, Relative ages of the Kanawha and Allegheny Series as indicated by the fossil plants: Geol. Soc. America Bull., v. 11, p. 145-178, 3 figs.
- and Thiessen, R., 1913, The origin of coal: U. S. Bur. Mines Bull. 38, 390 p. , 54 pls.
- Wier, C. E. , 1952, Geology and mineral deposits of the Jasonville Quadrangle, Indiana: Ind. Geol. Survey Bull. 6, 34 p. , 6 pls. , 6 figs. , 8 tables.
- and Wayne, W. J. , 1957, An introduction to the geology of Parke County, Ind.: Ind. Geol. Survey Circ. 2, 35 p. , 7 figs.
- Wilson, L. R., 1946, The correlation of sedimentary rocks by fossil spores and pollen: Jour. Sed. Petrology, v. 16, no. 3, p. 110120, 3 figs.
- Wood, J. M. , and Canright, J. E. , 1954, The present status of paleobotany in Indiana with special reference to the fossils of Pennsylvanian age: Ind. Acad. Sci. Proc. , v. 63, p. 87-91, 1 fig.
- Zeiller, R. , 1886, Flore fossile du bassin houiller de Valenciennes Etude Gites Minereux France, Atlas, Paris, 96 pls.

---

---

### PLATES 1-5

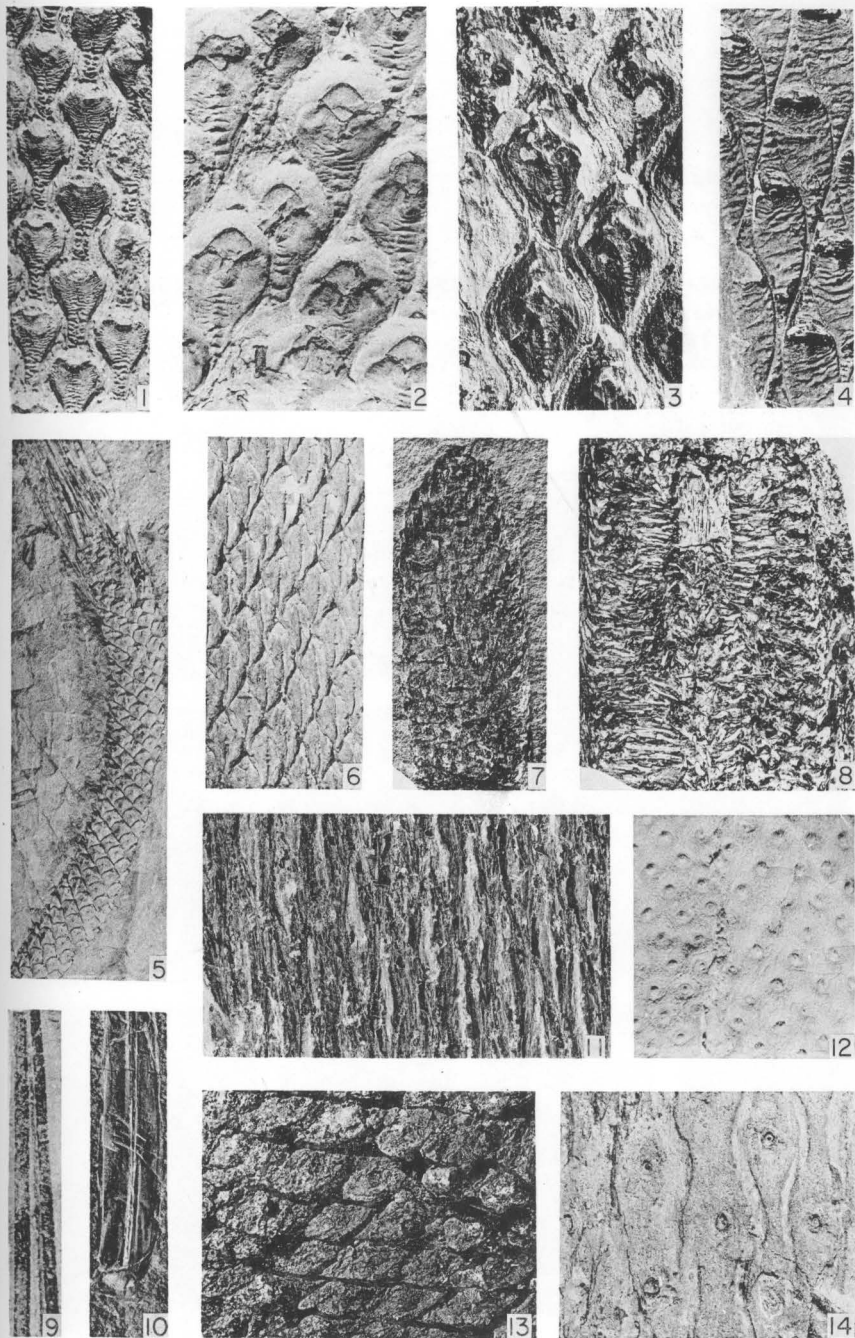
The numbers preceded by 1. U. or C. S. refer respectively to the accession numbers of the Indiana University Paleobotanical Collections and the collections of the Coal Section, Indiana Geological Survey. The site numbers listed correspond to those in table 3 and figure 3.

---

---

PLATE I

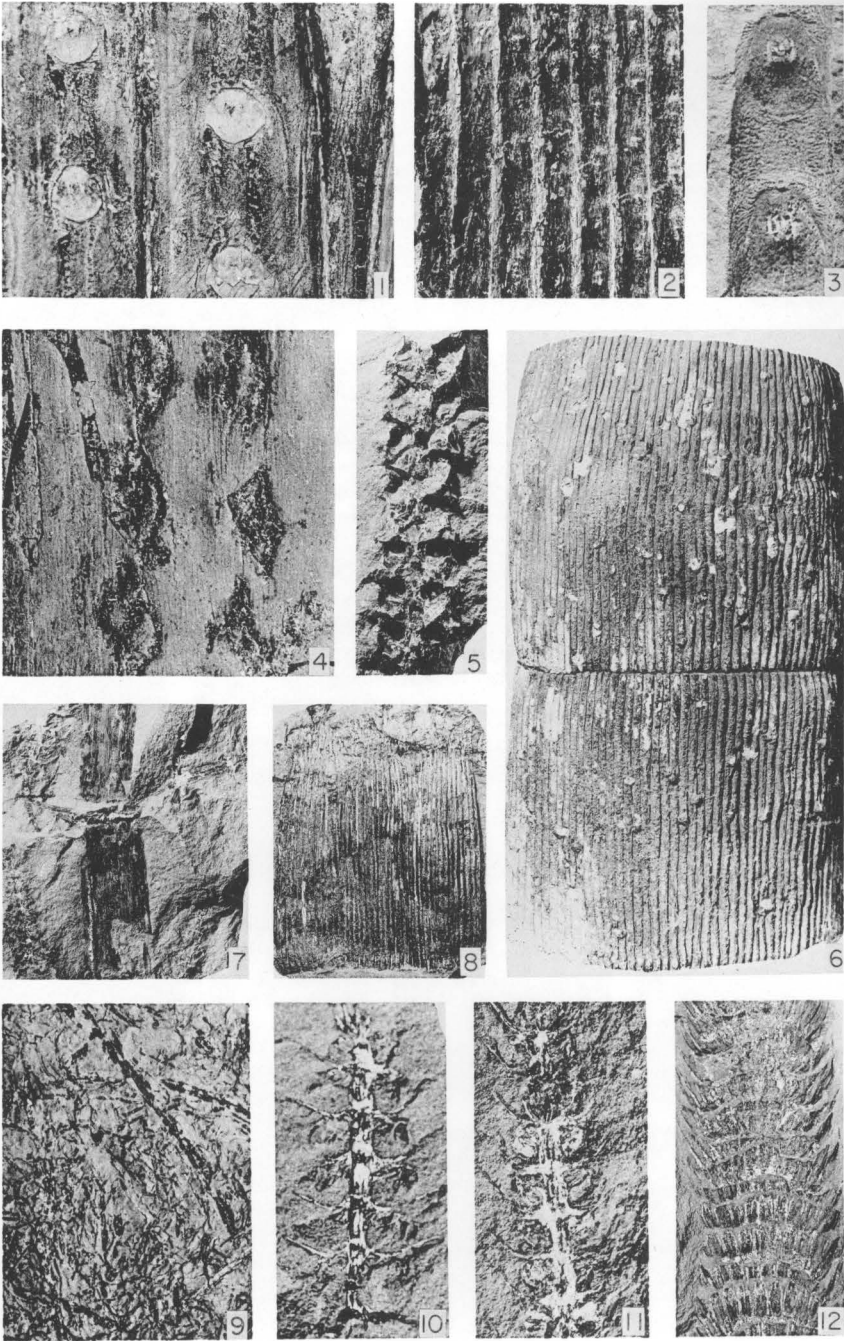
- Figure 1. *Lepidodendron volkmannianum* Stemb.; site unknown, Owen County; 1. U. 7; X 1/2
2. *Lepidodendron obovatum* Stemb.; site 29, Greene County; C. S. 577; X 2/3
3. *Lepidodendron modulatum* Lx.; site 28, Greene County; I. U. 210; X 1/2
4. *Lepidodendron wortheni* Lx.; site 28, Greene County; 1. U. 11; X 1 1/2
6. *Lepidodendron latifolium* (?) Lx.; site unknown, Orange County; 1. U. 3; X 1/3
6. *Lepidodendron aculeatum* Stemb.; site unknown, collected by C. A. Malott; C. S. 10; X 1/3
7. *Lepidostrobus* sp. Bgt.; site 28, Greene County; 1. U. 49; X 3/4
8. *Lepidostrobus* cf. *geinitzi* Schimp.; site 21. Vigo County; C- S- 11; X 1/2
9. *Lepidophyllum longifolium* Bgt.; site 88, Perry County; C. S. 403; X 2/3
10. *Lepidophyllum lanceolatum* (?) Bgt.; site 28, Greene County; 1. U. 211; X 1
11. *Bergeria* Presl.; site 39, Knox County; C. S. 484; X 1/3
12. *Stigimaria* sp. Bgt.; site 47, Lawrence County; C. S. 244; X 1/2
13. *Lepidophloios laricinus* Sternb.; site 21, Vigo County; C. S. 46; X 3/4
14. *Stigmaria ficoides* var. *undulata* Goepfert; site 4. Warren. County; C. S. 8; X 1



LEPIDODENDRALES

PLATE 2

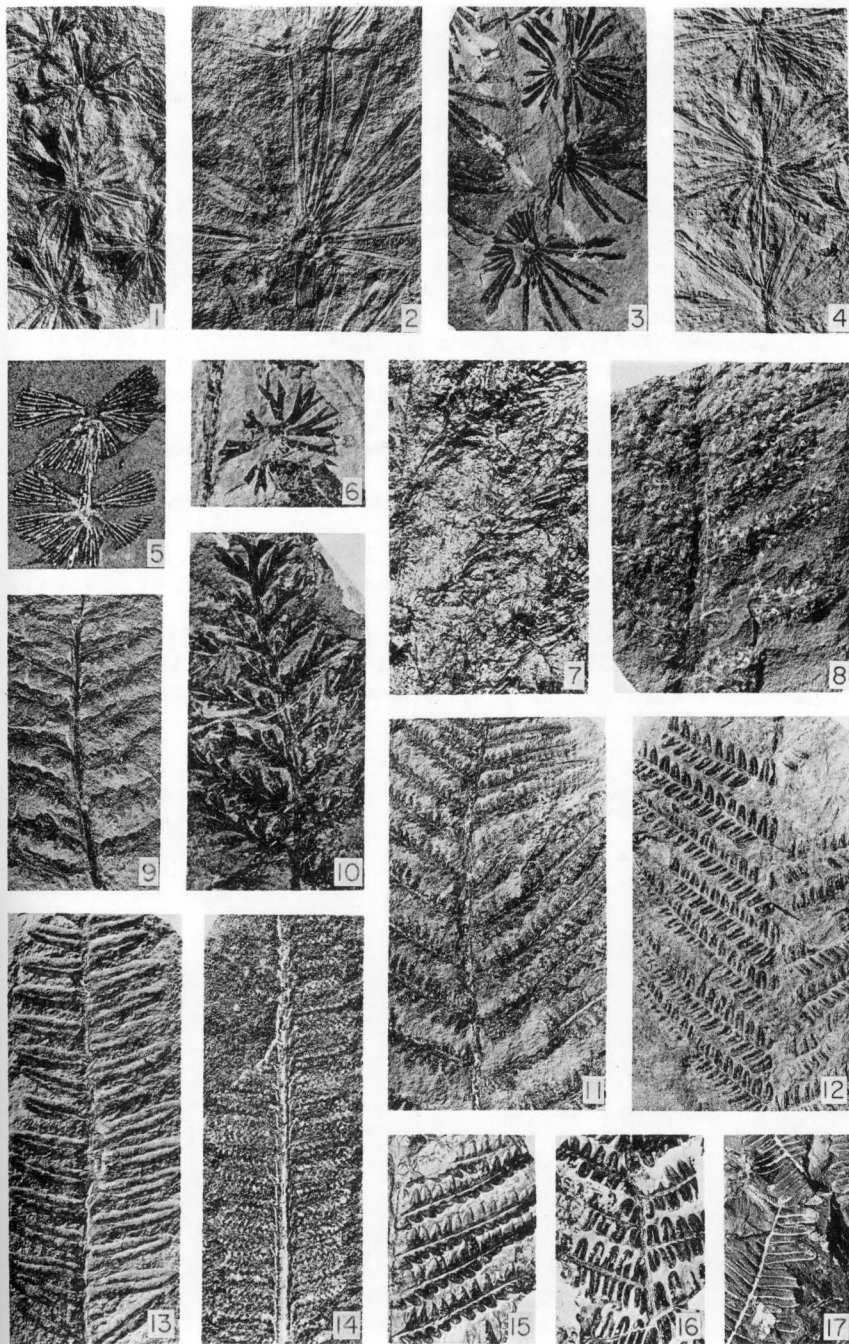
- Figure 1. *Sigillaria ovata* Sauveur; site 69, Posey County; C. S. 534; X 1/2  
2. *Sigillaria mamillaris* Bgt.; site 39, Knox County; C. S. 63; X 1/2  
3. *Sigillaria mamillaris* Bgt.; site 22, Sullivan County; I. U. 24;  
X 1 1/4  
4. *Syringodendron* Sternb.; site 39, Knox County; C. S. 455; X 2  
5. *Sigillariostrobus quadrangularis* Lx.; site 28, Greene County;  
I. U. 223; X 1/4  
6. *Calamites suckowi* Bgt.; site 28, Greene County; C. S. 94; X 1/4  
7. *Calamophyllites* sp. Grand 'Eury; site 28, Greene County;  
C. S. 154; X 2/5  
8. *Calamophyllites* sp. Grand 'Eury; site 28, Greene County;  
property of R. Neher; X 2/5  
9. *Pinnularia* sp. Lindley and Hutton; site 39, Knox County;  
C. S. 321; X 1  
10. *Cingularia* sp. Weiss; site 28, Greene County; I. U. 225; X 1  
11. *Palaeostachya* sp. Weiss; site 28, Greene County; I. U. 33; X 1  
12. *Macrostachya* sp. Schimper; site 28, Greene County; I. U. 29;  
X 3/5



LEPIDODENDRALES AND EQUISETALES

# PLATE 3

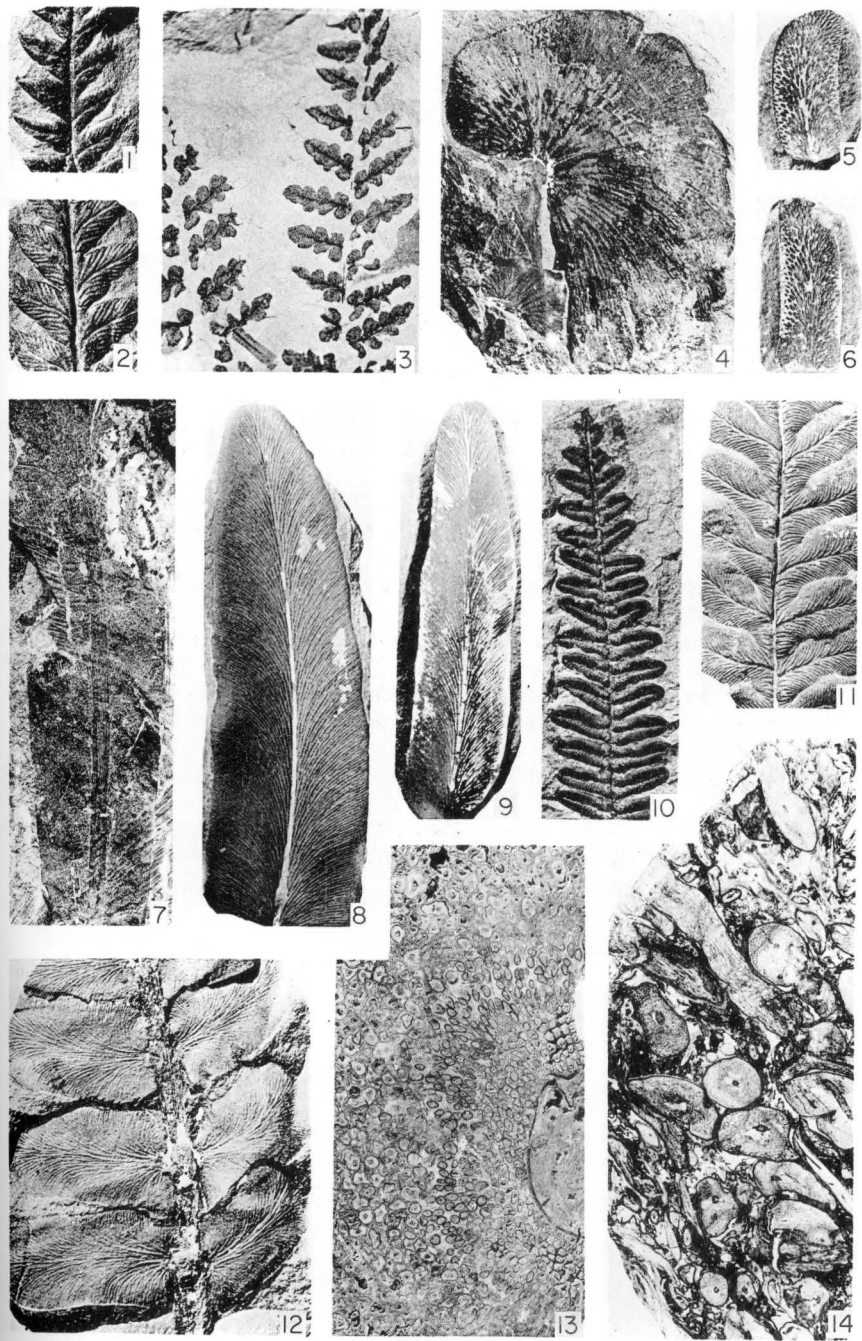
- Figure
1. *Annularia radiata* Bgt.; site 28, Greene County; I. U. 65; X 3/5
  2. *Annularia longifolia* Bgt.; site 28, Greene County; I. U. 224;  
X 1/2
  3. *Annularia stellata* Wood; site 28, Greene County; C. S. 117;  
X 3/5
  4. *Annularia stellata* Wood; site 28, Greene County; I. U. 62; X 3/4
  5. *Sphenophyllum emarginatum* Bgt.; site 22, Sullivan County;  
C. S. 135; X 1
  6. *Sphenophyllum saxilragaelolium* Bgt.; site 12, Parke County;  
C. S. 350; X 3/5
  7. *Asterophyllites equisetiformis* Bgt.; site 22, Sullivan County;  
C. S. 124; X 1/2
  8. *Zeilleria* sp. Kidst.; site 28, Greene County; I. U. 213; X 3/4
  9. *Renaultia chaerophylloides* Presl.; site 28, Greene County;  
I. U. 152; X 4/5
  10. *Diplothmema* sp. Stur; site 12, Parke County; C. S. 161; X 3/4
  11. *Asterotheca arborescens* Schloth.; site 28, Greene County;  
I.U. 117; X 3/5
  12. *Pecopteris* (*Senftenbergia*) *pennaeformis* Bgt.; site 69, Posey  
County; C. S. 325; X 2/5
  13. *Pecopteris* (*Asterotheca*) *crenulata* Bgt.; site 28, Greene  
County; I. U. 214; X 3/4
  14. *Ptychocarpus unitus* Bgt.; site 22, Sullivan County; I U. 126;  
X 1
  15. *Pecopteris* (*Dactylothea*) *plumosa* Artis; site 29, Greene  
County; C. S. 195; X 1/2
  16. *Pecopteris* (*Acitheca*) *polymorpha* Bgt.; site 39, Knox County;  
C. S. 476; X 1/2
  17. *Pecopteris* (*Asterotheca*) *candolleana* Bgt.; site 58, Pike  
County; C. S. 173; X I



EQUISETALES, SPHENOPHYLLALES, FILICALES, AND CYCADOFILICALES

# PLATE 4

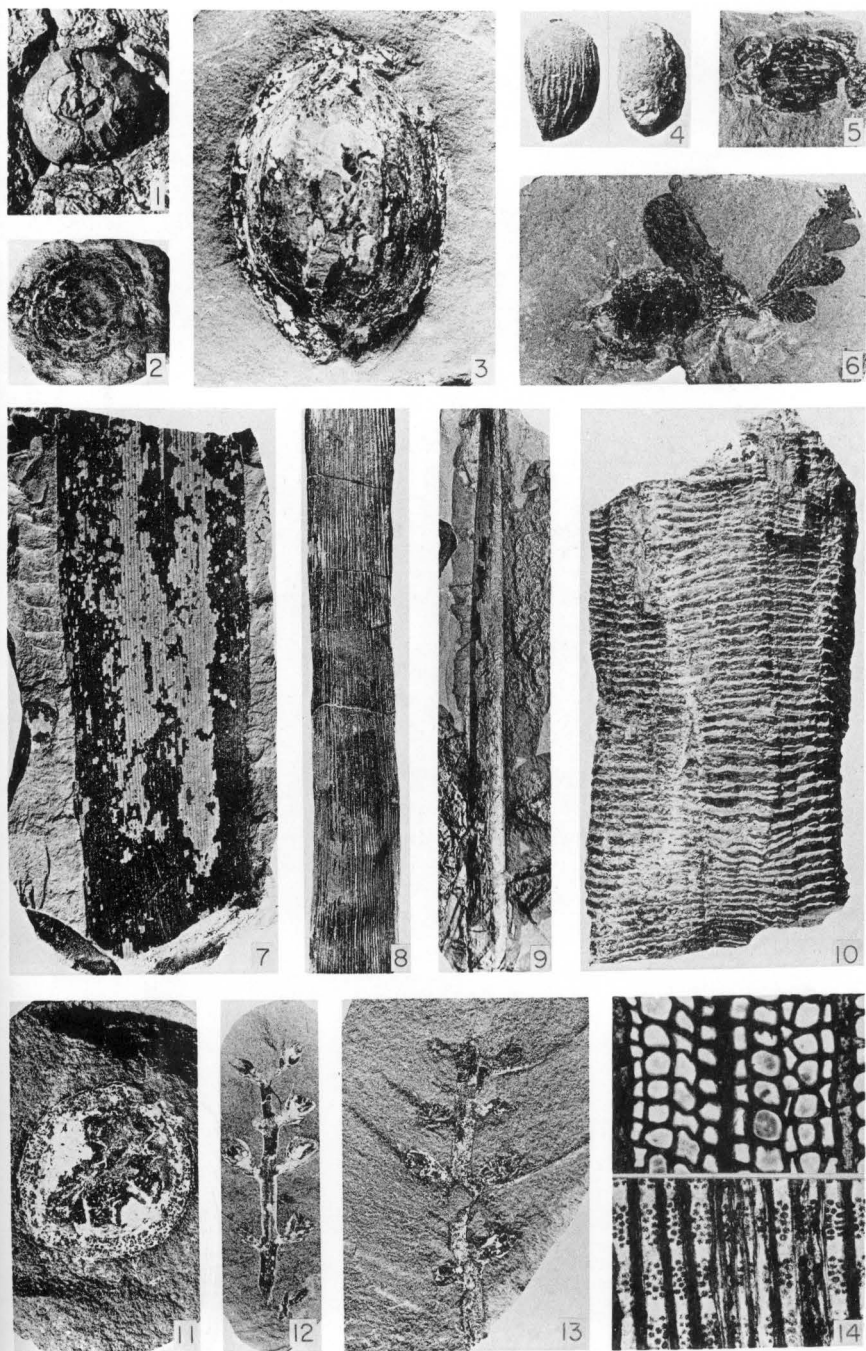
- Figure
1. *Mariopteris nervosa* Bgt.; site 69, Posey County; C. S. 211; X 1
  2. *Mariopteris nervosa* Bgt.; site 69, Posey County; C. S. 211; X 1
  3. *Maniopteris pottsvillea* White; site 47, Lawrence County; C. S. 367; X 1/3
  4. *Cyclopteris trichomanoides* Stemb.; site 64, Gibson County; C. S. 340; X 1
  5. *Linopteris obliqua* Bunb.; site 59, Pike County; C. S. 343; X 1
  6. *Linopteris obliqua* Bunb.; site 59, Pike County; C. S. 343; X 1
  7. *Megalopteris southwellii* (?) Lx.; site 29, Greene County; I. U. 221; X 1/2
  8. *Neuropteris scheuchzeri* Hoffm.; site 58, Pike County; C. S. 242; X 4/5
  9. *Neuropteris scheuchzeri* Hoffm.; site 58, Pike County; C. S. 242; X 4/5
  10. *Alethopteris ambigua* Lx.; site 39, Knox County; C. S. 213; X 3/4
  11. *Alethopteris (Callipteridium) sullivanti* Lx.; site 39, Knox County; I. U. 215; X 3/5
  12. *Mixoneura* sp. Weiss; site 58, Pike County; C. S. 361; X 1
  13. *Psaronius* sp. Cotta; site unknown, Greene County; I. U. 216; X 1/3
  14. *Psaronius* sp. Cotta; site 65, Gibson County; I. U. coal-ball collections; X 3/5



FILICALES AND CYCADOFILICALES

# PLATE 5

- Figure 1. *Trigonocarpus cf. adarnsii* Lx.; site 40, Knox County; C. S. 300; X 1
2. *Samaropsis* sp. Goepp.; site 28, Greene County; C. S. 348; X 3/4
3. *Holcospermum sulcatum* (?) Stemb.; site 28, Greene County; I. U. 217; X 1
4. *Holcospermum marnillatus* Lx.; site 62, Pike County; C. S. 302; X 1
5. *Holcospermum* sp. Nathorst; site 28, Greene County; I. U. 218; X 5/6
6. *Holcospermum* sp. Nathorst and *Odontopteris* sp. Bgt.; site 28, Greene County; I. U. 218; X 5/6
7. *Cordaitea principalis* Germar; site 12, Parke County; C. S. 315; X 3/4
8. *Dorycordaitea palmaeformis* Goepp.; site 28, Greene County; C. S. 583; X 1/2
9. *Poacordaitea microstachys* Goldenb.; site 12, Parke County; C. S. 284; X 1/2
10. *Artisia transversa* (Artis) Stemb.; site 63, Pike County; C. S. 341; X 7/8
11. *Cordaicarpus* sp. Geinitz; site 28, Greene County; I. U. 212; X 1
12. *Cordaianthus* sp. Grand'Eury; site 28, Greene County; I. U. 219; X 1/2
13. *Cordaianthus* sp. Grand'Eury; site 28, Greene County; I. U. 220; X 1
14. *Callixylon newberryi* Daws.; Henryville, Clark County; photomicrographs of transverse and radial thin sections; slides prepared by J. J. Galloway; X 75



CYCADOFILICALES AND CORDAITALES